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Resilient India : Disaster free India

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25 Years of Risk to Resilience

Training Module

on

Comprehensive Earthquake Risk Mitigation and Management

National Institute of Disaster Management

(Ministry of Home Affairs, Government of India)

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COMPREHENSIVE EARTHQUAKE RISK MITIGATION AND MANAGEMENT

Training Module

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National Institute of Disaster Management
(Ministry of Home Affairs, Government of India)
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Training Module on Comprehensive Earthquake Risk Mitigation and Management

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Resilient India - Disaster Free India

मधुप व्यास, भा. प्र. से.
कार्यकारी निदेशक
Madhup Vyas, IAS
Executive Director

सत्यमेव जयते

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Foreword

Earthquakes remain among the most severe natural hazards globally, causing significant human casualties, infrastructure damage, economic losses, and adverse long-term developmental effect. India is highly vulnerable to seismic hazards, with a large part of the country falling under earthquake-prone zones. Rapid urbanisation, increasing infrastructure exposure, and unplanned development in vulnerable regions further intensify earthquake risks and associated cascading impacts.

Preparedness and capacity building remain central to reducing earthquake risks and strengthening resilience. In this context, the National Institute of Disaster Management (NIDM), under the Ministry of Home Affairs, Government of India, has continuously undertaken training, research, and capacity-building initiatives to support Disaster Risk Reduction (DRR) efforts across the country.

The present Training Module on Comprehensive Earthquake Risk Mitigation and Management is an important initiative aimed at strengthening the knowledge and capacities of administrators, engineers, planners, academicians, trainers, disaster management professionals, and other stakeholders involved in earthquake risk reduction. The module provides a comprehensive understanding of seismic hazards, vulnerability assessment, preparedness, mitigation strategies, institutional frameworks, resilient construction practices, and community-based approaches for earthquake risk management.

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Aligned with the priorities of the Sendai Framework for Disaster Risk Reduction 2015–2030 and India's vision of a resilient and Viksit Bharat, this module is expected to serve as a useful reference for promoting earthquake preparedness, risk-informed development, and a culture of safety and resilience across the country.

I hope this module will contribute meaningfully towards strengthening national capacities for earthquake risk mitigation & management, and also support the collective effort towards building a safer and disaster-resilient India.

(Madhup Vyas)

Preface

In the wake of recent natural disasters and rapid development of infrastructures, it is of utmost importance to ensure that our communities are prepared for the potential impacts of deadly earthquakes. The recent earthquake event of Turkey-Syria occurred on Feb. 2023, which caused more than 50,000 deaths, has been another eye opener to all the nations failing to adhere to earthquake safety construction practices. As the frequency of catastrophic incidents are rising globally, it is crucial to concentrate on planning and design guidelines, resilient infrastructure investments, and the involvement of multi-stakeholders including communities.

This training module has been designed to provide essential information and tools to help trainers and trainees to grasp clear understanding of earthquake processes, and its risk mitigation and management concept. The module will cover discussions on wide range of topics such as, causes and effects of earthquakes; preparedness and response towards earthquakes; best practices for earthquake risk mitigation and management; and lessons learnt from past case studies are also highlighted. The module incorporates the practical advices and tools for creating emergency plans, conducting hazard-risk assessments, and implementing earthquake risk mitigation measures. Additionally, the module includes guidance on how to identify and respond to warning signs of an impending earthquake.

One of the key goals of this training module is to empower individuals and organizations with the knowledge and skills to reduce the potential impact of earthquakes. The final outcome of this module has been produced after an extensive investigation of training programmes conducted by NIDM and other stakeholders, nationally and worldwide and also through various literature survey both primary and secondary. Another important goal of this training module is to understand the importance of community preparedness and resilient community. Earthquakes can have a devastating physical and socio-economical impact on communities. It is essential that the Government work at local level with the communities to prepare for and respond to these events. This module includes information on how to build community resilience, as well as how to engage and mobilize individuals and organizations in the community to act towards Build Back Better.

I sincerely extend my gratitude to Shri Madhup Vyas, Executive Director, NIDM for sharing his vision and showing encouragement towards this document. My appreciation goes to Col. Manoram Yadav, SM, Joint Director, NIDM for his support as well. I would also like to thank the team of expert reviewers, Prof. P R Bose and Sh. V K Sharma, who have contributed into the refinement of this training module. Their expertise and wisdom have helped ensure that the module is accurate, informative, and useful as per current needs. I also wish to express my appreciation to RID Team including Dr. Prateek Roshan, Consultant and Ms. Avipsha Mohanty, Jr. Consultant, Akshay Jaychandran, Intern, Publication team, NIDM and other various stakeholders who have supported the development of this module.

In conclusion, I urge all trainers/leaders/scientists and training institutes/organisations to take advantage of this training module and to use the information and tools provided to help improve their preparedness and resilience in the face of earthquakes. Together, we can develop stronger and more resilient communities that are better prepared to withstand the impacts of earthquakes.

(Dr. Amir Ali Khan)
Professor & Head, Resilient Infrastructure Division, NIDM

Contents

Abbreviations/Acronyms Used

ATI	Administrative Training Institute
BBB	Building Back Better
BIS	Bureau of Indian Standards
BMTPC	Building Materials and Technology Promotion Council
CBDP	Community Based Disaster Preparedness
CCA	Climate Change Adaptation
DDMA	District Disaster Management Authority
DMMG	Disaster Mitigation and Management Group
DRDO	Defence Research and Development Organization
DRR	Disaster Risk Reduction
EEE	Earthquake Environment Effects
EEWS	Earthquake Early Warning System
EOC	Emergency Operation Center(s)
EOP	Earthquake Operation Plan
ESF	Emergency Support Function
GDP	Gross Domestic Product
GIS	Geographic Information System
GO	Governmental Organization
GPS	Global Positioning System
GSHAP	Global Seismic Hazard Assessment Program
GSI	Geological Survey of India
ICT	Information and Communication Technology
IMD	Indian Meteorological Department
IOTWS	Indian Ocean Tsunami Warning System
IRP	International Recovery Platform
IRS	Incident Response System
IS	Indian Standards
ISET	Indian Society of Earthquake Technology
ISSMFE	International Society of Soil Mechanics and Foundation Engineering
MCE	Maximum Considered Earthquake
MoEFCC	Ministry of Environment Forestry & Climate Change
MoES	Ministry of Earth Sciences
DST	Department of Science and Technology
NBC	National Building Code

NDMA	National Disaster Management Authority
NDMF	National Disaster Management Fund
NDRF	National Disaster Response Force
NERMP	National Earthquake Risk Management Project
NGO	Non-Governmental Organization
NIDM	National Institute of Disaster Management
NPCBEERM	National Program for Capacity Building of Engineers in Earthquake Risk Management
NPDM	National Policy on Disaster Management
NPEEE	National Program on Earthquake Engineering Education
PDNA	Post-Disaster Needs Assessment
PGA	Peak Ground Acceleration
PGV	Peak Ground Velocity
RVA	Rapid Visual Assessment
SDMA	State Disaster Management Authority
SDRF	State Disaster Response Force
SFDRR	Sendai Framework Disaster Risk Reduction
SME	Small and Medium-Sized Enterprises
UNESCAP	United Nations Economic and Social Commission for Asia and the Pacific
WASH	Water Sanitation and Hygiene
WHO	World Health Organization

Terminologies Related To Earthquake

Aftershock	A smaller earthquake that occurs after a larger earthquake, in the same area as the main shock.
Aftershock sequence	A series of aftershocks that follow the main shock, can occur for days, months, and even years.
Building collapse	The failure of a building's structural integrity during an earthquake, leading to partial or complete collapse.
Capacity	The ability of individuals, organizations, or communities to cope with and recover from disasters or other challenges.
Communication	The exchange of information between individuals, organizations, and communities during a disaster, including warning systems, public alerts, and emergency notifications.
Damage	Harm or injury caused when something is broken or spoiled.
Disaster	An event or series of events that result in significant damage, loss of life, or disruption of normal functioning of a community or society.
Disaster management	The process of preparing for, responding to, and recovering from disasters.
Disaster Mitigation	Actions taken to reduce or prevent the impact of hazards and disasters, such as building seawalls or improving building codes.
Economic loss	The financial impact caused by the destruction of buildings and infrastructure, as well as the disruption of businesses and services.
Emergency management	The process of coordinating and directing resources to, respond to and recover from emergencies, including disasters, accidents, and other unexpected incidents.
Emergency Operations Center	A centralized location where emergency response and recovery coordination and management activities are conducted during a disaster.
Emergency response	The actions taken by emergency personnel and organizations to save lives, provide medical care, and meet the basic needs of those affected by the disaster.
Epicentre	The point on the Earth's surface directly above the focus (the point of origin) where the earthquake originates.
Evacuation	The process of moving people from an area that is at risk of or has been affected by a disaster, to a safer location.

Fault	A fault is a planar fracture or discontinuity in a volume of rock across which there has been significant displacement sometime causing earthquake.
Fire (Earthquake induced)	Earthquakes can cause fires by rupturing gas lines, damaging electrical systems, or causing other types of ignition.
Ground failure	Loss of strength or stability of soil or rock caused by the ground shaking during an earthquake, such as landslides, liquefaction, and subsidence.
Hazard	A dangerous condition or event that has the potential to cause harm or damage to people, property, or the environment.
Hazard assessment	The process of identifying, analyzing, and evaluating potential hazards, such as earthquakes or floods, to determine the risks they pose to people, property, and the environment.
Hazardous materials	Substances that, if not properly controlled, can pose a threat to human health, the environment, and/or property. Examples include chemicals, radioactive materials, and biological agents.
Intensity	A measure of the strength of ground shaking during an earthquake, typically reported on the Modified Mercalli Intensity scale.
Landslides (Earthquake induced)	The movement of soil and rock down a slope as a result of the shaking caused by an earthquake.
Magnitude	A measure of the size of an earthquake, typically reported on the Richter scale or the moment magnitude scale.
Preparedness	Activities undertaken in advance of a disaster to enhance the ability of individuals, organizations, or communities to respond effectively, such as developing emergency plans or stocking supplies.
Recovery	The process of restoring and rebuilding affected communities and infrastructure following a disaster, including activities such as debris removal, rebuilding homes and businesses, and providing financial assistance to those impacted.
Recovery period	The time following a disaster when affected communities work to restore normal functions, rebuild infrastructure, and recover from the physical, emotional, and economic impacts of the disaster.
Recovery planning	The process of developing strategies and actions to facilitate the recovery of communities and infrastructure

	following a disaster, including identifying resources, setting priorities, and engaging stakeholders.
Relief	The provision of immediate assistance to people affected by a disaster, such as food, water, medical care, and shelter.
Resilience	The ability of individuals, organizations, or communities to adapt to and recover from disasters or other challenges, and to maintain essential functions during and after the event.
Response	Actions taken immediately following a disaster to assist those affected, such as search and rescue, medical care, or shelter.
Risk	The likelihood of a hazard occurring and the potential consequences that could result from it.
Seismic waves	The vibrations that travel through the Earth's crust and cause ground shaking during an earthquake. There are two main types of seismic waves: P-waves and S-waves
Seismogram	A record of ground motion produced by a seismometer during an earthquake.
Seismometer	A device used to measure ground motion during an earthquake.
Shelter	A safe place to protect people from the hazards of a disaster, such as a designated evacuation center or a personal shelter-in-place location.
Tsunami	A large ocean wave often caused by a submarine earthquake or volcanic eruption.
Vulnerability	The susceptibility of people, property, or the environment to harm or damage caused by a hazard or disaster.

Context

Earthquake, a natural phenomenon, have proved to become the deadliest natural disaster in the world by causing severe shaking of the ground leading to significant property damage and human casualties. More than 7,50,000 people have died and more than 125 million people have been harmed by earthquakes worldwide between 1998 and 2017 (Shafapourtehrany et al. 2022). Apart from direct impact, it can also trigger liquefaction, tsunamis, and landslides, among other things which increases its severity. The world's most destructive and costliest earthquakes, including the Northridge 1994, and Sumatra-Andaman 2004 quakes and the most recent Turkey-Syria earthquake of February, 2023 have been reported to harm large infrastructures such as roads, buildings, airports, bridges and even infrastructure tens of miles away from the epicenter. The 2004 Indian Ocean earthquake and tsunami resulted in the deaths of over 230,000 people in 14 countries, including India, with an estimated economic loss of around $10 billion in India alone. As per the UN study from 1996-2015, 90 percent of the 1.35 million people who had died in disasters lived in low or middle-income countries. However, the magnitude, severity, length, local geology, building plans and designs, and other aspects of the earthquake all contributes to the catastrophe.

More than 59 percent of India is vulnerable to destructive earthquakes, and witnessed some of the largest earthquakes in recorded history. India has a varied topography, with the enormous Himalayas in the north, the Peninsula, and the Western Ghats in the south. This phenomenon due to geographical attributes is more common in the northeast hills and the Himalayan region, for eg. the Kashmir earthquake of 2005 resulted in over 87,000 deaths and an estimated economic loss of around $5 billion. Some major earthquakes have also happened in the peninsular regions such as Koyna 1967, Latur 1993, and Jabalpur 1997. The 2001 Gujarat earthquake resulted in the deaths of over 20,000 people and an estimated economic loss of around $2 billion. The Latur earthquake of 1993 resulted in over 9,000 deaths and an estimated economic loss of around $300 million. Major problem caused by the earthquakes in India is due to the housing typologies. The constructions without proper planning and seismic guidelines is a widespread practice compounding the impact of earthquake. This has become a serious issue because a significant portion of the population lives in urban areas, which are rapidly growing and contributing to the nation's economy. As per 2011 census, 31.6 percent of Indians live in urban regions, which account for 63 percent of the nation's GDP and are growing exponentially every year. However, the infrastructure and building safety practices received less attention. Thus, considering the seismic zones (Zone V to Zone II) and seismic microzonation of seismically active areas, while planning any developmental activities would help reducing the impacts in any future events. There is a pressing need to focus on design guidelines, safer infrastructure investments, and the involvement of various stakeholders in disaster mitigation and management.

This training module has been developed to help trainers and trainees (multi-stakeholders) with the knowledge and skills necessary to understand and manage earthquake risk effectively. The module covers practical topics such as modifying seismic safety measures, designing earthquake-resistant structures, and improving infrastructure and resident safety. The training is aimed at a wide range of participants, including government officials, NGOs, engineers, and other stakeholders involved in disaster management. The module's components include lectures, case studies, and interactive activities that allow participants to apply their knowledge in real-world scenarios.

PART- A
INSTRUCTION MANUAL

1. BASIC TRAINERS GUIDE

1.1. AIM OF THE COURSE

Training module will provide clear, systematic and replicable guidelines to impart and share the knowledge and abilities linked to earthquake risk mitigation and management amongst the target group, which are anticipated to play a significant role in decreasing impacts of the earthquake hazard.

1.2. OBJECTIVES

The training module would delve into the pre-disaster and post-disaster mitigation and management for earthquake to work in the following direction:

- To improve education, training, and awareness of earthquake hazards and its mitigation options;
- To enable participants with knowledge on comprehensive earthquake risk management;
- To facilitate participants with basic tools, skills and techniques for the concept of building back better;
- To encourage community-based earthquake management strategies, local participation, and use of modern technologies and ICT; and
- To mainstream DRR in developmental strategies for enhancing earthquake safety in the future.

1.3. TARGET GROUPS

This module will be useful for:

- The senior and middle level officers/policy-makers/functionaries from the Centre/State/Local departments working in field related to Disaster Management, Revenue Department, Geology and Mines, Geological Survey of India, Rural and Urban Development.
- Targeted government officials, particularly from public works department and planning organizations, as well as design professionals and utility operators, such as Engineers, Urban Planners, Architects, and Young Professionals etc. in order to improve the planning and development of build environment and infrastructure.
- Academician/faculties/teachers and research scholars who are familiar with contemporary technologies like remote sensing, GIS, and instrumentation and engaged in the activities related to earthquake and disaster management can be given priority.
- Stakeholders from different fields including government agencies, NGOs, PSUs, private sector organizations, and targeted communities such as local leaders, women, youth etc., to ensure a holistic and inclusive approach to earthquake risk mitigation and management.

1.4. ENTRY BEHAVIOUR

Trainers should possess a graduate/ post graduate level of educational qualifications to be able to understand the training contents clearly in relation to earthquake hazard. The curriculum covers basic aspect of earthquake risk assessment and analysis hence trainees with no experience in this field can also take part from various background. However, the level of training can be modified as per the skills and experience of the target group to maintain homogeneity and efficiency.

1.5. TRAINING NEEDS

Earthquake are the biggest killers and cause destruction and irreparable damage. The earthquake early warning system is still not adequate and continued to be a part of research with limitations. The earthquake early warning window limited to few seconds also does not provide large scope of changing the scenario. Hence, the importance of achieving resilience is targeted through awareness, capacity building and building earthquake safe infrastructures. This training module will provide a systematic approach for a forum to talk about earthquake preparedness and reducing the anthropogenic influences negatively. Interaction with individuals from various organizations may highlight the crucial requirements, challenges and gaps on the current developmental plans. Vulnerable section of communities and different stakeholders, those who have been impacted by past earthquakes, need to be aware of, informed about, and ready for any future earthquake hazards. It is vital to talk about proper building design, non-structural vulnerable elements, and how local populations can provide safety measures. Understanding the comprehensive earthquake management will also guide the various stakeholders about their roles and responsibilities in achieving resilience from earthquake risk. The mainstreaming of DRR practices in developmental plans as mentioned in PMs 10 point agenda on DRR will be tackled through such capacity building initiatives.

1.6. TRAINING MATERIALS

Training venue: A suitable venue is required to host the training program. The venue should have adequate space to accommodate participants and equipment, and be equipped with appropriate facilities such as chairs, tables, projectors, and screens.

Trainers: Qualified trainers with expertise in earthquake risk mitigation and management are required to deliver the training program. The trainers should be experienced in giving trainings to senior officials and be able to provide clear explanations and demonstrations.

Course material: Comprehensive course material such as manuals, presentations, and reference books should be developed and provided to participants to support their learning and understanding of the subject matter.

Audio-visual aids: Audio-visual aids such as projectors, videos, and presentations can be used to enhance the learning experience and help participants better comprehend the concepts covered in the training program.

Simulations and exercises: Practical simulations and exercises can be conducted to help participants apply their knowledge in realistic scenarios, which can help reinforce the concepts covered in the training program.

Evaluation and feedback: A robust evaluation and feedback system should be established to assess the effectiveness of the training program. It also provide participants with the opportunity to give feedback on the training content and its delivery by experts.

1.7. ROLES AND RESPONSIBILITIES OF USER ORGANIZATION/ TRAINERS

The trainers must have a deep understanding of earthquake risk and its implications, as well as practical experience in designing and implementing earthquake-resistant structures and infrastructure. In addition, the trainers should be able to provide valuable insights into disaster mitigation and management strategies based on their experiences working with various stakeholders, including governments, NGOs, and communities. Overall, the quality of the trainers is critical to the success of the training module and the effectiveness of efforts to manage earthquake risk in India. Professionals working in structural engineering, architects, urban planners, and academician from disaster management/earthquake engineering/ geology/seismology/ geophysics background can cater to different learning units of the module.

USER ORGANIZATION/ INSTITUTE: The institute/organization shall make all necessary logistical arrangements for conducting a successful training program. The user organization shall take responsibility of arranging nominations and communication to target group. Monitoring of the training program as per the pre training assessment and post training feedback and assessment should be reviewed by competent authority of the user organization. The organization shall also invest in getting the experienced trainers and resource person having expertise in the subject matter. The promotion of the training program should be widely circulated well in time for awareness and publicity on earthquake risk mitigation. The outcomes of the training provided by the trainer/program coordinator should be reviewed by the competent authority to take any further necessary action if required.

1.8. NUMBER OF TRAINEES

35-40 individuals from various organizations.

1.9. LANGUAGE

English can be used for delivering lectures and presentations however, if necessary, it can be translated into Hindi or other regional languages.

1.10. VENUE OF THE PROGRAM

Any classroom of sufficient capacity with required logistics.
GSI training centers, DMMG training centers, State ATIs, NIDM, universities or institutes are some examples where regular trainings, proper resources and smart classrooms are provided with amenities.

1.11. TIME FRAME

The course of training module has been set for three days. However, additional topics (as suggested in the module) can extend the course to five days, as per the requirement and suitability of the trainee's need. To cater the need for senior officials, half-day/ one-day workshop framework has been also prepared.

1.12. TRAINING METHODS

Lectures/Interactive Sessions/ Powerpoint presentations/ Field exercise/ Case Studies/ Panel discussions/ Group work/ Mock drills/ Demonstrations/ Videos/ Reading materials.

1.13. MEDIA AND EQUIPMENT

Smart Classroom, laptops, Projector, Laser pointer, white board, mike and speaker, Camera, video recorder, printer, pen drive, chart papers etc.

1.14. COST OF TRAINING

The cost of training may include TA/DA for individuals/resource persons/ trainers, training kits, stationery costs, field visit expenses, local transportation charges, photography, certificate printing, cost of boarding and lodging and other miscellaneous and administrative charges.

1.15. EXPECTED OUTCOME

The training programme is expected to give participants

- In-depth knowledge of the methods for reducing earthquake risk and managing associated risks
- Overall sensitization of officials and providing necessary advanced knowledge and skills.
- It is also expected to increase the capacity of participants in various facets/ dimensions of reducing and managing earthquake risk.
- It will further help participants to launch capacity building initiatives related to earthquake risk mitigation and management at the state/ district/ organization/departmental level.

1.16. EVALUATION AND VALIDATION

Both formal and informal methods will be used to evaluate the training programme.

- Every day, a recapitulation session will be held to go over the course material and to solicit trainees comments on the instructors.
- At the conclusion of the programme, a formal verbal feedback may be taken.
- The exercises and field visit outcomes would serve as the basis for the evaluation of skill transfer, and participants would be expected to put their newly learned information to use in managing and mitigating earthquake risks.
- A questionnaire for evaluation to be given to the participants, who will then fill it out and submit it to trainer.
- A common feedback form will be given to all participants to evaluate the course sessions, interaction with resource persons, exercises, field visits, demonstrations, logistics, food quality and meeting course objectives.
- The post-training assessment may further be taken for a period of a year,

where at 3 months interval, participantsare requested to fill questionnaire to monitor their performance, capacity building related outputs given at their level and achieved behavioural changes related to earthquake hazard.

1.17. CERTIFICATION

Each participant will be awarded a certificate on successful completion of the programme as per the given terms and conditions set by course coordinators on attendance and performance.

1.18. TRAINERS TIPS

- Building trust and rapport with participants will help making session interesting and receptive.
- Trainer should be receptive to take guidance from the module and if required modify sessions day, time and learning units as per the given additional topics, requirement and suggestions of the participants.
- Training materials should be kept ready and checked before the training.
- During the inauguration/introduction session, the trainees should be asked to switch off or keep their mobiles/cell phones in silent mode during sessions and advised to attend only the urgent calls that too by going out of the training hall.
- Trainer must break the lengthy lecture sessions into interactive exercises and discussions as much as possible.
- Participants should be given a scope for recapitulation before beginning of day. Summary and discussion session at the end of day to be given dedicated 15 minutes.
- Having group exercise with/ without field visit is must. Groups should be made keeping in mind the different themes and affiliation of the participants. Mixed groups shall be promoted.
- Some sessions should take into account the past lessons and experiences at local level to address the hazards and vulnerabilities holistically.
- WhatsApp Group comprise of all participants and organizing team members should be made 15 days before the start of training. This will help acknowledge the issues regarding boarding and lodging; sharing reading materials, presentations of lectures; coordination during field visits and group exercises; and to stay connected even after the training for post training assessment.
- Participants list with names, addresses, contact numbers, emails, etc. should be circulated for verification from the trainees, marking daily attendance, and for necessary corrections.
- Feedback of every session must be taken to evaluate the performance of each resource person.

PART- B
CONTENT

2. CONTENT AND STRUCTURE OF THE MODULE

The following nine sub-modules is proposed to serve as the foundation for earthquake training program. Further to make the module effective for different level target group with different background, experience; senior level officers and policy makers, the additional topics and readings are also suggested. The additional topics will provide the flexibility to tailor-made the training content as per the need of the target group, group level of officers, experience and work type. Further, the additional topics may be used to extend the days of training program to a five day training program or may even be replaced by some of the mentioned submodules as per the decision of the program coordinators. Apart from training, the session of sub-module may be used for conducting workshop for senior level officers/ policy makers.

SUB- MODULE	TOPICS COVERED
Inaugural Session and Ice breaking	• Introduction of participants • Experience sharing • Ice breaking activity
Disaster Management -An Overview	• What is disaster? • Types of disaster • Disaster Management-an overview • Vulnerability of disaster in India, its impact and measures taken. • Phases of Disaster Management and Technological Framework
Introduction to Earthquake	• Earthquake phenomenon, causes and consequences – an overview of Indian and Global scenario • Seismic Zonation • Effects of earthquake on natural environment, built environment, socio-economic and psychological aspects
Strategies for Earthquake Risk Mitigation	• Earthquake forecasting and early warning • Earthquake risk mitigation measures- structural and non-structural • Retrofitting measures • Pre-disaster and post-disaster preventive measures • Liquefaction and Seismic Microzonation
Earthquake Preparedness	• Earthquake preparedness and its components • Capacity building • Community-based earthquake preparedness • Earthquake education, training and capacity enhancement
Post-Earthquake Relief and Response	• Assessing initial needs • Organizations, services and departments • Vulnerability assessment • Role of media in emergency response • Damage Assessment
Short Term Earthquake Recovery and	• Rehabilitation of physical infrastructures • Social rehabilitation

Rehabilitation	• Psychological rehabilitation
Long-Term Recovery -Reconstruction Strategies	• Concept of Building Back Better • Housing reconstruction • Economic recovery • Case studies of post-earthquake long-term recovery and rehabilitation
Closing Session	• Feedback, evaluation and certification • Post-Training assessment • Valedictory session

Additional Topics	
Case Studies of long term recovery and reconstruction (Past earthquakes)	• Case studies of major earthquakes for long term recovery and reconstruction with lesson learnt eg from. Sikkim Earthquake, 2011, Kashmir Earthquake 2005, Gujarat Earthquake, 2001 and Latur Earthquake 1993
Use of modern tools, science and technology	• Earthquake safe modern construction practices- Use of AI, modern technology and tools such as types of base isolation technique, use of various types of dampers and energy dissipaters etc.
Traditional Knowledge for earthquake mitigation	• Earthquake safe traditional construction practices in India such as Koti Banal and Kath-Kuni of Himachal Pradesh, Dhajji Dewari and Taq system of Jammu & Kashmir, Bhunga House of Gujarat, Assam type house and Khasi House on stilts from North East India etc.
Mainstreaming DRR	• Mainstreaming DRR in Housing Sector- understanding the techno-legal framework of earthquake resistant buildings
Retrofitting	• Seismic retrofitting of buildings – case studies to address different ways to increase the strength of the building for resilience
Ground Failure	• Case study: Liquefaction induced ground failure and resisting measures, causes and use of seismic microzonation map in planning
Post-Earthquake Response	• Emergency response logistics and supply chain management in the aftermath of an earthquake, IDRN
Field Visit and Exercise	• Field visit to any earthquake vulnerable area • Exercises: Rapid Visual Screening (RVS), and Earthquake Risk Index (ERI)
Demonstration	• Fire evacuation drills • Earthquake evacuation Mock drills, • Preparation and use of earthquake emergency kits • First Aid and Life Safety

Additional Topics : For Senior Level Policy Makers	
Technical Sessions	• Advances in use of science and engineering of earthquakes to structural and non-structural risk reduction practices • Role of local bodies- rural and urban for earthquake risk reduction in techno-legal framework for disaster management • Strengthening Disaster Risk Governance to manage earthquake risk • Investing in Post-Earthquake Reconstruction and Rehabilitation for resilience • Monitoring the role of major stakeholders in capacity development for earthquake risk mitigation • National Perspective on covering Earthquake Risk Mitigation and Management: Sendai Framework, SDGs, PM 10 Point Agenda for DRR and beyond
Panel Discussion	• Mainstreaming Earthquake Risk Reduction for Sustainable Development – Viksit Bharat by 2047 • Challenges of state/districts under Seismic Zone V and IV and way forward
Plenary Session	• Progression of India towards building earthquake risk resilience: Action Plan and Recommendations

2.1 DAY WISE SUMMARY OF THE TRAINING MODULE ON COMPREHENSIVE EARTHQUAKE RISK MITIGATION AND MANAGEMENT

DAY 1			
Session Theme	**Session Objectives**	**Methodology**	**Time**
REGISTRATION	• To get participants registered and mark their attendance daily (session-wise) • To make all necessary arrangements and provide help desk for all participants	Physical and/or Digital Registration form	9:00-9:30am
INAUGURATION	• To formally welcome the participants and chief guests • To introduce the participants & facilitators • To set objectives, scope, aim and expected outcomes of the programme	Welcome & Inaugural address with Vote of thanks	9:30-10:30am

EXPECTATIONS, EXPERIENCE SHARING AND GROUND RULES	• To help the participants open up and familiarise with their fellow participants and course coordinators. • To identify learners' needs and expectations from training program. • To check the level of experience and understanding of participants related to technical sessions	Icebreaker, Group Exercises & experience sharing	10:30 -11:30 am
TEA BREAK			
DISASTER MANAGEMENT – AN OVERVIEW	• An introduction about hazard, disaster and the types of disaster • To provide an overview on disaster management and its phases and framework • Earthquake vulnerability of India, its impact and measures taken	Interaction, Lecture	11:30 am -1:00 pm
LUNCH			
INTRODUCTION TO EARTHQUAKE	• To explain earthquake cause and origin • To discuss about seismic parameters and seismic zonation • To describe the effects of earthquake on built environment, natural environment, and socio-economic factors.	Interaction, Lecture	1:45 -3:15 pm
TEA BREAK			
STRATEGIES FOR EARTHQUAKE RISK MITIGATION	• To introduce the concept of earthquake forecasting and early warning • To explain the mitigation measures in structural and non-structural terms • To discuss the concept of retrofitting • To provide an insight on pre-disaster preventive measures and post-disaster preventive measures. • To describe about the mitigation strategies in liquefaction prone areas and need of seismic microzonation	Interaction, Lecture	3:30 -5:00 pm

SUMMING UP	• Identify key takeaways of each session • Discussion and take up any unanswered queries • Share reading materials homework or give exercise to meet next day's objective	Interaction	5:00 -5:30 pm
DAY 2			
RECAPITULATION	• To refresh learnings and trainees retentiveness • To establish continuity of learning from the previous day • To discuss queries emerged after end of previous day	Debriefing	9:30 -10:00 am
EARTHQUAKE PREPAREDNESS	• To introduce the disaster preparedness phase and its components • To explain the concept of capacity building • To strengthen the awareness of community-based disaster preparedness	Presentation & Discussion	10:00 -11:15 am
TEA BREAK			
INITIATIVES FOR EARTHQUAKE PREPAREDNESS	• To highlight the needs of earthquake education and training • To discuss about assembling emergency supplies and other resources	Presentation, Lectures, Interaction	11:30 am - 1:00 pm
LUNCH BREAK			
POST-EARTHQUAKE RELIEF AND RESPONSE	• To discuss about the essential needs to be addressed in a short - span of time in a disaster event • To understand the guidelines/ SOP of various organizations, centres, and forces	Lectures, Interaction	1:45 -3:15 pm

TEA BREAK			
MANAGEMENT OF THE AFFECTED AREA AFTER EARTHQUAKE	• To discuss about the process of debris removal, disposal of dead bodies, and clearing pathways • The information regarding media management, search modalities, and financial mechanism	Case studies, Interaction	3:30 -5:00 pm
SUMMING UP	• Identify key takeaways of each session • Discussion and take up any unanswered queries • Share materials, homework or give exercise to meet next day's objective	Interaction	5:00 -5:30 pm
DAY 3			
RECAPITULATION	• To refresh learnings and trainees retentiveness • To establish continuity of learning from the previous day • To discuss queries emerged after end of previous day	Debriefing	9:30 -10:00 am
TEA BREAK			
SHORT TERM-EARTHQUAKE RECOVERY-REHABILITATION	• To enumerate various aspects of post-earthquake recovery and rehabilitation process • To discuss about physical, socio-economical and psychological rehabilitation	Lecture, Interaction	10:00 -11:15 am
LONG-TERM EARTHQUAKE RECOVERY - RECONSTRUCTION	• To discuss the concept of Building Back Better • To describe the housing reconstruction practices • To discuss the concept of economic recovery	Presentation, Lecture, Interaction	11:30 am -1:00 pm

LUNCH BREAK			
CASE STUDIES OF EARTHQUAKE RECOVERY ACTIVITIES	• Describe how the recovery measurements taken in Gujarat after 2001 post-earthquake as case study. • To explain the role of NGOs and community in earthquake risk management • To discuss gaps in coordination and collaboration between Govt. & NGOs. Discuss Kashmir 2005 earthquake	Presentation, Interaction	1:45 am -3:00 pm
SUMMING UP	• Identify key takeaways of each session • To have discussion and take up any unanswered queries • Share materials, homework or give exercise to meet next day's objective	Interaction	3:00-3:30pm 3:30-4:00pm
FEEDBACK, EVALUATION, AND CERTIFICATION, VALEDICTORY FUNCTION	• To get the feedback of the participants about the programme • To formally close the programme To distribute certificates among participants	Physical and/or Digital Feedback and course evaluation form, Certificate distribution	4:00 -5:00 pm
TEA BREAK			
	ADDITIONAL DAYS		
DAY 4			
CASE STUDY OF POST-EARTHQUAKE PROGRAMME IN LATUR 1993, GUJARAT 2001, SIKKIM 2011 etc.	• Identify best practices in post-earthquake disaster management. • Analyse stakeholder roles in post-disaster recovery efforts. • Develop a sustainable framework for post-disaster recovery programs. • Understand the importance of PDNA	Case studies, power point presentation, Interaction	9:30 -11:30 am

TEA BREAK			
EARTHQUAKE SAFE CONSTRUCTION PRACTICES USING MODERN TOOLS/ TECHNIQUES AND TRADITIONAL SAFE CONSTRUCTION PRACTICES	• To learn earthquake-resistant design principles and assess building safety using modern tools and techniques • To understand earthquake impacts and develop mitigation strategies • Learn about seismic-resistant features of traditional Indian construction practices	Video clips for base isolation techniques, Interaction, Case studies, power point presentation	11:30 am -12:15 pm
SEISMIC RETROFITTING OF BUILDING – CASE STUDIES OF GUJARAT/ OTHER STATES	• To discuss the different retrofitting measures and understand methods to increase the strength of an old building • Analyse the retrofitting past examples as good practices • Develop an action plan for promoting seismic retrofitting among the participants	Presentation, Interaction	12:15 am -1:00 pm
LUNCH BREAK			
LIQUEFACTION INDUCED GROUND FAILURE AND ITS MITIGATION MEASURES	• Understand the fundamental principles of liquefaction-induced ground failure and the potential impact on infrastructure and human life • Learn about the various methods and techniques used to assess vulnerability to liquefaction and identify susceptible areas for ground failure • Explore mitigation measures and engineering solutions for resisting liquefaction-induced ground failure • Understand the use of seismic microzonation map while planning to reduce the liquefaction induced ground failures	Interaction, Case study	1:30 am -2:45 pm

EMERGENCY RESPONSE LOGISTICS AND SUPPLY CHAIN MANAGEMENT IN THE AFTERMATH OF AN EARTHQUAKE	• Understand principles of emergency logistics and supply chain management after an earthquake • Develop practical skills for assessing needs, planning operations, and managing inventory • Gain comprehensive understanding of logistics and supply chain role in disaster response	Interaction	2:45 -3:30pm
TEA BREAK			
LESSONS LEARNED FROM RECENT EARTHQUAKES IN INDIA AND THEIR APPLICATION IN FUTURE DISASTER PLANNING	• Understand the factors that contributed to the damage caused by earthquakes and their impact on communities • Learn best practices in earthquake risk management from case studies in India and other countries • Develop an action plan for improving disaster preparedness in community or organization	Interaction	3:45 – 4:30pm
RAPID VISUAL ASSESSMENT OF VULNERABLE INFRASTRUCTURE AND EARTHQUAKE RISK INDEX	• Develop understanding of how to do RVS of any building and calculation of Earthquake risk index	Exercise, Field survey	4:30 – 5:30 pm
DAY 5			
MAINSTREAMING DRR IN HOUSING SECTOR	• Understand associated risk with different housing typology • Implementation of techno-legal regime to promote DRR in housing & building sector	Discussion, Powerpoint, Case study	9.30am -10.30am
FIELD VISIT TO ANY EARTHQUAKE VULNERABLE AREA	• Identify potential hazards, risks, vulnerability and capacity to the community, economic loss, damage to infrastructure and environment at the selected field area	Field Survey	10:30 am -1:00 pm

LUCH BREAK			
FIRE EVACUATION DRILLS, MOCK DRILLS, EARTHQUAKE EMERGENCY KITS, FIRST AID SAFETY	• Understand the importance of drills, kits, and preparedness for safety during a disaster • Learn best practices for conducting effective drills and using emergency kits • Develop basic first aid skills and knowledge for responding to common injuries and emergencies	Demonstrations	1:30 -5:30 pm

2.2 ONE DAY /HALF DAY WORKSHOP/ BRAINSTORMING PANEL DISCUSSION FOR SENIOR LEVEL POLICY MAKERS

Technical Sessions

- Advances in use of science and engineering of earthquakes to structural and non-structural risk reduction practices.
- Role of local bodies- rural and urban for earthquake risk reduction in techno-legal framework for disaster management
- Strengthening Disaster Risk Governance to manage earthquake risk.
- Investing in Post-Earthquake Reconstruction and Rehabilitation for resilience.
- Monitoring the role of major stakeholders in capacity development for earthquake risk mitigation.
- National Perspective on covering Earthquake Risk Mitigation and Management: Sendai Framework, SDGs, PM 10 Point Agenda for DRR and beyond.

Panel Discussion

- Mainstreaming Earthquake Risk Reduction for Sustainable Development – Viksit Bharat by 2047
- Challenges of state/districts under Seismic Zone V and IV and way forward.

Plenary Session

- Progression of India towards building earthquake risk resilience: Action Plan and Recommendations

3. MODULE OVERVIEW

This section provide brief of sessions and topics to be covered in all submodules. The inaugural and closing session provides the guidance to the coordinators on logistics, pre-requirements, post training assessments, and other general requirements. The inaugural will help set proper tone of the program. The guidance for certification, feedback and assessment of participants is provided in closing session to end any training program with extracted outcomes and way forward. Other sessions incorporates the technical aspects of each sub module with session objective and suggested reading. Learning units with timeframes are also suggested for each session to maintain the standard and coverage of each suggested topic.

3.1 SUB-MODULE 1: INAUGURAL SESSION

SESSION 3.1.1: REGISTRATION

1. Filling the registration form by the participants through Google forms/ online registration portals or directly at the registration desk on the first day.
2. To mark attendance of the already registered participants present.
3. To provide a help desk for all participants, guests and resource persons.

SESSION 3.1.2: PROGRAM INAUGURATION

Participants of the programme would come from various backgrounds and areas of expertise, therefore, it is crucial to give them the course outline. Following that, the institution's head and other dignitaries should offer a formal inaugural speech. This session can be used to talk about the amount of time allotted for each programme, the lunch and tea breaks, the creation of teams or groups, the interaction and discussion that takes place during the sessions, and the facilities that are available to engage participants. Generally these are followed as:

1. Welcome speech by the Moderator of the program.
2. Elaboration of course outlines by the coordinator.
3. Introductory speech by the Head of the department.
4. Keynote address by the Guest of Honour.
5. Information regarding various norms during the entire program

SESSION 3.1.3: PRE-TRAINING ASSESSMENT AND DISCUSSION

Pre-training assessment of the participants is important in understanding the background and interests. The trainers may introduce themselves with the responsibility they have at their workplace and involve all the participants to have an interaction with each other.

The main objective of the session will be taken as following:

1. Understanding the entry behaviour of the participants.
2. Survey of the participants to understand their issues and experiences.
3. To let participants share their expectation about the program and familiarise with each other.

SESSION 3.1.4: TRAINING AIDS

Attendance sheet, Registration form, Question paper, pen and marker, Training programme schedule, suggested reading materials.

3.2 SUB-MODULE 2: DISASTER MANAGEMENT – AN OVERVIEW

To understand the concept of disaster, it is important to have an idea about hazards, its parameters, types, capacity and vulnerability important to understand the associated risk. Most of the disaster increase in severity due to lack of understanding, preparedness and mitigation measures. Disaster events, such as earthquakes, can have devastating consequences for communities. They often result in the loss of many lives, damage to critical infrastructure and buildings, as well as economic and social structures. Additionally, these events can have long-term impacts on human health, including physical and mental health. It is essential to implement effective disaster management strategies to mitigate these consequences and reduce the risk of future disasters.

This sub module is set to help participants familiarize with the fundamentals of disaster and related terminologies which will be used throughout the course. With the increasing focus on disaster risk management and evolution of the approach with time, many terms were coined for establishing better understanding, implementation, and execution. It is imperative to learn all the terminologies associated with disaster management to better understand the fundamental concept of disaster management cycle. This sub-module can be further divided into three sessions.

SESSION 3.2.1: DISASTER MANAGEMENT

According to the World Health Organization, the United Nations Department of Humanitarian Affairs, the Gunn's multilingual Dictionary of Disasters Medicine and International Relief, disaster is defined as a serious disruption of the functioning of the society, causing widespread human, material or environmental losses that exceeds the local capacity to respond, and calls for external assistance. The disaster can be caused either naturally or human-made. About 59 percent of the total land area in India is highly vulnerable to earthquakes (National Institute of Disaster Management, 2014), with increasing population and infrastructure facilities, the probability of the disaster is becoming more and more intense. In this session, the participants should be taught about the basic of disaster, types of disaster that affects the human society and the public health consequences. The participants should be able to understand the various causes of the disaster.

Session Learning Units:

a) What is disaster?
b) Types of disaster and causes of disaster
c) What is hazard and cause of hazards?
d) How disaster is different from hazard?

Time required	**20 minutes**
Session objectives	1. To make participants understand about the disaster, different types of disaster and their cause 2. Participants can differentiate disaster from hazard 3. Understand the types of hazards and its causes
Keywords	Disaster, Hazard, Risk, Natural Disaster, Man-made disaster
Mode of delivery	Presentations, Documentaries, Interaction
Suggested Reading	a.) What is disaster? Disaster: how the Red Cross Red Crescent reduces risk by IFRCRCS https://www.preventionweb.net/files/10583_159600drrbrochureen1.pdf "What is Disaster" by IFRC https://www.ifrc.org/our-work/disasters-climate-and-crises/what-disaster "Disasters and Emergency" by WHO https://www.who.int/teams/integrated-health-services/clinical-services-and-systems/surgical-care/disasters-and-emergencies#:~:text=The%20WHO%20SAC%20program%2C%20together,injuries%20encountered%20in%20disaster%20situations. b.) Types of disaster and causes "Natural Disasters & Assessing Hazards and Risk" by the National Oceanic and Atmospheric Administration. https://www.weather.gov/safety/ "Human caused hazards" Maine Emergency Management Agency. https://www.maine.gov/mema/hazards/human-caused-hazards "Disasters and their Management" by the United Nations Office for Disaster Risk Reduction. https://www.undrr.org/ c.) What is a hazard and their causes. "Hazard identification and prevention" NDLON-OSHA. https://www.osha.gov/sites/default/files/2018-12/fy10_sh-20854-10_hazard_id_facilitatorguide.pdf "Hazards" CCOHS. https://www.ccohs.ca/topics/hazards/"Disaster Education" BRI and GRIPS https://www.preventionweb.net/files/3442 DisasterEducation.pdf d.) How disaster is different from hazard? "Hazard vs Disaster: The principle behind disaster management" By Saurab Babu Posted on January 21, 2017 https://eco-intelligent.com/2017/01/21/hazard-vs-disaster-the-principle-behind-disaster-management/

	"Hazards, Disasters, and Risks" by National Institute of Health. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7123175/

SESSION 3.2.2: VULNERABILITY OF DISASTER IN INDIA, IMPACT AND RISK

The primary objective of this session is to familiarize with the vulnerability profile of our country. For understanding the profile the session can discuss about how India has dealt with disasters in the past and the lessons learnt through them. These lessons will enlighten participants about how the techno-legal framework to manage and mitigate disaster, the funds required, and involvement of various organizations came into action.

Session Learning Units:

a) Define Vulnerability
b) Define Risk and related terminologies
c) Impact of disaster on vulnerable areas

Time required	**60 minutes**
Session objectives	1. To understand the vulnerability profile of India 2. To understand the risk and associated terminologies 3. To get idea about various organizations, and funding agencies state-wise and national-wise
Keywords	Vulnerability, Risk, Capacity, Techno-legal framework
Mode of delivery	Power point presentation
Suggested Reading	a) Vulnerability of disaster in India India's vulnerability to Disasters by iasscore https://iasscore.in/bharat-katha/indias-vulnerability-to-disasters b) Impact of disaster in India "Disaster Management in India" by Ministry of Home Affairs http://sdmassam.nic.in/pdf/publication/undp/disaster_management_in_india.pdf c) Measurements taken "Comparative Analysis of Disaster Management system between the State of Odisha and Gujarat" by Sanjeev Kumar and Balram Pradhan https://www.questjournals.org/jrhss/papers/vol10-issue6/Ser-4/L10066474.pdf d) Carter, W. N. (2008). Disaster management: A disaster manager's handbook. https://publichealth.tulane.edu/blog/what-is-disaster-management/ e) Disaster Management- Terminology: Disaster_terminology.pdf (nidm.gov.in)

SESSION 3.2.3: PHASES OF DISASTER MANAGEMENT AND TECHNO-LEGAL FRAMEWORK

After understanding the concept of disaster, a brief introduction is to be given to the different disaster management stages. This session will provide a profound idea about organizing, planning, and application of measures towards preparing for, responding to and recovering from disasters. Disaster management stages will focus on Disaster Risk Reduction (DRR) by focusing on preparedness to decrease the impact of disaster and the risk associated.

Session learning Units:

a) Mitigation Phase
b) Preparedness Phase
c) Recovery Phase
d) Response Phase
e) Institutional mechanism

Time required	**40 minutes**
Session objectives	1. Provide basic concept of disaster management 2. Explain various phases of disaster management cycles 3. Describe various cycles with examples
Keywords	Mitigation, Preparedness, Response, Recovery
Mode of delivery	Presentation, Case Studies
Suggested Reading	a) Disaster Management Cycle: what Is Disaster Management? Understanding Emergencies From Prevention to Mitigation https://publichealth.tulane.edu/blog/what-is-disaster-management/ b) Mitigation Phase "History of earthquake mitigation activities" by FEMA https://www.fema.gov/emergency-managers/risk-management/earthquake/state-assistance-program-grants/history-mitigation-activities "Earthquake mitigation Handbook" by FEMA https://www.conservationtech.com/FEMA-WEB/FEMA-subweb-EQ/INDEX.HTM "Earthquake Risk Reduction in Buildings and Infrastructure Program" by NIST https://www.nist.gov/programs-projects/earthquake-risk-reduction-buildings-and-infrastructure-program c) Preparedness Phase "Earthquake Preparedness What Every Child Care Provider Needs to Know" by FEMA https://www.ready.gov/sites/default/files/2020-03/earthquakes_what-child-care-providers-need-to-know.pdf

	"Earthquake Preparedness checklist" by Anthony Redon https://speaker.asmdc.org/earthquake-preparedness-checklist "Quakesmart Toolkit" by Ready Business https://www.ready.gov/sites/default/files/2020-04/ready-buisiness_quakesmart_toolkit.pdf d) Recovery Phase "Earthquake Safety at Home" by FEMA https://www.fema.gov/sites/default/files/2020-08/fema_earthquakes_fema-p-530-earthquake-safety-at-home-march-2020.pdf "Long term disaster recovery plan" by https://abag.ca.gov/sites/default/files/oakland_long_term_disaster_recovery_plan.pdf "Earthquake Recovery Resources" by theforakergroup https://www.forakergroup.org/earthquake-recovery-resources/ e) Response Phase "Earthquake Action Plan" St. Philip Catholic Church https://www.stphilipwoodland.com/67 f) Institutional Mechanism

3.3 SUB-MODULE 3: INTRODUCTION TO EARTHQUAKE

SESSION 3.3.1: INTRODUCTION

India is considered one of the most earthquake-prone regions in the world. Before getting familiar with the mitigation and management of the earthquake, it is essential for one to understand the origin and cause of earthquake hazard and its major parameters. A basic knowledge of the seismology would provide trainees the understanding of the probability of earthquake and the vulnerability from an earthquake

Session Learning Units:

1. Origin and cause of an earthquake
2. Types of Earthquake
3. Earthquake parameters
4. Impact of an Earthquake
5. Earthquake Scenario in India and Globally

Time required	**60 minutes**
Session objectives	1. Describing the concept of earthquake and the science behind the origin of the earthquake 2. Explain each parameters of the earthquake and its relation

	3. To describe the impact and effect of a major earthquake 4. Visualization of earthquake scenarios in India and globally
Keywords	Seismology, Magnitude, Intensity
Mode of delivery	Presentation, Discussion, videos
Suggested Reading	a) “The Science of earthquake” by USGS https://www.usgs.gov/programs/earthquake-hazards/science-earthquakes b) “Earthquakes” https://www.ncess.gov.in/images/Earthquakes_Comp.pdf c) Earthquake Damage, Danger & Destruction https: www. earthquakeauthority.com/Blog/2020/How-Earthquakes-Cause-Damage-Destruction d) Earthquake measurements by NIDM https://nidm.gov.in/easindia2014/err/pdf/earthquake/earthquakes_measurement.pdf e) “The Human Impact of Earthquakes: a Historical Review of Events 1980-2009 and Systematic Literature Review” by National Library of Medicine https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3644288/ f) Earthquakes in India: Types & Causes Explained https://www.godigit.com/guides/natural-disasters/causes-of-earthquakes g) Types of earthquakes based on various factors https://dreamcivil.com/types-of-earthquake/

SESSION 3.3.2: SEISMIC ZONATION

The occurrence of the earthquake is not evenly distributed in India. But the regular occurrence of the earthquake necessitates the need for understanding the associated seismic risk and the seismic hazard zonation of our country. The seismic zonation mapping at larger scale (micro-zonation) would help the public about varying severity from seismicity in an area.

This session would provide the participants with the adequate knowledge of the current seismic zonation maps. Also, the session will discuss the proposed new seismic zonation and micro-zonation and its benefits.

Session learning Unit:

1. What is seismic hazard and seismic zoning?
2. Why is seismic zoning necessary in India?
3. Current seismic zones of India and proposed new seismic zonation strategies

Time required	30 minutes
Session objectives	1. Introducing the concept of seismic zonation and seismic microzonation. 2. Understanding the practical use and importance of seismic zonation in India.
Keywords	Seismicity, zonation, micro-zonation
Mode of delivery	Presentation, Seismic maps, Handouts
Suggested Reading	a) What is a seismic zone, or seismic hazard zone? By USGS https://www.usgs.gov/faqs/what-seismic-zone-or-seismic-hazard-zone b) Seismic Mapping by Ministry of Earth Sciences https://pib.gov.in/PressReleasePage.aspx?PRID=1740656 c) Seismic Factors/ Zones in India and its Importance in Construction https://happho.com/seismic-factorszones- india-importance construction/ d) Introduction to Seismic zones and codes, Global and National seismic hazard assessment mapping programs https://www.sefindia.org/forum/download.php?id=8392&sid=261c4e22ceabe7eb37b725bb0db103bd

SESSION 3.3.3: EFFECTS OF EARTHQUAKE

Through this session, trainees would be able to grasp the understanding on impact and effect of an earthquake that must be reduced to safeguard the created built environment from a seismic event. Earthquakes can cause widespread destruction to both the natural environment and the built environment. However, due to the higher impact caused by damage to the built environment, earthquakes can have particularly devastating consequences for communities. It is crucial for disaster management efforts, to prioritize the resilience of the built environment and ensure that structures and infrastructure are designed to withstand the effect of seismic activity. Additionally, it is vital to consider how this might affect the socioeconomic and psychological components of the community as well.

It is also important to note that the impact of earthquakes can vary significantly for urban and rural sectors. In urban areas, the concentration of critical infrastructure and densely populated areas can lead to higher levels of damage and loss of life. On the other hand, rural communities may be more vulnerable to the indirect effects of earthquakes, such as disruptions to supply chains and market access, which can have long-term social and economic impacts. Disaster management efforts for earthquake must take these differential impacts into account and prioritize the most vulnerable communities.

Session Learning Units:

1. Effects on built environment and natural environment
2. Effect on socio-economic aspect of a society
3. Secondary effects due to impact of earthquake

Time required	**60 minutes**
Session objectives	1. Understanding the effect of earthquake on natural and built environment 2. An insight on what determines the impact of earthquake. 3. To discuss the secondary effects of an earthquake event
Keywords	Built environment, socio-economic, secondary effect
Mode of Delivery	Presentation, Case Studies
Suggested Reading	(a) Earthquakes' Impact on Society https://quantectum.com/earthquakes-impact-on-society/ (b) The Indian Ocean Tsunami and its Environmental Impacts by Hari Srinivas https://www.gdrc.org/uem/disasters/disenvi/tsunami.html (c) How Disasters Affect People of Low Socioeconomic Status by SAMHSA https://www.samhsa.gov/sites/default/files/dtac/srb-low-ses_2.pdf (d) Impact of earthquakes and their secondary environmental effects on public health https://ui.adsabs.harvard.edu/abs/2017EGUGA..19.3884M/abstract (e) What determines the impact of an earthquake https://www.rgs.org/CMSPages/GetFile. aspx?nodeguid=3af83003-6a54-4a13-9b65- ef78b463f86e&lang=en-GB

3.4 SUB-MODULE 4: STRATEGIES FOR EARTHQUAKE RISK MITIGATION

Effective earthquake risk mitigation requires a comprehensive approach that combines both pre-disaster measures and post-disaster responses. Pre-disaster measures can include identifying high-risk areas, retrofitting of existing buildings to withstand seismic activity, creating emergency response plans, and educating the public on earthquake safety. Post-disaster responses can include search and rescue operations, providing immediate medical assistance, restoring critical infrastructure, and developing long-term recovery plans. This sub-module will hence reflect on the different aspects of mitigation measures which can be applied at different stages of disaster management cycle.

SESSION 3.4.1: EARTHQUAKE PREDICTION

One of the key challenges in earthquake risk mitigation and management is the lack of accurate and reliable earthquake prediction mechanisms. Currently, scientists use a combination of methods to try and predict earthquakes areas, including monitoring seismic activity, studying historical earthquake patterns, and analysing the movement of tectonic plates.

Session Learning unit: Historical and current scientific research and updates on earthquake prediction mechanism at global and national level.

Time required	**30 minutes**
Session objectives	1. To understand about earthquake prediction mechanism 2. To discuss about the history of the prediction 3. Understand why earthquake prediction is difficult and the available prediction causes
Keywords	Prediction, earthquake
Mode of delivery	Presentation, Case Studies
Suggested Reading	Earthquake prediction, forecasting and mitigation https://www.geolsoc.org.uk/~/media/shared/documents/policy/earthquake%20briefing.pdf?la=en

SESSION 3.4.2: EARTHQUAKE FORECAST AND WARNING

Earthquake Early Warning System is a valuable tool in providing timely alerts for earthquakes. This session discusses about the past assessment of the events and security measures adapted for the preparation of the seismic event globally. The Indian Meteorological Department has been developing an Earthquake Early Warning System (EEWS) to issue alerts to residents in affected areas based on seismic data from seismometers across the country. The National Disaster Management Authority (NDMA) with NCS and MoES has been involved in establishing an advanced national seismic network and early warning system for India. Other initiatives include smartphone apps and research projects aimed at improving the accuracy and effectiveness of EEWS, representing important steps towards improving earthquake preparedness and reducing the impacts of future seismic events.

Session Learning Units:

1. Earthquake Early Warning System (EEWS) concept
2. Past assessment at International level and national level
3. Challenges regarding the implementation of the earthquake early warning system

Time required	**40 minutes**
Session objectives	1. Understanding the concept of EEWS 2. Discuss the implementation process and 3. Good Practices worldwide on the early warning system
Keywords	EEWS, risk, assessment
Mode of delivery	Presentation, Case Studies
Suggested Reading	(a) Early warning. U.S. Geological Survey https://www.usgs.gov/programs/earthquake-hazards/science/early-warning (b) Earthquake Early warning. IIT Roorkee https://ndmindia.mha.gov.in/images/pdf/EARTHQUAKE-EARLY- WARNING.pdf (c) Earthquake Early Warning Systems as an Asset Risk Management Tool. https://www.mdpi.com/2673- 4109/2/1/7 Limitations and challenges of early warning systems: A case study of the 2018 Palu-Donggala Tsunami. https://reliefweb.int/report/indonesia/limitations-and-challenges-early-warning-systems-case-study-2018-palu-donggala

SESSION 3.4.3: EARTHQUAKE RISK MITIGATION MEASURES – STRUCTURAL AND NON-STRUCTURAL

Understanding the lack of good prediction and early warning for earthquake, the mitigation measures that include precautions for building safety from earthquakes need to be adopted depending upon the risk of an area. Risk Sensitive Land Use Planning should be done to reduce the vulnerability from future earthquake risk. However, the structural retrofitting of vulnerable and seismically deficient infrastructure becomes a critical step to ascertain resilience. The aim of this session is providing brief idea about the various structural and non-structural measurements practiced in India and globally.

Session Learning Units:

1. Structural mitigation measures
   - 1.1. Bureau of Indian Standards
   - 1.2. Retrofitting of the building
   - 1.3. Construction typology evaluation
2. Non-structural mitigation measures
   - 2.1. Land-use planning
   - 2.2. Capacity building
   - 2.3. Community-based awareness
   - 2.4. Insurance

Time required	90 minutes
Session objectives	1. Describing the various earthquake risk mitigation measures adopted by Bureau of Indian Standards for a building 2. To address the common non-structural mitigation measures which can be easily implemented
Keywords	Retrofitting, Land-use, Capacity Building
Mode of delivery	Presentation, Case Studies
Suggested Reading	a) Bureau of Indian Standards (BIS) website https://www.bis.gov.in/ b) Indian Seismic Codes. IIT Kanpur. https://www.iitk.ac.in/nicee/EQTips/EQTip11.pdf c) Seismic Retrofitting Strategies of Reinforced Concrete Buildings. https://iitr.ac.in/Departments/Earthquake%20Department/static/e-learning/seismic_retrofitting_p1.pdf d) Building typology classification and earthquake vulnerability scale of Central and South Asian building stock. https://www.sciencedirect.com/science/article/abs/pii/S2352710216303485 e) Urban Planning as an Instrument for Disaster Risk Reduction in the Uttarakhand Himalayas.JSTOR. https://www.jstor.org/stable/48695044 f) Earthquake Capacity Building and Risk Reduction Measures In Gujarat Post Bhuj 2001 Earthquake. https://www.iitk.ac.in/nicee/wcee/article/13_2018.pdf g) Community-based disaster management: a review of progress in China. https://link.springer.com/article/10.1007/s11069-012-0471-3 h) Management of earthquake by NDMA https://nidm.gov.in/PDF/pubs/NDMA/a.pdf i) SEEDS (2018) Community based Disaster Preparedness https://www.seedsindia.org/uploads/2020/07/Task-force-handbook-English.pdf j) Earthquake Risk Reduction Development and Disaster Management Programme in India https://www.ijsrd.com/articles/IJSRDV2I11176.pdf

TIPS: *Provide interactive session showcasing video clips of using techniques for seismic retrofitting such as base isolation, use of dampers, cross bracings etc.*

SESSION 3.4.4: PRE-DISASTER AND POST-EARTHQUAKE PREVENTIVE MEASURES

This session aims at discussing the long-term, short-term measures that can be taken before and after the disaster so as to prevent the same damage or maximum damage that an earthquake can cause in future. The session also gives information about the do's and don'ts before, during, and after the earthquake.

Session Learning Units:

1. Pre-disaster preventive measures
2. Post-disaster preventive measures
3. Earthquake Do's and Don'ts

Time required	**20 minutes**
Session objectives	1. To point out the major long-term and medium-term preventive measurements before an earthquake 2. To provide the precautions that should be taken during different phases of earthquake
Mode of delivery	Presentation, Earthquake Do's and Don'ts chart or IEC material, Mock Drill or Demonstration
Suggested Reading	a) Earthquake Do's and Don'ts's https://www.ndma.gov.in/Natural-Hazards/Earthquakes/Dos-Donts b) Earthquakes https://www.cdc.gov/disasters/earthquakes/index.html

SESSION 3.4.5: LIQUEFACTION AND SEISMIC MICROZONATION

Earthquake shaking has the ability to turn loosely packed, water-saturated soil to behave as liquid and the phenomena is called liquefaction. Liquefied soil loses its density and ultimately the ability to support infrastructures built on them. To understand the impact of earthquake, the secondary effects like liquefaction need to be dealt in detail. For example, most of the northern Indo-Gangetic Plains have the tendency to observe this phenomena which can bring large devastation to the cities like Delhi. Hence, liquefaction and their identification through seismic microzonation has been given importance in this session. Participants in this training session will gain a better understanding of several approaches for determining potential for liquefaction as well as corrective actions to lessen the impact. In this session, the seismic microzonation study for the assessment of earthquake hazard is also covered.

Session Learning Units:

1. Liquefaction phenomena
   - 1.1. Liquefaction of sands
   - 1.2. How to reduce liquefaction hazards
2. Seismic Microzonation
   - 2.1. Importance of seismic micro-zonation
   - 2.2. Delhi Micro-zonation

Time required	30 minutes
Session objectives	1. To understand the phenomenon of liquefaction, specifically in relation to sands, and identify potential hazards associated with it. Learn about the methods and techniques to reduce liquefaction hazards. 2. To recognize the importance of seismic microzonation and its applications in earthquake risk assessment and mitigation.
Keywords	Liquefaction, Seismic hazards, Microzonation
Mode of delivery	Slide share presentation, Case Studies
Suggested Reading	a) What is liquefaction? https://www.usgs.gov/faqs/what-liquefaction#:~:text=Liquefaction%20takes%20place%20when%20loosely,cause%20major%20damage%20during%20earthquakes. b) Liquefaction Susceptibility https://earthquake.usgs.gov/education/geologicmaps/liquefaction.php c) Reducing the Risks of Non-Structural Earthquake Damage https://www.fema.gov/node/reducing-risks-non-structural-earthquake-damage d) Seismic Microzonation: Principles, Practices and | Experiments. http://civil.iisc.ernet.in/~anbazhagan/pdf/Anbu%20IISc%20J-5.pdf e) Seismic Microzonation https://nidm.gov.in/ e a s i n d i a 2 0 1 4 / e r r / p d f / e a r t h q u a k e / s e i s m i c _microzonation pdf f) An overview on the seismic zonation and microzonation studies in India https://www. s c i e n c e d i r e c t . c o m / s c i e n c e / a r t i c l e / a b s / p i i /S0012825209000828

3.5 SUB-MODULE 5: EARTHQUAKE PREPAREDNESS

SESSION 3.5.1: EARTHQUAKE PREPAREDNESS AND ITS COMPONENTS

Earthquake preparedness attempts to aid individuals in preventing disaster threats and ensuring that those who may be affected by a disaster will receive the appropriate care. The elements of disaster preparedness are also covered in this session, along with a general overview of forecasting and warning systems. Participants would be able to comprehend the difficulties encountered when setting up a disaster preparedness system and how to make plans to succeed in this stage of management by the end of the session.

Session Learning Units:

1. Components of Earthquake preparedness
2. Good practices of earthquake

Time required	**45 minutes**
Session objectives	1. Introducing the concept of earthquake preparedness 2. Understanding how to establish a successful disaster preparedness planning 3. Sensitize trainees about the good practices concerning preparedness measures for an earthquake.
Keywords	Preparedness, Planning, Vulnerability Assesment, Early Warning
Mode of delivery	Presentation, Case Studies
Suggested Reading	a) How to prepare for an earthquake. Red cross. https://www.redcross.org/get-help/how-to-prepare-for-emergencies.html b) Emergency Management in the United States. FEMA. https://training.fema.gov/emiweb/downloads/is111_unit%204.pdf c) Emergency Management in BC: Reference Manual. British Columbia. http://pepbc.com/documents/reference_manual.pdf d) Matrix of IEC material for earthquake Safety and Preparedness https://ndma.gov.in/sites/default/files/PDF/Earthquake/Matrix-of-IEC-Materials_20180614.pdf e) Earthquake Do's and Don'ts https://nidm.gov.in/PDF/IEC/EQ-15.pdf

SESSION 3.5.2: CAPACITY BUILDING

Training and capacity building is a cross-cutting element that extends across the different components of disaster risk management. Capacity building is an ongoing process that equips officials, stakeholders and the community to perform their functions in a better manner during a crisis/disaster. Under this session, trainees will focus on role and responsibilities of Policymakers, implementing agencies, local authorities, civil society organizations and everyone involved in earthquake risk mitigation. All these stakeholders need to acquire the appropriate concepts, tools and methodologies necessary to become informed and engaged contributors. The participants will also have the opportunity to learn how to interact with different stakeholders and include communities in tasks like education, establishing institutions, community-based education, coordination, volunteering and outreach of information.

Session Learning Units:

1. Capacity building
1.1 Elements of capacity building
1.2 Earthquake related capacity building initiatives in India

Time required	30 minutes
Session objectives	1. Introducing the Capacity Building strategies for Earthquakes 2. Understanding how to establish more interactive partnership between different stakeholders involved in Earthquake management activities.
Keywords	Capacity Building, Training, NGO
Mode of delivery	Presentation, Good practices case studies
Suggested Reading	a) Earthquake capacity building and risk reduction measures https://www.iitk.ac.in/nicee/wcee/article/13_2018.pdf b) Capacity development. UNDP. https://unsdg.un.org/sites/default/files/UNDG-UNDAF-Companion-Pieces-8-Capacity-Development.pdf c) Capacity building and training materials. WHO. https://www.who.int/activities/capacity-building-and-training-materials d) ADBI Capacity Building and Training. Asian Development Bank. https://www.adb.org/adbi/capacity-building-training

SESSION 3.5.3: COMMUNITY-BASED EARTHQUAKE PREPAREDNESS

State and civil society leads a major role in successful preparedness strategies. The state can provide the collaborative effort from knowledge, technology, skills, and resources. The disaster reduction needs some community-based involvements from NGO's. By including young people and local communities in planning, preparation, rescue, and damage assessment, capacity for managing an earthquake event can be increased. This session would help trainees to understand how NGO's and a community can play major ways in Community-Based Disaster Preparedness.

Session Learning Units:

1. Community-Based Disaster Preparedness (CBDP)
2. Community Based DRR Approach – Discussion on NDMA Guidelines on CBDRR

Time required	45 minutes
Session objectives	1. Introducing the concept of Community-based Disaster Preparedness 2. Understanding the role of community in mainstreaming DRR
Keywords	NGO, Disaster, Community, CBDRR
Mode of delivery	Presentation, Case Studies

Suggested Reading	a) National program for capacity building of architects in earthquake risk management https://nidm.gov.in/PDF/safety/earthquake/link14.pdf b) A guide to community-based disaster risk reduction in Central Asia. UNDRR. https://www.undrr.org/publication/guide-community-based-disaster-risk-reduction-central-asia c) Community Based Disaster Risk Management. NDMA. https://ndma.gov.in/sites/default/files/PDF/Guidelines/CBDRR_Guidelines_Oct_2024.pdf

SESSION 3.5.4: EARTHQUAKE EDUCATION, TRAINING AND CAPACITY ENHANCEMENT

The session is designed to discuss the importance of earthquake education and training for enhancing the capacity to deal with seismic events. This session aims to provide an overview of various training and education programs that can help individuals, communities, and organizations to prepare for and respond to earthquakes effectively. It also focuses on the key capacity-building initiatives and their impact on mitigating the impact of earthquakes.

Session Learning Units:

1. Planning of earthquake risk mitigation and prevention at local level
2. Training and exercises

Time required	**45 minutes**
Session objectives	1. Explain the step involving the preparedness cycle to build capabilities 2. To provide information regarding trainings and capacity building exercise
Keywords	Capacity building, Training, Exercises
Mode of delivery	Presentation, Discussion, Experience sharing
Suggested Reading	Earthquake education and disaster risk program https://www.preventionweb.net/files/3426_Earthquake full.pdf

3.6 SUB-MODULE 6: POST-EARTHQUAKE RELIEF AND RESPONSE

The post-earthquake relief and response session is a critical aspect of earthquake risk management. This session focuses on the immediate actions and steps to be taken after an earthquake to help affected individuals and communities. The main objective is to provide humanitarian assistance, medical aid, food, water, and shelter to the affected people. Additionally, the session also emphasizes the importance of conducting damage assessments and initiating the recovery and rehabilitation process. Effective post-earthquake relief and response measures can significantly reduce the impact of earthquakes on communities and help them to recover quickly.

SESSION 3.6.1: ASSESSING INITIAL NEEDS

Any large earthquake event has the tendency to bring large devastation along with aftershocks which themselves can be fatal and damaging. In the immediate aftermath of an earthquake, individuals, organisations, and regional/national level bodies must all contribute. In view of causing a large scale of devastation, various initiatives are required for rescue, relief and rehabilitation as well as reconstruction works. At an early stage, assistance for the impacted persons is urgently needed from the community and Government bodies. The need for immediate response and the Standard Operation Procedure during the initial hours of the seismic events would be addressed in this session.

Session Learning Units:

1. Search and Rescue
2. Medical First Response
3. Psychosocial Support
4. WASH
5. Immediate Shelter
6. Incident Response System

Time required	**60 minutes**
Session objectives	1. To explain information regarding the basic needs for the affected people 2. Providing information regarding how emergency response to be initiate in a short time period. 3. Describe innovative tools that are being developed to assist in response efforts.
Keywords	Relief, Response, Shelter
Mode of delivery	Presentation, Discussion of case studies of Relief operations, Audio- Visuals
SuggestedReading	a) Post-earthquake impact and need assessment file:///C:/Users/Hp/Downloads/tmi_needs_assessment_final_report_sept2015-resized_copy%20(1).pdf b) INSARAG GUIDELINES 2020. https://www.insarag.org/methodology/insarag-guidelines/ c) UN Disaster Assessment and Coordination (UNDAC). https://www.unocha.org/our-work/coordination/un-disaster-assessment-and-coordination-undac d) Be the One Who Makes a Difference When “Minutes Matter”. American Red Cross. https://www.redcross.org/take-a-class/lp/cpr-first-aid-aed-certification-new-hero e) Emergency Medical team. WHO. https://www.who.int/emergencies/partners/emergency-medical-teams

	f) Mental Health and Psychological support. IFRC. https://www.ifrc.org/our-work/health-and-care/community-health/mental-health-and-psychosocial-support#:~:text=IFRC%20Reference%20Centre%20for%20Psychosocial,health%20and%20psychosocial%20support%20experts. g) Water, Sanitation and Hygiene (WASH). UNICEF. https://www.unicef.org/wash h) Shelter. UNHCR. https://www.unhcr.org/shelter.html i) Incident Response System. NDMA. https://ndma.gov.in/Capacity_Building/Ops_Comm/IRS

SESSION 3.6.2: ORGANIZATIONS, SERVICES, AND DEPARTMENTS

During an emergency event, the people affected need support in rebuilding their lives. The decision making bodies in collaboration with various other organizations, departments and agencies in State-level and National-level quickly come into action as per their roles and responsibilities already defined and or given at the time of emergency. This session give details about National, State and local level bodies which activates their work as per SOP in all the post-earthquake phase. The session also intend to give some standard operating procedures by various forces in State-level and National-level.

Session Learning Units:

1. Emergency Operation Centres (EOC)
2. National Disaster Response Force (NDRF)
   2.2. State Disaster Response Force (SDRF)
3. National Disaster Management Authority (NDMA)
   3.1. State Disaster Management Authority (SDMA)
   3.2. District Disaster Management Authority (DDMA)
4. National Institute of Disaster Management (NIDM)
5. Fire and Emergency Services
6. Civil Defence and Home Guards
7. Armed Forces
8. Emergency Support Functions (ESF)
9. Other State-level and District-level Authority and Committees

Time required	**45 minutes**
Session objectives	1. To understand the guidelines of various organizations, departments, and services 2. Brief explanation on the objective of all units at all levels
Keywords	Emergency, Relief and Response
Mode of delivery	Presentation and Discussion

Suggested Reading	a) Comprehensive landslide risk assessment https://nidm.gov.in/pdf/modules/landslide.pdf b) Emergency Operation Center How-to Quick Reference Guide. https://www.fema.gov/sites/default/files/documents/fema_eoc-quick-reference-guide.pdf c) NDRF website https://www.ndrf.gov.in/ d) NDMA Guidelines https://ndma.gov.in/Governance/Guidelines e) Emergency preparedness. NFPA. https://www.nfpa.org/Public-Education/Staying-safe/Preparedness/Emergency-Preparedness f) Civil Defense. Ministry of Home Affairs. https://dgfscdhg.gov.in/civil-defence g) Humanitarian Assistance and Disaster Relief. https://www.ids.nic.in/hadr.php h) Emergency Support Function. FEMA. https://www.fema.gov/cbrn-tools/key-planning-factors-chemical-incident/appendix_f

SESSION 3.6.3: DAMAGE ASSESSMENT

To make the right decision for supporting the community during their recovery and rehabilitation, quantification of damage and loss incurred need proper documentation. Accordingly, it is important to evaluate the actual physical damage done to infrastructure and buildings in a standard scientific manner. Undertaking these assessments is a complex process that calls for quick decision in a limited amount of time regarding the situation, location, and demands of the individuals. Additionally, it is important to examine the socioeconomic effects of different groups throughout these assessment stages as well.

Session Learning Units:

1. Damage Assessment
    1.1. Rapid Visual Screening (RVS) Assessment
    1.2. Detailed safety assessment
    1.3. Engineering evaluation
2. Post Disaster Need Assessment (PDNA)
3. Dealing with debris

Time required	**45 minutes**
Session objectives	1. Information regarding various phases of earthquake risk assessment process 2. Explain how to deal with the debris
Keywords	Assessment, damage, debris, vulnerability
Mode of delivery	Presentation, Enabling exercises, Case studies, handouts of standard format of PDNA.

Suggested Reading	a) Earthquake guidelines on preparing, responding and recovery Rehab and Recons Ref-imp.pdf b) Rapid Visual Screening of Buildings for Potential Seismic Hazards: A Handbook. FEMA. https://www.fema.gov/sites/default/files/2020-07/fema_earthquakes_rapid-visual-screening-of-buildings-for-potential-seismic-hazards-a-handbook-third-edition-fema-p-154.pdf c) A Primer on Rapid Visual Screening (RVS) Consolidating Earthquake Safety Assessment Efforts in India https://ndma.gov.in/sites/default/files/PDF/Technical%20Documents/RVS-Doc-11-2020.pdf d) Post Disaster Needs Assessment (PDNA) – Training Modules.. https://nidm.gov.in/PDF/Modules/PDNA_TOT_2021.pdf e) Public Assistance Debris Monitoring Guide. FEMA. https://www.fema.gov/sites/default/files/documents/fema_debris-monitoring-guide_sop_3-01-2021.pdf f) Post-Earthquake Rapid Damage Assessment Needs and Challenges http://saarc-sdmc.org/sites/default/files/programmes_doc_upload/Day3-Session-2-Mr-Shashank-Mishara.pdf

SESSION 3.6.4: ROLE OF MEDIA IN EMERGENCY RESPONSE

The role played by media in any phase of disaster management is crucial in mobilizing the required support and solution. Media can assist in providing right information at right time, that provide information on aftermath of an earthquake that include casualties, damage, the supplies, and skills that are needed. Though various advanced communication means are available for early warnings, evacuation plans and help in post-disaster activities, the success of all efforts depends largely on the understanding the officials have with the media. This session discusses about the various technologies in media and impact of media.

Session Learning Units:

1. Media and Emergency Response
2. Role of Media and its importance in Post disaster

Time required	**45 minutes**
Session objectives	1. Provide information how media can help inform a wider audience 2. Negative and positive aspects of media in handling disaster management

Keywords		Media, disaster, communication
Mode of delivery		Presentation, Case study
Suggested Reading	a)	Role of media in disaster management https://www.academia.edu/7402446/Role_of_Media_in_Disaster_management_Dr_Dave_2
	b)	National Conference on Media in Disaster Management – 2020. https://npdrr.nidm.gov.in/pdf/pre_events/PE11/Media_Conference.PDF
	c)	The Role of Social Media In Crisis Preparedness, Response and Recovery. Jason Christopher Chan (RPO). https://www.oecd.org/governance/risk/The%20role%20of%20Social%20media%20in%20crisis%20preparedness,%20response%20and%20recovery.pdf
	d)	The role of media in crisis management: A case study of Azerbaijan earthquake https://www.researchgate.net/publication/312160918_The_role_of_media_in_crisis_management_A_case_study_of_Azarbayejan_earthquake

3.7 SUB-MODULE 7: SHORT TERM EARTHQUAKE RECOVERY-REHABILITATION

The phases of disaster response and relief are transient, but by carefully planning and carrying out a long-term recovery programme after an earthquake, an afflicted area could achieve overall development. Rehabilitating local services connected to meeting urgent needs is the initial stage of the process. Replacement of broken structures, upgrading of infrastructure, and replacement of temporary accommodations are all included in rehabilitation.

SESSION 3.7.1: PHYSICAL REHABILITATION

In this session, trainees will learn about the process of short-term and long-term physical rehabilitation. It includes reconstruction of physical infrastructure, such as, houses, buildings, railways, roads, communication network, water supply, electricity etc.

Session Learning Units:

1. What is Physical Rehabilitation?
2. Need for Disaster Resilient house construction practices

Time required	30 minutes
Session objectives	1. Introducing the concept of physical recovery and rehabilitation 2. Explain the basic aspects of physical rehabilitation
Keywords	Physical, Rehabilitation, Construction, Recovery
Mode of delivery	Presentation
Suggested Reading	a) Earthquake guidelines on preparing, responding and recovery https://reliefweb.int/report/world/earthquakes-guidelines-preparing-responding-and-recovering b) Building Codes Toolkit For Building Owners and Occupants. https://www.fema.gov/sites/default/files/documents/fema_building-codes-toolkit_07-19-2021.pdf

SESSION 3.7.2: SOCIAL REHABILITATION

The earthquake disaster can impact the community differently for different social background. The vulnerable groups would need special social support to survive the impact of disaster. Thus, construction of infrastructure such as community centres, day care centres, anganwadis, old age homes, etc., is a vital part of social rehabilitation. Social rehabilitation aims at strengthening the existing health facilities and infrastructure, educational activities, and rehabilitation of women and children affected by the disaster. This session would help participants understand various aspects of ensuring social and economic rehabilitation.

Session Learning Units:

1. Healthcare facilities and Infrastructure Rehabilitation
2. Rehabilitation of educational activity
3. Rehabilitation of women, children and specially-abled group

Time required	30 minutes
Session objectives	1. Discuss the social aspects of rehabilitation 2. Describing various activities to ensure social and economic aspects of rehabilitation
Keywords	Social, Rehabilitation, Economic
Mode of delivery	Presentation
Suggested Reading	a) Rehabilitation: Social and Economic aspects https://egyankosh.ac.in/handle/123456789/26585 b) UNICEF: The United Nations Children's Fund. https://www.un.org/youthenvoy/2013/09/unicef-the-united-nations-childrens-fund/ c) OCHA. https://www.unocha.org/about-ocha d) Community Health. IFRC. https://www.ifrc.org/our-work/health-and-care/community-health

SESSION 3.7.3: PSYCHOSOCIAL REHABILITATION

Not only the societal issues and structures are harmed in the event of an earthquake but one must consider the trauma experienced by the afflicted population. Only after careful monitoring of the affected individuals' mental health, the psychosocial rehabilitation can be carried out properly. This session would focus on the process of psychological recovery and the steps that should be followed to solve the issue.

Time required	**20 minutes**
Session objectives	1. Discuss the psychological aspects of rehabilitation 2. Understand the steps that needed to be taken to treating people suffering from trauma
Keywords	Psychosocial, Mental Health
Mode of delivery	Presentation
Suggested Reading	Rehabilitation: Social and Economic aspects https://egyankosh.ac.in/handle/123456789/26585

3.8 SUB-MODULE 8: LONG-TERM POST-EARTHQUAKE RECOVERY - RECONSTRUCTION

The process of long-term recovery is used to resolve the problems brought on by the earthquake and rebuild the area with an appropriate strategy and measures for the future disaster in mind. This requires a protracted period that involves engaging the local government, enacting building codes, helping community members grow their capacities and transferable skills, and setting priorities for the requirements that existed prior to an earthquake.

SESSION 3.8.1: BUILDING BACK BETTER (BBB)

Building Back Better is a concept that emerged in the aftermath of disasters, which aims to rebuild communities and infrastructure in a way that is more resilient and sustainable than before. It involves not only reconstructing damaged or destroyed buildings and infrastructure, but also addressing underlying vulnerabilities, such as inadequate building codes, poor land-use planning, and lack of access to resources and services. The goal is to create more resilient communities that can better withstand future disasters and minimize their impact. Building Back Better is an important approach to disaster recovery and risk reduction, and has been widely adopted by governments, NGOs, and international organizations around the world.

Session Learning Units:

1. Concept of Building Back Better (BBB)
2. The need for BBB
3. Implementation of BBB
4. Sendai Framework for Disaster Risk Reduction (SFDRR)
5. Case study for Building Back Better (Gujarat Earthquake, 2001 and Sikkim Earthquake 2011)

Time required	45 minutes
Session objectives	1. Introduce the concept of Building Back Better (BBB) and its guidelines 2. Discuss the key elements required to improve the post-disaster reconstruction and recovery practices to BBB.
Keywords	Recovery, Reconstruction, SFDRR
Mode of delivery	Presentation, Case Studies
Suggested Reading	a) “Building Back Better” Principles for reconstruction https://buildbackbetter.co.nz/wp-content/uploads/2017/02/Build-Back-Better-Principles-for-Reconstruction-Published-Chapter.pdf b) Building Back Better by UNDP https://stories.undp.org/building-back-better c) Building Back Better from the crisis – World Bank https://documents1.worldbank.org/curated/en/163861645554924417/pdf/IDA20-Building-Back-Better-from-the-Crisis-Toward-a-Green-Resilient-and-Inclusive-Future.pdf d) Recovery – IFRC https://www.ifrc.org/our-work/disasters-climate-and-crises/recovery e) What is Sendai Framework for Disaster Risk Reduction. UNDRR. https://www.undrr.org/implementing-sendai-framework/what-sendai-framework#:~:text=The%20Sendai%20Framework%20focuses%20on,existing%20risk%20and%20increase%20resilience. f) Reconstruction and Rehabilitation: https://www.devalt.org/newsletter/may01/lead.htm g) Case Studies: Gujarat 2001: Housing reconstruction and retrofitting after the 2001 Kachchh, Gujarat earthquake (2004) https://www.iitk.ac.in/nicee/wcee/article/13_1723.pdf Building Back Better: A More Resilient Sikkim Post 2011 Earthquake: https://reliefweb.int/report/india/building-back-better-more-resilient-sikkim-post-2011-earthquake-southasiadisastersnet Sikkim Earthquake (2011)- Reconstruction Strategy https://nidm.gov.in/PDF/pubs/SikkimEQ_ReconstuctionStrategy2011.pdf

SESSION 3.8.2: HOUSING RECONSTRUCTION

Housing reconstruction refers to the process of rebuilding homes that have been damaged or destroyed due to natural disasters, conflicts, or other reasons. It is an important aspect of disaster recovery and aims to provide safe and adequate housing for affected populations. Housing reconstruction efforts often involve a range of stakeholders, including governments, aid agencies, NGOs, and the affected communities themselves, and can take many forms, from simple repairs to complete rebuilding projects.

Session Learning Units:
1. Process of reconstruction of shelter and other construction
2. Approaches for reconstruction
3. Housing reconstruction through engineering and individual rural housing
4. Repair and retrofitting

Time required	**25 minutes**
Session objectives	1. Explain the sustainable and safer way to reconstruct the shelter to ensure better safety and security. 2. Introducing various approaches for the reconstruction of the shelter.
Keywords	Reconstruction, Building, Shelter
Mode of delivery	Slide share presentation, Case Studies
Suggested Reading	a) Earthquake guidelines on preparing, responding and recovery https://reliefweb.int/report/world/earthquakes-guidelines-preparing-responding-and-recovering b) The Sphere Handbook: Shelter and Settlements. https://spherestandards.org/wp-content/uploads/Sphere-Handbook-2018-EN.pdf c) Recovery Guidance Note – UNDP. https://www.undp.org/publications/recovery-guidance-note d) Global Program for Resilient Housing – World Bank. https://www.worldbank.org/en/topic/disasterriskmanagement/brief/global-program-for-resilient-housing e) UN-Habitat: United Nations Human Settlements Programme. United Nations. https://www.un.org/youthenvoy/2013/08/un-habitat-united-nations-human-settlements-programme/

SESSION 3.8.3: ECONOMIC RECOVERY

Planning for long-term needs adequate resources financially. Even though the pre-disaster management has been properly managed, the situation emerging due to the immediate event is unpredictable.

Session Learning Units:
1. Action steps for the Economic Recovery

Time required	**20 minutes**
Session objectives	1. Explain the sustainable way to reconstruct the shelter and to ensure its safety and security. 2. Introducing various approaches for the reconstruction of the shelter
Keywords	Reconstruction, Economic, Recovery
Mode of delivery	Slide share presentation, Case Studies
Suggested Reading	a) Earthquake guidelines on preparing, responding and recovery https://reliefweb.int/report/world/earthquakes-guidelines-preparing-responding-and-recovering

SESSION 3.8.4: CASE STUDY: GUJARAT POST-EARTHQUAKE RECOVERY STRATEGY

In many areas of Gujarat, the destructive earthquake that struck India on January 26, 2001, resulted in fatalities and damage to physical infrastructure. The recovery from the tragedy was controlled in each sector with adequate management and reconstruction policy. This session covers the overall recovery strategy approach adopted by all partners and sectors.

Session Learning Units:

1. Community empowerment and social impact mitigation
2. Assessing immediate needs and strategy for each sector
3. Environmental impact
4. Long term reduction

Time required	**120 minutes**
Session objectives	1. Case study regarding the Gujarat post-earthquake recovery program 2. Correlating how the approach has been taken in each sector
Keywords	Gujarat, Recovery, Reconstruction
Mode of delivery	Slide share presentation, Case Studies
Suggested Reading	Gujarat earthquake reconstruction and rehabilitation policy http://www.gsdma.org/uploads/Assets/iec/earthquakerr06172017024901390.pdf Gujarat 2001: Evaluation of Post Disaster Mitigation Strategy of Bhuj Earthquake https://www.ijariit.com/manuscripts/v3i6/V3I6-1275.pdf

SESSION 3.8.5: KASHMIR REHABILITATION

The session titled “Kashmir rehabilitation” focuses on the recovery efforts and rehabilitation strategies implemented after a catastrophic earthquake that struck the Kashmir region of India on October 8, 2005.. This earthquake caused significant damage to physical infrastructure and resulted in numerous fatalities. The session aims to provide an overview of the overall recovery approach adopted by various partners and sectors involved in the rehabilitation efforts. The focus is on the management and reconstruction policies that were implemented to aid in the recovery process. By attending this session, participants will gain insights into the challenges of rehabilitation after a disaster and the strategies and policies that can help in the recovery efforts.

3.9 SUB-MODULE 9: CLOSING SESSION

The closing session includes summarizing the training, involving participants to share their views, opinions and information.

SESSION 3.9.1: FEEDBACK, EVALUATION AND CERTIFICATION

At the end of the training program, evaluation of the knowledge acquired and attitude of the participants would determine their exit behaviour. The feedback from the participants would enable to modify the future training session and module as per feedback.

Trainers should encourage honest and constructive feedback by asking open-ended questions and actively listening to responses. It is also important to acknowledge and address any concerns or issues raised by participants and take steps to improve future training programs based on feedback received.

Trainers should ensure that participants have met the necessary requirements for certification and that certification is provided in a timely manner. The certification process should be transparent and clearly communicated to all participants. Trainers should also ensure that only authorized personnel are responsible for signing the certification and that all necessary documentation is in order.

Session Objective:

1. To assess the exit behaviour of the participants
2. To determine the knowledge and skills achieved through the training program
3. To provide certificates to the participants at the end of the course

Time duration: 60 minutes
Mode of delivery: Informal discussion, Quiz on the course
Training Aid: Flipchart, marker, pen

SESSION 3.9.2: VALEDICTORY FUNCTION

Time duration: 45 minutes

The valedictory function marks the end of the training program and is a crucial step towards summarizing the key learnings and recognizing the participants' achievements. To ensure a successful valedictory function, trainers should begin by reviewing the training objectives and highlighting the program's key takeaways. Additionally, trainers can encourage participants to share their feedback on the training and ask any final questions they may have. During the function, trainers can recognize the participants' achievements and issue certificates of completion to those who have successfully completed the program. Depending on the organization's policies, the certification can be signed by trainers or other authorized personnel. To reinforce the key concepts and lessons learned during the training program, trainers can organize exercises during the valedictory function. These exercises can include role-playing activities, group discussions, or quizzes that test the participants' knowledge and understanding of the material.

It is crucial to make the valedictory function a memorable and engaging experience for the participants. Trainers should ensure that the function is conducted in an organized and professional manner, and they should also take the opportunity to deliver closing remarks to inspire the participants and leave a lasting impression.

PART- C
ANNEXURES

4. BACKGROUND MATERIAL

4.1 Submodule 2: Disaster Management- An Overview

4.1.1 Introduction to Disaster

Disasters are events that cause widespread damage, destruction, and loss of life, and can be triggered by natural or human-made factors. With the growth of infrastructural facilities and populations worldwide, disasters have become increasingly prevalent, resulting in greater physical and economic risks, particularly in rural areas and under developed and developing countries.

Understanding of disaster is important for effective disaster management which requires proactive measures to prevent, prepare for, and respond to disasters, as well as to facilitate recovery efforts in their aftermath. Governments, international organizations, and communities worldwide are working together to develop disaster risk reduction strategies, emergency response plans, and sustainable recovery programs that prioritize the safety, health, and wellbeing of all affected populations. By taking steps to increase resilience and reduce vulnerabilities, we can help mitigate the impact of disasters and build more resilient communities.

The impact of climate change causing changes in climate conditions, has increased the likelihood of weather-related natural disasters. Hotter global temperatures increase the risk of droughts as well as increase the intensity of storms and create wetter monsoons. This lead to issue of global warming, which is the result of the accumulation of greenhouse gases including carbon monoxide, methane, and nitrous oxide. These gases' ability to retain heat raises temperatures, which also contributes to the rise in sea level and depletion of glaciers, causing a number of catastrophes.

Different acts can result in a variety of outcomes, including both natural and man-made disasters. For example: Deforestation is one of the primary causes of flooding, droughts, and desertification in the tropics. The semi-arid region is becoming more susceptible to drought, even in places where there is enough rainfall (Sena, L & Woldemichael, K., 2006). A severe drought reduces agricultural output, and if proper actions are not taken, the situation of a food shortage would worsen. Epidemics are another significant issue that could get worse if population density and migration rise. The pressures of migration, squalor, and overcrowding would raise the mortality rate in the future. A rise in infectious diseases would also result from pest infestation on agricultural food products.

Flooding is most common natural disaster making for 42 percent of all disasters worldwide as per the data captured by the Institute for Economics and Peace between 1900 and 2019. Death through falls, electrocution, and the result of landslides are the immediate effects of flooding. Any event that occurs at sea, like an earthquake, can potentially cause a tsunami. The earth's crust suddenly slips during vibrations, causing an earthquake. It is typically regarded as the terrifying and most destructive calamity to ever occur. The contamination of the air, water, and soil is becoming another negative consequence on people as a result of population growth and urbanisation. The pollution of the terrestrial, river, and marine environments has increased significantly over the past few decades. Fires can be either residential or wildfires. It is primarily brought on by lightning, strong winds, earthquakes, volcanic eruptions, floods, and human-initiated intentional fires.

4.1.1.1 What is disaster?

The World Health Organization (WHO) defines disaster as “a sudden ecological phenomenon of sufficient magnitude to require external assistance” resulting in more deaths, damage, or losses to infrastructure, the environment, vital services, or sources of livelihood than the afflicted population can typically handle. Natural disasters like earthquakes, hurricanes, and floods can also be caused by humans, as can chemical and industrial mishaps.

Disasters frequently cause fatalities and injuries, forced evictions from homes, destruction of infrastructure and property, and interruption of vital services including communication, transportation, and healthcare. Disasters can have long-term impacts in addition to the immediate ones, such as psychological suffering, financial difficulty, and environmental deterioration.

Vulnerability which is described as the characteristics and circumstances that make a community, system, or asset susceptible to the damaging effects of a hazard, is a crucial consideration in disaster management. Disasters can have direct, secondary, and indirect repercussions. Physical injury and death are direct consequences, while secondary effects may include the release of fires or dangerous materials. Indirect effects can also disrupt the movement of products and services, employment, and other essential aspects of daily life.

Effective planning for disaster preparedness, response, and recovery are crucial for reducing the effects of disasters. Making disaster management plans and following protocols, training staff, and storing supplies like food, water, and medical equipment are all parts of preparation. Response entails taking swift action to prevent death, alleviate pain, and control the situation. Rebuilding and restoring the damaged communities to its pre-disaster status is the goal of recovery.

4.1.1.2 Types of disaster

Disasters can vary in duration, ranging from sudden and brief disruptions such as earthquakes that happen in seconds, to frequent and destructive catastrophes that occur on a weekly or monthly basis. They are usually categorized as either natural or manmade on the basis of their origin.

Natural disaster

A natural disaster is an event caused by natural phenomena, such as extreme weather conditions, geological activity and/or combinations of different forces, biological processes that results in significant damage or loss of life. This can be either a slow or an abrupt process which can bring natural calamity. The following are examples of disasters with an abrupt onset: earthquake, flash flood, hurricane, cyclone, or typhoon;

tornado; fire; tsunami; storm surge; avalanche; volcanic eruption; and extreme cold and heat. Drought, desertification, sea-level rise, and epidemics are some examples of slow-moving disasters.

Fig. 1 : (a) Collapse of the house due to earthquake (Fountain, H., 2017). (b) Desertification scenario (GCAP, 2022). (c) Forest fires (The Guardian., 2021). (d) Landslide in Uttarakhand (Economic Times)

Several types of natural disasters, are as follows:

- Floods: Caused by heavy rainfall, storm surges, or overflowing rivers, resulting in extensive damage to property and infrastructure.
- Earthquakes: Caused by tectonic activity in the earth's crust, resulting in shaking, ground rupture, and displacement of soil and rock, which can lead to severe damage to buildings and infrastructure.
- Cyclones: Powerful storms that form over warm ocean waters, causing high winds, heavy rainfall, and storm surges, leading to significant property damage and loss of life.
- Landslide: Caused by the movement of rock, soil, and debris down a slope, often triggered by heavy rainfall, earthquakes, or volcanic activity, resulting in extensive damage to property and infrastructure in its pathway.
- Wildfires/Forest Fire: Uncontrolled fires that spread rapidly across forests, grasslands, or other areas, caused by a combination of dry weather conditions,

high winds, and human activity, resulting in damage to property and loss of wildlife.

- Volcanic eruptions: Explosive releases of ash, lava, and gas from a volcano, often causing widespread damage to property and infrastructure and posing a significant threat to human life.

Natural disasters have a profound impact on the global economy and food security, affecting large populations worldwide. Over the last decade, there has been a noticeable increase in the frequency and intensity of natural disasters (Botzen, W. W.et al.,2019), with developing nations being the most severely affected in terms of direct economic losses.

One of the major contributing factors to the economic impact from natural disasters is the poor construction practices of buildings. Lack of awareness and resources to withstand such events, in turn, leads to significant damage to infrastructure, buildings, and housing, resulting in a substantial loss of livelihoods and economic activity.

Furthermore, natural disasters can cause widespread food insecurity, as crops are often destroyed, and supply chains are disrupted, leading to shortages and price spikes. The most vulnerable communities, such as those living in poverty or in remote areas, are often the hardest hit by these impacts, resulting in hunger and destitution.

To address the challenges posed by natural disasters, it is essential to invest in Disaster Risk Reduction (DRR) and strengthening of the early warning systems. Preparedness measures, including building resilient infrastructure and promoting climate adaptation is also crucial to enhance the capacity of communities to respond to disasters swiftly and effectively. Implementing DRR strategies can help reduce the impact of natural disasters, ensuring that vulnerable communities are better protected and able to recover quickly from the impacts of these events.

Human-made disasters

Human-made disasters are events caused by human activity or negligence, resulting in significant damage to the environment, infrastructure, or human life. Human activities such as fires, explosions, toxic chemical releases, inferior quality of construction, levee or dam failure, nuclear reactor accidents, deforestation etc. are the main causes of man-made disasters. In recent years, disasters caused by humans or related to anthropogenic activities are increasing and becoming more frequent. Understanding the interlinking of human development with ecosystem and environment is getting increasingly important. For instance, societies that are close to industrial facilities are exposed to dangerous gases, contaminated gas, and toxic waste. A bad health outcome would be that this would cause significant health problems eg Bhopal Gas tragedy 1984.

Some examples of human-made disasters and their causes include:

Industrial Accidents: Such as explosions, fires, and toxic gas releases from factories, oil refineries, and chemical plants, often caused by poor maintenance, equipment failure, or human error.

Nuclear Accidents: Such as the Chernobyl (1986) and Fukushima (2011) disasters caused by nuclear power plant malfunctions or accidents, which can result in radiation exposure, environmental contamination, and long-term health impacts.

Transportation Accidents: Such as plane crashes, train derailments, and shipping accidents, caused by human error, technical malfunctions, or environmental factors.

Terrorist Attacks: Such as bombings, shootings, and cyber-attacks, intended to cause harm to people or infrastructure, often motivated by political, religious, or ideological reasons.

Wars and Conflicts: Such as civil wars, international conflicts, and genocides, caused by political, economic, or ideological differences between nations, groups, or individuals.

Cyber Attacks: Such as hacking, phishing, and malware attacks, intended to disrupt or damage computer systems, networks, or data, often motivated by financial gain, espionage, or activism.

Human-made disasters can have significant long-term consequences, including economic disruption, environmental degradation, and loss of life. Prevention, preparedness, and effective response strategies are essential to mitigate the impact of human-made disasters and support recovery efforts.

4.1.1.3 What is hazard and their causes?

As per UNDRRR, hazard is “a process, phenomenon or human activity that may have potential to cause loss of life, injury or other health impacts, property damage, social and economic disruption or environmental degradation”. In simpler term, the possible source of harm or danger that could result in injuries, damage to property or the environment, or even fatalities is known as a hazard. Natural hazards like earthquakes, cyclones, and wildfires as well as man-made ones like chemical spills, explosions, and nuclear mishaps are examples of hazards. Hazards can also result from a mix of natural and human elements, like catastrophic weather occurrences brought on by climate change.

Natural occurrences including geological processes (earthquakes, landslides, volcanic eruptions), meteorological events (hurricanes, floods, droughts), and biological variables (epidemics, pandemics) can all result in natural hazards. Natural forces of the earth and interactions between its systems and the atmosphere may lead to these dangers.

Man-made dangers can come from a variety of sources, including technology catastrophes (nuclear accidents, cyber assaults), industrial activity (chemical spills, explosions), transportation (accidents in the air, on land, and at sea), infrastructure failures (building collapses, bridge failures), and air, land, and sea travel. These dangers are brought on by human activity, carelessness, or a lack of upkeep and regulation.

However, the natural and man-made causes can both result into hazard for example, the deforestation and change of slope due to road construction and heavy rainfall can be the cause of landslide. Similarly, the risk from flood increasing due to lowering of drainage capacity and increasing erosion of the embankments can result from a combination of natural and human sources. To create efficient risk management techniques and lessen their effects, it is imperative to understand the complexity of the system and origins of hazard.

The High Powered Committee (HPC) formed by Government of India in 1999 had identified 30 hazards affecting India and divided them into five categories based on their characteristics and on general considerations (National Centre for Disaster Management, 2002).

Table 1: Classification of different types of hazards

Water and Climate related	Geologically related	Chemical, Industrial and Nuclear related	Accident related	Biologically related
Floods and drainage management	Landslides and mudflows	Chemical and industrial disasters	Forest fires	Biological disasters and epidemics
Cyclones	Earthquakes	Nuclear disasters	Urban fires	Pest attacks
Tornadoes and hurricanes	Dam failures / dam bursts		Mine flooding	Cattle epidemics
Hailstorm	Mine fires		Oil spill	Food poisoning
Cloud burst			Major building collapse	
Snow avalanches			Serial bomb blasts	
Droughts			Festival relates	
Sea erosion			Electrical disasters and fires	
Thunder and Lightning			Air, road and rail accidents	
			Boat capsizing	
			Village fire	

Source: Repul Kanji (2019): Understanding Disaster Risk Management: An easy-to-use training module

4.1.1.4 How disaster is different from hazard?

While the terms “disaster” and “hazard” are often used interchangeably, they have distinct meanings. A hazard is a potential source of harm or danger, while a disaster is the actual occurrence of a hazard that results in significant damage, loss of life, and disruption to society.

Hazards can be man-made or natural, such as chemical spills or industrial accidents. Natural hazards include earthquakes, floods, and storms. Risk reduction and mitigation techniques can be used to manage hazards, which exist whether or not they cause damage.

On the other hand, disasters happen when a risk affects society and results in major harm, fatalities, and disruptions to vital services like healthcare, transportation, and communication. Emergency responses are frequently needed after disasters to preserve lives, calm the situation, and start the recovery process.

In conclusion, a hazard is a possible cause of harm or danger, whereas a disaster is when a hazard actually occurs and causes considerable harm, fatalities, and societal upheaval. Risk reduction and mitigation measures can be used to manage hazards, whereas disasters necessitate an immediate emergency reaction to preserve lives and launch recovery operations.

Disasters can have a wide range of potentially harmful repercussions on both people and the environment. The biggest contributing factor is poverty. It has been shown that the wealthiest individuals survive and bounce back the fastest from catastrophic events. Resources would become extremely scarce as people grew, which finally brought about conflict. Once more, the competition for resources causes rapid urbanisation. Cultural change brought on by altered resource utilisation would result in further conflict. Future disasters would be caused by a lack of awareness regarding environmental destruction and building collapse (Sena, L & Woldemichael, K., 2006).

4.1.2 Define Vulnerability, Risk and other related terminologies

Vulnerability: As per UNDRR, Vulnerability is "the conditions determined by physical, social, economic and environmental factors or processes which increase the susceptibility of an individual, a community, assets or systems to the impacts of hazards". The term "vulnerability" describes how susceptible a society, system, or asset is to the negative consequences of risks due to external factors and internal features.

Risk: As per UNDRR, Risk is defined as the potential loss of life, injury, or destroyed or damaged assets which could occur to a system, society or a community in a specific period of time, determined probabilistically as a function of hazard, exposure, vulnerability and capacity.

Exposure: As per UNDRR, the situation of people, infrastructure, housing, production capacities and other tangible human assets located in hazard-prone areas.

Capacity: As per UNDRR, the combination of all the strengths, attributes and resources available within an organization, community or society to manage and reduce disaster risks and strengthen resilience. Capacity may include infrastructure, institutions, human knowledge and skills, and collective attributes such as social relationships, leadership and management.

Coping capacity: Is defined as the ability of people, organizations and systems, using available skills and resources, to manage adverse conditions, risk or disasters. The capacity to cope requires continuing awareness, resources and good management, both in normal times as well as during disasters or adverse conditions. Coping capacities contribute to the reduction of disaster risks.

Risk Assessment: is the systematic approach of assessing the risk possess to an individual and populations by exposures.

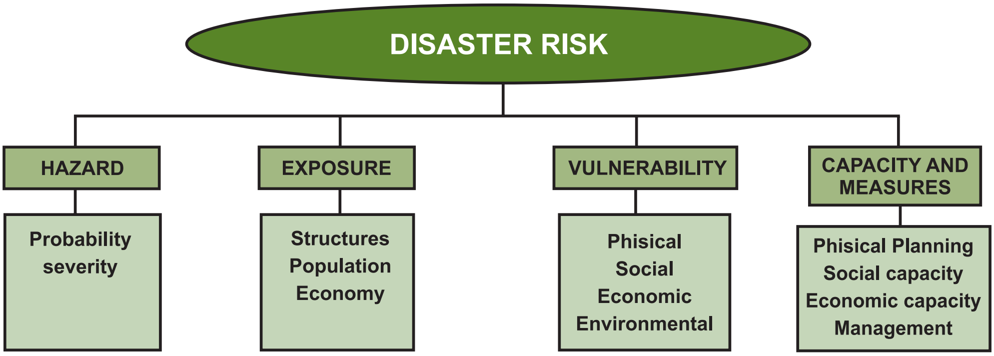

Fig. 2 : Disaster risk (Davidson, 1997, UN-ISDR 2004)

Source: Stagge, K. S. (2015). Methodological Approach Considering Different Factors Influencing Vulnerability–Pan-European Scale. https://www.researchgate.net/publication/331919810_Methodological_approach_considering_different_factors_influencing_vulnerability_-_pan-European_scale

4.1.2.1 Vulnerability of India from disasters

India is a diverse country and are vulnerable to varying degree of natural and man-made disaster due to its unique geo-climatic and socio-economic conditions. Not only its topographic features, but environmental degradation, population growth, urbanization, industrialization, and non-scientific development practices contribute to the vulnerability. The four distinct physiographical regions of country pose different vulnerability to different types of hazards such as Himalayan region is vulnerable to seismic activities, alluvial plains are prone to periodic flooding, the peninsular region are impacted by drought and the coastal region are prone to cyclones. Apart from these, the impact of disasters in India is often disproportionately borne by the poor and marginalized communities, who have limited access to resources and are more vulnerable to the effects of disasters. These communities may lack proper housing, infrastructure, and healthcare, which increases their vulnerability to disasters and exacerbates the impact of disasters on their lives and livelihoods.

According to the National Disaster Management Authority, around 40 million hectares of land in India is exposed to floods (around 12 percent of the total land area), 68 percent of land is vulnerable to droughts, landslides and avalanches, 58.6 percent landmass is earthquake-prone, and tsunamis and cyclones are a regular phenomenon for 5,700 km of the 7,516-km long coastal line. According to the Global Climate Risk Index report 2019, India is the 14th most vulnerable country in the world, due to extreme weather-related events. Floods are the most frequent disaster in India, accounting for 52 percent of the total occurrences of calamities, followed by cyclones (30 percent), landslides (10 percent), earthquakes (5 percent) and droughts (2 percent).

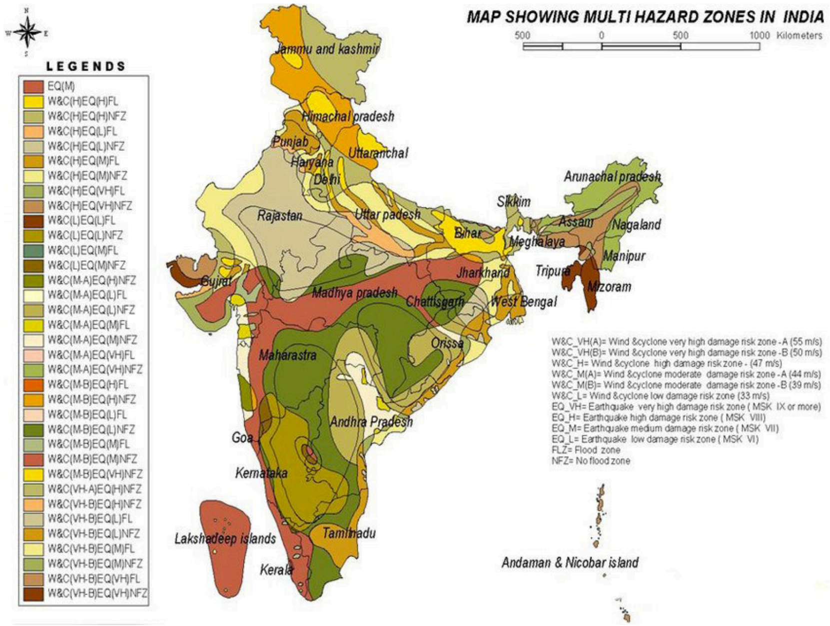

Fig. 3 : Multi hazard map of India

Source: Mechler, R., T. Schinko, K. Awasthi, S. Bhatt, A. Chaturvedi, J. Toast, W. Ederer et al. "Climate Risk Management [CRM] Framework for India: Addressing Loss and Damage (L&D)." (2019). https://www.researchgate.net/figure/Multi-hazard-map-of-India_fig10_336458951 Retrieved on July 26, 2024

4.1.2.2 Impact of disaster on vulnerable areas

According to the Global Climate Risk Index report 2019, it was recorded that India lost around 2,736 lives in 2017 due to disasters, further, economic losses in India due to such calamities accounted for around $13,789 million, the 4th highest in the world. In terms of disaster damage to infrastructure, crops and livelihood, floods are the costliest, causing 63 percent of damages, followed by cyclones (19 percent), earthquakes (10 percent) and droughts (5 percent). In terms of human casualties, the earthquake is the most lethal disaster in India with 33 percent of casualties, followed by floods (32 percent), cyclones (32 percent) and landslides (2 percent) (World Bank, 2012). In terms of share of natural disaster fatalities over the period of time, lightning is the most lethal, accounting for 35 percent of total disaster deaths, followed by cold wave (17 percent), heat strokes (14 percent), landslides (12 percent), floods (11 percent) and cyclones (10 percent).

In the aftermath of a disaster, vulnerable areas may experience a range of impacts, including physical damage to infrastructure and buildings, loss of homes and livelihoods, disruptions to essential services such as water and electricity, and adverse health impacts due to exposure to hazardous materials or contaminated water. Disasters can also exacerbate existing social and economic inequalities, as vulnerable communities may have limited access to resources and face greater barriers to recovery. For example, low-income families may struggle to rebuild their homes and replace their possessions, while informal settlements may face eviction or displacement due to safety concerns. Moreover, the psychological impact of disasters can be significant, especially on vulnerable communities. Disasters can lead to trauma, anxiety, and depression, which can affect individuals and communities' long-term well-being and resilience.

4.1.3 Phases of Disaster Management

Disaster Management is the discipline which deals with every stage of disaster in order to avoid risks and reduce its vulnerability. This includes preparing, supporting, and rebuilding. The disaster management plan aims at identifying the potential disaster that hinders the development of an area. This field requires a multidisciplinary team and stakeholder/ committee approach. An emergency committee should there to provide idea about mentioned disaster in an area (VUSSC., 2010).

The following terms are some of the key ones used in relation to disaster preparedness and prevention:

Emergency refers to the extraordinary steps that are taken to avert a tragedy. It is described in terms of the socioeconomic, political, and epidemiological conditions under which it takes place. Permanently reducing the likelihood of a calamity is Mitigation. The terms "primary mitigation" and "vulnerability reduction" are used interchangeably. Efforts at secondary mitigation also aim to lessen hazard's impacts. The steps made to stop a natural disaster from harming people or financial resources are known as Prevention. It is one of the most important elements for many developing nations. Assessment of vulnerabilities and hazard identification form the foundation of prevention planning. Before a calamity occurs, capacities are built up as part of preparation. It gauges the accessibility of resources for food, cash reserves for emergencies, seeds, medical facilities, warning systems, and other things (Sena, L & Woldemichael, K., 2006).

Response is the activity that need to done after the impact of a disaster so as to reduce the suffering, reducing the impacts, and consequences of the disaster. Reconstruction consists of socioeconomic and preventative actions. The goal of rehabilitation is to re-establish the fundamental social functions. Resilience is the capacity to recover.

Disaster management is a cyclic process where the end of one phase is the beginning of the other. The mitigation and preparedness are the phases that formulated for getting ready for an anticipation of a disaster.

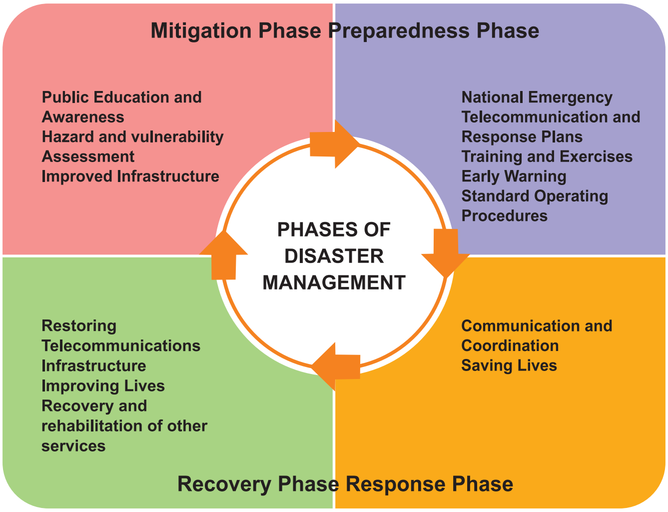

Fig. 4 : Stages of Disaster Management (Asilum, J., 2019).

4.1.3.1 Mitigation Phase

The mitigation phase of disaster management involves activities aimed at reducing or eliminating the risks associated with potential hazards, minimizing the impact of disasters, and enhancing overall community resilience. It is the process of identifying, assessing, and taking action to reduce the risks and impact of disasters on people, property, and the environment.

During the mitigation phase, experts analyze the likelihood and potential impact of various hazards and develop strategies to minimize or eliminate the risks associated with them. This may involve measures such as building codes and regulations, land-use planning, hazard mapping, structural measures and public education and awareness campaigns.

Mitigation efforts can help reduce the severity of the disaster and the extent of damage, making it easier to respond and recover. Effective mitigation strategies can also lead to long-term benefits, such as improved infrastructure, better resource management, and increased community resilience.

Examples of mitigation strategies include constructing buildings with reinforced materials to withstand earthquakes, implementing floodplain management regulations to prevent construction in areas prone to flooding, and developing emergency response plans and drills to prepare for disasters.

The mitigation phase is essential in disaster management as it helps to prevent or reduce the impact of disasters, saving lives and property.

4.1.3.2 Preparedness Phase

The preparedness phase of disaster management involves taking proactive measures to prevent or reduce the impact of disasters before they occur. This phase includes developing disaster management emergency plans, conducting risk assessments, and establishing communication networks and early warning systems.

One critical aspect of preparedness is identifying potential hazards and vulnerabilities and assessing the risks associated with them. This process involves examining potential threats such as natural disasters, technological hazards, or other emergency situations that could affect a community, organization, or individual.

Another important aspect of preparedness is developing and implementing emergency plans and procedures. These plans should include evacuation routes, shelter locations, communication protocols, and emergency supply kits. Establishing communication networks and early warning systems is also essential to ensure that people can receive timely information and warnings about impending disasters.

In addition to these specific measures, preparedness also involves promoting awareness and education about disaster management. This includes educating the public about the potential risks, providing information about emergency preparedness, and engaging in community-based training and exercises.

4.1.3.3 Response Phase

The response phase of disaster management is a critical stage that involves immediate action to address the aftermath of a disaster. The primary goal of the response phase is to save lives, stabilize the situation, and meet the basic needs of affected individuals and communities. During this phase, emergency responders, aid organizations, and government agencies work together to provide essential services such as medical care, food, water, shelter, and security.

The response phase begins as soon as the disaster occurs, and the initial response typically involves search and rescue operations, evacuation, and medical treatment for those injured. Once the immediate needs of affected individuals have been met, attention shifts to providing more comprehensive aid and support to affected communities.

Effective response efforts rely on effective communication and coordination between various stakeholders. Emergency responders and aid organizations work closely with local authorities and community members to identify needs, prioritize actions, and ensure that resources are deployed effectively. Collaboration between local and international organizations is also critical in the response phase to ensure that resources are available where they are needed most.

4.1.3.4 Recovery Phase

The recovery phase of disaster management refers to the efforts made to restore normalcy and rebuild the affected community after a disaster. This phase begins immediately after the response phase and can continue for an extended period, depending on the scale and severity of the disaster.

During the recovery phase, the focus is on restoring critical infrastructure, such as water and electricity supplies, transportation, and communication networks. The goal is to bring essential services back online as quickly as possible to facilitate the resumption of daily activities and support the recovery of affected individuals and businesses.

Recovery efforts also involve addressing the emotional and psychological needs of those affected by the disaster. Mental health support services are critical in helping individuals and communities cope with the traumatic experiences they have endured. This may involve counselling, support groups, and other forms of psychological support.

Rebuilding damaged homes and businesses is also a crucial part of the recovery phase. This requires a coordinated effort between local and national authorities, the private sector, and non-governmental organizations (NGOs) to provide financial support, technical assistance, and other resources necessary to rebuild infrastructure and restore livelihoods.

4.1.3.5 Institutional Framework and Technological Framework

Global Milestones by international organizations

- UN declared the 1990-2000 decade as the International Decade for Natural Disaster Reduction (IDNDR)
- 1994: World conference on Natural Disaster held in Yokohama, Japan by United Nation and adopted the Yokohama strategy.
- United Nations Office for Disaster Risk Reduction (UNISDR) created in 1999 to implement UN Disaster Risk Reduction strategy.
- 2005-2015 Hyogo Framework for Action (HFA): This 10 year plan was adopted during the second World Conference on Disaster Reduction in 2005, 168 states adopted the first global framework for DRR. The Hyogo Framework is a global document; as such, it addresses DRR issues in all types of environments and settings.
- 2015-2030 -Sendai Framework for Disaster Risk Reduction- a successor of Hyogo framework aims to achieve, a substantial reduction of disaster risks and loss of lives, livelihoods, and health and the economic, physical, social, cultural, and environmental assets of people, businesses, communities, and countries by preventing new disaster risks and reducing existing ones through the implementation of integrated and inclusive measures that strengthen resilience by 2030. (SFDRR 2015). It is a non-binding agreement, which the signatory nations, including India, will attempt to comply with on a voluntary basis.
- Sustainable Development Goals 2015-2030: launched on September 2015 through UN summit aiming to end poverty in all forms. It is grounded in the Universal Declaration on Human Rights and international human rights treaties and emphasises the responsibilities of all states to respect, protect and promote human rights.

Institutional Mechanism in India

The Indian government views mitigation and prevention as a crucial element in the nation's growth. Disaster Risk Mitigation (DRR) places a strong emphasis on incorporating disaster reduction into development policies and practises. The Disaster Management bill, after being passed by parliament's both houses and after the consent from the president of India on December 2005, Disaster Management (DM) Act 2005 came to be in effect. The DM Act, 2005 lays down institutional and coordination mechanisms for effective disaster management at the national, state, and district levels. As mandated by this Act, the Government of India (GoI), created a multi-tiered institutional system at each level as shown in the fig 5.

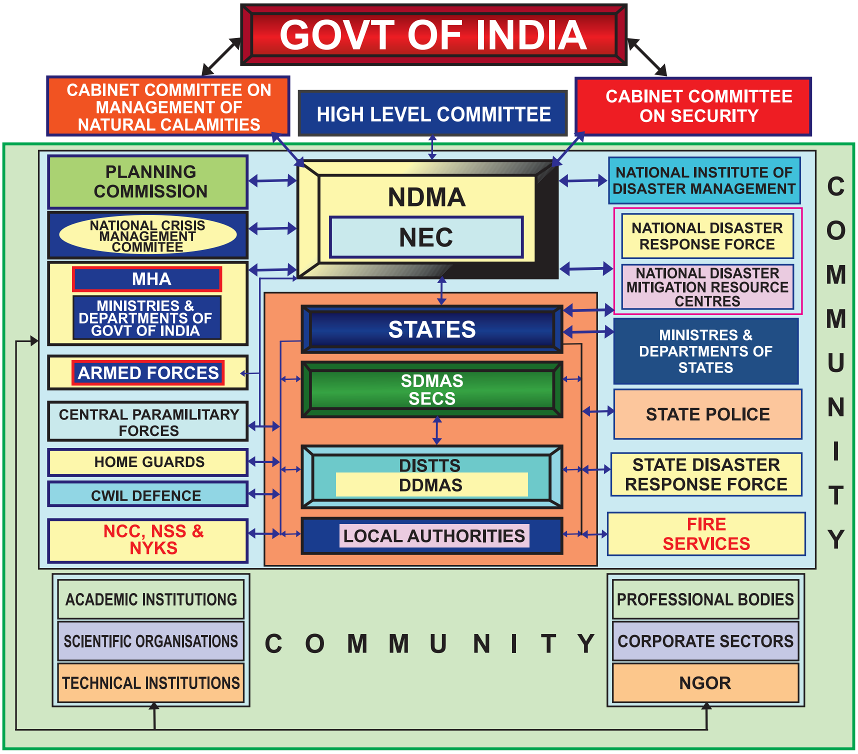

Fig. 5 : Institutional setup for disaster management in India (Source: Gupta, P. S. (2014) https://shorturl.at/afEM8)

The National Disaster Mitigation Fund (NDMF) is provided on the recommendations of the 15th Finance Commission, GoI for mitigation purposes. Mitigation is divided into two categories: structural mitigation, which aims to reduce the likelihood of disaster for the construction industry, and non-structural mitigation, which includes legislation, public awareness, knowledge development, commitment from the general public, and methods. For example, for Earthquake, the government has implemented National Earthquake Risk Mitigation Project (NERMP), National Building Code (NBC), and

Building Material & Technology Promotion Council (BMTPC).

As per the role of different ministry and departments, stakeholders are given nodal responsibilities and open for independent research and studies, such as Indian Meteorological Department (IMD) is nodal agency for early warning, the Ministry of Environment and Forest (MoEF), the Ministry of Earth Sciences (MoES), the Department of Science and Technology (DST), and organisations like the Defence Research & Development Organization (DRDO) and the Indian Space Research Organization (ISRO) all take part actively.

All of these areas are targeted by the National Policy on Disaster Management (NPDM, 2009), which also develops a strategy for a community-based disaster management system. The management of disasters still needs more attention, and all stakeholders, NGOs, communities, and the media must be involved. It is crucial to promote the study of disaster mitigation through academic programmes, career training, and improved training facilities.

National Disaster Management Authority (NDMA)

To help the state governments, and other organizations create disaster management (DM) plans, the NDMA has developed recommendations for the handling of earthquakes. The rules are designed to lessen the short-term effects of earthquakes as well as the medium- and long-term risk of earthquakes.

The State Disaster Management Authority (SDMA) is responsible for overall disaster management planning and coordination at the state level. During an earthquake, the SDMA would be responsible for coordinating the response efforts of various state government departments, as well as coordinating with the National Disaster Management Authority (NDMA) and other state DMAs.

The District Disaster Management Authority (DDMA) is chaired by District Collectors/ DM responsible for disaster management planning and coordination at the district level. During an earthquake, the DDMA would be responsible for coordinating the response efforts of various district-level government departments, as well as coordinating with the SDMA and other local agencies.

Both SDMA and DDMA would work together to provide assistance and support to affected communities, including emergency medical care, search and rescue operations, and the distribution of relief supplies. They would also work to mitigate the impact of the disaster by implementing measures such as early warning systems and disaster risk reduction programs.

National Institute of Disaster Management (NIDM)

The National Institute of Disaster Management (NIDM) was established by an Act of Parliament with the goal of serving as India and the region's leading institution for capacity building. In the area of disaster management, NIDM has been given nodal duties for policy advocacy, research, documentation, training, capacity building, and human resource development. As a resource NIDM has created certain earthquake safety rules, IEC materials, documented earthquake case studies, etc. These may cover the causes of building damage, fundamental building rules, and what happens during an earthquake. They talk about how to be ready for an earthquake both beforehand and afterwards, as well as how to safeguard homes.

National Disaster Response Force (NDRF)

The main organization in charge of reacting to earthquakes and other natural disasters in India is the National Disaster Response Force (NDRF). They have received training in search and rescue, first aid, relief, and rehabilitation activities that may be given to affected areas immediately (Singh, O, P., 2016). To manage the comprehensive response and recovery operations following a disaster, the NDRF also closely collaborates with other governmental and non-governmental groups. The NDRF would be dispatched to the affected area as soon as a seismic event occurred to assess the damage and help individuals in need. The force is equipped to handle both domestic and foreign disaster response operations.

State Disaster Response Force (SDRF)

The State Disaster Response Force (SDRF) is a specialized unit of the police force formed under DM Act 2005, that is trained to respond to natural disasters such as earthquakes. Their role during an earthquake includes search and rescue operations, providing medical assistance, and helping with evacuation and relief efforts. In order to respond quickly to disasters, SDRF is crucial, and it is strategically positioned in ideal areas with good access to roads, railheads, and airports for speedy deployment at disaster sites. Programs for community capacity building and awareness raising also make use of the force.

Emergency Operation Centers (EOC)

During an earthquake, an Emergency Operation Centre (EOC) has the responsibility of managing and coordinating the response and recovery operations of many agencies and organisations. Information is received, evaluated, and distributed to decision-makers and first responders from the EOC, which acts as a central command and control hub. The EOC also organises logistics and resources, including transportation, transportation systems, and medical help. Various organisations congregate in an EOC to coordinate resources and actions for immediate response and recovery. It is a hub for operations where management and coordination are made easier. Depending on the size of the response required, the EOC is set up away from the disaster locations and placed close to government buildings such the local, district, or state headquarters. Establishing priorities for the distribution of resources among various sites and handling off-concerns like shelters, ordering resources from distant jurisdictions or through state or central jurisdictions, and overall coordination and communication between agencies handling various aspects of emergency response are the main goals of the EOC (IGNOU., 2013).

Fire and Emergency Department

The Fire and Emergency Services Department is responsible for a number of tasks during an earthquake. Their main responsibility is to protect the public by responding to crises, carrying out search and rescue missions, treating the injured and averting dangerous situations such as gas leaks and fires. To ensure a quick and efficient response to the disaster, they collaborate with other emergency response authorities and aid in evacuation efforts.

Also, the department is essential for determining the extent of damage to buildings and infrastructure, managing that damage, securing hazardous structures, and controlling traffic so that emergency vehicles can reach the scene. The department is also responsible for informing and educating the public about earthquake safety precautions reduce the risk of harm and fatalities. In addition to its duties in response and recovery, the agency also trains its personnel and the general public through monthly earthquake drills and training programmes so they are ready to respond appropriately in the event of a disaster. To protect public safety, reduce damage, and prevent loss of life, the Fire and Emergency Services Department is essential to earthquake reaction and recovery activities.

Civil Defense

In the event of an earthquake, Civil Defense has two main responsibilities: to protect and educate the general population about the possible dangers of one, and to act swiftly and effectively (NDMA, 2012). The CD Act, passed by Parliament in 1968 and later revised, covers the entire of India. The major goal was to work toward salvaging destroyed buildings, structures, and property and to dispose of the deceased, among other things. They make sure that the ports, trains, roads, bridges, and canals, as well as factories, mines, oil fields, and laboratories conducting scientific and technical research, are all secure. They also take specific precautions to address fire outbreaks. To ensure that communities are prepared for earthquakes and that response and recovery operations are coordinated and successful, civil defense also works closely with other government agencies and non-governmental organizations.

Armed Force

The Indian military forces have already provided disaster relief to a number of nations, giving international disaster response another facet. Many of India's neighbours look up to it in many ways, especially when they are faced with a catastrophic disaster (Raj, A., 2008). Although there is no need to prioritize the various secondary roles of the armed forces, aid to civil authorities in disaster management needs no clarification or emphasis. Only when a crisis is obviously beyond the control and capacity of the local administration does the civil authority need to requisition the military forces. In the event of a disaster, it does not necessarily follow that the military forces will only be called into action after the civil administration has used all of its options and resources.

Role of Municipal Authorities/Local Bodies
It is the duty of the Local Government/Municipality to examine the unsafe buildings in the city and initiate strict action against the owners to take measures to retrofit or repair such structures.

Other State-level and District-level Authority and Committee
The involvement of the departments/institutes/organizations is enumerable. These include National Disaster Mitigation Resource Centres and State Disaster Mitigation Resource Centres, National Crisis Management Committee, National Executive Committee, Role of the Nodal and Other Central Ministries/Departments, State Emergency Operation Centre, State Disaster Management Authority, and State Executive Committee.

4.2 SUB-MODULE 3: INTRODUCTION TO EARTHQUAKE

4.2.1 Introduction

The collision and sliding of tectonic plates cause earthquakes. As the plates move slowly past each other, immense energy builds and is suddenly released, causing the ground to shake and generating seismic waves that propagate through the Earth's crust. The movement of tectonic plates is caused by forces within the Earth's mantle, which are driven by heat and convection currents. When the plates meet or slide past each other, friction and pressure cause them to stick and build up energy, which is released as an earthquake. It is a phenomenon resulting from the sudden release of energy accumulated in the earth's crust. When the strain energy exceeds the strength of the rock inside accretionary prism on the earth surface, it radiates outwards, resulting in deadly natural hazards. Two plates clash or move past one another, which causes the majority of large earthquakes. On oceanic ridges where plates are separating, smaller earthquakes occur. According to the elastic rebound theory, strains increase when plates hit and reach a certain threshold. It abruptly releases all of its energy after breaking through this point, creating an earthquake. An earthquake can be distinguished by the depth of the rupture or stress release, where the shallow earthquake occurs at a depths of 0 to 70 km, the intermediate earthquake at a depth of 70-300 km and the deep earthquake at a depth of 300-700 km.

Seismic waves are produced by a powerful vibration that happens during an earthquake. It begins at the starting location and spreads out in all directions. By identifying the P-wave and S-wave, a seismogram can pinpoint the earthquake's location. Secondary impacts of earthquakes include landslides, fires, starvation, disease, and tsunamis.

Hazards related to seismic activity include ground motion, ground cracks, mass waste, and liquefaction. The following are examples of secondary and tertiary hazards: tsunami, seiche waves, habitat disruption, changes in groundwater levels, population displacement, and job loss. As a result, the earthquake has both immediate and long-term effects. Large earthquakes typically occur infrequently and in poorly populated areas. The majority of earthquakes that happen each year are modest in size. In the course of human history, there have been five earthquakes with a magnitude greater than nine and 20 earthquakes that have killed more than 20,000 people. In the future, earthquake prediction will become increasingly crucial. The ability to predict earthquakes accurately and reliably is crucial because it can help to save lives, reduce property damage, and improve disaster preparedness efforts. By providing advanced warning of an impending earthquake, people can evacuate or take protective measures to minimize the impact of the disaster. Additionally, earthquake prediction can help authorities to better allocate resources and prioritize response efforts, including search and rescue operations, medical care, and infrastructure repair. As technology and scientific understanding of earthquakes continue to advance, the ability to predict earthquakes will become more accurate and effective, further enhancing our ability to mitigate the impacts of these destructive natural disasters.

4.2.1.1 Origin and cause of an earthquake

An earthquake is a natural disaster that occurs when there is a sudden release of energy from the Earth's crust, resulting in shaking and ground displacement. Earthquakes can have devastating effects, causing significant damage to buildings, infrastructure, and communities. Here are the origin and causes of an earthquake:

Plate Tectonics: The Earth's crust is made up of several large plates that move relative to each other. When two plates collide, one may be forced beneath the other, building stress along the plate boundary. This stress is eventually released as an earthquake.

Faults: A fault is a crack or fracture in the Earth's crust where two blocks of rock move past each other. When these blocks suddenly move, energy is released in the form of an earthquake.

Volcanic Activity: Earthquakes can also be caused by volcanic activity. As magma moves beneath the Earth's surface, it can cause stress on the surrounding rocks, leading to earthquakes.

Human Activity: Some earthquakes can be caused by human activity, such as mining or the construction of large dams. These activities can cause stress on the Earth's crust, leading to earthquakes.

The origin and cause of an earthquake can be complex and vary depending on the location and geological characteristics of the region. However, understanding the causes of earthquakes can help to improve earthquake prediction and preparedness, saving lives and reducing their impact.

4.2.1.2 Earthquake Parameters

There are some important terminologies used in discussing earthquakes.

Epicentre is the point on the Earth surface directly above the origin point where the earthquake occurs. It is referred as the region experiencing maximum ground motion.

Depth of an earthquake gives important information about the tectonic settings and structure of the earth. Usually, the depth of the earthquake is between 2-3 km below the surface. The deepest earthquake occurs in the region of subduction at a depth reaches 700 km.

Focus of an earthquake is the point at some depth in the earth where radiation starts. This point is where earth's crust start rupturing.

Magnitude is the size of an earthquake. It varies tremendously and is measured on seismogram. Richter scale is used for measuring magnitude. It gives an idea about the amount of energy released based on the amplitude of the seismic waves. One unit increase in magnitude corresponds to 30-fold increase in the energy.

Foreshock and Aftershock are small events that occur before and after the main earthquake. This is confined to a patch of area. This mainly happened due to the residual stress from the main event.

Focal mechanism is the orientation of the fault plane and the direction of the first plate move.

Seismic moment is the measure of the size of the event. It is proportional to the average stress drop across the fault and the area of the fault that moves during an earthquake.

Energy release is estimated indirectly through fault motion and stress drop. The energy is propagating through the surface as P-wave and S-wave.

Earthquake intensity is the severity of ground shaking. It is measured through Mercalli scale. Each scale represents the type of motion and type of damage it creates.

4.2.1.3 Impact of an Earthquake

Earthquakes can have significant impacts on communities, infrastructure, and the environment. The impact of an earthquake can vary depending on several factors, such as its magnitude, the location of the epicentre, and the population density of the affected area. Here are some of the impacts of an earthquake:

Damage to buildings and infrastructure: Earthquakes can cause significant damage to buildings, bridges, roads, and other infrastructure. This damage can result in injuries or deaths and cause long-term economic losses.

Displacement of people: Earthquakes can cause displacement of people, either due to damage to their homes or because of the risk of further earthquakes or aftershocks. This displacement can lead to temporary or permanent relocation and can have significant social and economic impacts.

Loss of lives and injuries: Earthquakes can cause significant loss of lives and injuries. The severity of the impact depends on several factors, such as the magnitude of the earthquake, the population density of the affected area, and the preparedness and response of emergency services.

Environmental impacts: Earthquakes can trigger landslides, tsunamis, and liquefaction. These impacts can cause significant environmental damage and have long-term effects on local ecosystems.

Economic impacts: Earthquakes can cause significant economic impacts, including the loss of infrastructure, businesses, and jobs. The cost of recovery and reconstruction can also be high, leading to long-term economic losses.

In summary, earthquakes can have significant impacts on communities, infrastructure, and the environment. The impact of an earthquake depends on several factors, and effective earthquake preparedness and response can help reduce the severity of the impacts.

4.2.1.4 Earthquake scenario in India and Globally

India and the world have a long history of devastating earthquakes, and as one of the most seismically active regions of the world, India is particularly vulnerable to these disasters. Understanding the earthquake scenario in India and globally is essential to developing effective preparedness and response strategies.

India Earthquake Scenario

India is located on the boundary of two tectonic plates, the Indian and the Eurasian plates. The Indian plate is moving northwards at a rate of about 5 cm per year, leading to the collision and subduction of the Indian plate beneath the Eurasian plate, which causes seismic activity. According to the National Centre for Seismology, India experiences an average of about 200 earthquakes each year, with a magnitude of 3 or higher on the Richter scale.

Some of the deadliest earthquakes in India include the 1905 Kangra earthquake, which had a magnitude of 7.8 and caused over 20,000 deaths, the 2001 Bhuj earthquake, with a magnitude of 7.7 and over 20,000 deaths, and the 2015 Nepal earthquake, which had a magnitude of 7.8 and caused widespread damage in India's northern regions.

India has taken several steps to improve earthquake preparedness and response, including establishing the National Disaster Response Force (NDRF) and implementing building codes and regulations to ensure earthquake-resistant infrastructure. However, there is still a need for continued efforts to improve earthquake preparedness and response, particularly in vulnerable areas.

Global Earthquake Scenario

Earthquakes occur globally, with some of the most devastating earthquakes in recent history occurring in Asia, South America, and Europe. One of the deadliest earthquakes in modern history was the 2010 Haiti earthquake, with a magnitude of 7.0 and over 220,000 deaths.

Other notable earthquakes include the 2011 Tohoku earthquake and tsunami in Japan, with a magnitude of 9.0 and over 15,000 deaths, and the 2008 Sichuan earthquake in China, with a magnitude of 7.9 and over 69,000 deaths.

The impact of earthquakes globally can be devastating, causing significant damage to infrastructure and loss of lives. However, advancements in technology and improved preparedness and response strategies have helped to reduce the impact of earthquakes in some regions.

List of prominent Earthquakes in India

DATE	LOCATION	MAGNITUDE	REMARKS
8 February, 1900	Coimbatore	6.0/VII	Shock was felt throughout south India. Coimbatore and Coonoor worst affected.
4 April, 1905	Kangra	8.0/X	~19,000 deaths. Considerable damage in Lahore. High intensity around Dehradun and Mussorie VIII
15 January, 1934	Bihar – Nepal	8.3/X	~7,000 deaths in India and ~3,000 deaths in Nepal. Liquefaction in many areas.
26 June,	Andaman & Nicobar Islands	7.7/VIII	Triggered Tsunami-1.0m high on the east coast, causing many deaths.
15 August, 1950	Assam-Tibet	8.6/XII	About 1,500 deaths in India and ~2,500 in China. Caused huge landslides which blocked rivers and later caused flood.
21 July, 1956	Anjar (in Kutch)	6.1/IX	About 115 deaths. Part of Anjar on rocky sites suffered much less damage comparatively
10 December, 1967	Koyana, Maharashtra	6.5/VIII	About 180 deaths. Caused significant damage to the concrete gravity dam.
21 August, 1988	Bihar-Nepal	6.6/IX	About ~709 deaths.
20 October, 1991	Uttarkashi	6.4/IX	~750 deaths. 56m span Gawana bridge 6 km from Uttarkashi collapsed.
30 September, 1993	Killari, Maharashtra	6.2/IX	~8,000 deaths. Most deadly earthquake in India since Independence.
22 May, 1997	Jabalpur	6.0/VIII	~40 deaths and ~1,000 injured. Concrete frame buildings with open ground storey suffered damage.
26 January, 2001	Bhuj (Kutch)	7.7/X	~13,800 deaths. Numerous modern Multi-storey buildings collapsed. Number of medium and small earth dams severely damaged.
26 December, 2004	Sumatra	9.4/VI (in Andaman)	Caused most devastating Tsunami in the history resulting in ~2,27,898 deaths in 14 countries.
8 October, 2005	Kashmir	7.6/VIII	Poor performance of masonry buildings caused many life losses. Unique construction found in this region Dhajji-Diwari showed very good seismic performance
28 September, 2011	Sikkim	6.9/VI	~80 deaths. Large number of landslides, significant damage to the buildings and infrastructure.

Source: (S, K, Jain., 2016)

LIST OF DEADLIEST EARTHQUAKES IN THE WORLD

YEAR	DAY AND MONTH	LOCATION	DEATH	MAGNITUDE
1516	23 January	Shansi, China	830000	8
1976	27 July	Tangshan, China	225,000	7.5
1138	9 August	Aleppo, Syria	230,000	
2004	26 December	Off west coast of northern Sumatra	225,000+	9.0
2010	12 January	Haiti	222,570	7.0
856 AD	22 December	Damghan, Iran	200,000	
1927	22 May	Near Xining, China	200,000	7.9
1920	16 December	Gansu, China	200,000	7.8
893	23 March	Ardabil, Iran	150,000	
1923	1 September	Kwanto, Japan	143,000	7.9
1948	5 October	Ashgabat, Turkmenistan	110,000	7.3
1908	28 December	Messina, Italy	70,000 -100,000	7.2
1290	September	Chihli, China	100,000	
2008	12 May	Eastern Sichuan, China	87,587	7.9
2005	8 October	Pakistan	80,361	7.6
1667	November	Shemakha, Caucasia	80,000	
1727	18 November	Tabriz, Iran	77,000	
1932	25 December	Gansu, China	70,000	7.6
1755	1 November	Lisbon, Portugal	70,000	8.7
1970	31 May	Peru	66,000	7.9
1935	30 May	Quetta, Pakistan	30,000 -60,000	7.5
1693	11 January	Sicily, Italy	60,000	
1268		Sicilia, Asia Minor	60,000	
1990	20 June	Iran	50,000	7.7
1783	4 February	Calabria, Italy	50,000	

Source: (Infoplease, 2017)

4.2.1.5 Types of Earthquake

There are several types of earthquakes, which can be classified based on their causes and characteristics. Here are some of the common types of earthquakes:

Tectonic earthquakes: These earthquakes are caused by the movement of tectonic plates. Tectonic plates are large pieces of the Earth's crust that move and collide with each other. When these plates move, they create stress, which can build up and result in an earthquake.

Volcanic earthquakes: These earthquakes are caused by volcanic activity. Volcanic earthquakes occur when magma or volcanic gases move beneath the Earth's surface, causing vibrations.

Collapse earthquakes: These earthquakes are caused by the collapse of underground cavities, such as mines or caverns.

Explosion earthquakes: These earthquakes are caused by the detonation of explosives. They are commonly associated with human activities, such as mining or military operations.

Induced earthquakes: These earthquakes are caused by human activities, such as the injection of fluids into the ground, hydraulic fracturing, or the construction of large dams.

Aftershocks: Aftershocks are smaller earthquakes that occur after a larger earthquake. They are caused by the readjustment of the Earth's crust following the main earthquake.

Understanding the different types of earthquakes is essential for developing effective earthquake preparedness and response strategies. While some earthquakes are predictable, others can occur unexpectedly, making it crucial to be prepared for any eventuality.

4.2.2 Seismic Zonation

According to the estimated ground motion, regions are categorised into seismic zones. Peak ground acceleration (PGA) or peak ground velocity (PGV) are used to describe it. There are many individual studies for seismic zonation. The early maps were based on qualitative whereas the subsequent maps were quantitative. The data attained through empirical seismic attenuation law is analysed by Bureau of Indian Standards.

The location and features of an earthquake are provided by a seismicity map, and the characteristics of the ground shaking in a particular area are represented by a seismic zone, which aids in the creation of earthquake resistance designs (Mohapatra, A, K & Mohanty, W, K., 2010).

Currently there are four different categories of seismic zones in India: II, III, IV, and V. The most seismically active region is located in seismic zone V. The north-eastern region of India, Andaman and Nicobar, the Kangra Valley in Himachal Pradesh, the eastern portion of Uttaranchal, the Rann of Kutchh in Gujarat, and Sri Nagar in Jammu & Kashmir are all included in this region. Kolkata is located on the border of seismic zones III and IV, whereas the nation's capital Delhi is located in seismic zone IV. Following a large occurrence, Seismic Zonation is regularly updated. Latur, for instance, used to be in seismic zone I but was relocated to seismic zone III as a result of the earthquake in 1993 (Mohapatra, A, K & Mohanty, W, K., 2010).

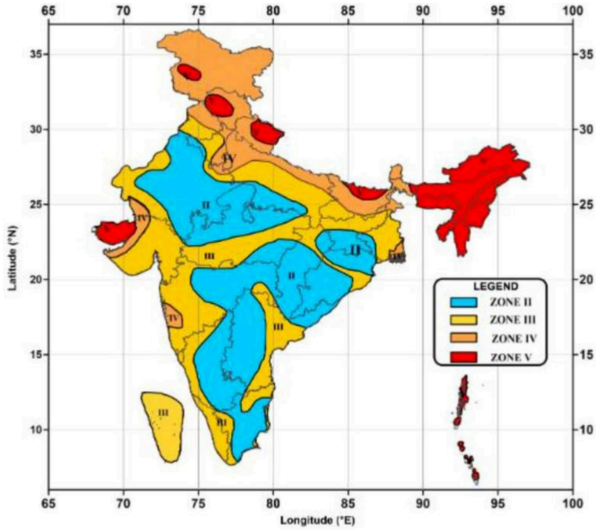

Fig. 6 : Seismic Zones of India Map IS 1893 (Part 1). 2016, BIS

Image Source: Ministry of Earth Sciences. Page visited: 29/12/2022 (https://pib.gov.in/PressReleasePage.aspx?PRID=1740656)

Because they aid in making decisions for urban planning, seismic zones are significant. Based on the size and strength of the shaking brought on by an earthquake, it designates areas that are vulnerable to earthquakes. Zonation is a multi-disciplinary subject that needs the assistance of experts in geology, geophysics, geotechnical engineering, and other related fields. Seismic zonation maps are highly helpful because of the numerous seismic dangers that resulted from fast urbanisation and population growth in many areas.

4.2.2.1 What is seismic hazard and seismic zoning?

Seismic hazard refers to the potential of an area to experience damaging earthquakes, which can result in significant loss of life, damage to infrastructure, and economic impact. Seismic hazard assessment is essential for developing effective earthquake preparedness and response strategies, as it provides information on the likelihood of earthquakes and their potential magnitude. Seismic hazard is typically expressed in terms of probabilistic estimates of ground motion or acceleration at a given location.

Seismic zoning is a process of dividing an area into zones based on its seismic hazard, with the aim of regulating land use and building construction to mitigate the risk of earthquakes. Seismic zoning takes into account factors such as the geology of the area, historical earthquake activity, and local soil conditions. The most common way of expressing seismic zoning is through the use of seismic hazard maps, which show the relative levels of seismic hazard in different areas.

In India, seismic hazard and seismic zoning are critical components of earthquake preparedness and response. India is located in a seismically active region, with a high risk of earthquakes. The Bureau of Indian Standards (BIS) has developed seismic building codes that are based on seismic hazard and seismic zoning, with the aim of improving the earthquake resistance of buildings and infrastructure.

The BIS has divided India into four seismic zones, based on their seismic hazard. Zone V is the most seismically active, with a high likelihood of earthquakes of magnitude 8 or higher, while Zone II is the least seismically active, with a low likelihood of earthquakes of magnitude 5 or higher. Building codes and regulations are more stringent in higher seismic zones, with the aim of ensuring that buildings and infrastructure can withstand earthquakes of the expected magnitude in the area.

4.2.2.2 Why is seismic zoning necessary in India?

Seismic zoning is necessary in India for several reasons. India is located in a seismically active region, with a high risk of earthquakes. The country has a long history of devastating earthquakes, such as the 2001 Gujarat earthquake, which killed over 20,000 people and caused significant damage to infrastructure.

Seismic zoning is necessary in India to regulate land use and building construction in areas with high seismic hazard.

Seismic zoning is also necessary for emergency management and disaster response. Local authorities can use seismic hazard maps and zoning to develop evacuation plans and emergency response strategies, with the aim of minimizing the loss of life and damage to infrastructure in the event of an earthquake. For example, in the event of an earthquake, it is important to know which areas are at the highest risk and which areas are likely to be safer, so that people can be evacuated to safer areas.

4.2.2.3 Seismic Zones of India and and proposed new seismic zonation.

India has been divided into four seismic zones by the Bureau of Indian Standards (BIS) based on the seismicity and vulnerability of different regions. The seismic zones of India are as follows:

Zone II: This is the least active seismic zone in India, comprising areas that are least vulnerable to earthquakes. This includes regions such as parts of the Indo-Gangetic plains, some parts of Gujarat, Rajasthan, and the northern plains of India. The maximum considered earthquake (MCE) in this zone is less than or equal to 5.

Zone III: This seismic zone comprises areas that are moderately vulnerable to earthquakes. It includes regions such as parts of Jammu and Kashmir, Himachal Pradesh, Uttarakhand, the North-Eastern states, and parts of Bihar and West Bengal. The MCE in this zone is between 5 and 5.9.

Zone IV: This seismic zone comprises areas that are more vulnerable to earthquakes. It includes regions such as parts of Jammu and Kashmir, Himachal Pradesh, the Kutch region of Gujarat, Uttarakhand, the North-Eastern states, parts of Bihar, West Bengal, the Andaman and Nicobar Islands, and the Lakshadweep Islands. The MCE in this zone is between 6 and 6.9.

Zone V: This is the most active seismic zone in India, comprising areas that are highly vulnerable to earthquakes. It includes regions such as the Himalayan region, the entire North-Eastern region, parts of Gujarat and Maharashtra, and the Andaman and Nicobar Islands. The MCE in this zone is greater than or equal to 7.

Proposed changes in the seismic zonation map

The Earthquake Zone Map (Fig. 4) is a reflection of the relative peak ground accelerations likely across the landmass of India. These peak ground accelerations can be statistically correlated to the intensity of earthquake ground shaking measured on the 1964 MSK Scale. In the seventh revision by BIS (under process, 2023), suggested major changes, a revised Earthquake Zone Map based on Probabilistic Earthquake Hazard Assessment has been introduced. The Indian landmass shall be considered to be demarcated into five earthquake zones, namely Earthquake Zones II, III, IV, V and VI. The PGA hazard values were utilized to prepare a contour map, with five level of peak ground acceleration (PGA), <=0.15g, 0.15g–0.30g, 0.30g–0.45g, 0.45g– 0.60g and >=0.60g, respectively. The final earthquake zone factors were assigned as: 0.15g, 0.30g, 0.45g, 0.60g and 0.75g, corresponding to Earthquake Zones II, III, IV, V and VI, respectively. These values correspond to a return period of 2,475 years.

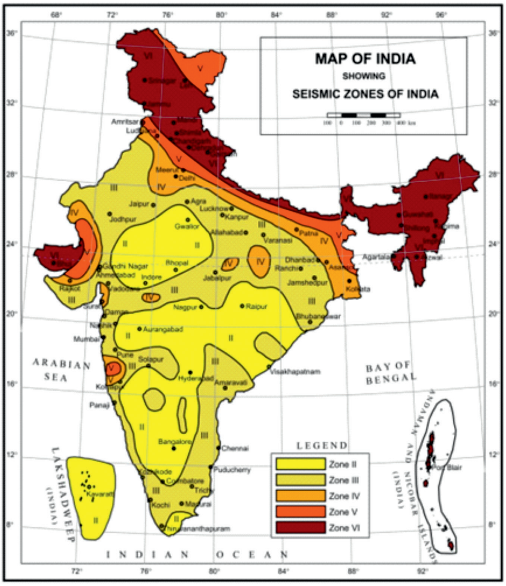

Fig. 7 : Under submission: Draft Earthquake Zone map of India by BIS. Earthquake zone map based on mean horizontal Peak Ground Acceleration (PGA) values expected at the ground Surface estimated by PSHA corresponding to a return period of 2,475 years

Source:https://www.services.bis.gov.in/tmp/WCCED21022343_26042023_2.pdf retrieved on July 25, 2025

4.2.3 Effects of Earthquake

An earthquake is a sudden shaking or trembling of the Earth's surface, caused by the release of energy stored in the Earth's crust. The effects of an earthquake can be devastating, leading to loss of life, injuries, and widespread damage to buildings and infrastructure. The impact of an earthquake can depend on several factors, including the magnitude of the quake, the depth of the earthquake's focus, and the nature of the local geology.

The immediate effects of an earthquake can include collapsed buildings, bridges, and other structures, as well as fires, landslides, and flooding. These can cause injury and death, as well as significant disruption to essential services such as electricity, water, and transportation.

Long-term effects can also occur, including displacement of affected populations, economic disruption, and damage to the environment. In addition, earthquakes can trigger secondary hazards such as aftershocks, which can continue for weeks or even months after the initial quake, and tsunamis, which can cause significant damage and loss of life in coastal areas.

Effective earthquake preparedness and response can help mitigate the impact of earthquakes. This includes measures such as building earthquake-resistant structures, developing warning systems to alert people to incoming earthquakes, and implementing emergency response plans to facilitate the rapid and coordinated deployment of aid and support to affected populations.

4.2.3.1 Effect of earthquake on built and natural environment

Effect of earthquake on built environment

Earthquake affects a whole community and disrupts the commercial and social life. It is very hard to quantify the cost of loss that happen during an event. First and foremost, the absence of appropriate protection allows event to cause major damage. This is the most basic element to quantify the severity of an earthquake. The 1906 San Francisco earthquake was one of the most devastating earthquakes in American history, with a magnitude of 7.8. The earthquake caused widespread destruction to the built environment of the city, including the collapse of buildings, fires, and damage to infrastructure. The disaster resulted in an estimated 3,000 deaths and left more than half of the city's population homeless.

The earthquake caused significant damage to the city's infrastructure, including water and gas lines, resulting in widespread fires that burned for several days. The collapse of buildings, including multi-story brick buildings, was a major cause of death and injury. The earthquake also triggered landslides, which further damaged buildings and infrastructure. The countries like Japan and New Zealand constructs the buildings that are earthquake resistant because of the frequent occurrence of the earthquake.

Fig. 8 : (a) Collapse of the building due to the earthquake in Oakland (b) consequences of Loma Prieta earthquake in San Francisco (Anderson, G., 1997)

The mass of the buildings is the primary factor that determines the earthquake forces they experience. The larger the mass of a building, the greater the force it will experience during an earthquake. This force is known as the seismic force, and it is caused by the acceleration of the building's mass in response to the ground motion generated by the earthquake. The seismic force can cause significant damage to buildings that are not designed to withstand it, highlighting the importance of earthquake-resistant design in areas prone to seismic activity. The building is more likely to damage the heavy, rigid, and brittle structures. By strengthening the locations, ductility can be added to these constructions. The harm is more likely to happen to larger loads (Boughton, G., 1995). Large buildings present in densely inhabited areas might increase vulnerability. A rapid incident might result in significant structural damage and fatalities because there is no adequate notice before the earthquake occurs. In an earthquake, the structural integrity of a building is put to the test, and often, the most significant and vulnerable parts of the building are the first to collapse. This is due to the forces exerted on the building, which can cause weaknesses or defects in the structure to give way, resulting in a catastrophic failure. The first collapse of a building can trigger a chain reaction, leading to the collapse of other sections and putting occupants and nearby structures at risk. Therefore, it is critical to ensure that buildings are designed and constructed to withstand seismic forces, with particular attention paid to the most vulnerable areas, to minimize the risk of collapse during an earthquake. Due to the low-quality materials used, many walls are in bad condition and may crack when the ground shakes. In the corner, the movement of the walls coincides. As a result, the cracks first appear at the corner leading to walls collapse.

Another direct impact of an earthquake on the properties of the soil is liquefaction. The building is impacted by the rising of water from the earth as a result of the change in pore pressure. The rise of water from the earth due to changes in pore pressure during liquefaction can impact electrical transformers, water tanks, and hot water systems, causing damage and potential economic losses for the community. Sparking can be produced by damaged wiring, broken appliances, and ruptured gas pipes. Production would be impacted since the facilities will be damaged.

Effect of Earthquake on Environment

One of the most destructive natural disasters that can have a significant impact on the environment is an earthquake. They can drastically alter landscapes, degrade the quality of the air and water resources, and severely harm natural habitats. The trembling and shifting of the ground brought on by earthquakes can also result in secondary hazards including landslides, liquefaction, and tsunamis, which can further harm the environment. In this situation, it is essential to comprehend how earthquakes affect the environment in order to create effective disaster management plans that can lessen the effects of these disasters on the ecosystem.

Liquefaction, may have a substantial negative influence on the environment. The sinking of the land's surface as a result of liquefaction's ground deformation may change the area's drainage patterns. This may result in floods and the creation of new wetlands, which may alter the composition of the ecosystem and have an impact on plant and animal habitats.

Fig. 9 : (a) Liquefaction in Canterbury (EurekAlert!) (b) Landslide from Kumamoto earthquake (Petley, D., 2016)

Landslides may be brought on by violent earth vibrations. This could happen either during the immediate rupture or the later events. They can easily demolish the structure and obstruct the highways or rail lines.

Tsunami: During an oceanic earthquake, a tsunami may occur. The waves that result from this would be deep and able to cover more ground. A greater wave is created when the energy from the shallow water propagates to the surface. Tsunamis can cause significant damage and are more disruptive. In closed water areas like lakes, reservoirs, swimming pools, etc., smearing occurs as well. The buildings close to the water bodies might sustain damage as a result.

Fires: As liquefaction and ground rupture cause natural gas and water mains to rupture, fires may start. By severing electrical lines, spilling flammable liquids, and flinging hot embers from stoves, ground tremors can potentially start fires. Due to the disruption of firefighting services, the damage brought on by the earthquake, such as the collapse of power lines and the rupture of gas pipelines, may allow fires to start and spread quickly. The effects of fires on the natural environment can be severe. They can destroy natural habitats, vegetation, and wildlife, leading to soil erosion, landslides, and floods. The release of smoke and toxic gases can pollute the air and harm the respiratory health of humans and animals. Fires can also impact the quality of water resources by depositing ash and debris in water bodies, leading to the death of aquatic organisms.

4.2.3.2 Effect on socio-economic aspect of a society

Economic losses, both directly and indirectly affects almost 154 countries out of 245 all over the world. Of which, developed countries has the most economic losses compared to all other. This includes Japan and China who have large influence on the overall losses. The economic loss of the 2001 earthquake in India was 10000 crores. The overall market scenarios had changed and sales drastically falls during that time (Gokhale, V, A., 2004).

Earthquake not only affects the architecture of a city but as a whole architecture practice. As a result of numerous earthquakes in large cities, modern building practices have undergone significant change. Many structural experts are now worried about how professionally the building practices are being conducted. In many regions of the world, the increased understanding of earthquake safety is a huge comfort. The clients are aware that they should seek professional advice when intending to construct a residential building in an earthquake-prone area. As a result, builders are also profiting from it.

However, earthquakes also have an impact on people's minds. This might be temporary or permanent. The immediate effects are more severe, but they only last for a minute to an hour. Even if there are fewer cases, it is still quite harmful because it can lead to mental or heart conditions. The effects that persist longer than hours or days are the long-term ones. The effectiveness of this is lower than the immediate impacts, but it is important to remember that age-related problems have age-specific causes. As a result, the population impacted varies depending on their age groups, mental health, or financial problems. According to reports, those who are afflicted by Acute Stress Disorders, Post-Traumatic Stress Disorder, Depression, and Adjustment Disorder are the ones who are impacted by an earthquake's effects. Children's growth conditions may potentially be impacted by such occurrences.

4.2.3.3 Secondary effects due to impact of an earthquake

Earthquakes can cause a wide range of secondary effects in addition to the immediate impact of ground shaking. Some of the most common secondary effects of earthquakes include:

Landslides: Earthquakes can trigger landslides in mountainous regions, which can result in damage to buildings, roads, and other infrastructure.

Tsunamis: Earthquakes that occur under the ocean can cause tsunamis, which can result in widespread damage along coastal areas.

Soil liquefaction: The intense shaking of an earthquake can cause soil to lose its strength and behave like a liquid, which can result in damage to buildings and infrastructure.

Fires: Earthquakes can damage gas and electrical lines, leading to fires that can spread quickly and cause widespread damage.

Structural collapse: Buildings and other infrastructure that are not built to withstand earthquakes can collapse, resulting in loss of life and widespread damage.

Dam failures: Earthquakes can cause dams to fail, leading to flooding and widespread damage downstream.

Disease outbreaks: Earthquakes can disrupt infrastructure and cause people to be displaced from their homes, which can lead to the spread of diseases.

These secondary effects can often be just as devastating as the immediate impact of an earthquake, and can result in widespread damage and loss of life. It is important for emergency management and disaster response teams to be prepared for these secondary effects and to take steps to minimize their impact in the aftermath of an earthquake.

4.3 SUB-MODULE 4: STRATEGIES FOR EARTHQUAKE RISK MITIGATION

4.3.1 Earthquake prediction

One of the key challenges in earthquake mitigation and management is the lack of accurate and reliable earthquake prediction mechanisms. Currently, scientists use a combination of methods to try and predict earthquakes, including monitoring seismic activity, studying historical earthquake patterns, and analyzing the movement of tectonic plates.

Seismic monitoring involves the use of instruments to detect and measure the vibrations caused by earthquakes. These instruments can detect both large and small earthquakes, and the data they collect is used to understand the patterns of seismic activity in a specific area.

Historical earthquake patterns are studied by analyzing the location, magnitude, and frequency of past earthquakes. Scientists use this information to identify potential areas of high seismic activity and to develop earthquake hazard maps.

Tectonic plate movement is also studied to try and predict earthquakes. Scientists use GPS and other technologies to track the movement of tectonic plates and to identify areas where plates are moving towards each other or away from each other. This information can be used to identify areas that are at high risk of experiencing an earthquake.

Despite these efforts, it is still not possible to accurately predict the timing and location of earthquakes. Scientists continue to work on developing new and improved methods for earthquake prediction, including the use of advanced technologies such as artificial intelligence and machine learning.

In the meantime, it is important for individuals and organizations to focus on being prepared for earthquakes, rather than relying on the ability to predict them. This includes creating emergency plans, conducting risk assessments, and implementing mitigation measures. It is also essential to stay informed about the latest earthquake prediction research and to be aware of the warning signs of an impending earthquake.

In conclusion, while scientists continue to work on developing accurate and reliable earthquake prediction mechanisms, it is important for individuals and organizations to focus on being prepared for earthquakes. By taking action to reduce the potential impact of earthquakes and by staying informed, we can create stronger and more resilient communities that are better prepared to withstand the impacts of earthquakes (United States Geological Survey., 2021).

There are 12 parameters for earthquake prediction:

- Seismic activity: The number and magnitude of earthquakes in a specific area over a certain period of time.
- Tectonic plate movement: The movement of tectonic plates and the potential for plate boundaries to create seismic activity.
- Ground deformation: The changes in the shape of the earth's surface caused by movement of tectonic plates or changes in the Earth's crust.
- Groundwater level changes: The changes in groundwater level in a specific area, which can indicate potential seismic activity.
- Radon gas levels: The levels of radon gas in the atmosphere, which can indicate changes in the Earth's crust.
- Changes in temperature: Temperature changes in the atmosphere, which can indicate changes in the Earth's crust.
- Changes in atmospheric pressure: Changes in atmospheric pressure, which can indicate changes in the Earth's crust.
- Electric and magnetic field changes: Changes in electric and magnetic fields, which can indicate changes in the Earth's crust.
- Changes in animal behavior: Changes in the behavior of animals, which can indicate potential seismic activity.
- Changes in vegetation: Changes in vegetation, which can indicate changes in the Earth's crust.
- Changes in soil structure: Changes in soil structure, which can indicate changes in the Earth's crust.
- Changes in the Earth's gravity field: Changes in the Earth's gravity field, which can indicate changes in the Earth's crust.

It's important to note that not all of these parameters are considered to be reliable indicators of earthquakes. Some parameters may be affected by other factors, such as weather or human activity, which can make it difficult to determine if they are related to seismic activity. Additionally, many of these parameters require advanced technology and equipment to measure, making it difficult to gather data in remote or inaccessible areas (National Centre for Disaster Prevention., 2021).

In recent years, early warning and earthquake prediction systems have advanced significantly in India. The earthquake early warning system in India is run by the

National Centre for Seismology (NCS), which is part of the Ministry of Earth Sciences. The NCS has created the "India Quake" earthquake early warning system, which uses information from a network of seismic stations to identify and send out alerts to the public and the appropriate authorities.

IIT Roorkee has also been working on the creation and implementation of an earthquake early warning system at Uttarakhand and India's northeast. The technology employs real-time information from a network of seismometers to identify earthquakes and give the general public a head start on preparation.

Further research is going on to use Artificial Intelligence (AI) in predicting earthquakes based on historical data by analyzing patterns. AI can play an important role in monitoring earthquakes that often go unnoticed by traditional methods. Predictive models can identify potential seismic activity and provide early warning signals, allowing decision-makers to take appropriate measures to mitigate the impacts of earthquakes. For example, in Japan, researchers of the Japan Agency for Marine-Earth Science and Technology (JAMSTEC) are using predictive analytics to study the potential for earthquakes in the Nankai Trough, an area with a high risk of earthquakes. Their developed model has been successful in identifying potential earthquake hazards, enabling authorities to take necessary measures to minimize damage.

Use of AI can also be seen to estimate earthquake source parameters based on the ground motion data recorded at the installed sensors. Mathematical models that are used to estimate them, however, AI can play an important role in determining the source parameters more accurately where mathematical models have certain limitations. AI can recognize complex patterns and anomalies in seismic data when traditional methods might not able to capture.

4.3.2. Earthquake Forecast and Warning

Earthquake forecasting and warning are two different but related concepts in the field of earthquake prediction. Earthquake forecasting is the scientific study of the likelihood of future earthquakes in a specific area, based on past seismic activity and other geological data. Earthquake warning, on the other hand, involves the rapid dissemination of information about an imminent earthquake to people who may be affected, with the aim of allowing them to take precautions and minimize the impact of the earthquake.

Earthquake forecasting is a complex and ongoing field of research, with scientists using a wide range of techniques to study and analyze seismic data. These techniques include the monitoring of earthquake swarms, the analysis of patterns of seismic activity over time, and the study of fault lines and other geological features that are associated with earthquakes. While earthquake forecasting is not yet an exact science, it has the potential to provide valuable information to emergency management and disaster response teams, allowing them to prepare for and respond to earthquakes more effectively.

Earthquake warning systems are becoming increasingly common in many parts of the world, including Japan, Mexico, and parts of the United States. These systems use seismic sensors to detect earthquakes and rapidly disseminate information about their location and magnitude to people who may be affected, often through a combination of mobile alerts, sirens, and other communication methods. AI-powered systems can be trained with the help of seismic data to analyse the magnitude and patterns of earthquakes and predict the location of earthquakes and aftershocks. Seismic data can be used by artificial intelligence to assess the magnitude and patterns of earthquakes. Such information may be useful in predicting the occurrence of earthquakes. Researchers and Scientists around the globe are developing their own earthquake and aftershock prediction software. Google and Harvard, for example, are working on an AI system that can forecast seismic aftershocks.

While earthquake warning systems can provide valuable time for people to take precautions and minimize the impact of earthquakes, they are not yet widely available in many parts of the world, including in India.

4.3.2.1 Earthquake Early Warning System concept

An Earthquake Early Warning System (EEWS) is a technological solution that provides advance warning of an impending earthquake to the general public, businesses, and government agencies. The concept of an EEWS is to detect the initial seismic waves from an earthquake, which travel faster than the damaging waves, and provide advance notice of the incoming ground shaking to people in the affected area. The warning time can range from a few seconds to several minutes depending on the distance between the earthquake epicenter and the population centers.

The basic components of an EEWS include a network of seismometers that detect the initial seismic waves, a data processing center that analyzes the data and estimates the size and location of the earthquake, and a communication network that disseminates the warning messages. The warning messages can be transmitted through a range of communication channels, including text messages, cell phone apps, social media, television, and radio.

EEWS has been successfully implemented in several countries, including Japan, Mexico, and the United States. In Japan, the EEWS has been in operation since 2007, and has been credited with saving lives during several earthquakes, including the 2011 Tohoku earthquake and tsunami, which resulted in more than 15,000 fatalities. Similarly, in Mexico, the EEWS provided several seconds of warning before the magnitude 7.1 earthquake struck Mexico City in 2017, which gave people time to evacuate buildings and seek safety.

In India, the NCS, MoES with NDMA has developed an app of EEW for the country. The system is currently being tested in a few cities and is expected to be rolled out to other parts of the country soon. The implementation of an EEWS in India has the potential to save many lives and minimize the damage caused by earthquakes, which are a common occurrence in the country.

The purpose of an earthquake early warning system is to detect P-wave component of earthquakes and send out quick alerts to earthquake-prone areas before arrival of S-wave of earthquake waves which travel more slowly than the electromagnetic signal that was once used to transmit information, it is possible to identify the early signals. The warning period would be seconds or minutes, but it might assist people and institutions in acting quickly (Wason, H, R., 2012).

In northern India, IIT Roorkee has deployed 84 accelerometers to monitor and identify earthquakes in Uttarakhand state to determine their location and magnitude, and predict their arrival time. IIT-R with Uttarakhand Government has also launched app called BhuDEV (Bhukamp Disaster Early Vigilantè), the cutting-edge Earthquake Early Warning App (PIB, 2024). The method uses a point source methodology to calculate the magnitude of the earthquake. The system is designed to provide advance warning to the public and relevant authorities to take appropriate disaster response and mitigation measures. When an earthquake of magnitude 6 or more happens, the system notifies all student residences as well as the emergency management centre for each district in Uttarakhand (K, Ashok et al., 2014).

The EEW has undergone new modifications to improve prediction accuracy. The development of the EEW will assist in the establishment of a tsunami warning system. In the future, EEW is anticipated to manage seismic disasters to a greater extent. Ground Motion Alert and Advance Notice of Ground Motion are the two subcategories of Earthquake Early Warning. When expected ground motion has a seismic intensity of 3 or higher, the former transmits; when predicted ground motion has a seismic intensity of 5 or greater, the latter transmits. The Earthquake Early Warning (EEW) system in India uses radio, television, and mobile phones to disseminate notifications to the public and relevant authorities. The system is capable of transmitting two types of alerts: Ground Motion Alert and Advance Notice of Ground Motion. The former is transmitted when expected ground motion has a seismic intensity of 3 or higher, while the latter is transmitted when predicted ground motion has a seismic intensity of 5 or greater.

Implementation:

Digital communication and seismic data instruments aid in data collection and warning issuance, which is the primary driving factor behind EEWS. The growth of the seismic network makes it simpler to collect data and create more precise alarm systems. The requirement for a trustworthy EEW is demonstrated by the earthquakes in Mexico City in 1985, Kobe in 1995, and China in 2008. With greater methodological advancement, one of the best warning systems was used during the Tohoku-Oki earthquake in 2011. Then, the newly developed technology spread to other parts of the globe.

4.3.2.2 Past assessment of EEW at National and International Level

Earthquake forecasting and warning systems have been a topic of interest and research at the international and national levels for several decades.

At the international level, organizations such as the United States Geological Survey (USGS), the Japan Meteorological Agency (JMA), and the European-Mediterranean Seismological Centre (EMSC) have developed earthquake forecasting and warning systems. These systems use a variety of techniques, including seismometers, GPS, and satellite imagery, to detect and monitor seismic activity in real-time. These organizations also work collaboratively to share data and information on seismic activity and to develop new forecasting and warning technologies.

At the national level, many countries have developed their own earthquake forecasting and warning systems. For example, the USGS has developed an earthquake early warning system for the west coast of the United States, known as ShakeAlert. Mexico has also implemented an early warning system called SASMEX, which provides alerts to people in Mexico City when an earthquake is detected.

In India, the National Centre for Seismology (NCS), is the nodal agency of the Government of India for monitoring of earthquake activity in the country. NCS maintains National Seismological Network of more than 160 stations, having state of art equipment and spreading all across the country. NCS monitors earthquake activity all across the country through its 24x7 monitoring stations. Indian Meteorological Department (IMD) has been working on developing an earthquake early warning system. The system is currently being tested in a few cities and is expected to be rolled out to other parts of the country soon.

Assessments of earthquake forecasting and warning systems are ongoing at both the international and national levels. These assessments are aimed at evaluating the effectiveness of existing systems, identifying areas for improvement, and developing new technologies and techniques to improve earthquake forecasting and warning capabilities.

4.3.2.3 Challenges regarding the implementation of the warning system

The warning time is one of EEW's main obstacles. Since receiving the alarm beforehand would be challenging if the network were situated distant from a populated area, such as an offshore region. Receiving the alarm in advance has also been a problem with some hardware. The mobile application that can receive messages is one of the options that scientists are working on, but it has not been proven with many users. The algorithm that can determine the level of ground shaking is another area of worry. According to recent study, extra time is needed to estimate the arrival of the p-wave and predict ground shaking.

4.3.3 Earthquake Risk Mitigation Measures-Structural and Non-Structural

Earthquake risk mitigation aims at reducing the level of seismic risk. The mapping of hazard and mitigation planning has been taking place widespread but the much-needed measures are towards reducing damage, economic losses, and casualties. This is divided into two: structural and non-structural. Structural measures are any physical construction to reduce or avoid possible impacts of hazards, or the application of engineering techniques or technology to achieve hazard resistance and resilience in structures or systems. Non-structural measures are measures not involving physical construction which use knowledge, practice or agreement to reduce disaster risks and impacts, in particular through policies and laws, public awareness raising, training and education.

4.3.3.1 Structural mitigation measures

In order to allow structures to be retrofitted to lessen seismic damage, structural mitigation is crucial. Structural mitigation is expensive and necessitates a broad spectrum of compliance, maintenance, inspection, and renewal challenges. They are divided into a number of categories, one of which is resistance building, which makes sure that the design is built to lessen the forces caused by various disasters (FEMA, 2004). Structural mitigation measures are strategies designed to reduce the impact of disasters on buildings and infrastructure. These measures involve modifying the physical characteristics of buildings and infrastructure to make them more resistant to natural disasters such as earthquakes, hurricanes, and floods.

Some examples of structural mitigation measures include reinforcing walls, roofs, and foundations, using stronger materials, and designing buildings to be more flexible and able to absorb seismic or wind forces. Other measures include improving drainage systems to prevent flooding, building levees or seawalls to protect against storm surges, and constructing buildings on higher ground or using elevated foundations to mitigate flood risk.

Building may undergo structural change, including the addition of sheer walls, the removal of cripple walls, anchor bolts, frame anchor connections, floor framing, chimney reinforcement, base isolation systems, etc., depending on how disaster-prone the area is. Another technique to lessen the impact of an earthquake on a building is to construct a barrier, retention system, and deflection system.

4.3.3.1.1. Bureau of Indian Standards (BIS)

The Bureau of Indian Standards (BIS) is an autonomous body that is responsible for the standardization and quality control of products and services in India. The BIS is responsible for developing and issuing standards for the construction of buildings, including those in Delhi, Shillong, Kolkata, and other main cities in India. These standards are known as the Indian Standards (IS) codes and they provide guidelines for the design, construction, and maintenance of buildings to ensure their safety and durability.

The IS codes are based on the latest international standards and are regularly updated to reflect the latest advancements in building technology and materials. The BIS also provides technical assistance and training to builders, architects, and engineers to ensure that they are familiar with the IS codes and can apply them correctly in their projects.

The BIS has developed specific IS codes for the construction of buildings in seismic zones, such as those in Delhi, Shillong, Kolkata, and other main cities in India. These codes provide guidelines for the design and construction of buildings to ensure that they are able to withstand the forces of an earthquake and minimize damage and loss of life.

In addition to the IS codes, the BIS also provides certification services for buildings that have been constructed in accordance with the codes. This ensures that the buildings are in compliance with the safety standards and are fit for occupancy.

Some of the prominent BIS codes are:

IS 1893:2002 - This code provides guidelines for seismic design of structures and includes provisions for retrofitting of existing buildings.

IS 1893 (Part 1)- 2016: Criteria for Earthquake Resistant Design of Structures - Part 1 : General Provisions and Buildings

IS 1893 (Part 4)- 2015 Criteria for Earthquake Resistant Design of Structures Part 4 Industrial Structures Including Stack - Like Structures (First Revision)

IS 4326:2013- Earthquake resistant design and construction of buildings - Code of practice

IS 13827:1993 -Improving Earthquake Resistance of Earthen Buildings - Guidelines

IS 13828:1993 - This code provides guidelines for repair and strengthening of reinforced concrete structures damaged by earthquakes.

IS 13935:2009- This code provides guidelines for Seismic Evaluation, Repair and Strengthening of Masonry Buildings.

IS 13920:2016- Ductile Design and Detailing of Reinforced Concrete Structures Subjected to Seismic Forces - Code of Practice (First Revision)

These codes provide technical specifications and guidelines for the design, construction, and retrofitting of buildings and infrastructure to improve their resilience to earthquakes. Adherence to these codes can significantly reduce the vulnerability of buildings and infrastructure to seismic forces and contribute to the creation of more disaster-resilient communities.

4.3.3.1.2. Retrofitting of the building

Retrofitting of a building refers to the process of making improvements or modifications to an existing building or structure to make it more resilient to various hazards, including earthquakes, floods, fire, and other natural or human-made disasters. Retrofitting can involve adding new structural elements or reinforcing existing ones to improve the building's overall strength and resistance to damage. A structure's performance, strength, and durability are all enhanced by retrofitting. These days, both new and old buildings adopt this technique. There are various methods for doing this, including the Center Core Method, Surface Treatment Methods including the Bamboo Band Method, Shotcrete Method, and Ferrocene Method. AI can also help in the design and retrofitting of buildings to withstand earthquakes. By analyzing building design, construction materials, and seismic data, AI algorithms can identify weaknesses in building design and provide recommendations for retrofitting. This can help prevent building collapses and reduce the number of casualties during earthquakes. In California, engineers are using AI to retrofit old buildings to make them earthquake-resistant. The technology has been successful in identifying structural weaknesses in buildings and providing solutions to make them safer.

There are different types of retrofitting techniques used in building construction, depending on the building's design, age, and construction materials. Some of the most common types of retrofitting techniques are:

Structural retrofitting: This technique involves adding new structural elements, such as columns, beams, and shear walls, to strengthen the building's structure and increase its resistance to earthquakes or other hazards.

Non-structural retrofitting: This technique involves making modifications to non-structural elements, such as walls, ceilings, and partitions, to improve their resistance to damage and collapse during a disaster.

Foundation retrofitting: This technique involves strengthening or modifying the building's foundation to make it more resilient to seismic forces.

Seismic retrofitting: This technique involves adding seismic-resistant features to buildings to make them less vulnerable to damage from earthquakes. Seismic retrofitting can include adding base isolation systems, dampers, and energy dissipation devices to reduce the building's movement during an earthquake.

Fireproofing retrofitting: This technique involves adding fire-resistant materials to the building's structure and non-structural elements to improve its resistance to fire hazards.

The development of hospitals, institutions, and commercial buildings can benefit from the centre core technique. It increases shear strength without adding mass. It fits in with architectural and historical settings. The bamboo band approach is helpful for masonry construction since it requires less technological innovation but provides twice the stability. Compared to Ferro cement, which is inexpensive and doesn't require a skilled worker, shotcrete technology takes more time but produces behaviour that is durable and consistent. Numerous cutting-edge materials, such as Fiber Reinforced Polymer, Carbon Fiber Reinforced Polymer, Glass Fiber Reinforced Polymer, and Basalt Fiber Reinforced Polymer, are used in the retrofitting process (Pareek, K et al., 2016).

Fig. 10 : (a) Center Core Technique (Pareek, K et al., 2016). (b) Shotcrete Technique (Conservation Wiki., 2021). (c) Bamboo-band Technique (Pareek, K et al., 2016). (d) Ferrocement (Vijayaraja, 2014). Date Visited: 31/12/2022

4.3.3.1.3. Construction typology evaluation

Based on its susceptibility to disaster, each region needs specific building construction. Strength, stiffness, and ductility of each construction must be assessed for this. Building types that are not adequately designed and built have been identified by previous earthquakes. As a result, it is built on vulnerability classifications that consider ground motion. Building typology should consider the area's structural system, the type of materials used, the size of the project, and socioeconomic factors. The two main factors that can affect structural vulnerability are the construction material and load-bearing structures. The secondary characteristics are building height, level of code design, and duration of construction (FEMA., 2004).

Again, the topographical and geological conditions will determine the construction materials. The geology of the ground, both above and below, can have a significant impact on the building materials. Many areas are embracing earthquake-resistant indigenous techniques. However, that relies on the region's cultural riches and heritage. The building may be impacted by climate conditions such as temperature extremes, precipitation, and temperature variation. The structure's location, such as its slope or closeness to water bodies, may have a secondary impact on the risk.

In India, several traditional housing techniques have been used for centuries that are naturally resistant to earthquakes. These techniques incorporate specific features and building materials that have proven to be effective in withstanding seismic forces.

One such technique is the use of timber and bamboo as structural elements. These materials are known for their flexibility and ability to absorb shocks, making them ideal for earthquake-prone regions. The construction of wooden frames and posts, with bamboo or thatch roofs, can also reduce the weight of the building and make it less vulnerable to collapse during an earthquake.

Another traditional technique is the use of mud and stone as building materials. Mud is an effective material for earthquake-resistant construction because it can absorb vibrations without cracking or collapsing. Stone is also a popular building material for earthquake-resistant buildings, especially in hilly regions, as it provides strength and stability to the structure.

In addition to using specific building materials, traditional Indian housing techniques also incorporate architectural features that improve the building's resilience to earthquakes. For example, sloping roofs and curved walls are commonly used to distribute the weight of the building and reduce the impact of seismic forces. The use of thick walls and low-rise buildings can also help reduce the risk of collapse during an earthquake.

4.3.3.2. Non-structural mitigation measures

Non-structural mitigation measures are steps that can be taken to reduce the impact of earthquakes on buildings and infrastructure, without changing the physical structure itself. These measures can be regional to individual scale, cost-effective and easy to implement, and can help to reduce the risk of injury and damage during an earthquake.

Some examples of non-structural mitigation measures include:

Vulnerability Assessment: It is the process of identifying and evaluating the risk, and potential impacts of natural or man-made hazards on a particular system or community. In the context of earthquakes, vulnerability assessment involves the identification of the physical, social, economic and environmental vulnerabilities of buildings, infrastructure, communities and ecosystem to seismic hazards.

The process of vulnerability assessment includes:

- Hazard analysis: Identifying the earthquake hazards that can affect the system or community. This includes understanding the seismicity of the region, identifying the faults that can generate earthquakes, and estimating the magnitude and frequency of earthquakes.
- Asset inventory: Identifying the buildings, infrastructure, and other assets that can be affected by earthquakes.
- Exposure assessment: Determining the level of exposure of the assets to the earthquake hazard. This involves evaluating the vulnerability of the assets based on their location, age, construction type, and other relevant factors.
- Vulnerability analysis: Analyzing the potential impact of earthquakes on the assets and the community. This includes assessing the potential damage, loss of life, and economic impacts.

- Risk assessment: Integrating the hazard analysis, asset inventory, exposure assessment, and vulnerability analysis to assess the overall risk of earthquakes to the system or community.

The results of vulnerability assessment can be used to develop earthquake risk mitigation and preparedness strategies. For example, the vulnerability assessment can identify the buildings and infrastructure that are most at risk and prioritize retrofitting and strengthening measures. It can also identify the populations that are most vulnerable and develop evacuation plans and emergency response strategies.

Securing furniture and equipment: Unsecured furniture and equipment can become hazardous during an earthquake. Simple measures like installing latches on cabinets and bookshelves, using non-skid pads under equipment, and securing computers and other electronics can help prevent injuries and damage.

Hazard assessments: Conducting a hazard assessment can help identify potential hazards causing risks for buildings and infrastructure, allowing for targeted mitigation measures to be implemented.

Building codes and standards: Strict building codes and standards can help ensure that buildings are designed and constructed to withstand seismic activity. These codes can include requirements for earthquake-resistant design, materials, and construction techniques.

Public awareness and education: Educating the public on earthquake safety measures and emergency preparedness can help to reduce the risk of injury and damage during an earthquake.

Implementing non-structural mitigation measures can help to reduce the impact of earthquakes on buildings and infrastructure, and can help to save lives and reduce property damage. Planning for land use, protecting open space, reserving protective resources, denying service to high-risk regions, controlling density, regulating building usage, regulating the use of natural resources, and other similar actions are some of these approaches (FEMA., 2004).

4.3.3.2.1. Capacity Building

Refer Session 4.4.2 (Sub-Module 5: Earthquake Preparedness)

4.3.3.2.2. Land use planning

There are limitations placed on how certain types of land can be used. That depends on the geographical context of the region, such as a coastline zone, a hillslope region, a floodplain region, or a microclimatic setting. Any building's damage is based on the geometry and soil types in the area. So, taking everything into account, there should be effective risk sensitive land-use planning (Fahim, F., 2012).

4.3.3.2.3. Community-based awareness

Refer Session 4.4.3 (Sub-Module 5: Earthquake Preparedness)

4.3.4 Pre-disaster and post-disaster preventive measures

Pre-disaster and post-disaster preventive measures are essential aspects of disaster management that aim to mitigate the impact of disasters on individuals, communities, and infrastructure. Pre-disaster measures are proactive steps taken before a disaster occurs to reduce the likelihood of damage and prepare for an effective response, while post-disaster measures involve responding to the immediate aftermath of a disaster and taking steps to rebuild and recover.

Pre-disaster preventive measures include activities such as risk assessment, hazard mapping, and early warning systems. Risk assessment involves evaluating the likelihood and potential impact of different types of disasters and identifying vulnerable areas and populations. Hazard mapping provides a visual representation of the potential risk from different types of disasters, allowing for better planning and preparedness efforts. Early warning systems provide timely information to people and communities, allowing them to prepare and evacuate if necessary.

Post-disaster preventive measures focus on the immediate response to a disaster, such as search and rescue operations, emergency medical care, and the provision of food, shelter, and other essential supplies. Once the immediate needs are met, the focus shifts to recovery and rebuilding efforts, such as debris removal, repairs to critical infrastructure, and the provision of financial assistance to those affected.

For quick response planning, use of modern tools like AI is also seen to be in use in the event of an earthquake. By analyzing satellite images and other data sources, AI algorithms can quickly identify the affected areas and provide critical information to rescue teams. This can help speed up the rescue and recovery process and save more lives. For example, in Nepal, researchers used AI to analyze satellite images of the 2015 earthquake and identified areas with the highest need for aid. This type of information is crucial in helping organizations prioritize their relief efforts and provide aid to those in need.

Effective pre-disaster and post-disaster preventive measures also require a coordinated effort between governments, emergency services, NGOs, and communities. By working together, these stakeholders can develop and implement effective strategies that reduce the likelihood and impact of disasters, protect vulnerable populations, and support the recovery and rebuilding of affected communities.

Information on post-disaster preventive measures, such as maintaining law and order, evacuating people, recovering bodies, providing medical care, supplying food and water, providing shelters, communication and transportation infrastructure, and assessing the impacted areas should also be provided.

4.3.4.1. Pre-disaster preventive measures

Pre-disaster preventive measures are steps that can be taken to reduce the risk of disasters occurring or to minimize their impact. These measures can be implemented before a disaster strikes, and can help to reduce the risk of injury, loss of life, and damage to property.

Here are some examples of pre-disaster preventive measures:

Hazard assessments: Conducting a hazard assessment can help identify potential hazards and risks in an area, allowing for targeted mitigation measures to be implemented.

Land-use planning: Proper land-use planning can help to reduce the risk of disasters. This can include zoning regulations that restrict development in areas prone to flooding, landslides, or other hazards.

Building codes and standards: Strict building codes and standards can help ensure that buildings are designed and constructed to withstand potential hazards. These codes can include requirements for earthquake-resistant design, materials, and construction techniques.

Early warning systems: Early warning systems can help to provide advance notice of potential disasters, allowing people to evacuate or take other safety measures.

Public awareness and education: Educating the public on disaster preparedness and safety measures can help to reduce the risk of injury and damage during a disaster.

Disaster drills and exercises: Conducting disaster drills and exercises can help people to practice emergency procedures and identify areas for improvement in disaster preparedness plans.

Implementing pre-disaster preventive measures can help to reduce the risk of disasters and their impact on communities. By identifying potential hazards, implementing mitigation measures, and educating the public on disaster preparedness, we can work towards creating safer and more resilient communities.

Real-time Structure health monitoring (SHM) – AI is playing an important role in monitoring structures in the more proficient way. The structures are equipped with sensors that monitor stress, corrosion, and movements caused by traffic and environmental factors. For example, Japan, known for its vulnerability to earthquakes, has implemented cutting-edge SHM systems in many of its skyscrapers and significant structures. A prime example is the Tokyo Skytree, one of the tallest structures in the world, which incorporates advanced seismic damping technology. Sensors throughout the tower monitor vibrations and adjust movement through hydraulic dampers to stabilize the structure during an earthquake. This technology represents a significant advancement in how buildings can adapt to and withstand seismic events.

In the United States, one of the most noteworthy applications of SHM can be seen with the Golden Gate Bridge in San Francisco. The data collected is crucial for maintenance teams to predict potential failure points and plan preventive maintenance, ensuring the bridge's longevity and safety, especially considering the seismic activity in the area.

4.3.4.2. Post-disaster preventive measures

Post-disaster preventive measures are steps that can be taken after a disaster has occurred to reduce the risk of further harm or damage. These measures can help to ensure the safety of people affected by the disaster, as well as to prevent further damage to property and infrastructure.

Here are some examples of post-disaster preventive measures:

Emergency response and recovery: After a disaster, emergency response teams can provide assistance to people affected by the disaster, including search and rescue, medical care, and food and shelter. Recovery efforts can also be initiated to restore critical infrastructure, such as roads, bridges, and utilities.

Hazard assessments: After a disaster, it is important to conduct a hazard assessment to identify any ongoing risks or hazards. This can help to determine which areas may need additional measures to prevent further damage or harm.

Temporary housing: Providing temporary housing to people who have been displaced by a disaster can help to ensure their safety and well-being.

Debris removal: Removing debris from affected areas can help to prevent further damage and hazards, and can facilitate recovery efforts.

Infrastructure repair and reinforcement: Repairing and reinforcing critical infrastructure, such as buildings, bridges, and roads, can help to prevent further damage or collapse.

Education and awareness: Educating the public on how to prevent further damage or harm after a disaster can help to reduce the risk of injuries and fatalities.

Implementing post-disaster preventive measures can help to ensure the safety of people affected by disasters, as well as to prevent further damage or harm. By conducting hazard assessments, providing emergency response and recovery efforts, and reinforcing critical infrastructure, we can work towards creating more resilient communities in the aftermath of disasters.

4.3.4.3. Earthquake Do’s and Don’ts

Following earthquake do’s and don’ts can help to ensure your safety during and after an earthquake as shown in Fig 11. It’s important to stay informed and prepared for earthquakes, as they can strike without warning.

Do’s:

- Drop, cover, and hold on: When an earthquake occurs, drop to the ground, take cover under a sturdy piece of furniture, and hold on until the shaking stops.
- Stay indoors until the shaking stops: Stay indoors and away from windows and exterior walls until the shaking stops.
- Turn off gas, water, and electricity: If you smell gas or suspect a leak, turn off the gas immediately. Turn off the water and electricity if you suspect damage to these systems.
- Use stairs, not elevators: If you’re in a multi-story building, use the stairs instead of the elevators.
- Stay informed: Listen to local news and follow instructions from emergency officials.

- Check for injuries: After the earthquake, check yourself and others for injuries and seek medical attention if necessary.

Don'ts:

- Don't panic: Remain calm and follow earthquake safety procedures.
- Don't use elevators: Avoid using elevators, as they may malfunction during an earthquake.
- Don't run outside: Running outside during an earthquake can be dangerous due to falling debris and other hazards.
- Don't use candles or matches: Use a flashlight to avoid the risk of fire from broken gas lines or other hazards.
- Don't overload phone lines: Avoid using the phone except for emergencies to prevent overloading phone lines.
- Don't touch downed power lines: Stay away from downed power lines or electrical wires, and report them to the authorities immediately.

Fig. 11 : Earthquake Do's and Don'ts

Source: India.com (2023) https://www.india.com/news/india/earthquake-in-delhi-ncr-latest-news-today-22-march-dos-and-donts-to-ensure-safety-before-during-and-after-tremors-noida-faridabad-gurugram-pakistan-afghanistan-himachal-pradesh-5957341/

4.3.5 Liquefaction and Seismic microzonation

With rapid earthquake shaking, the sandy soil would turn into muddy water and starts flowing and thereby collapse the structure, a phenomenon called liquefaction. The strength of the soil is reduced and the ability to support structures also decreases. This may also cause landslides and collapse of dams.

4.3.5.1. Liquefaction phenomena

Individual soil particles that will come into contact with one another make up the soil deposit. The strength to support the weight above it grows as the bonds between the pieces are tightly held. Thus, it generates the shear strength needed to support buildings and other structures.

But upon considerable loading, such as shaking of the ground brought on by an earthquake or blasting, deforms the soil and lessens its strength. Less interaction between the particles results from this. As the soil arrangement changes, soil particles strive to shift into a denser structure. However, during the first shaking, there shouldn't be enough time for the soil water to escape through the pore space. As pore pressure rises, contact force decreases. By decreasing the soil's shear resistance, this destroys the soil deposit. The link between the particles will weaken and start to behave like a liquid when pore water pressure reaches an excessive level (Maithili, K, L., 2017).

4.3.5.1.1 Liquefaction of sand

Liquefaction of sands refers to the process in which water-saturated granular soils (usually sands) lose their strength and stiffness during an earthquake or other strong ground-shaking event, causing them to behave like a liquid instead of a solid.

During an earthquake, the shaking of the ground can cause the soil particles to rearrange themselves, which can cause the pore pressure within the soil to increase. If the increase in pore pressure is sufficient, it can overcome the confining stress within the soil and cause it to lose its strength, stiffness, and ability to support loads.

Liquefaction can lead to a variety of effects, including:

Settlement of structures: Liquefaction can cause the ground to settle, which can lead to damage or collapse of buildings, bridges, and other structures.

Ground cracks: Liquefaction can cause the formation of ground cracks, which can further weaken the soil and lead to additional liquefaction.

Landslides: Liquefaction can cause landslides, which can result in significant damage and loss of life.

Tsunamis: Liquefaction can also cause underwater landslides or collapse of coastal land which may generate tsunamis.

Liquefaction is a significant geotechnical hazard in many parts of the world, including areas of high seismic activity such as Japan, California, and New Zealand. Engineers and geologists use a variety of methods to assess the potential for liquefaction and to design structures and foundations to resist its effects. These methods include field investigations, laboratory testing, and computer modeling.

4.3.5.1.2. How to reduce liquefaction hazard

There are certain methods that can lessen the risk of liquefaction. The main method is soil improvement technique, which fortifies and increases density to prevent soil collapse. The Vibroflotation method, Dynamic Compaction, Stone Columns, Compaction Piles, Deep Soil Mixing, Compaction Grouting, Permeation Grouting, Jet Grouting, Passive Site Stabilization, Microbial Geotechnology, Induced Partial Saturation, and Drainage Techniques are a few of the methods that can be used to accomplish this (Maithili, K, L., 2017).

Another strategy is to build liquefaction-resistant structures, which fortify buildings against the effects of liquefaction by engineering their foundational elements to do so. This method works best when the soil is prone to liquefaction yet is required for building due to a shortage of space, the best spot, and a favourable location. Shallow foundation aspects and Deep foundation aspects are two approaches that could be used. Avoiding soil that is liquefaction vulnerable is the other strategy. These can be verified using a variety of criteria, including historical, geological, compositional, and state criteria.

4.3.5.2. Seismic Microzonation

Seismic microzonation is a scientific process that involves the detailed study of a specific geographic area to identify the characteristics of seismic hazards and soil. It is the first step in earthquake risk mitigation study and requires multidisciplinary approach with major contributions from the fields of geology, seismology, geophysics, geotechnical and structural engineering. By identifying the areas of high risk and developing mitigation strategies, seismic microzonation helps to minimize the damage and loss of life caused by earthquakes. The information obtained through this process is also useful in developing building codes, urban planning, development of any master Plan and emergency management Plan.

Seismic microzonation help divide an area into smaller zones based on the local geological, geotechnical, and seismological conditions. This helps in identifying areas that are more susceptible to ground shaking, liquefaction, or landslides. Depending upon the level of investigation, the technical committee of International Society of Soil Mechanics and Foundation Engineering (ISSMFE) has recommended three levels of microzonation: Grade 1 belongs to general zone which is of the ratio 1:50,000 to 1:1,00,000, Grade 2: Detailed zone which is of the ratio 1:10,000 to 1:1,00,000 and Grade 3, which is Rigorous zone of ratio 1:5,000 to 1:25,000. It is mandatory that any subsurface which is extremely sensitive to the earthquake ground shaking is needed to investigate.

4.3.5.2.1. Importance of Seismic Microzonation

The purpose of seismic microzonation is to identify areas that are more susceptible to earthquake damage due to their soil conditions, geological setting, and proximity to active faults. Seismic Microzonation of cities in India having population of 5 Lakh and above is also considered. The purpose is to generate inputs for constructing earthquake risk resilient buildings / structures to reduce and mitigate the impacts of earthquake shaking and for minimising the damages to structures and loss of lives for safer urban planning (NIDM, 2018). Some of the key importance of seismic microzonation are:

- Disaster mitigation: Seismic microzonation provides valuable information for disaster mitigation planning and emergency response. By identifying areas that are more susceptible to earthquake damage, planners can take steps to improve building codes, strengthen critical infrastructure, and design evacuation routes to minimize loss of life and property damage.
- Risk assessment: Seismic microzonation is also important for risk assessment, which involves evaluating the likelihood and potential consequences of a seismic event. This information is used to make informed decisions about land use, zoning, and infrastructure development.
- Design of structures: Seismic microzonation provides valuable information for the design of structures. By understanding the soil conditions and seismic hazard of an area, engineers can design buildings and other structures to resist the effects of earthquakes and reduce the risk of damage or collapse.
- Public safety: Seismic microzonation also helps to ensure public safety by identifying areas that are more susceptible to earthquake damage. This information can be used to develop public education programs that teach people how to prepare for earthquakes and reduce the risk of injury or death.

Delhi Microzonation- A case study

Delhi Microzonation is a study that aims to assess the seismic vulnerability of different areas in Delhi to earthquakes. A thorough survey and mapping of numerous criteria, including soil type, land use, building density, and structural vulnerability, among others, were part of the study. The survey results were used to create seismic hazard maps and vulnerability profiles of various Delhi in neighbourhoods, which were then used to decide which mitigation measures should be prioritized.

The Delhi Microzonation study aids in identifying regions that are more likely to sustain damage in the case of an earthquake and in the development of suitable mitigation actions to reduce the risk of human and material loss. Delhi, one of India's most densely inhabited and earthquake-prone cities, can benefit greatly from the study in terms of improving earthquake preparedness and response.

The Geological Survey of India (GSI), the National Disaster Management Authority (NDMA), and other technical specialists conducted the study. The study's conclusions assist in locating sites that require retrofitting, enhancing soil quality, and enhancing emergency response systems. The ongoing Delhi Microzonation research seeks to strengthen the city's seismic risk tolerance and lower the likelihood of property and life loss in the event of an earthquake.

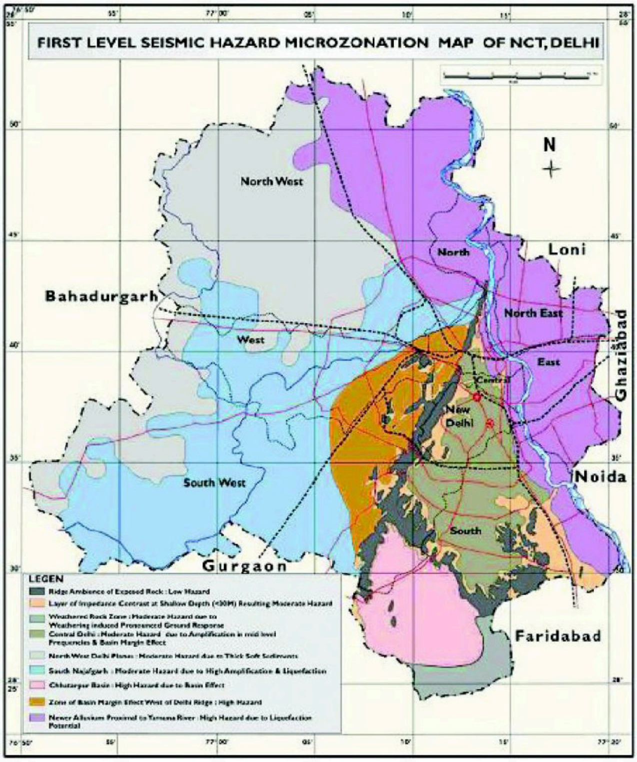

Fig. 12 : Seismic hazard microzonation map for Delhi at 1:50000 scale

Source: Dattatrayam, R. S., Suresh, G., Baidya, P. R., Prakash, R. A. J. E. S. H., Gautam, J. L., Shukla, H. P., & Singh, D. (2014, September). Standards and methodologies of seismological data generation, processing and archival & guidelines for data sharing and supply. In Proc. Indian Natl. Sci. Acad. (pp. 679-696). https://www.researchgate.net/publication/273178713_Standards_and_Methodologies_of_Seismological_Data_Generation_Processing_and_Archival_Guidelines_for_Data_Sharing_and_Supply retrieved on July 29, 2024

4.4 SUB-MODULE 5: EARTHQUAKE PREPAREDNESS

4.4.1. Disaster Preparedness and its components

Measures done to be prepared for a disaster and lessen its impacts are referred to as disaster preparedness. Disaster preparedness is a multifaceted profession that calls for expertise in all aspects which will help reduce the disaster impact in future from institutional development to health care to training and logistics. The preparedness strategies considers both pre and post disaster phases to increase efficiency, efficacy, and reduce overall impact. This includes testing early warning systems, familiarizing the officials with Plan and SoPs, regular training or awareness of first responders, and creating organisational structures for good coordination.(IFRRCS, 2020).

Preparedness thus focuses on plans to respond to a disaster threat. By estimating the emergency needs and resources at different level helps in planning a well-designed plan to structure the entire post disaster response.

The disaster preparedness plan also intends to improve local community preparedness, which includes empowering locals to lower risks and set up their own local response system. Developing a community preparedness Plan targets on creating exercises that target common hazards and provide guidance on how to handle them. Disaster preparedness is interlinked with mitigation strategies. Risk assessment for mitigation calls for three crucial details: (1) finding the issue, (2) estimating its size, and (3) identifying the top priority right away. Five crucial necessities are needed for the initial need assessment: water and sanitation, health services, housing, food, nutrition, and coordinating activities. The key focus of a preparedness plan is making sure that both of these assessments are completed. The ability to act rapidly when necessary is the primary goal of any preparedness Plan.

Preparedness can be government based and local population-based preparedness. One group is the government component, which is in charge of managing disasters and emergencies as well as making sure that all governmental and other service organisations and activities are prepared. The majority of effective practises are found in first response, which includes the military, emergency management, medical services, and law enforcement agencies. Planning, equipment and resources, practise, training, and statutory authority are the five main parts of the government's readiness activity. Public preparation attempts to give people the tools they need to aid themselves and the community. It starts with a documented plan that can be implemented in a variety of circumstances. There are several ways to educate the general population, including media communication, commercials, posters, endorsements, campaigns, schools, businesses, churches, libraries, special events, and social networks.

4.4.1.1. Components of earthquake preparedness

There are nine components for disaster preparedness.

Vulnerability Assessment	Planning	Institutional Framework
Information systems	Resource Base	Warning systems
Response Mechanism	Public education and training	Rehearsals/ Mock Drills

Table Source: International Federation of Red Cross and Red Crescent Societies (2020). Page visited date: 02/01/2023

Vulnerability Assessment: To determine the location's susceptibility, all available information gathered through vulnerability assessment should use in the preparedness activities. Information development for during and post disaster scenarios can also aid in effective disaster preparedness.

Planning: For all the activity, the planning is required in a way that are implementable in specific affected area. For earthquake safety, most important is to plan the developmental activities in a resilient and sustainable way. In doing so, use of existing/ making new standards, policies, building codes and guidelines for earthquake resilience, involving the competent authority while construction and incorporating risk sensitive land use planning in the Master Plan, urban Plan of any city is required. The use of earthquake hazard map, seismic zonation map and seismic microzonation is useful. The planning stage requires the expertise of multiple stakeholders hence planning for efficient coordination among them is must. Developing and practicing an emergency plan can help to ensure that people know what to do in the event of an earthquake. This can include identifying safe areas in buildings, establishing communication protocols, and training staff on how to respond to an earthquake.

Robust Institutional Framework: The planning stage for earthquake risk mitigation requires the expertise of multiple stakeholders hence planning for efficient coordination among them is must. A coordination should be there in the preparedness cycle that depend upon a region's traditional and governmental structure. This aspect requires a structure for decision making. Each ministry is responsible for the implementation of planning.

Information Systems: This is regarding data collection and early warning systems. An adequate monitoring system can provide information on the onset of the disaster.

Resource base: First, it is important to recognise the needs that were present during the early stages of the crisis. Food, housing, medications, communication systems, rescue personnel, clean up tools, etc. are a few of the essentials.

Warning System: A warning system can save many lives. By giving proper notice to the public, they can either escape from the place or take precautions.

Response Mechanisms: Various response mechanisms should be implemented based on the warning systems.

Public education and training: There are many different ways to educate the public, such as teaching children and young adults how to handle emergency situations in school by introducing a special course on preparedness and other topics for young adults, Extension programmes for local communities and villages to offer pertinent information for the task they should perform, and Public information through print, radio, and television media. (Refer 5.2. Capacity Building)

Rehearsals: There should be a suitable drill for disaster preparedness that places an emphasis on training and testing the system as a whole.

4.4.1.2. Good Practices for Earthquake safety

Earthquakes can strike suddenly and without warning, causing significant damage and loss of life. Therefore, it is essential to know and take steps to prepare for earthquakes and minimize their impact. The common should be known to every individual having the risk of earthquake in their local area. Here are some good practices for earthquake preparedness:

- Develop an emergency plan: Develop an emergency plan that includes evacuation routes, a communication plan, and a meeting place for family members in case you get separated. Make sure all family members know the plan and practice it regularly.
- Prepare an emergency kit: Prepare an emergency kit that includes enough food, water, medication, and other supplies to last at least three days. Make sure the kit is easily accessible in case you need to evacuate quickly.
- Secure your home: Secure heavy items such as bookcases, cabinets, and appliances to prevent them from falling during an earthquake. Use flexible connectors for gas appliances and install latches on cabinet doors.
- Know your building: Know the age and construction of your building, as older buildings may be more vulnerable to earthquake damage. If you live in an earthquake-prone area, consider hiring a professional to evaluate your home's seismic safety.
- Stay informed: Stay informed about earthquakes and their potential impact by monitoring local news and weather reports. Sign up for emergency alerts and notifications from your local government or emergency management agency.
- Practice Drop, Cover, and Hold On: Practice the "Drop, Cover, and Hold On" technique, which involves dropping to the ground, taking cover under a sturdy desk or table, and holding on until the shaking stops through regular mock drill.
- Have a backup plan: Have a backup plan in case your primary plan fails. Make sure you have a secondary meeting place and communication plan in case the primary one is inaccessible or compromised.

4.4.2. Capacity Building

Capacity building encompasses education, the creation of institutions, community-based training, information sharing, and coordination, under Disaster Risk Reduction (DRR), all of which support the construction of partnerships between multiple groups involved in disaster management and mitigation. Understanding the local area's political, physical, social, economic, cultural, and environmental variables is essential for this task. The main goal of capacity development is to enhance the state of the human resources in order to give disaster-prone populations sustainable capacity.

One of the important studies of capacity building is done in Gujarat earthquake for a long-term measurement. Their strategies include introduction of earthquake engineering in civil engineering and architecture, education program for practicing engineering in earthquake engineering and upgradation of skills in government engineering.

Capacity building is an integral part of non-structural measures, which is an essential aspect of earthquake risk mitigation. One of the key elements of capacity building for non-structural measurements is training. This includes training for professionals, such as engineers and architects, as well as training for community members and local officials. Training can help individuals and organizations understand the risks associated with earthquakes, and how to take action to reduce those risks.

Another important aspect of capacity building is the development of guidelines and standards for non-structural measurements. These guidelines and standards can help ensure that buildings, infrastructure, and emergency response plans are designed and implemented in a way that minimizes the potential impact of an earthquake.

The use of advanced technologies and equipment can also play an important role in capacity building for non-structural measurements. For example, the use of building information modeling (BIM) can help architects and engineers design buildings that are more resilient to earthquakes. The use of advanced sensing and monitoring equipment can also help identify potential risks and vulnerabilities in existing buildings and infrastructure.

In addition to training, guidelines and standards, and advanced technologies, it's essential to involve the community and local officials in the capacity building process. This includes engaging community members in disaster preparedness and risk reduction efforts, as well as working with local officials to develop and implement emergency response plans.

In conclusion, capacity building includes training, guidelines and standards, and advanced technologies, as well as involving the community and local officials in the process. By taking action to reduce the potential impact of earthquakes, we can create stronger and more resilient communities that are better prepared to withstand the impacts of earthquakes.

4.4.2.1. Elements of Capacity Building

There are various elements for capacity building.

(1) *Education on disaster prevention and response.*
It is important to educate the vulnerable communities and local population about the disaster and how it can affect the area. It should also emphasize on preventive measures and strategies on how to deal with the disaster.

(2) *Training to communities*
It aims at teaching local people how to response to the disaster through training programs. It helps them survive and help other people as well.

(3) *Collaboration with relief agencies*
It is crucial that various governmental and non-governmental organisations, including local NGOs, the civil defence and fire departments, the Indian Red Cross Society (IRCS), and village, gram panchayat, and block panchayats, collaborate and contribute.

(4) *Mock drills*
Mock drills are simulated exercises that, through constant practise, help communities become more united in the event of a disaster. The fake drill's primary goal is to increase local residents' courage and leadership abilities.

(5) *Household preparation*
This is the evaluation plan, which calls for keeping the bare minimum of clothing and placing all valuables in waterproof bags.

(6) *Understanding warning and de-warning messages*
The other duty that can be accomplished through training and involvement of stakeholders is the capacity to comprehend the early warning.

(7) *First-aid preparation*
To deal with accidents and injuries, a first-aid kit must be set up in addition to all the training and exercises.

4.4.2.2. Earthquake related Capacity Building initiatives by Government of India

India is highly vulnerable to earthquakes, and the government has taken several capacity building initiatives to strengthen earthquake preparedness and response. Some of the major initiatives are:

National Disaster Management Authority (NDMA): The NDMA is responsible for coordinating and implementing policies and programs related to disaster management, including earthquake preparedness. NDMA has published many guidelines related to earthquake such as Simplified Guidelines for Earthquake Safety (2021), A Primer on Rapid Visual Screening (RVS) Consolidating Earthquake Safety Assessment Efforts in India (2020) etc. Several projects were initiated up by NDMA in collaboration for earthquake mitigation such as:

- National Earthquake Risk Mitigation Project (NERMP): (2013 -2015)
- National School Safety Programme (NSSP): (NDMA) in partnership with Ministry of Human Resource Development (MHRD) , State/UT Governments, National and international agencies worked in 43 districts of 22 States /UTs of the country falling in seismic zone IV & V
- Pilot project to improve Earthquake Resiliency of Masonry Lifetime Structures and upcoming construction

National Institute of Disaster Management (NIDM): The NIDM is the premier institute for training and capacity building in disaster management, including earthquakes risk mitigation and management. It provides training and certification programs for government officers, professionals and academicians.

National Centre for Seismology (NCS): The NCS is responsible for monitoring and recording earthquakes in India. It also provides seismic hazard and risk assessments and early warning alerts. launched 'India Quake' – An App for Earthquake Parameter Dissemination in 2017, BhooKamp is a mobile app of National Center for Seismology (NCS) released on 2019 to provide earthquake alerts and updates to the public.

Bureau of Indian Standards (BIS) undergoes several revision of building codes to incorporate earthquake-resistant features. These codes provide guidelines for construction practices to mitigate earthquake risks, ensuring that buildings and infrastructure are more resilient to seismic events. The trainings related to standardization and NBC codes is also given through its training institutes.

Coalition for Disaster Resilient Infrastructure (CDRI) is a multi-stakeholder global partnership of national governments, UN agencies and multilateral development banks, private sector and knowledge institutions that aims to build resilience into infrastructure system for ensuring sustainable development. One of the CDRI's strategic priorities is to provide Capacity-building which includes disaster response and recovery support; innovation, institutional and community capacity-building assistance; and standards and certification.

In conclusion, the Indian government has taken several capacity building initiatives to strengthen earthquake preparedness and response, including the establishment of specialized agencies, training and certification programs, public awareness campaigns, and infrastructure evaluations. These initiatives aim to reduce the impact of earthquakes and increase the safety of people and infrastructure in vulnerable areas.

4.4.2.3. Community-based earthquake preparedness

Community-Based Disaster Preparedness (CBDP) aims at community collaboration and internal resource mobilisation for a more systematic and effective utilisation of external resources needed to implement plans and initiatives that the community members have determined to be the most pertinent. CBDP aims at providing awareness to the community regarding the risk of the place that they are living in. It also aims at emphasizing the methods and strategies adopted by the community which belongs to high risk areas and look at how to improve and make use of the resources in order to withstand the impact of the disaster. All the activities should be involving local people who gets the role as proactive and not as a passive target for the intervention (ASDMA, 2013). Their involvement and intervention will ensure the collective action during emergencies. CBDP also aims at building community leadership and trained community cadres through participatory approach and solution that comes from people themselves.

It is crucial to inform the people about the risk and teach them how to reduce it. The focus of public education is to promote preparedness for catastrophes and mitigate the impact of disasters. Through public education, people can become more aware of the potential hazards and risks associated with natural disasters such as earthquakes, floods, and cyclones. This awareness can help them take preventive measures to reduce the risk of loss of life and property. Pre-disaster risk reduction, pre-disaster preparedness, post-disaster response, and recovery should be the main topics of public education. When the risk reaches a certain point, warning systems can advise the general public of the need for action. (FEMA., 2004).

4.4.2.4 Importance of CBDP

The majority of a disaster's effects are felt at the local level, making it easier to identify and manage the social, economic, and physical risks there. Local issues receive less discussion and attention, and only local communities may act to address their problems. Since locals are more knowledgeable than others when it comes to available options, CBDP is once again more pertinent. The first action in any disaster is taken by the neighbourhood itself. Data and information analysis should be done in a way that the general public can understand, using terminology that is appropriate for the area. Since locals are involved in CBDP, both their actual needs and innate wants are well known and may be met with the right intervention (ASDMA., 2013).

4.4.3. Earthquake education, training, and capacity enhancement

The target audience for earthquake education and training should be determined. But not everyone receives education using the same techniques. As a result, classifying and rating people would be more efficient in terms of time and effort. Vulnerable individuals who are unable to anticipate, cope with, resist, or recover from an earthquake should receive earthquake education. These individuals include kids, expectant mothers, malnourished individuals, and disabled individuals. People with these limitations must therefore receive knowledge from professionals and trained individuals (ASDMA., 2013).

4.4.3.1. Planning of earthquake risk mitigation and prevention at local level

Planning for earthquake risk mitigation and prevention at the local level is essential to reduce the impact of earthquakes on communities and infrastructure. Here are some steps that can be taken at the local level:

Identify vulnerable areas: The first step in earthquake risk mitigation is to identify the areas that are most vulnerable to earthquakes. This can be done through seismic hazard and risk assessments.

Retrofit existing buildings: Existing buildings should be retrofitted to make them earthquake-resistant. This includes strengthening of critical structural elements, adding shear walls or bracing, and improving foundation design.

Develop emergency response plans: Local communities should develop emergency response plans that include evacuation plans, shelter locations, and communication plans.

Conduct drills and training: Regular earthquake drills and training sessions should be conducted to prepare communities for earthquake response and to reinforce the importance of earthquake safety measures.

Raise public awareness: Public awareness campaigns should be conducted to educate communities on earthquake safety measures, including the “Drop, Cover, and Hold On” technique.

Due to their physical, emotional, and cognitive capacities for safety as well as protection against emergencies and disasters, children are one of the vulnerable groups that depend on adults. The gap between knowing and acting on knowledge can be narrowed by promoting readiness education among kids. Education about earthquakes can increase children’s resilience and information sharing to lower the likelihood of disasters at their homes. Students might receive their education in large part from their families and schools. They can coordinate the emergency removal of kids to safety during an incident and assure first assistance.

Another vulnerable category that has many issues during disasters is women. The level of education, awareness, and readiness of all family members can be ensured by educating women. After finishing their training programme, they can take part as an active member as well. Reproductive health issues should also be taken into consideration. They may receive training at schools, mosques, workplaces, etc. Senior citizens need specialised training for their physical limitations and cognitive impairment. Through such a training programme, they should assist the mental health of the younger generation. Disability-related individuals should receive training in self-defence techniques as well. They should receive training that focuses exclusively on surviving the catastrophe.

4.5. SUB-MODULE 6: POST-EARTHQUAKE RELIEF AND RESPONSE

Post-earthquake response after may include emergency procedures, including evacuation, search and rescue, and relief. In the aftermath of an earthquake, various stakeholders may be involved in a variety of response and recovery operations. Immediately following an earthquake, rescue and relief efforts should be prioritised as per the disaster management plan. The trigger mechanism or setting of an incident command system is an essential component of any disaster response. It is designed to energise and activate the mechanism of response and mitigation upon receiving a warning of an imminent disaster.

4.5.1. Assessing initial needs

Understanding the evaluation for the communities' short- and long-term needs is one of the post-quake phase's main goals. Based on the priorities established by each sector's integrated strategy, this is done. Staff from the community and non-profit organisations must work together on this. Seven different sectors must be evaluated: Water, sanitation, and hygiene come first, followed by shelter, agriculture, and means of subsistence, then education, health, infrastructure, and protection (Thapa, I., 2015).

When an earthquake occurs, the community members will be the first to respond, and they will require aid from the police, the State Disaster Response Force (SDRF), the Fire Department, and the Medical Service. A First Information Report that outlines the disaster's severity, the steps being taken locally, the capacity of the community to cope, the top priorities right away, and the expected course of events should be distributed. The daily situation report about damage assessments and the need for basic necessities is then due.

4.5.1.1. Search and Rescue

The goal of search and rescue is to discover whether there are any affected lives present during a disaster. It requires a group of teams, including a squad leader who develops the search strategy, maintains records, and makes recommendations to the commander, and rescuers who physically carry out the squad leader's plan. The strategy calls for a variety of communication aids, including walkie-talkies, flags, and cones for marking. Equipment for reconnaissance and vision, as well as warning alert devices, are needed for the process (Thapa, I., 2015).

4.5.1.2. Medical First Response

Rapid medical intervention is required to identify and evaluate potential threats to human health. Experts with competence should evaluate the sufferers' nutritional and physical health. It should be possible to obtain medical resources at the closest locations, and there should be a sufficient supply of medical supplies such as kits and disinfectants. The vaccination of youngsters and pregnant women is required. Measures for preventing vectors must be taken. There is a very high likelihood that a water-borne illness may occur. As a result, proper measurement needs to be done for this issue as well.

4.5.1.3. Psychosocial support

To lessen the stress and trauma experienced by the affected population, psychosocial and mental health treatments should be made available as soon as possible following the disaster. In the impacted areas, a mental health officer must be appointed, and quick evaluation for psychosocial support is crucial. For psycho-social first aid and to transport the unwell individual to the hospital, trained personnel are required. First aid should be administered by community people, as well as members of the relief and rescue efforts. In the immediate aftermath of a tragedy, this service can be arranged in relief camps (Thapa, I., 2015).

4.5.1.4. Water, Sanitation and Hygiene (WASH)

The provision of clean water for drinking, washing, and other domestic purposes, the final disposal of waste, and health promotion initiatives to support these behaviours among the impacted population are all referred to as WASH. Severe illnesses include diarrhoea, hepatitis, cholera, typhoid, dysentery, intestinal helminths, malaria, and trachoma are caused by improper management of WASH. This infection may spread through contact with water, from hand to mouth, or by flies and mosquitoes that breed close to waste disposal facilities and bodies of still water. Communities and the government could control this by properly designing, constructing, and maintaining water and sanitation systems, assessing vulnerability, and using multi-sectoral strategies (Health Emergency and disaster Risk Management., 2017).

4.5.1.5. Immediate shelter

Shelter is important for sustaining family and community in certain circumstances. It is necessary to provide sufficient space for shelter for the affected people. Also, it is important to provide artificial lights to provide personal security and to provide tools, equipment and material for repair, reconstruction and maintenance.

4.5.1.6. Incident Response System (IRS)

An incident response system is a critical component of earthquake response, as it helps to organize and coordinate the efforts of emergency responders, government agencies, and other organizations during the immediate aftermath of an earthquake. The goal of an incident response system is to quickly and effectively respond to the needs of affected communities and to minimize the damage caused by the earthquake.

The incident response system typically includes a designated incident command center, which serves as the hub for all emergency operations. This command center is staffed by a team of experts from various fields such as emergency management, health, housing, and social services, who work together to coordinate the response and recovery efforts.

The incident response system also includes a system for communicating important information to the public and other stakeholders. This may include setting up emergency shelters, providing information about the location of emergency services, and issuing evacuation orders.

In the event of an earthquake, the incident response system is activated immediately to begin assessing the extent of the damage, identifying the needs of the affected population, and deploying resources to meet those needs. This may include providing food, water, and medical assistance to survivors, as well as assessing the condition of damaged infrastructure and identifying any immediate safety hazards (United Nations Office for Disaster Risk Reduction., 2017).

The incident response system also includes a process for conducting search and rescue operations, which are critical in the immediate aftermath of an earthquake. This may include deploying search and rescue teams, as well as providing equipment and resources to support these operations.

Overall, an incident response system is a critical component of earthquake response. It helps to organize and coordinate the efforts of emergency responders and other organizations, and to quickly and effectively respond to the needs of affected communities. This helps to minimize the damage caused by the earthquake and to ensure that affected communities receive the assistance they need in a timely and effective manner.

4.5.2. Organizations, Services, and Departments

Refer 4.1.3.5. Institutional Framework and Technological Framework

4.5.2.1. Damage Assessment

An important emphasis of post-earthquake damage assessment is the actual structural harm done to buildings and other structures. This assessment approach must consider the type and extent of damage as well as the immediate needs in order to paint a complete picture and build a prompt and effective response strategy. The damage assessment can be divided into Rapid Visual Assessment (RVA), Detailed Safety Assessment, and Engineering Evaluation (IFRC, 2020).

4.5.2.1.1. Rapid Visual Screening (RVS) Assessment

There are different methods to assess seismic evaluation of existing buildings, however, it is usually started from undergoing a rapid visual screening (RVS), followed by preliminary assessment and detailed evaluation. RVS of buildings is the first step of the building vulnerability assessment. A building's RVS can be used to better identify its structural flaws. It entails a planned sequence of technical observations based on observable information. It examines a building's age, material, technology, form, pattern of openings, and any clear symptoms of structural distress. This approach only relies on visual observations, so while it gives a decent overall sense of safety, it cannot be relied upon to be highly accurate.

It is obvious that thorough analyses are required to determine the building's earthquake safety. RVS is a mostly qualitative, visual technique. It aids in classifying structures that have suffered minor, moderate, and catastrophic damage. All buildings must undergo RVS as a preliminary screening procedure after an earthquake (NDMA, 2020).

PRACTICAL EXERCISE

Suggested Readings for RVS exercise:

1. TARU (2014) A guide book for integrated rapid visual screenings of buildings

   https://ssdma.nic.in/Uploads/PdfFiles/Fire_safty_handout.pdf

2. NDMA (2020) A Primer on Rapid Visual Screening (RVS) Consolidating Earthquake Safety Assessment Efforts in India

   https://ndma.gov.in/sites/default/files/PDF/Technical%20Documents/RVS Doc-11-2020.pdf

4.5.2.1.2. Detailed Safety Assessment

All partially and significantly damaged buildings must undergo a thorough safety assessment. This approach, which identifies the essential broad acts, is based on extremely specific technical observations.

4.5.2.1.3. Engineering evaluation

Buildings that are being considered for designed rehabilitation or retrofitting must first undergo an engineering review. Non-destructive tests, soil analyses, and structural engineering studies are all part of it. This evaluation aids in identifying construction flaws brought on by ageing and earthquake-related invisible structural damage as well as building code compliance.

4.5.3. Post Disaster Need Assessment

Making assessments can be difficult due to the extensive devastation and dislocation that follows a sudden calamity like an earthquake. In order to swiftly determine where people are, what condition they are in, what they are doing, what their needs and resources are, and what services are still available to them, an evaluation must first identify where individuals are.

Post-disaster needs assessment is a critical process that helps identify the immediate and long-term needs of affected communities following a disaster. The assessment is typically carried out by a team of experts from various fields such as emergency management, health, housing, and social services. The goal of the assessment is to gather accurate and comprehensive information about the impacts of the disaster, and to use that information to guide the development of an effective response and recovery plan.

The assessment process typically begins with a rapid assessment, which is carried out immediately after the disaster to identify the most pressing needs of the affected population. This may include providing food, water, and medical assistance to survivors, as well as assessing the condition of damaged infrastructure and identifying any immediate safety hazards.

Once the immediate needs have been addressed, a more detailed and comprehensive needs assessment is conducted. This assessment typically involves a team of experts conducting interviews and surveys with affected communities, as well as assessing the condition of homes, schools, and other critical infrastructure. The information gathered during this phase is used to identify the specific needs of the affected population, such as housing, healthcare, and social services.

In addition to identifying the needs of the affected population, post-disaster needs assessments also help to identify the resources and capacities available to meet those needs. This includes assessing the availability of personnel, equipment, and funding, as well as identifying any gaps or constraints that may impact the response and recovery effort.

The government conducted a PDNA to evaluate the damage and determine the needs for recovery in response to the 2018 Kerala floods, which impacted more than 1.4 million people. According to the evaluation, the flooding severely damaged infrastructure, such as roads, bridges, and buildings, and disrupted vital services including the delivery of water and power. Similar to this, following the 2019 Cyclone Fani in Odisha, the government carried out a PDNA to assess the losses and harm brought on by the disaster and determine what needs to be done for recovery and rehabilitation. According to the study, the storm extensively damaged infrastructure, including housing, electricity, and telecommunication, forcing millions of people to flee their homes and losing their means of subsistence.

Overall, post-disaster needs assessments are a critical component of disaster response and recovery. They provide valuable information that is used to guide the development of effective response and recovery plans, and to ensure that the needs of affected communities are met in a timely and effective manner.

4.5.4. Dealing with debris

Large amounts of rubble and debris might be difficult to manage after a significant earthquake. Debris management alternatives are numerous, and the process can start with engaging survivors and the recovery process. There are options for dealing with debris such as salvaging parts of collapsed structures, payments for the clearance of the rubbles, filling of sites, and conversion into construction material (IFRC, 2020).

4.5.5. Role of media in emergency response

4.5.5.1. Media and emergency response

The need for "right information at right time" in disaster management has not altered over the years. People require warnings prior to the crisis as well as information on casualties, property damage, the supplies and expertise required, the best methods for bringing in these resources, the assistance that is available and being rendered, etc. after the disaster.

With its immediate reach, the media play a critical role in educating the public about disasters, warning of hazards, gathering and disseminating information about affected areas, alerting government officials, relief organisations, and the public to specific needs, and facilitating discussions about disaster preparedness and response. Print media and electronic media are the two main categories of media that exist. Newspapers, periodicals, and journals are considered print media, whereas radio, (both satellite and wireless), and television (cable, DTH, etc.) are major players in the electronic media (Dave, R, K., 2020).

4.5.5.2. Importance of Media in Post earthquake situations

There are both positive and negative impacts for media. The network's continuous and factual coverage of incidents and post-disaster events can aid decision making and response immediately after a disaster, thereby saving lives and property. The media is an invaluable asset in times of a disaster by disseminating information, especially at the local level where the news media have a "vested interest" in the home town. In order to address other significant public health issues, advisories regarding water safety and information about locations where the general public can access medical care are typically issued (Dave, R, K., 2020).

The media's tendency to misrepresent how people behave during and after disasters can lead to dramatic, exciting stories that are only partially correct. This has the drawback of exaggerating some aspects of the disaster and causing unwarranted worry. For the sake of sensationalism, news reporters may present sensationalist coverage that is skewed by ignoring the fact that on the other side of the street, all the houses are still standing with only minimal damage. At a high-profile event, media representatives frequently congregate, causing severe "congestion" in the vicinity.

4.6. SUB-MODULE 7: SHORT-TERM EARTHQUAKE RECOVERY - REHABILITATION

4.6.1. Physical Rehabilitation

A crucial component of rehabilitation is physical rehabilitation. One of the rehabilitation disciplines, physical rehabilitation, can be very helpful in providing humanitarian relief. The efficiency of physical rehabilitation services totally depends on the timing of the intervention; yet, it is not well understood how crucial timing is when giving treatments during disasters.

4.6.1.1. What is Physical Rehabilitation?

Rebuilding physical infrastructure, such as homes, buildings, railroads, roads, communication systems, water and energy supplies, etc., is included. Additionally, it includes both short-term and long-term plans for managing watersheds, canal irrigation, social forestry, stabilising crops, using alternative cropping methods, creating jobs, generating income, and protecting the environment (FEMA 2004).

Both short-term and long-term rehabilitation programmes are available. This sort of rehabilitation is primarily focused on alternative livelihood strategies that might help the communities cope with the effects of disasters, and it is economic in character.

4.6.1.2. Need for disaster resilient housing construction practices

Construction of disaster-resistant homes is a crucial factor that needs to be considered. Buildings that can withstand earthquakes must be positioned on solid bedrock areas. The locations selected should not be clayey, tight, or steep. They shouldn't be anywhere near locations with strong faulting and loose sands (FEMA 2004). Housing at the foot slope should be avoided and also should be away from quarrying. Along with land acquisition for relocation locations, adherence to land use planning, flood plain zoning, retrofitting or strengthening of undamaged homes, and the construction of model homes, the rehabilitation and reconstruction package must also include these elements. As a result, the physical rehabilitation strategy will need to carefully include disaster-resistant housing.

4.6.1.3. Components of Physical Rehabilitation

There are several components of disaster management that are essential for effective response and recovery. These include:

Disaster preparedness: This involves preparing for disasters before they occur, through activities such as risk assessment, emergency planning, and training and education of responders and communities.

Disaster response: This involves the immediate actions taken to respond to a disaster, including search and rescue, emergency medical care, and provision of basic needs such as food, water, and shelter.

Disaster recovery: This involves the process of rebuilding and restoring the affected community and infrastructure after the disaster, including physical rehabilitation for those who have been injured or disabled.

Risk reduction: This involves measures taken to reduce the risk of future disasters, such as mitigation and prevention measures, public education and awareness, and infrastructure improvements.

The components of disaster management are interconnected and require coordination and collaboration between various stakeholders, including government agencies, non-governmental organizations, communities, and individuals. Effective disaster management requires careful planning, resources, and investment and can help minimize the impact of disasters and support the recovery and rehabilitation of affected populations.

4.6.2. Social Rehabilitation

Social rehabilitation is a crucial component of disaster recovery, but it is frequently overlooked in most post-disaster programmes because it is seen as a community responsibility. Strengthening current healthcare infrastructure and educational programmes, restoring educational opportunities in the disaster-stricken area, and aiding women and children who have been adversely affected by the disaster are all included in this sort of rehabilitation.

4.6.2.1. Healthcare facilities and infrastructure

Many people sustain various degrees of injury as a result of an earthquake, yet the disaster's destruction renders medical facilities inaccessible at the moment. Therefore, the need for better healthcare facilities is recognised even during an emergency. To weather the effects of disaster, these vulnerable groups would require specialised social care. Therefore, a crucial component of social rehabilitation is the building of infrastructure like community centres, day care centres, Anganwadis, Balwadis, old age homes, etc. Wherever this infrastructure is lacking or has been destroyed by the disaster, there must be a sufficient plan in place to build it (Khan, A, A., 2017).

4.6.2.2. Rehabilitation of educational activities

Major catastrophes like earthquakes can demolish a number of structures, including educational facilities and equipment. However, it is essential to resume the educational activities that the authorities should oversee. By distracting the community, especially the young, from the negative and dismal thoughts brought on by the disaster, this not only preserves the continuance of the educational process but also benefits them. Counselling is necessary for both teachers and students in the disaster-affected communities in order to properly resume educational activities. These people need someone to empathise with their pain and loss. Additionally, they need support and inspiration to restart their lives.

4.6.2.3. Rehabilitation programs for women, children, and disadvantage group

Women and children are the most at risk from disasters in terms of their bodily, psychological, and/or financial well-being. Any rehabilitation programme must include a significant portion devoted to this group's recuperation. Programs like physical infrastructure and economic activity for women and children should be pertinent. The foundation of the entire rehabilitation programme for women is rigorous counselling, contact, and training. For the socioeconomic rehabilitation programme for women to be implemented effectively, several training programmes for NGO workers, Anganwadi workers, and other village level government functionaries must be launched (Khan, A, A., 2017).

Earthquake rehabilitation for disadvantaged groups is a critical aspect of disaster management, as these groups are often the most vulnerable and at risk during an earthquake. Disadvantaged groups can include people with disabilities, elderly individuals, low-income families, and indigenous communities. These groups often lack the resources and support to effectively prepare for and recover from an earthquake.

It's essential to involve disadvantaged groups in the rehabilitation process, and to take their specific needs into account when planning and implementing rehabilitation efforts. For example, people with disabilities may require special accommodations, such as accessible shelters or transportation. Elderly individuals may require additional support and assistance, such as home-based care or respite services. Low-income families may require financial assistance to rebuild their homes and livelihoods. Indigenous communities may require support to preserve their cultural heritage and traditional knowledge.

4.6.3. Psychosocial Rehabilitation

Compared to the stakeholders in disaster management, the psychological pain of losing family members and friends and the overall shock of the disaster event might take far longer to heal. Therefore, it is crucial that social welfare and psychological support programmes are considered as soon as a disaster occurs so that they can become an integral component of rehabilitation programmes. There is a need for a comprehensive Epidemiological Surveillance and Nutrition Centered Health Assessment to track the spread of disease in order to properly rehabilitate those who are unwell. The challenges of psychological rehabilitation should be addressed with a thorough health recovery plan. Multiple psychological effects could result from physical suffering and sickness. Additionally, there is a substantial likelihood of post-traumatic stress disorder following a disaster (Khan, A, A., 2017).

4.7. SUB-MODULE 8: LONG-TERM EARTHQUAKE RECOVERY-RECONSTRUCTION

4.7.1. Building Back Better

The process of rebuilding or recovering from a crisis or tragedy in a way that addresses underlying causes and provides a more resilient and sustainable future has been referred to as "building back better." The COVID-19 pandemic and climate change recovery efforts, which aimed to construct a more just and sustainable society, have been most frequently linked to the word (UNDP, 2008). This frequently involves making investments in green technology, infrastructure, and social programmes to aid underprivileged populations. Following an earthquake, the process of recovery and reconstruction presents an opportunity and can act as a catalyst for addressing underlying vulnerabilities. It can also result in significant social and economic transformations by maintaining an emphasis on participation, capacity building, quality, and accountability components.

4.7.1.1. Concept of Building Back Better

"Build Back Better" refers to a perfect reconstruction and recovery procedure that offers robust, long-lasting, and effective recovery solutions to communities hit by disasters. Making communities stronger and more disaster-resistant is the driving force behind the Build Back Better concept. According to data from the United Nations Environment Programme in 2008, there have been more natural catastrophes over time, which has been attributed to population growth, urbanisation in risky locations due to land constraint, and climate change (UNDP, 2008). The phrase "Build Back Better" implies that for communities to successfully recover from disasters, the built environment as well as the psychological, social, and economic climates must be improved holistically in order to increase overall community resilience.

4.7.1.2. The need for BBB

The process of repairing the negative physical, social, economic, and environmental effects of disasters is difficult and time-consuming. The fast restoration of impacted communities is frequently the goal of reconstruction and recovery programmes, which can reproduce and exacerbate the community's current vulnerabilities. By using the reconstruction process to enhance a community's physical, social, environmental, and economic conditions, BBB was described by Khasalamwa (2009) as a strategy to build a more resilient community. Resilience is defined as "the potential to recover or 'bounce back' after an event". In order to address the wide range of widespread challenges, including those described above, and to ensure that impacted communities are regenerated in a resilient manner for the future, the concept of BBB suggests a comprehensive holistic approach to post-disaster reconstruction.

4.7.1.3. Implementation of BBB

In order to rebuild better, a successful recovery effort needs effective and efficient recovery solutions. Better stakeholder management and the application of pertinent post-disaster legislation and regulation are two approaches to increase the efficiency and effectiveness of post-disaster recovery. When affected by disasters, local groups with useful local expertise are unable to function fully and are thus left out of the recovery process. A major problem in post-disaster reconstruction situations is the improper role allocation, coordination, and involvement of local-level stakeholders. The establishment of a distinct organisation to serve as a recovery authority is a measure adopted to enhance the management of numerous stakeholders during big catastrophes so that recovery can go more smoothly. Reconstruction initiatives can be improved through functional alliances and links across organisations. The government and other relevant entities who will be participating in future post-disaster activities should be given access to knowledge from past disasters.

4.7.1.4. Sendai Framework for Disaster Risk Reduction (SFDRR)

The Sendai Framework for Disaster Risk Reduction, adopted in 2015, is an international agreement that provides a framework for disaster risk reduction efforts globally. The framework includes four pillars: understanding disaster risk, strengthening disaster risk governance, investing in disaster risk reduction, and building resilience of communities and nations. The fourth pillar, building resilience, is particularly relevant to the concept of "building back better" after a disaster.

The first step in building back better is understanding the disaster risk. This includes assessing the potential impact of future disasters on a community and identifying the most vulnerable areas. By understanding the risks, communities can take proactive measures to reduce their vulnerability and increase their resilience (United Nation Office for Disaster Risk Reduction., 2015).

The second step is to strengthen disaster risk governance. This includes establishing laws and policies that support disaster risk reduction and building the capacity of local communities and governments to respond to disasters. By strengthening disaster risk governance, communities can ensure that they are prepared for future disasters and that their response and recovery efforts are effective (United Nation Office for Disaster Risk Reduction., 2015).

The third step is to invest in disaster risk reduction. This includes investing in infrastructure, such as building codes and early warning systems, as well as investing in community-based disaster risk reduction programs. By investing in disaster risk reduction, communities can reduce their vulnerability to disasters and increase their resilience.

The fourth and final step is to build resilience of communities and nations. This includes not only physical rebuilding but also addressing the social, economic, and environmental factors that contribute to disaster risk. Building back better means not only restoring what was lost but also ensuring that the community is more resilient to future disasters. This can be achieved by empowering communities to take an active role in disaster risk reduction, promoting sustainable development, and addressing issues of inequality and marginalization (United Nation Office for Disaster Risk Reduction., 2015)..

Overall, the Sendai Framework for Disaster Risk Reduction provides a comprehensive approach to disaster risk reduction, and the fourth pillar, building resilience, is key in the process of building back better after a disaster. By understanding disaster risk, strengthening disaster risk governance, investing in disaster risk reduction, and building resilience, communities can reduce their vulnerability to disasters and ensure that they are better prepared for future disasters.

4.7.1.5. Case study for Building Back Better (Gujarat 2001 earthquake)

The Gujarat earthquake of 2001 was a devastating event that claimed over 20,000 lives and left hundreds of thousands of people homeless. The quake caused widespread damage to buildings, infrastructure and livelihoods. In the aftermath of the disaster, the government and international organizations launched a massive rebuilding effort to help people rebuild their lives and homes.

The “building back better” approach was adopted to ensure that the reconstruction process would result in improved, more resilient and disaster-resistant structures. This approach was based on the principles of sustainable development, with a focus on using local materials, incorporating local knowledge and skills, and promoting community involvement in the rebuilding process.

According to the paper (IJDRR., 2010) the rebuilding process in Gujarat was characterized by a strong emphasis on community involvement and local ownership.

This involved working closely with communities to identify their needs, prioritize their rebuilding efforts and provide them with the necessary support to make their homes and livelihoods safe, secure, and sustainable.

The study also highlights several key elements of the building back better approach in Gujarat. For example, the use of earthquake-resistant construction techniques was emphasized, including reinforced concrete and masonry walls, steel reinforcement and seismic-resistant roofing systems. The local authorities also provided training and support to help people understand the benefits of these techniques and how to implement them.

Another important aspect of the rebuilding process was the integration of disaster risk reduction (DRR) measures into the design and construction of new structures. This involved incorporating measures such as safe evacuation routes, disaster-resistant infrastructure and community-based early warning systems. The paper highlights the significant benefits of these DRR measures, including improved safety and reduced disaster risk for communities.

In conclusion, the building back better approach in Gujarat has resulted in improved, more resilient and disaster-resistant structures that are better equipped to withstand future earthquakes and other natural disasters. By integrating DRR measures, promoting community involvement, and leveraging local knowledge and skills, the rebuilding process in Gujarat has helped to create a safer, more sustainable future for its people.

Build Back Better after Sikkim Earthquake 2011:
The earthquake caused widespread destruction, leading to significant loss of life, infrastructure damage, and displacement of communities. The event recovery and reconstruction as mentioned in the report titled “Building Back Better: A More Resilient Sikkim Post 2011 Earthquake,” published in the Southasiadisasters.net issue no. 98, October 2013, emphasizes the importance of the “Building Back Better” approach in post-disaster recovery, which focuses on not just restoring what was lost but improving resilience and reducing future risks. Key areas of focus include reconstructing earthquake-resistant infrastructure, involving local communities in the rebuilding process, and enhancing the capacity of local institutions to respond to future disasters. The earthquake also brought focus to the role of government and stakeholders in formulating policies that support sustainable development and disaster risk reduction, highlighting the need for effective governance structures. Lessons learned from Sikkim’s recovery underscore the importance of a comprehensive approach that integrates disaster risk reduction into development planning.

4.7.2. Housing Reconstruction

Housing reconstruction is a critical component of disaster management that aims to provide safe and sustainable housing for those affected by a disaster. When a disaster strikes, homes and buildings are often damaged or destroyed, leaving people without adequate shelter. Housing reconstruction seeks to address this issue by rebuilding or repairing homes and infrastructure to provide a safe and secure living environment.

Effective housing reconstruction requires a comprehensive approach that takes into account the unique needs of the affected population. This may involve working closely with local communities to understand their housing needs, preferences, and cultural considerations. Reconstruction efforts should prioritize the most vulnerable populations, such as low-income families, the elderly, and those with disabilities, to ensure that they receive the support they need.

Housing reconstruction efforts may involve a range of activities, from emergency repairs to full-scale rebuilding projects. Emergency repairs may include temporary measures to make homes habitable, such as installing tarps or repairing roofs. Full-scale rebuilding projects may involve constructing new homes or repairing existing structures to meet local building codes and safety standards.

To ensure the effectiveness and sustainability of housing reconstruction efforts, it is important to take a holistic approach that considers environmental, economic, and social factors. This may involve using sustainable building materials and practices, incorporating energy-efficient design features, and providing access to essential services such as water, sanitation, and electricity.

4.7.2.1. Process of reconstruction of shelter and construction

Following an earthquake, the process of creating shelters and buildings often entails numerous steps, including:

Emergency response: In the immediate wake of an earthquake, efforts are concentrated on search and rescue operations, emergency medical treatment for those hurt, and temporary housing for those who have been displaced.

Damage assessment: Teams of engineers, architects, and other specialists conduct a careful evaluation of the damage to buildings and infrastructure after the immediate emergency has been dealt with. This data is utilised to assess the extent of required repairs and create a rebuilding strategy.

Planning and design: A strategy for reconstruction is created based on the damage assessment. This includes making plans for the reconstruction of homes and other buildings in addition to creating new structures and infrastructure that can resist earthquakes in the future.

Procurement and logistics: Logistics are put in place to ensure that the materials and other resources required for reconstruction are transported to the damaged area and can be utilised effectively.

Construction: Rebuilding of structures such as homes, offices, and infrastructure officially starts. Depending on the severity of the injury, this may take several months or even years to complete.

Community recovery: After the construction is completed, efforts are made to help the affected community to recover, including providing support for businesses and livelihoods, and help people return to their homes and resume their normal lives.

4.7.2.2. Approaches for reconstruction

Traditional reconstruction: Utilizing the same blueprints and building materials as before the earthquake, homes and other structures are rebuilt using this strategy. Although it is sometimes the simplest and quickest solution, this strategy might not address problems with seismic safety or resilience.

Retrofitting: With this strategy, existing homes and structures are strengthened to increase their seismic resistance. This can be accomplished by either updating the foundation or by adding structural reinforcement, such as steel bracing or concrete shear walls. Although this method can be less expensive than constructing brand-new buildings, it can still be expensive and may not be practical for all types of buildings.

Relocation: In some circumstances, it might not be feasible or practicable to adapt or rebuild homes and buildings in an area with a high earthquake risk. Communities may be moved to safer regions in these situations. This strategy can be costly and cause a lot of disruption in people's lives, which can be challenging for communities.

Participatory and community-driven approaches: This strategy places a strong emphasis on community involvement and responsibility in the reconstruction process. It enables people to participate more actively in the planning, building, and decision-making processes for their houses and neighbourhoods. With this strategy, it is possible to ensure that the community's individual needs and preferences are met by the new housing and to promote a sense of communal ownership and empowerment.

Building with seismic-resilient techniques: A building's ability to withstand an earthquake can be improved by using seismic-resilient measures such base isolation, seismic dampers, and load-path systems that transmit stresses from the roof to the foundation. This can be more expensive than conventional construction techniques, but it can ensure that structures are safer and more earthquake-resistant in the long run.

4.7.2.3. Housing reconstruction through engineering and individual rural housing

Housing reconstruction by engineering refers to the process of rebuilding homes and other structures using professional engineering techniques and methods. This type of reconstruction typically involves the use of advanced materials, such as reinforced concrete and steel, and is often carried out by teams of engineers and construction professionals (United Nations Office for Disaster Risk Reduction., 2017)..

In contrast, individual rural housing reconstruction refers to the rebuilding of homes in rural areas by the residents themselves, often using locally available materials. This type of reconstruction may be less sophisticated and may not involve the use of professional engineers, but it can still provide safe and functional housing for residents (United Nations Office for Disaster Risk Reduction., 2017).

One of the main differences between these two types of reconstruction is the level of technical expertise involved. Engineering-led reconstruction typically requires specialized knowledge and skills in areas such as structural design and construction, whereas individual rural housing reconstruction may rely more on the experience and ingenuity of the residents.

Another key difference is the cost of the reconstruction. Engineering-led reconstruction is often more expensive due to the cost of materials and labor, while individual rural housing reconstruction may be more affordable as it often relies on locally sourced materials and labor.

Additionally, engineering-led reconstruction may require significant planning, design, and organization, while individual rural housing reconstruction is often more ad-hoc and may rely on the community to come together and work together.

Overall, both engineering-led and individual rural housing reconstruction have their own benefits and drawbacks, and the most appropriate approach will depend on the specific context and needs of the community.

4.7.2.4. Repair and retrofitting

Repair refers to the process of fixing damage caused by an earthquake, such as cracks in walls or broken windows. Retrofitting, on the other hand, refers to the process of strengthening existing buildings to make them more resistant to earthquakes. This can include adding reinforcing elements, such as steel or concrete, to the structure of the building, or adding seismic isolation devices to reduce the amount of shaking that the building experiences during an earthquake.

Retrofitting can be applied to both residential and commercial buildings and is a cost-effective measure to increase the safety of people and reduce damage to buildings during an earthquake. It can be applied to both new and old buildings, and to buildings that have already been damaged by earthquakes. Retrofitting can include structural measures such as adding shear walls, seismic isolation bearings, dampers, and bracing systems.

Both repair and retrofitting are important steps in making buildings more resilient to earthquakes and protecting the safety of building occupants. It is essential to consult experts in the field of seismic engineering to determine the best approach for your building and the cost-benefit analysis of the retrofitting process.

4.7.3. Economic Recovery

Economic recovery is a critical aspect of disaster management that focuses on restoring economic stability and sustainability in the aftermath of a disaster. Disasters can have a significant impact on local economies, leading to job losses, business closures, and reduced economic activity. Effective economic recovery efforts aim to minimize the economic impact of a disaster, facilitate the resumption of economic activity, and support the long-term recovery and growth of affected communities.

The economic recovery process typically involves providing financial support and resources to affected individuals and businesses, restoring critical infrastructure, and promoting economic development opportunities. This may involve the provision of grants, loans, and other financial assistance to businesses and individuals who have suffered losses due to the disaster. It may also involve the reconstruction and repair of critical infrastructure, such as transportation networks, energy systems, and communication networks.

In addition to providing immediate support, effective economic recovery efforts also seek to promote long-term economic sustainability and growth. This may involve supporting the development of new businesses and industries, promoting innovation and entrepreneurship, and investing in education and training programs that equip individuals with the skills and knowledge needed to succeed in a changing economy.

4.7.3.1. Action steps for the Economic recovery

Even though the process of economic recovery following an earthquake might be intricate and varied, there are a few crucial actions that can be taken:

Assessing the economic damage entails determining which companies, markets, and sectors have been impacted as well as the magnitude of the harm and the unique requirements of the affected areas.

Giving out emergency financial aid: This entails giving out financial aid, such as cash grants, loans, and tax relief, to people and businesses that have been impacted by the earthquake.

This involves supporting the delivery and distribution of goods and services, as well as working with businesses to assist them resume operations as soon as feasible.

Supporting small and medium-sized enterprises (SMEs): SMEs are frequently the foundation of regional economies and are particularly vulnerable to earthquake damage. It is crucial to give SMEs the assistance they require for a recovery, including access to financing and business services.

Encouraging investment: By emphasising the possibilities for restoration and rehabilitation and by offering financial incentives to businesses, promote investment in the impacted area.

Building resilience: Building economic resilience in the impacted area through the promotion of catastrophe risk reduction measures, the development of sustainable economic activities, and local economic diversification.

Coordination and collaboration: Assuring the effective and efficient implementation of relief and recovery services through working with a variety of stakeholders, including the government, NGOs, the private sector, and local communities.

However, these phases might serve as a broad framework for addressing the economic effects of an earthquake. It is crucial to remember that the recovery process will vary based on the particular conditions and setting of the earthquake.

4.7.4. Case study: Gujarat Post-earthquake recovery strategy

In 2001, a massive earthquake struck the Indian state of Gujarat, causing extensive damage to infrastructure and homes and leaving thousands of people dead or injured. The Gujarat government launched a comprehensive post-earthquake recovery strategy aimed at rebuilding the affected communities and infrastructure.

The recovery strategy involved a coordinated effort between various stakeholders, including the government, NGOs, and the private sector. The government established a separate agency, the Gujarat State Disaster Management Authority (GSDMA), to oversee the recovery effort and coordinate with other agencies.

The recovery effort focused on three main areas: reconstruction of damaged homes, restoration of critical infrastructure, and the provision of financial assistance to affected individuals and businesses. The government provided financial assistance and incentives to encourage private sector involvement in the rebuilding effort.

To support the recovery effort, the government also introduced a range of policy measures, such as updating building codes and regulations to ensure that new buildings were earthquake-resistant. The government also implemented a comprehensive disaster management plan, including the establishment of early warning systems, evacuation plans, and emergency response teams.

4.7.4.1. Community empowerment and social impact mitigation

In order to promote community empowerment and participation, the Gujarat government chose a community-based approach to rehabilitation. This included the creation of committees at the village level that were in charge of determining the needs of their communities and carrying out rehabilitation operations. The Gujarat government has made investments in enhancing local organizations' and communities' capacity to respond to catastrophes in the future and to carry out sustainable development initiatives (UNDP, 2004). Upgradation of skill in unorganized construction sector especially for masons and artisans were taken up at community level.

4.7.4.2. Assessing immediate needs and strategy for each sector

In the immediate aftermath of the earthquake, efforts were concentrated on search and rescue operations, emergency medical treatment for those hurt, and temporary housing for those who had been displaced. An extensive evaluation of the harm done to the infrastructures was done by teams of engineers and other specialists. This data was utilised to establish the scope of required repairs and create a plan for reconstruction. The Gujarat government established a scheme to help households rebuild their homes by offering financial support (ReliefWeb, 2001). Families were given technical support through the initiative to design and build earthquake-resistant dwellings.

4.7.4.3. Environmental impact

Significant environmental effects of the 2001 Gujarat earthquake included ground fissures, alteration to ground water system, and deforestation. Large numbers of people were displaced as a result of the damage of homes and infrastructure, placing stress on the nearby forests and natural resources.

The Gujarat government and other organisations put in place a variety of steps to lessen the effects of the earthquake on the environment. It was decided to build retaining walls, plant vegetation, and strengthen stream banks in order to manage slopes and stop soil erosion. The reforestation and afforestation of earthquake-affected areas included the planting of tree saplings and the restoration of degraded forests (Kumar, P &Pal, R., 2007). In order to identify potential environmental effects of the recovery and reconstruction activities and to create mitigation strategies for such effects, environmental impact assessments were done. There have been initiatives to protect natural resources and advance sustainable development. This includes promoting the use of sustainable agriculture methods and renewable energy sources. The Gujarat government and other organisations also made investments in enhancing local communities' ability to respond to catastrophes in the future and to carry out sustainable development initiatives (Patwardhan, A., 2002).

In order to lessen the effects of the earthquake on the environment and to encourage sustainable development in the affected areas, the Gujarat government and other organisations adopted a comprehensive and integrated strategy. With this strategy, it was possible to make sure that environmental preservation and protection were given equal priority to infrastructure rebuilding during the recovery and reconstruction phase.

4.7.4.4. Long term resilience

The Gujarat government's long-term earthquake resilience plan to lessen the effects of upcoming earthquakes includes some important components, including Identifying vulnerable locations and prioritising areas for disaster risk reduction measures requires undertaking a thorough risk assessment and mapping, creating and implementing building regulations and guidelines that are intended to improve the seismic resilience of new constructions and renovations to existing structures, putting land-use planning into practise to make sure that new construction is situated in earthquake-resistant zones (IFRC., 2001).

Additionally, creating and implementing public education and awareness campaigns to help people comprehend the dangers of earthquakes and how to safeguard their homes and other property. the creation and implementation of early warning systems that provide individuals advance notice of an upcoming earthquake so they can take the appropriate preparations. Creating a thorough disaster management strategy that explains each agencies and organization's roles and duties in the case of an earthquake. The seismic-resilient reconstruction of destroyed structures and infrastructure as well as the retrofitting of infrastructure and buildings that are highly susceptible to damage in future earthquakes (Government of Gujarat., 2002). Also, developing innovative technology and procedures to lessen the effects of earthquakes, as well as doing research and monitoring to better understand earthquakes.

4.7.4.5. Kashmir Rehabilitation program

The Kashmir earthquake of 2005 was a devastating disaster that affected the regions of Pakistan and India-administered Kashmir. The quake resulted in over 70,000 deaths, hundreds of thousands of injuries, and widespread damage to homes, infrastructure, and livelihoods. In response to the disaster, the government and international organizations launched a massive rehabilitation program to help people rebuild their lives and homes.

The rehabilitation program in Kashmir was focused on providing assistance to the most vulnerable communities, including women, children, and elderly persons. This involved providing emergency shelter, food, water, and medical assistance to those in need. The program also provided support for the rehabilitation of homes, infrastructure, and livelihoods, including the construction of new homes, schools, hospitals, and other public facilities.

According to the paper (JDRS, 2017), the rehabilitation program in Kashmir was characterized by a strong emphasis on community involvement and local ownership. This involved working closely with communities to identify their needs, prioritize their rebuilding efforts and provide them with the necessary support to make their homes and livelihoods safe, secure, and sustainable.

The paper (JDRS, 2017) highlights several key elements of the rehabilitation program in Kashmir. For example, the use of earthquake-resistant construction techniques was emphasized, including reinforced concrete and masonry walls, steel reinforcement and seismic-resistant roofing systems. The local authorities also provided training and support to help people understand the benefits of these techniques and how to implement them.

Another important aspect of the rehabilitation program was the integration of disaster risk reduction (DRR) measures into the design and construction of new structures. This involved incorporating measures such as safe evacuation routes, disaster-resistant infrastructure, and community-based early warning systems. The paper highlights the significant benefits of these DRR measures, including improved safety and reduced disaster risk for communities.

In conclusion, the rehabilitation program in Kashmir has helped to restore a sense of normalcy and stability to the affected communities. By integrating DRR measures, promoting community involvement, and leveraging local knowledge and skills, the rehabilitation program in Kashmir has helped to create a safer, more sustainable future for its people.

4.8. ADDITIONAL CASE STUDIES ON RECENT MAJOR EARTHQUAKES

4.8.1. Kutch Earthquake-2001

On the Republic Day of 2001, an earthquake jolted Gujarat at 8:46 am IST and it is often called as Kutch earthquake-2001. Like other disaster events, this earthquake also raised several concerns and issues and merging lessons need to be learnt. The epicentre of the Kutch earthquake was located at Bhuj and the magnitude of the earthquake was measured as 7.9 on the Richter scale. The earthquake completely ravaged the western part of Gujarat and tremors were felt in almost 70% of the Indian region and neighbouring countries of Pakistan and Nepal. The earthquake caused large scale damage to life and property. Over 20,000 reported fatalities and more than 1.6 lakh reported injuries occurred due to the earthquake .

The Kutch earthquake -2001 was one of the most devastating disaster events India had faced in recent past. The main earthquake shock was followed by more than 600 aftershocks. The damaged areas were widespread with huge destruction in rural areas. About 229 villages were destroyed completely and urban areas such as Bhuj, Bachau, Anjar, and Rapar were affected severely . Particularly, the Kutch district was completely ravaged. Damage assessment was a great challenge, the total asset losses were estimated as Rs 9,909 crores and reconstruction cost was estimated as Rs 10,575 crores. The overall financial losses estimated were of Rs 28,423 crores.

Fig. 13 : The city of Ahmadabad after Gujarat earthquake January 26, 2001Source: Gujaratplus.com (http://www.gujaratplus.com/news/archives/arc83.html), retrieved on 12th October 2019.

Lessons learnt

The Kutch earthquake was a wake-up call for the nation to look into the disaster preparedness of the country. The community was unprepared for what was likely to happen. After the earthquake, strong need was felt for raising awareness among the community and to strategize mitigation activities, both structural and non-structural. It was also felt to initiate large scale capacity building activities at all levels.

[1] Preliminary earthquake report, U.S. Geological Survey retrieved on 12th October 2019. http://c.usgs.gov/neis/eq_depot/2001/eq_010126/.

[2] The Kutch earthquake 2001, Recollections, lessons and Insights by Pramod.K.Mishra.

[3] World Bank and Asian Development Bank

[4] Government of Gujarat

Further, it was realized that it was essential to have a legal framework in disaster management at the national and state level. Gujarat is the first state in India to have enacted such legislation. After this earthquake, the Government of Gujarat decided to establish an organization for coordinating the very complex tasks of rehabilitation and reconstruction works. On 8 February 2001, within two weeks after the earthquake, the Gujarat State Disaster Management Authority (GSDMA), a separate agency, was constituted and registered as a society under the Societies Registration Act. The Government of Gujarat introduced a holistic and extensive rehabilitation and reconstruction programme designed to help the affected people comprehensively.

A reconstruction and rehabilitation policy was announced by the government of Gujarat after this earthquake which was called Gujarat Emergency Earthquake Reconstruction Program (GEERP). This program was divided into three stages as following:

- Short term phase - removal of debris, providing temporary shelters and initiation of repair/reconstruction works
- Medium-term phase - repair and reconstruction of public infrastructure, houses, social infrastructure and providing awareness programs for disaster risk reduction & mitigation activities; and
- Long-term phase - consists of capacity building of GSDMA towards long-term measures for disaster reduction and mitigation.

Owner driven reconstruction was the most innovative part of the post Gujarat earthquake reconstruction programme with a tremendous emphasis on community participation. The concept of public participation was adopted throughout the reconstruction programme. Various NGOs, local groups etc. were involved in the decision making and implementation of various components of the GEERP.

4.8.2. Indian Ocean Earthquake and Tsunami -2004

The Indian Ocean earthquake occurred on December 26, 2004, early morning at 7:59 am IST which led to subsequent Tsunami. Its epicentre was located in Sumatra, Indonesia. Coordinates lied between 3.316°N to 95.854°E and the moment magnitude of an earthquake was registered as 9.3 . According to the U.S. Geological survey, the initial death toll was recorded as 283,100 and more than 14,100 people were missing. The earthquake was caused due to rupture along the fault between Indian and Burma plates. The earthquake was also felt in South Asian countries to include India, Bangladesh, Myanmar, Malaysia, Sri Lanka, Thailand, and Maldives. The coasts of the Indian Ocean were struck by a tsunami due to sudden rise of the sea bed up to several meters at the time of the earthquake. Indian states of Tamil Nadu, Andhra Pradesh, Kerala, and Union Territory of Pondicherry were affected due to the Tsunami. The height of the waves was 1.6 m in the areas of Tamil Nadu. Nagapattinam and Kanyakumari districts in Tamil Nadu, Ernakulum and Kollam districts in Kerala, Prakasham and Krishna districts in Andhra Pradesh were severely affected . The first

[4] U.S. Geological Survey,https://www.usgs.gov/news/indian-ocean-tsunami-remembered-scientists-reflect-2004-indian-ocean-killed-thousands retrieved on 13th October 2019.

[5] U.S. Geological Survey

to hit by the huge tsunami was the Andaman and Nicobar Islands, just few minutes after the earthquake. The tsunami resulted in extensive devastation to the physical, environmental and built form of the island.

Fig. 14 : Devastation caused by tsunami in Tamil Nadu and city of Banda Aceh, Indonesia in 2004. Source: - USGS public domain, retrieved on 13th October 2019.

Lessons learnt

Immediately after the disastrous event, the UN adopted Hyogo Framework for Action for building the resilience of nations and communities to such types of disasters. Along with several global partners, the World Bank contributed to reconstruction and recovery efforts in Indonesia for establishing the Multi-Donor Fund for Aceh and Nias (MDF). This disaster event once again pointed towards the importance of early warning systems (EWS), hazard mitigation, and emergency preparedness. The much-needed emphasis was on investing in EWS. The government of Indonesia gained significant expertise in disaster management and preparedness by developing sophisticated early warning systems, sea level gauges, and seismometers. Another important lesson learnt was lack of strong institutional financing mechanisms to meet the challenges of such types of disasters which led to establishment of the National Agency for Disaster Management. After the tsunami government of Indonesia established an Aceh-Nias Rehabilitation and Reconstruction Agency with a robust mandate to prioritize and coordinate efforts and to deliver results.

4.8.3. Kashmir Earthquake-2005

On October 8, 2005, a major earthquake struck Pakistan at 9:20 am IST. The magnitude of the earthquake was estimated at 7.6. The earthquake also felt in surrounding

[7] Wikipedia,https://en.wikipedia.org/wiki/2004_Indian_Ocean_earthquake_and_tsunami#India, retrieved on 13th October 2019

countries India, Afghanistan, China, and Tajikistan. The epicentre of the earthquake was located about 19 kilometres from the Muzaffarabad in Pakistan occupied Kashmir (PoK) which lies between Lat. 34.539°N to Long 73.588°E. The earthquake caused huge devastation to lives and property; around 86,000 people were killed, more than 69,000 injured and extensive damage occurred in PoK. The heaviest damage occurred in the Muzaffarabad area of PoK where entire villages were destroyed and at Uri in J&K, India where 80 percent of the town was destroyed. At least 32,335 buildings collapsed.

Based on the losses due to the earthquake, it is categorized as one of the deadliest earthquakes in the recorded history. At least 1,350 people were killed and 6,266 injured in India . The northern region of Pakistan and Kashmir were severely affected due to the earthquake. According to records about 20,000 children died due to the collapse of the school buildings, more than 550,000 families were affected due to the earthquake who needed immediate shelter from the winter. Many NGOs, different countries, humanitarian organizations, and other international organizations worked hard and, collected donations in the form of food, tents, blankets and medical supplies, etc. as relief aid for the affected regions.

Fig. 15 : Image of Balakot (PoK) after the earthquake and collapsed stone masonry building.

Source: - BBC News (https://www.bbc.com/news/world-asia-34464815), retrieved on 13th October 2019.

Lessons learnt

Many people died in the Kashmir earthquake-2005 due to poorly constructed unplanned buildings. This area falls under a high seismic activity zone but there were poor efforts to enforce building codes. Natural disasters like earthquakes cannot be predicted, the

[8] U.S. Geological Survey, retrieved on 13th October 2019, https://earthquake.usgs.gov/earthquakes/eventpage/usp000e12e/technical

[9] Ibid 29, P 32.

foremost priority is to be accorded to construction of earthquake-resistant structures at proper locations in earthquake-prone areas. Seismic hazard is not given a great deal of attention in urban planning and policy decisions, and seismic design does not appear to be a high priority except for major or high-profile projects in this region. After this earthquake, it was observed that the recovery was faster in the areas where there was involvement of local communities in reconstruction, which underscores the need for emphasis on community-based disaster risk reduction.

4.8.4. Sichuan Earthquake-2008

A severe earthquake with a magnitude of 7.9 occurred at Sichuan province of China on May 12, 2008. It is often called Wenchuan earthquake. The earthquake occurred at 6:28 am UTC with a measured earthquake magnitude of 7.9 (U.S Geological Survey). The epicentre of the earthquake was located 80 km from the capital of Sichuan province, Chengdu. Landslides caused by the earthquake created catastrophic situations that caused huge casualties. Around 69,197 people were killed, more than 374,176 people were injured and about 4.8 million people were homeless and displaced. 10,000 people were killed only by collapsing school buildings. In Shifang chemical factories collapsed, killing hundreds of people and ammonia was released into the air. The Chinese government suffered a huge economic loss and started reconstruction by providing new houses for refugees, rebuilding schools and creating jobs for affected people.

Fig. 16 : Image of the town of Qushan, Beichuan County, China after 2008 Earthquake.

Source: - USGS, https://www.usgs.gov/media/images/damage-2008-great-sichuan-earthquake-china, retrieved on 14th October 2019.

Lessons learnt

We can never stop earthquakes from happening, but we must do our utmost to change mindsets from managing disasters to managing disaster risks. One of the lessons learnt was that emergency response must be better developed at the local level. Integrated community-based resilience programmes will increase the ability of communities and individuals to recover and adapt to hazards. The poor construction quality of most building structures; both in terms of seismic design and materials did not conform to the Chinese seismic design code. In the backdrop of lessons learnt from this disaster, Chinese government promptly issued an updated version of “Standard for Classification of Seismic Protection of Building Constructions” and a modified version of “Code for Seismic Design of Buildings”.

4.8.5. Haiti earthquake-2010

A most devastating earthquake hit Haiti on January 12, 2010, at 08:53 PM UTC followed by a cholera epidemic. The magnitude of the earthquake measured on the Richter scale was 7.0. The epicentre of the earthquake was identified approximately 25 kilometres from the Haiti capital city, west of Port-au-Prince. The earthquake not only destroyed the country’s infrastructure and governance but also caused damage to facilities and other resources.

As per the government of Haiti records, 230,000 people were killed and more than 300,000 people were injured due to the earthquake, and 2 million people were displaced . After ten months of the earthquake, Haiti encountered the largest epidemic of cholera which killed around 7,000 people and more than 500,000 people were infected. As of November 2010, the government of Haiti provided 19,000 transition shelters for around 96,000 individuals. Habitability assessment was carried on 400,000 buildings among that 54% of buildings were safe, 25% of houses needed repairs to be safe and 21% of buildings were unsafe which required demolition.

Fig. 17 : Image of Port-au-Prince, Haiti. Source: - Britannica (https://www.britannica.com/event/2010-Haiti-earthquake), retrieved on 17th October 2019.

[10] Haiti Earthquake Facts and Figures. Relief Web. https://reliefweb.int/report/haiti/haiti-earthquake-facts-and-figures , retrieved on 17th October 2019.

Lessons learnt

The response to provide immediate shelter was remarkable after the earthquake. Around 1.5 million people were provided shelter within 4-5 months after the quake. Good practices also emerged such as slum upgrading as a housing recovery process, effective information management and building habitability assessments, etc. A number of steps were taken by the government of Haiti after the earthquake to increase both the safety and quality of affordable housing. The government established a coordinating body for public building and housing construction that developed the country's first affordable housing policy and its first slum upgrading strategy. The "Guide to Preparing Disaster Recovery Frameworks" was an initiative by the Haiti government to standardize recovery coordination.

4.8.6. Japan earthquake-2011

Japan lies under the most active tectonic region of the world due to which it gets earthquakes frequently. Japan was struck by a devastated earthquake of magnitude IX on March 11, 2011. The epicentre of the earthquake was located in the Pacific Ocean about 130 km east of the city of Sendai. There were 700 aftershocks observed with intensities varying from 6 to 7.0. There was extensive loss of life. Around 15,703 people were reported as dead, more than 5,314 people were injured and around 500,000 people were affected due to earthquake and subsequent Tsunami. At least 300,000 buildings completely collapsed; 1 million buildings were damaged, around 4000 roads, 29 railways, and 75 bridges were also damaged . 25 million tonnes of estimated debris were created with a total economic loss of 360 billion USD to the nation and an estimated reconstruction cost of 185 billion USD . Millions of people were affected due to the earthquake by power cuts or other shortages. The nuclear power plant located at Fukushima was damaged badly in the disaster.

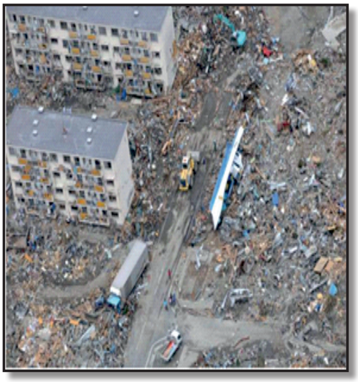

Fig. 18 : Aerial view of destruction in Sendai and two of the damaged containment buildings at Fukushima nuclear power plant. Source: - https://www.britannica.com/. Retrieved on 18thOctober 2019.

[11] U.S Geological Survey, retrieved on 18th October 2019. https://earthquake.usgs.gov/earthquakes/eventpage/official20110311054624120_30/impact

[12] Royal geographic society lesson: 6 Japans earthquake and tsunami case study, retrieved on 18th October 2019. https://www.rgs.org/CMSPages/GetFile.aspx?nodeguid=5288a78c-d689-46fa-a6e6-a1a9231d-84ac&lang=en-GB.

Lessons learnt

The great Japan earthquake was the first ever recorded disaster that includes an earthquake followed by a tsunami and nuclear power plant failure. The triple disaster gave a wake-up call to all developed or developing countries to check the extent of their laws and policies on disaster risk reduction. The most important lesson was that there was a need to pay attention to the prospects of nuclear/industrial/technological accidents triggered by natural hazards.

4.8.7. Nepal earthquake-2015

A powerful earthquake of magnitude 7.8 on the Richter scale struck Nepal on Saturday, April 25, 2015, at 11:56 local time . It is also called as Gorkha earthquake. The epicentre of the earthquake was identified about 80 km northwest of Kathmandu but tremors were felt around 80% of Nepal and a series of aftershocks were observed with the highest magnitude of 7.3 on the Richter scale. The impact of the earthquake resulted in 8,896 reported deaths, 22,303 reported injuries, 700,000 people displaced, more than 604,930 houses destroyed and around 8 million people affected . This type of mega disaster had not been experienced by Nepal for the last 80 years. As per government records, 14 districts were severely affected during the earthquake and a national emergency was declared by the government of Nepal. Humanitarian assistance for more than 3.5 million people was carried out by the Nepal Red Cross Society (NRCS).

Fig. 19 : Damage to buildings during earthquake in Nepal. Source: - https://www.fatfacefoundation.org/blog/2017-09-04-nepal-earthquake-2015-update, retrieved on 20th October 2019.

[13] USGS (United States Geological Survey) retrieved on 20th October 2019.

[14] Post Disaster Needs Assessment (PDNA) conducted by the Government of Nepal's National Planning Commission in 2015.

Lessons learnt

Weak law enforcement, poorly constructed buildings and lack of earthquake resistant construction practices made this disaster a catastrophe. Lack of preparedness, awareness and coordination among the different stakeholders during the earthquake was another lesson. Lack of modern technology, essential equipment for rescue and relief operations, and lack of communication was another reason for extensive loss of lives and damage to built-up environment.

4.8.8. Turkey earthquake-2023

On February 6, 2023, a magnitude 7.8 earthquake occurred in southern Turkey near the northern border of Syria. The earthquake was followed 11 minutes later by a magnitude 6.7 aftershock. Another earthquake of magnitude 7.5 earthquake occurred in southern Turkey near the northern border of Syria on same day. The earthquake occurred approximately nine hours after a magnitude 7.8 earthquake located 95 km to the southwest. The magnitude 7.8 earthquake resulted from strike-slip faulting at shallow depth. The preliminary location of the earthquakes places it within the vicinity of a triple-junction between the Anatolia, Arabia, and Africa plates. The location and mechanism of the 7.5 earthquake, along with aftershocks that have occurred since the M7.8 earthquake nine hours earlier, are consistent with the February 6 earthquake sequence having occurred within the broad East Anatolia fault zone, though not necessarily all on the same fault strands.

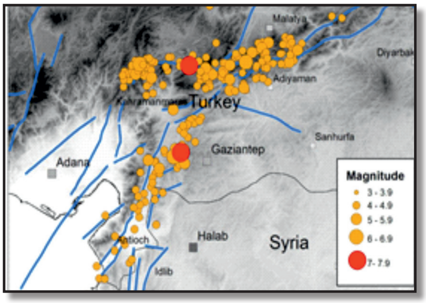

Fig. 20 : Impact of earthquake and evolution of the Southern Turkey Earthquake sequence along with mapped active faults (blue lines) by British Geological Society, retrived at 21 May 2023

Sources: Left Image https://www.scientificamerican.com/article/why-the-earthquake-in-turkey-was-so-damaging-and-deadly/

Right Image: https://www.bgs.ac.uk/news/the-kahraman-maras-earthquake-sequence-turkey-syria/

As per the USGS report, At least 50,399 people killed, 115,000 injured and 1.5 million homeless; 325,522 buildings severely damaged or destroyed, 4 million others damaged and 150,000 commercial infrastructure moderately damaged in 16 provinces across southern Turkey. Ground fissures formed on a highway near Antakya. A large fire destroyed 3,600 containers of industrial oil at a port at Iskenderun. Liquefaction and land subsidence occurred at Golbasi and in Hatay. Damage estimated at $100 billion U.S. dollars. At least 8,476 people killed, 14,500 injured and estimated 5.37 million homeless; 490 buildings destroyed and thousands damaged in northwestern Syria. A dam sustained cracks near Afrin. Damage estimated at $5.1 billion U.S. dollars. At least 10,460 buildings damaged in Lebanon. Some buildings damaged at Nicosia, Cyprus, at Erbil, Iraq and at Ashdod, Israel. A 20 m crack occurred in the Corniche at Alexandria, Egypt. A small tsunami was generated with wave heights of 17 cm at Famagusta, Cyprus and 13 cm at Erdemli and 12 cm at Iskenderun, Turkey. Maximum intensity XII was reported for this earthquake.

Lessons Learnt

1) The highway infrastructure performed very well overall in these events, whereas the residential and commercial building stock did not. Many buildings in Turkey century old and also made up of poor-quality materials. Reports have stated that those buildings, which constructed after the 1999 disaster are also not in line with earthquake safety standards.
2) Awareness and training of community to be able to respond when official rescuers aren't available in time to do so, are among the measures essential to saving the most lives in the immediate aftermath of a disaster.
3) Difficult weather conditions, including heavy rain and flooding, strong winds as well as increasingly hot weather in some areas, pose additional challenges to the humanitarian response.
4) Incidents of looting the vehicles carrying relief goods have taken place which hamper the rescue and search operation smoothly, the administration of the area need to be aware when to intervene to restore law and order.

4.8.9. Noto Peninsula earthquake, Japan- 2024

On January 1, 2024 an Mw7.5 earthquake occurred at a depth of 10 kilometres along an active fault across the Noto Peninsula in Ishikawa Prefecture, Japan, at 16:10 Japan Standard Time (JST). A foreshock of magnitude 5.5 occurred four minutes before the mainshock, followed by a magnitude 6.2 aftershock nine minutes later. About 60 aftershocks recorded in total in which at least seven had magnitudes of 5.0 and above. The tremors generated a wide range of cascading hazards, including geological uplift, liquefaction, landslides, fires and tsunamis. The hazards caused damage to buildings and infrastructure and more than 240 deaths (Suppasri, A. et al. 2024). Most casualties were caused by building collapse and delay in recovery causing hypothermia in the victims reflects the harsher winter climate of this Noto Peninsula. Due to good awareness for tsunamis, which arrived within a few minutes killed two people only. However, severe damage to roads significantly delayed early recovery as transportation was curtailed.

Fig. 21 : Damaged houses in Suzu, Japan

Source: Asahi Shimbun, EERI https://www.eeri.org/about-eeri/news/19340-eeri-response-to-january-1-2024-japan-earthquake)

Lessons Learnt

1) As liquefaction occurred over a wide area and because of large-scale uplift in Noto Peninsula, detailed geotechnical plans for project implementation are required if recovery and reconstruction are to be successful.

2) Several kinds of secondary hazard were caused by the 2024 Noto Peninsula earthquake, namely uplift, liquefaction, landslides, fires and tsunamis.

3) The lack of pre-disaster planning for road restoration delayed activities such as rescue, the supply of relief goods, debris removal and recovery of basic infrastructure.

4) In the aftermath of the Noto earthquake, which struck a region with a notably ageing population, the imperative for elderly care within evacuation centers was underscored.

5) Given the risks of hypothermia in winter and heatstroke in summer, special countermeasures are required for large disasters because they may occur during extreme weather.

5. REFERENCES

1. Allen, R, M & Melgar, D (2019). Earthquake Early Warning: Advances, Scientific Challenges, and Societal Needs. Annual Review of Earth and Planetary Sciences. EEWS world ref.pdf

2. America's Prepare Athon! How to prepare for an earthquake. fire and emergency supplies.pdf

3. Anderson, G (1997). Effects of Earthquakes. https://topex.ucsd.edu/es10/es10.1997/lectures/lecture20/secs.with.pics/node10.html

4. Asilum, J (2019). The Construction of Cultural Identity as a Platform for Attaining Community Participation in Disaster Risk Reduction and Management (DRRM); the Case of Masbate City, Philippines. https://www.researchgate.net/publication/338986001_The_Construction_of_Cultural_Identity_as_a_Platform_for_Attaining_Community_Participation_in_Disaster_Risk_Reduction_and_Management_DRRM_the_Case_of_Masbate_City_Philippines

5. Assam State Disaster Management Authority & Doctors for you (2013). Community Based Disaster Preparedness. Course Book. Doctors for you there to care. Community Based Disaster Preparedness-Peripheral Level.pdf

6. Bansal, B, K & Chaudhary, V. Microzonation Studies in India: DST initiatives. A Workshop on Microzonation. microzon ref 2.pdf

7. Bhagat, S, N (2017). Community-Based Disaster Management Strategy In India: An Experience Sharing. PDPU Journal of Energy & Management. 1 Community-Based-Disaster-Management.pdf

8. Botzen, W. W., Deschenes, O., & Sanders, M. (2019). The economic impacts of natural disasters: A review of models and empirical studies. Review of Environmental Economics and Policy.

9. Boughton, G (1995). Effects of earthquakes on built environment. Paper presented at Earthquake 1995 – WA State Emergency Service Seminar – Workshop.

10. Brabhaharan, P (2000). Earthquake ground damage hazard studies and their use in risk management, in the wellington region, New Zealand. 12WCEE. hazard manaement reference.pdf

11. Brooking Institute (2012). The year that Shook the rich: A review of Natural Disasters in 2011. https://www.brookings.edu/multi-chapter-report/the-year-that-shook-the-rich-a-review-of-natural-disasters-in-2011/

12. CONSERVATION WiKi. Part of Designing Buildings. (2021). https://www.designingbuildings.co.uk/wiki/Shotcrete_technology

13. Dave, R, K (2020). Role of media in disaster management. Gujarat State Disaster Management Authority. https://www.academia.edu/7402446/Role_of_Media_in_Disaster_management_Dr_Dave_2

14. UNDP (2004). "Disaster recovery and community empowerment: Lessons from Gujarat, India"

15. EurekAlert! Liquefaction in Canterbury. University of Texas Austin, Texas. https://www.eurekalert.org/multimedia/909402

16. Fahim, F (2012). Unit-3 Structural and non-structural mitigation measures. Indira Gandhi National Open University. https://egyankosh.ac.in/handle/123456789/58961

17. FEMA (2004). Non-structural Earthquake mitigation guidance manual. Prepared for Federal Emergency Management Agency. structural mitigation ref.pdf 2.pdf

18. Fountain, H. (2017). Reducing Earthquake Risk in Nepal. Eos, 98. https://doi.org/10.1029/2017EO082175

19. GCAP. (2022, February 28). What is the policy coherence between climate change and migration? Global Call to Action Against Poverty. https://gcap.global/es/news/what-is-the-policy-coherence-between-climate-change-and-migration/

20. Gokhale, V, A., Joshi, D, R & Abhayankar, A, L (2004). The psychological and socio-economic aspects of earthquake occurrence. 13th world conference on Earthquake engineering. Vancouver, B.C., Canada, Paper. 2927.

21. Government of Gujarat (2002). Post-earthquake recovery strategy for Gujarat.

22. Health Emergency and disaster Risk Management (2017). Water, Sanitation and Hygiene. Health Emergency and disaster Risk fact sheets. WASH.pdf

23. Holzer, T, L., Borcherdt, R, D., Comartin, C, D., Hanson, R, D., Scawthorn, C, R., Tierney, K & Youd, T, L (2002). A plan to coordinate NEHRP Post-Earthquake Investigations. Geological Investigation.pdf

24. https://www.internetgeography.net/2024-sea-of-japan-earthquake/

25. IAEA-TECDOC (1956). Seismic Instrumentation System and Its Use in Post-earthquake Decision Making at Nuclear Power Plants. IAEA TECDOC SERIES. Seismic instrumentation system.pdf

26. IGNOU (2013). Unit 13: Emergency Operation Centers. https://egyankosh.ac.in/handle/123456789/25893

27. IGNOU (2017). Unit-15: Rehabilitation and Reconstruction. https://egyankosh.ac.in/handle/123456789/25891

28. Infoplease, Sandbox Networks, Inc., 2017. [Online]. Available: https://www.infoplease.com/world/earthquakes/deadliest-earthquakes-record. [Accessed 17 October 2017].

29. International Federation of Red Cross and Red Crescent Societies (2020). Earthquake Guidelines on preparing, responding and recovering. Rehab and Recons Ref-imp.pdf

30. International Federation of Red Cross and Red Crescent Societies (2020). Introduction to disaster preparedness. Disaster Preparedness Training Program. https://www.preventionweb.net/files/2743_Introdp.pdf

31. International Federation of Red Cross and Red Crescent Societies (IFRC). (2001). Gujarat Earthquake response. [Online]. Available at: https://www.ifrc.

org/en/what-we-do/disaster-response/disaster-response-operations/gujarat-earthquake-response.

32. International Journal of Disaster Risk Reduction, (2010). Building Back Better: Post-Disaster Reconstruction in Gujarat, India. International Journal of Disaster Risk Reduction, 1(1), 41-50.

33. Jain, Sudhir K. "Earthquake Safety in India: achievements, challenges and opportunities." Bulletin of Earthquake Engineering 14, no. 5 (May 2016): 1337-1436.

https://ndma.gov.in/sites/default/files/PDF/Reports/EDRI_Report_final.pdf

34. Journal of Disaster Risk Studies, (2017). The 2005 Kashmir earthquake: a case study of post-disaster rehabilitation and reconstruction. Journal of Disaster Risk Studies, 9(1), 1-15.

35. K, Ashok., M, Himanshu., C, Bhanu., G, Ajay (2014). Earthquake Early Warning System for North India. https://www.researchgate.net/publication/270361759_Earthquake_Early_Warning_System_for_Northern_India

36. Khan, A, A (2017). Rehabilitation: Social and Economic Aspects. IGNOU. URI: http://hdl.handle.net/123456789/26585

37. Khyber Pakhtunkhwa (2015). Earthquake Recovery Plan. recovery imp reference.pdf

38. Kumar, P., & Pal, R. (2007). Mitigating the environmental impact of natural disasters: a case study of the 2001 Gujarat earthquake. Environmental Management, 40(3), 437-447.

39. Kumar, S & Sinha, A, K (2018). Economic consequences of earthquake. https://www.academia.edu/22738793/ECONOMIC_CONSEQUENCES_OF_EARTHQUAKE

40. Lang, D, H., Kumar, A, Sulaymanov, S & Meslem, A (2017). Building Typology Classification and Earthquake Vulnerability Scale of Central and South Asian Building Stock. Journal of Building Engineering.

41. Maithili, K, L (2017). A discussion of Liquefaction Mitigation Methods. International Research Journal of Engineering and Technology (IRJET). Volume: 04, Issue:12 liquefaction ref.pdf

42. Manakkara, S., Wilkinson, S., & Francis, T, R (2014). "Building Back Better" Principles for Reconstruction. Encyclopedia of Earthquake Engineering.

43. Ministry of Earth Sciences. Seismic Mapping. https://pib.gov.in/PressReleasePage.aspx?PRID=1740656

44. Ministry of Home Affairs. (2018). National Building Code of India. [Online]. Available at: https://mhupa.gov.in/sites/default/files/NBC%202016%20Volume%201%20to%205.pdf

45. Ministry of Home Affairs (2011). Disaster Management in India. Government of India. india dealing ref.pdf

46. Mishra, O, P (2020). Seismic Zonation Study of South Asian cities and Its implications to Urban Risk Resiliency under Climate Change Scenario.

International journal of Geosciences, 11, 197-237. microzonation ref.pdf

47. Mohapatra, A, K & Mohanty, W, K (2010). An overview of Seismic Zonation Studies in India. Indian Geotechnical Conference – 2010. IGS Mumbai Chapter & IIT Bombay. https://gndec.ac.in/~igs/ldh/conf/2010/articles/043.pdf

48. Motiram, B, H (2014). Earthquake Risk Assessment, Loss Estimation and Vulnerability Mapping for Dehradun City, India. risk assessment ref2.pdf

49. National Center for Disaster Prevention. (2021). Early warning systems for earthquakes. [Online]. Available at: https://www.cenapred.unam.mx/en/prevencion/sistemas-de-alerta-temprana-para-terremotos

50. National Centre for Seismology. (2017). Delhi Microzonation Project. [Online]. Available at: https://www.ncsm.gov.in/micro-zoning.php

51. National Disaster Management Authority (NDMA). (2012). Hand Book for Training and Capacity Building of Civil Defense & Sister Organization. Government of India. civil defense.pdf

52. National Disaster Management Authority (NDMA). (2020). A Primer on Rapid Visual Screening (RVS). Consolidating Earthquake Safety. Rapid visual assessment.pdf

53. National Disaster Management Guidelines (2007). Management of Earthquakes. Government of India. earthquakes pm.pdf

54. National Disaster Management Division. An Earthquake preparedness guideline. Ministry of Home Affairs. North Block, Delhi, India. NIDM.pdf

55. National Institute of Disaster Management (NIDM) (2018). Preventive and mitigation measures. East Asia Summit Earthquake Risk Reduction Centre. Post and pre earthquake ref.pdf

56. National Institute of Disaster Management (NIDM) (2018). Safety Tips: Designing Safe House in an Earthquake Prone Area https://nidm.gov.in/safety_earthquake.asp

57. National Geography. Natural disasters. Environment. https://www.nationalgeographic.com/environment/topic/natural-disasters-weather

58. National Institute of Building Sciences (2010). Earthquake-resistant design concepts. An Introduction to the NEHRP Recommended Seismic Provisions for New Buildings and Other structures. FEMA P-749. fema_earthquake-resistant-design-concepts_p-749.pdf

59. National Institute of Disaster Management (2020). Training module on comprehensive landslide risk assessment. Ministry of Home Affairs, Government of India. Landslides Module NIDM.pdf

60. National Institute of Disaster Management. Preventive and mitigation measures. East Asia Summit Earthquake Risk Reduction Center. Post and pre earthquake ref.pdf

61. National Institute of Management Authority (2007). National Disaster Management Guidelines. Management of Earthquakes. Government of India. earthquakes pm.pdf

62. Neves, M (2020). Challenges of earthquake early warning. Temblor. http://doi.org/10.32858/temblor.093

63. New Zealand Geotechnical Society INC (2021). Earthquake geotechnical engineering practice. Module 2: Geotechnical investigations for earthquake engineering. Building performance. Geotechnical investigation.pdf

64. Orallo, A, D (2011). Study on Earthquake risk and vulnerability management and lessons learned. Research report. ARDC visiting researcher. 18 page referecne.pdf

65. Pareek, K., Ansari, M, S., Verma, S., Saha, P (2016). Seismic retrofitting of the structure: An overview. Proceedings of International Conference on Recent Advances in Mechanics and Materials (ICRAMM-2016) https://www.researchgate.net/publication/331982934_SEISMIC_RETROFITTING_OF_THE_STRUCTURE_AN_OVERVIEW

66. Patwardhan, A. (2002). The Gujarat earthquake of January 26, 2001: lessons learned and challenges ahead. Natural Hazards, 26(1), 1-16.

67. Petley, D (2016). Landslides from the Kumamoto earthquake in Japan. https://blogs.agu.org/landslideblog/2016/04/18/kumamoto-earthquake-1/

68. PIB Chennai (2024): “BhuDEV” Transforming Earthquake Preparedness - A Joint Effort by IIT Roorkee and Uttarakhand Government.

https://pib.gov.in/PressReleasePage.aspx?PRID=2021462#:~:text=%22BhuDEV%E2%80%9D%20Transforming%20Earthquake%20 reparedness%20%2D,IIT%20Roorkee%20and%20Uttarakhand%20Government&text=In%20a%20landmark%20collaboration%20between,edge%20Earthquake%20Early%20Warning%20App.

69. Raj, A (2008). Armed Forces in Disaster Response: Role Reappraisal. CLAWS journal. Armed forces.pdf

70. ReliefWeb. (2001). India: Gujarat Earthquake. Retrieved from https://reliefweb.int/disaster/eq-2001-000119-ind

71. Sean, L & Woldemichael, K (2006). Disaster prevention and preparedness. Ethiopia Public Health Training initiative. disaster intro 19 ref1.pdf

72. Sheth, A., Jain, S, K & Thiruppugazh (2004). Earthquake capacity building and risk reduction measures in Gujarat Post Bhuj 2001 Earthquake. 13th World Conference on Earthquake Engineering. Vancouver, B.C., Canada.

73. Singh, O, P (2016). Disaster Response: Mechanism and Resources in India. NDRF.pdf

74. Singh, R (2013). Community-Based Disaster Preparedness Course Book. Assam State Disaster Management Authority & Doctors for you. CBDP ref.pdf

75. Suppasri, A., Kitamura, M., Alexander, D., Seto, S., & Imamura, F. (2024). The 2024 Noto Peninsula Earthquake: Preliminary Observations and Lessons to be Learned. International Journal of Disaster Risk Reduction, 104611. https://doi.org/10.1016/j.ijdrr.2024.104611

76. Thapa, I (2015). Post-Earthquake Impact and Needs Assessment. The Mountain Institute. initial needs ref.pdf

77. The Economic Times (2022). Uttarakhand: A land ravaged by natural disasters. https://economictimes.indiatimes.com/news/india/uttarakhand-a-land-ravaged-by-natural-disasters/articleshow/92630543.cms

78. The Guardian. (2021, December 7). Wildfires broke carbon emission records in US, Siberia and Turkey. https://www.theguardian.com/world/2021/dec/07/wildfires-broke-carbon-emission-records-us-siberia-turkey

79. United Nations Development Programme (UNDP). (2008). Building Back Better: A Review of Literature and Practice. UNDP, New York, NY.

80. United Nations Office for Disaster Risk Reduction. (2015). Sendai Framework for Disaster Risk Reduction 2015-2030. [Online]. Available at: https://www.unisdr.org/we/inform/publications/43291

81. United Nations Office for Disaster Risk Reduction. (2017). Housing reconstruction after disasters: A toolkit. [Online]. Available at: https://www.unisdr.org/we/inform/publications/60487

82. UNISDR (2017). Earthquake Hazard and Risk Assessment. Words into Action Guidelines: National Disaster Risk Assessment. Hazard Specific Risk Assessment. risk assessment ref1.pdf

83. United States Geological Survey. (2021). Earthquake prediction. [Online]. Available at: https://earthquake.usgs.gov/learn/topics/eqprediction.php

84. Vere-Jones, D (1995). Forecast earthquake and earthquake risk. International Journal 11 (1995) 503-538. vere-jones (1995).pdf

85. Vijayaraja (2014) Ferrocement. BUILTCIVIL. https://buildcivil.wordpress.com/2014/05/07/ferrocement/

86. Virtual University for Small States of the Commonwealth (VUSSC) (2010). Introduction to Disaster management. Course Manual. Commonwealth of Learning. disaster_management reference 2.pdf

87. Wason, H, R (2012). Recent action taken in India towards seismic risk assessment and reduction. 15WCEE. LISBOA2012. Indian scenario reference.pdf

88. World Bank (2005) “Post-earthquake recovery in Gujarat, India”

89. Zurich Insurance (2022). Is climate change making Natural hazards more worse? https://www.zurich.com/en/knowledge/topics/natural-hazards/how-climate-change-is-making-natural-disasters-worse

About the institute

The National Institute of Disaster Management (NIDM) was constituted under an Act of Parliament with a vision to play the role of a premier institute for capacity development in India and the region. The efforts in this direction that began with the formation of the National Centre for Disaster Management (NCDM) in 1995 gained impetus with its redesignation as the National Institute of Disaster Management (NIDM) for training and capacity development. Under the Disaster Management Act 2005, NIDM has been assigned nodal responsibilities for human resource development, capacity building, training, research, documentation and policy advocacy in the field of disaster management.

NIDM is proud to have a multi-disciplinary core team of professionals working in various aspects of disaster management. In its endeavour to facilitate training and capacity development, the Institute has state-of-the-art facilities like class rooms, seminar hall and video-conferencing facilities etc. The Institute has a well-stocked library exclusively on the theme of disaster management and mitigation. The Institute provides training in face-to-face, on-line and self-learning mode as well as satellite based training. In-house and off-campus face-to-face training to the officials of the state governments is provided free of charge including modest boarding and lodging facilities.

NIDM provides Capacity Building support to various National and State level agencies in the field of Disaster Management & Disaster Risk Reduction. The Institute's vision is to create a Disaster Resilient India by building the capacity at all levels for disaster prevention and preparedness.

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