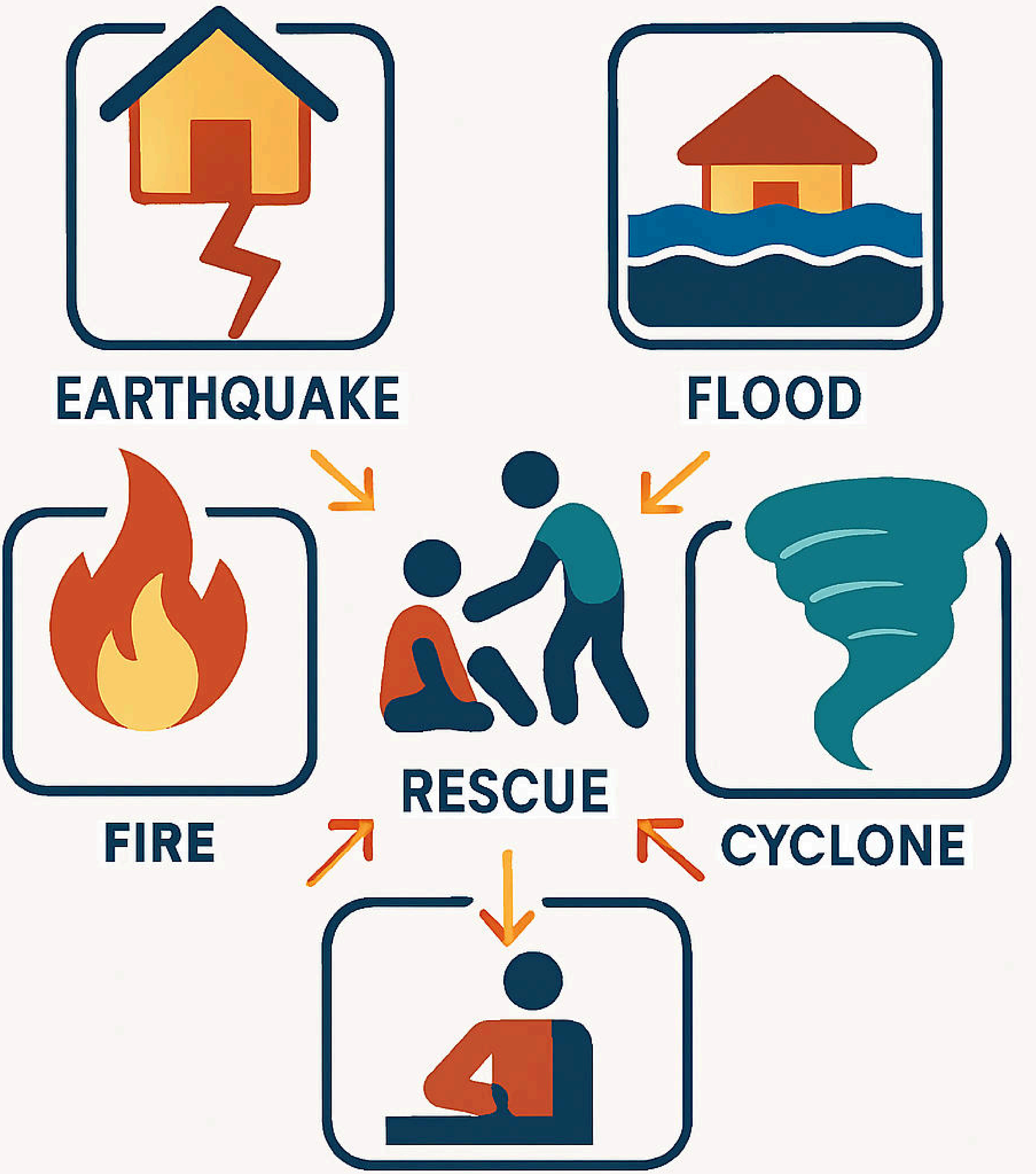
DISASTER MANAGEMENT



ANNAMACHARYA INSTITUTE OF TECHNOLOGY & SCIENCES
(An Autonomous Institution)

Title of the Course: **DISASTER MANAGEMENT**
Category: **OE – II**
Couse Code: 23A016GT
Branch/es: Civil Engineering
Semester: VI

Lecture Hours	Tutorial Hours	Practice Hours	Credits
3	-	-	3

Course Objectives:
The objectives of this course are to make the student :
1. To understand the fundamental concepts of natural disasters, their occurrence, and disaster risk reduction strategies.
2. To analyze the impact of cyclones on structures and explore retrofitting techniques for adaptive reconstruction.
3. To apply wind engineering principles and computational techniques in designing wind-resistant structures.
4. To evaluate earthquake effects on buildings and develop strategies for seismic retrofitting.
5. To assess seismic safety planning, design considerations, and innovative construction materials for disaster-resistant structures.

Course Outcomes:
After successful completion of this course, students will be able to:
1. Understand the fundamental concepts of natural disasters, their occurrence, and disaster risk reduction strategies.
2. Analyze the impact of cyclones on structures and explore retrofitting techniques for adaptive reconstruction.
3. Apply wind engineering principles and computational techniques in designing wind- resistant structures.
4. Evaluate earthquake effects on buildings and develop strategies for seismic retrofitting.
5. Assess seismic safety planning, design considerations, and innovative construction materials for disaster-resistant structures.

Unit 1 Natural Disasters 8
SENDAI Frame Work, Types of Natural Disasters, Disasters in Different Climatic and Geographical Regions, Hazard Maps (Earthquake and Cyclone) (World and India), Regulations for Disaster Risk Reduction, Post-Disaster Recovery and Rehabilitation (Socio-economic Consequences).

Unit 2 Cyclones 8
Cyclones and Their Impact– Climate Change and Its Impact on Tropical Cyclones, Nature of Cyclonic Wind, Velocities and Pressure, Cyclone Effects, Storm Surges, Floods, and Landslides. Behavior of Structures in Past Cyclones and Windstorms, Case Studies. Cyclonic Retrofitting, Strengthening of Structures, and Adaptive Sustainable Reconstruction. Life-Line Structures Such as Temporary Cyclone Shelters.

Unit 3 Wind Effects 10
Structural Response and Wind Loads– Basic Wind Engineering, Aerodynamics of Bluff Bodies, Vortex Shedding, and Associated Unsteadiness Along and Across Wind forces. Demo on Wind Tunnel Testing and Its Salient Features. Introduction to Computational Fluid Dynamics (CFD). General Planning and Design Considerations Under Windstorms and Cyclones. Wind Effects On Buildings, towers, Glass Panels, Etc., and Wind-Resistant Features in Design. Codal Provisions, Design Wind Speed, Pressure Coefficients. Coastal Zoning Regulations for Construction and

Reconstruction in Coastal Areas. Innovative Construction Materials and Techniques, Traditional Construction Techniques in Coastal Areas.

Unit 4 Seismic Risk Assessment 10

Seismology and Earthquake Effects– Causes of Earthquakes, Plate Tectonics, Faults, Seismic Waves; Magnitude, Intensity, Epicenter, Energy Release, and Ground Motions. Earthquake Effects– On Ground, Soil Rupture, Liquefaction, Landslides. Performance of Ground and Buildings in Past Earthquakes– Behaviour of Various Types of Buildings and Structures,
Collapse Patterns; Behavior of Non-Structural Elements Such as Services, Fixtures, and Mountings – Case Studies. Seismic Retrofitting– Weakness in Existing Buildings, Aging, Concepts in Repair, Restoration, and Seismic Strengthening

Unit 5 Seismic Safety 10

General Planning and Design Considerations; Building forms, Horizontal and Vertical Eccentricities, Mass and Stiffness Distribution, Soft Storey Effects, Seismic Effect of Building Configuration. Plan and Vertical Irregularities, Redundancy, and Setbacks. Construction Detailing of Various members, Innovative Construction Materials and Techniques. Local Practices– Traditional Regional Responses.

Prescribed Textbooks:

1. RS Agarwal, Disaster Management in Technology and Culture, Arise Publishers, 2007.
2. Edward A. Keller and Duane E. DeVecchio, Natural Hazards: Earth's Processes as Hazards, Disasters, and Catastrophes, 5th Edition, Routledge, 2019.

Reference Books:

1. Ben Wisner, J.C. Gaillard, and Ilan Kelman (Editors), Handbook of Hazards and Disaster Risk Reduction and Management, 2nd Edition, Routledge, 2012.
2. Damon P. Coppola, Introduction to International Disaster Management, 4th Edition, Butterworth-Heinemann, 2020.
3. Bimal Kanti Paul, Environmental Hazards and Disasters: Contexts, Perspectives and Management, 2nd Edition, Wiley-Blackwell, 2020.

Online Learning Resources:

1. https://nptel.ac.in/courses/124107010 2.
2. https://onlinecourses.swayam2.ac.in/cec19_hs20/preview

CO-PO Mapping:

Course Outcomes	Engineering Knowledge	Problem Analysis	Design/Development of solutions	Conduct investigations of complex problems	Modern tool usage	The engineer and society	Environment and sustainability	Ethics	Individual and team work	Communication	Project management and finance	Life-long learning	**PSO1**	**PSO2**
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23A016GT.2	2	3	2	-	2	-	-	-	-	-	-	2	3	-
23A016GT.3	3	2	3	3	-	-	3	-	-	2	-	-	-	3
23A016GT.4	2	3	3	-	3	-	-	2	-	-	-	-	3	-
23A016GT.5	2	2	3	3	-	3	3	3	2	-	-	-	-	3

UNIT 1

NATURAL DISASTERS

Unit 1: Natural Disasters

Syllabus: SENDAI Frame Work, Types of Natural Disasters, Disasters in Different Climatic and Geographical Regions, Hazard Maps (Earthquake and Cyclone) (World and India), Regulations for Disaster Risk Reduction, Post-Disaster Recovery and Rehabilitation (Socio-economic Consequences).

1. Disaster

A disaster is a sudden event that causes serious harm to people, property and the environment. It can be natural, like floods, earthquakes and cyclones, or human-made, like industrial accidents and fires. Disasters disturb normal life and create urgent situations that need quick action.

2. Management

Management is the process of planning, organizing and controlling activities to achieve a goal in an effective and orderly way. It helps ensure that resources are used properly and work is done smoothly. Good management leads to better coordination and faster results.

3. Disaster Management

Disaster management is the organized approach used to reduce the impact of disasters and support affected communities. It includes preparing in advance, giving early warnings, carrying out rescue work and helping people recover after the event. The goal is to save lives, reduce damage and restore normal conditions as quickly as possible.

3.1. Purpose of Studying Disaster Management

The purpose of studying this subject is to understand different hazards, learn how to stay prepared and reduce risks. It helps individuals and communities respond safely during emergencies and recover without long-term loss. This knowledge builds awareness, improves decision-making and supports the development of safer, more resilient societies.

4. Sendai Framework for Disaster Risk Reduction (2015–2030)

The Sendai Framework for Disaster Risk Reduction (SFDRR) 2015–2030 is the global strategy adopted by the United Nations to reduce disaster risks and strengthen resilience. It was approved at the Third UN World Conference on Disaster Risk Reduction held in Sendai, Japan, on 18 March 2015. The framework replaced the Hyogo Framework for Action (2005–2015) and provides a 15-year plan for minimizing disaster impacts on people, property and development.

4.1. Purpose of the Framework

The main purpose of the SFDRR is to guide countries in preventing and reducing disaster risks. It aims to lower the losses caused by natural, environmental, technological and biological hazards. The framework promotes a proactive approach where understanding and managing risk becomes more important than responding after a disaster occurs.

4.2. Scope of the Framework

The SFDRR covers a wide range of disasters such as

- Natural Hazards (Earthquakes, Floods, Cyclones)
- Technological and Industrial Accidents
- Biological Hazards (Epidemics)
- Slow-Onset Events (Drought, Climate-Related Risks)
- Small-Scale and Large-Scale Disasters
- Frequent and Infrequent Events

4.3. Expected Outcome (by 2030)

The framework aims for a **substantial reduction in disaster losses**, including

- Loss of Life
- Injuries and Health Impacts
- Loss of Livelihoods
- Damage to Infrastructure
- Economic, Social, Cultural and Environmental Losses

4.4. Overall Goal

The major goal is to **prevent new risks and reduce existing risks**. This is achieved by adopting integrated and inclusive measures such as

- Policy Reforms
- Risk-Sensitive Development
- Resilient Infrastructure
- Environmental Protection
- Social and Economic Preparedness
- Technological and Institutional Improvements

4.5. Guiding Principles

The SFDRR highlights several principles to support effective disaster risk reduction:

- Countries have the primary responsibility for risk reduction.
- Disaster risk management must involve all levels of government.
- Communities, civil society and the private sector must participate.
- Policies should safeguard life, property and livelihoods.
- DRR should promote human rights, equality and sustainable development.
- Actions must be people-centered and inclusive.

4.6. Priorities for Action

Priority 1: Understanding Disaster Risk

Countries must improve disaster risk knowledge by collecting data, mapping hazards, analyzing vulnerability and strengthening early-warning systems. Better understanding of risk supports effective planning.

Priority 2: Strengthening Disaster Risk Governance

Risk governance involves laws, policies, institutions and coordination mechanisms. Strong governance ensures that risk reduction is included in development planning and implemented effectively.

Priority 3: Investing in Disaster Risk Reduction for Resilience

Investment is essential for long-term safety. This includes

- Building Resilient Infrastructure
- Strengthening Health and Education Systems
- Improving Natural Ecosystems
- Promoting Awareness and Capacity-Building

Preventive investment is more cost-effective than repair and recovery.

Priority 4: Enhancing Preparedness and Building Back Better

Preparedness involves emergency planning, response training and early-warning dissemination.
“Build Back Better” focuses on using the repair and reconstruction phase to improve safety features, introduce stronger building standards and support mental and social recovery.

4.7. Global Targets (A–G)

To measure progress by 2030, the SFDRR identifies seven targets:

A. Reduce global disaster mortality
B. Reduce the number of people affected
C. Reduce economic losses relative to global GDP
D. Reduce damage to critical infrastructure and essential services
E. Increase countries with national and local DRR strategies
F. Enhance international cooperation to developing countries
G. Expand access to early-warning systems and risk information

4.8. Importance for India

India has aligned its National Disaster Management Plan (NDMP) with the Sendai priorities. The focus is on

• Expanding Early-Warning Coverage
• Strengthening Building Codes and Infrastructure Safety
• Improving Community-Level Preparedness
• Integrating Disaster Risk Reduction into Development Planning

5. Types of Natural Disasters

Disasters are generally classified into two broad categories based on their origin: Natural Disasters and Human-Induced (or man-made) Disasters. Some events may also be classified as socio-natural hazards, as their occurrence is attributed to the interaction of natural hazards with human activities like environmental degradation.

The sources provide detailed classifications of hazards and disasters, often grouped by their physical origin or cause:

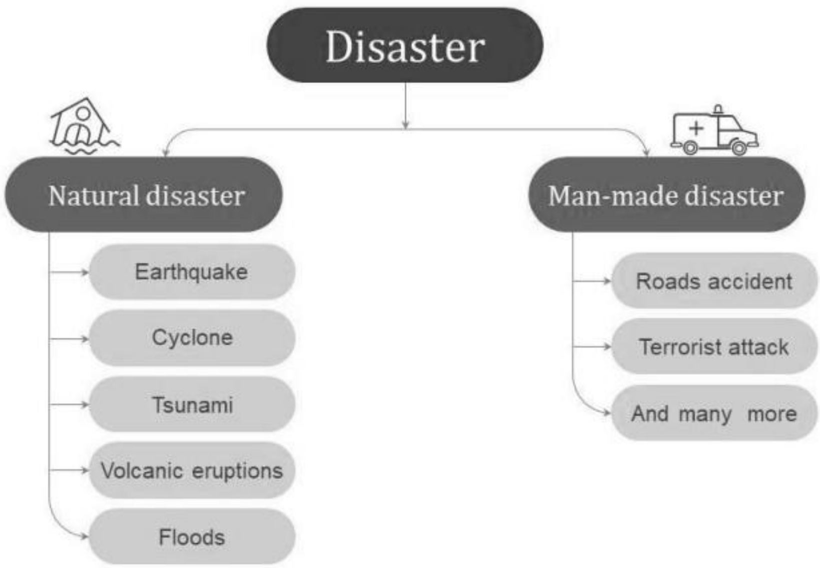


Figure1.1: *Classification of Disaster*

5.1. Natural Disasters

Natural disasters are hazardous events that occur naturally, resulting from physical processes within the earth or atmosphere, and are categorized broadly as natural hazards. These are defined as naturally occurring physical phenomena caused by rapid or slow onset of events.

The sources classify natural disasters into five major categories based on their origin:

Hazards	Origin and Nature	Examples
Geophysical Hazards (or Geological):	These originate from processes within the solid earth	Specific examples include: o Earthquakes. o Tsunamis (also known as seismic sea waves). o Landslides and Mudflows. o Volcanic activity/ eruptions. o Mass Movement (Dry).
Hydrological Hazards	These events are caused by deviations in the normal water cycle or the overflow of water bodies	This category includes: o Floods. o Snow Avalanches. o Cloud Burst. o Mass Movement (Wet).
Meteorological Hazards	These are caused by short-lived, micro- to meso-scale extreme weather and atmospheric conditions, lasting from minutes to days.	Examples often include hydro-meteorological events: o Cyclones (including Tropical Storms, Hurricanes, and Tornadoes). o Hailstorm. o Thunder and Lightning. o Dust Storm and Blizzard.
Climatological Hazards	These hazards result from long-lived, macro-scale atmospheric processes and multi-decadal climate variability	Specific disasters include: o Droughts. o Extreme Temperature, such as Heat Wave and Cold Wave. o Wildfire/Forest Fire (Natural). o Glacial Lake Outburst (GLOF).
Biological Hazards	These disasters arise from processes of organic origin or those conveyed by biological vectors	This group covers: o Epidemics (spread of disease or virus). o Pest Attacks and Insect infestations. o Cattle Epidemics. o Food Poisoning (from natural origins).

It is important to note that many disasters are sometimes categorized as **socio-natural hazards**, as their occurrence is often linked to the interaction of natural hazards with degraded or over-exploited environmental resources, such as floods and landslides.

5.2. Human-induced hazards

Human society is vulnerable to not only natural hazards but also human induced hazards which occur due to various factors such as poor planning and construction, overpopulation, environmentally insensitive practices, industrialization and urbanization, climate change and so on. These human activities can cause potential damage and threat to life, property, and environment. Human society is thus prone to Chemical, Biological, Radiological, and Nuclear (CBRN) disasters and events that might trigger disasters. Other human- induced disasters emerging from human activities include terrorist activities, violence, conflict, civil war, various types of accidents such as road, rail, air, sea, river, industrial, fires, building collapse, oil spills, urban flooding, mine flooding, etc.

6. Disasters in Different Climatic and Geographical Regions

Disasters are typically viewed as a combination of hazards and a risk conditions, often exceeding a community's capacity to cope using its own resources. Hazards themselves are classified based on their origin, especially in the context of increasing global complexity.

6.1. Classification of Hazards by Origin

The scope of modern disaster risk reduction (DRR) has significantly broadened to cover not only natural hazards but also man-made hazards and related environmental, technological, and biological hazards and risks. Major natural hazard categories include:

Hazard Category	Origin and Nature	Examples	India-Specific Context
Geophysical	Processes within the solid earth (geological hazard).	Earthquakes, Tsunamis, Volcanic eruptions, Mass movements.	About 57% of India's landmass is prone to seismic activity
Hydrological	Deviations in the water cycle or overflow of water bodies.	Floods, Flash floods, Avalanches, Wave action.	Over 40 million hectares (12% of land) are flood-prone (వరద); around 68% of cultivable area is drought-prone (కరువులు).
Meteorological	Short-lived, extreme weather (micro- to meso-scale).	Cyclones, Hurricanes, Tornadoes, Storm surges, Hail, Thunderstorms.	
Climatological	Long-lived atmospheric processes (intra-seasonal to multi-decadal climate variability).	Droughts, Extreme temperatures (Heat/Cold Waves), Wildfires, Glacial Lake	Increasing frequency of heatwaves and drought events
Biological	Organic processes or conveyed by biological vectors.	Disease outbreaks Pest attacks, Food poisoning.	COVID-19 highlighted severe social, economic, and psychological impacts

6.2. Disaster Profile of India by Region

India's diverse physiographic and geo-climatic conditions make it highly vulnerable to various disasters.

Geographical Region	Primary Disasters/Hazards	Key Vulnerabilities
Himalayan Region	Earthquakes, Landslides, Flash Floods, Snow Avalanches.	Geologically young mountain range subject to neo-tectonism; steep slopes and high atmospheric precipitation.
Indo-Gangetic Plains	Annual Floods (Riverine), Earthquakes (due to proximity to Himalayas), Droughts.	Densely populated alluvial plains drained by Himalayan rivers.
Coastal Region	Cyclones, Storm Surges, Floods, Tsunamis.	Long coastline (7,516 km); eastern coast is more vulnerable (Bay of Bengal cyclones occur four times more frequently than in the Arabian Sea).
Arid/Semi-Arid Areas	Recurring Droughts, Famine, Dust Storms.	Deficiency of rainfall over extended periods; 68% of cultivable land is drought-prone.

7. Hazard Maps (Earthquake and Cyclone)

Hazard mapping is the fundamental output of understanding disaster risk (SFDRR Priority 1), translating scientific analysis into planning tools [20, 24(c), 512, 2512]. The vulnerability maps for India are compiled in the **Vulnerability (బలహీనత) Atlas of India**, published by the Building Materials and Technology Promotion Council (BMTPC).

7.1. Earthquake Hazard Maps (Seismic Zoning)

The quantification of earthquake hazard is done using **Probabilistic Seismic Hazard Analysis (PSHA)**, which calculates the probability of exceeding critical ground motion levels by analyzing the magnitude, location, and rate of all potential earthquakes.

In India, the **Bureau of Indian Standards (BIS)** seismic zoning map (IS 1893:2016) divides the country into four zones based on expected maximum intensity:

Seismic Zone	Damage Risk Level	Expected MSK Intensity	Percentage of Area Covered	Major Regions / Cities Included
Zone V	Very High Damage Risk	MSK IX or higher	11.3%	Entire Northeast India, parts of Uttarakhand, Kutch region of Gujarat, Andaman and Nicobar Islands
Zone IV	High Damage Risk	MSK VIII	14.4%	New Delhi
Zone III	Moderate Damage Risk	MSK VII	31.1%	Mumbai, Chennai
Zone II	Low Damage Risk	Not specified	43.2%	Least seismically active regions of the country

Seismic Zone (Map Color)	Damage Risk Level	Expected Intensity (Approx. MSK)	Peak Ground Acceleration (PGA)	Major Regions / Cities Included
Dark Red / Red	**Very High** Damage Risk	**MSK IX** or higher	> 2.4 m/s^2	**Ring of Fire:** Japan, Philippines, West Coast of North & South America (Andes, California), Himalayas (India/Nepal), Turkey, Iran.
Orange	**High** Damage Risk	**MSK VIII**	1.6 - 2.4 m/s^2	Mediterranean region (Greece, Italy), Central America, New Zealand, Indonesia, parts of Alaska and the Caribbean.
Yellow	**Moderate** Damage Risk	**MSK VII**	0.8 - 1.6 m/s^2	Central China, Southeast Asia, parts of the US Midwest/East Coast, Southern Europe, East African Rift.
White / Green	**Low** Damage Risk	**MSK VI** or lower	< 0.8 m/s^2	**Stable Cratons:** Northern Russia, Canada, Australia, Western/Central Africa, Amazon Basin, Eastern South America.

7.2. Cyclone and Wind Hazard Maps

Windstorm hazard mapping plays a critical role in guiding structural design requirements to reduce property losses, especially in cyclone-prone coastal regions. In India, wind hazard zones are classified based on the **Basic Wind Speed**, expressed in **meters per second (m/s)**. For cyclone hazard assessment and comparison with meteorological records, these wind speeds are also commonly expressed in **knots**, where **1 m/s equals 1.94384 knots**.

Table: Integrated Wind and Cyclone Hazard Classification for India

Wind Zone	Design Wind Speed (m/s)	Wind Speed (knots)	Damage Risk Zone	Equivalent IMD Cyclone Intensity (MSW in knots)	Typical Indian Regions
Zone VI	55 m/s	≈ 107 knots	Very High Damage Risk Zone – A	Extremely Severe Cyclonic Storm (≥ 91 knots)	Andaman and Nicobar Islands, coastal Odisha, parts of Andhra Pradesh
Zone V	50 m/s	≈ 97 knots	Very High Damage Risk Zone – B	Extremely Severe Cyclonic Storm (≥ 91 knots)	Coastal Gujarat, Odisha coast, Andhra Pradesh coast
Zone IV	47 m/s	≈ 91 knots	High Damage Risk Zone	Very Severe Cyclonic Storm (64–90 knots)	Tamil Nadu coast, West Bengal coast, Parts of Maharashtra
Zone III	44 m/s	≈ 86 knots	Moderate Damage Risk Zone – A	Very Severe Cyclonic Storm (64–90 knots)	Interior coastal belts of eastern and western India
Zone II	39 m/s	≈ 76 knots	Moderate Damage Risk Zone – B	Severe Cyclonic Storm (48–63 knots)	Inland districts adjoining coastal states
Zone I	33 m/s	≈ 64 knots	Low Damage Risk Zone	Cyclonic Storm (34–47 knots)	Interior mainland regions

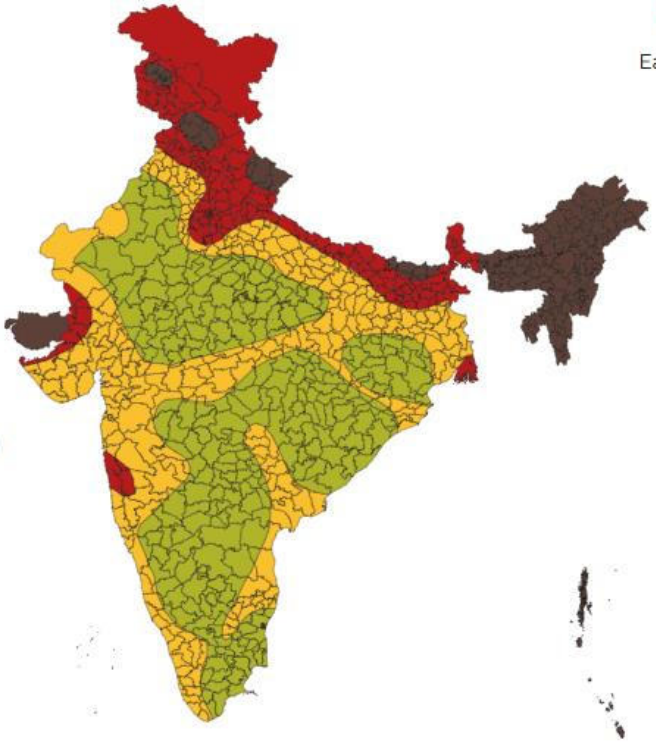
Table: Wind Hazard Classification of India (Based on Basic Wind Speed, V_β)

Basic Wind Speed, V_β (m/s)	Damage Risk Zone	Wind Hazard Severity	Typical Indian Regions
55	Very High Damage Risk Zone – A	Extremely High Wind Hazard	Andaman & Nicobar Islands, parts of Northeast India, pockets of the eastern coast
50	Very High Damage Risk Zone – B	Very High Wind Hazard	Coastal Gujarat, Konkan coast, Odisha coast
47	High Damage Risk Zone – A	High Wind Hazard	Tamil Nadu coast, West Bengal coast, Andhra Pradesh coast
44	Moderate Damage Risk Zone – A	Moderate Wind Hazard	Interior coastal belts of eastern and western India
39	Moderate Damage Risk Zone – B	Moderate to Low Wind Hazard	Inland districts adjoining coastal states
33	Low Damage Risk Zone	Low Wind Hazard	Interior mainland regions

Earthquake Hazard Map of India

All India

The map is based on the most recent information available.



Zone II : Low Damage Risk Zone (MSK VI or less)

Zone III : Moderate Damage Risk Zone (MSK VI)

Zone IV:High Damage Risk Zone(MSK VIII)

Zone V:Very High Damage Risk Zone(MSK IX or more)

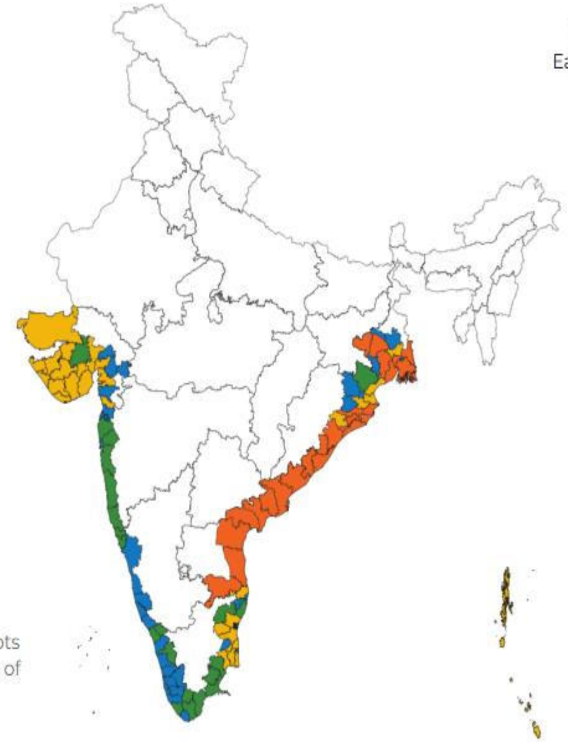
Source: Building Materials and Technology Promotion Council

Cyclone Occurrence Map of India

All India

Earthquake Flood Wind Hazard Cyclone

The map is based on the most recent information available.



Maximum Sustained Wind (MSW) in Knots

- 34-47
- 48-63
- 64-90
- 91 or more

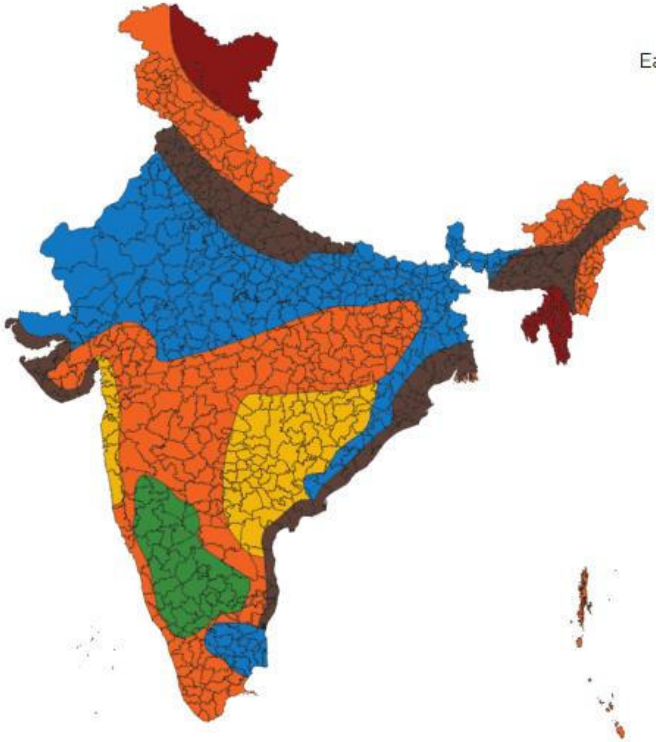
The Cyclone Occurrence Map of India has been developed based on maximum/ estimated 3-minute average Maximum Sustained Wind in knots (1 knot = 0.5144 m/s) that affected coastal districts of India during 1891-2008, as per data provided by IMD.

Wind Hazard Map of India

All India

Earthquake Flood Wind Hazard Cyclone

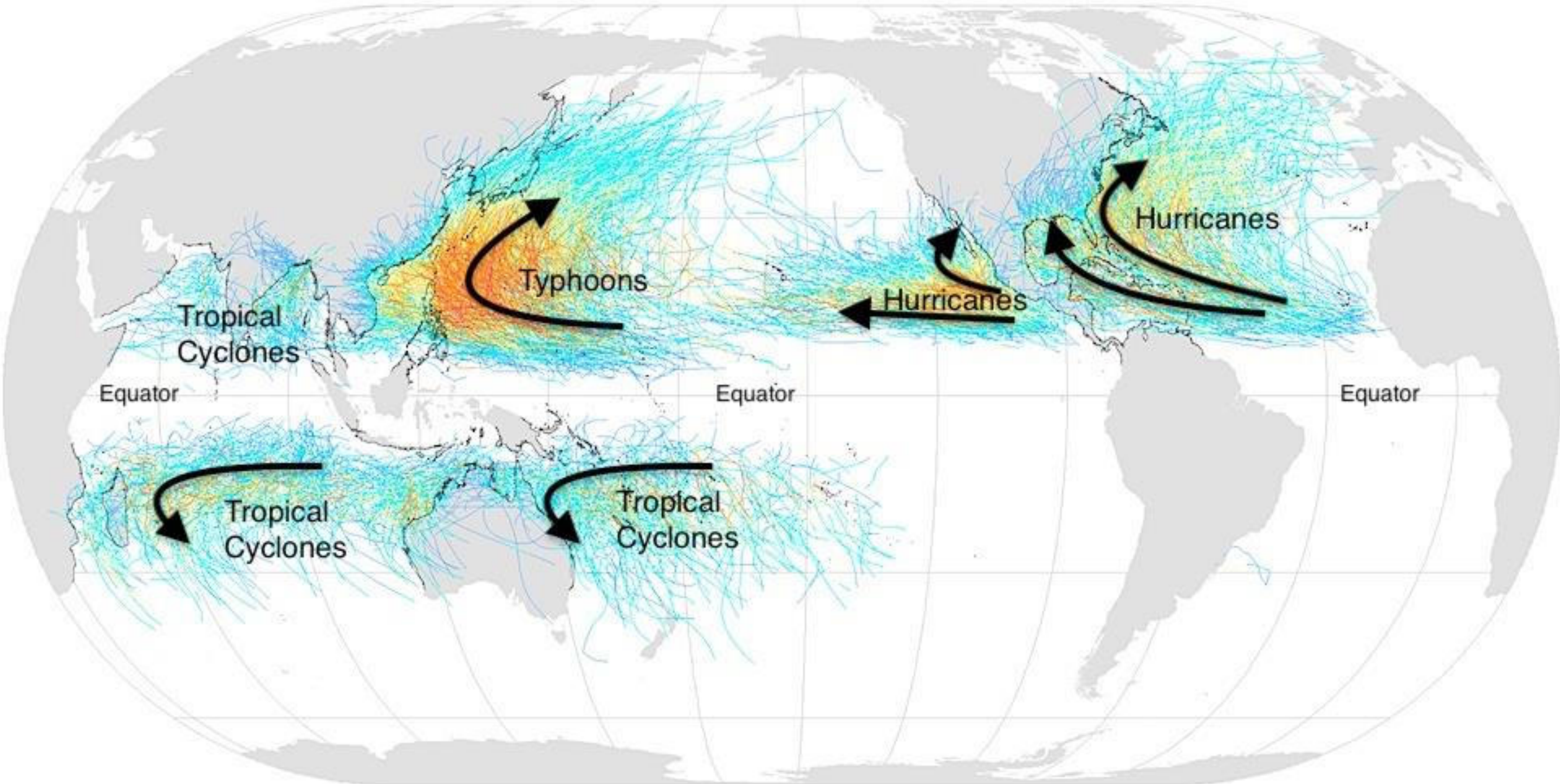
The map is based on the most recent information available.



- Low Damage Risk Zone (Vb=33 m/s)
- Moderate Damage Risk Zone-B (Vb=39 m/s)
- Moderate Damage Risk Zone-A (Vb=44 m/s)
- High Damage Risk Zone-A (Vb=47 m/s)
- Very High Damage Risk Zone-B(Vb=50 m/s)
- Very High Damage Risk Zone-A(Vb=55 m/s)

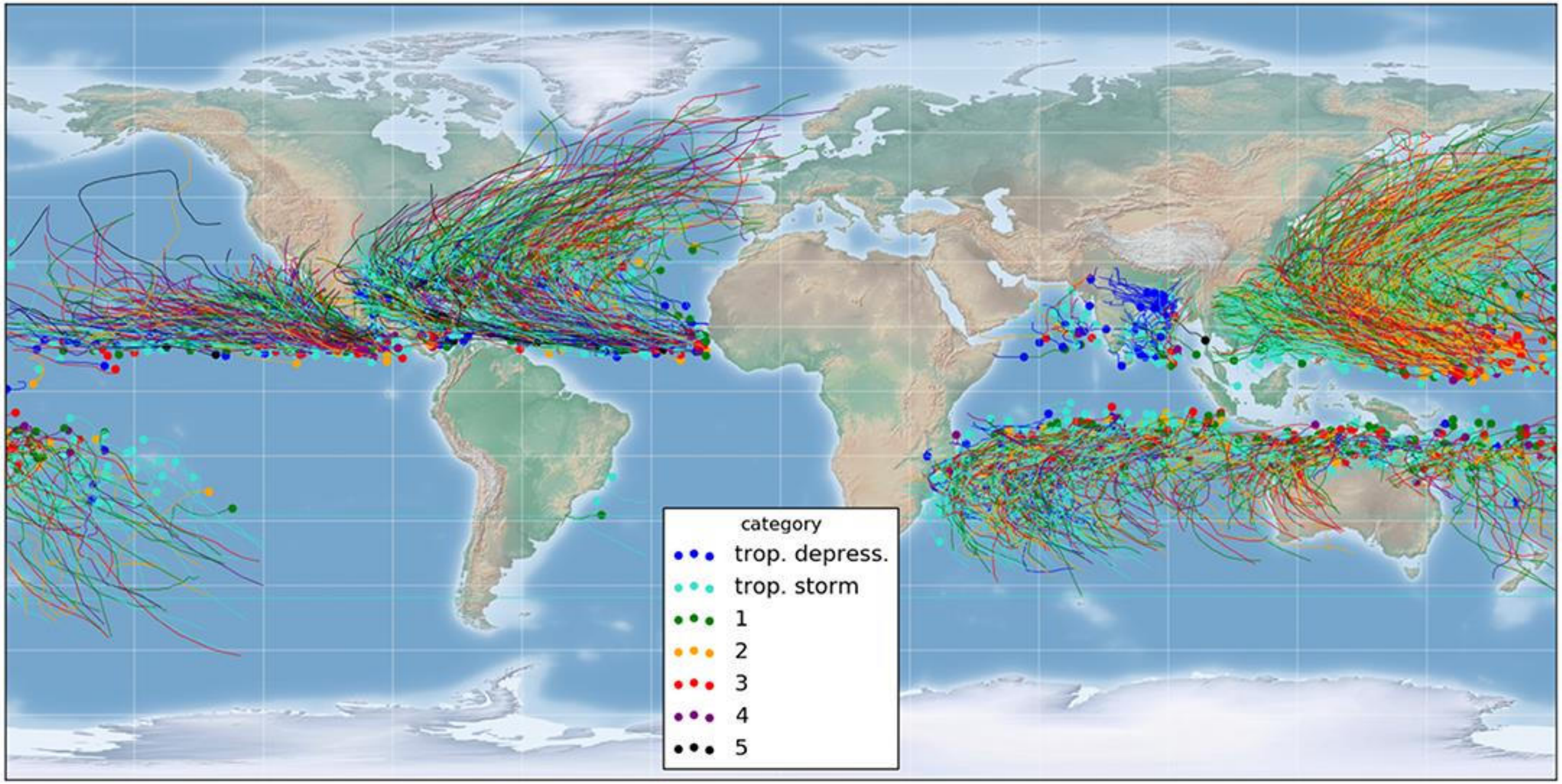
Source: Building Materials and Technology Promotion Council

Tropical Cyclones, 1945–2006



Saffir-Simpson Hurricane Scale:

tropical depression	tropical storm	hurricane category 1	hurricane category 2	hurricane category 3	hurricane category 4	hurricane category 5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8. Regulations for Disaster Risk Reduction (DRR)

DRR relies on robust legal and institutional frameworks (SFDRR Priority 2) to move from reactive relief to proactive risk management.

8.1. Global Policy Evolution (SFDRR)

The **Sendai Framework for Disaster Risk Reduction (SFDRR) 2015-2030** is the key international instrument, promoting systemic resilience by focusing on multi-hazard and climate-related risks.

1. **Goal:** To prevent new and reduce existing disaster risk through integrated legal, social, economic, and institutional measures, strengthening resilience, and improving preparedness, response, and recovery.
2. **Four Priorities for Action (Implementation Pathway)**:
    - **Priority 1: Understanding Disaster Risk:** Requires scientific analysis, such as using PSHA and cyclone zoning to assess hazards, vulnerabilities, and exposures.
    - **Priority 2: Strengthening Disaster Risk Governance:** Demands committed leadership and engagement from all sectors and institutional levels (all-of-society approach).
    - **Priority 3: Investing in DRR for Resilience:** Emphasizes proactive, cost-effective structural and non-structural measures (e.g., retrofitting buildings, developing early warning) to minimize losses and prevent new risks.
    - **Priority 4: Enhancing Preparedness and "Build Back Better" (BBB):** Links response capacity directly to long-term sustainable recovery.
3. **Global Targets (SFDRR A-G):** Include reducing mortality (Target a), affected people (Target b), economic loss relative to GDP (Target c), and damage to critical infrastructure (Target d). They also mandate increasing national and local DRR strategies (Target e) and access to multi-hazard early warning systems (Target g) by 2030.

8.2. India's Regulatory Framework

India adopted the SFDRR, SDGs, and the Paris Agreement, transitioning to a proactive stance.

1. **Disaster Management (DM) Act, 2005:** Provides the core legal framework for a multi-tiered institutional structure (NDMA, SDMA, DDMA) to manage disasters effectively. It mandates the integration of DRR measures in development plans and established financial mechanisms like the National Disaster Response Fund (NDRF).
2. **National Policy on Disaster Management (NPDM), 2009:** Explicitly mandates mainstreaming disaster management into developmental planning, promoting a culture of prevention and mitigation, and ensuring efficient response/relief.
3. **Operational Mechanisms and Codes:** Key regulations operationalize resilience measures (SFDRR Priority 3):
    - **Building Codes:** New structures must comply with **Bureau of Indian Standards (BIS)** codes for earthquake resistance (structural measures).

- **Techno-Legal Regime:** Includes enforcing Land Use Planning regulations and development control rules to impose safety requirements and restrict construction in hazard-prone areas.

9. Post-Disaster Recovery and Rehabilitation

Recovery refers to decisions and actions taken after a disaster to restore or improve pre-disaster conditions, focusing on building long-term resilience.

9.1. The Recovery Phase Structure

The long-term management following a disaster typically involves three stages:

Phase	Description	Examples of Activities
Relief / Immediate Response	Saving lives, immediate needs met in the aftermath.	Search and rescue (SAR), evacuation, provision of food, water, temporary shelter, and medical care.
Rehabilitation	Short-term restoration of basic services and community life.	Physical (restoring roads, water supply), Social (counseling, restoring education), Economic (livelihood support, financial aid).
Reconstruction	Long-term measures to permanently rebuild infrastructure and livelihoods, aiming for higher safety standards.	Construction of permanent, hazard-resistant housing ("Build Back Better") and full restoration of physical infrastructure.

9.2. The "Build Back Better" (BBB) Doctrine

BBB is a targeted strategy in recovery and reconstruction (SFDRR Priority 4) that reduces vulnerability to future disasters and ensures the results are sustainable and resilient.

- **Goal:** To integrate disaster risk reduction measures into development efforts and rebuild better than the pre-disaster state.
- **Application:** BBB applies across sectors:
  - **Infrastructure:** Introducing measures like earthquake-resistant designs, strengthening embankments, replacing damaged assets with technologically updated alternatives, and enforcing land-use planning in high-risk zones.
  - **Livelihoods:** Promoting resilient agriculture (e.g., flood-resistant crops), implementing business continuity systems for small and medium enterprises (SMEs), and providing low-interest financing mechanisms.

9.3. Socio-Economic Consequences

Disasters exert a profound and differentiated socio-economic impact, characterized by high monetary loss and disproportionate consequences for vulnerable populations. Rehabilitation aims to address these consequences through integrated interventions.

Consequence Area	Description of Impact	Rehabilitation Focus
Economic/Livelihood Loss	Massive direct property losses and indirect losses from business interruption, crop destruction, and disruption of infrastructure and supply chains.	**Economic Rehabilitation:** Providing compensation, loans, and livelihood restoration programs; strategically supporting local production and SMEs to prevent long-term economic drag.
Social Vulnerability & Poverty	Disasters exacerbate poverty by destroying the limited assets and fragile housing of the poor, often forcing internal migration. Vulnerable groups (women, children, elderly) face heightened exposure and decreased coping capacity.	**Social Rehabilitation:** Ensuring inclusive planning, strengthening access to social safety nets, rebuilding community services (schools, health centers), and focusing on groups that require specialized support, such as single-headed households.
Health and Psychological Trauma	Disasters cause immediate casualties, injuries, and long-term consequences including Post-Traumatic Stress Disorder (PTSD), depression, and anxiety among survivors.	**Physical and Psychological Rehabilitation:** Providing immediate emergency medical response followed by long-term psychosocial care, trauma counseling, and mental health services to restore overall well-being.

References:

1. Goyal, Pradeep K., and Anil Kumar Gupta. ***Disaster Management***. All India Council for Technical Education (AICTE), 2023.
2. Indira Gandhi National Open University (IGNOU). ***Disaster Management: Act, Policy and Institutional Arrangements***. BPAG-171, IGNOU, 2012.
3. Indira Gandhi National Open University (IGNOU). ***Natural Hazards and Disaster Management***. MGGE-003, Block 1, IGNOU, 2021.
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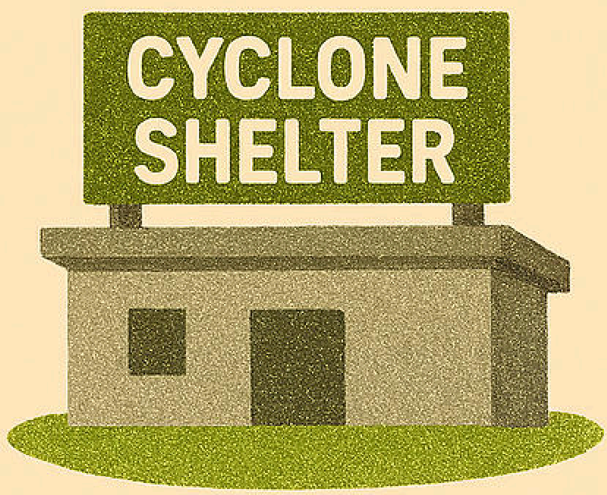
UNIT 2
CYCLONES



Unit 2: Cyclones

Syllabus: Cyclones and Their Impact– Climate Change and Its Impact on Tropical Cyclones, Nature of Cyclonic Wind, Velocities and Pressure, Cyclone Effects, Storm Surges, Floods, and Landslides. Behavior of Structures in Past Cyclones and Windstorms, Case Studies. Cyclonic Retrofitting, Strengthening of Structures, and Adaptive Sustainable Reconstruction. Life-Line Structures Such as Temporary Cyclone Shelters.

1. Cyclones

Cyclones, specifically tropical cyclones, are large-scale air masses that rotate around a strong center of low atmospheric pressure, characterized by inward spiraling winds. These systems are referred to by various regional names: hurricanes in the Atlantic and Northern Pacific, typhoons in the Northwestern Pacific, and cyclones in the Indian Ocean.

2. The Nature and Formation of Tropical Cyclones

Tropical cyclones function like massive heat engines, using warm ocean waters and moist air as fuel. They form almost exclusively in tropical regions between 5° and 30° latitude, as they require the Coriolis force generated by the Earth's rotation to initiate a circular motion. Six primary requirements must be met for their formation:

- Sufficiently warm sea surface temperatures (above 26-27°C).
- Atmospheric instability and high humidity in the lower to middle levels of the troposphere.
- Presence of a pre-existing low-level disturbance and low vertical wind shear.
- A fully developed cyclone features a funnel-like structure with a calm center called the eye, a surrounding eye wall with the strongest winds, and outer spiral rain bands.

3. Impacts of Tropical Cyclones

The primary hazards associated with cyclones include **strong winds, torrential rain, and storm surges**.

- **Storm Surges:** This is the most destructive impact, typically accounting for 90 per cent of all tropical cyclone deaths. A storm surge is a coastal flood or tsunami-like rise in water caused by low pressure at the cyclone's core "sucking" the water upward and winds "piling" the water against the coast.
- **Physical Damage:** High-speed winds can destroy houses, power grids, and communication towers, while turning loose debris into lethal flying objects.
- **Inland Flooding:** While wind speed diminishes over land, cyclones can carry massive moisture inland, causing severe riverine flooding and landslides.
- **Socio-Economic Consequences:** Disasters like the 1999 Odisha Super Cyclone resulted in nearly 10,000 deaths and widespread homelessness. Secondary impacts include crop destruction, saline water intrusion that ruins soil fertility, and waterborne disease outbreaks like cholera and malaria.

4. Climate Change and Its Impact on Cyclones

Climate change is recognized as a major driver of intensified disaster risk. Projections and observations indicate that while the annual number of cyclones globally may not show a clear trend, their intensity and severity are increasing.

- **Increased Intensity:** Rising sea-surface temperatures provide more energy to the storms, leading to higher peak wind speeds and heavier associated precipitation.
- **Sea Level Rise:** Global warming causes thermal expansion of the oceans and glacier melt, leading to rising sea levels. This exacerbates the effects of storm surges, allowing cyclonic coastal flooding to reach further inland.
- **Ecosystem Fragility:** Warming damages natural buffers such as coral reefs and mangroves, which are vital for absorbing the energy of storm surges and protecting coastal communities.
- **Unpredictability:** Rapid intensification of storms—where a weak depression turns into a severe cyclonic storm in a very short period—has been noted in recent events like Cyclone Ockhi (2017), challenging existing forecasting models.

5. Vulnerability Profile of India

India is one of the most cyclone-prone countries in the world due to its 7,516 km coastline and unique topography.

- **Geographic Exposure:** Approximately 8% of India's landmass is vulnerable to cyclones. The East Coast (Bay of Bengal) is significantly more vulnerable than the West Coast (Arabian Sea), experiencing cyclones at a ratio of approximately 4:1.
- **High-Risk Zones:** States most affected include Odisha, Andhra Pradesh, West Bengal, and Tamil Nadu on the east, and Gujarat and Maharashtra on the west.
- **Structural Vulnerability:** High population density in coastal districts, combined with non-engineered constructions and the removal of natural vegetation for development, amplifies the risk to human life and property.

6. Nature of Cyclonic Wind, Velocities, and Pressure

A cyclone is a large-scale air mass characterized by inward spiraling winds that rotate around a strong center of low atmospheric pressure. In the Northern Hemisphere, these winds rotate in a counterclockwise direction, while they rotate clockwise in the Southern Hemisphere. Depending on their location and intensity, they are referred to as hurricanes, typhoons, or severe cyclonic storms.

A fully developed tropical cyclone is funnel-shaped, typically 150 to 1,000 km across and 10 to 15 km high. It consists of three primary parts:

- **The Eye:** The calm central part with the **lowest pressure** and highest temperature, usually ranging from 20 to 30 km in radius.
- **The Eyewall:** A ring surrounding the eye containing the **most powerful winds** and deep convection.
- **Spiral Rain Bands:** The outer part of the storm, which can be hundreds of kilometers long.

Wind velocities are used to classify these disturbances in India:

- **Low Pressure Area:** Winds less than 17 knots (31 kmph).
- **Depression:** 17 to 27 knots (31 to 49 kmph).
- **Cyclonic Storm:** 34 to 47 knots (62 to 88 kmph).
- **Super Cyclonic Storm:** Winds exceeding **120 knots (222 kmph)**. For example, the **1999 Odisha Super Cyclone** reached wind speeds of 300 kmph.

7. Cyclone Effects

The principal threats from a cyclone are **gales and strong winds**, torrential rain, and storm surges.

- **Infrastructure Damage:** High winds destroy houses (especially thatched and kutcha structures), power grids, and communication towers, turning loose debris into lethal flying objects.
- **Socio-Economic Impact:** Cyclones ruin standing crops, kill livestock, and deposit salt on agricultural land, increasing salinity and causing food shortages.
- **Health Hazards:** Standing water and the destruction of sanitation systems lead to outbreaks of diseases such as **malaria, cholera, and viral infections**.

8. Storm Surges

A **storm surge** is an abnormal rise in sea level associated with low-pressure weather systems. It is considered the most destructive cyclonic hazard, historically accounting for **90 percent of all tropical cyclone deaths**.

- **Mechanism:** The reduced pressure at the cyclone's core "sucks" the water upward, while the strong winds "pile" the water up against the coast.
- **Impact:** This results in sudden **coastal inundation**, where seawater can flow up to **40 kilometers inland**, destroying buildings and eroding beaches.

9. Floods

A **flood** is an overflow of water onto land that is normally dry. Cyclones are a major cause of flooding due to their associated **heavy and prolonged rainfall**.

- **Flash Floods:** These are sudden, high-velocity floods occurring within six hours of intense rain, often associated with cyclonic storms.
- **Riverine Floods:** Cyclonic rain can cause rivers to exceed their capacity and overtop their banks.
- **Destructive Power:** Moving floodwaters can sweep away bridges, houses, and vehicles, and weaken building foundations.

10. Landslides

A **landslide** is the downward and outward movement of a mass of rock, debris, or earth under the influence of gravity.

- **Connection to Cyclones:** Landslides are frequently **secondary disasters** triggered by the heavy rainstorms and floods produced by cyclones.
- **Mechanism:** Torrential rains saturate the soil, increasing **porewater pressure**, which destabilizes the slope.
- **Consequences:** Rapid landslides are particularly dangerous as they can bury entire villages, block roads and river flows, and destroy communication lines.

11. Behavior of Structures in Past Cyclones and Windstorms

The behavior of structures during cyclones and windstorms is a critical field of study, as these events frequently cause extensive damage to both **engineered and non-engineered infrastructure**. Past disasters show that physical damage is often measured by casualties and the destruction of **residential, commercial, and critical infrastructure**, such as power grids, roads, and communication networks.

12. Structural Performance in Past Cyclones

Historical data indicates that **non-engineered structures**, such as those built of mud, wood, or unreinforced masonry, are the most vulnerable to high wind speeds.

- **Residential Damage:** High-velocity winds frequently tear roofs off buildings, leading to wall collapses. During the 1999 Odisha Super Cyclone, wind speeds reached 300 kmph, resulting in the severe damage or destruction of approximately 1.65 million households.
- **Infrastructure Failure:** Cyclonic winds are a major cause of failure for power transmission networks and communication towers. It has been observed that many of these failures occur because the structures were not designed for the specific 100-year return period wind velocities of the region.
- **Foundations and Erosion:** Storm surges associated with cyclones can inundate land up to 15 km inland, applying immense hydrostatic pressure. The erosive force of moving water can drag soil from beneath building foundations, causing them to crack or tumble entirely.

13. Case Study:

- **Odisha Super Cyclone (1999)**

The Odisha Super Cyclone remains one of the most devastating examples of structural failure in India's history.

  - **Impact:** Over **15 million people** were affected, with a loss of nearly **10,000 lives**.
  - **Behavior of Buildings:** While about 7,000 people died due to the tidal surge, others were killed by **falling objects or being blown away** due to the failure of building envelopes and the subsequent creation of **lethal flying debris**.
  - **Legacy:** This event led to the creation of the **Odisha State Disaster Management Authority (OSDMA)** and a focus on **structural mitigation**, such as constructing multipurpose cyclone shelters.

- **Phailin (2013)**

In contrast to 1999, Cyclone Phailin demonstrated the success of non-structural preparedness despite structural losses.

  - **Impact:** Although approximately 256,633 houses were damaged, the death toll was remarkably low (45 reported) due to the successful evacuation of millions.
  - **Structural Vulnerability:** The cyclone highlighted that even with better forecasting, kutcha houses (fragile, temporary structures) remain extremely susceptible to total failure during "very severe" cyclonic storms.

- **Kerala Floods (2018)**

While primarily a hydrological disaster, the 2018 Kerala event illustrated the fragility of modern infrastructure to high-water events.

- **Critical Facilities:** The Kochi International Airport was shut down for two weeks after floodwaters breached the periphery wall, damaging roughly 20 per cent of its solar panels and destroying power storage facilities.
- **Housing and Landslides:** Over 17,000 houses were destroyed, many due to deep-seated landslides triggered by the saturation of soil on steep terrains where human modifications (sloping cuts) had destabilized the land.

14. Lessons and Mitigation Approaches

- **Engineered vs. Traditional:** While engineered structures are generally more resistant, traditional construction methods like the Taq and Dhajji Dewari systems have shown high resilience to environmental shocks.
- **Retrofitting:** Projects by bodies like the BMTPC focus on retrofitting lifeline structures (schools and hospitals) to ensure they remain functional post-disaster**.**
- **Building Codes:** India is divided into wind hazard zones based on Basic Wind Speeds (ranging from 33 m/s to 55 m/s); structures in "Very High Damage Risk Zones" mandate specialized engineering to resist uplift and lateral forces.

15. Cyclonic retrofitting

Cyclonic retrofitting refers to the reinforcement or upgrading of existing structures to make them more resistant and resilient to the damaging effects of high-velocity winds and storm-related hazards. This structural mitigation approach aims to reduce physical, social, and economic vulnerability by ensuring that buildings—both engineered and non-engineered—can withstand the forces generated by a cyclonic agent.

15.1. Specific Structural Measures

The primary focus of cyclonic retrofitting is to prevent structural failure caused by wind pressure and uplift forces.

- **Anchoring Systems:** Houses must be strengthened by ensuring all elements holding the structure are properly anchored to the foundations to resist the uplift or "flying off" of roofs and other objects during a storm.
- **Wind Velocity Standards:** It is recommended that critical infrastructure, specifically communication and power transmission towers, be retrofitted or designed to withstand a 100-year return period wind velocity to prevent the widespread network collapses seen in past disasters.
- **Building Envelope Protection:** Retrofitting often involves reinforcing the building envelope (roofs, walls, and windows), as the failure of these components often leads to the destruction of the interior contents and poses a lethal threat to occupants from flying debris.

15.2. Prioritizing Lifeline Structures

Disaster management frameworks emphasize the protection of facilities that are essential for the functioning of a community during and after a crisis.

- **Critical Facilities:** Priority for retrofitting is given to lifeline buildings, such as hospitals, schools, fire stations, airport control towers, and administrative centers.
- **Public Awareness:** Agencies like the Building Materials and Technology Promotion Council (BMTPC) have implemented pilot projects to retrofit "lifeline structures"

like schools to demonstrate the effectiveness of these technologies and generate public awareness regarding safety.

15.3. Governance and Technical Requirements

Retrofitting is not a mere physical repair but a technical process guided by formal standards and building codes.

- **Professional Evaluation:** Before any structural strengthening begins, a formal evaluation of the building's vulnerability in its specified hazard zone must be conducted by a Registered Structural Engineer.
- **Integration with "Build Back Better":** Retrofitting is an integral part of the "Build Back Better" (BBB) doctrine, which utilizes the recovery phase after a disaster as an opportunity to upgrade infrastructure to higher safety standards than existed previously.
- **Building Codes:** New and retrofitted constructions should comply with the National Building Code (NBC) and relevant Bureau of Indian Standards (BIS) codes, which divide the country into wind damage risk zones based on basic wind speeds.

16. Strengthening of structures

Strengthening of structures is a primary component of structural mitigation, defined as any physical construction or engineering technique implemented to reduce or eliminate the potential impacts of hazards. This process involves both building new infrastructure to higher standards from the start and the retrofitting of existing buildings to enhance their resistance to environmental forces.

16.1. Earthquake-Resistant Strengthening

For seismic hazards, the goal is to ensure structures can withstand ground shaking without collapsing.

- **Design and Codes:** All new constructions must comply with the Bureau of Indian Standards (BIS) codes and building bye-laws to ensure they are designed for the specific seismic zone.
- **Construction Features:** Key principles for quake-resistance include structural stability (achieved through uniform rigidity and adequate tying elements), ductility (using materials like steel or bamboo to absorb energy), and keeping a low center of gravity to lessen overturning probability.
- **Reinforcement Techniques:** Specific features such as tie-bands, triangulation of frames, corner reinforcement, and the use of the Taq or Dhajji Dewari systems (traditional timber-frame methods) have proven effective in keeping structures intact during tremors.

16.2. Cyclonic and Wind Strengthening

Strengthening against cyclones focuses on resisting high-velocity wind pressure, uplift forces, and torrential rain.

- **Anchoring Systems:** To prevent roofs and other objects from "flying off," it is essential to ensure that all elements holding the structure are properly anchored to the foundations.

- **Critical Infrastructure:** It is recommended that communication and power transmission towers be designed or retrofitted to withstand a 100-year return period wind velocity to prevent network collapses.
- **Protective Buffers:** In addition to structural reinforcement, planting shelter belts (rows of trees) acts as a physical shield to break wind energy before it hits the structures.

16.3. Floodproofing and Water Resistance

Strengthening in flood-prone areas involves modifying structures to minimize damage from inundation and hydrostatic pressure.

- **Elevation:** Buildings should be constructed on raised platforms, stilts, or earth mounds to keep living areas above the design high flood level.
- **Dry Floodproofing:** This involves using measures to make a building envelope substantially impermeable to floodwater, such as sealing walls with impervious materials.
- **Wet Floodproofing:** This technique involves retrofitting the building with specific openings that allow floodwaters to flow in and out, which minimizes hydrostatic pressure on the walls and prevents structural collapse.

16.4. Retrofitting and Lifeline Structures

Retrofitting refers specifically to the reinforcement or upgrading of existing, undamaged structures to improve their hazard resistance.

- **Prioritization:** High priority is given to lifeline structures—such as schools, hospitals, fire stations, and airport control towers—that must remain functional during and after a disaster.
- **Implementation:** Before strengthening begins, a formal vulnerability assessment must be conducted by a registered structural engineer to identify specific weaknesses.
- **Build Back Better (BBB):** Strengthening is central to the "Build Back Better" approach, which utilizes the reconstruction phase as an opportunity to implement higher safety standards than existed before the disaster.

17. Adaptive sustainable reconstruction

Adaptive sustainable reconstruction is a long-term development effort that views the post-disaster recovery phase as a "window of opportunity" to build back communities and infrastructure in a manner that is superior to their pre-disaster state. Guided by the "Build Back Better" (BBB) principle—which is Priority 4 of the Sendai Framework—this process focuses on reducing physical, social, and environmental vulnerabilities to prevent the reproduction of original risky conditions.

1.7.1. The Adaptive Framework for Reconstruction

Reconstruction is distinct from immediate relief; it focuses on the medium- to long-term rebuilding of resilient services, housing, and facilities.

- **Renewal over Recovery:** In adaptive systems, the term "recovery" is often replaced by "renewal," "re-organization," or "regeneration" to signify that the goal is not a return to the status quo, but a shift toward a new, safer normal.
- **Systemic Adjustments:** Adaptive reconstruction requires adjusting to actual or expected climatic changes. This includes using vulnerability assessments to identify

root causes and implementing land-use planning to curtail rebuilding in high-risk areas.
- **Evidence-Based Planning:** Modern reconstruction utilizes spatial technology (GIS and Remote Sensing) to map hazard zones and provide rational, scientific justifications for site selection and building designs.

17.2. The Five Pillars of Sustainable Reconstruction

For reconstruction to be sustainable, it must meet present needs without compromising future generations across five key dimensions:

1. **Institutional Sustainability:** Strengthening governance, establishing clear regulatory frameworks, and ensuring the enforcement of building codes.
2. **Technical Sustainability:** Utilizing **hazard-resistant construction** and transferring technical skills to local workers through demonstrative "model houses".
3. **Environmental Sustainability:** Integrating **nature-based solutions**, such as wetlands restoration or mangroves for coastal protection, and ensuring reconstruction does not degrade natural resources.
4. **Social Sustainability:** Promoting **gender equity** and inclusion for persons with disabilities, and ensuring democratic participation in the planning process.
5. **Economic Sustainability:** Focusing on **livelihood restoration**, providing low-interest financing for affected businesses, and building economic resilience against future shocks.

17.3. Sector-Specific Interventions

- **Infrastructure Reconstruction:** This includes introducing earthquake-resistant designs, modernizing telecommunications, and "right-sizing" infrastructure (e.g., ensuring hospitals have adequate bed counts) to meet actual community needs.
- **Livelihood Recovery:** Sustainability is achieved by promoting resilient production systems, such as transitioning to flood-resistant crops or livestock (e.g., farming ducks instead of chickens in flood-prone areas).
- **Owner-Driven Reconstruction (ODR):** A preferred sustainable approach where owners rebuild their own homes with technical and financial support from the government, which increases community ownership and ensures traditional wisdom is integrated with modern engineering.

17.4. Case Studies in Sustainable Reconstruction

- **Gujarat Earthquake (2001):** Implemented a comprehensive programme involving social rehabilitation, livelihood restoration, and an Owner-Driven Reconstruction model that trained thousands of masons in hazard-resistant techniques.
- **Kosi Flood (2008):** Focused on restoring lost connectivity by rebuilding roads and bridges with new cross-drainage structures where new streams had formed during the deluge.
- **Kerala Floods (2018):** Established the "Rebuild Kerala Initiative" (RKI), which adopted higher standards for infrastructure and ecological safeguards to ensure the state could better withstand future floods.

18. Life-Line Structures Such as Temporary Cyclone Shelters.

Lifeline structures are critical facilities and systems—such as schools, hospitals, power grids, and communication networks—that are socially, economically, or operationally essential to the functioning of a community, particularly during the extreme circumstances of an emergency. In the context of cyclonic hazards, **multipurpose cyclone shelters** (MPCS) serve as a primary structural mitigation measure, designed to provide safe refuge for vulnerable populations and minimize the high death tolls historically associated with storm surges.

18.1. Categories and Functions of Shelters

Shelter provision is a critical determinant for survival in the initial stages of a disaster. Post-disaster housing often follows a progression:

- **Emergency Shelters:** These are used for brief periods to deliver life-saving support and are the most basic form of refuge.
- **Temporary Shelters:** Intended for short-term use (weeks), these can include tents or public mass shelters in community halls or places of worship.
- **Temporary Housing:** These structures, such as prefabricated units or rental houses, allow victims to re-establish daily routines for six months to three years while waiting for permanent solutions.
- **Multipurpose Functionality:** In India, many cyclone shelters are designed to serve other community needs during "normal" times, such as schools, community centers, or health clinics, ensuring they are maintained year-round.

18.2.Management and Operational Requirements

Effective shelter management requires coordination between local authorities, NGOs, and the community.

- **Village Disaster Management Teams (DMT):** Local "Shelter Management Teams" are responsible for identified buildings before, during, and after a disaster.
- **Stockpiling:** Preparedness involves pre-stocking shelters with essential supplies, including food, potable water, medicines, firewood, lanterns, and sanitary materials.
- **Logistics:** The success of the 2013 Cyclone Phailin evacuation, where over one million people were moved, was attributed to shelters that were extremely well-stocked with adequate medical and food supplies.

18.3.Structural Strengthening and Retrofitting

To ensure these lifeline structures remain "safe, effective, and operational" during a storm, specific engineering standards must be met:

- **Wind Resistance:** It is recommended that lifeline infrastructure be designed to withstand wind velocities associated with a 100-year return period.
- **Anchoring and Elevation:** Buildings should be properly anchored to foundations to resist uplift forces and constructed on stilts or raised platforms to avoid inundation from storm surges.
- **Retrofitting:** Agencies like the BMTPC implement pilot projects to retrofit existing lifeline structures (e.g., schools and hospitals) in high-risk zones, reinforcing them to prevent collapse during future events.

18.4.Social and Practical Considerations

- **Inclusivity:** Shelters must follow universal design principles to ensure they are physically accessible to persons with disabilities and the elderly.

- **Property Security:** Effective evacuation often depends on the community's trust that their abandoned homes and livestock will be secure while they are in shelters.
- **Hygiene:** Proper sanitation and waste management within shelters are vital to prevent the outbreak of waterborne diseases like cholera and malaria following the storm.

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