AN INTRODUCTION TO THE

Vulnerability Atlas of India

3rd Edition

A Tool to natural disaster prevention, preparedness and mitigation for housing and related infrastructure

Building Materials & Technology Promotion Council
Ministry of Housing & Urban Affairs
Government of India

Prelude

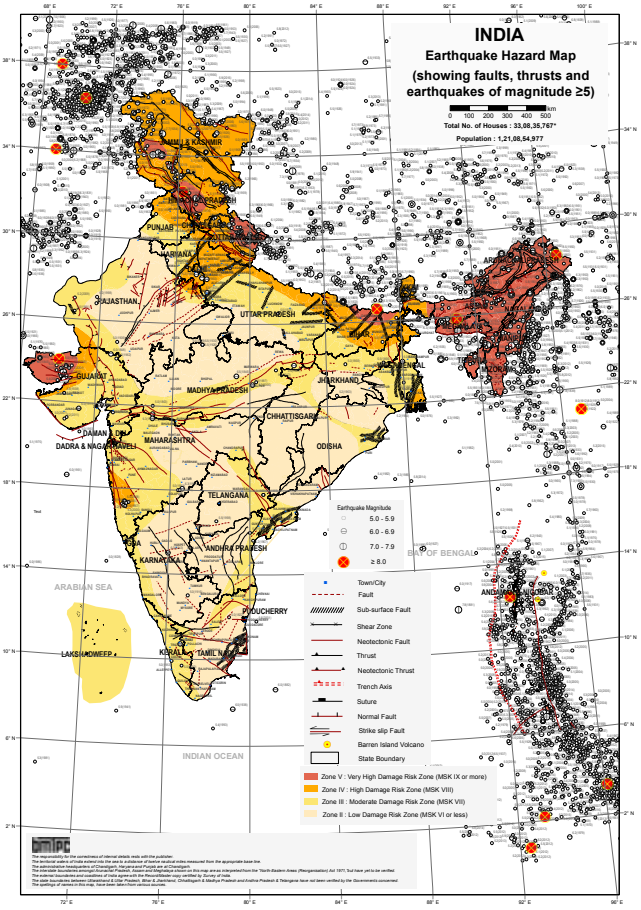
The Government of India has taken several initiatives at policy level for strengthening disaster reduction strategies recognizing the vulnerability of Indian sub-continent:

- **Disaster Management Act enacted in 2005**
- **National Policy for Disaster Management in 2009**
- **National Disaster Management Plan in 2016.**

Internationally also, 1990-2000 was declared as International Decade for Natural Disaster Reduction (IDNDR) by UN General Assembly, which was subsequently supported by Yokohama Strategy for Safer World in 1994, Hygo Framework for Action (2005-2015) and Sendai Framework for Disaster Risk Reduction in 2015-2030.

All these policy frameworks brought paradigm shift in disaster risk management from post disaster relief centric measures to pro-active pre-disaster preventive measures.

With its vast territory, large population and diverse geo-climatic conditions, Indian sub-continent is exposed to natural catastrophes historically. Natural hazards which can be broadly classified into geophysical hazards (earthquakes, landslides & tsunamis), hydrological hazards (floods), meteorological hazards (cyclones, storm surges), and climatological hazards (thunderstorms) are common occurrence in India. While the vulnerability varies from region to region, a large part of the country is exposed to such natural hazards which often turn into disasters causing significant disruption of socio-economic life of communities leading to loss of life and property. Concerned with the impact of natural disasters in the background of the International & National resolutions, Sustainable Development Goals (SDGs) and realising that the preparedness and prevention are integral components of the development process, the Governments at the Central and State levels are gradually evolving strategies, policies and programmes for natural disaster mitigations and prevention. In the process cutting edge technologies are being introduced in fields like forecasting, satellite and remote sensing, computerised systems of vulnerability and risk assessment and other technologies for warning and monitoring. Also, there have been concerted efforts made by Ministry of Housing & Urban Affairs, Government of India to bring paradigm shift in its approach towards disaster risk reduction. The traditional 3 Rs (Rescue, Relief & Restoration) are now replaced by 3 Ps (Prevention, Preparedness & Proofing) resulting in pro-active pre-disaster preventive measures.



BMTPC : Vulnerability Atlas - 3rd Edition : Peer Group, MoHUA, GOI; Map is Based on digitised data of SOI; Seismic Zones of India Map IS 1893 (Part I): 2002, BIS; Earthquake Epicentre from IMD; Seismotectonic Atlas of India and its Environs, GSI; Houses/Population as per Census 2011; *Houses including vacant & locked houses. Disclaimer: The maps are solely for thematic presentation.

Hazard Vulnerability Risk

Hazard Vulnerability in India

Indian Subcontinent: among the world's most disaster prone areas

- 57% of land vulnerable to Earthquakes
- 18% of land vulnerable to High Wind Velocity (55 & 50 m/s)
- 7% of land vulnerable to Floods
- 12.6% of land vulnerable to landslides in hilly regions of 18 states

> 1 million houses damaged annually + human, social, other losses

Earthquakes

- 11.3% land is liable to severe earthquakes (MSK IX or more)
- 14.4% land is liable to MSK VIII (similar to Latur / Uttarkashi)
- 31.1% land is liable to MSK VII (similar to Jabalpur quake)

Biggest quakes in: Andamans, Kuchchh, Himachal, Kashmir, North Bihar and the North East regions.

Wind and Cyclones

- 1891-2017: 273 cyclones (106 severe) in the East Coast
- 30 cyclones in West Coast (16 severe) in the same period
- In 19 severe cyclonic storms, death toll > 10,000 lives

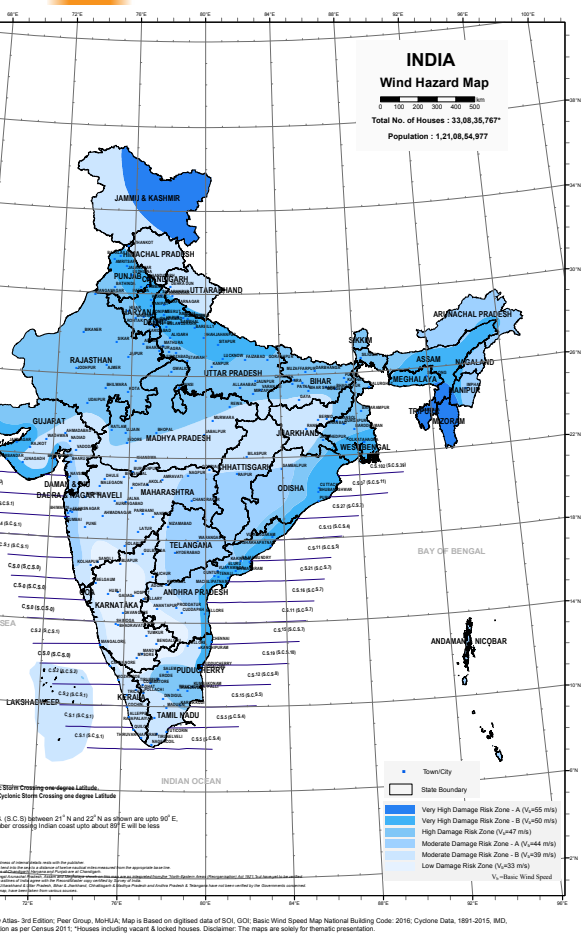
In 21 cyclones in Bay of Bengal (India+Bangladesh), 1.25 million lives have been lost

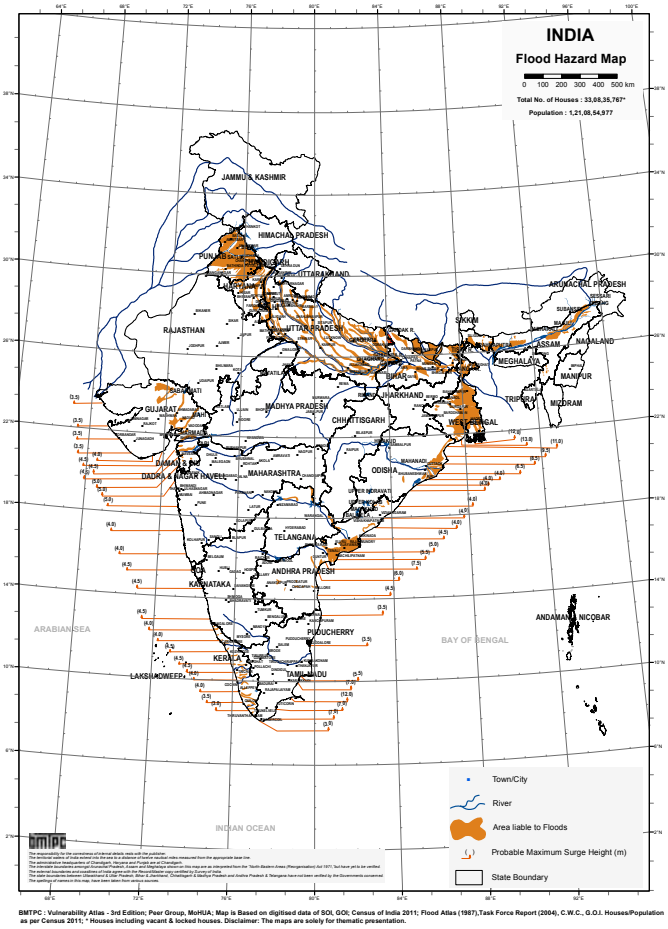
Floods

- Floods in the Indo-Gangetic-Brahmaputra plains are an annual feature. On an average, a few hundred lives are lost.
- Millions are rendered homeless.
- Lakhs of hectares of crops are damaged every year.

Landslides

- 12.6 percent of landmass (~0.42 million km^2) in the mountainous/ hill regions are landslide prone spreading mainly over 18 States.





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A Qualitative Shift in Strategy

A Qualitative Shift in India's Strategy

The Government recognised the need for a shift from a *post disaster reactive* approach to a *pre-disaster pro-active* approach:

- Preparedness
- Mitigation
- Prevention

This will minimise the damage, losses and trauma to the people on one hand and reduce the costs of relief, rehabilitation and reconstruction.

The Disaster Management Act 2005 – enacted on 23rd December, 2005 lays down institutional and coordination mechanism at all level and provides for establishment of Disaster Mitigation Fund and Disaster Response Fund at national, state and district level.

This shift in strategy is feasible because of:

- Advancements in Science and Technology
- Effective implementation has shown decline in casualties.
- Advancements in forecasting technologies and warning systems
- Government policy to strengthen Hazard Mapping, R&D and Standardisation
- Enlargement and reinforcement of disaster prevention systems, equipment and facilities.

Goals of Disaster Prevention

Objectives:

The objectives of India's National Policy for natural disaster reduction is to reduce:

- loss of lives
- property damage
- economic disruption

Goals:

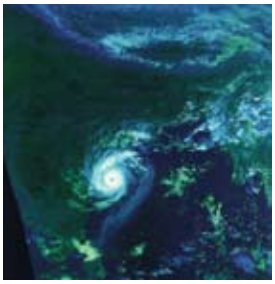
- Creating Public Awareness about Safety from Disasters
- Amending/Enacting legislation for safety from Hazards
- Planning development areas with safety from Hazards
- Protection of habitations from adverse hazard impacts
- Constructing new buildings safe from Hazards
- Retrofitting existing buildings for improving hazard resistance

Stakeholders in the process of disaster mitigation

- Policy makers
- Urban Managers
- Decision Makers
- Administration
- Professionals (architects and engineers at various levels)
- Professional Institutions
- R&D Institutions
- Financial Institutions
- Insurance Sector
- Community
- NGOs
- Common Man

Legislation Needed

- Amendments to town/country planning acts and Master plan area development rules
- Land use zoning in hazard prone areas and establishing techno-legal regimes
- Incorporation of safety requirements in building bye-laws of local bodies/panchayats – applicable to new buildings and extensions of old buildings. Empowering local bodies to exercise control
- Legislation to upgrade hazard resistance of critical buildings for use and safety of large number of people – schools, hospitals, cinemas, congregation halls, water tanks, towers, telephone exchanges, fire stations, headquarters of police and administration.



Vulnerability Atlas of India

Revision of the Atlas

Changes in the hazard scenario in the country since publication of 2006 Atlas:

- Formation of new States (2) and new Districts (47).
- Revision of Indian Standards and national Building Code by BIS.
- Availability of latest data on faults and thrusts from Seismotectonic Atlas published by GSI.
- Availability of basin wise atlases for Probable Maximum Precipitation (PMP) by CWC and IMD
- Availability of new Housing Data as per Census 2011
- Availability of field verified landslide incidence data from GSI
- Availability of climatological data for thunderstorms in terms of number of thunderstorms at a station from 1981 to 2010 from IMD

To examine the above issues closely the Ministry of Housing & Urban Affairs constituted the Peer Group with representation from different concerned agencies namely GSI, IMD, IIT Roorkee, NRSC, CSIR-SERC with BMTPC as Secretariat.

Vulnerability Atlas of India - 1997

BMTPC since its inception is committed towards promoting disaster mitigation measures through preparedness and brought out its first Vulnerability Atlas of India in 1997 under the auspices of Expert Group set up by the erstwhile Ministry of Urban Development. It was first of its kind tool for the Disaster Management authorities, agencies, related stake holders and citizens of India for identifying the level of damage risk (degree of vulnerability) of housing stock with respect to earthquakes, floods and cyclones, in any part of the country.

This Atlas has since served as a useful tool for policy planning on natural disaster prevention and preparedness specially for hosing and related infrastructure. The IDNDR also adjudged the project with High Demonstrative Value.

Vulnerability Atlas of India - 2006

The 2nd edition Vulnerability of India was brought out by BMTPC in 2006 under the guidance of Peer Group set up by the then Ministry of Housing & Urban Poverty Alleviation using GIS tools and digitized maps were developed providing hazard and seismo-tectonic information upto district level. Based on 2001 Census Housing Stock data, housing risk tables upto districts were published as per distribution of houses by predominant material of roof and wall.

Vulnerability Atlas of India - 2019

The third edition of the Vulnerability Atlas of India includes hazard maps of earthquakes, wind/cyclones, floods, landslides, thunderstorms and district-wise vulnerability risk tables based on available latest data in order to help in enhancing preparedness of Governments and various other agencies in mitigating natural disasters. The 3rd edition was brought out by BMTPC under the guidance of Peer Group chaired by Padamshree Prof. A.S. Arya who worked as a chairman for all the three Expert/Peer Groups responsible for bringing out three editions of Vulnerability Atlas of India. The Atlas will be a useful tool not only for public but also for urban managers and National & State Authorities dealing with disaster mitigation and management.

Hon'ble Prime Minister of India, released the digital version of Third Edition of Vulnerability Atlas of India on the occasion of Global Housing Technology Challenge - India (GHTC-India), Construction Technology India 2019 Expo-cum-Conference on 2nd March, 2019 at New Delhi organized by Ministry of Housing & Urban Affairs.

New Additions

Special Features in Revised Atlas

- Digitisation of all data sets in the maps including boundaries of the States/Districts according to the Survey of India Map as well as the boundaries of the various hazard zones, thus improving their accuracy.
- Inclusion of railways, national highways, expressways and water bodies and inclusion of Housing/ Population data as per Census 2011 in hazard maps.
- Inclusion of landslide Incidence Maps with detailed note on landslide occurrences and effects.
- Inclusion of Map showing frequencies of Thunderstorms at different stations in the country and corresponding note on causes and effect of thunderstorms.
- The Vulnerability and Risk Tables of Housing Data in each district is now based on wall types and roof types as per 2011 Census data. The district names and reference numbers are taken according to 2011 Census for ease of cross reference.

Landslide Incidence Maps

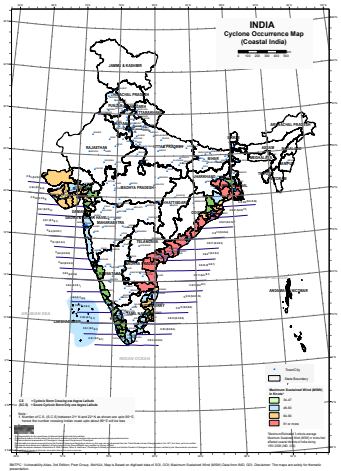
Landslide Incidence Maps based on the field verified data (about 9000) from GSI has been included for India and States/UTs of Jammu and Kashmir, Uttarakhand, Himachal Pradesh, Maharashtra, Kerala, Karnataka, Tamil Nadu, Tripura, West Bengal, Goa and North Eastern States including Sikkim. The Landslide Incidence Maps also provides Annual State Rainfall Normals (mm) in the base layer, as provided by IMD.

Thunderstorm Incidence Map

Based on the climatological data for thunderstorms from IMD in terms of number of thunderstorms at a station from 1981 to 2010, the Landslide Incidence Map of India has been included in the Atlas.

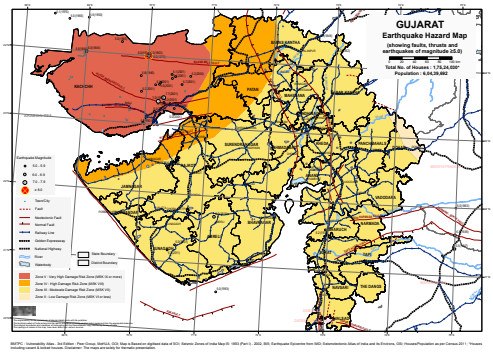
Cyclone Occurrence Map (Coastal India)

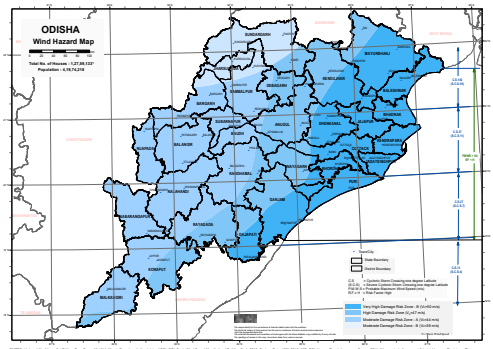
The Cyclone Occurrence Map of India has been developed based on maximum/estimated 3-minute average Maximum Sustained Wind (MSW) in knots (1 knot = 0.5144 m/s) that affected coastal districts of India during 1891-2008, as per data provided by IMD.

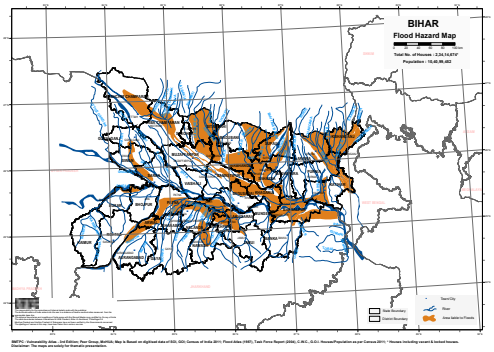


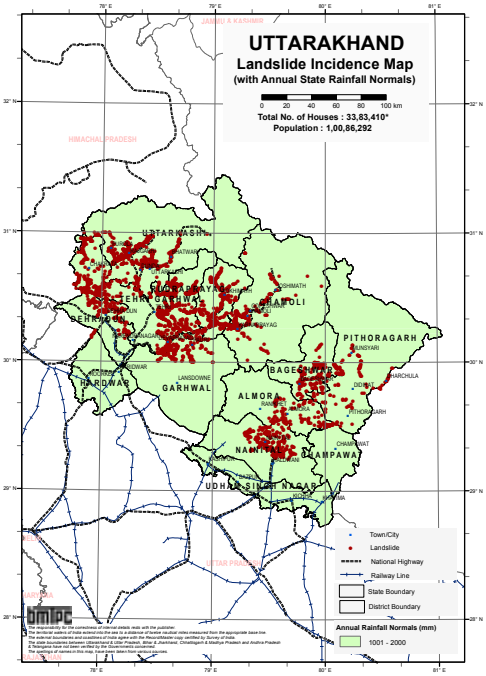
The Digitized Hazard Maps

The monitoring of hazards is carried out by the most important organisations in the country: Seismic occurrence and cyclone hazard monitoring by India Meteorological Department (IMD) and flood monitoring by the Central Water Commission (CWC). In addition noteworthy contributions are made by Geological Survey of India (GSI) and the Department of Earthquake Engineering, IIT Roorkee in this regard. The Bureau of Indian Standards (BIS) publishes Seismic Zoning Map and the Basic Wind Map including cyclonic winds for the country. The Seismic Zoning Map was revised in 2002 and Basic Wind Map was revised in 2016 by BIS. The CWC published a Flood Atlas of India. These hazard maps have been used to prepare 1:2 million scale maps by superposing the above available data on digitised Survey of India map as the base map. The earthquake, wind & flood hazard maps and landslide incidence maps are drawn for each State and UT separately. Thunderstorm incidence map and cyclone occurrence map have been developed at country level.









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State/UT-wise Hazard Maps

- State/UT-wise hazard maps
  - Earthquakes
  - Cyclones
  - Floods
  - Landslides
- Each administrative district boundary clearly marked with hazard intensity
- Maps drawn at 1:2 million using digitised Survey of India maps as base.

Earthquake Hazard Maps

- Based on Seismic Zoning map of India given in IS 1893:2002.
- Seismo-tectonic features as per Seismo-Tectonic Atlas of GSI.
- Epicentres and years of occurrence of earthquakes (>5.0 intensity), as per IMD catalogue of earthquakes.

Wind & Cyclone Hazard Maps

- Based on wind speed maps given in NBC 2016.
- Alongwith design wind speed, the number of cyclones which has crossed each latitude of the sea coast in the past are also marked.

Flood Hazard Maps

- Based on the Flood Atlas of India prepared by the Central Water Commission.
- Other low lying areas outside river flood plains (which are also flooded during heavy rains due to choked drainage path) could not be plotted because of lack of data, which has to be collected by each state administration.

Landslide Incidence Maps

- Based on the field verified data (about 9000) from GSI.
- Annual State Rainfall Normals (mm) in the base layer from IMD.

Thunderstorm Incidence Map of India

- Based on the climatological data for thunderstorms from IMD in terms of number of thunderstorms at a station from 1981 to 2010.

Cyclone Occurrence Map of Coastal India

- Based on maximum/estimated 3-minute average Maximum Sustained Wind (MSW) in knots, as per data provided by IMD.

The Risk Tables

Building Types identified for Disaster Vulnerability

Number of housing units of various types classified by wall material type and roof type, and number of buildings of each type.

Distribution of Houses by Predominant Materials of Roof and Wall and Level of Damage Risk

INDIA

Wall / Roof		Census Houses		Level of Risk under								
				EQ Zone				Wind Velocity m/s				Flood Prone Area in %
		No. of Houses	%	V	IV	III	II	55 & 50	47	44 & 39	33	
				Area in %				Area in %				
INDIA				11.3	14.4	31.1	43.2	18.0	30.3	45.1	6.6	7.3
WALL												
A1 - Mud & Unburnt Brick Wall	Rural	58,330,614	19.1									
	Urban	8,119,213	2.7									
	Total	***66,449,827***	***21.8***	*VH*	*H*	*M*	*L*	*VH*	*H*	*M*	*L*	*VH*
A2 - Stone Wall not packed with mortar	Rural	7,751,666	2.5									
	Urban	2,689,476	0.9									
	Total	***10,441,142***	***3.4***	*VH*	*H*	*M*	*L*	*H*	*M*	*L*	*VL*	*VH*
Total - Category - A		***76,890,969***	***25.2***									
B - Burnt Bricks Wall & Stone wall packed with mortar	Rural	104,552,560	34.3									
	Urban	75,035,035	24.6									
	Total	***179,587,595***	***58.9***	*H*	*M*	*L*	*VL*	*H*	*M*	*L*	*VL*	*H/M*
Total - Category - B		***179,587,595***	***58.9***									
C1 - Concrete Wall	Rural	3,699,096	1.2									
	Urban	7,284,583	2.4									
	Total	***10,983,679***	***3.6***	*M*	*L*	*VL*	*VL*	*L*	*VL*	*VL*	*VL*	*L/VL*
C2 - Wood wall	Rural	2,132,342	0.7									
	Urban	648,929	0.2									
	Total	***2,781,271***	***0.9***	*M*	*L*	*VL*	*VL*	*VH*	*H*	*M*	*L*	*H*
Total - Category - C		***13,764,950***	***4.5***									
X - Other Materials	Rural	30,097,412	9.9									
	Urban	4,541,522	1.5									
	Total	***34,638,934***	***11.4***	*M*	*VL*	*VL*	*VL*	*VH*	*H*	*M*	*L*	*VH*
Total - Category - X		***34,638,934***	***11.4***									
TOTAL HOUSES*		**304,882,448**										
ROOF												
R1 - Light Weight Sloping Roof	Rural	79,430,355	26.1									
	Urban	21,269,826	7.0									
	Total	***100,700,181***	***33.1***	*M*	*M*	*L*	*VL*	*VH*	*VH*	*H*	*M*	*VH*
R2 - Heavy Weight Sloping Roof	Rural	74,034,404	24.3									
	Urban	19,649,099	6.4									
	Total	***93,683,503***	***30.7***	*H*	*M*	*L*	*VL*	*H*	*M*	*L*	*VL*	*H*
R3 - Flat Roof	Rural	53,098,931	17.4									
	Urban	57,399,833	18.8									
	Total	***110,498,764***	***36.2***	*Damage Risk as per that for the Wall supporting it*								
TOTAL HOUSES*		**304,882,448**										

Housing Category : Wall Types

Category - A : Buildings in field-stone, rural structures, unburnt brick houses, clay houses

Category - B : Ordinary brick building; buildings of the large block & prefabricated type, half-timbered structures, building in natural hewn stone

Category - C : Reinforced building, well built wooden structures

Category - X : Other materials not covered in A,B,C. These are generally light.

Notes : *1. Flood prone area includes that protected area which may have more severe damage under failure of protection works. In some other areas the local damage may be severe under heavy rains and chocked drainage.*

2. Damage Risk for wall types is indicated assuming heavy flat roof in categories A, B and C (Reinforced Concrete) building

3. Source of Housing Data : Census of Housing, GOI, 2011

Housing Category : Roof Type

Category - R1 - Light Weight (Grass, Thatch, Bamboo, Wood, Mud, Plastic, Polythene, GI Metal, Asbestos Sheets, Other Materials)

Category - R2 - Heavy Weight (Tiles, Stone/Slate)

Category - R3 - Flat Roof (Brick, Concrete)

EQ Zone V : Very High Damage Risk Zone (MSK > IX)

EQ Zone IV : High Damage Risk Zone (MSK VIII)

EQ Zone III : Moderate Damage Risk Zone (MSK VII)

EQ Zone II : Low Damage Risk Zone (MSK < VI)

Level of Risk : VH = Very High; H = High; M = Moderate; L = Low; VL = Very Low

* Total No.of Houses excluding Vacant/Locked Houses

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Level of Risk under								
EQ Zone				Wind Velocity m/s				Flood Prone Area in %
V	IV	III	II	55 & 50	47	44 & 39	33	
Area in %				Area in %				
11.3	14.4	31.1	43.2	18.0	30.3	45.1	6.6	7.3
VH	*H*	*M*	*L*	*VH*	*H*	*M*	*L*	*VH*
VH	*H*	*M*	*L*	*H*	*M*	*L*	*VL*	*VH*
H	*M*	*L*	*VL*	*H*	*M*	*L*	*VL*	*H/M*

The percentage area of the district likely to be subjected to a particular intensity of hazard

The damage risk to buildings indicated as Very High (VH), High (H), Medium (M), Low (L) and Very Low (VL).

Through these tables, one can find the damage risk to the house types in different regions of the country w.r.t. earthquakes, wind/cyclones & floods. The houses falling under Very High to High damage risk require immediate attention in terms of strengthening & maintenance. Also tables indicates existing housing stock and multi-hazard proneness of the region.

The Risk Tables

Example: District Kendrapara, Odisha

Distribution of Houses by Predominant Materials of Roof and Wall and Level of Damage Risk

Table No. : OR 10 — **State : ODISHA** — **KENDRAPARA**

Wall / Roof		Census Houses: No. of Houses	Census Houses: %	Level of Risk under: EQ Zone V	EQ Zone IV	EQ Zone III	EQ Zone II	Wind Velocity m/s: 55 & 50	Wind Velocity m/s: 47	Wind Velocity m/s: 44 & 39	Wind Velocity m/s: 33	Flood Prone Area in %
				Area in %		87.0	13.0	100				48.4
WALL												
A1 - Mud & Unburnt Brick Wall	Rural	237,793	56.4									
	Urban	6,136	1.5									
	Total	***243,929***	***57.9***			*M*	*L*	*VH*				*VH*
A2 - Stone Wall not packed with mortar	Rural	976	0.2									
	Urban	38	-									
	Total	***1,014***	***0.2***			*M*	*L*	*H*				*VH*
Total - Category - A		***244,943***	***58.1***									
B - Burnt Bricks Wall & Stone wall packed with mortar	Rural	139,540	33.1									
	Urban	14,240	3.4									
	Total	***153,780***	***36.5***			*L*	*VL*	*H*				*H/M*
Total - Category - B		***153,780***	***36.5***									
C1 - Concrete Wall	Rural	1,451	0.3									
	Urban	286	0.1									
	Total	***1,737***	***0.4***			*VL*	*VL*	*L*				*L/VL*
C2 - Wood wall	Rural	3,866	0.9									
	Urban	434	0.1									
	Total	***4,300***	***1.0***			*VL*	*VL*	*VH*				*H*
Total - Category - C		***6,037***	***1.4***									
X - Other Materials	Rural	16,090	3.8									
	Urban	680	0.2									
	Total	***16,770***	***4.0***			*VL*	*VL*	*VH*				*VH*
Total - Category - X		***16,770***	***4.0***									
TOTAL HOUSES*		**421,530**										
ROOF												
R1 - Light Weight Sloping Roof	Rural	289,583	68.7									
	Urban	10,984	2.6									
	Total	***300,567***	***71.3***			*L*	*VL*	*VH*				*VH*
R2 - Heavy Weight Sloping Roof	Rural	4,484	1.1									
	Urban	456	0.1									
	Total	***4,940***	***1.2***			*L*	*VL*	*H*				*H*
R3 - Flat Roof	Rural	105,649	25.1									
	Urban	10,374	2.5									
	Total	***116,023***	***27.6***	*Damage Risk as per that for the Wall supporting it*								
TOTAL HOUSES*		**421,530**										

Probable Maximum Precipitation at a Station of the district in one day for arial extent of 1000 sqm. 716 mm

Housing Category : Wall Types

Category - A : Buildings in field-stone, rural structures, unburnt brick houses, clay houses

Category - B : Ordinary brick building; buildings of the large block & prefabricated type, half-timbered structures, building in natural hewn stone

Category - C : Reinforced building, well built wooden structures

Category - X : Other materials not covered in A,B,C. These are generally light.

Notes *: 1. Flood prone area includes that protected area which may have more severe damage under failure of protection works. In some other areas the local damage may be severe under heavy rains and chocked drainage.*

2. Damage Risk for wall types is indicated assuming heavy flat roof in categories A, B and C (Reinforced Concrete) building

3. Source of Housing Data : Census of Housing, GOI, 2011

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Category - R2 - Heavy Weight (Tiles, Stone/Slate)

Category - R3 - Flat Roof (Brick, Concrete)

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Level of Risk : VH = Very High; H = High; M = Moderate; L = Low; VL = Very Low

* Total No.of Houses excluding Vacant/Locked Houses

Building Materials & Technology Promotion Council — **Peer Group, MoHUA, GOI**

As an example, let us refer to a District Kendrapara (OR 10) of the State of Odisha. It is seen that 87% area of the district lies in seismic intensity MSK VII zone (Zone III) and 100% area in the 50 & 55 m/s wind velocity zone. Also 48.4% of its area is flood prone. The probable maximum precipitation is 716 mm, that is, quite a high figure. According to 2011 census, there are 421,530 housing units in the district, 58.1% of which are of category A (very weak type), 36.5% of category B (moderate strength) and only 1.40% of category C (the strong types). Also 4% houses are of other materials such as bamboo, thatch, grass, leaves. The risk of damage from earthquakes to Category A houses is 'medium', and to Category B (36.5% of total) it is 'low'. The example district lies in the cyclone prone area of the Odisha coastal area and have very high risk to 62.9% [57.9%(Cat.A1) + 1.0%(Cat.C2) + 4.0%(Cat.X)] housing units, hence the life and property of this population living in the district is at great cyclone risk. The district has also great risk of flooding, storm surges & tsunami. Hence serious attention has to be paid to the district from cyclone, tsunami & storm surge disaster prevention, mitigation and preparedness points of view.

Risk of Damage to House Types

Distribution of houses based on Predominant materials of roof and wall

Wall Types

Category-A: Buildings in field-stone, rural structures, unburnt brick houses, clay houses

Category-B: Ordinary brick building; buildings of the large block and prefabricated type, half- timbered structures, building in natural hewn stone

Category-C: Reinforced building, well built wooden structures

Category-X: Other materials not covered in A, B and C. These are generally light structures.

Roof Types

Category-R1: Light Weight (Grass, Thatch, Bamboo, Wood, Mud, Plastic, Polythene, GI Metal, Asbestos Sheets, Other Materials)

Category-R2: Heavy Weight (Tiles, Stone/Slate)

Category-R3: Flat Roof (Brick, Concrete)

With these groupings, the vulnerability of each subgroup have been defined separately for any given intensity of earthquake, wind or flood hazard.

The damage risk to various house types is based on their average performance observed during past occurrences of damaging events. In view of numerous variations in the architectural planning, structural detailing, quality of construction and care taken in maintenance, the performance of each category of houses in a given event could vary substantially from the average observed. For example, under seismic occurrence, the following observations have been made in many cases:

All Masonry Houses (Categories A and B)

- Quality of construction comes out as a major factor in the seismic performance particularly under intensities MSK VII to IX. Good quality constructions perform much better than poor quality constructions in any category. Appropriate maintenance increases durability and maintains original strength.
- Number of storeys in the house and the storey height are other factors. Higher the storey and more the number of storeys, greater is the observed damage.
- Size, location and number of door and window openings in the walls also determine seismic performance, since the openings have weakening effect on the walls. Smaller and fewer openings and located more centrally in the walls are better from seismic performance viewpoint.
- Architectural layout, particularly in large buildings, that is, shape of building in plan and elevation, presence of offsets and extended wings, also play important role in initiation of damage at certain points and its propagation as well. More symmetrical plans and elevations reduce damage and unsymmetrical ones lead to greater damage.
- Where clay/mud mortar is used in wall construction, its wetness at the time of earthquake is very important factor in the seismic performance since the strength of fully saturated mortar can become as low as 15% of its dry strength.

Wooden Houses

- Quality of construction, that is, seasoning of wood and the joinery are important in seismic and cyclonic wind performance. Better the quality better the performance.
- Wood decays with time due to dry rot, insect and rodent attack, etc., therefore, the joints tend to become loose and weak. The state of maintenance of the wooden building will determine its performance during earthquake, high wind, as well as flooding.
- In houses with sloped roofs, a shallow angle for the roof, extended eaves projection, and reentrant corners lead to higher damage.
- In light roofs, pressures often exceed the dead weight leading to blowing-off of roofs.

Reinforced Concrete Houses

- Mutltistorey RC frame buildings resting on soft soils and having soft first storey, unconnected wall panels and floating columns in the superstructure collapsed even in Seismic Zone III.
- Besides bad configuration, improper planning and structural design, poor quality of construction lead to total collapses of 5 to 10 storeyed RC frame buildings.
- In reinforced concrete construction, good structural design and detailing and good quality construction only would ensure excellent performance. Carelessness in any of these can lead to poor behaviour both under earthquakes and cyclones.
- Also, buildings not designed as per BIS codal provisions behave poorly during damaging events.

Usefulness of the Atlas

The Peer Group

- **Dr.A.S.Arya (Chairman)**
  Professor Emeritus, IIT Roorkee and Member, BSDMA, Government of Bihar
- **Shri Prabhas Pande (Member)**
  Former Addl.Director General, GSI, Lucknow (in personal capacity)
- **Prof. Y. Singh (Member)**
  Professor, Earthquake Engineering, IIT Roorkee
- **Dr. (Mrs.) S. Selvi Rajan / Dr. K. Balaji Rao / Dr. P. Hari Krishna (Member)**
  Chief – Scientist (Wind Engg) / Chief – Scientist (S.C.E&T/R.R.S.) / Sr.Principal Scientist CSIR-Structural Engineering Research Centre, Chennai
- **Dr. M. Mohapatra (Member)**
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- **Dr. Shailesh Kr.Agrawal (Convener)**
  Executive Director, BMTPC
- **Shri Dalip Kumar / Shri S.K.Gupta / Shri J.K.Prasad (Co-Convenor)**
  Sr.Field Officer (DC&E) / Dy.Chief (TDE&IC) / Former Chief (Building Materials), BMTPC

Secretariat: BMTPC

Householder

A householder can use the maps to locate herself/himself in her/his district boundary and find the intensity of earthquake or wind hazard applicable to her/his locality. She/He can also find if her/his place is prone to floods or storm surge from the sea. From her/his district table, she/he can find for herself/himself the level of risk that exists to the type of her/his own house. She/He can also find the landslide and thunderstorm incidences in her/his area. If she/he finds that the situation is risky, she/he should take appropriate action to upgrade and strengthen her/his house to meet the threat of the hazard.

Disaster Manager

The disaster manager of the district can easily determine the location and percent of area of the district most susceptible to hazard occurrences, the probable maximum hazard intensities, the type and number of housing units existing in the district and the risk to them from the hazards. Knowing the extent of the problems of future disasters, the district authorities can formulate development plans for

(a) preventive actions required for hazard resistant construction, retrofitting and upgrading of existing buildings,
(b) reducing the impact of different types of hazards,
(c) installation of a warning system and required drills for its use,
(d) setting up a hierarchical structure for preparedness down to the village level,
(e) training of manpower for various tasks in the emergency,
(f) implementation of land zoning regulations in flood plains and coastal areas and building byelaws with disaster resistant features in various towns and cities, etc.

Members of State Legislatures and National Parliament

Members of State Legislatures and the National Parliament can study the hazard problems in their constituencies and propose disaster mitigation programmes for their districts and the whole State for inclusion in the State Plans and the National Plans.

State and National Authorities and NITI Aayog

The State and National authorities and NITI Aayog may identify the districts most prone to severe disaster situations and those with multi-hazard situations requiring priority action in future planning, formulating integrated mitigation policies covering Awareness, Education and Training, Preventive and Preparedness Measures, Improvement in Warning Systems, etc. Development projects will need to include mitigation measures against the disaster impacts at the initial plan formulation as well as execution stages so that whatever is developed should not suffer damage later. The Atlas will be found immensely useful in that regard.

The Vulnerability Atlas has been structured to serve as a tool towards natural disaster prevention, preparedness and mitigation for housing and related infrastructure at local as well as national levels.

VULNERABILITY ATLAS OF INDIA

An indispensable tool for pre-disaster pro-active approach in disaster management

Building Materials & Technology Promotion Council, Ministry of Housing & Urban Affairs, Government of India will be happy to collaborate with national and international agencies/organizations:

- Providing a common understanding on vulnerability analysis and mitigation practices.
- Setting up a regional collaborative mechanism in the above areas.
- Assisting other countries in the process of preparation of Vulnerability Atlas wishing to undertake similar efforts.
- Collaborating in national capacity building programmes targeted at local authorities, and private sector practioners on disaster mitigation & management practices.

The digital version of Third Edition of the Vulnerability Atlas of India is available at **http://www.bmtpc.org** with links on websites of Ministry of Housing & Urban Affairs i.e. **http://mohua.gov.in** and **https://ghtc-india.gov.in/** for wider access by various stakeholders.

The Hardcopy of the Atlas can be procured at a cost of Rs.5000 / US$200 (Postage Extra) from BMTPC, New Delhi.

For further information, please contact:

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UNCHS (Habitat II): Views on the Vulnerability Atlas of India

"We would like to indicate our interest in exploring possible collaborative activities between the Government of India and UNCHS (Habitat) both, in bringing the application of Atlas to the local/district level, and in possible dissemination to other countries as part of regional cooperation initiatives".

Android & iOS Mobile App on "Earthquake Hazard Map of India" available at : www.bmtpc.org
(http://bmtpc.org/newsdetails.aspx?mid=38)

BMTPC's Publication related to Disaster Mitigation and Management

- Building A Hazard Resistant House : A Common Man's Guide
- Guidelines for Improving Earthquake Resistance of Housing
- Guidelines for Improving Wind/Cyclone Resistance of Housing
- Guidelines for Improving Flood Resistance of Housing
- Earthquake Tips
- Design & Construction of Earthquake Resistant Structures – A Practical Treatise for Engineers and Architects
- Manual for Restoration and Retrofitting of Buildings in Uttarakhand and Himachal Pradesh
- Seismic Retrofitting of MCD School Buildings in New Delhi
- Disaster Risk Reduction - A Handbook for Urban Managers
- Guidelines for Multi-Hazard Resistant Construction for EWS Housing Projects
- Guidelines on "Rapid Visual Screening of Buildings of Masonry and Reinforced Concrete as Prevalent in India"
- Methodology for Documenting Seismic Safety of Housing Typologies in India
- Guidebook on Earthquake Resistant Design and Construction