



MANIPUR EARTHQUAKE-2016

RELIEF TO RECOVERY



National Institute of Disaster Management
(Ministry of Home Affairs, Government of India)



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2022

National Institute of Disaster Management

Ministry of Home Affairs, Government of India

Plot No. 15, Block-B, Pocket-3, Sector-29, Rohini, Delhi-110042

Website: <https://nidm.gov.in>

Manipur Earthquake 2016 : Relief to Recovery

ISBN: 978-81-957965-5-7

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Edition : 2022

Author :

Dr. Amir Ali Khan

Published by :

National Institute of Disaster Management (NIDM), Ministry of Home Affairs, Government of India, Delhi-110042.

Citation :

Khan, A. A. (2022). Manipur Earthquake 2016: Relief to Recovery. National Institute of Disaster Management, Delhi, India. Pages 90.

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FOREWORD

Earthquakes are known as one of the most perilous and lethal disaster in the world. As per CRED /UNISDR data of 1998-2017, the number of disasters resulting from earthquakes contributed only 8% of global disaster; however, number of death in such events is staggering high (around 56% of the total death during the period). Earthquakes have a potential to damage infrastructure and destroy the built environment beyond repair. The example of earthquake and tsunami induced damages in Japan (2011) is still fresh in mind. This event alone resulted in the loss of US\$ 239 billion (UNDRR / Centre for Research on the Epidemiology of Disasters, 2020). Such events underline the importance of incorporating earthquake risk mitigation efforts in earthquake prone areas well in time.

About 58.6% of the total area of our country lies in the seismic zones III-V, while the rest cannot be called as earthquake-free. The entire North-Eastern region and most of the parts of Indian Himalayan belt fall under the Seismic Zone IV and V, representing the highest zone of seismicity containing 'Very High Risk'. It is a fact that the earthquakes "don't simply kill" but cause collapsing of entire system. It takes long and sustained efforts to revive and rebuild the affected area. In the present scenario, ill-planned/unplanned and unregulated development activities increase our vulnerability to earthquake risk manifolds.

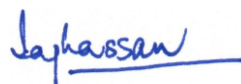
Our North-Eastern Region is one of the most seismically active regions of the world. Two major earthquakes ($M > 8.0$) and about 20 large earthquakes ($M 7+$) since 1897 have occurred in this region. In Manipur, the unprecedented growth of multi-storey buildings and unregulated urbanization, especially in the Imphal town, has made the risks associated with earthquakes humongous. At least 10 people were killed and more than 300 people were injured in the recent earthquake of Manipur (Magnitude 6.7), struck on January 4, 2016. This had refreshed

आपदा प्रबंधन महाविचार: पूरा भारत भागीदार

the terrible memory of the 7.2 magnitude earthquake of 1988, pinpointing the need of detailed investigation and review of the process of infrastructure development in this area for safety of the people and other developmental gains.

‘Manipur Earthquake – 2016: Relief to Recovery’, has been written to collate and understand the impact and damage pattern, which will help build better and resilient infrastructure in future. The document covers the 2016 event in details from impact to rescue, relief and recovery; and focuses on the damage assessment of structures in the affected areas. Some major issues and causes of damage have been discussed, along with good practices which were initiated post-disaster including retrofitting measures and outlining way forward.

National Institute of Disaster Management has undertaken numerous initiatives for disaster risk reduction and capacity building of stakeholders in this area. The present report is an effort to foster the Hon’ble Prime Minister’s 10 Point Agenda on DRR, which, as per the point number 9, stipulates ‘to ensure that the opportunity to learn from a disaster is not wasted and to document the learning from major disasters in the country’. I am hopeful that this report will go a long way in mitigating the impact of earthquakes not only in Manipur but also other states to plan better preparedness, response and rehabilitation efforts.



(Taj Hassan)

PREFACE

North East Region of the country is highly prone to earthquakes of varying magnitudes. Entire Region falls under Zone V according to Seismic Hazard Zonation Map of the country. The Region has already faced few of the damaging earthquakes. Fortunately, not much damage had resulted in recent past due to earthquakes in this region. Despite being in Zone V and availability of earthquake safe traditional construction practices in the region, the built form of the region is not so conducive to face earthquakes. There is a need to invest in earthquake risk mitigation measures through structural and non-structural means.

This Report is having inputs from the visits of the author to Manipur in 2016 (along with Prof. Chandan Ghosh, NIDM) and 2019 to organize training programmes. During these visits useful discussions were held with the participants of the programmes, local faculties involved and few officials of the State Government. The report, primarily, is based on literature survey, both online and offline, keeping the attention of the document on ill-planned and/or unplanned construction practices being followed not only in Manipur but throughout the NE region.

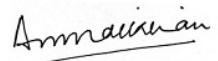
Author takes this opportunity to express his sincere thanks to all who have contributed towards compilation and finalization of this document. Shri Taj Hassan, Executive Director, NIDM has always encouraged to do quality work and bring NIDM on forefront. Author sincerely extends his gratitude to Shri Taj Hassan, Executive Director, NIDM for sharing his vision and showing encouragement towards this document. Former Executive Director, NIDM, Maj. Gen. (Retd.) Manoj Kumar Bindal, VSM, took several initiatives to make NIDM as one of the best Institute of prime importance at national level. Author thanks Maj. Gen. (Retd.) Manoj Kumar Bindal, VSM, for his unwavering support to carry out the case study on Manipur Earthquake 2016 as well as to other initiatives for NIDM.

Author expresses his appreciation to Prof (Dr.) Chandan Ghosh, Head, Resilient Infrastructure Division, NIDM who visited Manipur after the earthquake (2016) and also provided guidance in making this document more meaningful. Sh. Surendra Thakur, Consultant (HR & Admin.) deserve special thanks for his encouragement, support and guidance in compilation of this document.

Well-deserved thanks to the reviewers of this document Er. Rajesh Dutta (ASDMA), Prof. Devesh Walia (NEHU) and Maj Gen. (Retd.) V.K. Naik for giving valuable suggestions and comments for refining this document as and when needed. Special thanks to officers of Manipur State Government, PWD, Manipur and faculties of Manipur University for providing useful information.

Special thanks are due to the Resilient Infrastructure Division team members, Mr. Mahesh Kamaji, former Young Professional, NIDM and Ms. Yogita Garbyal, Young Professional, NIDM for their hard work in compilation and finalization of the Report.

Finally, Author is grateful to NIDM team and other stakeholders who extended their willing support, cooperation and commitment by devoting their expertise to make valuable contributions to the development of this document specially Shri S K Tiwari, Librarian and Publication (I/C) and Ms. Karanpreet Kaur Sodhi, Junior Consultant for their useful assistance.



(Amir Ali Khan)

Associate Professor

CONTENTS

FOREWORD	iii
PREFACE	v
LIST OF FIGURES	x
LIST OF TABLES	xiii
LIST OF ABBREVIATION	xiv
EXECUTIVE SUMMARY	1
1 INTRODUCTION	3
1.1 Background	3
1.2 General profile of India	5
1.3 Disasters-Indian scenario	5
1.4 Hazard/vulnerability profile of India	8
1.5 Hazard/vulnerability profile of North-East India	10
1.6 Objectives of the Study	12
2 MANIPUR PROFILE	13
2.1 Introduction	13
2.2 Land and people	13
2.3 Demography	13
2.4 Topography	14
2.5 Soil and geology	15
2.6 Geography	17
2.7 Forest cover and land use patterns	18
2.8 Socio-Economic aspects	20
2.9 Infrastructure	21
2.9.1 Vernacular housing in Manipur	22
2.9.1.1 Meitei Yumjao	22
2.9.1.2 Shing-Khim house	25
2.10 Hazard/vulnerability profile of Manipur	26
2.10.1 Earthquake hazards in Manipur	26
2.10.2 Floods in Manipur	30

2.10.3	Landslides	32
2.10.4	Fires	32
2.10.5	Drought	33
3	MANIPUR EARTHQUAKE-2016	35
3.1	Introduction	35
3.2	Origin of occurrence and affected areas	37
3.3	Assessment of the Impact	38
3.3.1	Damage Assessment to Infrastructure	39
3.3.1.1	Socio-economic Infrastructure	39
3.3.1.2	Physical Infrastructure	40
3.3.2	Detailed Assessment of Damaged Structures	44
3.3.2.1	Reinforced Concrete Construction practices in Manipur	44
3.3.2.2	Building deficiencies observed	45
3.3.2.3	Floating column failure	47
3.3.2.4	Short column effect	48
3.3.2.5	Soft storey failure	50
3.3.2.6	Mass irregularities	52
3.3.2.7	Maintenance condition and quality of construction materials	53
3.3.2.8	Failure due to lack of ductile detailing	54
3.3.2.9	Failure due to lack of earthquake resistant design	56
3.3.2.10	Failure due to soft soil	56
3.3.2.11	Masonry structures	57
3.3.2.12	Mud and adobe houses	59
3.3.2.13	Conclusions from the damage assessment	60
3.4	Rescue, Relief and Recovery	61
3.4.1	Role of the Government of India in rescue and relief operations	61
3.4.2	Government of Manipur in rescue and relief operations	62
3.4.3	Role of NDRF and SDRF	64
3.4.4	Role of other stakeholders	65
3.4.4.1	NGOs	66
3.4.4.2	Local Community	68

3.4.5 Post Earthquake Reconstruction and Retrofitting	69
3.4.5.1 Reconstruction and rehabilitation works	69
3.4.5.2 Post Earthquake retrofitting works in Imphal	71
4 LESSONS LEARNT AND WAY FORWARD	75
4.1 Way Forward	76
4.1.1 Multi-Hazard Resistant Construction and Retrofitting	76
4.1.1.1 Standards, codes and guidelines for earthquake resistant design	76
4.1.1.2 Retrofit strategies	78
4.1.2 Capacity Enhancement at Local Level	79
4.1.3 Improving the Response System and Management	80
4.1.4 Post Disaster Needs Assessment (PDNA)	81
4.1.5 Insurance against the odds	82
5 ANNEXURE	83
6 BIBLIOGRAPHY	87

LIST OF FIGURES

Figure 1	: Number of disasters during 1998-2017	4
Figure 2	: Number of deaths due to various disasters during 1998-2017	4
Figure 3	: Multi Hazard/Vulnerability Map of India	9
Figure 4	: Earthquake hazard map of India	9
Figure 5	: Map showing major tectonic features of north-east India after GSI 2000	11
Figure 6	: Geological Map of Manipur	16
Figure 7	: Forest Cover map of Manipur (2017-2018)	18
Figure 8	: House plan of typical Yumjao house	24
Figure 9	: Exterior look and roofing pattern of a typical Yumjao house	25
Figure 10	: Traditional Shing-Khim house in Manipur	26
Figure 11	: Earthquake hazard map of Manipur state.	27
Figure 12	: Flood hazard Map of Manipur	31
Figure 13	: Landslide Incident Map of Manipur	32
Figure 14	: Location of epicenter of the January 4, 2016 earthquake and past earthquakes of magnitude M 6.0 and above.	36
Figure 15	: Showing major cracks developed in Kabui Khullen village in Tamenglong district	38
Figure 16	: Collapse of a two-storey building in Keishampat, Imphal.	42
Figure 17	: Failure of power line near Noney.	42
Figure 18	: Damaged Imphal Ima Market	43
Figure 19	: Showing emergence of a new spring in Lungkhuijang, Noney	43
Figure 20	: Landslide occurred at Noney (Lungkhuijang)	44
Figure 21	: A residential building with floating column at Singjamei, Imphal.	47
Figure 22	: Formation of short column due to partial height of brick masonry infill walls	48

Figure 23	: Short column effect due to presence of partial infill walls at Tamenglong, Manipur.	49
Figure 24	: Column damages due to short column effect in Imphal.	49
Figure 25	: Collapse of first storey of building at Saikul bazaar in sadar hills due to soft storey.	50
Figure 26	: Soft first storey in Laxmi Market and severe damage to column	51
Figure 27	: Failure of columns due to soft storey in Saikul bazar, Sadar hills.	51
Figure 28	: Damaged building due to mass irregularity at Govt. Polytechnic, Takyelpat.	53
Figure 29	: Corroded reinforcement in slab, beam at Government Polytechnic building, Manipur.	54
Figure 30	: Base of first storey column with widely spaced ties and spalled concrete, (Bishnupur Market.) and new market	55
Figure 31	: Concealed drain water pipes inside the exterior columns	55
Figure 32	: Collapsed frame of a soft-storeyed RCC structure (women vendor's market) in Saikul.	56
Figure 33	: Damaged Central Agricultural University gate due to landfill soil.	57
Figure 34	: Collapsed masonry building at Leimakhong area Manipur.	58
Figure 35	: Cracks observed in a masonry building with cement mortar bond at Leimakhong area Manipur.	59
Figure 36	: Collapsed Mud wall house near the epicenter region Noney, Tamenglong.	60
Figure 37	: Disaster Management structure in Manipur state	62
Figure 38	: Rescue and relief operations by NDRF and Army after Manipur earthquake.	65
Figure 39	: Oxfam's Non-Food Items kit distribution	67
Figure 40	: Relief material distribution at Molhoi village, Leimakhong cluster, Senapati district, Manipur on 19th March 2016.	68

Figure 41	: Interim market space for women vendors built after the earthquake in Saikul	69
Figure 42	: Earthquake resistant housing models introduced in senapati	70
Figure 43	: Bamboo based Toilet Building” at Imphal, Manipur.	71
Figure 44	: A view of Inter-State Bus Terminal at Imphal after the earthquake.	72
Figure 45	: Severe damage to RC columns at the Inter-State Bus Terminal, Imphal after the earthquake	72
Figure 46	: Retrofitting of RC column by replacing circular ties with helical reinforcement	72
Figure 47	: Propping damaged RCC structures by newly constructed columns not connected to the beam above in Saikul.	74

LIST OF TABLES

Table 1	: Quinquennial trend of total affected people and damage caused by different disasters in India.	6
Table 2	: List of Ten Deadliest Disasters in the last century in India.	7
Table 3	: Demography of Manipur as per 2011 census	14
Table 4	: District wise geographical area with population as per 2011 census.	17
Table 5	: Detail Statistics of Land use of Manipur as on 2018	19
Table 6	: General information of the state agriculture	20
Table 7	: General information of the state infrastructure	22
Table 8	: Distribution of houses by predominant materials wall; level of risk in Manipur as per 2011 census	28
Table 9	: District wise housing pattern in Manipur	29
Table 10	: Estimated population and potential damage exposed to earthquake shaking	36
Table 11	: Exposure of selected cities to the 2016 Manipur earthquake	37
Table 12	: Details of houses damaged during the earthquake	41
Table 13	: Relief materials procured in connection with earthquake	64
Table 14	: Earthquakes in Manipur flashback	83
Table 15	: Extent of damage due to earthquake in Manipur	85

LIST OF ABBREVIATION

ADRA	Adventist Development and Relief Agency
BIS	Bureau of Indian Standards
BMTPC	Building Materials & Technology Promotion Council
CAG	Comptroller and Auditor General of India
CASA	Church's Auxiliary for Social Actions
CBRI	Central Building Research Institute
CBRN	Chemical, Biological, Radiological and Nuclear
CGD	Child Gender Disability
CRED	Centre for Research on the Epidemiology of Disasters
CSSR	Collapsed Structure Search and Rescue
DBE	Design Basis Earthquake
DEOC	District Emergency Operation Centre
DRDA	District Rural Development Authority
DRDO	Defence Research and Development Organization
FRP	Fibre Reinforced Polymer
GEERP	Gujarat Emergency Earthquake Reconstruction Program
GSDMA	Gujarat State Disaster Management Authority
GSDP	Gross State Domestic Product
GSI	Geological Survey of India
HADR	Humanitarian Assistance and Disaster Relief
IBR	Indo-Burma Ranges
IFRC	International Federation of Red Cross and Red Crescent Societies
IGSSS	Indo-Global Social Service Society
IMD	India Meteorological Department
IMR	Indo-Myanmar Ranges
IRMA	Integrated Rural Management Association

ISBT	Inter State Bus Terminal
IST	Indian Standard Time
MDF	Multi Donor Fund
MHA	Ministry of Home Affairs
MSDMA	Manipur State Disaster Management Authority
NDMA	National Disaster Management Authority
NDRF	National Disaster Response Force
NIDM	National Institute of Disaster Management
NRCS	Nepal Red Cross Society
NSDP	Net State Domestic Product
PDNA	Post Disaster Needs Assessment
SAI	Sports Authority of India
SASE	Snow and Avalanche Study Establishment
SDRF	State Disaster Response Force
SEC	State Executive Committee
SEOC	State Emergency Operation Centre
UNDRR	United Nations office for Disaster Risk Reduction
USAR	Urban Search and Rescue
USGS	United States Geological Survey
UTC	Universal Time Coordinated

EXECUTIVE SUMMARY

An earthquake measuring M6.7 on the Richter scale struck Manipur on January 4, 2016, in the early morning at 04: 35 am IST, killing at least 10 people and causing injuries to more than 300 people. The epicentre of the earthquake located in the Tamenglong district which lies between Lat 24.8°N, Long 93.5°E in Manipur about 30 km west of the state capital Imphal. It was the largest earthquake to strike Manipur after M7.2 earthquake in 1988. The tremors were widely felt in all the North-Eastern states of India. The shaking intensity in Imphal city and adjoining areas during the event varied from VI to VII on the Mercalli scale. A few aftershocks of magnitude less than 4.0 were also felt within a day of the mainshock. That tremor, plus subsequent aftershocks, caused extensive damage to houses and infrastructure. Extensive catastrophic damage occurred to Government buildings, three Ima Keithels (women's market), secretariat building, market complex, ISBT (Inter State Bus Terminal), Central Agriculture University, Sports Authority of India, Government Polytechnic buildings, and other private buildings, etc. Due to the adverse situation and impact of the earthquake, thousands were left homeless and displaced. The affected people took shelter in the community halls, schools, waiting shed, relative's houses, clubs, churches, etc. In the 9 districts of Manipur, around 351 villages and 16733 people were affected. Out of 4184 damaged houses around 738 houses were fully damaged, 747 houses were severely damaged and 2699 houses were partially damaged. The estimated total damage to houses and public properties was around 27,473.62 lakhs. The worst affected districts in Manipur were Imphal, Tamenglong, Noney, and Thoubal.

In this document an attempt has been made to collect information and data about the earthquake for outlining the damage pattern, rescue, relief and recovery operations held after the earthquake and to study the post-earthquake measures taken for rehabilitation, reconstruction, and retrofitting of the structures to extract the lessons learnt from the management of the earthquake.

1 INTRODUCTION

1.1 BACKGROUND

Over the past two decades, India and other parts of the world have been experiencing an increase in the frequency and intensity of disasters causing physical, social and economic impacts which are devastating for many developing countries. The lessons from the previous disasters indicate that hazards may be natural while the disasters are mostly “man-made”. They to a great extent, result from the failures of development practices and policies which distort the trajectory of sustainable development, mostly influencing the poorest sections.

Generally, disasters have been considered as devastating events. Losses due to disasters are increasing exponentially. Natural and human-induced disasters have been causing extensive loss of life and property and huge damage to private and public infrastructure eroding gains of development and leading to increased expenses on relief and rehabilitation. Changing climatic conditions, environmental degradation and other factors like increasing urbanization are likely to increase disaster risks. The combined bits of knowledge assembled through national encounters and worldwide activities have highlighted that the disasters "don't simply occur" in current scenario, they frequently result from the failures of development itself. These ill-planned/unplanned and unregularized development activities increases our vulnerability to disaster risks as well. As per the published report on economic losses, poverty and disasters by CRED during the last two decades i.e. 1998-2017, climate-related and geophysical disasters killed 1.3 million people and left a further 4.4 billion injured, homeless, displaced or in need of emergency assistance. While geophysical events such as earthquakes and tsunamis caused the majority of the fatalities, 91% of all disasters were brought by storms, floods, heat waves, droughts and other extreme weather events in 1998-2007¹. Disaster hit nations experienced direct economic losses estimated at USD 2,908 billion², of which 77% of the total losses and around USD 2,245 billion losses occurred due to climate related disasters. This has increased from 68% (USD 895 billion) of losses (USD 1,313 billion) reported between 1978 and 1997. Overall, reported losses from extreme weather events rose by 151% between these two 20-year periods.

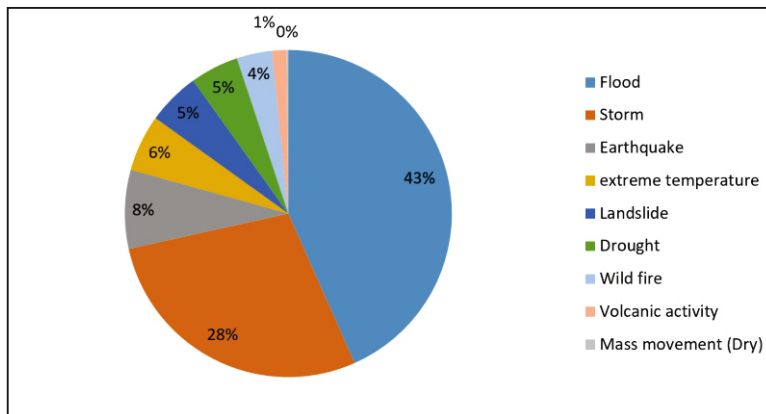
Though the number of disasters resulting from earthquakes contributed only eight percent of disasters globally, geophysical disasters - primarily earthquakes - killed

¹Economic Losses, Poverty and Disasters 1998-2017 by CRED and UNISDR.

²The World Bank - Results Brief - Climate Insurance (2017) Available at: <https://www.worldbank.org/en/results/2017/12/01/climate-insurance>. Retrieved on 28th September 2019.

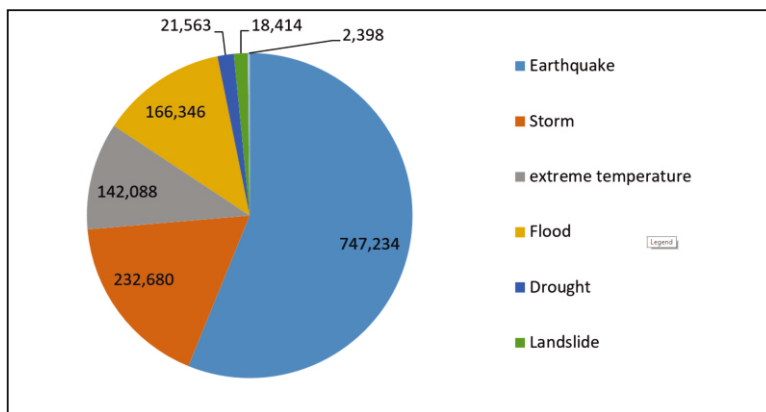
more people than any other type of disaster in the past 20 years, with the cumulative toll of 747,000 fatalities exacerbated by the vulnerability of poor and badly prepared populations exposed to two major events: the 2004 Indian Ocean tsunami and the Haiti earthquake of 2010³. Population growth, economic development, and rapid urbanization place more people in harm way more than ever before in earthquake zones.

Figure 1: - Number of disasters during 1998-2017



Source: - *Economic Losses, Poverty and Disasters 1998-2017* by CRED and UNISDR.

Figure 2: - Number of deaths due to various disasters during 1998-2017



Source: - *Economic Losses, Poverty and Disasters 1998-2017* by CRED and UNISDR.

³EM-DAT: The Emergency Events Database - Université catholique de Louvain (UCL) - CRED, D. Guha-Sapir - www.emdat.be, Brussels, Belgium. Retrieved on 28th September, 2019.

1.2 GENERAL PROFILE OF INDIA

India is the 7th largest country in the world; one of the oldest civilizations in the world with a kaleidoscopic variety and rich cultural heritage. It has achieved all-round socio-economic progress since its independence. India has become self-sufficient in agricultural production and is now one of the industrialized countries in the world and one of the few nations to have gone into outer space to conquer nature for the benefit of the people. India lies entirely in the northern hemisphere, having geographical coordinates extend between latitudes 8° 4' and 37° 6' North, longitudes 68° 7' and 97° 25' East. It covers an area of 3,287,590 square kilometres⁴. It has a land frontier of about 15,200 km. The total length of the coastline of the mainland, Lakshadweep Islands and Andaman & Nicobar Islands is 7,516.6 km. The country represents 28 states and 8 union territories. The country is surrounded by three huge water bodies; the Bay of Bengal to the east, the Arabian Sea to the west and the Indian Ocean to its south which gives the country a distinct geographical entity. Tropic of Cancer passes through the middle of the country which makes India into two halves with the tropical zone in the south and subtropical in the north. The mainland comprises four regions namely plains of the Indus and the Ganga, Great Mountain zone, southern peninsula, and the desert region. The climate of India is broadly classified as a tropical monsoon type. The entire country has a tropical climate marked by relatively high temperatures and dry winters.

As per the socio-economic profile, the population growth of India is tremendously increasing day by day due to rapid urbanization and industrial growth. From the 2011 census data, the estimated Indian population is 121 crores with a literacy rate of 74.04 percent and the sex ratio of 940 females to 1000 males. An average annual exponential growth rate of 1.64 percent was observed during 2001-2011⁵. The life expectancy rate consisted of 65.8 years (Males) and 68.1 years (Females) in the period 2006-2011.

1.3 DISASTERS - INDIAN SCENARIO

According to data available at the Centre for Research on the Epidemiology of Disasters (CRED), India is in the second place in terms of the number of people affected by various disasters during 2015. Disasters are primarily triggered by natural or human included hazards or their combination. From the past disasters profile of India, it can be said that the India is vulnerable to floods, droughts, cyclones, earthquakes, landslides, avalanches and forest fires. According to the

⁴National Portal of India, <https://www.india.gov.in/india-glance/profile>, last accessed on October 7, 2019.

⁵Census 2011 from censusindia.gov.in

World Disasters Report 2016, published by the International Federation of Red Cross and Red Crescent Societies, a total number of 1,12,627 people were reported killed between 1993 and 2015 in India due to disasters, and the total number of people affected for the same period was approximately 84.55 crores⁶.

During recent decades (1995-2016), India have experienced increase in floods causing large scale damage resulting in greater loss of property and life. Extreme events like cyclones, cloudburst and sediment disasters have occurred more frequently or once a year causing huge damages. Tsunamis and earthquakes do not have high frequency of occurrence but left a huge impact when they occurred in terms of loss of lives and damages. As per the United Nations Office for Disaster Risk Reduction's (UNISDR) Global Assessment Report on Disaster Risk Reduction 2015, India estimated Average Annual Loss from multi-hazard disasters of approximately USD 9.8 billion per year, of this, the average annual loss from floods is \$7.4 billion every year⁷.

Table 1: - Quinquennial trend of total affected people and damage caused by different disasters in India.

	Total affected people			Total economic damage in USD		
	2001-2005	2006-2010	2011-2015	2001-2005	2006-2010	2011-2015
Earthquake	6,478,634	-	634,550	3,623,000	-	120,000
Tsunami	654,512	-	-	1,022,800	-	-
Riverine Flood	120,970,121	53,505,869	21,862,429	9,392,696	8,094,151	18,524,000
Flash flood	3,700,045	8,931,465	-	26,000	123,000	-
Coastal flood	-	7,200,000	-	-	275,000	-
Landslide	5,020	-	513,673	50,000	-	1,100,000
Tropical Cyclone	77,250	5,750,300	14,470,004	28,416	300,000	8,271,096

Source: - Adapted from Data Collection Survey for Disaster Prevention in India Final Report (2015) by Japan International Cooperation Agency Yachiyo Engineering Co., Ltd. and compiled by the EM-DAT Retrieved from <https://openjicareport.jica.go.jp/pdf/12245155.pdf>

⁶World Disasters Report 2016, International Federation of Red Cross and Red Crescent Societies, IFRCGO. Retrieved on 18th September, 2019.

⁷https://economictimes.indiatimes.com/news/politics-and-nation/india-loses-9-8-billion-every-year-due-to-disasters/articleshow/47150713.cms?utm_source=contentofinterest&utm_medium=text&utm_campaign=cppst

Table 2: - List of Ten Deadliest Disasters in the last century in India.

Name of the event	Year	State and area	Fatalities
Earthquake	1905	Kangra, Himachal Pradesh	20,000 Deaths
Cyclone	1977	Andhra Pradesh	10,000 deaths, hundreds of thousands homeless, 40,000 cattle deaths, destroys 40% India's of food grains.
Latur Earthquake	1993	Latur, Marthawada, region of Maharashtra.	7,928 People died and another 30,000 were injured.
Orissa super Cyclone	1999	Orissa	10,000 deaths.
Gujarat Earthquake	2001	Bhuj, Bachau, Anjar, Ahmadabad and Surat in Gujarat state.	25,000 deaths and 6.3 million people affected.
Tsunami	2004	Coast line of Tamil Nadu, Kerala, Andhra Pradesh, Pondicherry, and Andaman & Nicobar Islands of India.	10,749 deaths, 5,640 persons missing, 2.79 million people affected, 11827 hectares of crops damaged and 3,00,000 fisher folks lost their livelihoods
Maharashtra Floods	2005	Maharashtra state	1094 deaths, 167 injured and 54 Missing.
Kashmir Earthquake	2005	Kashmir state	At least 1350 people killed with 6266 people injured in J& K region
Kosi Floods	2008	North Bihar	527 deaths, 19,323 livestock perished, 22, 2,754 houses damaged and 33, 29,423 persons affected.
Cyclone Nisha	2008	Tamil Nadu	204 deaths and 800 million USD worth damages.

Source: - Based on various sources including Topics 2000, Natural Catastrophes-the current position, Special Millennium Issue, Munich Re Group, 1999. Centre for Research on Epidemiology of Disasters (CRED) EM-DAT, Belgium. Retrieved on 6th October, 2019.

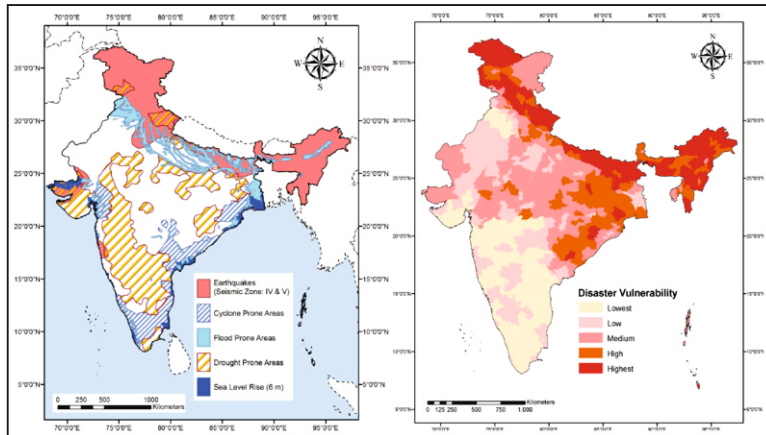
1.4 HAZARD/VULNERABILITY PROFILE OF INDIA

It is the interaction of hazards and vulnerability which leads to a disaster. Owing to its unique geographical, topographical and environmental conditions, India has always been vulnerable, to varying degrees, to a large number of natural, as well as, human-made disasters. The Indian subcontinent is one of the world's most disaster-prone areas. Almost 85 percent of India's area is vulnerable to one or multiple hazards. Of the 28 states and 8 union territories, 22 are disaster-prone. Around 58.6 percentage of the landmass is prone to various intensities of earthquakes; more than 12 percent of the land (around 40 million hectares) is prone to floods and erosion; 78 percentage of coastline (around 5,700km out of 7,516km) is prone to various tsunamis and cyclones, from the total cultivable land about 68 the percent of land is prone to droughts; and 15 percent of landmass covering hilly areas are vulnerable to avalanches and landslides⁸. Apart from this India is also vulnerable to chemical, biological, radiological and nuclear (CBRN) emergencies and various other manmade disasters. Vulnerabilities related to Socio-economic conditions, demographics, development within high risks zones, unplanned urbanization, environmental degradation, geological hazards, epidemics, and climate changes are increasing, causing huge disaster risks in India.

Figure 3, shows the hazard and vulnerability maps of India; one classifies the country based on high to low vulnerability to disasters and another portrays hazard profile with various disaster types recurrent in the country. It can be observed that the highest vulnerability to disasters is found in the northern part and some portions of eastern coastal areas, whereas the lowest proneness is observed in the southern parts. The northern part is highly exposed to earthquakes, landslides, and floods while most of the southern part is exposed to cyclones (mainly eastern parts) and droughts (mainly western parts).

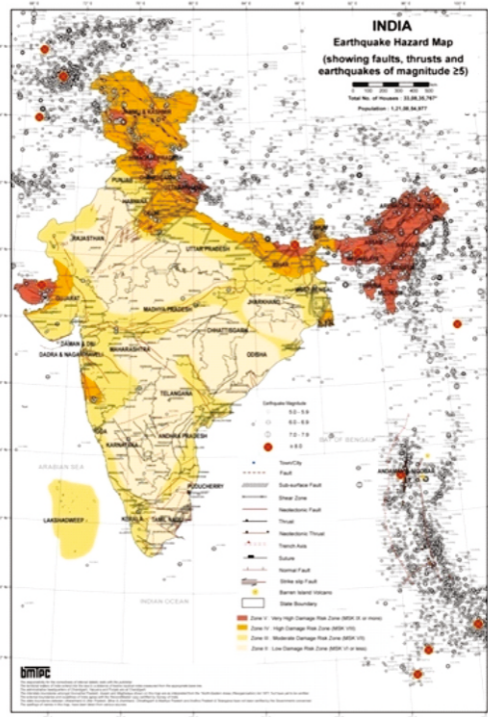
⁸National Disaster Management Authority, "Vulnerability profile of India". Data Retrieved on October 7, 2019, from <https://ndma.gov.in/en/vulnerability-profile.html>.

Figure 3: - Multi Hazard/Vulnerability Map of India



Source: Chakraborty, Anusheema & K. Joshi, P. (2016). Mapping disaster vulnerability in India using analytical hierarchy process, Retrieved on October 15, 2019 from Reseachgate.net

Figure 4: - Earthquake hazard map of India



Source: - BMTPC (2019) Vulnerability Atlas of India, 3rd Edition
https://bmtpc.org/DataFiles/CMS/file/Publication/VAI_3rd2019.pdf Retrieved on 20th October, 2019.

The natural geological setting of the country is the primary basic reason for its high vulnerability. The geo-tectonic features of the Himalayan region and adjacent alluvial plains make the region susceptible to earthquakes, landslides, water erosion, etc. Of the earthquake-prone areas, 12 percent is prone to very severe earthquakes, 18 percent is prone to severe earthquakes and 25 percent is prone to damageable earthquakes. Andaman and Nicobar Islands, Himachal, Kutch, the North-East and the Himalayan regions are particularly prone to the biggest earthquakes. Peninsular India is considered to be the most stable portion, but occasional earthquakes in the region show that geo-tectonic movements are still going on within its depth. India has been divided into four seismic zones according to the maximum intensity of earthquake expected (Figure 4). Of these, Zone V is the most active which comprises of the whole of Northeast India, the northern portion of Bihar, Uttarakhand, Himachal Pradesh, Jammu & Kashmir, Gujarat and Andaman & Nicobar Islands.

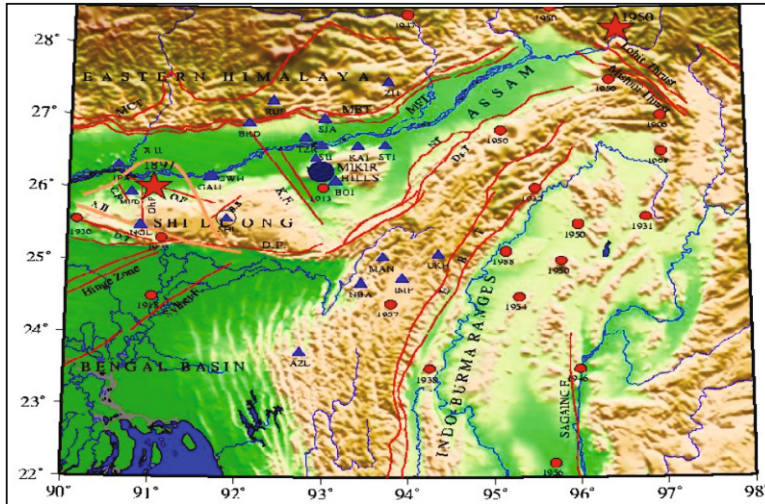
1.5 HAZARD/VULNERABILITY PROFILE OF NORTH-EAST INDIA

North-East India is one of the most multi-hazard prone areas in the Asian region facing different disasters like earthquake, flood, landslides and cyclonic storms etc. The North-East region of India represents eight states covering a geographical area of about 26.2 million hectares and a population of 40 million, around 82 percent of the population is from rural areas with low population density consisting of large indigenous tribal communities (34–91 percent)⁹ and most of the area falls under forest. The region consists of two major river basins namely Barak and Brahmaputra.

The North-East part of India is highly vulnerable to natural and climate-induced disasters. Past experiences reveal that North-East India is one of the most seismic hazard-prone regions of India. Several major earthquakes shook the region and caused large devastation. There are three major source regions or seismic blocks in this region namely ; The Eastern Himalayan belt, The Indo-Burma border region and the Shillong Plateau, causing frequent earthquakes of varying intensities. The North-East region of the country is one of the major seismically active intra-continental regions of the world. The region is jawed between the two arcs, the Himalayan arc to the north and the Indo-Burmese arc to the east.

⁹N. H. Ravindranath et al "Climate change vulnerability profiles for North East India". current science, Vol. 101, No. 3, 10 August, 2011

Figure 5: - Map showing major tectonic features of north-east India after GSI 2000



Source: - ASDMA (2015) *Literature Survey of Available Earthquake Hazard Assessment Studies related to North Eastern Region* (http://sdmassam.nic.in/download/literature_survey.pdf). Retrieved on 10th November, 2019.

The region bounded by latitude 22-29°N and longitude 90-98°E, produced two great earthquakes ($M > 8.0$) and about 20 large earthquakes $M7+$ since 1897. These two devastating earthquakes occurred in the region on 12th June 1897 and 15th August 1950 respectively. Both the earthquakes measured 8.7 on Richter Scale causing large scale damage in the entire region¹⁰. In the Figure 5, two great earthquakes ($M > 8.0$) are annotated by larger star symbols, and the large earthquakes ($8.0 > M > 7.0$) by circles. The major tectonic features in the region are indicated as; MCT: Main Central Thrust, MBT: Main Boundary Thrust, MFF: Main Frontal Fault, DF: Dauki Fault, DT: Dapsi Thrust, DhF: Dudhnoi Fault, OF: Oldham Fault, CF: Chedrang Fault, BS: Barapani Shear Zone, KF: Kopili Fault, NT: Naga Thrust, DT: Disang Thrust and EBT: Eastern Boundary Thrust. States like Manipur or Mizoram, due to their geographical location, bear the consequences of both N-S and E-W convergence resulting in frequent observations of earthquakes that are shallow as well as deep in nature. Manipur has witnessed several large intensities of earthquakes causing huge damage to property and life. Apart from Manipur lying in severe seismic hazard zone V, the unprecedented growth of multi-storey buildings and ill-planned urbanization especially in the Imphal town has made the risk

¹⁰ Literature Survey of Available Earthquake Hazard Assessment Studies related to North Eastern Region report, 2015. http://sdmassam.nic.in/download/literature_survey.pdf

associated with earthquakes gigantic. Any large seismic event in this area will lead to huge destruction. There is a huge decline in the traditional type of housing which used to withstand the seismic activities and are replaced by Kutcha houses made with mud and un-burnt brick or stone or unreinforced concrete which constitute more than 50% of housing type in the state. The vulnerability of the state to earthquakes is increasing every year with growth and increasing population near the cities. Manipur therefore, requires a detailed study on the likely impact of earthquakes to facilitate suitable earthquake resistant housing and resilient infrastructure.

1.6 OBJECTIVES OF THE STUDY

- To gather information and data about the hazard & vulnerability profile & disaster events witnessed by Manipur.
- Understanding what ground motions can be expected at various places in Manipur with populated areas which are socially and economically significant.
- To outline possible causes, impacts and rescue and relief operations held in the aftermath of the Manipur Earthquake disaster of 2016.
- To collate and understand the impact and damage pattern caused by 2016 Manipur Earthquake to build better and resilient infrastructure in future

The data presented in this document is heavily dependent on the secondary sources and is obtained from several online and offline sources such as memorandums submitted by the State Government, information collected from disaster management authorities of the state, different international and national disaster management websites, several published reports and articles, different media and online communication sources etc. Source and data used in this study are secondary in nature, thus, limiting the study.

2 MANIPUR PROFILE

2.1 INTRODUCTION

Manipur is often called “Land of Jewells” in the state’s local language. It is one of the Border States in the North-eastern part of India sharing international boundary of about 352 kilometres with Myanmar in the east. It also shares borders with the North-Eastern states of Assam, Mizoram, and Nagaland. The total area of the state is 22,327 square kilometres which constitutes 0.7 percent of the Indian geographical area. 90 percent of the total area in Manipur is covered by hills, surrounding central valley. The climatic condition varies from tropical to sub-alpine with average annual rainfall ranging from 1,200 mm to 2,700 mm and the average annual temperature ranging from 14.5°C to 38°C.

2.2 LAND AND PEOPLE

Manipur has a population of 2.85 million of which urban and rural population are 29.20 percent and 70.80 percent respectively (Census, 2011). The urban population of the state is on increasing trend since last decade mainly in Imphal, the capital of state. The average population density of the state is 128 persons per sq km¹¹. Manipur is endowed with rich natural resources. Lush green forests in the hills, fertile alluvial soil in the river basins, swift-flowing rivers and streams, a large number of freshwater lakes including the Loktak, and an optimum climate influence the economy of the state. Manipur’s economy is majorly based on agriculture, forest produce, industries, mining, business, and tourism.

2.3 DEMOGRAPHY

As per the 2011 census data, Manipur state population was 28,55,830 which constitutes nearly 0.24 percent of the total population of India. (The population density of Manipur is 128 per sq km, where the majority of the population occupies the valley region with a population density as high as 631 per square km and the density of the hilly region population is about 44 per square km.) The male population of the state is calculated as 13, 69,764 and the female population is 13, 51,992 with a sex ratio of 987 females for 1000 males. The literacy rate of the state is 79.85 percent and the total number of workers in the state is estimated as 9,45,213. Because of the very large population density, the Manipur valley region is more vulnerable to damages due to earthquakes which include the districts of Imphal East, Imphal West, Thoubal and Bishnupur. High population density is observed in Imphal west and Thoubal with 998 per sq.km. and 821 per sq.km. respectively. The

¹¹Census 2011, <https://www.census2011.co.in/census/state/manipur.html>

table 3 below provides district wise urban population, rural population, sex ratio and population density with literacy rate.

Table 3: - Demography of Manipur as per 2011 census

Name of the district	No. of villages	population	Urban population	Rural population	Sex ratio	Population density per sq km	Literacy rate (percentage)
Imphal West	124	5,17,992	3,22,879	1,95,113	1031	998	86.1
Imphal East	195	4,56,113	1,83,207	2,72,906	985	643	81.9
Thoubal	103	4,22,168	1,51,333	2,70,835	1002	821	74.5
Bishnupur	49	2,37,399	87,505	1,49,894	999	479	75.9
Churachandpur	600	2,74,143	18,357	2,55,786	975	60	82.8
Senapati	686	4,79,184	7,476	4,71,672	937	146	63.6
Chandel	437	1,44,182	16,847	1,27,335	933	44	71.1
Ukhrul	213	1,83,998	27,187	1,56,811	943	40	81.4
Tamenglong	174	1,40,651	19,363	1,21,288	943	32	70.1

Source: - 2011 census data retrieved on 8th October, 2019.

2.4 TOPOGRAPHY

Physiographically the state is divided into two different physical regions; the outer area consists of narrow valleys and rugged hills; the inner area consists of the topography of a flat plain with allied landforms. Hilly region comprises of five districts namely Churachandpur, Senapati, Ukhrul, Chandel and Tamenglong, whereas Imphal east, Imphal west, Thoubal, and Bishnupur are the four districts in the valley.

The valley region consists of an area of 1842 sq.km. and it is roughly an oval shape. Elevation in this region is about 745 meters to 850 meters above the mean sea level. 550 sq. km. of valley is occupied by lakes, wetlands, barren uplands and hillocks. The Loktak Lake is located in the central area of the Manipur valley occupying an area of about 60 sq.km. in the dry season and 104 sq.km. in the rainy season. The

valley is oval shape with a NNW-SSE orientation. The Imphal city stands at an altitude of 790 m above m.s.l. The hilly region consists of an area of about 20,571 sq.km.; hills gradually slope towards the south and have an elevation of about 900 meters to 3000 meters above the mean sea level. Naga Hills extended towards south which consists series of parallel young fold ranges¹².

The hill ranges can be divided into two groups-Manipur western hills and the Manipur eastern hills. The whole western part of the state is occupied by parallel ridges. Valley of Manipur western hills run from north to south direction about 180 km long. In the north-west region, these hills are relatively high. The Manipur Eastern Hills run about 200 km along the Indo-Myanmar border, 30 km in the southern part and 50 km in the northern part; Mapithel, Mullein, Chingngai, etc are some of the main ranges of the Manipur Eastern Hills and Siroi (2,567 m), Khayangbung (2,833 m), Kachaobung (2,498 m), etc are some of their important peaks¹³.

2.5 SOIL AND GEOLOGY

The soil cover is broadly divided into two types, the red ferruginous soil in the hilly region and the alluvium in the valley. The soil of hills are poor in lime potash and low phosphorous content. The soil in the valley are alluvial in origin and are mostly loamy sand to silty clay loam in texture. Chemically acidic soil abounds resulting from the washing down of the salts in rainwater and also on account of the leaching effect. The pH value varies from 5.4 to 6.8¹⁴. The soils are characterized by low to high organic matter (2-5 percent, in some places even more than 5 percent).

Geological formations in the Manipur region are divided into six groups namely Tipam, Surma, Barail, Disang, ophiolite-melangae suite and metamorphic complex. Figure 6 below illustrates the geological features of Manipur. Geological formations of the state comprise one of the youngest mountain chains formed during Alpine –Himalayan orogeny and are constituted of cretaceous and tertiary sediments with a very little amount of metamorphic and igneous rocks associated with pelagic sediments like chert, limestone, shale, and sandstone sediments¹⁵.

Tectonically, the whole of Manipur forms a part of the great geosynclines that apparently had original basin topography of ridges and furrows. Sediments started depositing in the geosynclines, argillaceous sediments deposited in the furrows and arenaceous and calcarious sediments in the ridges.

¹²https://shodhganga.inflibnet.ac.in/bitstream/10603/5374/9/09_chapter%202.pdf.

¹³ Ibid 12, P15

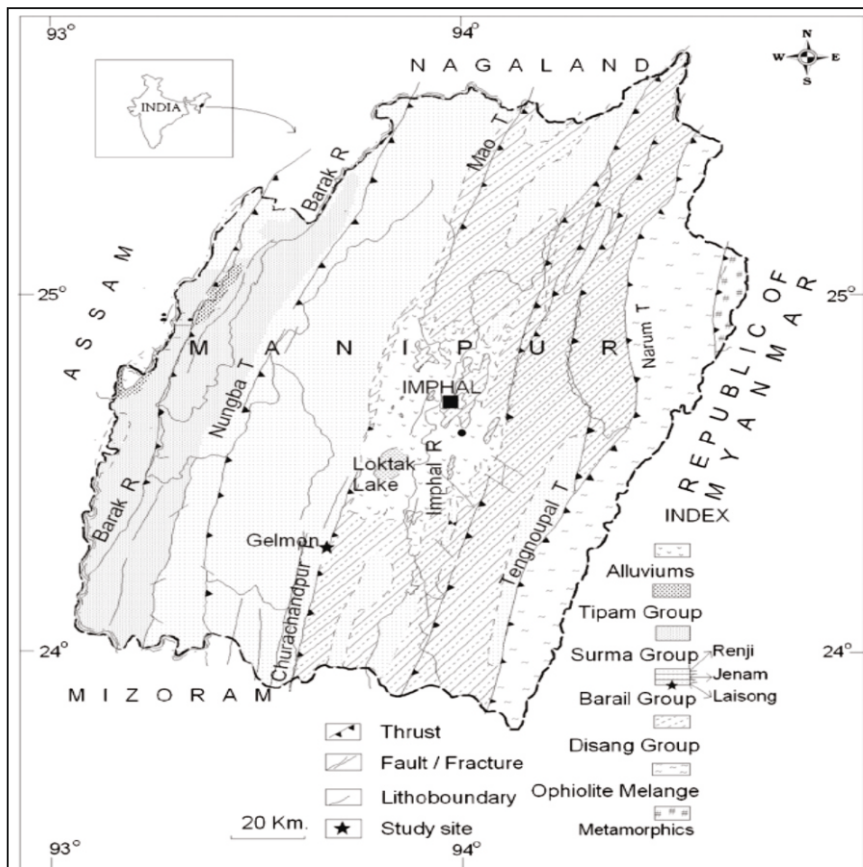
¹⁴ Invest in Manipur. https://investinmanipur.nic.in/gp_soil.htm. Retrieved on 23rd January, 2020.

¹⁵ Singh Rajkumar, Hemanta& Klein, Hendrik. (2014). First perissodactyl footprints from Flysch deposits of the Barail Group (Lower Oligocene) of Manipur, India. *Journal of Earth System Science*. 123. 413-420. 10.1007/s12040-013-0396-6.

Thus, Manipur constitutes a part of the Burmese Arc, which extends northward into the eastern syntaxial bend of the Himalayas and southwards as extension of the Patkai and Kohima synclinoria trending NNE-SSW.

Seismological signature in Manipur is govern by the hills of the eastern frontier of India including Manipur whose isostatic and seismic balances are yet to be attained. Manipur falls in one of the most seismically active zones of the Trans-Asiatic Earthquake Belt. This is of tectonic origin associated with momentary relief of mechanical strain arising from mutual displacement (vertical and horizontal) of separate blocks of lithosphere where the Indo-Burma border may be a plate boundary between Indian and Burmeses plates.

Figure 6: - Geological Map of Manipur



Source: Rajkumar, H. S., & Klein, H. (2014). First perissodactyl footprints from flysch deposits of the Barail Group (Lower Oligocene) of Manipur, India. *Journal of Earth System Science*, 123(2), 413-420. Retrieved on 18th October, 2019.

2.6 GEOGRAPHY

The state have geographical area of about 22,327 sq.km. (8,621sq miles) and is isolated between Latitude 23°83'N to 25°68'N and Longitude 93°03'E to 94°78'E; at an elevation of 790 meters above the mean sea level¹⁶. Manipur is surrounded by the Blue Mountains. These mountain ranges create a moderated climate, preventing the cold winds from the north from reaching the valley and barring cyclonic storms. Two river systems viz. the Barak-Bramhaputra System and the Chindwin-Irrawaddi System drained the entire State. The Imphal or Manipur River meanders through the Manipur valley in a NW-SE direction. Its important tributaries are the Kongba, the Iril, the Thoubal, the Heirok Sekmai, the Khuga and the Chakpi rivers. Table 4, describes the district wise geographical area, population and density in the state.

Table 4: - District wise geographical area as per 2011 census.

Sl. No.	District	District Hq.	Area (Sq. Km)	Density (per Sq. Km)
1	Bishnupur	Bishnupur	496	415
2	Imphal East	Porompat	710	555
3	Imphal West	Lamphelpat	519	847
4	Thoubal	Thoubal	514	713
5	Chandel	Chandel	3,317	37
6	Ukhrul	Ukhrul	4,547	31
7	Senapati	Senapati	3,269	116
8	Tamenglong	Tamenglong	4,391	25
9	Churachandpur	Churachandpur	4,574	50

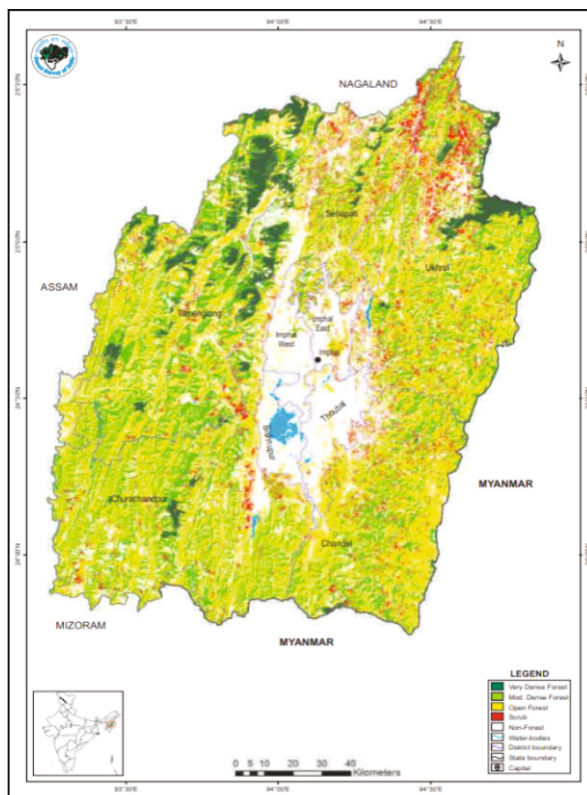
Source: - 2011 census data, retrieved on 8th October, 2019.

¹⁶https://en.wikipedia.org/wiki/Manipur#cite_note-www.e-pao.net-49

2.7 FOREST COVER AND LAND USE PATTERNS

The recorded forest area of the state is 17,418 sq.km, which is 78.01 percent of its geographical area. The reserved forest constitutes 8.42 percent, protected forests constitutes 23.95 percent and un-classed forest is 67.63 percent of the recorded forest area. Manipur has one national park and one wildlife sanctuary covering an area of 224 sq. km; which constitutes 1.01 percent of the state's geographical area. Loktak Lake with an area of 26,600 ha is a wetland of international importance that has been designated as a Ramsar site. As of 2017, the extent of the bamboo bearing area in the forests of the state is 10,687 square kilometres, about 47.82 percent of geographical area¹⁷. The figure 7 below, illustrates the forest cover in all the districts of the Manipur state.

Figure 7: - Forest Cover map of Manipur (2017-2018)



Source: India state of forest report 2019, (<https://fsi.nic.in/isfr19/vol2/isfr-2019-vol-ii-manipur.pdf>)

¹⁷Draft Manipur State Bamboo policy, 2017, by National Bamboo Mission, <https://nbm.nic.in/Documents/Policies/DraftManipurBambooPolicy.pdf>

Table 5: - Detail Statistics of Land use of Manipur as on 2017-18.

LAND USE	AREA (Ha)	PERCENTAGE
Total geographical area	2,233,000	-
Reporting area for land utilization	2,117,000	100.00
Forests	1,699,000	80.25
Not available for cultivation	27,000	1.27
Permanent pastures and other grazing lands	1,370	0.07
Land under misc. Tree crops and groves	5,950	0.28
Cultivable waste land	740	0.04
Fallow lands other than current fallows	60	0
Current fallows	140	0.01
Net area sown	383,000	18.08

Source: Land Use Statistics, India State of Forest Report, Ministry of Agriculture, GOI, 2019. Retrieved on 17th December, 2021 <https://fsi.nic.in/isfr19/vol2/isfr-2019-vol-ii-manipur.pdf>

Forest Cover in the State has decreased by 499.10 sq km as compared to the previous assessment reported in ISFR 2017. The total area for land utilization was about 2,117,000 ha in the year 2017-2018 out of which the net sown area contributes to 18.08 percent which is 3.83 lakh hectares. The table 6 below provides the district-wise state agriculture information.

Table 6: - General information of the state agriculture

Name of the district	Agriculture sector		
	Cultivated area (in ha)	Total no of farmers	No. of small and marginal farmers
Imphal West	49850	213387	47378
Imphal East	47020	194848	49505
Thoubal	46240	195319	61891
Bishnupur	47190	109937	33514
Churachandpur	43660	122655	32876
Senapati	24670	233622	47897
Chandel	21460	76238	22485
Ukhrul	21630	87929	20205
Tamenglong	38570	70675	14696

Source: - 2011 census data.

2.8 SOCIO-ECONOMIC ASPECTS

There are 41 different ethnic groups in Manipur; these groups present complex socio-economic phenomena, Meitei, Kuki-chin (generally known as Kukis) and Nagas are the major groups having Meitei ethnic group represents around 53 percent of the population of Manipur state, followed by Naga tribes at 24 percent and various Kuki-chin tribes at 16 percent. Among these Meitei people are generally residing in the valley areas whereas the Nagas and Kukis are majorly found in the hills. People are predominantly mongoloid and speak Tibeto-Burman languages. Agriculture has a significant share in the state's domestic product and provides the largest share of employment. The majority of the population in Manipur lives in villages and over two-third of it is directly or indirectly dependent on agriculture for sustenance. About nine-tenths of the total cultivated area grows cereals, mainly rice. In hilly region maize is grown extensively. Pulses, oilseeds, particularly mustard and sunflower, as well as sugarcane are grown in various parts of the state on a limited scale. Food and cash crops are grown mainly in the valley region. Traditionally people cultivate on high slopes.

At prevailing prices for 2016-2017, the Gross State Domestic Product (GSDP) of Manipur was estimated to be Rs. 22,028 crores with an average increase of 10.75 percent compared to the year 2015-2016 at constant and GSDP in 2016-17 was estimated at Rs. 16,812 crores with an average increase of 5.955 percent compared to the previous year at constant (2011-2012) prices. For the year 2016-17, the Net State Domestic Product (NSDP) at prevailing prices was estimated at Rs. 19,824 crores with an average increase of 11 percent over previous year. The Net State Domestic Product (NSDP) at constant (2011-12) prices for the year 2016-17 was placed at Rs. 15,015 crores with an increase of 6.20 percent compared to the previous year. The per capita income at constant (2011-12) prices for the financial year 2016-17 was estimated at Rs. 4,656 which was higher than that of the preceding year by about 3.9 percent¹⁸.

2.9 INFRASTRUCTURE

Transport and communication are the basic infrastructure for generation of economic activity and for bringing prosperity and well-being in the state. A well-developed transport and development system play a vital role in sustained economic growth. There is practically no railway network in the state. Two railheads – one at Dimapur in Nagaland (215 km away from Imphal) and the other at Jiribam (225 km away from Imphal) serve the state. The state has one airport at Imphal, which connects with the rest of the country. Roads, therefore, constitute the only means of the transport system in the state for the movement of men, material, and services within and outside the state. The national highways covering 967 km constitutes 11.18 percent of total road length whereas state highways constitute 7.72 percent. The total road network stands at around 8,648 km, of which surfaced roads cover 4,573 km and unsurfaced roads cover 4,075 km. The road density of the state is 45 km compared to all India having figure of 62 km¹⁹. The valley districts are better served by roads than the hilly districts. Since road transport is the only means available, the cost of incoming and outgoing goods is naturally high. The communication system comprises postal services, telegraph services, telephone, and mobile services. Over the years the state has witnessed a steady growth in communication. BSNL is the major service provider in the state. The Table 7 provides district wise general information of the state's infrastructure.

¹⁸Economic Survey, Manipur, 2016-17' by Directorate of Economics and Statistics Government of Manipur Imphal. Retrieved on 20th October 2019.

¹⁹State profile of Manipur at glance, http://dcmsme.gov.in/dips/state_wise_dips/state%20profile%20of%20manipur.pdf retrieved on 18th October 2019.

Table 7: - General information of the Manipur state infrastructure

Name of the district	No. of PHC	No. of Primary schools	No. of Panchayat Ghar	No. of Drinking water schemes	No. of Irrigation schemes
Imphal West	9	627	37	41	46
Imphal East	11	698	56	48	
Thoubal	13	571	40	57	47
Bishnupur	7	375	24	21	19
Churachandpur	11	492	-	62	74
Senapati	14	886	-	156	35
Chandel	6	373	-	52	9
Ukhrul	8	430	-	109	29
Tamenglong	6	421	-	47	37

Source: - Memorandum on the situation caused by M6.7 massive earthquake in Manipur on 4th January, 2016 by Department of Relief and Disaster Management, Government of Manipur.

2.9.1 Vernacular housing in Manipur

Vernacular architecture is the building design and construction technology developed by local people determined by their cultural and social system, economy and local climate. The predominant construction techniques have been evolved in Manipur over a period of time which has been shaped by the availability of local construction materials, rigid topography, climate conditions, numerous earthquakes and other related hazards which have impacted the region since time immemorial. The predominant vernacular architecture of the state which incorporates earthquake safe construction practices has been discussed below.

2.9.1.1 Meitei Yumjao

The dominant tribes in Manipur are belong to Meitei group of people. This ethnic group of people living in the plains usually follow the general pattern of house

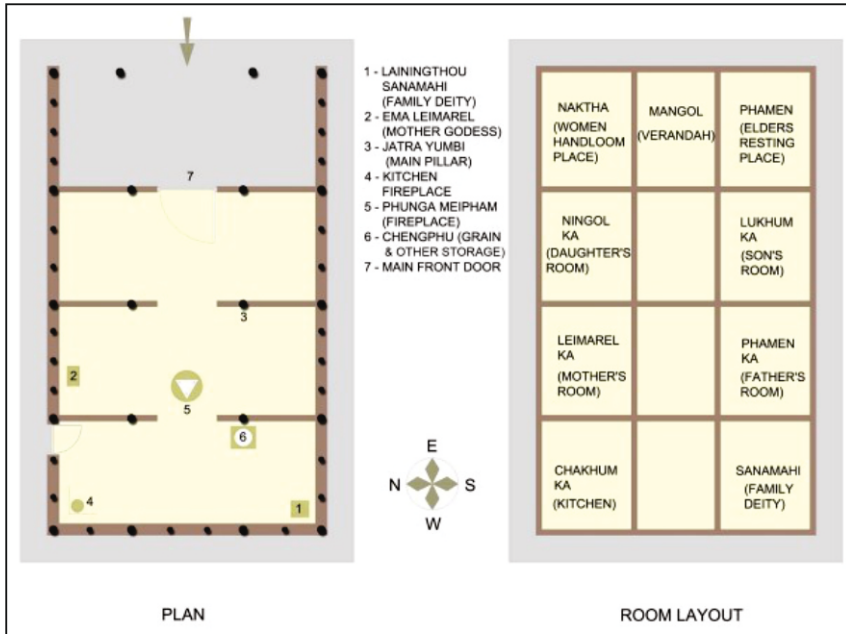
architecture prevalent in the north-east. The layouts of dwellings, and their design, are to a great extent influenced by the social and economic status of persons within the existing environment.

In the past generations, Meitei Yumjao was a perfect dwelling house of an ideal Meitei family. It was built with locally available material like bamboo of different strength and size according to the requirement. The mode of wall construction defined the type of Meitei Yumjao. The complete straw reinforced mud thick wall up to the roof height, embedding the main load bearing post bamboos with Pungjei in different heights as reinforcement steel gross rod was one type of commonly found Meitei Yumjao's houses. The distribution of the kas (rooms) in the entire house shows the concept and necessity to provide specifically separate spaces for different purposes and individuals. Different rooms (kas)- such as Naktha (women handloom place), Mangol (Verandah) or waiting room, Phamen (elders resting place), Ningol Ka (daughter's Room), Lukhum Ka or Piba Ka (son's room), Leimarel Ka (mother's room), Phamen Ka (father's room), Chakhum Ka (Kitchen) and Sanamahi (family deity), others such as grain storage (Kot) space are commonly made behind the houses and as per the requirements reflecting privacy and identity given to each member of the family.

The ancient Manipuri Yumjaos or houses are believed to be sustainable, eco-friendly and affordable. It gives a cooling effect during hot mid-summer sunshine and a warming effect during the chilling winter period. The materials used in Yumjaos are very good insulators for different temperature, humidity and pressure ranges, with moderate to high resistance from wind and rainfall. This type of structures performed well during the earthquakes except for minor damages.

The simple design and light materials used in Yumjaos also proved to effectively cope with the devastating effects of the earthquakes that rocked Manipur time and again.

Figure 8: - House plan of typical Yumjao house



Source: - BobbyKangjam, (e-pao.net). Retrieved on 12th November, 2019.
 (http://e-pao.net/epSubPageExtractor.asp?src=manipur.Arts_and_Culture.Meitei_Yumjao_The_Endangered_Art)

In general maintenance of the Manipur Yumjao house is done every year "Cheiraoba"- Meitei ChahiHouba (New Year) in the month of SajibuTha (April month) to start a fresh new life with a clean and healthy environment and pray for good fortune in the coming year. Change of thatch roof is generally done once in eight to ten years according to the thickness and nature of the thatch used.

Figure 9: - Exterior look and roofing pattern of a typical Yumjao house



Source: - BobbyKangjam, (e-pao.net). retrieved on 12th November, 2019.
 (http://e-pao.net/epSubPageExtractor.asp?src=manipur.Arts_and_Culture.Meitei_Yumjao_The_Endangered_Art)

2.9.1.2 Shing-Khim house

Shing-Khim (meaning wooden house) was constructed using locally available materials. They are single storey structures consisting of wooden planks connected by steel flats with bolts and nails. The superstructure is generally supported on a wooden post and an exterior basement wall of random rubble masonry was provided for thermal insulation. However, in many cases, these houses are constructed on RC columns or simply rested on grade. Pitched roofs made of asbestos or corrugated galvanized iron sheets (CGI) on wooden truss are common in this area. Timber joints, beams and posts, timber stud frame and boarding for wall, boarding for the floor, trussed timber rafters with boarding and asbestos/ CGI sheets are used in the construction of Shing-Khim houses. During the earthquake, Shing-Khim type of houses commonly found in rural areas reported no damage and showed good performance²⁰.

²⁰M 6.7, 4 January 2016 Imphal earthquake: dismal performance of publicly-funded buildings, Durgesh c. rai et al. current science, vol. 113, no. 12, 25 December 2017.

Figure 10: - Traditional Shing-Khim house in Manipur



Source: - Durgesh c rai et al, current science, vol. 113, no. 12, 25 December 2017.

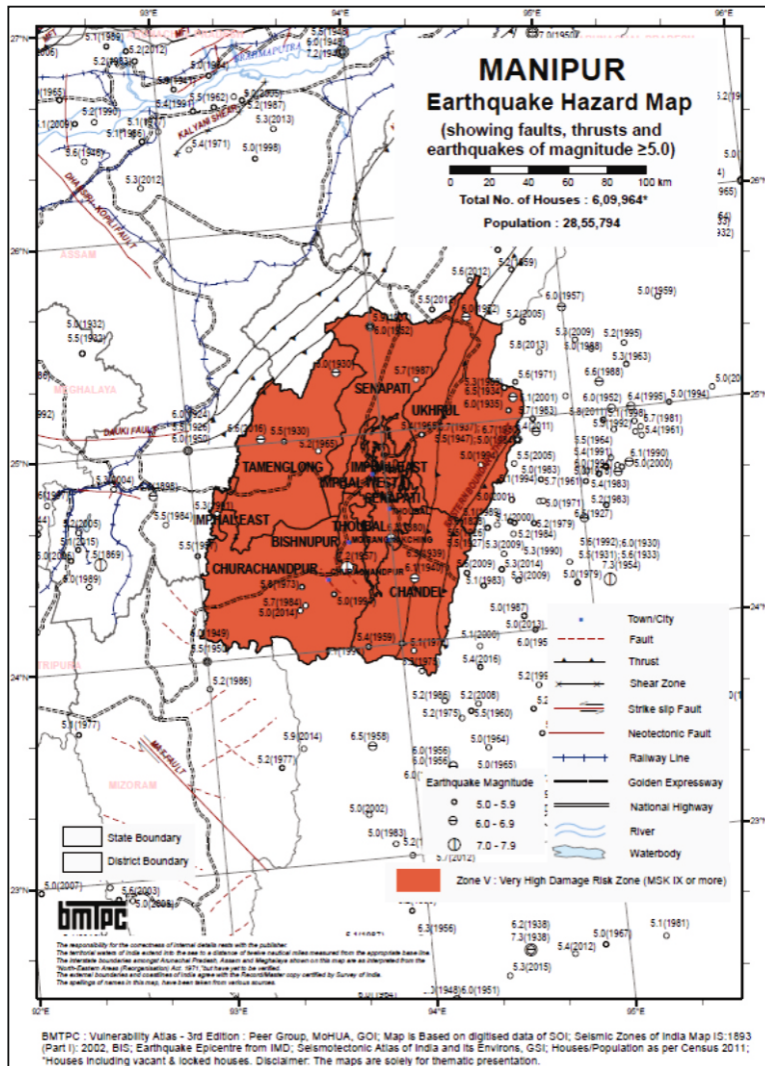
2.10 HAZARD/VULNERABILITY PROFILE OF MANIPUR

Owing to its geo-climatic, geological and physical features, Manipur is vulnerable to all major natural hazards (drought, flood, cyclone, earthquake, landslides, fires, etc.). In addition, the state is also vulnerable to biological disasters and other technological/man-made disasters.

2.10.1 Earthquake hazards in Manipur

Manipur is one of the severely affected and seismically active hazardous regions in the world due to its geographical location. The region has witnessed several large intensity earthquakes in the past causing huge loss of life and property. Based on the levels of intensities sustained during the past earthquakes, Manipur is classified as a severe seismic hazard zone (Zone-V) by the Indian code of practice for earthquake resistant design of structures i.e., IS 1893-2016. Most past earthquakes in western Manipur are shallow. But some, especially those recorded in the eastern parts and along and across the Myanmar border have greater depths. Areas lying in central Manipur are especially vulnerable to damage during earthquakes as they lie in the Imphal Valley. In Manipur, while all the districts are vulnerable to earthquakes, the damage is most likely to occur in Imphal town, which has multi-storey buildings built without any consideration for the incorporation of earthquake resistant construction. The earthquake hazard map of Manipur showing faults, thrusts and earthquakes of magnitude greater than or equal to 5.0 is given in Figure 11 below.

Figure 11: - Earthquake hazard map of Manipur state.



Source: - BMTPC vulnerability atlas, Retrieved on 20th October, 2019.

According to 2011 census data, 52 percent of the wall types in Manipur state housing stock are made with mud and unburnt brick or stone not packed with mortar; this typology will impose very high-level risk in this region. Whereas remaining wall types made with unreinforced concrete, wood and other materials, impose a medium level of risk. 91.6 percent of the total housing typology in the state is made

with lightweight sloping roofs. Together these two categories account for two-thirds of the total housing stock in the state. Both these categories of construction when not executed properly are highly susceptible to earthquake damage. The proportion of some of the traditional forms of wall construction that are quite earthquake-resilient is declining. Table 8 provides data on roof and wall types of the state's housing stock.

Table 8: - Distribution of houses by wall materials; level of risk in Manipur as per 2011 census.

Wall/Roof	Classification	Number of houses	Percentage	Level of risk under eq. zone-v
Wall				
A1- Mud &Un burnt Brick Wall	Rural	210,319	35.0	Very High
	Urban	101,919	17.0	
	Total	312,238	52.0	
A2- Stone wall not packed with mortar.	Rural	2,338	0.40	Very High
	Urban	2,357	0.40	
	Total	4,695	0.80	
Total - Category - A	316,933		52.8	
B- Burnt bricks wall and stone wall packed with mortar	Rural	26,307	4.4	High
	Urban	54,944	9.1	
	Total	81,251	13.5	
Total - Category - B		81,251	13.5	
C1-Concrete Wall	Rural	1,421	0.2	Medium
	Urban	4,548	0.8	
	Total	5,969	1.0	
C2-Wood Wall	Rural	49,875	8.3	Medium
	Urban	12,825	2.1	
	Total	62,700	10.4	
Total - Category - C		68,669	11.4	
X-Other materials	Rural	103,451	17.2	Medium
	Urban	30,331	5.0	
	Total	133,782	22.2	
Total- Category-X		133,782	22.3	

Total Houses	600,635			
Roof				
R1- Lightweight				
sloping Roof	Rural	377,822	62.9	Medium
	Urban	172,386	28.7	
	Total	550,208	91.6	
R2-Heavy weight sloping Roof	Rural	8,659	1.4	High
	Urban	9,012	1.5	
	Total	17,671	2.9	
R3- Flat Roof	Rural	7,230	1.2	Damage risks as per that the wall supporting it.
	Urban	25,526	4.2	
	Total	32,756	5.4	
Total Houses	600,635			

Source: -BMTPC housing vulnerability tables last accessed on October 21, 2019.
(http://bmtpc.org/DataFiles/CMS/file/VAI2019/risk_tables/pdf/MANIPUR_2018%201.pdf).

According to 2011 census data, the total number of houses in Manipur was 6,14,753; out of which 2,92,061 houses were pucca type, 2,98,424 houses were kutcha type and 24,268 houses were huts. The percentage of kutcha houses and huts were more than 50 percent of the housing stock in the state. The performance of these kutcha houses and huts are poor in the event of an earthquake which means the state is extremely vulnerable in the event of earthquakes. Table 9 illustrates the district wise housing pattern in the state as per census data of 2011.

Table 9: - District wise housing pattern in Manipur.

Name of the District	No. of pucca houses	No. of kutcha houses	No. of huts	Total
Imphal West	71,099	95,060	5,234	1,71,393
Imphal East	56,570	31,585	3,691	91,846
Thoubal	54,190	26,514	4,591	85,295
Bishnupur	27,729	14,807	2,355	44,891
Churachandpur	22,050	26,716	1,150	49,916
Senapati	31,262	49,022	1,764	82,048

Chandel	11,125	16,413	1,559	29,097
Ukhrul	9,465	24,518	1,807	35,790
Tamenglong	8,571	13,789	2,117	24,477
Total	2,92,061	2,98,424	24,268	6,14,753

Source: 2011 census data retrieved on 21st October, 2019.

2.10.2 Floods in Manipur

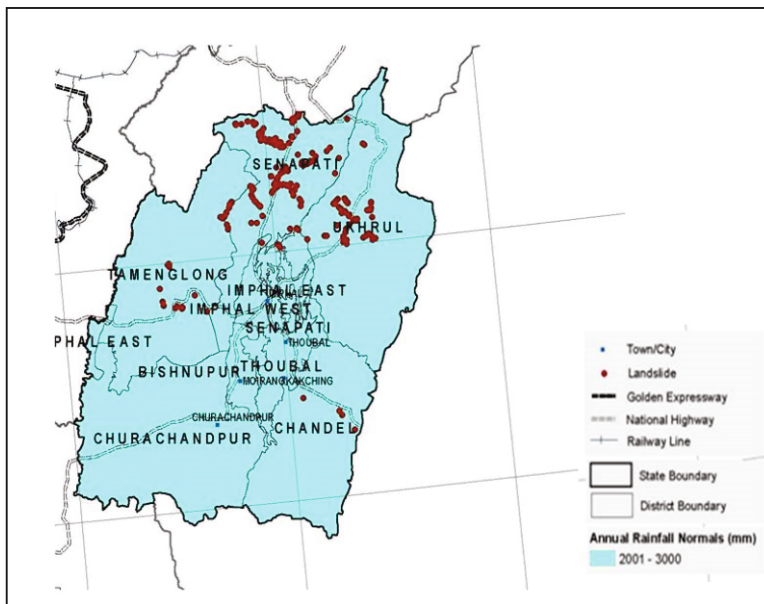
As per 2011 census data, about two-third of the population of Manipur state is concentrated in the valley region surrounded by mountain hills. Rivers from these mountain hills flow into the valley and very often lead to flash floods and landslides during rainy season. All the major river systems in the State including the Barak River are vulnerable to flash floods/flooding during the rainy season. The rapid increase in the valley's built-up areas is also an important factor for the recent increase in flash floods in urban areas²¹. There are many vulnerable points along the riverbanks of the major rivers of Manipur Valley, which get breached every year during the rainy season. In these areas, erosion, sliding, and slumping of the banks are common. River flooding is a common phenomenon faced by the state in the past however, it has manifested into a disaster during the last few years. The issue of drainage failures in urban areas, increased run-off loads in hard surfaces, large scale deforestation are causing increase in erosion capacity of flowing water. Similarly, illegal encroachment near river channels and engineering defective construction of dams and bridges, creating barriers in the free flow of excess water during heavy rainfall in catchment areas also multiplies the impact. Figure 12 illustrates the Manipur state river system and flood hazard zones.

²¹ Community Response, Preparedness and Disaster Risk Reduction A Case Study of Manipur Floods 2015, BupinderZutshi et al, European Scientific Journal.

2.10.3 Landslides

As Manipur is majorly a hilly state, landslides and mudslides are quite common. In 2004, several landslides affected Senapati District. Mudslides due to the construction of the Jiribam-Tupul Railway line have affected many families in Tamenglong District. Over the decades, due to an increase in population as well as construction in areas along the national and state highways, the incidences of landslides have shown a disturbing and damaging trend of occurrence with higher damage to life and property. Hill districts of Manipur i.e. Churachandpur, Tamenglong, Senapati, Ukhrul and Chandel are most vulnerable to landslides. Figure 13 illustrates the landslide hazards in Manipur.

Figure 13: - Landslide Incident Map of Manipur



Source: - BMTPC vulnerability Atlas retrieved on 29th November, 2019.

2.10.4 Fires

Fires are very common in the state. As bamboo is extensively used in the construction of residential huts, many a time the whole dwellings are reduced to ashes before any measures for fire fighting are instituted. In March 2009 the whole Wino Bazar area in the heart of Ukhrul district headquarters in Manipur was

destroyed completely by a devastating fire. In states like Manipur, forest fires have a close link with a livelihood. People residing within forests or nearby areas are dependent on forests for their source of income/ day-to-day fuel. The incidences of forest fire are more prevalent in the forest areas adjoining the valley. Villagers set fire to forests to get flush of new grass for their cattle and collection of firewood. The hill forests get burnt every year due to wildfire spreading from the burning of Jhum. Most of the fires occur in unclassified forests wherein the Forest department has very little or no control. The extent of the area affected by a forest fire in the state is estimated to be about 2000 sq. km. annually²².

2.10.5 Drought

In recent years, the state has been facing the prospect of drought due to diminishing rains, which is the direct result of loss of forest cover due to excessive felling of trees. In the context of Manipur, causes of drought are natural and also man-made. Several type of weather changes have also altered the normal rainfall pattern in the area leading to proneness to drought. In the last few years, it has been observed that human activities like soil erosion and deforestation have also caused drought²³.

²² Manipur state Disaster Management plan volume 1 retrieved on 29th November, 2019.

²³ Ibid 22, P 33.

3 MANIPUR EARTHQUAKE-2016

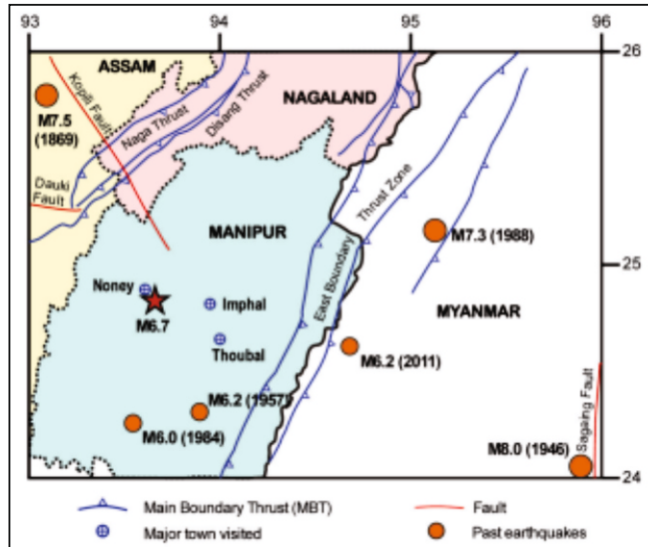
3.1 INTRODUCTION

Earthquakes of low to moderate intensity are recorded in Manipur regularly. The state of Manipur has witnessed dozens of large earthquakes, the biggest in recent times being, the 1988 M7.2 earthquake. Area wise central Manipur is especially vulnerable to damage during earthquakes as they lie in the Imphal Valley, the lowest point of which lies the Loktak Lake. Much of the valley floor provides for strong shaking from even far-off quakes as its soft soil amplifies the wave motions. Hence keeps on experiencing minor tremors off and on. The earthquakes that occurred in Manipur from 1926 onwards are tabulated in the Table 14 of Annexure.

Strong tremors have been felt across the NE region of India, around 794 lakh people experienced light shaking and 90 lakh people felt medium to strong shaking. Most of the population in Manipur received light to strong shaking and the potential damage observed was very light to moderate in the earthquake region. Table 10 describes potential damage exposed to earthquake shaking.

A powerful earthquake of magnitude 6.7 on the Richter scale struck Manipur on Monday, January 4, 2016, early morning at 04:35 am IST by killing at least 10 people and causing injuries to more than 300 people. As per the Indian Meteorological Department, the epicentre of the earthquake was identified near Noney in Tamenglong district 33km from the state capital Imphal (Figure 14). This earthquake caused huge damage to properties and lives in Imphal West, Senapati, Imphal East, Thoubal, Bishnupur and Tamenglang districts of Manipur. Due to the devastation caused by the earthquake, thousands were left homeless; the affected population took shelter in the community halls, schools, clubs, churches and relative's houses, etc. Government during relief distributed food items, emergency torchlights, syntax water tanks, and tarpaulin groundsheets to the affected people.

Figure 14: - Location of epicenter of the January 4, 2016 earthquake and past earthquakes of magnitude M 6.0 and above.



Source: - M 6.7, 4 January 2016 Imphal earthquake: dismal performance of publicly-funded buildings, DurgeshC. Rai et al.current science, vol. 113, no. 12, 25 December 2017.

Table 10: - Estimated population and potential damage exposed to earthquake shaking

Estimated Modified Mercalli Intensity	Received Shaking	Estimated Population exposed in lakhs	Potential Damage	
			Resistant structures	Vulnerable structures
I	Not Felt	0	None	None
II-III	Weak	73.720	None	None
IV	Light	794.690	None	None
V	Moderate	80.150	Very Light	Light
VI	Strong	19.410	Light	Moderate
VII	Very Strong	4.58	Moderate	Moderate/Heavy
VIII	Severe	0	Moderate/Heavy	Heavy
IX	Violent	0	Heavy	Very Heavy
X	Extreme	0	Very Heavy	Very Heavy

Source: - USGS last accessed on October 22, 2019.

Table 11: - Exposure of selected cities to the 2016 Manipur earthquake

Modified Mercalli Intensity	City	Population exposed
VII	Imphal	224,000
VI	Moirang	17,000
VI	MayangImphal	22,000
VI	Silchar	152,000
VI	Yairipok	9000
VI	Thoubal	44,000
V	Sylhet	237,000
V	Guwahati	899,000
IV	Aizawl	265,000
IV	Shillong	133,000
IV	Chittagong	392,000
IV	Agartala	203,000

Source: - USGS retrieved on October 22, 2019.

3.2 ORIGIN OF OCCURRENCE AND AFFECTED AREAS

The earthquake of 4th January 2016 in Manipur occurred in an area where India and Eurasia tectonic plates collide. The two continental plates are converging at a relative rate of 48mm/year approximately²⁴, producing a large number of earthquakes that make the region one of the most seismically active in the world. Focal mechanism indicates slip occurred on either a right-lateral fault plane dipping moderately to the east-northeast or on a left-lateral fault dipping steeply to the south-southeast. The earthquake was generated by a strike-slip fault, where sections of the Earth move like two blocks rubbing alongside each other at vertical, or nearly vertical, fracture points. The precise location of the fault where movement triggered the quake isn't known. As per U.S.G.S. it was broadly related to this plate boundary deformation at a depth of close to 31 miles, within the lithosphere, or Earth's crust and upper mantle, of the India plate²⁵.

²⁴USGS (<https://earthquake.usgs.gov/earthquakes/eventpage/us10004b2n/executive>) last accessed on October 22, 2019.

²⁵Ibid 24, P 37.

3.3 ASSESSMENT OF THE IMPACT

The preparedness and response phase in the disaster management cycle is critical in reducing the impact of disasters. The involvement of multi-stakeholders demands efficient inter-departmental coordination. Besides, it is important to constantly review and improve the systems in place. Focus on these two areas help in bringing a tangible improvement in disaster response.

Noney, a large village located in Nungba Sub-Division of Tamenglong district, Manipur, having a total of 635 families and population of 3854 (as per population census 2011), being the epicentre, experienced a high degree of destruction. Around 27 houses were partially damaged in the area and 1 mud house was fully damaged. Cracks had appeared on the roads and many other places in the area. Many deep cracks were found developed in the both sides of the hill slope of Noney aligned in the north east direction. The length of the major cracks in this area was about 300m with a maximum spacing of 1 foot. More than 80 per cent of the houses were damaged and experts pointed out that large crack lines dried available water sources due to the quake's impact. Subsidence of 6 inches was observed in the eastern portion of the crack²⁶. The cracks in the area not only passed through the soil cover but also to the weathered bedrocks indicating a strong intensity of the earthquake.

Figure 15: - Showing major cracks developed in Kabui Khullen village in Tamenglong district



Source: - *Bariamdichamang, Epao.net, retrieved on 28th October, 2019.*

²⁶Memorandum on the situation caused by M6.7 massive earthquake in Manipur on 4th January, 2016 by Department of Relief and Disaster Management, Government of Manipur.

The earthquake affected not only Manipur but other states in the region too. In Assam, it injured around 30 people and affected 40 buildings (mostly in Guwahati). People were also jolted out of sleep in Tripura. The tremors also made many rushing out of their homes and hotels in the Meghalaya capital, Shillong and other parts of the state. Cracks in buildings were also reported from Mizoram's capital, Aizawl, located 348 km from the epicentre.

3.3.1 Damage Assessment to Infrastructure

According to a joint rapid needs assessment conducted by Sphere India for 13 villages of worst affected districts of Tamenglong, Senapati and Imphal West, huge damage occurred to shelters. Around 362 households were fully damaged and 731 households were partially damaged in Nunga block of Tamenglong district, Kangpokpi, Saitu and Saikul blocks of Senapati district and Haorang block of Imphal West.

3.3.1.1 Socio-economic Infrastructure

Food security and livelihood

In the most severely affected areas the Government of Manipur had provided relief camps, supplied ration, food and even cash to the affected households. People of Imphal west and Senapati district, who were living in villages were mostly daily wage labours. Since the event was erratic, most of the families managed to accommodate at their relative's houses nearby. Some were also staying in the relief camps whose houses were completely damaged. The earthquake event hampered their daily work which impacted their livelihood. Food supply went insufficient in houses, many were not able to go and pay to buy food as most people were busy cleaning, shifting and rebuilding their houses. In Tamenlong district people with mainly agricultural practice faced no major food security issues but some families faced loss of food grains due to damage of granaries.

Functioning and accessibility of local markets soon became normal after the earthquake which gave the availability of food and other items for purchase²⁷.

Water sanitation and hygiene

Most communities in this region store water in the syntax tanks in their houses. The earthquake made water coming from daily supply mixed with mud, which forced the people to only use stored water till water quality reached to normal stage. Most of the

²⁷ Joint Rapid Needs Assessment Report: Manipur Earthquake 2016 (<https://sphereindiablog.files.wordpress.com/2016/01/10-01-2016-jrna-reports-on-manipur-earthquake-2016-6-pm3.pdf>)

people had personal toilets in their houses with no considerable damages hence people continued using them. No critical WASH needs were reported in the state. Some of the kachcha latrines constructed under Swachh Bharat Abhiyan Scheme in Tamenlong district were found damaged while some communities often practice open defecation in this region. People in this area practice safe water handling procedures such as boiling the water and using it for drinking. No critical water sanitation and hygiene issue was observed after the earthquake and no water scarcity was reported. Moreover, the water quality remained at the same level day after the earthquake was observed.

Health

The health system functioned normally with adequate resources after the earthquake. Common diseases such as cold and fever were only observed. There was no outbreak of disease reported. Even at the village level all health services functioned normally; however, some villages faced a problem where there was no primary health centre or sub-centre in their village. Two days after the earthquake health teams from both Government and private were deployed. A central medical team was also sent to the earthquake affected areas to guide the local medical teams comprising of surgeons, anaesthesiologists, orthopaedics and other technicians. In all villages, people were found in shock especially women, children and aged. People felt a general sense of not feeling well after the catastrophe.

Education

In view of rescue operations and the safety of children, the Manipur Government announced holidays for the next 7 days for all government and private schools in the state. However, all education institutions functioned normally after 10 days of the earthquake.

3.3.1.2 Physical Infrastructure

Most of the houses in Manipur are Pucca, Semi- Pucca and Kutcha types. Houses in Tamenglong and Senapati district are of semi pucca type with the cemented floor, GI sheets on the roofs and Mud Walls. Coming to kutcha houses, these are constructed with Mud walls with Bamboo or wood, wooden planks on the floor and GI sheets on the roof. Damage to Reinforced concrete buildings was observed on a very large scale in the earthquake. Several factors influenced the multiple damages; it is very hard to find out the single cause of damage. The principal causes of damage to buildings have been identified as faulty construction practices, poor quality of materials, floating columns, soft stories, and inconsistent seismic performance.

Reinforced concrete construction is the most common type of construction in Manipur. The highest concentration of RC buildings is located in Imphal city and damages were observed in such buildings. Damage to two publicly funded five years old buildings in the famous Ima Keithal market, which performed poorly during the 4th January 2016 earthquake, disrupted business of a large number of vendors. The specialty of this market is all the traders are women, the quake made a huge impact on the livelihood of the families in this region. The quake caused widespread damage to the market – broken walls, bent pillars, and cement crumbled with the tremors. The very next day after the earthquake the traders shifted their business to the public road outside. Similarly, one newly constructed 3 storey RCC building at Sports Authority of India was demolished within a few months after its construction. Central Agricultural University buildings were also damaged during the earthquake. These structures were constructed on landfill soil and performed extremely poorly. Buildings at Government Polytechnic and Inter State Bus Terminal and a few other government supervised buildings also performed poorly and were damaged during the earthquake. Severe damages occurred in the main academic block, administrative building, multipurpose hall, hostel building and administrative building etc. during the earthquake at Government Polytechnic, Imphal. Most of the walls cracked severely, almost all front columns crushed and staircases also damaged²⁸.

Although the number of buildings damaged by pounding was small, yet there were few examples where the primary causes of damage to the building was the hammering of adjacent buildings. A total of 4184 houses were damaged during the earthquake, out of which 738 houses were fully damaged, 747 houses were severely damaged and 2699 houses were partially damaged. The details of houses damaged are tabulated below in Table 12.

Table 12: - Details of houses damaged during the earthquake

House Type	Fully damaged	Severely damaged	Partially damaged	Total
Pucca Houses	104	114		218
Kutcha Houses	634	633	2,699	3,966
Total	738	747	2,699	4,184

Source: - Audit Report on Social and General Sectors for the year ended 31st March 2017 by Comptroller Auditor General of India.

²⁸ Preliminary Report on damages caused by Earthquake on 4 Jan 2016 for Government Polytechnic, Imphal by Controller of Technical Education, Manipur to the Commissioner (HR & Tech. Edn.), Govt of Manipur.

Figure 16: - Collapse of a two-storey building in Keishampat, Imphal.



Source: - Deepak oinam, e-pao.net. Retrieved on 26th October, 2019.

Figure 17: - Failure of power line near Noney.



Source: - Deepak oinam, e-pao.net. Retrieved on 26th October, 2019.

Figure 18: - Damaged Imphal Ima Market



Source: - Oxfam India. Retrieved on 8th October, 2019.

Figure 19: - Showing emergence of a new spring in Lungkhuijang, Noney



Source: - epao.net. Retrieved on 4th November, 2019.

A new spring also emerged in the hill slope of Noney as shown in Figure 19 above. The location of the new spring lies in dried-up drainage. The spring emerged in a landslide portion of the drainage at an elevation of 840m.

Figure 20: - Landslide occurred at Noney (Lungkhuijang)



Source: - epao.net, retrieved on 4th November, 2019.

3.3.2 Detailed Assessment of Damaged Structures

Recovery, reconstruction, and rehabilitation are critical phases of the disaster management cycle. They offer an opportunity to reduce risks from future hazards. 'Build Back Better' approach followed in the recovery programmes after major recent disasters give us valuable lessons on how to approach this phase. It is anticipated that the experiences mentioned would help the stakeholders in planning an effective, efficient and time-bound action plan in the event of disasters.

After the earthquake, it has been identified that the principal reasons for the building's poor performance during the earthquake were mass irregularities, lack of earthquake-resistant design practices, floating columns, soil and foundation effects, poor quality of construction materials and faulty construction practices. Damage intensity of IV to VI was observed in most of the damaged structures.

3.3.2.1 Reinforced Concrete Construction practices in Manipur

Damage to Reinforced Concrete buildings was observed on a very large scale in Imphal city. Most of the buildings here have moment resisting building framing

system with monolithic construction of reinforced slabs, beams and columns in the range of G+1 to G+5 storey height. The upper floors of the buildings are constructed with unreinforced infill brick walls. Some of the buildings are constructed with infill walls on overhanging portions or on balconies of the upper floors which create a floating box type situation as there is no clear path of transferring loads from upper floors. Most columns are designed for axial loading without considering horizontal loads and framing the action. 10 to 15cm thick reinforced slabs are monolithically constructed resting on beams. Isolated footings of around 1 to 1.5m depth are observed in foundations. Most of the buildings are constructed by considering gravity loads only, very few buildings are constructed by considering earthquake loads and ductile detailing.

3.3.2.2 Building deficiencies observed

The following sections highlight some common deficiencies observed in multi-storeyed RC buildings in Manipur. The building deficiencies can be broadly classified as local deficiencies and global deficiencies.

3.3.2.2.1 Local deficiencies

Local deficiencies lead to the failure of individual elements of the building. The observed deficiencies of the elements are summarized as follows:

Columns

In columns, inadequate shear capacity, lack of confinement in column core, lack of 135° hooks, faulty location of splice just above the floor with inadequate tension splice length, inadequate capacity of corner columns under biaxial seismic loads, the existence of short and stiff columns are main deficiencies which may lead to collapse of buildings during earthquakes fully or partially.

Beams and beam-to-column joints

The deficiencies in beams and beam-to-column joints include shear reinforcement not adequate for flexural capacity, inadequate anchorage of bottom rebar and inadequate plastic hinge rotation capability due to lack of confinement.

Slab-to-column connections

The slab-to-column connections may have deficiencies in inadequate reinforcement at monolithic connections between beam, column and slab and absence of drag and chord reinforcement. Earthquakes, however, have demonstrated that slab-column frames are vulnerable to brittle punching shear

failures in the slab-column connection region and dropping of the slab, which are costly to repair.

Structural walls

Deficiencies in structural walls include lack of adequate boundary elements, inadequate reinforcement at the slab-to-wall or beam-to-wall connections, lack of out of plane bending capacity in unreinforced masonry walls and lack of tie reinforcement in precast elements.

Deficient construction practices

Deficiencies in construction may arise from frequent volume batching, additional water for workability, inadequate compaction and curing of concrete, top 100 to 200 mm of column length casting separately leading to deficient plastic hinge region, inadequate side face cover leading to rebar corrosion and poor-quality control, etc.

3.3.2.2 Global deficiencies

Global deficiencies can broadly be classified as plan irregularities and vertical irregularities. The items left out are listed under miscellaneous deficiencies. Some of the observed irregularities are as follows:

Plan irregularities

Severe configuration irregularities in the plan occur due to re-entrant corners and variations in perimeter strength and stiffness. It is difficult to establish definite parameters and rational rules for the structural design of irregular buildings, due to infinite types of irregularities that can be expected. Buildings with simple and regular plan configuration behave well in the earthquake. The shape of the building should be judged in the plan view to check whether it's a regular or irregular configuration. Buildings with large re-entrant corners, (i.e., plan shapes such as L, V, +, Y, etc.) show poor performance during earthquakes. Each wing of such building tends to vibrate as per its dynamic characteristics which generally differ from the response of the building as whole, producing local forces causing stress concentrations at the junctions of the wings.

Vertical irregularities

In general, major configuration irregularities in elevation occur due to the presence of soft first storey/weak storey/discontinuous shear walls. Vertical geometric irregularity from set-back towers, in-plane discontinuity for columns along the perimeter of the building should be carefully identified.

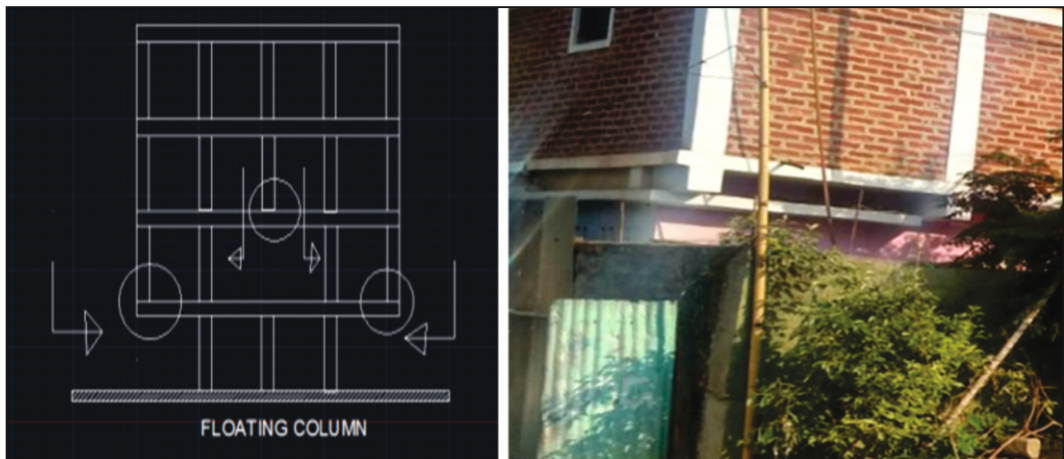
Miscellaneous deficiencies

The building performance is degraded due to the absence of tying of the lateral load resisting elements. If the stair slab is simply supported without adequate bearing length, a collapse of the slab closes the escape route for the residents. Other poor design concepts such as not providing adequate spacing between adjacent buildings or seismic joints between segments of a building also degrade the building performance. Deficiency in the analysis includes buildings designed as only gravity load resisting system, neglecting the effect of infill walls, inadequate geotechnical data to consider near source effects also leads to deficiencies.

3.3.2.3 Floating column failure

Vertical members which do not have a foundation and rest on a beam in the upper floors of the structure are called a floating column. The floating column acts like a point load on the beam, through the beam the load is transferred to the columns. Under vertical loading, this type of construction doesn't create any problem but it is very vulnerable during earthquakes as it has no path for transferring the lateral loads to the foundation. Ductile detailing of the beam-column joint is necessary to avoid this type of situation.

Figure 21: - A residential building with floating column at Singjamei, Imphal.



Source: - A case study on Manipur earthquake of 4th January, 2016 , IJETSR ,
 Dr. Th. Kiranbala Devi¹, Oinam Manoranjan Singh.

Discontinuing a load-carrying member along its length or height is harmful to the earthquake performance of the building. Discontinuing a column in the lower storey of the building is not desirable.

3.3.2.4 Short column effect

It is observed in those columns where free column length is reduced due to attached brick wall up to a certain length. If a column length cannot be fully utilized during earthquake sway due to restriction in its movement, it is also called as short column effect. To sustain the short column effect the Indian standard code IS 13920-1993 for ductile detailing of RC structures recommends providing confining reinforcement throughout the height of the column.

Figure 23 and 24 illustrates damages due to short column effect caused by partially infill brick walls during the earthquake in Manipur.

Figure 22: - Formation of short column due to partial height of brick masonry infill walls

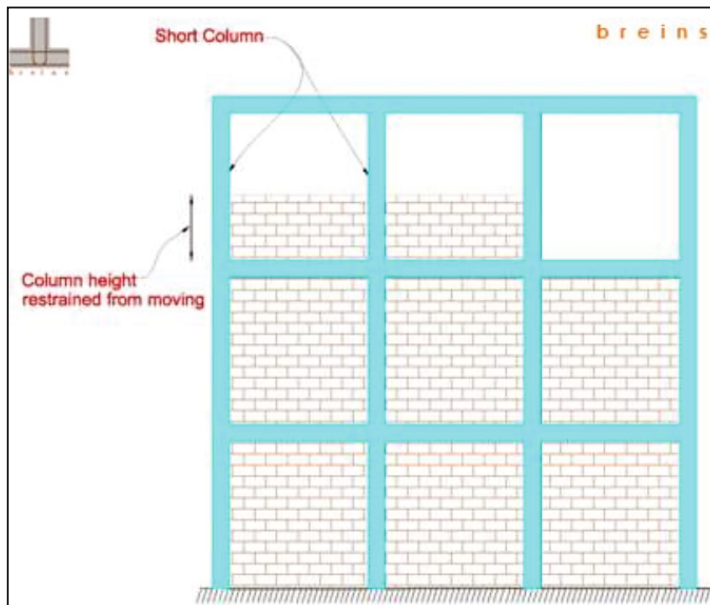


Figure 23: - Short column effect due to presence of partial infill walls at Tamenglong, Manipur.



Source: - Deepak Oinam, epao.net. Retrieved on December 6, 2019.
(http://www.epao.net/epGallery.asp?id=7&src=News_Related/Calamities_News_Gallery/EarthquakeNoney20160104_2).

Figure 24: - Column damages due to short column effect in Imphal.



Source: -Shankar khangembam, epao.net. Retrieved on December 6, 2019.
http://www.e-pao.net/epGallery.asp?id=1&src=News_Related/Calamities_News_Gallery/Earthquake20160104_5.

3.3.2.5 Soft storey failure

Rapid infrastructure development in Imphal due to urbanization and population growth is leading to scarcity of land in the urban area. The ground floors of multi-storey residential and commercial buildings are built without infill walls usually to provide open space to accommodate vehicular parking. As specified in seismic provisions, any significant change (60 percent or 70 percent) in stiffness of particular storey compared to the storey above or below is known as soft storey and significant change (80 percent) in the strength of a particular storey compared to the storey above or below is known as weak storey. In general, when the building is constructed without infill walls in the ground storey is considered as a soft storey. In such buildings, when earthquake occurs, the building oscillates like an inverted pendulum, where the maximum stress is concentrated in ground floor columns leading to create plastic hinges in the ends of the columns while upper floors move like a rigid body as seen from above Figure 2 taken from IITK, BMPTC Earthquake tips. Figure 25 below depicts an entire first storey of a building collapsed due to the soft storey effect in Saikul bazaar, Manipur during the earthquake.

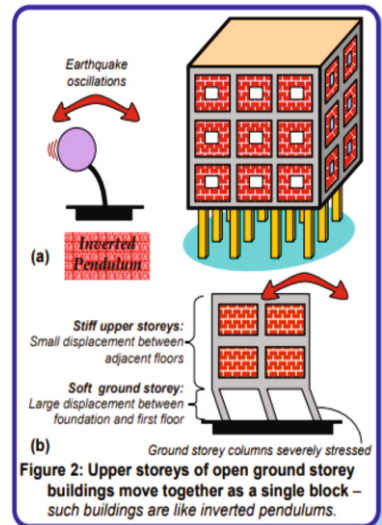
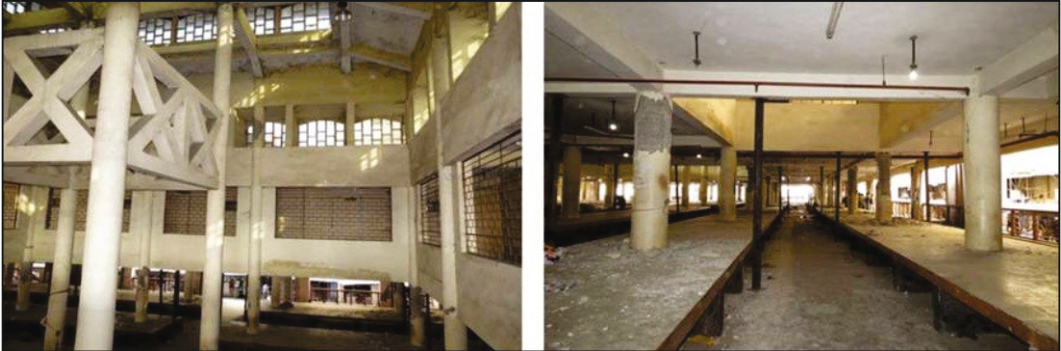


Figure 25: - Collapse of first storey of building at Saikul bazaar in sadar hills due to soft storey.



Source: - Shankar khangembam, epao.net. Retrieved on December 6, 2019.
(http://www.e-pao.net/epGallery.asp?id=1&src=News_Related/Calamities_News_Gallery/EarthquakeSaikhul20160105).

Figure 26: - Soft first storey in Laxmi Market and severe damage to column



Source: - M 6.7, 4 January 2016 Imphal earthquake: dismal performance of publicly-funded buildings, Durgesh c. rai et al. current science, vol. 113, no. 12, 25 December 2017.

Figure 27: - Failure of columns due to soft storey in Saikul bazar, Sadar hills.



Source: - Shankar khangembam, epao.net. Retrieved on December 6, 2019.
(http://www.e-pao.net/epGallery.asp?id=1&src=News_Related/Calamities_News_Gallery/EarthquakeSaikhul20160105).

Studies on the behaviour of buildings in past earthquakes indicate that the open ground story buildings have consistently shown poor performance. Special attention is required during the designing and analysis of soft stories for earthquake safety; as the plastic hinges when formed at the ends of the columns in ground floor collapse of the entire structure is unavoidable.

The newly built Saikul bazaar in Sadar hills was extensively damaged due to soft storey failure (figure 27). The design and analysis of soft storey buildings requires special attention. From the observation, it has been identified that most of the buildings having soft storeys in Imphal collapsed due to buckling of columns in ground storey where appropriate provision was not made for soft storey in design. On the other hand, in some buildings damages were reduced considerably due to appropriate provisions for soft storey. Besides soft storey effect, a combination of several other unfavourable reasons caused severe damage to buildings in this region during the earthquake.

3.3.2.6 Mass irregularities

Abundant mass prompts an increase in lateral inertia forces, reduced ductility of vertical load resisting elements and increased propensity towards collapse. Irregularity of mass distribution brings about irregular responses and complex dynamics. It may be inferred from the characteristic- sway mode of a building that the excessive mass on higher floors creates more unfavourable effects than those on lower floors. The importance of the configuration of a building was aptly summarized by Late Henry Degenkolb, a noted Earthquake Engineer of USA, as: "If we have a poor configuration to start with, all the engineer can do is to provide a band-aid - improve a poor solution as best as he can. Conversely, if we start-off with a good configuration and reasonable framing system, even a poor engineer cannot harm its ultimate performance too much."²⁹ Figure 28 shows a clock tower which was completely crushed and sat on the top of the building due to mass irregularity at Government Polytechnic, Imphal.

²⁹Venkat Reddy (2011), Engineering Geology, Pg. 112, Vikas Publishing House Pvt Ltd

Figure 28: - Damaged building due to mass irregularity at Govt. Polytechnic, Takyelpat.



Source: - Report on result of the earthquake by controller of technical education, Government of Manipur. Retrieved on December 8, 2019. (http://techedu.mn.gov.in/files/report_on_result_of_earthquake.pdf).

3.3.2.7 Maintenance condition and quality of construction materials

Generally, the life span of RCC buildings is taken as 100 years. However, after 25-to 30 years due to aging and weathering effects or inadequate maintenance and care, building may expect some repairs after 30 years. Concrete constructions need proper regular maintenance. Lack of quality control and faulty construction practices may lead to severe damages in the event of earthquakes. In many buildings corrosion of embedded steel reinforcement caused damage to the building by spalling concrete. Poor concrete placement or porous concrete and insufficient concrete cover may lead to the corrosion of embedded steel. Several buildings constructed about 5 to 10 years back were damaged due to a lack of quality control. Surprisingly some of the publicly funded buildings such as Manipur Institute of Technology, Sports Authority of India and Government Polytechnic College had a

poor quality of construction materials³⁰. Figure 29 shows damages caused to slab at Government Polytechnic, Manipur, due to poor maintenance and quality of construction materials.

Figure 29: - Corroded reinforcement in slab, beam at Government Polytechnic building, Manipur.



Source: - Report on result of the earthquake by controller of technical education, government of Manipur. Retrieved on December 8, 2019. (http://techedu.mn.gov.in/files/report_on_result_of_earthquake.pdf).

3.3.2.8 Failure due to lack of ductile detailing

The vertical members in RC buildings i.e., columns contain steel reinforcement of longitudinal bars and transverse ties. The shear failure causing shear damage of brittle nature, must be avoided in columns by providing transverse ties at close spacing, otherwise it will create severe damage to the building during the earthquakes. The large spacing of ties and absence of 135° hook ends caused brittle failure. This should be avoided by providing closed ties with 135° hooks as required according to Indian Ductile Detailing Code IS 13920-1993. Such type of hook ends prevents the opening of loops, buckling of vertical bars and consequently

³⁰M 6.7, 4 January 2016 Imphal earthquake: dismal performance of publicly-funded buildings, Durgesh c. rai et al. current science, vol. 113, no. 12, 25 December 2017.

concrete bulging. Most of the constructed buildings in Manipur observed to have a lack of ductile detailing. The columns provided in the Ima market have a circular cross-section and thicker columns were provided on the periphery to conceal PVC rainwater pipes (RWP) of 150 mm diameter inside the columns (figure 30). This further compromised the confinement of core concrete in these columns³¹.

Figure 30: - Base of first storey column with widely spaced ties and spalled concrete, (Bishnupur Market.) and new market



Source: - M 6.7, 4 January 2016 Imphal earthquake: dismal performance of publicly-funded buildings, Durgesh c. rai et al. current science, vol. 113, no. 12, 25 December 2017.

Figure 31: - Concealed drain water pipes inside the exterior columns



Source: - M 6.7, 4 January 2016 Imphal earthquake: dismal performance of publicly-funded buildings, Durgesh. Rai et.al.current science, vol. 113, no. 12, 25 December 2017.

³¹Ibid 30, P 54

3.3.2.9 Failure due to lack of earthquake resistant design

In Saikul, a women's market completely collapsed due to soft storey which was constructed less than 2 years before the earthquake. Besides soft storey, several problems in the design of structure and detailing of reinforcement lead the structure to collapse. Weak-column–strong-beam design; inadequate overlap in reinforcement bars at the column–beam junction; inappropriate stirrup details; and inappropriate spacing of reinforcement bars in the columns makes the structure weak. Figure 32 shows the failure of RCC structure due to lack of earthquake resistant design.

Figure 32: - Collapsed frame of a soft-storeyed RCC structure (women vendor's market) in Saikul.



Source: - Chandan Gosh, NIDM.

3.3.2.10 Failure due to soft soil

Local soil condition impacts seismic damage because of the enhancement of ground movement. The type of soil in Imphal involves sandy clay, silty clay, and clayey alongside organic matters deposited in various layers. As the vast majority of the soil deposits in the Imphal valley involves soft soil which is very vulnerable to cause damages to the structures during a quake, special care is required to design the structures on soft soils. The Central Agricultural University (west of Imphal) campus was constructed on landfill soil. It performed extremely poorly during the earthquake due to soft soil effect. Figure 33 depicts the damage to Central Agricultural University gate due to landfill soil.

Figure 33: - Damaged Central Agricultural University gate due to landfill soil.



Source: - Gahalaut, V.K. & Kundu, Bhaskar. (2016) *The 4 January 2016 Manipur earthquake in the Indo-Burmese wedge, an intra-slab event. Geomatics, Natural Hazards and Risk. 7. 1-7. 10.1080/19475705.2016.1179686.*

3.3.2.11 Masonry structures

Unreinforced Brick Masonry is the one of the oldest forms of construction and it has a very long history. Even today Unreinforced Brick Masonry is widely used for low-rise buildings because of economy, ease in construction, eco-efficiency, durability and various other considerations. Normally Unreinforced Brick Masonry buildings are designed for vertical loads and since masonry has adequate compressive strength, the structures behave well as long as the loads are vertical. When such masonry buildings are subjected to lateral initial loads during an earthquake, the walls develop shear and flexural stresses. Being quasi-brittle in nature, it possesses low shear and flexural strengths thus making the Unreinforced Brick Masonry buildings as one of the most vulnerable type of buildings during an event of earthquake. Masonry buildings with light roofs such as tiled roofs or GI sheets are more vulnerable to out-of-plane vibrations since the top edge can undergo large

deformation. Out-of-plane flexure of Unreinforced Brick Masonry walls had resulted in catastrophic collapses. Masonry buildings in mud mortar or lime mortar are prone to severe damage due to a lack of bond strength. Many houses with poor bonding were observed to have collapsed during the earthquake in Manipur.

Figure 34: - Collapsed masonry building at Leimakhong area Manipur.



Source: - Deepak Oinam, [epao.net](http://www.e-pao.net/epGallery.asp?id=13&src=News_Related/Calamities_News_Gallery/Earthquake_Leimakhong20160107_2), retrieved on December 6, 2019. http://www.e-pao.net/epGallery.asp?id=13&src=News_Related/Calamities_News_Gallery/Earthquake_Leimakhong20160107_2

Figure 35: - Cracks observed in a masonry building with cement mortar bond at Leimakhongarea Manipur.



Source: - Deepak Oinam, *epao.net*, retrieved on December 6, 2019.
(http://www.e-pao.net/epGallery.asp?id=9&src=News_Related/Calamities_News_Gallery/EarthquakeNoney20160104_2).

3.3.2.12 Mud and adobe houses

Mud houses are mostly constructed by poor people because of their low cost, easy availability of construction material, low-level skill for construction and excellent insulation against heat and cold. During seismic motion, heavy walls develop large inertia forces, which they are unable to resist, and thus they suddenly collapse, preventing evacuation. There are numerous examples of the complete collapse of such buildings in past earthquakes. These are very weak in shear, tension and compression. Separation of walls at corners and junctions takes place easily due to underground shaking. The cracks pass through the poor joints, after that, the walls fail either due to bending or shearing in combination with the compressive loads. Extensive damage to most of these constructions was observed during the earthquake in Manipur.

Figure 36: - Collapsed Mud wall house near the epicenter region Noney, Tamenglong.



Source: - Deepak Oinam, epao.net, retrieved on December 6, 2019.

3.3.2.13 Conclusions from the damage assessment

The 4th January 2016 earthquake in Manipur caused severe damages to buildings in this region. It is hard to find the single cause of the damage. Experience during the Manipur earthquake has shown that most of the losses occurred due to faulty construction practices. India has a thorough set of codes, standards and measures governing earthquake resistant design. These are, however, advisory in nature. An outcome of this was that the designers had little incentive to conform to the standards and codes, and even the engineered buildings did not conform to the recommendations of the relevant codes and standards. Thus, the challenges in earthquake engineering affect the whole society; furthermore, it is required to focus on understanding of seismic safety from past experiences.

Manipur 2016 earthquake is another tragic case of the overall failure of knowledge spreading on earthquake-resistant construction practices among the society and specifically, engineering community. It is suggested that the lead has to be taken by

the engineering professionals to improve the social status, dissemination of knowledge on earthquake resistant construction and the importance of the construction industry.

3.4 RESCUE, RELIEF AND RECOVERY

Due to the sudden impact of the earthquake creating adverse situations leaving thousands of people displaced and homeless, the post disaster rescue and relief started with providing shelter to affected population in schools, community halls, waiting sheds, clubs, churches etc. State Government provided supplies of requisite relief materials and provided financial assistance to the earthquake affected people. The information on injuries and damage to shelters, household items and public property were also compiled with the help of NGOs. The most affected districts were Senapati, Tamenglong, Imphal East and Imphal West.

3.4.1 Role of the government of India in rescue and relief operations

National Crisis Management Committee (NCMC) headed by the Cabinet Secretary met at 10.30 am on January 4, 2016, to assess the situation and provide all necessary help from the Government of India. The National Disaster Management Authority (NDMA) took immediate action and started coordinating search, rescue, and relief operations with the State Governments, Ministry of Home Affairs, Ministry of Defence, NDRF, Ministry of Telecom and other concerned Government departments and agencies. The Ministry of Home Affairs actively monitored the situation. Teams from the National Disaster Response Force (NDRF) were sent from Guwahati to affected areas. The injured were admitted to state government hospital in Imphal. The cost of restoration and repair of the damaged houses was estimated at Rs. 24.84 crores and Government of India released Rs.14.65 crores in September 2016 under the relief assistance for the state. On the recommendation of the NCMC, NDMA sent an expert team comprising of experts from IIT Jodhpur, National centre for Seismology New Delhi, CBRI Roorkee and NBCC New Delhi, for post-earthquake reconnaissance and survey. The team visited Imphal and adjoining areas from January 14 to January 17, 2016. The findings by the expert team revealed that the general damage was observed in many areas and unexpected severe damage to the structures at shaking intensity of VI-VII in Imphal proves lack of earthquake resistant features, poor quality of construction materials, lack of enforcement of existing regulations, negligence during the constructions and poor construction practices made huge damage.

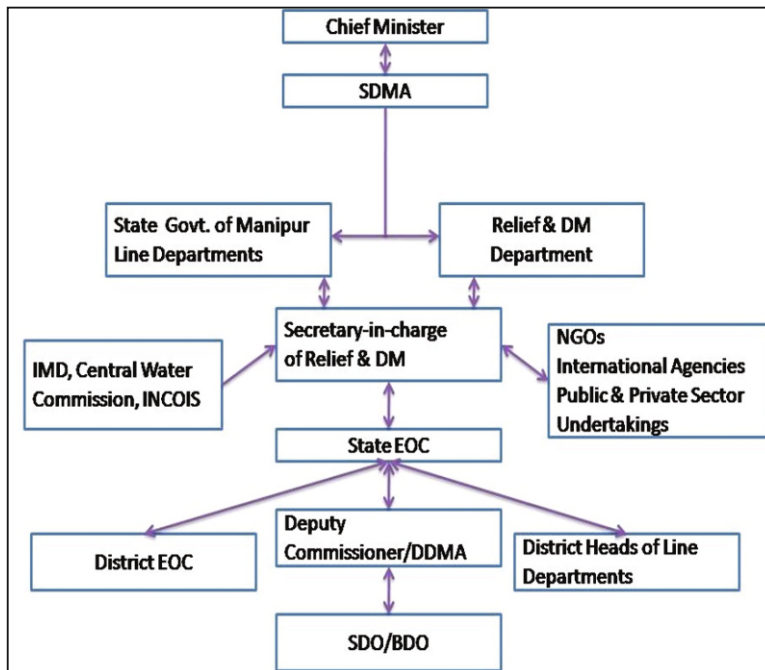
3.4.2 Government of Manipur in rescue and relief operations

Manipur State has a long history of earthquakes albeit of low magnitude. The state action plan to fight against earthquake related disaster for rescue and relief consist of five activities:

- the declaration of earthquake disaster,
- trigger mechanism on receiving the report of the occurrence of an earthquake,
- institutional mechanism of the State Government to respond to earthquake disaster,
- response mechanism of the concerned line departments along with the roles
- responsibilities of each one of them and immediate relief to be provided to the affected population³².

The disaster management structure of Manipur is depicted in Figure 37.

Figure 37: - Disaster Management structure in Manipur state



Source: - Manipur State Disaster Management Plan volume-1, retrieved on 8th October, 2019.

³²Manipur state disaster management plan volume 2. Retrieved on 20th October, 2019

The Relief & Disaster Management Department is primarily responsible for emergency response and relief in the State, while the Manipur State Disaster Management Authority (MSDMA) is designated as the nodal agency for the formulation of policies, long term planning, coordination and monitoring of disaster mitigation, and preparedness in the State. The Earth Sciences Department of Manipur University carried out seismological research and monitoring activities.

The Department of Relief and Disaster Management, Government of Manipur, carried out rescue and relief operations in coordination with the National Disaster Management Authority with the help of NDRF and the Manipur SDRF from 4th January 2016, to 15th January 2016 and relief camps were organized in the worst-affected areas.

The search and rescue operations were carried out in the Imphal city and adjoining village areas by a combined team of SDRF and NDRF under the advice of the Secretary, Relief and Disaster Management in coordination with the Deputy Commissioner concerned. In Imphal East, the team covered Kongba, Pangei, Luwangshangbam, Top Khongnang Makhong area opposite Mayanglambam Lampak, Khuman Lampak, Deulahland, etc and in the Imphal West, the team covered Iriosemba, Uripok, Keisampat, Wahengleikai, Mantripukhri, Ima market, Ministers Block, (Manipur Secretariat, North Block, Imphal), Thangal Bazar area, etc. In the operation, one fully collapsed building was found in Deulahland area under Imphal East district and some buildings were found tilted. There was no instance of the victims found trapped inside the debris of the damaged structure at the time of operation³³.

The District administration had undertaken rescue and relief operations in the earthquake affected villages and provided food, shelter, medicines and other essential items to the affected people. Relief camps were opened in three worst affected districts of Imphal West, Tamenglong and Senapati. The families kept in relief camps were offered free food and other necessary assistance in accordance with the guidelines of the Government of India as well as of the state Government. Victims were provided with food grains, kerosene, drinking water, candles, edible oil, tarpaulins etc. besides financial assistance for procuring domestic essentials. The Government of Manipur identified basic needs of the affected people and purchased some relief materials costing Rs. 406.68 lakhs. The details of relief materials procured are mentioned in Table 13.

³³Memorandum on the situation caused by M6.7 massive earthquake in Manipur on 4th January, 2016 by Department of Relief and Disaster Management Government of Manipur.

Table 13: - Relief materials procured in connection with earthquake

Relief material	Quantity (Nos.)	Amount (in lakh)
Family Tent	2000	278.00
Dispensary Tent	50	35.55
Bath and Toilet Tent	250	32.13
Shelter Tool Unit	500	23.50
LED Lantern	5000	37.50
	Total	406.68

Source: - Audit Report on Social and General Sectors for the year ended 31st March, 2017 by Comptroller Auditor General of India.

A central medical team was sent to Manipur to assist in treatment of injured people. The Manipur government decided to close all schools for a week. Telecom connectivity was more or less normal in Imphal. A team of engineers from Power Grid Corporation was sent to Manipur for assisting the government in restoration of power in the state.

As a part of the response and recovery process, the Manipur state government announced a grant of Rs 5 lakh each to the families of the deceased and promised financial assistance to the injured. The state government released Rs 1.5 crore each for Senapati, Tamenglong and Imphal West, while the other districts were given Rs 50 lakh each. Twenty-five Congress MLAs jointly announced donation of two month's salary to the chief minister's relief fund for the earthquake. The state government sought Rs 500 crore as aid from the Centre to rehabilitate victims of the earthquake and to reconstruct damaged houses and buildings. The state government sent the samples of the damaged two Ima (women's) markets to IIT Guwahati to analyse the construction materials used in the building and further decide if the buildings were to be retrofitted or reconstructed³⁴.

3.4.3 Role of NDRF and SDRF

NDRF and SDRF helped extensively in the rescue and relief during the Manipur earthquake. After the event, Disaster Management Division of the Ministry of Home Affairs (MHA), deputed two NDRF teams from Guwahati for rescue operations and another one as stands by at Silchar in Assam.

³⁴<https://sphereindiablog.files.wordpress.com/2016/01/14-01-2016-sitrep-7-manipur-earthquake-2016.pdf>

Figure 38: - Rescue and relief operations by NDRF and Army after Manipur earthquake.



Source: - <https://www.bellenews.com/2016/01/04/world/asia-news/india-6-7-earthquake-hits-manipur-killing-at-least-nine-people/>. Retrieved on October 23, 2019.

3.4.4 Role of other stakeholders

Inter-Agency groups of Manipur, and other NGO's visited the worst affected villages of Senapati (Kholmuveng, MaibungLikli, Charhazare, Motbung Nepali Part II and Makokching) Tamenglong (KabuiKhullenand, Nungnang, Noney and Nungba), Imphal West (Kanto Sabal ward no. 8, Leimakhong Chingmang Ward no. 7, Changangei and Kanglatombi) districts for field assessment on 7th & 8th January, 2016, in coordination with Government of Manipur to provide humanitarian assistance.

3.4.4.1 NGOs

As per the joint assessment report from all inter-agency group's field assessment some of the work done by active humanitarian groups are as follows: -

3.4.4.1.1 Habitat for Humanity India and PwC India

As a part of disaster response efforts, PwC India and its member organization Habitat for Humanity jointly handed over 51 reconstructed houses and a community centre to the affected people in Tamenglong district on November 21, 2016. In addition to this PWC India undertook a behaviour change communication program (BCC) to bring awareness on the importance of health and hygiene by distributing health and hygiene kits to earthquake-affected families.

3.4.4.1.2 OXFAM India

Oxfam India helped in carrying out rapid need assessment along with ADRA India and European Commission Humanitarian Aid during January 5 to 6, 2016 in worst-affected districts Senapati, Tamenglong, Imphal East and Imphal West. Oxfam India started its response in Kabui Khullen village. It reached out to help around 300 affected households from 18 villages in Tamenglong and Senapati districts of Manipur. Emergency shelter kits were distributed to 52 households in the village where the houses were destroyed. People were found to be in urgent need of shelter and relief material such as blankets and tarpaulins. Providing shelter, access to clean water and hygiene posed significant challenges in the immediate aftermath of the earthquake due to structural damages to the pipelines and damages to local water sources in the region. Oxfam distributed NFI kits (Non-Food Items) each containing one groundsheet, one tarpaulin and a solar lamp for the earthquake-affected people in Kabui Khullen village and 18 other villages in Senapati and Tamenglong districts. Oxfam India also provided 5 community filters for the affected villages where people didn't have access to safe drinking water.

Figure 39: - Oxfam's Non-Food Items kit distribution



Source: - OXFAM India. Retrieved on 8th October, 2019.

3.4.4.1.3 CASA (Church's Auxiliary for Social Actions)

CASA actively supports and works for a sustainable society by creating opportunities for the participation of socially and economically marginalized sections through networking, alliance building and strengthening of their organizations. CASA teams arrived at the earthquake-affected areas of the Manipur to interact with the victims of the quake. CASA aimed to facilitate the 810 severely affected households in 51 villages of Senapati and Tamenglong districts. It provided shelter materials and non-food items including hygiene kits to survive from biting cold. The relief materials distributed by CASA included the following:

1. Fleece Blankets-4 pieces.
2. Hygiene Kit (Each kit consists of one dettol 100ml, 1 kg detergent powder, cotton roll 200 grams, 5 tooth brushes, 1 tooth paste 100 grams, 1 pack sanitary napkins containing 8 pieces, 4 bath soaps, 2 towels, 1 soap case, 1 sewing kit including 8 needles, 10 buttons and two 2 rolls of thread, 10 shampoo sachets, one mirror and two combs.)
3. Solar lantern – one piece.
4. Tarpaulin 22x16 feet for roof- one piece.
5. Tarpaulin 20x10 feet groundsheet- one piece.

CASA coordinated with the District Administration and block administration, local churches, institutions and village committees right from assessment of the situation to relief and response. Based on the relative loss suffered both in terms of people

and property CASA identified the beneficiaries with the help of local churches and village leaders.

3.4.4.1.4 IRMA (Integrated Rural Management Association)

IRMA in partnership with Save the Children and Oxfam India responded to the earthquake for the immediate needs of the affected families in the Sadar hills area of Senapati district. Around 330 households were covered for providing various relief items from Saikul block, Kangpokpi and Saitu block of Senapati district. The affected households were provided with relief materials containing cotton blankets, solar lamps, tarpaulins, standard utility kits, standard hygiene kits, mosquito nets and education kits for 660 children. Apart from these child-friendly spaces were also set up, one in each of the clusters, with different kinds of playing facilities. IRMA continued this project from the first week of February to April 26, 2016.

Figure 40: - Relief material distribution at Molhoi village, Leimakhong cluster, Senapati district, Manipur on 19th March, 2016.



Source: - irma.org.in, retrieved on 12th October, 2019.

3.4.4.2 Local Community

In the event of a disaster, the community is always the first responder in the affected neighbourhood. Around 70-80 percent of the rescue and search operations from the collapsed buildings were carried out by the local community before the involvement of the state machinery and specialized Search and Rescue teams. The need to conduct training programmes for the local people in earthquake vulnerable areas to respond effectively in the event of an earthquake emerged very clearly.

3.4.5 POST EARTHQUAKE RECONSTRUCTION AND RETROFITTING

Damage assessment, rehabilitation, retrofitting, repair and reconstruction are critical factors involving natural disasters such as earthquakes. Due to social, technological and economic problems, reconstruction is complicated after an earthquake. For the retrofitting of existing structures, ascertainment of the level of performance of the existing building through proper assessment is important. Following such assessment, a proper strengthening scheme needs to be adopted or developed for achievement of the required level of performance for the life-safety of the occupants.

3.4.5.1 Reconstruction and rehabilitation works

The State Government rebuilt a temporary marketplace for women in lieu of the damaged market place in Saikul. The quality of this newly constructed interim market place was good. The newly constructed market was handed over to the local traders in March 2016.

Figure 41: - Interim market space for women vendors built after the earthquake in Saikul



Source: - K. Kishore and C. Ghosh, *Lessons from Manipur: Managing Earthquake Risk in a Changing Built Environment*, A. Singh et al. (eds.), *Development and Disaster Management*.

An earthquake resistant house model was introduced in Manipur after the earthquake. The house model was funded by the State Government under a special project sanctioned by the Central Government especially for Senapati district to provide urgent relief to victims affected by the earthquake. This new model was developed to withstand natural disasters especially earthquakes. Three different models were provided for the affected people under State funds integrated with the Indira Awas Yojana and the Swachh Bharat programmes. The first model included fly ash and concrete cement materials while the second model included materials from traditional Manipuri bamboo walling reinforced with GI wires to withstand an earthquake. The third model included the common features of bricks and cement structure.

Figure 42: - Earthquake resistant housing models introduced in Senapati



Source: - e-pao.net, retrieved on 28th December, 2019. (<http://e-pao.net/GP.asp?src=2..220316.mar16>).

First-time introduction of a bamboo toilet in Manipur and 5 days training at Mantripukhri forest complex, Imphal was conducted as part of relief operations by BMTPC. BMTPC is actively involved in developing and promoting bamboo-based technologies in the North-Eastern Region and other bamboo growing areas. Two types of bamboo toilets were constructed using local bamboo. The models were, single toilet for household usages and twin model for community usages like schools and other public places.

Figure 43: - Bamboo based Toilet Building at Imphal, Manipur.



Source: - BMTPC annual report 2016-2017. Bamboo varieties of Manipur are very useful for construction of low-cost dwellings. Promoting bamboo-based technology in constructions will help in promoting earthquake-resistant affordable housing.

3.4.5.2 Post Earthquake retrofitting works in Imphal

Major damages were observed in many RC columns at Inter State Bus Terminal (ISBT). It was inaugurated in 2011, but even after five years, the bus terminal was not completely functional. It consisted of RC columns with circular cross-section. Many of these columns experienced severe damage due to the earthquake. The retrofitting of damaged RC columns was done by providing helical reinforcement in place of circular ties and adding another layer of longitudinal reinforcement inside the concrete column core³⁵.

³⁵ Ibid 30, P 54

Figure 44: - A view of Inter-State Bus Terminal at Imphal after the earthquake.



Figure 45 : - Severe damage to RC columns at the Inter-State Bus Terminal, Imphal after the earthquake



Figure 46: - Retrofitting of RC column by replacing circular ties with helical reinforcement



Source: - M 6.7, 4 January 2016 Imphal earthquake: dismal performance of publicly-funded buildings, Durgesh c. rai et al. current science, vol. 113, no. 12, 25 December 2017.

Prof (Dr.) Somanath Ghosh, structural consultant for PWD, Imphal, organized non-destructive testing (Schmidt Rebound Hammer Test and Ultrasonic Pulse Velocity Test) on existing RCC structural members of New Laxmi market during 19th -23rd June, 2016. The guidelines of IS codes like IS1893, IS 456, IS 13920 and IS 4326 were considered. Findings from the assessment revealed that the RCC structure of new market, suffered from huge damages including total collapse of a few columns and severe damages to many columns. Few stair flights were damaged to some extent. Non-load-bearing internal as well as external brick walls in many locations suffered from huge damages and also needed total replacement. The retrofitting works were carried out using a composite construction concept where steel members were used along with concrete. A detailed construction methodology and specification of materials had also been adopted to achieve the ductile behaviour of the structure.

Proper assessment is required to determine the level of damage in the building. Based on that then appropriate retrofitting or strengthening system must be adopted to achieve the adequate level of building performance, as per the Indian standard code IS 13935. However, people had retrofitted and repaired their houses inappropriately in the absence of technical input, thus rebuilding the risk. Here, is an example of single storeyed RCC building in Saikul which had suffered severe damage to columns and this structure has been retrofitted by constructing a fresh RCC columns next to the original damaged columns by avoiding the beam-column joint shown in figure 47. These types of construction practices are unethical so there is a need to conduct training programs for masons.

Figure 47: - Propping damaged RCC structures by newly constructed columns not connected to the beam above in Saikul.



Source: - K. Kishore and C. Ghosh, Lessons from Manipur: Managing Earthquake Risk in a Changing Built Environment ,A. Singh et al. (eds.), Development and Disaster Management.

4 LESSONS LEARNT AND WAY FORWARD

The frequent occurrence of earthquakes in and around Manipur cannot be ruled out due to the strike-slip fault in the plate boundary region between the Indian and the Burmese plates. Therefore, earthquake resistant construction has to be a non-negotiable practice in Manipur along with the superior quality of materials and workmanship. The lessons which need to be learnt from the management of this earthquake can be summarised as follows:

- Poor construction practices are prevalent due to non-implementation of building codes and lack of enforcement of building bye-laws etc. Even the engineered buildings did not conform to the recommendations of the relevant codes and standards. Thus, the challenges related to earthquake engineering are quite high which are affecting the whole society.
- It was a case of poor dissemination of available knowledge leading to a lack of awareness towards earthquake risk and earthquake-resistant construction practices throughout the community and specifically, the engineering community. Lack of awareness among the stakeholders led to improper use of modern construction technologies along with the modern construction material, which in turn led to an increase in vulnerability of building stock in the state.
- There was a lack of awareness on the role of insurance against natural calamities such as earthquakes. Insurance may not only be used for recovering some damages but also towards earthquake risk mitigation at the state level.
- Appropriate planning and availability of Early Warning Systems are essential for enhancing the level of preparedness down to community level.
- A formal post disaster needs assessment is of great help to the administration for identifying the post disaster needs of communities and arriving at after the disaster. The PDNA will also help the state government in identifying the priority areas for recovery and reconstruction.
- There is a need to further improve the response system through regular updating of response plans at all levels and conduct of mock exercises for disaster response.
- Focus on a better mass casualty management system and medical preparedness will help in managing disaster situations effectively.

4.1 WAY FORWARD

In view of the lessons learnt from the Manipur earthquake-2016 and its relief and reconstruction efforts to build a resilient future, it would be necessary to take a multi-hazard, comprehensive and holistic approach towards disaster management. It is important to understand that for disasters like earthquakes, where precise forecasting/prediction and early warning is still in the nascent stage, a strong preparedness and response mechanism needs to be developed. To prevent damages from future earthquakes/disasters, efforts need to be made for a disaster safe built environment. At the same time, the state must have an efficient response system, for which the Manipur State Disaster Management Authority must always remain geared up and up-to-date to face the challenge. The regular capacity building and training exercises at all levels from the state level to district and local community will certainly help in providing better coordination among the stakeholders during emergency management of any disaster event.

4.1.1 Multi-Hazard Resistant Construction and Retrofitting

There is a famous saying that earthquakes do not kill people but buildings with faulty construction do; which highlights the need to manage the transition to a safe built environment and to build resilience at the state level. This transition needs to be supported by the systematic transfer of both design and execution skills for RCC construction on the one hand and the strengthening of institutional capacities for enforcement of building bylaws on the other hand. Multi-hazard safe construction practices need to be promoted at the state level to reduce the vulnerability of the built environment against various prevailing hazards.

At the same time, there is a need to document the earthquake safe traditional construction practices at state level. Such construction practices can be further researched and improved for earthquake safety. The extensive use of RCC for house construction in rural areas has increased the vulnerability of such areas in absence of trained manpower to effectively use these modern construction practices.

4.1.1.1 Standards, codes and guidelines for earthquake resistant design

On the subject of earthquake resistant design and construction of buildings, various codes and guidelines have already been framed and published by the Bureau of Indian Standard. The list of references given in this report contains all these along with other relevant information. The scope of these guidelines/codes is to highlight the essential and important features of earthquake occurrence, its effects on

habitat, and principles of earthquake resistant design and construction, which would achieve 'non-collapse' protection of buildings from the onslaught of probable maximum earthquakes. It will, therefore, be prudent that in the design and construction of earthquake safe buildings, whether by architects and engineers or in the informal sector, reference must be made to the basic code IS: 1893 (Part-1)-2002 which has been revised in 2016. For engineered buildings, additional reference will be needed to IS: 4326-1993 and IS: 13920-1993.

Two codes, namely, IS: 13827-1993 and IS: 13828-1993 are specific to the low strength masonry and earthen buildings respectively. Such buildings are mostly in the rural and semi-urban areas in the informal sector. The principles and details given in IS:13935-1993 are for improving seismic resistance of existing buildings through repair, and seismic strengthening or retrofitting techniques which are applicable to various building types, as per the nature and detail of the building.

- The earthquake hazard has been well addressed in Bureau of Indian Standards. In addition to the National Building Codes of India-2016, here is a list of different code of practices for earthquake resistant design of structures:
- IS: 1983-(Part I) 2002 "Criteria for Earthquake Resistant Design of Structures (Fifth Revision)" 2002.
- IS: 13920-1993 "Ductile Detailing of Reinforced Concrete Structures subjected to Seismic Forces - Code of Practice" November 1993.
- IS: 4326-1993 "Earthquake Resistant Design and Construction of Buildings - Code of Practice (Second Revision)" October 1993.
- IS: 13828-1993 "Improving Earthquake Resistance of Low Strength Masonry Buildings - Guidelines" August 1993.
- IS: 13827-1993 "Improving Earthquake Resistance of Earthen Buildings - Guidelines", October 1993.
- IS: 13935-1993 "Repair and Seismic Strengthening of Buildings - Guidelines", November 1993.

4.1.1.2 Retrofit strategies

Earthquake affected RCC buildings may suffer structural damages (columns, beams, slabs and reinforced concrete walls) and also non-structural damages. Architectural /non-structural components also get easily affected during the earthquake. The architectural repairs such as patching up of cracks and fall of plaster, repairing windows and doors, replacing of glass panes, repairing and checking electric conduits or wires etc., do not restore the original structural strength of structural components in the building. Any attempt to carry out only repairs to architectural/non-structural elements neglecting the required structural repairs may have serious implications on the safety of the building in context of future earthquakes. Thus, seismic retrofitting is the only solution, which is defined as the modification of existing structures to make them more resistant to seismic activities, ground motion or soil failure due to earthquake. It improves the existing buildings and increases the global capacity of the building to face future earthquakes safely.

The earthquake in 2001 at Bhuj has been a watershed event in the earthquake engineering practice in India, which brought the earthquake retrofitting of structures to the forefront. A large number of structures were retrofitted, in urban and rural areas, during the post-earthquake reconstruction programme in Gujarat. Retrofit strategy refers to options of increasing the strength, stiffness and ductility of the selected elements or the building as a whole. Goals of the seismic retrofitting programme can be to:

- Increasing the lateral strength and stiffness of the building.
- Increasing the ductility and enhancing the energy dissipation capacity.
- Eliminating sources of weakness or those that produce the concentration of stresses.
- Enhancement of redundancy in the number of lateral loads resisting elements.
- Cost effectiveness in long run.

Retrofit strategies can be grouped under local and global strategies. Local retrofit strategies include local strengthening of building elements like slabs, beams, columns, slab-to-column or beam-to-column joints, foundations and walls. Local strengthening allows one or more under-strength elements or connections to resist the strength demands predicted by the analysis, without affecting the overall response of the structure. This scheme tends to be the most economical alternative

when only a few of the building's elements are deficient. Whereas global retrofit strategies aim to stiffen the building, by providing additional lateral load resisting elements such as infill walls, shear walls etc. or to reduce the irregularities or mass of a building. The retrofitting strategy selected must be able to achieve the performance objective. A combination of retrofit strategies may also be selected under a retrofit scheme of a building.

4.1.2 Capacity Enhancement at Local Level

Focus on enhancing capacities of technical workers, community awareness, education and training of officers and staff for both disaster response and mitigation is crucial for achieving better coordination from all stakeholders to ensure the safety of people and structures sustainably. Training Need Assessment (TNA) studies must be carried out to identify the capacity gaps and address the long-term need for improving the disaster management system at all levels. Availability of resources is equally important for building capacity. Proper monitoring, maintenance and refilling of consumable items under any emergency resources including all machinery and ICT tools must be done regularly. Updating of resources like use of modern equipment for better damage assessment is highly needed; however, it is equally important that the staff is well trained in operation of new tools effectively.

One of the most challenging tasks in earthquake preparedness and mitigation is the sensitization of all stakeholders towards the prevalent seismic risk and educating and training them to participate in earthquake preparedness and mitigation efforts. There must be an emphasis on understanding and awareness building towards earthquake risk at all levels and related mitigation strategies and their implementation. It is necessary to have coordination among SDMA and all the line departments of the state government in preparedness, mitigation, and response to disasters. Once the community starts recognizing the importance of incorporating seismic safety measures in construction of residential buildings, tremendous gains can be achieved in earthquake mitigation.

Comprehensive capacity building programmes for professionals and artisans involved in construction of buildings/residences must be conducted at regular intervals. This will increase the practical implementation of the right procedures by providing quality training to all engineers, architects, local masons/artisans, bar benders and contractors in building construction and retrofitting techniques. The pool of trained human resources must be maintained and registered with proper record. The trained manpower must appropriately be certified for proof of their expertise. Increasing the capacity of qualified engineers and architects will also lead

to quality assurance and quality control in the new constructions. Apart from these, the training of trainers is also required for the teachers and professionals from technical engineering and architectural colleges. Enhancing capacity towards earthquake risk mitigation and management will also need a strong networking among technical institutes, Govt. bodies and community. Constant engagement of community in disaster management action programmes will help all stakeholders to reach people at risk and prioritize their action. At national level, the retrofitting measures are still not considered as a mitigation tool due to lack of proper awareness. It thus, highlights the need for enhancing public awareness among various stakeholders through all possible means including appropriate literature/documents distribution, related to building safety, at state level.

4.1.3 Improving the Response System and Management

Manipur has a State Disaster Management Plan (SDMP) to guide the state government under any phase of disaster management. Accordingly, after any disaster event, the concerned monitoring authority informs the Principal Secretary/Relief & DM by the fastest means. The Secretary-in-charge of Relief & DM then activates all departments for emergency response including the State EOC and District EOCs. District EOCs, State EOC and other control rooms need to work at full capacity and strength on 24X7 basis during the warning and response phase. It must be ensured that EOCs have appropriate facilities and arrangements for effective control and coordination, intelligence gathering, operations and logistics management under one roof for holistic and efficient management of disasters at the state and district levels.

Even after the formulation of SDMP, there is no reason as to why the response plan cannot be improvised especially for earthquake disasters where there is no early warning system available. To avoid confusion in post disaster response a functional Incident Response System (IRS) must be an integral part of the SDMP. Responsible Officers, Nodal Officers, Incident Commanders and Incident Response Teams (IRT) must be identified and trained as per their duties and roles at the state, district and sub-district level. An appropriate IRS requires good coordination arrangements among state, district and local level authorities through sharing responsibilities, information, resources and communication. Timely activation of the IRS and emergency response mechanism will need a time bound strategy and fixed responsibilities.

Emergency mock drills and other disaster management exercises must be kept as a dynamic process that requires proper timeline activities for SDMA and DDMA

officers to keep them motivated and updated as per the present conditions and situations. The simulation exercises are very useful towards networking of different stakeholders, improving coordination and strengthening capacities. It is of absolute importance for seismically active regions to have earthquake emergency casualty management plan at the local, district and state level. Provision for mobile hospitals must be an integral part of the State DM Plan.

India Disaster Resource Network (IDRN), which provides a nationwide resource inventory electronically, can serve the purpose of a state/district knowledge management resource and should be regularly updated.

4.1.4 Post Disaster Needs Assessment (PDNA)

Post Disaster Needs Assessment (PDNA) is a process to identify the needs for short- and long-term recoveries after a disaster. The PDNA is, generally, conducted towards the end of the response and relief phase after any major disaster event. The PDNA results in a well-integrated document for effective recovery and reconstruction needs. The PDNA process must be led by the Relief and Disaster Management Department of the affected state which is primarily responsible for emergency, response and relief at the state level. The PDNA exercise is carried out in active collaboration from other important stakeholders including the private sector and international development partner agencies. The process may help the state government in better planning and implementation during recovery. The PDNA process highlights the need for building-back-better and makes the government officials think beyond the physical reconstruction and rehabilitation towards resilient recovery. The process generally emphasises development practices with disaster management practices.

Any effective PDNA can compile all relevant information from physical loss, damages and disruption to sector-wise identification of ownership of impacted properties, overall social and economic impact and any subsequent aggregation to ascertain overall disaster effect at all levels. The process helps in identifying and estimating the short-term and long-term post disaster recovery and reconstruction needs and the priority areas.

For Manipur Earthquake 2016, Joint Rapid Need Assessment was carried out by humanitarian agencies and shared with the State Government; however, it lacked cohesiveness and reflections in terms of the works of other stakeholders. Hence, standardized assessment procedures like PDNA must be used as a standard procedure in an inclusive way to ensure transparency and accountability of the

efforts from different stakeholders. This will help promote equality and mainstreaming of cross-cutting issues so that it can be effectively linked with the disaster recovery framework.

4.1.5 Insurance against the odds

It is to point out that developed countries have exclusive property insurance policies tailor-made for specific localities. So, earthquake-prone states like Manipur need to consider having a law that encourages all stakeholders to consider property insurance seriously. The disaster insurance has multiple benefits. The survivors of calamities/disasters would not have to depend on assistance from the government or charity or heavy borrowing for repair/reconstruction etc. In addition, the insurance companies would offer housing cover only for good structures; this, in turn, would pressurise builders to construct top-quality houses/complexes. In case of poorly constructed houses/buildings, the insurance premium will be high to cover the associated risks with poor/low quality of construction, which will further encourage people to go for retrofitting of structures to reduce earthquake associated risks.

5 ANNEXURE

Table 14: - Earthquakes in Manipur flashback

Some of Major Earthquakes in Manipur Since 1926				
Date	Magnitude	Epicenter (Longitude and latitude)	Time	Location
18th August 1926	6.0	24.50N, 94.50E	23:58:48 UTC	Manipur (Indo-Myanmar Border region), East of Palel
15th March 1927	6.5	24.50N, 95.00E	16:50:32 UTC	Sagaing Division (Indo-Myanmar Border region), East of Thaungd
20th May 1927	6.0	24.50N, 94.50E	10:51 UTC	Manipur (Indo-Myanmar Border region), Near Kangpat
11th July 1930	6.0	25.00N, 93.80E	07:06:34 UTC	North of Imphal, Manipur
22nd September 1930	6.0	25.30N, 93.80E	14:19:14 UTC	Manipur, Near Karong
2nd June 1934	6.5	25.10N, 94.70E	05:04:27 UTC	East of Ukhrul, Manipur (Indo-Myanmar Border region)
23rd April 1935	6.0	25.10N, 94.70E	16:45:41 UTC	Manipur (Indo-Myanmar Border region), East of Ukhrul,
9th September 1937	6.0	24.90N, 94.70E	23:37:27 UTC	Manipur (Indo-Myanmar Border region), East of Ukhrul
21st March 1937	6.0	25.50N, 94.00E	16:12:02 UTC	Manipur-Nagaland Border region, SW of Kohima
6th May 1938	6.5	24.90N, 94.70E	03:40:57 UTC	Manipur (Indo-Myanmar Border region), East of Ukhrul
27th May 1939	6.7	24.30N, 94.10E	03:45:37 UTC	South of Palel, Manipur
11th May 1940	6.0	24.90N, 94.10E	21:00:19 UTC	Near Imphal, Manipur
8th March 1947	6.0	24.90N, 94.70E	14:33:05 UTC	Indo-Myanmar Border region, East of Imphal
30th April 1952	6.0	25.500N, 94.50E	01:49:22 UTC	SE of Kohima (Manipur-Nagaland Border region)
7th November 1952	6.0	25.500N, 94.00E	04:33:57 UTC	Manipur-Nagaland Border region, SW of Kohima
1st July 1957	7.25	24.400N, 93.80E	19:30:22 UTC	Southern Manipur, Near Moirang

30th September 1983	6.0	25.0393N, 94.6695E	10:39:27 UTC	East of Ukhrul, Manipur (Indo-Myanmar Border region)
5th March 1984	6.2	24.5160N, 94.6204E	10:39:27 UTC	Manipur (Indo-Myanmar Border region), East of Palel
6th May 1984	6.2	24.2152N, 93.5256E	15:19:11 UTC	Manipur-Mizoram Border region, NE of Aizwal
18th May 1987	6.2	25.2287N, 94.2076E	01:53:51 UTC	Northern Manipur, Near Karong
6th August 1988	7.2	25.149N, 95.127E	00:36:24UTC	East of Imphal (Indo-Myanmar Border region)
15th April 1992	6.3	24.2680N, 94.9275E	01:32:11 UTC	NW of Mawalik, Chin Division (Indo-Myanmar Border region)
18th September 2005	5.7	24.653N, 94.807 E	12:56 IST	Myanmar - Manipur border
4th September 2009	5.9	24.381N, 94.712E	19:51:03 UTC	Myanmar-Manipur border
4th January 2016	6.7	23.830 N to 25.680 N, 93.030 E to 94.780 E	04:35 IST	Manipur, Tamenglong district

Source:-Amateur Seismic Centre, <http://www.asc-india.org/>, Pune, India (last accessed on October 7, 2019.)

Table 15: - Extent of damage due to earthquake in Manipur

S.No	Items	Details
1	Total number of districts in the state	9
2	Number of districts affected	9
3	Number of villages affected	351
4	Population affected	16733
5	Houses damaged	
	Number of houses damaged	4184
	i. Fully damaged pucca houses	104
	ii. Fully damaged kutcha houses	634
	iii. Severely damaged pucca/kutcha houses	747
	iv. Partially damaged pucca/kutcha houses	2699
6	Number of human lives lost	10
7	Number of persons with grievous injuries	20
8	Number of persons with minor injuries	100
9	Damage to public properties	
	a) PWD Buildings and other buildings	Fully collapsed and severe damage in columns, beams & roofs
	b) PHED drinking water supply works	Damage to Intake arrangement, pump house, pipeline & pipe support
	c) Power	Damage to poles, transformers, conductors & lightning arresters
	d) Schools	Damage in walls, floors, doors and windows
	e) Community assets	Fully collapsed, damage in wall, floor, and roofs
	f) PHC	Severely damaged in walls, roofs, and floor
10	Estimated value of the damage to public properties	Rs. 24989.25 Lakhs
11	Estimated total damage to houses and public properties	Rs. 27473.62 Lakhs

Source: -Memorandum on the situation caused by M6.7 massive earthquake in Manipur on 4th January, 2016 by Department of Relief and Disaster Management, Government of Manipur.

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About the Author:

Dr. Amir Ali Khan, Associate Professor
Resilient Infrastructure Division
National Institute of Disaster Management
Ministry of Home Affairs, Government of India



National Institute of Disaster Management (NIDM)
(Ministry of Home Affairs, Government of India)

Plot No. 15, Block-B, Pocket-3, Sector-29, Rohini, Delhi-110042
Website: <https://nidm.gov.in>

ISBN 978-81-957965-5-7

