# Juni KhyatISSN: 2278-4632(UGC Care Group I Listed Journal)Vol-13, Issue-05, No.01, May: 2023EARTHQUAKE RISK MANAGEMENT : A STEP TOWARDS SAFETY WITH SPECIAL<br/>REFERENCE TO NORTH EAST INDIA

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#### Abstract

Earthquake is a natural calamity which strikes suddenly without any warning. It involves violent shaking of the earth's surface. Earthquake may cause huge damage or loss to life, property, economy and environment. A risk is the outcome of a surprisingly bad or good specified future cause of action and risk management is the collective effort to achieve the desired goals with the help of planning, organising, directing and controlling resources. Effective risk management requires detailed information about the event which is easily accessible, updated and understood. This paper tries to give the idea of basic concepts of risk, risk management and earthquake risk management. An attempt has been made to discuss the earthquake risk management in India and North East India. The paper also intends to analyze the safety measures adopted in the North East India. The study is carried out based on data collected from various secondary sources and represented with the help of tables, figures, etc. Powerful and damaging earthquakes have been occurring almost in all parts of India. It is noteworthy to mention here that Government of India has introduced lots of novel activities to make the earthquake preparedness more effective. North East India has been experiencing moderate to large earthquakes at frequent intervals. Government of India along with the state governments has adopted several safety measures for earthquake risk management in the country but these are not upto the mark of satisfaction to safe the loss.

Keywords : Earthquake, phenomenon, hazard, risk, risk management.

#### 1. Introduction

An earthquake is a natural calamity and one of the most vulnerable natural hazards which occurs without any warning and involves sudden and unexpected tremor of the surface of the earth. It is called a natural hazard because the occurrence of earthquake increases risk of loss or damage. Earthquake can strike at any time, at any place. Earthquakes are of tectonic in origin. There are seven major plates with numbers of minor plates of the earth's crust which move steadily and continuously in the interior part. These moving crustal or lithospheric plates are mainly responsible for the occurrence of this natural calamity. Earthquakes may cause devastating damage or loss to life, property, economy and environment where they occur. The world is becoming increasingly vulnerable to natural disasters like earthquake. Normally earthquakes having 6 or more size of magnitude on Richter scale contributing vast casualties. The 90% of casualties due to the happening of earthquake are the outcome of fallout of buildings. Other events associated with earthquake viz. landslides, avalanches, flash floods, fires, tsunamis, etc. are responsible for the remaining 10% of casualties. Earthquake may also disrupt essential services namely water supply, sewerage systems, communication, power supply, transport network, etc. and may lead to destabilize the economic and social structure of the region where it occurs. The various types of loss or damage can be reduced by adopting effective earthquake risk management strategies. The knowledge of earthquake risk management and proper implementation of its various steps or measures are very much essential in the earthquake prone and highly vulnerable areas like North East India for the safety and wellbeing of people living in the region by maintaining its congenial environment.

The study on this earthquake prone region will certainly open up new ideas to the research workers for elaborating the real facts of happenings in the area where the field workers, administrations and other organizations may engage themselves for enhancing the safety measures more better which are lacking behind. This work may enhance both academic and practical benefits to the concerned people.

#### 2. Materials and Methods

The present study is done mainly based on the data or information and concepts collected from various secondary sources. This paper is prepared after thorough reviewing of books, research papers, e-journals, internet, etc. The studies made on the earthquake happenings and risk management scenario of the recent past in the context of India and North East India by the researchers are consulted thoroughly. Finally, the understanding of the problem and findings are materialised with the help of text, table, map and diagram. The procedural steps of the earthquake risk management are mentioned and analysed sequentially in the later part of the study so that better understanding of the work may highlight. The discussion and analysis are made more elaborative so that the reality of the concerned study may expose to the readers.

# 3. Results and Discussion

# 3.1 Concept of Risk

A risk is the probability of an indescribably bad or indescribably good specified future event. It can be of two categories, i.e. positive or negative. There is no possibility of a mishap whose chance of occurrence is zero. Hence, risk occurs when the probability of similar event arises. Risk is the likelihood of loss. It is the convincing number of loss of life, persons injured, loss of property and breakdown of economic activity because of the occurrence of a natural calamity. Risk is connected with population, properties, economic activities including public services, etc. in a particular. The strength of risk associated with the level of hazard and the elements at risk located in the hazard prone areas. The level of risk is higher if the hazard corresponds with greater concentration of liabilities and properties. Risk can be depicted in structural damage, social aspect and economic failure.

# 3.1.1 Dimensions of Risk :

Risk has three independent dimensions. These are -

i) Direction (positive or negative).

ii) Degree of probability (very high or very low).

iii) Magnitude of the consequences (very small or very large).

# 3.1.2 Elements of Risk :

Risk has four major elements (Fig.1). These are hazard, location, exposure and vulnerability. *Hazard* :

Hazard is a calamitous even or the possibility of occurrence of a substantially ruining phenomenon viz. an earthquake, a cyclonic storm, a large flood, etc. within a specific time span. It is a physical effect that is generated owing to the occurrence of some natural events.

Location :

It is another important element of risk. It is always relative to the community at risk.

#### Exposure :

It is the value and importance of the various types of structures and lifeline systems in the community.

Vulnerability :

It is the level of loss of an element at risk or a number of elements. It results from the occurrence of a natural or man-made feature of a certain magnitude and expressed on a scale from 0 (signifying no damage) to 1 (signifying total damage).

# 3.2 Risk Management

Management has different meanings and these are valid in their appropriate context. A number of experts are of different opinions in defining 'risk management'. It can be defined as a conglomeration of planning, organising, directing and controlling resources to achieve desired goals. Considering this definition of management along with the definition of risk provides us a clear concept of risk management: 'Risk management is the process of planning, organising, directing and controlling resources to achieve

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given objectives when surprisingly good or bad events are possible'. To quote H. Felix Kloman, risk management is analysing and then acting appropriately on risk.

### 3.2.1 Need of Risk Management :

Majority of the people and organisations opt for management of risk for three principal reasons, these are -

i) Protecting resources from astonishing losses,

ii) Preparing to seize improbable opportunities, and

iii) Limiting uncertainty of loss or damage.

# 3.2.2 Steps of Risk Management :

H. Felix Kloman has suggested four steps of risk management, where first two constitute *analysis* and last two are the *action part*. These are -

Evaluate loss exposures :

This is the most vital step, as the loss exposure has not been recognised and analysed and it cannot be managed. The three ideas are used for genuine identification of many loss exposures. These are -

i) types of values exposed to loss,

ii) setting up of techniques or tools for evaluating loss exposures,

iii) notion of ideas to monitor the importance of loss exposure to reach the desired goals. *Appraise possible risk management technique:* 

It is used for depicting any definite loss exposures, any probability of a specified loss. The risk management tools normally fall into two major types :

i) *Risk control techniques* : to make an end of the wide losses from occurring (more particularly minimising the size and unpredictability of losses),

ii) *Risk financing techniques* : giving attention for the losses which may unavoidably

occur.

Establish a risk management programme :

This step can be grouped into two categories, namely,

i) Taking technical decision : what method should be implemented for the risk management,

ii) *Taking managerial decision* : how and when the particular method should be materialised and who should take the risk and responsibility.

Adapt to change :

Risk management occurs as the world is so dynamic with diverse problems. The perfect risk management programme needs proper initiative in changing the factors which shaped the original programme. Change never comes to an end and what is true, its process of managing risk also never ends. **3.3** Forthquake **Pick Management** 

# 3.3 Earthquake Risk Management

Earthquake risk management is the systematic process of using administrative decisions, operational skills and capacities to implement policies, strategies and coping capacity of the society and communities to lessen its impact. Effective earthquake risk management decision requires detailed information about the event which is easily accessible, updated and understood. The following steps may be adopted for the better earthquake risk management planning :

i) Identify and analyse exposure,

ii) Examine prevailing earthquake risk management techniques,

iii) Select proper earthquake risk management techniques,

iv) Implement suitable techniques, and

v) Monitor results.

#### 3.4 Earthquake Risk Management in India

The India is vulnerable to different hazards. Earthquake is one of the most devastating natural calamities. It brings untold sufferings to lives and properties. The natural hazard like earthquake has been occurring in all parts of our country. As per the recent seismic map of India (Fig.2), more than 59 % of its

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land area including the capital city of the country is under grave risk to our people. The complete Himalayan belt is regarded vulnerable to occurrence of big earthquakes of more than 8 magnitudes. This region has been experiencing by earthquakes of varying intensities in the past and similar threats remain. The Himalayas were formed by a head on collision of the Indian and Eurasian plates. The Indian plate continues to push the Asian plate northward at the rate of about 2 cm per year. This means that in every 100 years India moves 200 cm north against the Asian plate and this colliding force has been giving continuous pressure. As a result, earthquakes of various intensities have been occurring in the region. In the Himalayan region, four devastating earthquakes such as Shillong earthquake in 1897, Kangra earthquake in 1905, Nepal-Bihar earthquake in 1934 and Assam earthquake in 1950 have been recorded.

It is noteworthy to mention here that 10.9% of the total geographical area of the country falls in the seismic zone V (entire North East including all the seven states, northern part of Bihar, Kutch district, parts of Himachal Pradesh, parts of Jammu & Kashmir, Andaman and Nicobar Islands) which is highly vulnerable having great risk whereas 17.3% of its geographical area comes into the jurisdiction of seismic zone IV (entire Gangetic plain and some parts of Rajasthan) which is less vulnerable in comparison to seismic zone V. As per Vulnerability Atlas of India made by the Building Materials Technology Promotion Council, as many as 229 districts of India come under the jurisdiction of seismic zones IV and V.

Government of India has made different endeavour to make stronger the preparedness of earthquake in India with National Earthquake Risk Mitigation Project. Disaster Risk Management Programme was operated during 2002-2009 in association with the State Governments under a multidonor resource structure to minimize damages of people in hazard prone districts of the country. Under the auspices of the programme different resource materials were made ready and highly circulated for management of risk. The National Disaster Management Authority (NDMA) has made available its Guidelines on Management of Earthquakes on 16 May, 2007 for public to give something monumental the communities, city managers, decision makers etc. for better preparedness and earthquake mitigation. The guidelines expects the institutionalization of actions modelled on scientific plans putting preearthquake pre-earthquake workings such as prevention, mitigation and preparedness and post-earthquake components such as emergency response, rehabilitation and recovery. The Disaster Management Act, 2005 emphasises institutional and organizational coordination provisions for successful execution of disaster management schemes at various levels namely, national, state and district. As per this Act, the Government of India has initiated a multi-tiered institutional arrangement of the National Disaster Management Authority (NDMA) pioneered by the honourble Prime Minister, Prime Minister, the State Disaster Management Authorities (SDMAs) headed by Chief Ministers and the District Disaster Management Authorities (DDMAs) chaired by District Collectors and co-chaired by elected representatives of the local authorities of the concerned districts. These groups of working authorities have been established to strengthen the disaster preparedness, mitigation and emergency responses.

The purpose of all these activities connected with the earthquake risk management is to develop a strong community which is informed and prepared to face similar disasters in future so that it will pave the way for reducing the loss of lives and damage to property and infrastructure. The member countries of East Asia Summit (EAS) have also suggested for preparing Master Plans of Earthquake Risk Reduction with great emphasis on assessment, preparedness, mitigation, response, recovery and reconstruction in a recent workshop on Building Regional Framework (BRF) for Earthquake Risk Management held at New Delhi, November 8-9, 2012.

Although the awareness level of earthquake risk prevalent in the country, the systemic strategy to face damaging earthquakes are low. Awareness programme which has been advocating by the government and other related organizations and the overall method of reducing the damage of this natural calamity are unthinkable and not up to the mark.

3.5 Earthquake Risk Management in North East India

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The North East India has been experiencing moderate to large earthquakes at frequent intervals. As many as 18 big earthquakes (magnitude 7 or more) during the last hundred years have been occurring in this region. Normally, the region experiences earthquake with magnitude greater than 6 every year. The region has been facing the greater degree of earthquake risk and vulnerability. The high seismicity in North East India is caused mainly due to the collision tectonics between Indian plate and Eurasian plate in the north and subduction tectonics along the Indo-Myanmar Range in the east (Fig.3). This process is still going on in the region. The two great earthquakes namely, Shillong Earthquake (magnitude 8.7) in June 12, 1897 and Assam Earthquake (magnitude 8.7) in August 15, 1950 have recorded 1542 and 1520 casualties respectively.

States of NE India	Zone -V
Arunachal Pradesh	Lower Subansiri, Upper Subansiri, Lohit, East Siang, West Siang, Upper
	Siang, East Kameng, West Kameng, Tirap, Tawang, Changlang, Papum
	Pare and Dibang Valley.
Assam	Tinsukia, Sibsagar, Dibrugarh, Golaghat, Jorhat, Nagaon, Upper
	Dhemaji, Lakhimpur, Nagaon, Morigaon, Sonitpur, Darrang, Kamrup,
	Nalbari, Barpeta, Bongaigaon, Kokrajhar, Goalpara, Dhuburi, Karbi
	Anglong, Cachar, NC Hills, Karimganj and Hailakandi.
Manipur	East Imphal, West Imphal, Senapati, Bishnupur, Ukhrul, Tamenglong,
	Churachandpur, Thoubal and Chandel.
Meghalaya	East Khasi Hills, West Khasi Hills, East Garo Hills, West Garo Hills,
	South Garo Hills, Jaintia Hills and Ri-Bhoi.
Mizoram	Aizawl, Lunglei, Saiha, Serchhip, Champai, Lawngtlai, Mamit and
	Kolasib.
Nagaland	Kohima, Dimapur, Phek, Mokokchung, Mon, Wokha, Tuensang and
-	Zunheboto.
Tripura	North Tripura, South Tripura, West Tripura and Dhalai.

Table-1 : List of districts located in Seismic Zone-V

Source : BMTPC, 2006

# **3.6 Step Towards Safety**

It is the prime importance and duty of all involved with the earthquake risk management process to safeguard the people, property and environment of the entire North East India. National Earthquake Risk Mitigation Project (NERMP) of Government of India has also formulated several safety measures or steps for the risk management of earthquake in India together with North East India. Some of the important measures or steps of safety are as follows :

1. Proper assessment of earthquake risk :

The proper earthquake risk assessment can minimize the losses or damages from the occurrence of future events. The developing scenarios of earthquake happenings in the region is to be well analysed and various programmes implemented are to be examined.

2. Construction of new structures :

Any type of new constructions, public infrastructures, amenities and assets upcoming in the region will have to abide by the codal provisions of the National Building Code 2005 as the North East India falls in very high seismic risk zone. Further, it is also necessary to follow the earthquake resistant building codes. The administrators holding respective positions are given exclusive responsible for granting building permissions, granting bank loans, monitoring building plants, analysing soil types before construction, etc.

3. Review of safety of existing lifeline structures :

The bounden duty of the District administration is to scrutinise the critical lifeline infrastructure and public properties and to bring out structural safety audit of similar structures. In this connection, the

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administration may take the guidance of trained technical personnel. On the basis of the study, the preferential list of such structures has to be prepared by the district administration. After that the seismic strengthening and retrofitting has to be identified with the help of State Government resources. Moreover, it is to be mentioned that the National Disaster Management Authority in association with the State Governments has already completed the retrofitting of a number of district hospitals and schools from the North East India.

4. Capacity building of technical person :

The architects, engineers and masons involved in the construction activities must have supported the technical skills and knowledge of earthquake resistant techniques relating to construction. The structural safety audit of the existing critical structures and seismic strengthening and retrofitting are also at the same time necessary. Besides, the NDMA has taken up the initiative of National Earthquake Risk Mitigation Project in association with State Governments in the seismic zones IV and V. The capacity building of technical persons is another significant activities expected in this project. It is monitored by carefully chosen engineering and architecture colleges including Industrial Training Institutes, Polytechnics and persons from IIT, Guwahati in the states of North East India. The training programmes under this project will definitely make better the capability of technical personnel in the industries to agreeing to do earthquake resistant construction.

5. Public consciousness on earthquake risk and vulnerability :

The stakeholders are required to have larger consciousness on the earthquake risk and vulnerability in the states of North east India to minimize the loss of lives, damage of properties and infrastructure. The National Disaster management Authority in association with the State Governments and State Disaster Management Authority introduces a lot of public consciousness drives on earthquake risk and vulnerability in the earthquake prone areas with the help of print and electronic media, hoardings, street plays, wall paintings, etc. Special programmes may be arranged in the educational institutions for the students to spread the public consciousness along with their neighbouring communities. The Disaster Management Task Forces at the village level have been established in different villages to support tasks namely, search and rescue, need and damage assessment, first aid, water and sanitation, shelter management, searching and disposal of dead bodies, etc. in the affected localities. The general consciousness of the programmes will also be assisted by similar stakeholders such as corporate sectors, NGOs and the public having common interests namely, Mahila Mandals, Self Help Groups, Yuvak Mandals, etc.

6. Regulation and enforcement of a techno-legal system :

The great loss of lives and damage to people may be reduced by complying set of rules and executing a perfect techno-legal system. This system includes modification of town planning bye-laws, building by-laws, earthquake resistant building codes, development control regulations, National Building Code (2005), etc. in the areas covering from urban to sub-urban and rural areas with different local administrative bodies. The actual implementation of a techno-legal system is important for the creation of a conducive environment. It may assure the security of people resided in disaster prone areas.

7. Institutional ability development :

Government of India has made stronger the institutional ability in the North Eastern states for disaster management with the proper involvement of each and every concerned State Governments. It includes making stronger communication linkages including seismic monitoring stations. Moreover, the improvement of scientific capability of related institutions covering academic, professional and research institutions will be of utmost necessity. The inclusion of disaster management contents in the institutional syllabi, research and development activities, documentation of techniques and healthy practices, etc. in the earthquake affected areas.

8. Advanced emergency response ability in the region :

Government of India has provided experienced and better persons of the National Disaster Response Force in Guwahati for helping the people living in the states of North East India. Well trained

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members of the group have already visited different parts of the region and made necessary discussion with the concerned officials and district administrations. They have also conducted different programmes for improving capability building with the communities. The respective State Governments have been advised to set up State Disaster Response Force units from their available police force and they should be well prepared with necessary life enchanting equipments as early as possible. In this connection, the volunteers of the Nehru Yuvak Kendra, Indian Red Cross Society, National Social Service, National Cadet Crops, Home Gaurds and Civil Defence, etc. will also be prepared for carrying out specific disaster management related tasks to help the administration. Further, the members of the Gram Panchayats will also be made confident to take the role of a dynamic leader in working disaster management endeavours effectively at the local levels.

9. Mitigation :

In practice, there is no universally well acceptable solution to alleviate disaster risk, as the aim is to reduce the effect of disaster. The successful mitigation results in a substantial change in the awareness level of the people at risk. It may change the existing physical environment of the society as a whole.

10. Preparedness :

The preparedness implies the condition of readiness to manage a threatening disaster and the effects about the things. The concept of earthquake preparedness can help in making plan for emergencies arising from an earthquake. Preparedness contains educating the masses on the causes and characteristics of an earthquake and what they should perform if earthquake occurs. The preparedness of community is important for minimising the bad effects of earthquake. Different public consciousness programmes can be planned and executed properly to touch every stakeholder and may essentially reduce the social impact and property loss of an earthquake.

11. Recovery, rehabilitation and reconstruction :

The post-earthquake evaluation of damages or losses is to be made immediately as far as possible for its recovery, rehabilitation and reconstruction. Provisions for sufficient relief camps must be there for the affected people immediately after an earthquake and rehabilitate them proper way in secured place. The design of acceptable post-earthquake shelter for areas of various geographical conditions is fundamentally important. All areas of the community and local bodies should at the beginning highlight search and rescue of affected mass. It is important to provide emergency medical assistance specially during the first 72 hours. Special care should be provided to the survivors who need insistent relief assistance viz. food, water, shelter, medicine, cloth, etc. immediately after the earthquake occurrence. At the same time, proper heed should be paid for reestablishing different communications, reopening damaged roads, conducting loss or damage assessment, searching assessment and rescue in remote areas. Programmes should be implemented to rejuvenate the economy of the earthquake prone areas. Financial support by means of one time immediate free support and in the later stage by providing loans to individual and business persons from the concerned organisations may be provided to strengthen the wrecked economy of the affected people.

12. Action plan for earthquake risk assessment and management :

Action plan should be taken for proper earthquake risk assessment and management for the entire North Eastern Region to safe its people, property and environment as far as possible. Government, NGOs, other organisations and active participation of common people are essential to fulfill the objectives of the plan prepared for.

#### 4. Conclusion

Earthquakes have been causing huge damage or loss to life, property, economy and environment in North East India. That is why the knowledge of earthquake risk management and its proper implementation is very much essential for all sectors of society more specially in this region.

Government of India has introduced various pioneering initiatives along with the state governments to strengthen the earthquake risk management in the country in general and seismic zone-V

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in particular through NDMA, SDMA, SSMA and NERMP. The Government has also initiated for preparing and improving Master Plans for Earthquake Risk Reduction paying special importance on assessment, preparedness, mitigation, response, recovery and reconstruction in the entire country.

It is noteworthy to mention here that although the steps or measures of earthquake risk management have been adopted in the country including North Eastern Region, these are not upto the mark of satisfaction to safe the loss or damage. Alerting all personnel to risk management concerns and stimulate positive communication among everyone is more important in earthquake risk management.

Proper management of earthquake risk requires the cooperation of administration and common people, because earthquake risk closely links with us. We should work morally in a collective spirit towards each other in reducing earthquake risk for the better safety of the people. What is more in this respect, we at least need to give and envisage maintaining sincerity in our communications. We have also check out the rights and duties of the communities at local and regional levels relating to risk. Rights and duties are necessarily correlative, as the saying goes.

Earthquake risk can be minimized by developing better and widespread understanding about the risk and strenuous efforts from the stakeholders. To achieve the desired goal of Disaster Resilient North East by conforming the security and well-being of its people, property and environment, close association and coordination among the National Disaster Management Authority, North East Council and various departments of Government of India and State Governments are topmost necessary.

The change is the ultimate reality of the world and hence the process of managing risk of any event including earthquake never ends. We all must have to ready to adopt the changing situation as we can't stop the occurrence of earthquake with our maximum effort including various managerial steps to minimise further devastation.

The present study may provide the scope for further study to improve it in a better way so that safety of all properties and lives may be ascertained in the region from the occurrence of natural calamity like earthquake. The use of geo-spatial technique in the earthquake risk management may be considered more effective than the techniques used ever before in this respect.

#### References

1. Agarwal, P.N. : A recent earthquake in Northeast India: *Proceeding 2<sup>nd</sup> International Seminar On earthquake prognostic*, Berlin, Friedr. Veiweg and Sohn., 24-27 (1986)

2. Angelier, J., Baruah, S. : Seismotectonics in Northeast India : A Stress Analysis of Focal Mechanism Solutions of Earthquakes and its Kinematic Implications. Geophysical Journal International, **178** (1), 303-326 (2009)

3. Bapat, A., Kulkarni, R. C., and Guha, S. K.: Catalogue of Earthquakes in India and Neighbourhood from Historical Period up to 1979, Indian Society of Earthquake Technology, Roorkee, India (1983)

4. Bhatia S.C., Kumar M. R., and Gupta H. K. : A probabilistic seismic hazard map of India and adjoining regions, Annali di Geofisica, **42**, 1153–1164 (1999)

5. Bhattacharjee, S. : Earthquakes in Northeast India Mitigation - A Possible Approach, Status of Landslides in Northeast India and Natural Disaster Management (Ed. G. D. Sharma), Assam University Press, 77-84 (1998)

6. Bilham, R. and England, P. : Plateau 'pop-up' in the great 1897 Assam earthquake, Nature, **410**, 806–809 (2001)

7. Coleman, T.S. : A Practical Guide to Risk Management, Research Foundation Publications, New York, (2011)

Evans, P. : The Tectonic Framework of Assam, Journal of Geological Society India ,5, 80–86 (1964)
Gupta, H.K. and Singh, H.N. : Seismicity of northeast India region: Part II: Earthquake swarm precursory to moderate magnitude to great earthquakes, Journal of Geological Society of India, 28, 367-406 (1986)

10. Gupta, H.K. : Patterns preceding major earthquakes in northeast India, Current Science, **64** (11&12), 889-893 (1993)

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# (UGC Care Group I Listed Journal)

#### **ISSN: 2278-4632**

# Vol-13, Issue-05, No.01, May: 2023

11. Head, G.L. : Risk Management - Why and How : An Illustrative Introduction to Risk Management for Business Executives, International Risk Management Institute, INC., Texas (2009)

12. Imtiyaz, A.P. and Avadh, R. : Probabilistic Assessment of Earthquake Hazards in the North-East Indian Peninsula and Hindukush Regions, Pure Applied Geophysics, **149**, 731–746 (1997)

13. Kaila, K. L. and Rao, N. M., : Seismic zoning maps of Indian subcontinent, *Geophys. Res. Bull.* **17**, 293–301, National Geophysical Research Institute, Hyderabad, India (1979)

14. Kayal, J.R. : Earthquake source process in Northeast India: A review. *Himalayan Geology*, **17**, 53-69, (1996)

15. Kayal, J.R. : Seismicity of Northeast India and Surroundings - Development over the past 100 years, Journal of Geophysics, **19** (1), 9-34 (1998)

16. Kayall, J.R. : Shillong plateau earthquakes in northeast India region: complex tectonic model, Current Science, **91**(1), (2006)

17. Khattri, K.N., Rogers, A.M., and Algermissen, S. T., : A seismic hazard map of India and adjacent areas, *Tectonophysics* **108**, 93–134 (1984)

18. Oldham, T. : A catalogue of Indian earthquakes from the earliest time to the end of A. D. 1869, *Mem. Geological Survey of India*, **19**, 163-215 (1883)

19. Menon, N.V.C. : Earthquake Risk Management in the North East, Dialogue, **10** (3) (2009) 20. Nath, S. K. : An Initial Model of Seismic Microzonation of Sikkim Himalaya through thematic mapping and GIS Integration of Geological and Strong Motion Features, *Journal of Asian Earth Science* , **25**, 329–343 (2005)

21. Nath, S.K. et al : Seismic Scenario of Guwahati City; *Proceeding of International Workshop on Earthquake Hazard Mitigations*, 210–218 (2007)

22. NDMAHomepage,http://www.ndma.nic.in3Dec2012

23. NIDMHomepage,http://www.nidm.gov.in4Dec2012

24. Parvez, I.A. and Ram, A. : Probabilistic Assessment of Earthquake Hazards in the North East Indian Peninsula and Hindukush Regions. Pure and Applied Geophysics, **149**, 731-746 (1997)

25. Das, S. et al : A Probabilistic Seismic Hazard Analysis of Northeast India, Earthquake Spectra, **22** (1) 1–27 (2006)

26. Sankar, K. et al : Earthquake hazard in Northeast India – A seismic microzonation approach with typical case studies from Sikkim Himalaya and Guwahati city, *Journal of Earth System Science*,**117** (2), 809–831(2008)

27. Shrivastav, P.P. : Earthquake Disasters in the North Eastern Region The Malady and the Remedy. In National Workshop on Earthquake Risk Mitigation Strategy in North East (Ed. by P. G. D. Chakrabarty and C. Ghosh), Guwahati, 165-175 (2011)

28. Steinbrugge, K.V. : Earthquakes, Volcanoes and Tsunamis : An Anatomy of Hazards, Skandia America Group, New York (1982)

29. Tiedemann, H. : Earthquakes and Volcanic Eruption: A Handbook on Risk Assessment, Swiss Reinsurance Company, Switzerland (1992)

30. Tiwari, R.P. : Earthquake Hazards and Mitigation in India with Special Reference to Northeastern India, ENVIS Bulletin **8** (2), 15-22 (2000)

31. Sarma, H., Borah, J., & Sarma, T. RELATIONSHIP BETWEEN HEARD SIZE AND MILK PRODUCTION IN GREATER GUWAHATI REGION OF ASSAM, INDIA,(2022)

32. Sarma, T., & Saikia, S. (2021). Status Of Groundwater Arsenic Contamination And Human Health In Hajo Circle, Assam, India. *NVEO-NATURAL VOLATILES & ESSENTIAL OILS Journal/ NVEO*, 11297-11305.

33. www.nicee.org accessed on 30-11-2012.



Fig.1. Elements of Risk



Fig.2. Recent Seismic Zone Map of India (IS 1893-2002)



Fig.3.Techtonic setting of North Eastern Region of India and its surroundings (after Evans, 1964 and Krishnan, 1960)