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IMPACT OF EARTHQUAKE DISASTERS ON NEW URBANIZATION PATTERN IN NORTH EASTERN REGION OF INDIA

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ABSTRACT

Earthquake disasters, which are basically related to slow earth processes, have remained common phenomena in the recent past and have created significant havoc. The North Eastern Region of India has remained geologically sensitive and is under constant threat seismically. The region has a complex structural framework, and comprises seven major geo-tectonic terrains, viz., Eastern Himalaya, Mishmi Block, Naga Hills, Assam Valley, Shillong Plateau & Mikir Hills, Arakan-Yoma Folded Belt, and Bengal Basin, which are geodynamically active. Seismicity is very common in the region, which has been experiencing earthquakes ranging from major to minor intensity frequently. The seismic studies indicate that ArakanYoma/Tripura folded belt region is most active, followed by Shillong Plateau, NE Himalaya and Bengal Basin. In Arunachal, seismicity is aligned along the Main Boundary Thrust, Main Central Thrust, Lohit, and Mishmi thrusts. Unplanned development, particularly concrete construction, is increasing day by day without consideration of their vulnerability to earthquakes, especially in the hilly areas. An example from Itanagar, the capital of Arunachal Pradesh, demonstrates that the capital towns, urban towns, and business towns of this region have reached beyond the critical level of their bearing capacity. Population pressure is forcing people to construct their houses on the hill slopes. This is disturbing the natural slope, thereby increasing landslide

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hazards. The concern is not just increasing population, but also the eco-system which is prone to natural hazards. The people are constructing concrete buildings, most of which are without engineering design, and even the houses have paved the way for multistorey masonry buildings. This has increased vulnerability to the disaster and, therefore, there is a strong need for proper planning to ensure sustainable development. The need is to have a long-term program of natural hazards assessment and mitigation through an integrated approach with participation of the society and scientific community. An effective strategy for disaster mitigation has been suggested in this article.

INTRODUCTION

Earthquake disasters in the recent past have created several havocs. Valdiya (1999) has demonstrated that slow-going geological phenomena in the last 10,000 years have effected, and continued to threaten, the security of the environment and the people. He further stressed upon the need for having a better perspective of the schemes of the things by analyzing the development in the last 10,000 years of the Holocene, and to chalk out the strategies for coping with the resultant problems accordingly. This may also be relevant to the North Eastern Region (NER) of India.

The NER encompasses eight states (see Figure 1), viz., Arunachal Pradesh, Assam, Meghalaya, Nagaland, Manipur, Mizoram, Tripura, and Sikkim. The region as a whole has remained geologically and geodynamically sensitive. There are three mountain systems of different origins that exist in juxtaposition (Valdiya, 1998). These are: i) the Himalayan Ranges, ii) the Mishmi Hill Ranges, and iii) the Naga-Patkai-Arakan Ranges (see Figure 2). The NER falls under the high seismic zone (i.e., Zone V) of India (see Figure 3), and has been identified as one of the six most seismic prone zones in the world. Historical seismic data show that all the tectonic zones of NER have remained seismically active for the past 100 years. The region has a complex structural framework, comprised of seven major geo-tectonic terrains, viz., Eastern Himalaya, Mishmi Block, Naga Hills, Assam Valley, Shillong Plateau and Mikir Hills, Arakan-Yoma Folded Belt, and Bengal Basin (see Figure 4), which are geodynamically active. There have been a number of thrusts, faults and lineaments in these terrains, viz., Himalayan Frontal Fault (HFF), Main Boundary Thrust (MBT), Main Central Thrust (MCT), Bame Fault, Lohit Thrust, Mishmi Thrust, Brahmaputra Fracture, Kopili Lineament, Dauki Fault, Yamuna Lineament, and a number of thrust slices of Arakan-Yoma Folded Belt. These thrusts and lineaments represent zones of crustal weakness and are the source of earthquake activity, which is evident from the earthquake epicenters found, aligned along the thrusts and lineaments. In fact, the Arunachal Himalaya is being pressed by the northward moving Indian shield striking against the Asian Plate. The Naga-Patkai-Arakan

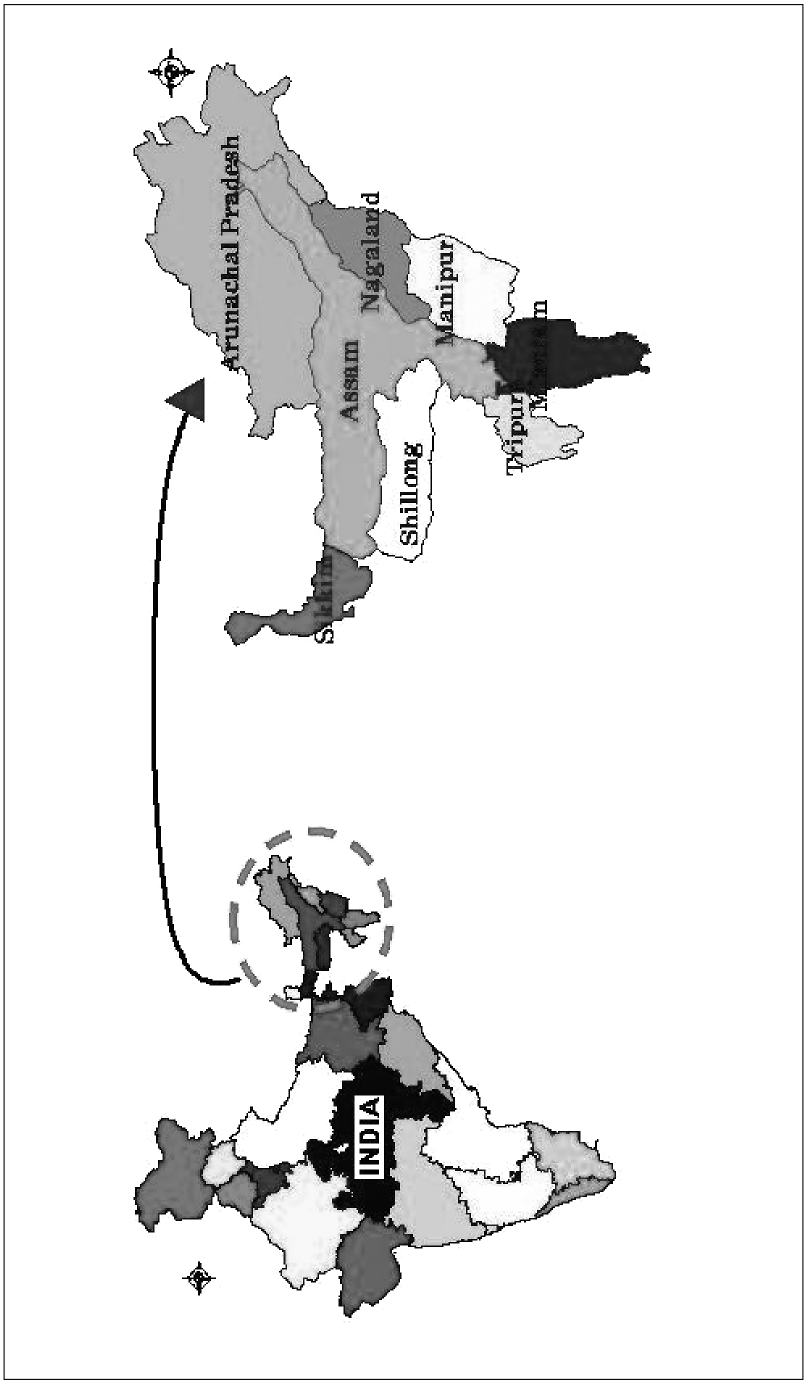

Figure 1. Location map of the North Eastern States of India.

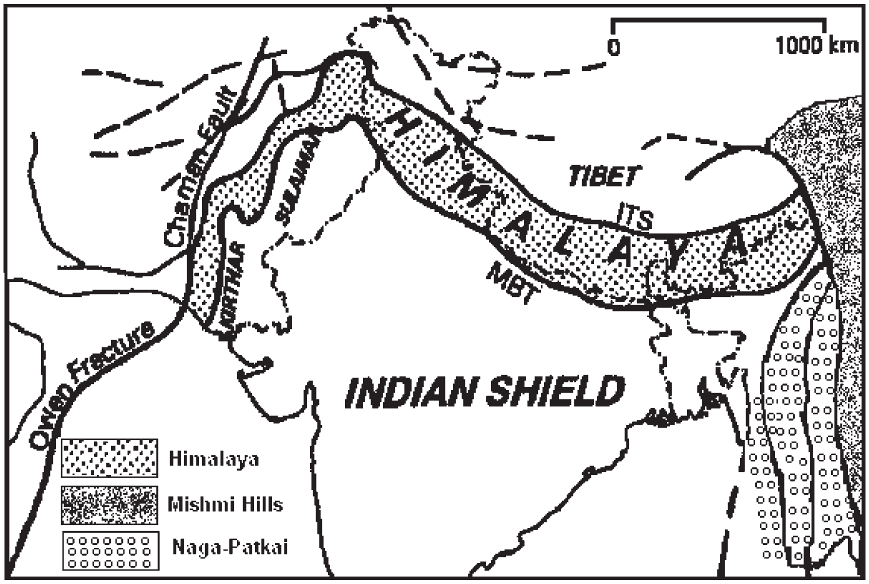

Figure 2. Juxtaposition of three mountain systems, viz., Himalayan ranges, Mishmi Hill ranges and Naga-Patkai hill ranges. (After Valdiya, 1998.)

ranges, on the other hand, link up with the Andaman-Nicobar Island Arc, which is an active zone where Indian Ocean floor is descending under the Malaysian Plate (see Figure 5a and 5b – after Valdiya, 2002).

SEISMIC DATA

Seismicity is very common in the NER, which has been experiencing earthquakes that range in intensity from minor to major levels. The seismic record shows that this region has experienced two great earthquakes of M > 8.7, 20 earthquakes of M > 7, 29 earthquakes of M between 6 to 7, and innumerable number of smaller earthquakes till 1976 (see Figure 6). The data for a period of 5 months per year (1980-86) further show a total of 7,000 earthquakes in various parts of the region (Kayal, 1996). In Subansiri alone in Arunachal Pradesh, nearly 1,000 earthquakes were recorded in 10 months time in 1990 (Kayal, De, & Ram, 1992).

In addition, University of Roorkee (UOR) and Geological Survey of India (GSI) have operated MEQ observatories in the Shillong Plateau and Assam Valley for short time periods to monitor micro earthquakes for the period 1979-1990. The seismic studies indicate that ArakanYoma/Tripura folded belt

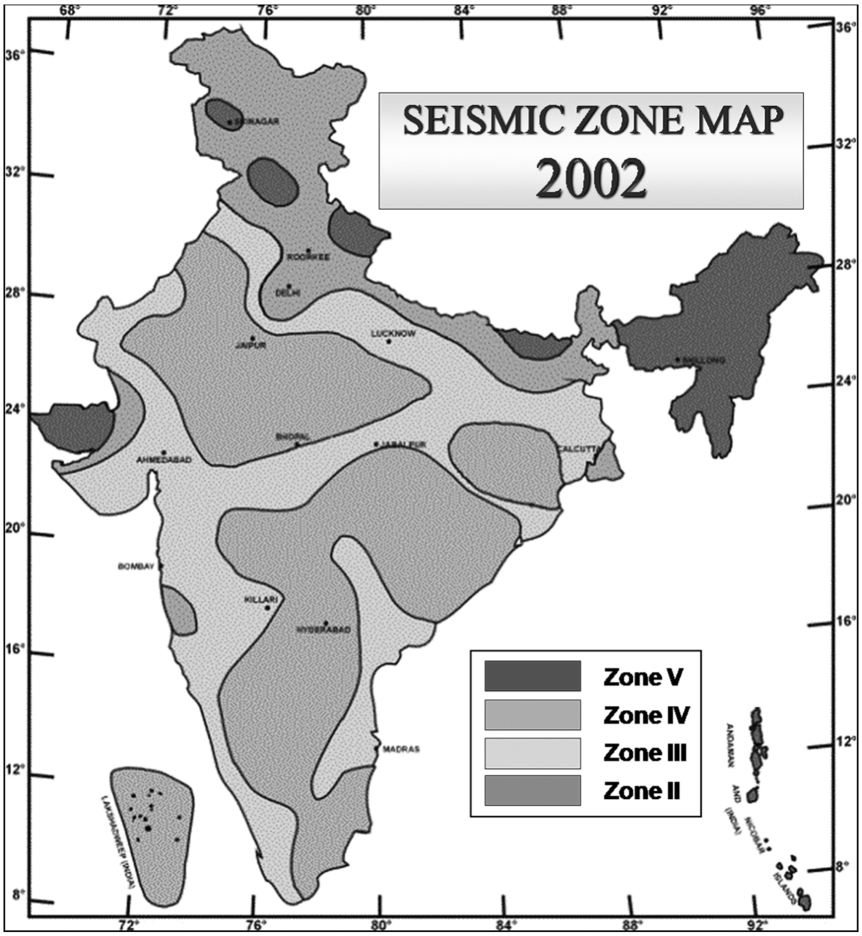

Figure 3. Map showing seismic zones of India.

region is most active, followed by Mishmi-Lohit Thrust Region, Shillong Plateau, NE Himalaya, and Bengal Basin (Verma, Roonwal, & Gupta, 1993). High seismicity is also noticed all along the Brahmaputra that lies on the northern fringes of the Shillong Plateau. Microseismicity studies show that the western margin of the Shillong Plateau is relatively more active (Kayal, 1987), which has been corroborated by Mukhopadhyay (1990) who has shown that several lineaments trending NNW-SSE and NNE-SSW, are active in the western part of the Shillong Plateau. In Arunachal Pradesh, seismicity is mostly aligned along the MBT, MCT, Lohit Thrust, and Mishmi Thrust.

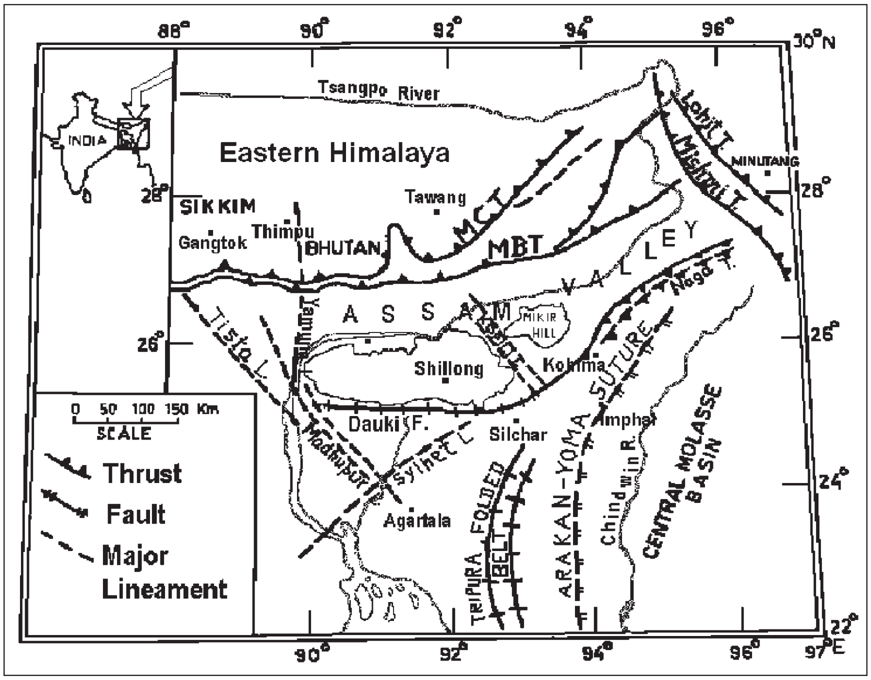

Figure 4. Simplified tectonic map of the North Eastern Region of India.

The data given above represent the seismic recording carried out from time to time in a limited network, and the actual figure may, therefore, be much higher. It is unfortunate that there had not been continuous recording or monitoring the earthquake events in the past, which otherwise have been recorded mainly on project mode basis. Now, local seismic station networks in the NER have been established for some time, which includes the seismic stations mainly operated by Regional Research Laboratory (RRL) Jorhat (renamed as North East Institute of Science & Technology (NEIST); Indian Meteorological Department, Government of India (IMD); National Geophysical Research Institute (NGRI); and Manipur University (MU)) to contribute toward the generation of seismological database.

Database generated by the local seismic network for the period November 1997 to December 1999 (Sitaram, 2002) shows that out of the total number of 263, 1536, and 1481 earthquake events recorded, about 55, 311, and 402 events were located in the NER during the years 1997, 1998, and 1999, respectively. The magnitude of these events was between 2.1–5.9 in 1997, 1.6–5.3 in 1998, and 1.6–5.4 in 1999; whereas the depth range was between 7–114 km in 1997,

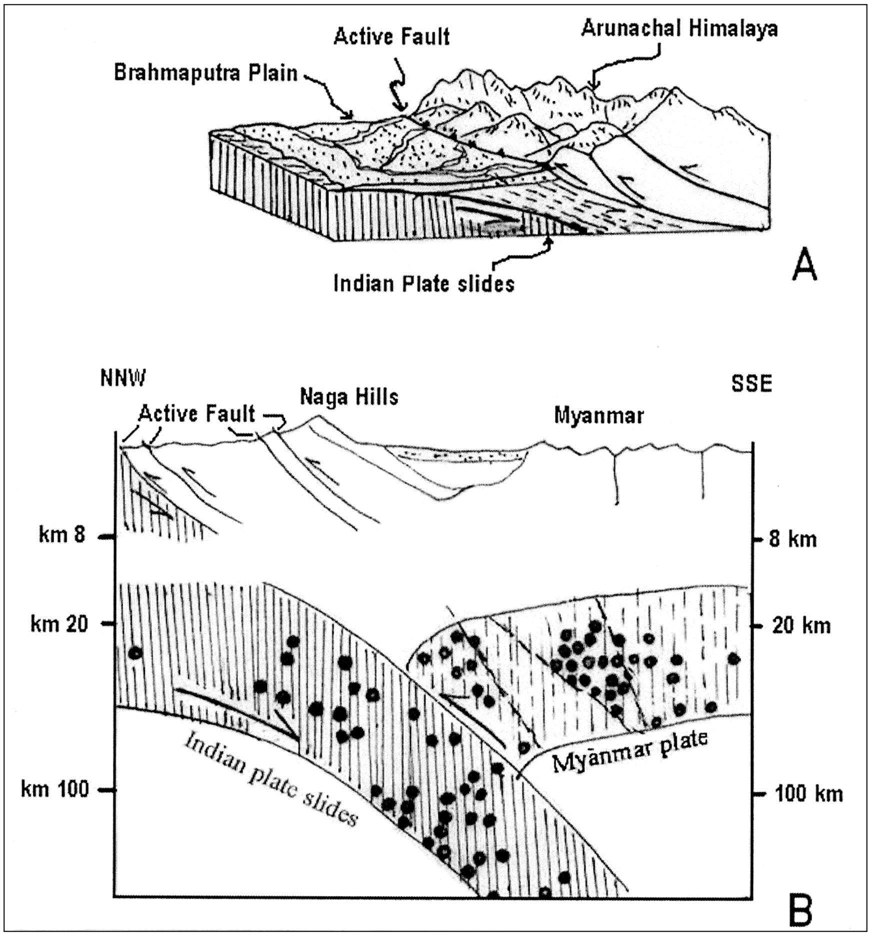

Figure 5. Indian Plate sliding under the Arunachal Himalaya (A) and Myanmar Plate (B). (After Valdiya, 2002.)

4–163 km in 1998, and 6–201 km in 1999. These earthquake events are controlled by specific local structural situations, viz., plate tectonic–collision phenomenon along the Eastern Himalaya and Indo-Myanmar border; and tectonic forces along thrusts, faults, and lineaments. According to Sitaram (2002) this comparatively low percentage is mainly due to inadequate monitoring coverage of the regional seismicity with the local network.

The latest seismic data for the year 2003 show 223 tremors of magnitude varying from 1.1 to 5.6 in the region, covering Assam, Arunachal, Shillong Plateau, Bengal Plains, and Indo-Myanmar region (RRL, 2004). Beside these, a single tremor of M 5.3 in Bhutan Himalaya has also been recorded.

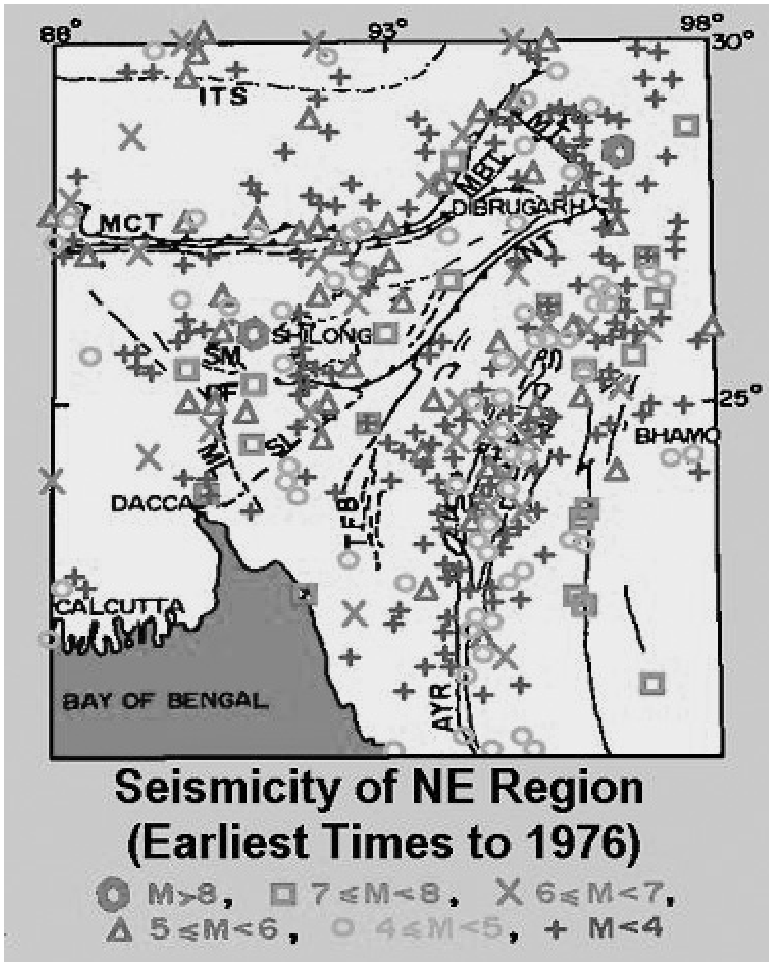

Figure 6. Seismicity of the North Eastern Region of India, from earliest time till 1976.

DISASTERS' IMPACT ON URBANIZATION

The seismic data mentioned above provide only a limited view of seismicity of the NER because the seismic stations were operated only over a limited area, yet it is alarming. However, casual observers are not aware of the hazards associated with the region's seismicity. Unplanned developmental activities, particularly modern concrete construction, are increasing day by day, without consideration of the risks and vulnerabilities that arise from earthquakes. Singh (2003) has suggested to take extraordinary care in dealing with the developmental activities to minimize its adverse effect on the geoenvironment.

Increase in population in the last four decades is more than three times the 1950 level. Population pressure is forcing people to construct their houses on hill tops and slopes, thus disturbing the natural slopes and making these prone to landslide hazards. The concern is not only with increasing population, but also with the urban pattern in the delicate eco-system. In fact, everyone wants to settle down in the urban towns, which have developed and mushroomed over the years. However, the land resources for urban settlement are limited and, thus, almost all the capital, urban, and business towns in these regions have reached the critical level of unsustainability.

Urbanization on an unprecedented scale is being experienced in almost all the states of the NER. Rapid urbanization results in not only the setting up of new settlements but also results in overcrowding of land with buildings and buildings with people. Itanagar Capital Complex in Arunachal Pradesh is an example, where concrete multistorey buildings are coming up like mushroom growth (see Figure 7) without considering the fragile nature of geological formations. Geologically, the Capital Complex is situated entirely on the Siwalik sediments and unconsolidated Quaternary deposits with a number of active faults and some prominent thrusts (Singh, 2007). The Quaternary sediments, occurring as riverine-terraces material and valley-fill deposit, consist of poorly sorted boulders, pebbles, and gravels set in a loose matrix of mud, sand and clay (see Figure 8). The geotechnical studies (Singh, 2009), on the other hand, suggest that the average angle of internal friction ϕ is between 25° and 39°, and cohesion progressively increases vertically downward from the slope surface, where the cohesion values "C" vary between 0.25 and 0.40. The SPT values indicate that the insignificant penetration starts at the depth of 9 m. The moisture content varies from 11.55%–22.86%, which is comparatively high. The plasticity index varies from 10.20 to 12.60. The slope material consists predominantly of medium to medium dense reddish-colored clayey soil containing sand and gravel. As per Indian Standard Classification, it is classified as CI, representing silt and clay of low compressibility. All these parameters suggest that the area is not very suitable for such a heavy construction. However, the local inhabitants have now started encroaching on land on hill tops and slopes (see Figures 9, 10a, and 10b) for construction of residential and commercial complexes due to paucity of land in the plains and valleys. In this process of unregulated construction, people have even started occupying areas of natural drains for construction of buildings (see Figure 11), thereby, misusing modern construction technology by creating tunnels to the natural drain (see Figure 12) without due consideration to the volume of rainfall water in the catchment area. Slope cutting and blocking of the natural drains in an unscientific manner are causing serious threats to the hill slopes and settlements.

Figure 7. Urban agglomeration in Itanagar Capital Complex, Arunachal Pradesh, March 2002.

Figure 8. Poorly sorted boulders, pebbles, and gravels set in a loose matrix of mud, sand, and clay belonging to Quaternary sediments. Location—opposite Gyan Ganga School, Chander Nagar, Itanagar, July 2003.

The capital of Mizoram, Aizawl, is another example of rapid urbanization, where demographic pressure is exercising excessive stresses on land in the form of concrete jungle. Such unsystematic expansion of development imposes imbalances on the fragile ecosystem, translating to slope failures that may result in heavy loss to the life and property. The immature topography of Mizoram consists of siltstone, shale and sandstone of Surma Group (Tertiary age) and is having varying thickness (2–20 m) of overburden. Heavy landslides in Chhimptuipvi District of Mizoram on 17th and 18th May 1995 is a classic example, where two important township of Saiha and Lawngtlai along with a major section of road and vast forest area were badly affected, and 39 people lost their lives and 24 people suffered various degree of injuries.

The township of Kohima—the capital of Nagaland—is also reeling under the heavy population pressure culminating in major construction activities in and around Kohima. Earthquake induced landslide on August 6, 1988 damaged nearly 4,000 m^2 of area of Tuli Paper Mill in Nagaland, causing a heavy monitory loss that runs into crores. The mill is located on overburden material consisting of silt and clayey silt.

Signs of ground distress are recorded at several places in the Mawrynkhong Village, East Khasi Hills in Meghalaya (Awasthi, 2002). The development of

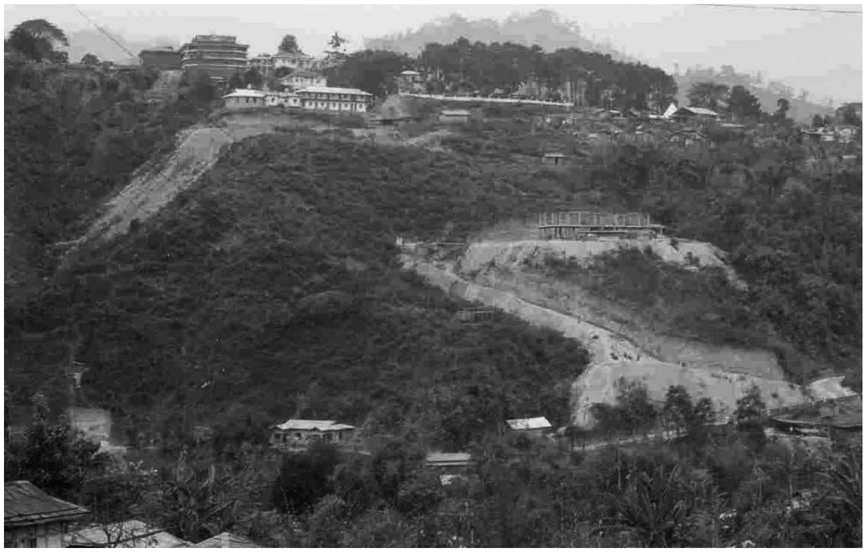

Figure 9. A stabilized hill slope being disturbed by construction of houses, below Banquet Hall, Itanagar, March 2002.

these signs of ground distress is attributed to the slope profile, poorly cohesive foundation grade material, lack of proper drainage, leading to piping action, natural drainage congestion and blocking due to structures of poor quality, and constant toe erosion of slopes.

It is pertinent to note that the 1897 earthquake (M 8.7) in Meghalaya killed more than 1,600 people, and another 1950 earthquake (M 8.7) in Assam killed 1,500 people. That was the situation when the population was sparse and the concrete structures were few. In the current situation, destruction and causalities may be much more with the increase in population which is more than three times the level of 4 decades ago, and where old patterns of house construction have been abandoned. It is interesting to note that the construction of "Assam-type houses,"[1]

[1] "Assam-type houses" are basically single or double storied wooden houses made up of cement plastered wooden gridded structure with tin roof. Such houses are built on the concrete pillars, which are nearly 4' to 6' (depending upon the base of the foundation) under the ground. These pillars have clamps on the top, where wooden posts are fixed. The walls are then made of splint bamboo matting, which are plastered by cement and sand on both sides. This structure is covered either by iron corrugated sheets or thatch, with false ceiling of cloth lining. The shape of the houses is normally simple rectangular and the length is restricted to three times of the width. The houses as a whole are kept symmetrical about both its axes and the center of gravity is low. Further, the houses are very stable for their light weight, where the walls have very less dead load on the top. These houses are characterized by their simplicity, symmetry, and rectangular shape due to which they behave very well during earthquakes.

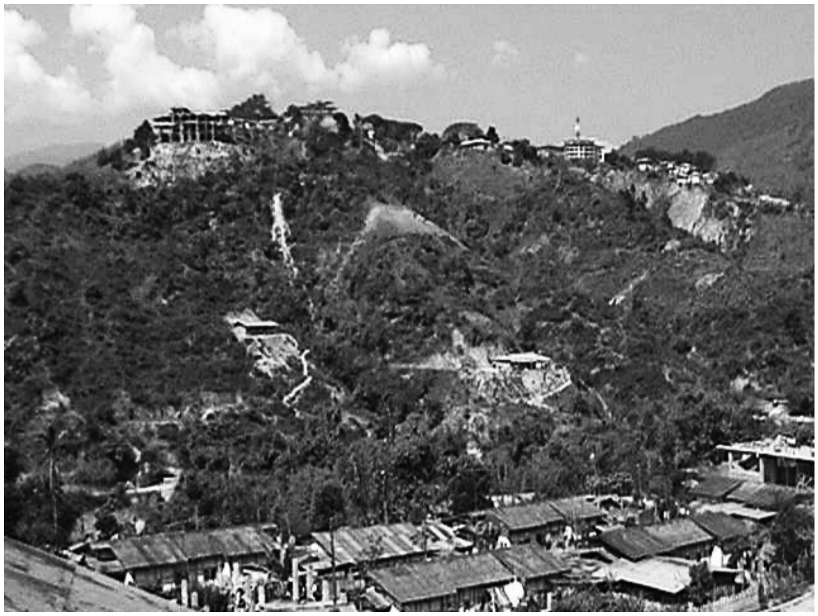

Figure 10a. A multistorey house under construction at the top of the hillock, near Banquet Hall, Itanagar, February 2005.

which gained popularity after the earthquake of 1897 due to their capacity to dissipate earthquake shocks easily, is losing its charm as modernization is targeted. In Arunachal, traditional houses are also earthquake resistant, which are made up of wooden pillar and bamboo with palm leaf roof (see Figure 13). But the scenario has changed now and people are rather obsessed with haphazard construction of concrete buildings, without giving scientific engineering design and without following building codes. Even single storey houses are being replaced by multistorey masonry buildings. If the present trend of construction and population growth continues, an earthquake of M > 7.5 may bring enormous damage to property and great loss of life.

In Assam, construction of buildings is either on the Brahmaputra Alluvium or on hills composed mainly of granitic gneisses. Of these, building construction on alluvium is much more alarming as such areas are highly vulnerable in case of a major earthquake, which may form liquefaction causing collapse of the buildings.

NEED OF THE DAY

With the increasing frequency of earthquakes and landslides, particularly after the Uttarkashi earthquake of Himalayan region (1991; M 6.6), Latur earthquake

Figure 10b. Closer view of the Figure 10a, showing the building under high risk, February 2005.

(1993; M 6.1), Chamoli earthquake (1999; M 6.5), and Gujrat earthquake (2001; M 8.1), people in NER have become aware of disasters caused by the natural hazards. They are now seriously analyzing and trying to understand the relationship between causes and effects, and also visualizing the long-term implications of disasters. Since earthquakes cannot be predicted, there is an urgent need for proper planning for natural hazards assessment and mitigation. Understanding temporal evolution of some of the natural hazards has, however, led to recognition of their space-time pattern and, to some extent, our ability to predict the probabilities of their recurrence. Accordingly, efforts are being made to design and implement protective systems that are not only cost-effective but also maintained and serviced locally. Hazard-resilient land-use planning is the basic requirement that should be integrated with administrative protocols of building codes and by-laws enforcement.

There is a strong need to create awareness among the people to regain their earlier prevailing culture of "Assam-type houses," which are earthquake resistant. For modernization, however, the newly developed "Bamboo Processing Technology," may be used where the processed bamboo has become an ideal material for housing construction. The processed bamboo has high tensile strength and very good weight to strength ratio, which is good enough to replace timber, steel,

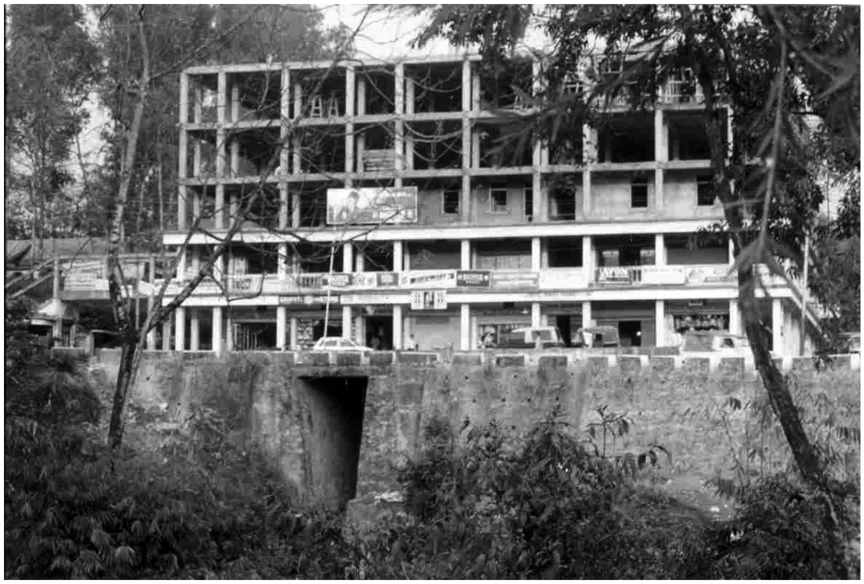

Figure 11. A five storey building over a natural drain, near Bank Tinali, Itanagar, March 2002.

wood, and aluminum. The strength-weight ratio of bamboo also supports its use as a highly resilient material against forces created by high velocity winds and earthquakes. Such houses have a reasonable life of 30 to 40 years.

Other than the construction of buildings, communication links are also vital in the region. Road network is considered to be the "life-line," particularly in the hilly terrain. Singh (2002) has suggested to adopt an integrated approach from anticipation to preparedness, relief, rehabilitation, and recovery, and proposed various suitable actions, such as set up of close network of seismic observatories and GPS stations, preparation of hazards zonation maps, study of historical earthquakes (palaeoseismicity), enforcement of law for building codes, public awareness programs, etc. The present need, therefore, is to educate the general public regarding the danger from earthquake hazards and their mitigation strategies. "*Prevention is better than Cure*" and prevention begins with information. Thus, integrated knowledge about preparedness, rescue, relief, rehabilitation, resettlement, etc., has to be provided to all the stakeholders. This is possible through a long-term program for hazards assessment and mitigation by an integrated approach with participation of the society and scientific community.

Gaur (1998), while discussing basic agenda for development of mitigation programs for disasters in the Himalaya, has suggested four related activities: a) advance action for long-term protection; b) preparedness for efficient response

Figure 12. Building construction in progress in the down stream
of the natural drain of Figure 11, near Bank Tinali, Itanagar, March 2004.

to a hazardous event; c) recovery and rehabilitation; and d) research for improving design of appropriate engineering and social structures effectively embed in the local culture. Valdiya (2002), on the other hand, is of the opinion that environmental security and hazard management programs must form an essential part of the paradigm of development of the mountain state. He further stressed the need of formulation of a public policy for hazard management and suggested, specifically for the State of Arunachal Pradesh, formation of a State Commission to be named as "Arunachal Pradesh Natural Hazards Management Commission." Such a State Commission may be formed in every State of the NER.

An effective strategy for disaster mitigation is suggested which may include the following activities:

1. *Advance Planning.* It involves:
   (a) Identification of hazard-prone regions on the basis of historical and current knowledge as well as conceptual anticipation.
   (b) Design of engineering specifications for various kind of structure, particularly construction of high rise buildings, urban agglomeration, etc.
   (c) Assessment of risk faced by existing structure and design for retrofitting, wherever necessary.

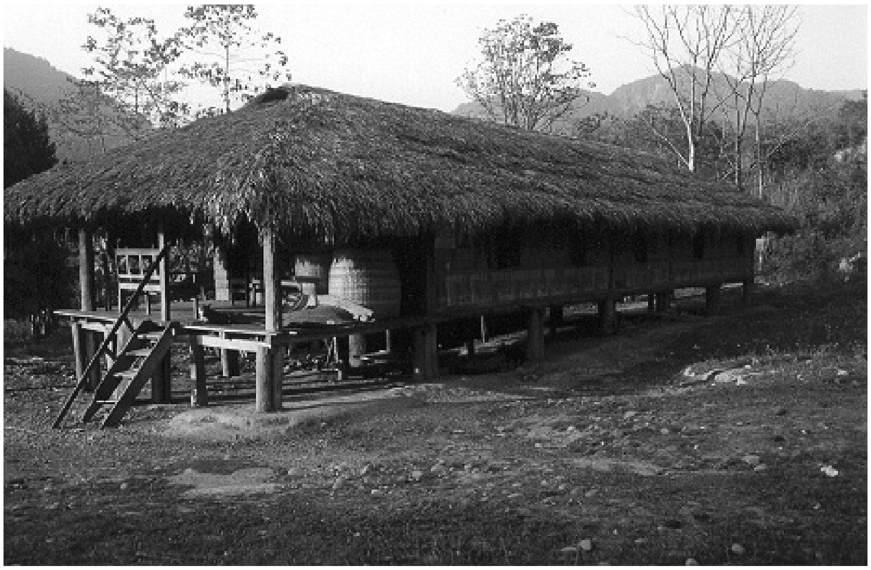

Figure 13. A traditional house in Arunachal Pradesh made of wood and bamboo with palm leaf roof, March 2002.

(d) Design and operational readiness of protocols for effective rescue and relief measures, prevention of epidemics, emergency operations of essential services.

(e) Regular dissemination of information through carefully designed bulletins to evoke a constructive response and avoid panic.

2. *Awareness Creation.* There are varied opinions regarding the occurrence of next great earthquake in NER. This has created panic in the public, especially when the media propagates future occurrence of earthquakes based on prediction by some scientist. Though highly scientific and theoretical seismological studies could make prediction for space (where?), but never about time (when?). The need of the day is, therefore, to educate the general public regarding the danger from seismic hazards and their mitigation strategies.
3. *Mapping of Areas for Vulnerability Assessment.* There is a requirement of carrying out the mapping of cities and rural areas to review their vulnerability. Such microzonation programs have to be formulated prioritizing specific areas and cities to be mapped in various states of the NER of India, which may suggest the areas suitable for development activities or vulnerable to the disasters. A classic example is observed in Lower Dibang Valley District, Arunachal Pradesh, where a bridge over Deo Pani

River near Roing has been collapsed (see Figure 14) as it was situated near the Himalayan Frontal Fault, which is considered to be active. Similarly, Hunli—a sub-divisional headquarter—has been established on the old landslide debris in Lower Dibang Valley District (see Figure 15), which has been reactivated making the area vulnerable.

4. *Enforcement of Building Codes.* Although certain standards have been laid down for construction of earthquake-resistant building in the seismic zones, more often than not it is observed that these codes and standards are not followed religiously. Enforcement of such laws will otherwise go a long way in ensuring safety and longevity of the people and civil construction.
5. *Mitigation Strategy.* Earthquake hazard mitigation strategy primarily includes structural and non structural measures. In addition, the suitability and adequacy of response and relief infrastructure in the urban areas following an earthquake event also need to be integrated.
6. *Financial and Insurance Institutions.* Institutions providing construction finance have to be sensitized to the need for making their investment secure by insisting on well organized and earthquake resistant construction by the loanee, where necessary mandatory insurance of all buildings above a stipulated value, size, or category, both public and private, have to be ensured through suitable legislation.

Figure 14. A collapsed bridge over Deo Pani River near Roing, Lower Dibang Valley District, Arunachal Pradesh, February 1999.

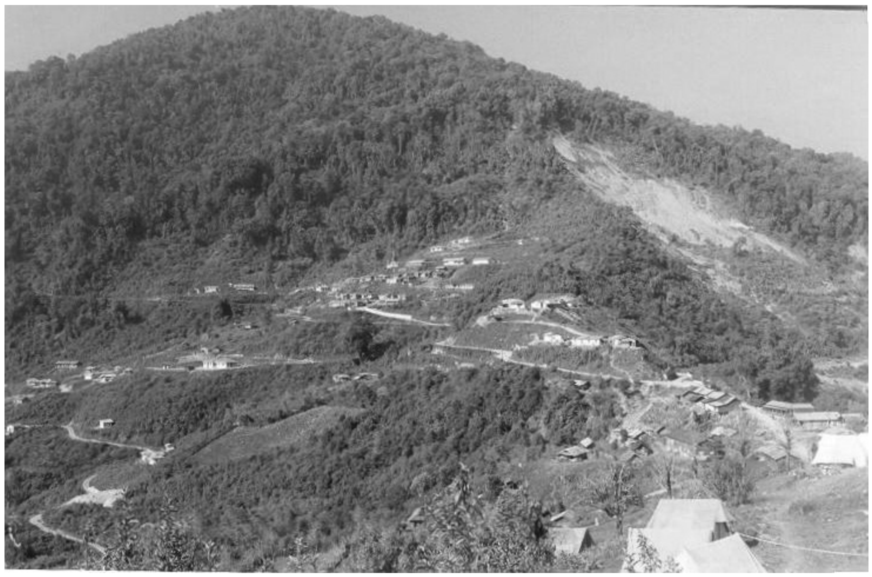

Figure 15. Hunli—a sub-divisional headquarter, situated on the old landslide debris, Lower Dibang Valley District, Arunachal Pradesh, February 1999.

7. *Pre- and Post-Disaster Management Strategies.* NER by virtue of its topography and location in seismic zone V is vulnerable to earthquakes. Any activity disapproved by the nature is bound to trigger a disaster. Disasters cannot be prevented, but certainly its effects can be reduced by following precautions. Thus, there is a need to carry out pre- and post-disaster management plan encompassing the following:
   (a) Administrative Management.
   (b) Quick Damage Assessment.
   (c) Search and Rescue.
   (d) Mechanics and Equipment.
   (e) Distribution of Relief Management.
   (f) Logistics and Resource Management.
   (g) Resource Inventions.
   (h) Need based Supply.
   (j) Issue of Relief Store as Kits.
   (k) Transport Management.
   (l) Medical Relief Management.
   (m) Requirement of Temporary Shelters and Relief Camps.
   (n) Communication Arrangements.

(o) Disposal and Dead Carcasses.
(p) Co-ordination with NGOs.

8. *Training of Stakeholders.* Training of the first responders, community, and all other stakeholders is a pre requisite for successfully combating the disasters. There is a need to institutionalize the complete training and have a central agency like the Administrative Staff College located in Guwahati to co-ordinate the same for all the states of the NER.
9. *Rehabilitation and Resettlement.* It is a consequential aspect to be taken up on priority basis to provide living atmosphere to the affected people in which they use to live before the calamity. It is essential to regain social life, status, and self-confidence of the affected people. It is not an easy task because many people have sentimental attachments to their parental belongings and socio-cultural relations.
10. *Research and Development.* This strategy aims at meticulous scientific preparedness through development of low-cost and locally-supportable technologies. Efforts should be made for improvement of slope stability, landform classification, etc., and further research be taken up in estimating and mapping the hazard intensities in the threatened areas. For extension of knowledge, it is desirable to have a meaningful interaction between the *scientists and technical experts*, on one hand, and *administrators and planners*, on the other hand, on a regular basis, which may help in better understanding of the natural hazard mitigation and management.

CONCLUSIONS

A large number of developmental activities involving hydro-electric power projects, infrastructure, etc., are also under progress in the NER. These developmental activities as well as the new urbanization pattern that has arisen from the modern concrete multistoreyed building have significant effects on the environment. A holistic view has to be taken on all the developmental activities and urbanization patterns due to the location of the region in Seismic Zone V. There is an urgent requirement for sensitization of all stakeholders to make them aware of risks and vulnerabilities and seek their support and co-operation on the creation of a Disaster Management Plan consisting of structural and non structural measures.

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