Sikkim Earthquake of 18th September, 2011

A Report

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January, 2012

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Foreword

Experience sharing is the key to learning and improving. This is all the more relevant for disaster management as the disaster incidences are sometimes separated by long periods of quiescence and moreover stakes being real high one cannot afford to wait for the disaster to strike. Sharing of experiences is thus vital to improving and strengthening mechanisms and institutions so as to be prompt and effective when the disaster strikes.

Uttarakhand has socio-economic and geo-tectonic conditions similar to Sikkim and therefore on the aftermath of the Sikkim Earthquake of 18^{th} September, 2011 a team of the Department of Disaster Management was constituted to visit the earthquake affected areas of Sikkim and to interact with the key government officials and others so as to suggest improvements in the preparedness, mitigation, response and recovery mechanism set up in Uttarakhand. The team consisted of four officials namely, Dr. Piyoosh Rautela, Executive Director, Disaster Mitigation and Management Centre, Dr. Girish Chandra Joshi, Senior Executive, Disaster Mitigation and Management Centre, Shri Atul Singh, Section Officer, Department of Disaster Management and Rehabilitation, Government of Uttarakhand and Dr. Achal Kumar Mittal, Member, Hazard Safety Cell and Scientist, Central Building Research Institute, Roorkee. The team visited Sikkim between 9^{th} and 15^{th} November, 2011.

During the brief period of stay at Sikkim the team concentrated its attention on Sikkim East and Sikkim North districts. Besides the affected population the team interacted with a number of government officials who had played crucial role in managing the situation.

The authors are also thankful to B.K. Kharel, Relief Commissioner, Government of Sikkim, Shri D. Anandan, District Magistrate, Sikkim East District, Shri Prabhakar Verma, Additional District Magistrate, Sikkim North District and Shri A.B. Karki, Sub Divisional Magistrate, Sikkim East District for sharing their experiences with the team members. The visit of the Uttarakhand was facilitated by Shri Bhupendra Sharma, State Project Officer, GoI – UNDP Disaster Risk Reduction Programme and Miss Kesang, District Project Officer, Sikkim North District. But for their support and information the objectives of this visit would not have been successfully fulfilled.

The assistance of Shri Sidharth Behra and Shri Piyush Mohanty, M. Tech. students of CBRI, Roorkee, in preparing the report is highly appreciated.

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10^{th} February, 2012
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1. Seismological information

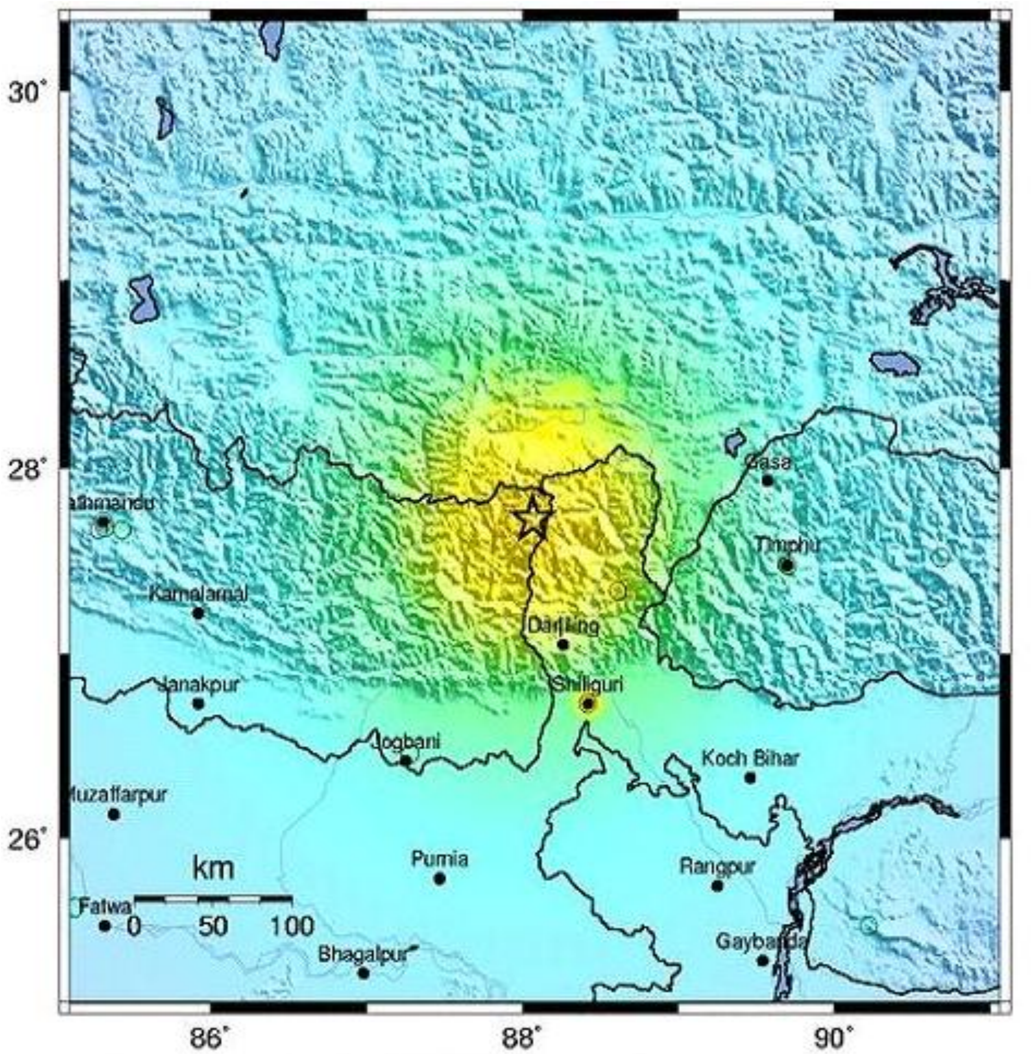
The Indian subcontinent is among the world's most disaster prone areas. Almost 85 percent of the India's area is vulnerable to one or multiple hazard. Of the 28 states and 7 union territories, 22 are disaster-prone. An earthquake of magnitude 6.8 occurred on 18th of September, 2011 at 18:11 hrs IST in Sikkim - Nepal Border region. This region has experienced relatively moderate seismicity in the past, with 18 earthquakes of magnitude 5 or greater being experienced over the previous 35 years within 100 km of the epicenter of the September 18th event. The largest of these was magnitude 6.1 earthquake of 19th November, 1980 that had its epicenter around 75 km to the southeast of the 18th September event. The preliminary hypo-central parameters of the 18th September, 2011 earthquake, as estimated by the Seismic Monitoring Network of India Meteorological Department (IMD) are as given below:

Date and time of occurrence	:	18/09/2011 at 18:11 hrs (IST)
Magnitude	:	6.8
Focal depth	:	10 Km
Epicenter latitude and longitude	:	27^{o} 42'N & 88^{o}12'E
Region	:	Sikkim-Nepal Border region

The event that falls under the category of Severe Earthquake was also reported to be widely felt in Sikkim, Assam, Meghalaya, and northern parts of West Bengal, Bihar, parts of other eastern and northern regions of India. The epicenter lies in a seismically known and active belt called Alpine-Himalayan Seismic Belt.

The entire area of Sikkim lies in Zone IV of the Seismic Zonation Map of India (IS1893: 2002). The seismic Zone IV is broadly associated with seismic intensity VIII on the Modified Mercalli Intensity (MMI) Scale.

The Sikkim and adjoining region is known to be part of the seismically active region of the Alpine-Himalayan seismic belt, with four great earthquakes of the world of magnitude 8.0 and above occurring in this region. Earthquakes in this region are broadly associated with strain accumulation associated with the northward tectonic movement of the Indian Plate and its subsequent abrupt release. The strain is generally released by activity along Himalayan faults and thrusts of regional dimensions of which Main Boundary Thrust (MBT) and Main Central Thrust (MCT) are particularly important. Other prominent geological / tectonic features in and around Sikkim include Tista lineament, Kunchenjunga lineament, Purnea - Everest lineament, Arun lineament and Dhubri fault in the southeast.



PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	<.17	.17-1.4	1.4-3.9	3.9-9.2	9.2-18	18-34	34-65	65-124	>124
PEAK VEL.(cm/s)	<0.1	0.1-1.1	1.1-3.4	3.4-8.1	8.1-16	16-31	31-60	60-116	>116
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

Fig. 1. Intensity map of Sikkim Earthquake of 18th September, 2011 (Source: USGS).

Historical and instrumentally recorded data on earthquakes show that the Sikkim and adjoining area lies in a region prone to be affected by moderate to great earthquakes in the past. Some noteworthy earthquakes that have affected the region are:

Sl. No.	Earthquake	Date	Magnitude
1.	Cachar Earthquake	10.01.1869	7.5
2.	Shillong Plateau Earthquake	12.06.1897	8.7
3.	Dhubri Earthquake	02.07.1930	7.1
4.	Bihar-Nepal Border Earthquake	15.01.1934	8.3
5.	Arunachal Pradesh – China Border Earthquake	15.08.1950	8.5
6.	Earthquake near Gangtok	19.11.1980	6.1
7.	Nepal-India Border Earthquake	21.08.1988	6.4
8.	Sikkim Earthquake	14.02.2006	5.7
9.	Bhutan Earthquake	21.09.2009	6.2

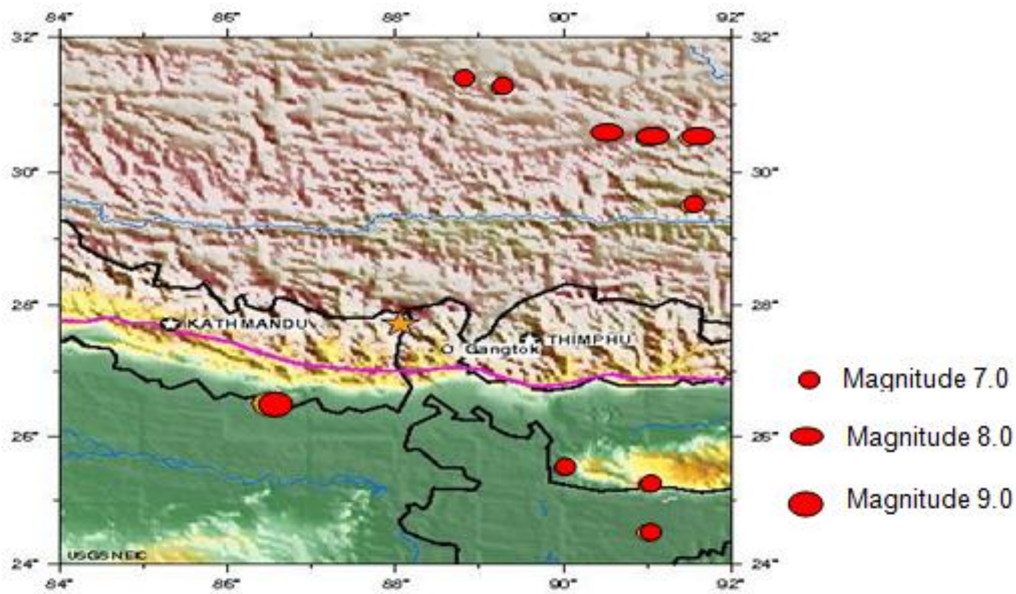


Fig. 2. Map depicting earthquakes of magnitude greater than 7 in the area around Sikkim since 1990.

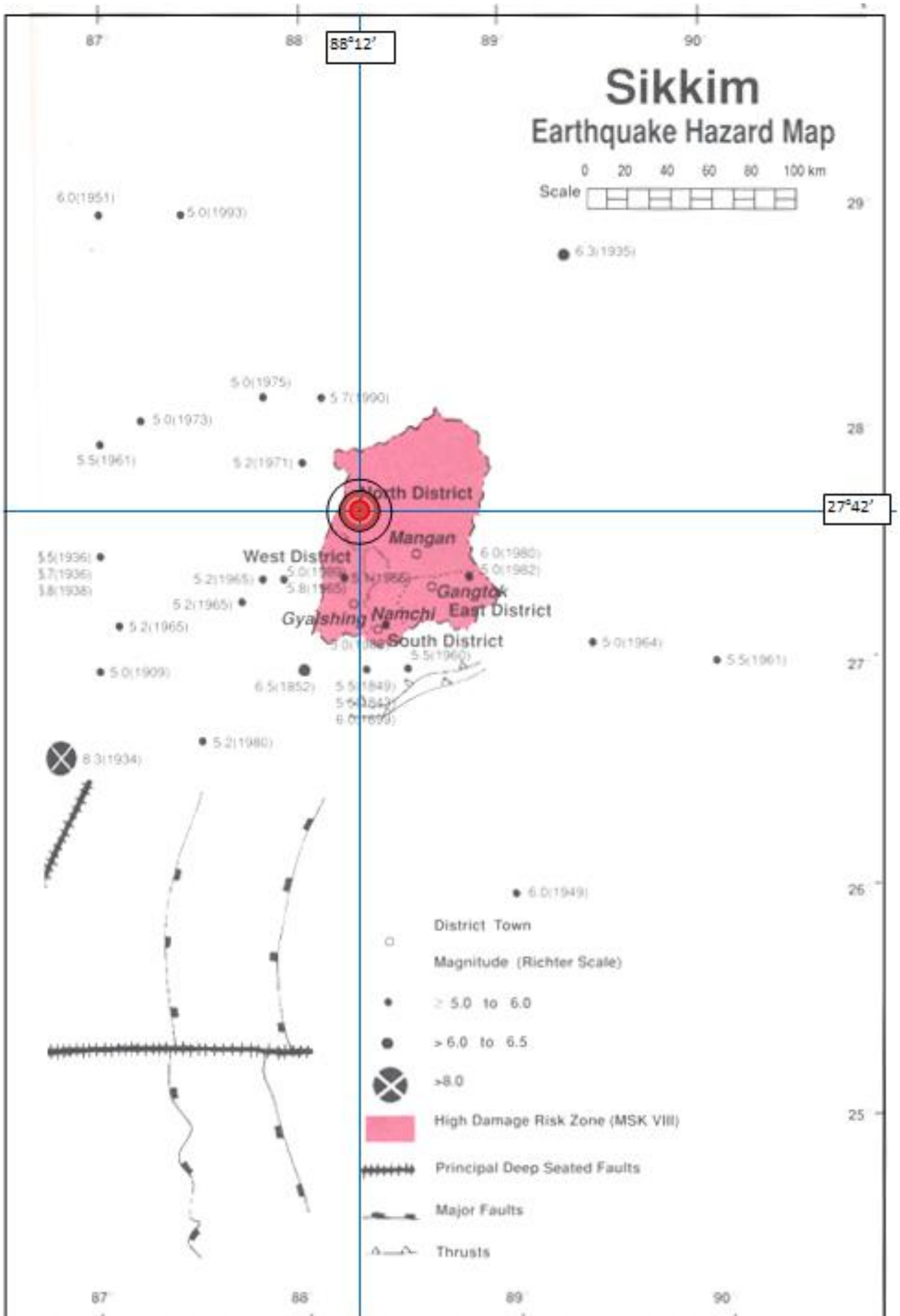


Fig. 3. Earthquake Hazard Map of Sikkim state.

2. Geotechnical / geological information

Researchers have divided the Himalayas into a series of longitudinal tectono-stratigraphic domains that include i) Sub Himalayas, ii) Lesser Himalayas, iii) Higher Himalayas, and iv) Tethys Himalayas (Neogi *et al*., 1998). These are separated by major tectonic discontinuities.

In the Sikkim region, the different lithounits (Acharyya, 1998) are dispersed in an arcuate regional fold pattern (Neogi et al., 1998). The 'core' of the region is occupied by Lesser Himalayan low-grade metapelites and interbedded metapsammite belonging to the Daling Group (Proterozoic to Mesozoic). The distal parts of the region are characterized by medium- to high-grade crystalline rocks of the Higher Himalayan Belt (Higher Himalayan Crystalline Complex, HHC). A prominent ductile shear zone, the Main Central Thrust (MCT) separates the two belts. In this region, the MCT is the southernmost occurrence of a number of northward-dipping ductile shear zones within the Higher Himalayan Crystalline Complex. Gondwana (Carboniferous - Permian) and molasse-type Siwalik (Miocene–Pliocene) sedimentary rocks of the Sub-Himalayan Zone (not shown in the map) occur in the southern part of the region. In the extreme north, a thick pile of Cambrian to Eocene fossiliferous sediments of the Tethyan Zone (Tehtyan Sedimentary sequence, Fig. 1b) overlie the HHC on the hanging wall side of a series of north-dipping normal faults constituting the South Tibetan Detachment System (STDS) (Gansser, 1964).

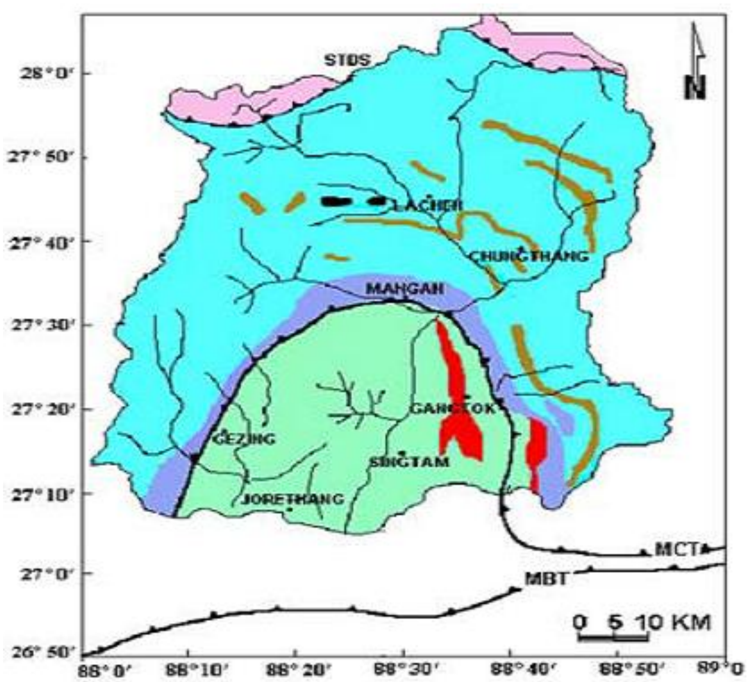


Fig. 4. Schematic geological map of Sikkim Himalaya (after Neogi et al., 1998)

3. Building typology in Sikkim

Most structures observed in Sikkim primarily fall under masonry (brick, block and stone), RCC and wooden building category. The buildings are observed to have either flat or sloping roofs made up of different materials that include GI sheet, thatch, RCC, RBC, and wood. The data from BMTPC Vulnerability Atlas has been analysed and the same is presented below.

The buildings stock of Sikkim has been categorized into four classes. Of these Category – C that consists of reinforced building and well built wooden structures accounts for 59 percent of the building stock. It is important to note here that this building class has low earthquake risk.

Table 1. Classification of Buildings in Sikkim (According to material used).

Category - **A**	Buildings in field-stone, rural structures, unburnt brick houses, clay houses
Category - **B**	Ordinary brick building: buildings of the large block and prefabricated type, half-timbered structures, buildings in natural hewn stone
Category - **C**	Reinforced building, well built wooden structures
Category - **X**	Other types not covered in A, B, C. These are generally light

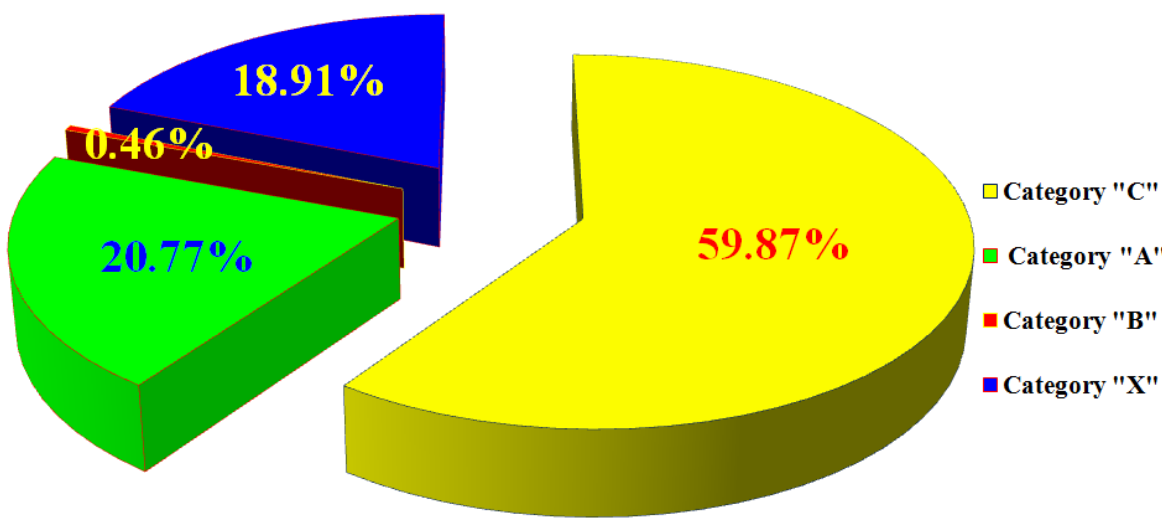


Fig. 5. Different categories of houses in Sikkim (Source Census of India, 1991).

Table 2. Distribution of different categories of houses in Sikkim together with their seismic risk (Source Census of India, 1991).

Category	**No. of Houses**	**Percentage (%)**	**Level of Risk under Earthquake**
Category - **A**	19,498	20.77	High
Category - **B**	429	0.46	Medium
Category - **C**	56,216	59.87	Low
Category - **X**	17,751	18.91	Very Low

4. Earthquake induced damages

Damage at a glance

1.	Human lives lost	60
2.	Houses damaged	34,159
3.	Government building damaged	1,255
4.	Roads damaged (in kilometers)	3,230
5.	Village footpaths (cement concrete) damaged	1,596
6.	Bridges / culverts damaged	8,135
7.	Water supply schemes damaged	1,529
8.	Minor irrigation works damaged	204
9.	Flood control management works damaged	533
10.	Schools damaged	759
11.	Hospitals damaged	377
12.	ICDS (Anganwadi) damaged	875
13.	Historic monuments, monasteries and religious institutions damaged	259
14.	Gram Panchayat offices damaged	60
15.	Community toilets damaged	155
16.	Village level cooperatives (MPCS) damaged	49
17.	Rural Product Marketing Centers (RPMC) damaged	8

(Source: Sikkim State Disaster Management Authority SSDMA Report)

4.1 Building Damage

Direct impact of the earthquake has primarily been the main cause of damage to the buildings but in some places the damage is also attributed to secondary causes that include slope instability, landslide / mud slide and rock fall triggered by the quake.

Baystholung village in Dzongu has suffered major damage due to a landslide. Mud slide with a lot of boulders has been responsible for destruction of several houses in Lachung a day after the main quake. In addition to these isolated incidents along the highways have destroyed several buildings at various places.

The damage to buildings of different typologies is described below separately.

4.1.1. Ekra and Timber plank houses/structures: These structures have experienced minimal direct seismogenic damage. In fact, it is the excellent performance of these buildings that is largely responsible for unduly low damage, destruction and death count is in the State.

The damage is observed to be mainly limited to the random rubble masonry support walls of these structures.

Occasionally the plaster on bamboo panels or the panel themselves is observed to have popped out.

In a few cases, the connection of the superstructure with the RC stilt in these structures is observed to have failed.

Damage is also observed at some isolated places in RC support frame structure.

Damage is also observed in the foundation, mainly on hill slopes.

Fig. 6. Partial collapse of RR support wall.

Fig. 7. Damage to the foundation of Ekra house.

Fig. 8 and 9. Type of foundations used in case of Ekra houses.

4.1.2 Framed buildings: These are observed to have experienced the most severe damage during the earthquake. Non-structural and structural damages incurred in these structures are summarized separately in the sections below.

4.1.2.1 Non-structural damage: Non –structural damages observed in the framed buildings are as summarized below:

- Cracking of plaster.
- Cracking at the interface of RC columns / beams, and filler walls.
- Cracking in filler wall ranging from hairline cracks to sever damage that includes separation and collapse of the whole panels.
- Peeling off of the decorative cladding such as tiles, stone and the like.
- Cracking at the interface of stairs and walls.

Fig. 10. Cracks at the interface of RC columns/beams.

Fig. 11. Damaged caused at the sill level

4.1.2.2 **Structural damage:** Structural damages in the framed buildings are mainly observed in the columns together with those in the beams at a few locations. These consists of one or more of the following:

- Hairline cracks in columns and beams.
- Spalling off of the concrete cover.
- Deformation in reinforcement ranging from very little to significant.
- Buckling of column reinforcement to various degrees just below the junction with beams or just above the floor.
- Excessive deformation in the member including tilting of column, settling of column, sagging in beam and the like.
- Tilting or settling of a part of the structure.
- Total collapse of all or a significant portion of the structure.

Fig. 12. Buckling in column due to insufficient restraint in lateral direction.

Fig. 13. Failure of the column near the flaring.

In some cases, it was found that the column faced damage due to the larger spacing of shear ties.

Fig. 14. Cracking at the beam column joint.

Fig. 15. Failure showing larger spacing of shear ties.

An interesting phenomenon observed during the field visit was that the beam-column joints that had flaring suffered relatively less damage as compared to the columns without flaring at the beam-column joint. The stress intensity however increased in the lower portion of column ensuring damage at a lower point.

Fig. 16. The joints without flaring.

Fig. 17. The joints with flaring.

4.1.3 Earthen houses: Many earthen houses have been noticed various types of damages. Such houses are not considered to be safe against earthquake and the wide spread of damage has been observed in this earthquake also. The damages are observed in the field were in the form of:

- Very fine cracks as well as wide cracks were visible in the infill walls.
- Partial collapse of wall also happened for some of the houses.
- Diagonal cracks propagating from openings.

Fig. 18. Partial collapse of earthen wall.

Fig. 19. Cracking of earthen wall.

4.1.4 Load bearing structures in masonry: In the masonry load bearing structures most damages observed in the field were in the form of:

- Cracks in the corners or at the wall junctions.
- Cracks near window openings and gable wall base.
- Failure of two wythes of the load bearing stone masonry wall.
- Poor construction features such as weak and very slender partition walls in brick/block/stone load bearing structures in masonry.

4.2 Damage to Roads

Roads were worst affected by seismogenic landslides and this greatly added to the trauma and misery of the masses as it disrupted communication and relief supplies could not made available to the disaster victims in time.

The roads were observed to have either breached or suffered total washout. The damages observed in the roads are as summarized below.

- Horizontal cracks were observed along the road. These warrant avoidance of plying of loaded and heavy vehicles.
- Accumulation of debris and boulders was observed along the road surface due to landslide from the uphill slide.
- Several retaining structures were observed to have been damaged, mostly due to down slope mass movement. These are required to be re-constructed.
- Subsidence was observed at many places and this is attributed to both piping action of water that took away the fines and differential settlement of ground surface induced by various local geological reasons.
- Load alignment was observed to have distorted at many stretches. Realignment would be the only alternative at some places to ensure smooth vehicular traffic.

Fig. 20. Damage to the edges of the road.

Fig. 21. Wide cracks in the road.

4.3. Damage to Drainage and bridge structures

Fig. 22. Damage to the bridge abutment.

Damages sustained by drainage and bridge structures are as summarized below.

- Longitudinal drains were completely buried diverting the surface runoff along the road.
- Abutment, wing walls, training works/guide walls of culvert and bridges scoured/cracked.
- Many structural damage of longitudinal and cross drains and cause ways caused by shooting boulders.
- Cable and bridge alignment distorted due to torsional moment, created by heavy tremor.

Fig. 23. Reactivation of colluvial material along the slope.

Fig. 24. Rock fall along the steep valley face.

4.4. Landslides

The physiographic set up of Sikkim makes it vulnerable to landslides and the seismic shaking initiated and reactivated a number of landslides and rock falls in the epicentral area. The severe rains that followed the earthquake event also contributed to the density and severity of landslides.

A few isolated instances of fissures and pavement failures were reported after the earthquake. The CARTOSAT 1 and CARTOSAT 2B satellite imageries of 29th and 30th September 2011 have revealed that 350 new landslides have occurred in the post-earthquake period. The spatial distribution of landslides from these satellite imageries can provide useful guidelines for vulnerability assessment, as also planning and formulation of mitigation strategies. Detailed analysis of the newly initiated landslides using imageries from adjoining areas would provide the state administration with complete inventory of landslides triggered by the earthquake.

The instability induced in the hill slopes due to the earthquake has certainly enhanced landslide vulnerability of the state and it is going to be a cause of major concern during the next monsoon. Disaster mitigation efforts need to be directed towards the identification of vulnerable regions, with emphasis on preventive steps as well as for planning relocation of settlements wherever necessary.

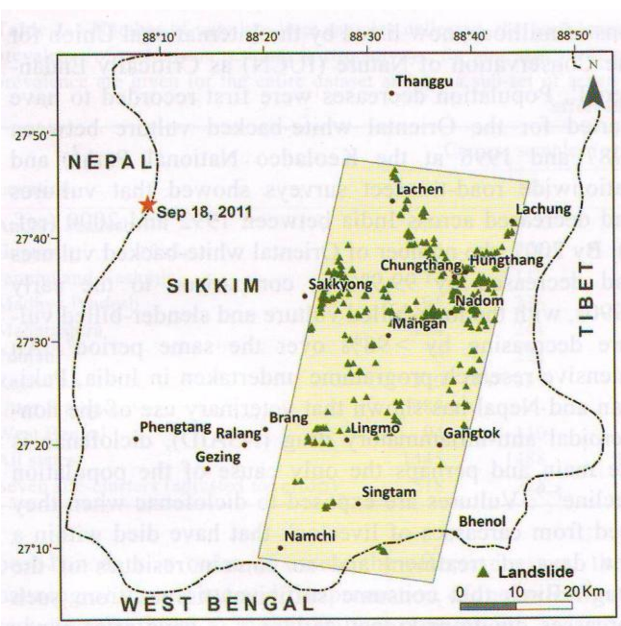


Fig. 25. Distribution of co-seismically generated landslides (area:2000 km²)

Fig. 26. Rock fall along the steep valley face.

5. Technical causes of damage to the buildings

5.1. Ekra and Timber plank houses

The technical reasons for damage incurred to the traditional Ekra and timber plank houses as analysed by the team are as summarized below:

- Damage to the Random Rubble walls has been caused because of poor quality construction and the absence of earthquake resisting features.
- Poor connection between stilts and the house frame has resulted in to separation of the two and lateral movement of the house superstructure.
- Failure of the RC support structure has happened in-spite of the light weight of supper structure because of failure of the foundation including sliding of the slope.

5.2. RC frame structures

The damages of the RC frame buildings are due to the following reasons:

- Lack of earthquake-resistant design and detailing,
- faulty construction practices,
- poor and low quality of construction materials,
- workmanship

Fig. 27. Damaged hollow blocks.

Fig. 28. 90^{o} tie hook opening up.

5.2.1. Causes for non-structural damage: Main caused of non – structural damage are as summarized below.

- Walls are excessively thin. In case of hollow block masonry, the blocks are often placed vertically on their edge. This makes individual blocks unstable, and thus adversely affects the stability of the entire wall.
- In a large number of cases the exterior walls are observed to rest on the cantilever slab with no RC columns in between. This results in extremely long and hence, slender walls.
- Bond amongst the concrete blocks is observed to be poor on account of smooth surface of the blocks.

- Surface of the columns is often observed to be super smooth which is attributed to the practice of spreading plastic sheets in the shuttering. This results in very poor bond with the filler walls.
- Improper connection as also total absence of connection was observed between the RC filler wall reinforcement and the reinforcement of the beams, slabs, and columns.
- Sand used for mortar is often observed to be too fine and containing too much silt.

5.2.2 Cause for structural damage: Main caused of non – structural damage are as summarized below.

- The columns were often observed to be too slender in relation to the overall height of the structure. The stirrups of the column were observed to have been bend at an angle of 90^{o} instead of 135^{o}. This is often responsible for the opening up of rings.
- Absence of rings in column through the junction with beam.
- Overlap between the longitudinal bars in columns too close to the junction with beam.
- Sand used for concrete is often too fine and contain too much silt.
- Aggregates grading is often at major variance with that prescribed in the code.
- Inadequate rings in columns due to excessive spacing, especially in the vicinity of junction with beams and floor.
- In many buildings there will be no confinement of steel reinforcement at beam and column ends,
- Stirrups were not found in the joint region,
- The infill walls are not properly connected with beams and columns.
- Poor quality of concrete**.**

Fig. 29 and 30. Column ring diameter lesser than 6 mm used in combination with 20 mm.

5.3. Earthen Houses

Found primarily in Lachen, these structures are not presently built in the area. Those in existence are rather old, built essentially by the previous generations.

- Pre-existing cracks in these houses attributed to a variety of reasons including earthquake, rain, land subsidence and the others, were observed to have widened and become more visible.
- New cracks were observed to have developed on account of in-plane shear stress caused by the recent quake.
- Roof of these houses was observed to be not anchored to the walls and hence, the roof is not able to control the lateral deformation of the walls.

5.4. Heritage Structures (Monasteries) –

During the field visit a number of monasteries and shrines in and around Gangtok, Chungthang, Lachen, and Lachung were visited. These were observed to have been built traditionally with random rubble walls and relatively light roof. Walls were observed to be typically massive and high. During the previous decades, RC elements such as columns and beams were observed to have been introduced on the inside to support the intermediate floors, door openings and the like. The roofs of these structures are generally observed to be of CGI sheeting supported on timber understructure. Tough the roofs are supported on the exterior walls there was absence of connection between the two. The outside face of the walls is generally observed to be white washed and not plastered while the inside face is plastered and decorated with elaborate paintings. Following are deduced to be the main reasons for the damage incurred in these structures.

- Poor interlocking among stones and among inside and outside wythes.
- Seismic forces.
- Absence of anchoring between the walls and the roofs.


Fig. 31 and 32. Rumghem Gompa

6. Managerial issues related with Sikkim Earthquake

1. The overall condition of the building stock in Sikkim is poor. Multi storeyed houses are common in Gangtok as also other urban / proto – urban areas. Limitation of land availability, particularly in urban / proto – urban areas is observed to force people to opt for vertical expansion so as to meet the growing demand. These multi storeyed houses are however observed to be built with scant regard to earthquake safety.
2. Inappropriate drainage measures, particularly in the urban areas including Gangtok is observed to have resulted in slope instability and ground subsidence related problems.
3. Earthquake induced landslides multiplied the problems of the people engaged in relief and rescue works. Surface connectivity with many far flung areas was cut off due to landslides. Many areas could not even be approached by air due to the bad weather conditions after the earthquake.
4. Communication was worst affected by the earthquake and both road and telecom communication with many far flung areas was snapped. There were many areas that were totally cut off from the State capital and relief supplies and workers could not be sent to these areas.
5. The need for the more helipads and the helicopters was felt during relief and rescue work. The exact coordinates of helipads and other potential emergency landing sites delayed effective response on the aftermath of the earthquake.
6. Even though NDRF team was quickly flown in to Bagdogra within twelve hours of the earthquake there was lack of coordination with the State authorities and NDRF could reach Gangtok in another 24 hours.
7. NDRF was not conversant with the terrain and they could not approach many of the far flung areas.
8. SDRF was not raised by the State and therefore there was no dedicated and trained manpower available for Search and Rescue.
9. Search and Rescue equipments were not available in adequate quantities with the State.
10. As per the directions from Government of India the State of Sikkim re-designated its Land Revenue Department as Department of Land Revenue and Disaster Management rather than raising a separate Department of Disaster Management. Dedicated manpower was therefore not available for undertaking various post-disaster activities.

11. Earthquake rendered a number of multi storeyed building in a very vulnerable state. These buildings are located in densely populated areas and are required to be demolished in view of the threat these pose to neighbouring structures. The State however does not have adequate know how and technical expertise required for demolishing these unsafe buildings.
12. VIPs visits to the earthquake affected areas caused inconvenience for the local authorities as they were busy with relief works.
13. Actions by the state government especially by providing cash (not cheques) relief to the affected persons in public gathering is said to have tremendous confidence building effect upon the masses and the same is quoted as being a good strategy.

7. Recommendations

Based upon the experiences shared with the State Government officials of Sikkim involved in post – disaster relief, rescue and rehabilitation works together with the observations made in the field the following recommendations are made for streamlining disaster management related issues in the State of Uttarakhand.

1. The state of the building stock in Uttarakhand is no different from Sikkim. The hilly terrain of the state faces severe constraints on horizontal expansion due to limited availability of land. Moreover the demand of housing stock and other infrastructure facilities is rising at a fast pace in almost all the urban and proto-urban centres of the state. This is most of the times related to elevation of administrative status of these centres. The masses are thus forced to opt for vertical expansion so as to meet the growing demand. Due to lack of awareness, not so easy access to technical expertise and the like the new constructions in the state are not being built using earthquake safe construction techniques. This is adding to the seismic vulnerability of the built environment in the state. In case of an earthquake this might result in heavy structural losses in the state and therefore the following measures are recommended for improving the situation:
   a) Strengthening of techno-legal regime with incorporation of appropriate BIS Codes for all civil works.
   b) Ensuring strict compliance of the techno-legal regime and discontinuing the practice of compounding.
   c) Mass awareness drive for bringing forth voluntary compliance of safe construction practices.
   d) Providing easy access to earthquake safe construction techniques to the masses and specially potential builders. Provision of circulating the necessary information can be resorted through the municipal bodies / authorities responsible for regulating construction works and the financial institutions.
   e) Seismic vulnerability assessment of the existing building stock is required to be undertaken. This could start with vulnerability assessment of the lifeline structures.

f) Improving seismic response of the existing building stock through retrofitting. The retrofitting of lifeline buildings needs to be taken up on priority basis while the licensing of the places of mass gathering (theaters, malls, conference halls) needs to be linked to their seismic safety.

g) Demolition of seismically unsafe buildings, particularly in the densely habituated areas as these are likely to pose a major threat to the neighbouring structures in the event of an earthquake.

h) Incentives for those opting for rebuilding / retrofitting of their vulnerable structures. This could be in the form of tax concession, soft loan and others.

i) As most structures in the rural and proto-urban areas are constructed solely by masons without any engineering support it is a must to concentrate upon the training of masons in earthquake safe construction.

j) In view of limited land availability in the hilly areas and compulsion of vertical expansion it is necessary to explore and provide avenues of safe vertical expansion. Present practice of limiting the upper limit of vertical expansion is leading to proliferation of unsafe, illegal buildings. This besides enhancing the vulnerability of the building stock is also leading to loss of revenue.

2. Like Sikkim slope instability is a major concern for the state of Uttarakhand. Slope instability in most cases is related to unscientific slope modification and inappropriate drainage measures. Many urban and proto-urban areas of the state are presently facing this problem. The following measures are therefore suggested for improving this situation:

a) The techno-legal regime for construction works should incorporate appropriate provisions for safe site development / slope modification. Geo-technical investigation of the site should be made mandatory in case of all major infrastructure development works.

b) A large proportion of the slope failure incidences in the state take place along the roads. Inappropriate slope modification practices and lack of geo-technical investigations before the construction are largely attributed to this. Geological investigations should necessarily be taken up before finalizing the alignment of all the roads so as to bye pass areas with high probability of slope failure.

c) The attempt to connect every single hamlet of the hilly terrain with road networks needs to be reconsidered.

d) Presently there exists no debris disposal policy in the state and rock mass excavated in slope modification is disposed off in down slope areas. This is leading to i) initiation of new landslides, ii) loss of vegetation, iii) loss of agricultural lands and water sources that are often overrun by the debris, and iv) increased pace of siltation of the downstream reservoirs. It is therefore a must to have a Debris Disposal Policy that could well be a part of a comprehensive Land use Policy for the state. There should be provision of notification of debris disposal sites in the Policy and punitive measures should be put in place for those not complying.

e) In all infrastructure development works there should necessarily be budgetary provision for safe debris disposal.

3. As was the case in Sikkim landline and mobile phone connectivity is most likely to be disrupted in the event of any major disaster. It is therefore required that satellite communication devices be provided to government functionaries at Block / Tehsil level. It is at the same time required that HAM radio be promoted in the far flung areas as these have proved vital in many previous disaster events across the globe.

4. It is necessary to have detailed list of the coordinates of all the functional helipads in the state together with that of the open spaces that could function as emergency landing sites.

5. In view of the difficult access and difficulty in reaching far flung areas of the state on the aftermath of any disaster event it is necessary that necessary relief items in adequate quantities be stored at appropriate places in the state.

6. It is often not possible to procure necessary relief items at the time of emergency. It is therefore necessary that vendors capable of ensuring bulk supplies of different items be identified and pre-contract agreement be entered into with them to reduce delays as also cost escalation.

7. On the aftermath of most disasters incidences the search and rescue work is often carried out by the local volunteers and is over by the time formal responders reach the site of the disaster. It is therefore necessary to raise trained and equipped search and rescue volunteer groups throughout the state, particularly in the vulnerable areas.

8. The Sikkim experience highlights the importance of raising State Disaster Response Force. In the past decision was taken to convert two battalions of PAC into State Disaster Response Force that were proposed to be trained and well equipped. These were to be stationed at Srinagar and Almora respectively. It is recommended that necessary action be taken to raise these units immediately.
9. There should at the same time be regular coordination meetings at both state and district level with the representatives of Armed Forces and Para Military Forces to ensure effective response on the aftermath of any disaster.
10. It is highly recommended that necessary Search and Rescue equipments be provided in appropriate numbers at Block / Tehsil level.
11. It is recommended that both State and District Disaster Management Authorities be empowered to manage the various issues concerning disaster management.
12. Demolition of the buildings rendered unsafe by the earthquake, particularly in the densely populated areas, was identified as a major issue during the Sikkim visit. It is therefore necessary that adequate know how of the safe demolition practices be gathered and the agencies providing these services be identified.
13. VIPs visits to the disaster affected areas often hinder the pace of relief and rescue works and unnecessarily add to the work load of the officials that are already overworked. It is therefore necessary to formulate guidelines for restricting VIP visits. To be acceptable this exercise needs to be taken up in consultation with different political parties.
14. Improvisations on traditional construction techniques with incorporation of modern building construction practices can help reduce earthquake vulnerability of the building stock of the state.
15. Providing cash relief to the Sikkim Earthquake victims was cited as being a big confidence boosting measure but experience in the state suggests that cash relief is often spent immediately and there are no long term gains. Moreover the priorities of women and children are not well taken care of. It is therefore suggested that the existing practice of extending relief through bank transfer / cheque be continued.

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