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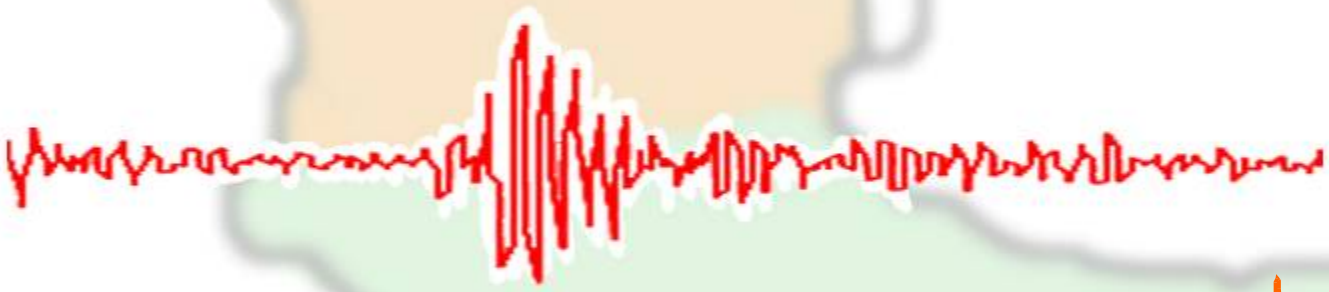
National Information Center on Earthquake Engineering

2011 SIKKIM EARTHQUAKE

Effects on Built Environment &
A Perspective on Growing Seismic Risk



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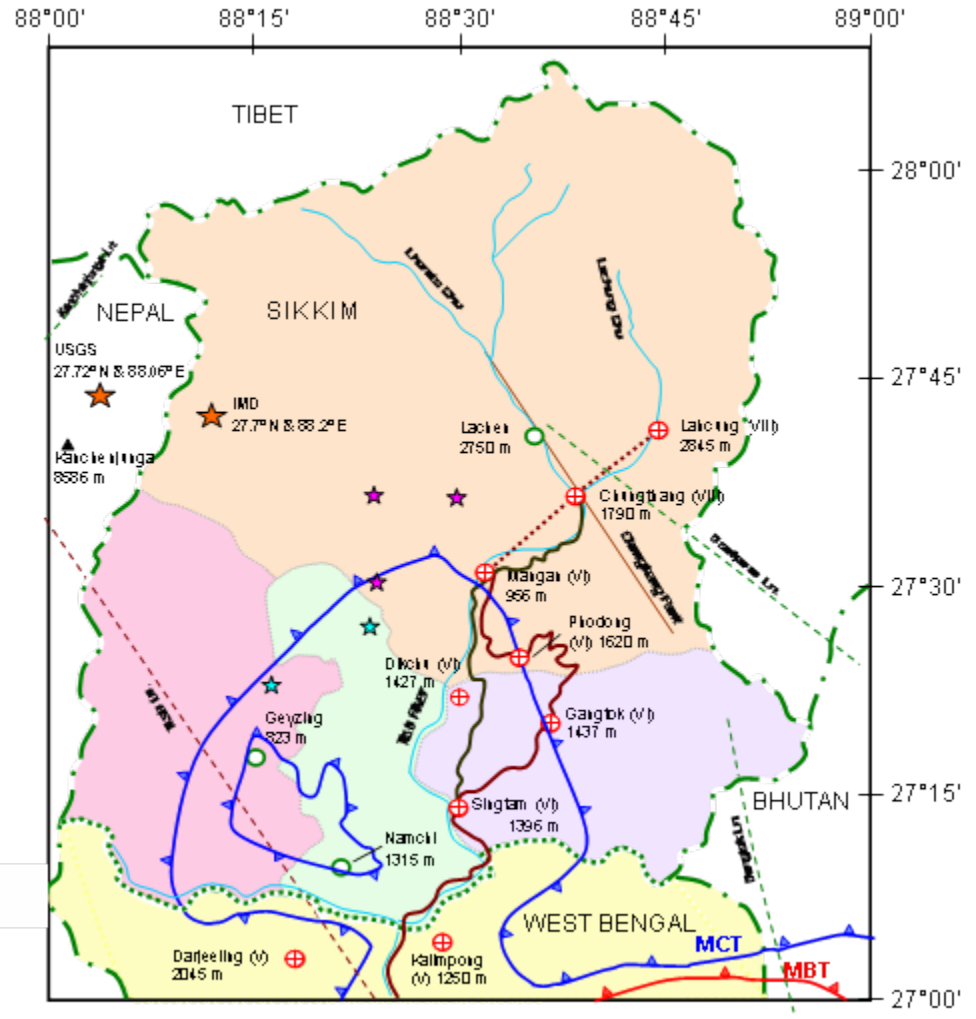
2011 Sikkim Earthquake

The M6.9 earthquake hit Sikkim on 18th September 2011 with its epicenter located at 27.72°N, 88.06°E, near India-Nepal border, about 68 km NW of Gangtok and at a focal depth of 19.7 km as reported by USGS. Three aftershocks of magnitude 5.7, 5.1 and 4.6 were also felt in Sikkim within 30 minutes of the earthquake.

The region is known for seismic activity between the Main Boundary Thrust (MBT) and the Main Central Thrust (MCT).



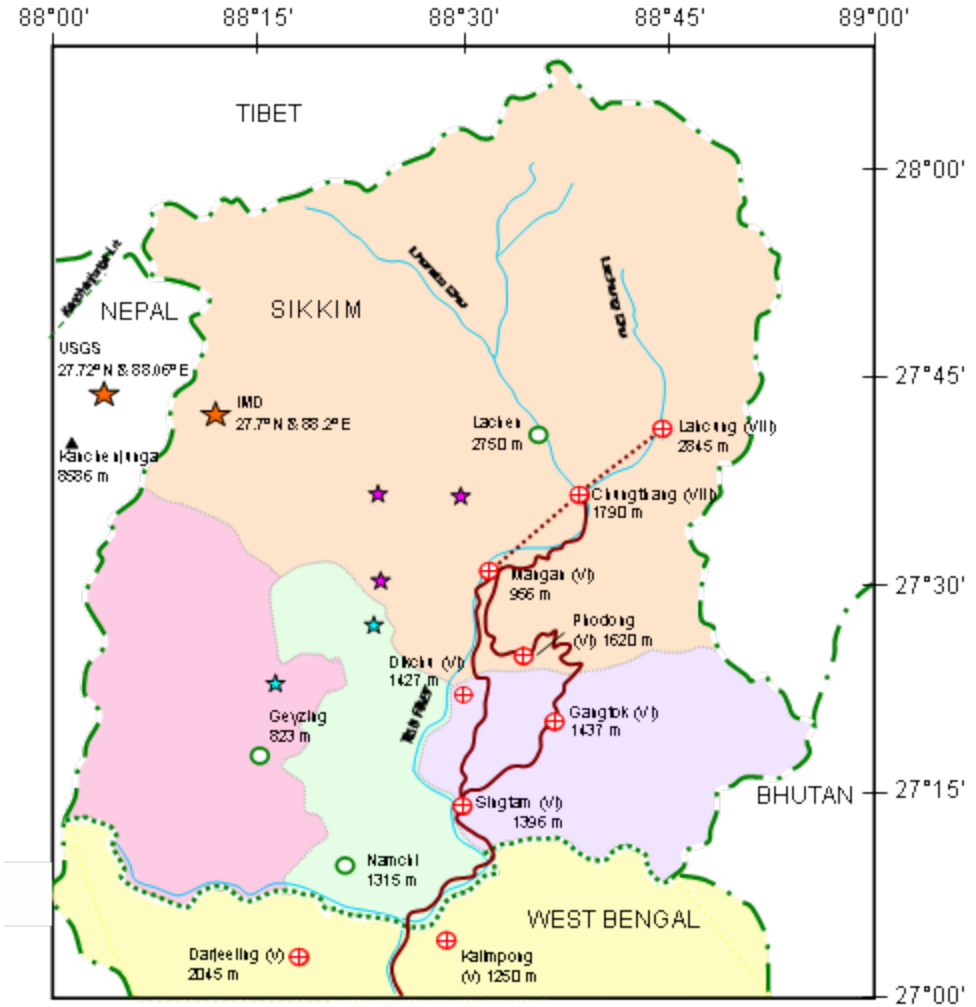
Major towns visited	Other major towns
Aftershock reported by USGS	Aftershock reported by IMD
Main Central Thrust (MCT)	Main Boundary Thrust (MBT)
River/Stream	Field trip on road
Field trip using Army Helicopter	

2011 Sikkim Earthquake…

The team visited several affected towns in the North and East Districts of Sikkim, such as Lachung, Chungthang, Mangan, Phodong, Gangtok, Dikchu, and Singtam.

Maximum observed shaking intensity during this earthquake was VIII on MSK scale.

About 100 deaths are reported in India with the maximum of at least 60 in the state of Sikkim and total loss of property was about Rs. One lakh crore.



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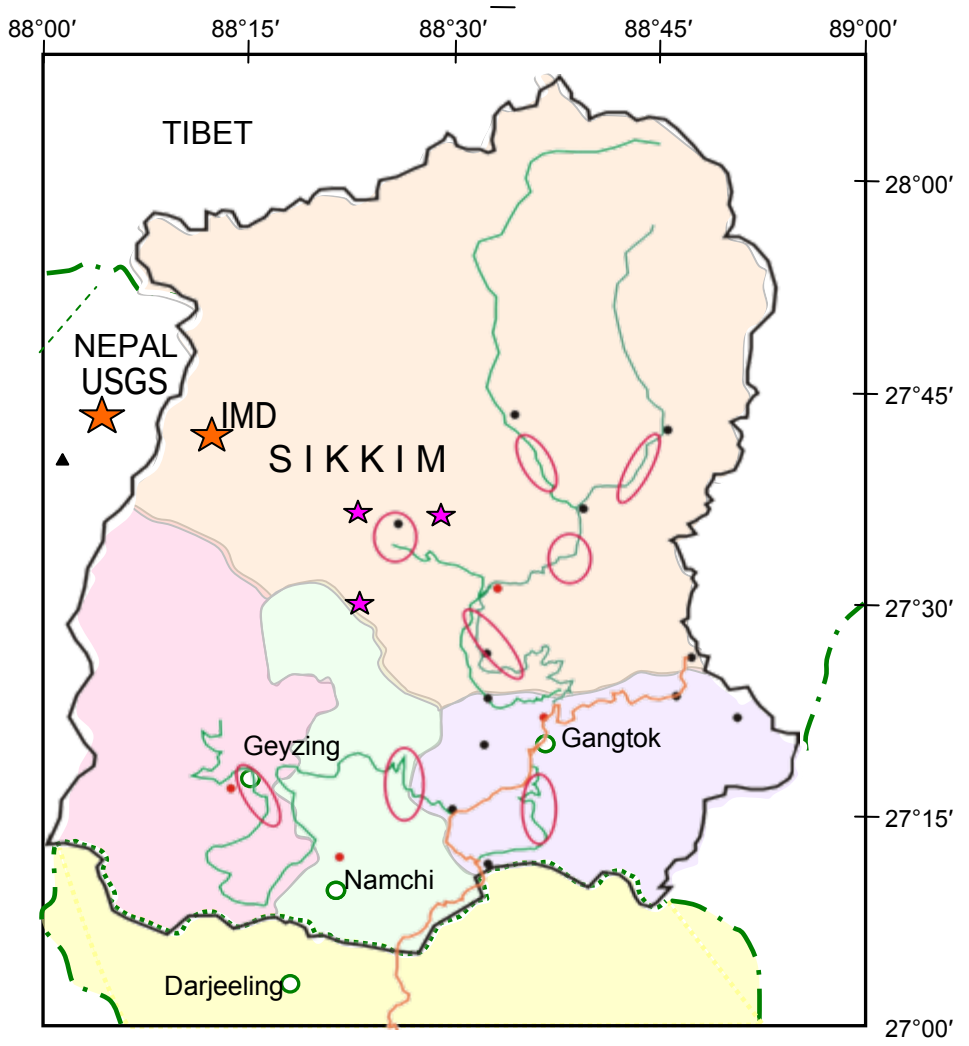
Landslide

Landslides disrupting the road network

More than 300 landslides occurred all over the state and disturbed the road connectivity to major towns like Mangan, Chungthang, and Lachung and even NH31A, main route connecting Sikkim and West Bengal.



Rockslide

Devastation in Lachung

Collapsed temple, Lachung

Huge rockslide that came two days after the earthquake damaged several housing units in Lachung.

Performance of RC Buildings

Collapse of the building highlights the structural deficiencies widely present in RC buildings in the affected region. This includes lack of earthquake-resistant design and detailing, faulty construction practices, poor quality of construction materials, workmanship, etc.

5-storey building at Lumshey Bastey, Gangtok

Performance of RC Buildings…

Pan-caking failure of two stories of a 9-storey building at Gangtok

Collapsed building colliding with adjacent building at Gangtok

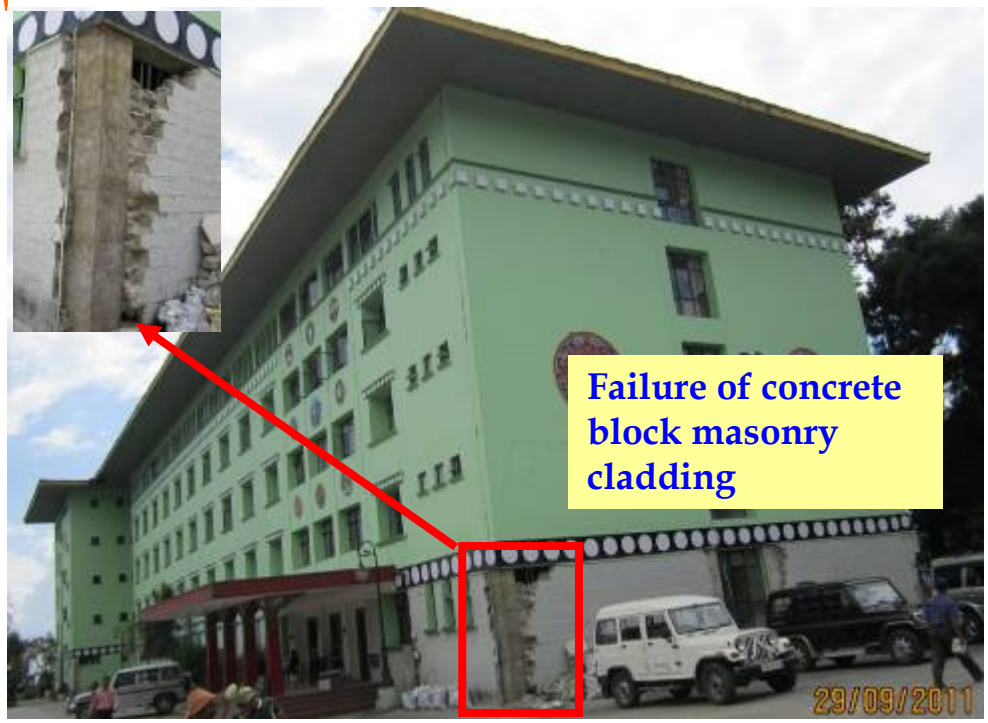
Performance of RC Buildings…

Pan-caking failure of school-cum-residential building at Chungthang

Severe damage in a 5-storey building at Chungthang

A large number of concrete and masonry buildings were severely affected in the town of Chungthang, highlighting serious deficiencies in the prevailing construction practices.

Performance of RC Buildings…



State Secretariat building at Tashiling, Gangtok

Failure at beam-column joint

The building constructed in mid-70's suffered damage in the 2006 Sikkim earthquake and underwent repair. Lack of seismic detailing of RC frame members and beam-column joints, poor quality of infill material and concrete were the main causes of its poor performance in recent and previous earthquakes.

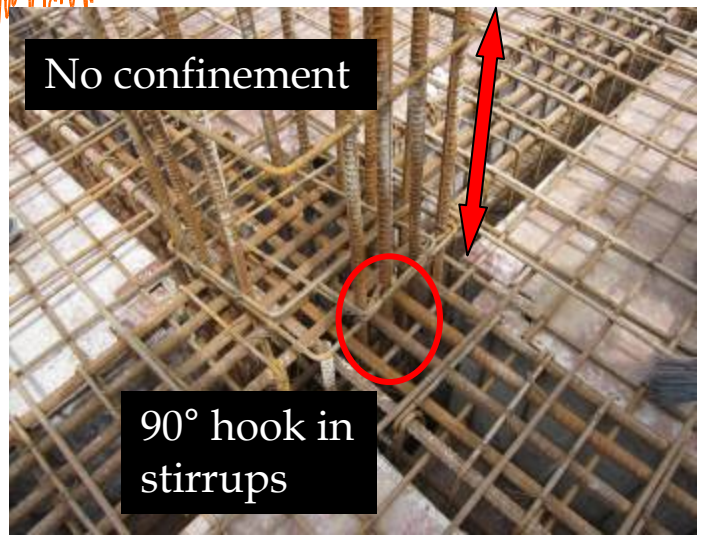
Performance of RC Buildings…

Failure of unsupported wall

Pounding between two adjacent buildings

It is common practice to construct buildings very close to property lines due to smaller plots in urban areas, and sometimes with no gap at all between the adjacent buildings leading to damage due to pounding.

Construction Practices



Large spacing of stirrup

Splicing near beam-column joint

Mot common problems observed in affected buildings are:

No confinement of reinforcement at beam and column ends,

No shear reinforcement (stirrups) in joint regions,

Stirrups of very small diameter bar and inadequate tying,

90° hook and insufficient length of such hooks,

Splicing at member ends instead of at the middle,

Construction (cold) joint at top end of the column near beam-column joint,

Poor quality of concrete.

Construction Practices…

Unavailability of raw building materials and expensive transportation cost lead to the use of various substandard construction materials. Use of weaker infill materials and thin walls at upper floors to increase the floor area, makes the walls vulnerable to in-plane and out-of-plane seismic forces.

Traditional Construction

Shee-Khim **houses**

Shee-Khim house is one of the traditional construction practiced in upper reaches of Sikkim. It is made of wooden frame and planks and supported on wooden posts. Houses are provided with random-rubble (R/R) masonry wall as basement enclosure.

Traditional Construction…

Ikra house

Another type of traditional housing practice in Sikkim is *Ikra* house. Walls are made up of bamboo panels fitted inside the wooden frames and plastered with cement/mud mortar. These are also supported on wooden posts.

Bamboo splints woven together and fitted inside the wooden frame

Minor damages in bamboo panels

Traditional Construction…

Failure of R/R masonry at basement level

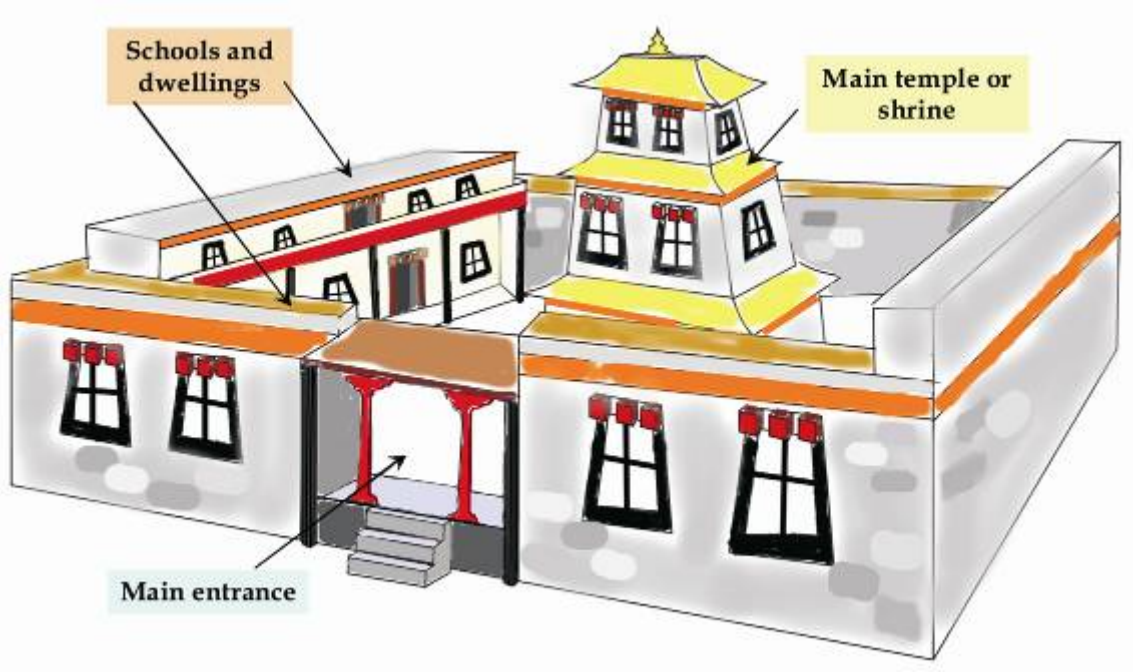
Traditional houses performed considerably well in this earthquake due to their simple configuration and inherent earthquake-resisting features.

Monasteries and Temples

Sikkim is dotted with numerous monasteries of significant heritage and cultural values. There are mainly two types of monasteries:

Tibetan gompas (monastery) are palace-like structures and serve as learning schools for the monks.

Mani-Lakhangs are only temples and are normally monitored by a few monks.



Typical monastery temple

Monasteries and Temples…

Construction style

The monasteries are simple one to three-tiered structure on symmetric plan with reduced floor area for upper stories. They were initially built with timber and stone masonry, while later additions were constructed in concrete and brick masonry.

The exterior walls are in stone masonry mostly random rubble while the floors and double pitched roof are in timber construction, using single post beam system.

The interior timber frames are intricately carved, while the interior wall surfaces are diligently painted with life-like imageries.

Typical monastery temple

Monasteries and Temples…

Damage to masonry wall of temple at Lachung

Damage to Ringhim Monastery, Mangan

Mostly all monasteries suffered damage to their infills which was R/R masonry in mud/cement mortar. Part of the structure built in timber escaped with minor to negligible damage.

Monasteries and Temples…

Enchey Monastery, Gangtok

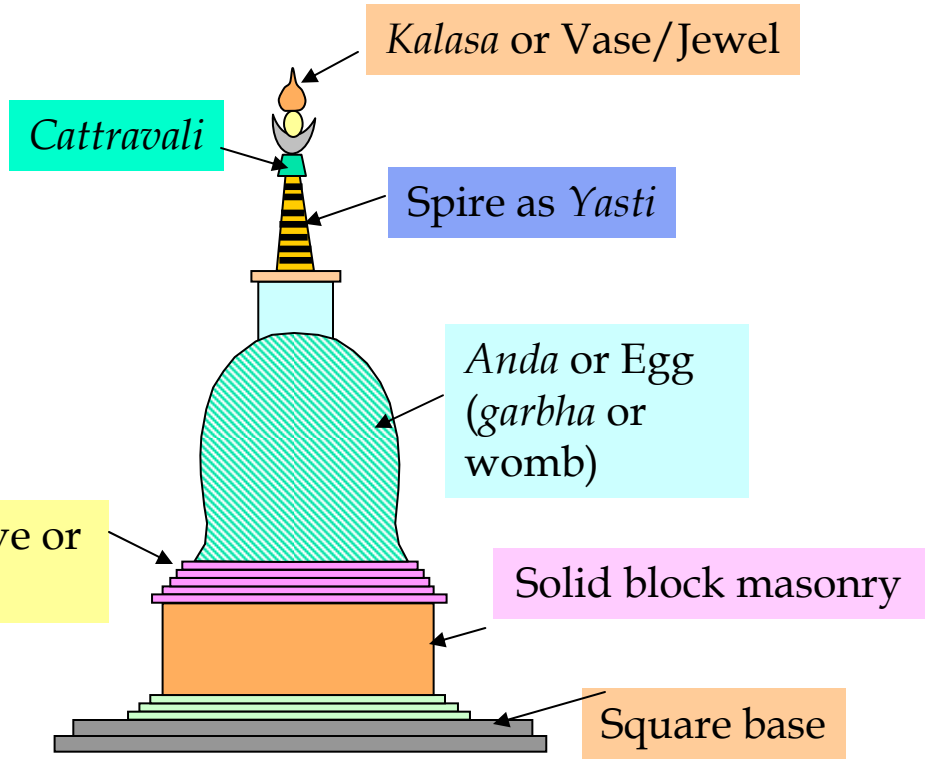
Minor damages as seen from inside

It is a three-tiered monastery shaped like Chinese Pagoda, built about 200 years ago during the reign of ***Thutob Namgyal***.

During this earthquake the R/R stone masonry wall at the top floor suffered some damage around the opening in the wall.

Stupas or *Chortens*

Stupas or ***Chortens*** are mound-like structure containing Buddhist relics (***typically the remains of Buddha***) and is used as a place of worship.



Such structure suffered damage mainly because of weak masonry and also because they are very old.

Bridges

Failure of wing wall (R/R masonry) of steel bridge (Ray Khola)

Failure of abutment of Pale Khola bridge

RC bridge (Andheri Khola) had no damage

No major damage to bridges have been reported.

Summary of Earthquake Effects

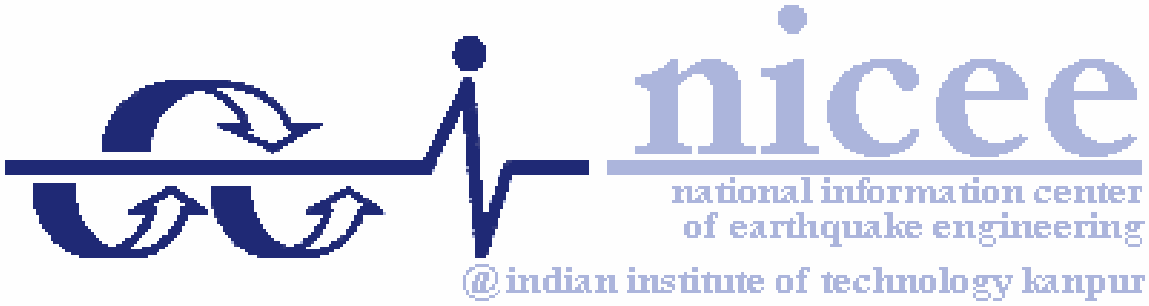
- The general pattern of damage to structures, landslides, rockfalls, etc. is consistent with the shaking associated with the M6.9 event.
- However, many dramatic building collapses and damages to structures, disproportionate to the observed intensity of shaking were primarily due to faulty construction practices and poor compliance with seismic codes.
- Many unique and inherently poor construction features such as weak and very slender partition walls in brick/block masonry or in lightly reinforced/plain concrete, construction on sloped ground, unstable slopes, weak retaining walls, etc., significantly add to the seismic vulnerability of structures.
- The traditional houses like *Shee-Khim* and *Ikra* performed well as expected as they evenly distributes the deformation which adds to energy dissipation capacity of the system.
- Monastery temples being old and weak were deficient in strength to resist the seismic loads and these need effective strengthening measures to safeguard against future tremors.

Implications for Future Action

- Rough terrain, complex topography and remote locations pose serious challenge for sound and quality construction in hilly areas. Lack of awareness about the seismic vulnerability of the area have led to haphazard planning of towns and construction on sites prone to landslides and sinking (ground settlement).
- All stakeholders must be educated about importance of earthquake-resistant construction and its role in mitigating future risk.
- Good concrete and masonry construction practice and suitable material should be used for light or strong partition walls.
- New building typologies of proven earthquake performance, such as confined masonry needs to be introduced for low rise buildings.
- Locally available materials (such as bamboo and other sustainable timber alternatives) and traditional technologies should be reinstated and integrated with modern construction practices to have an appropriate design for safe housing.
- Adhoc retrofitting practices of questionable performances do not necessarily make buildings resistant to future seismic events.
- Relevant BIS codes and guidelines like IITK-GSDMA guidelines for seismic evaluation and strengthening of building is recommended.

Closing Remarks

- The damage to built environment, economic loss and human casualties caused by Himalayan earthquakes are increasing rather proportionally with the growth of settlement and population.
- Despite the available knowledge base, the communities in high seismic regions such as Sikkim and neighbouring states are not adequately prepared due to lack of implementation of earthquake-resistant building technology. However, with adherence to seismic codes and recommended construction practices, it is possible to mitigate such large-scale disasters.
- NICEE @ IITK has several resources available at its website *www.nicee.org* for seismic risk mitigation of built-environment.



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