A BRIEF REPORT ON IMPACTS AND IMPLICATIONS OF 2011 SIKKIM (INDIA-NEPAL BORDER REGION) EARTHQUAKE

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EARTHQUAKE AND ITS SEISMOLOGICAL SETTING

The M6.9 Sikkim earthquake of September 18, 2011 struck at 18:10:48 IST lasted to about 30 to 40 seconds with its epicenter located at 27.72°N, 88.06°E near India-Nepal border region, about 68 km NW of Gangtok at a focal depth of 19.7 km. Three aftershocks of magnitude 5.7, 5.1 and 4.6 were also felt in Sikkim within 30 minutes of the initial earthquake. This region has experienced relatively moderate seismicity, with 18 earthquakes of M5 or greater over the past 35 years within 100 km of the epicenter of the September 18, 2011 event. The affected region lies in the high risk seismic zones of IV of Indian seismic code IS: 1893 with the expected shaking intensity of VIII (on MSK scale).

GENERAL OBSERVATIONS

The earthquake followed by heavy seasonal rains triggered more than 300 landslides, rock/mudslide causing much devastation (Fig. 1). Damage to buildings and infrastructure due to landslides dominated those due to direct ground shaking in some regions. Landslides cut off the severely affected areas from the rest and hampered the rescue and relief work in this difficult terrain.

General damage to buildings and other structures agreed well with the intensity of ground shaking observed at various places, with the maximum of VIII at Chungthang and Lachung, VI in and around Gangtok and Mangan on MSK scale. However, unexpected severe damage at an intensity of VI in Gangtok was observed in buildings such as the Secretariat building (Fig. 2), two multistory buildings in Balwakhani, and 5-storey building in Lumshey Basty. Similar damages were also reported from other towns such as Dikchu, Nayabazar, Singtam, etc.

Fig. 1 Rockslide at Lachung

Fig. 2 Damages observed in state secretariat building

PERFORMANCE OF STRUCTURES

The wrath of this earthquake was witnessed by both urban and rural communities but much of the damage was observed in the areas closer to the epicenter. Three major building typologies prevalent in the state are RC/ masonry buildings, and traditional *Ikra* type and *Shee-khim* houses (Fig. 3). Traditional constructions are built using locally available materials and have performed well because of their inherent earthquake resistance abilities.

Major towns like Singtam, Chungthan, including the state capital Gangtok where a large inventory of RC buildings have been added in the past thirty years were worst affected. It was rather disappointing to discover that a great majority of both governmental and private RC-frame buildings seriously lacked earthquake-resistant features which are so essential for a satisfactory seismic performance in the design level shaking. 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, extended floor plans in upper stories supported on cantilevered beams and slabs, construction on sloped ground, unstable slopes, weak retaining walls, poor construction material etc., significantly added to the seismic vulnerability of structures. Extensive damage to school and hospital buildings reported in the region exposed the seismic vulnerability of these important structures.

Fig. 3 Traditional *Shee-khim* house which suffered negligible damage

The poor earthquake performance of cultural heritage such as monasteries is a source of concern as almost all historic religious structures suffered varying degree of damages in this earthquake. Heavy damages have been observed to exterior walls at several monastery temples (Fig. 4).

The area has a number of highway and pedestrian bridges over rivers, rivulets, and gorges. However, no serious damage to any of the highway bridges was noticed in the areas visited. The road network in the state was disrupted due to massive landslides triggered after the earthquake.

Fig. 4 Partial collapse of stone masonry walls of a monastery temple at Mangan

IMPLICATION FOR FUTURE ACTION

Rough terrain, complex topography and remote locations pose serious challenge for sound and quality construction in hilly areas. Lack of awareness in the general public 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). Unavailability of raw building materials and the expensive transportation cost have caused use of various substandard construction materials. It is critical to promote good concrete and masonry construction practice and suitable material for light or strong partition walls. For low rise buildings, new building typologies of proven earthquake performance, such as confined masonry needs to be introduced (Fig. 5).

All stakeholders including builders, contractors, engineers, private owners, government officials and public at large must be educated about importance of earthquake resistant construction and its role in mitigating future risk.

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 strong and safe housing.

Monasteries which are important historic structure and adds to the cultural heritage of the state should be considered for retrofitting as well. Important structures such as schools and hospitals which are vital in the post-earthquake relief and rescue efforts must be built earthquake-resistant on a high-priority.

It has been observed that adhoc retrofitting practices of questionable performances are implemented after an earthquake. These impromptu remedies do not serve the purpose of safeguarding the structure and making it resistant to future seismic activities.

Sikkim, located in seismic zone IV, is prone to much larger earthquake than the present event; hence compliance to seismic codes can not be ignored. Relevant BIS codes and documents like IITK-GSDMA guidelines for seismic evaluation and strengthening of buildings is recommended.

Fig. 5. A building in construciotn using confined masonry

In summary, 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 disaster in the regions of high seismic activity.

NICEE at IITK has several resources available at its website www.nicee.org on addressing various aspects of seismic risk and its mitigation.

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