Learning from Earthquakes

M 6.9 Sikkim Earthquake of September 19, 2011

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An earthquake of magnitude 6.9 occurred at 6:11 pm local time on September 19, 2011, with an epicenter at the India-Nepal border region (Figure 1); the focal depth has been estimated as 19.7 km. The region is known to be seismically active, located in the Alpine-Himalayan seismic belt characterized by two major fault systems (MBT and MCT) associated with the collision of the Indian and Eurasian plates. The event was located north of MBT in the eastern Nepal-Sikkim Himalayas, which has been a region of intense seismic activity in recent times. Maximum shaking was experienced in India's northeastern state of Sikkim, followed by Tibet, Nepal, the Indian states of Bengal, Assam, Bihar, and Meghalaya, together with the neighboring countries of Bhutan and Bangladesh. The maximum shaking intensity attributed to this earthquake is VIII in the North Sikkim district in the regions of Chungthang and Lachung. The total death toll is about 112 persons, with 60 reported fatalities in the state of Sikkim alone. The earthquake was followed by aftershocks of magnitude 4.8 and 4.6 within 30 minutes of the main shock. The region falls into the second highest seismic zone of the Indian Seismic Code IS:1893, Zone IV, with an expected shaking intensity of VIII.

Figure 1. Epicenter of Sikkim earthquake and route of damage survey trip.

As the region is mountainous and rains preceded the earthquake, the event triggered massive landslides. Damage to buildings and infrastructure caused by landslides was more severe than damage due to direct ground shaking in some regions (Figures 2 and 3). Landslides cut off the severely affected areas, especially at higher altitudes, hampered rescue and relief work, and required the help of Army helicopters.

The affected area has a low population density of an average of 88 persons/sq. km. The state capital of Gangtok is the biggest city in the area. Much of the construction is of empirically constructed reinforced concrete (RC) buildings of four to nine stories adjoining each other on small plots, with buildings extending to the property lines. A majority of these buildings exhibited extensive damage to unreinforced masonry (URM) infill panel walls due to weak masonry and large unsupported length- or height-to-thickness ratio. Most buildings had a symmetric and uniform grid of beams and columns. Some buildings that had open stories collapsed, usually at mid-height (Figure 4), or had severe structural damage. Likewise, buildings with asymmetry in placement of URM infill walls, causing torsion, also were severely punished. Single RC buildings collapsed far from the meizoseismal area; e.g., at Jorethang in South Sikkim district about 80 km from Gangtok (Figure 5). Traditional *Ekra* housing made of bamboo or wood framing with lightweight infill panels of straw and plaster behaved exceptionally well.

continued on next page

Figure 2. *Landslide near the cable-stayed bridge at Nayabazar (South Sikkim District) restricted the use of the bridge for relief work after the earthquake (photo: C.V.R. Murty).*

Figure 3. *Damage due to rockslide and mudslide at Lachung (photo: D. Rai).*

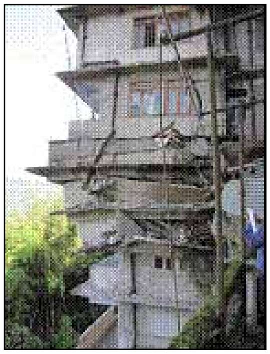

Figure 4. Pancaking of middle two stories in a nine-story building at Gangtok, East Sikkim (photo: D. Rai).

Figure 5. Pancaking of three stories in five-story house in Jorethang, South Sikkim (photo: A. Sheth).

Figure 6. All columns supporting roof of Phudong Monastery, North Sikkim, failed. (photo: A. Sheth).

M 6.9 Sikkum Earthquake

continued from previous page

Heavy damage has occurred to temple structures (shrine halls) of various Buddhist monasteries (Figure 6). Historic monastery temples are made of thick (two to five feet thick at base) external load-bearing rubble masonry wall in mud mortar. The internal framing was of wooden posts and beams. Monastery buildings of the past few decades include those made in RC, with beams and columns infilled with URM infill walls. In this RC construction, there is no frame action; the RC construction mimicked the historic wooden construction. Both sets of monasteries were damaged; some had partially collapsed, and others showed extensive structural damage. Few monasteries escaped with minor nonstructural damage, such as the King's monastery in Gangtok.

Sikkim is the second smallest state in India; about 31 hydropower projects have been sanctioned in the past three years, some of which are close to completion. No serious damage to these projects, which often involve long tunnels through mountains, has been reported to date. The earthquake's impact on these projects is currently being investigated.

News of the Membership

ASCE Honors Gould, Hawkins, Prakash

Three EERI members were recently named Distinguished Members of the American Society of Civil Engineers (ASCE). Only approximately 200 of the Society's 140,000 members worldwide have achieved the highest accolade of active distinguished membership. The awards were presented during ASCE's Annual Civil Engineering Conference in Memphis, Tennessee, October 20-22, 2011.

Phillip Gould, professor at Washington University, St. Louis, was recognized for developing innovative technology for the design and construction of large cooling tower shells, for applying finite element technology to the development of prosthetic heart valves, and for promoting earthquake hazard mitigation worldwide through research, teaching, and professional leadership.

Neil Hawkins, professor emeritus at the University of Illinois in Urbana, was recognized for his eminence as a leader in developing codes and standards for structural engineering practice, for his research on reinforced and prestressed concrete and the transfer of his results into practice, and for his achievements in the education of engineering students.

Shamsher Prakash, professor emeritus at the Missouri University of Science and Technology in Rolla, was recognized for his pioneering work on liquefaction of fine-grained soils and seismic analysis of rigid retaining walls, revolutionizing use of geotechnical engineering case histories in professional practice and education, and authoring the first comprehensive text on soil dynamics.

Publication

Printed *FEMA 455*

The printed (in color) version of *FEMA 455, Handbook for Rapid Screening of Buildings to Evaluate Terrorism Risk* is now available from the Applied Technology Council (ATC). The primary purpose of the screening procedure is to prioritize the relative risk among a group of buildings in a portfolio or community, but it can also be used to develop building-specific risk information. The procedure emphasizes the vulnerability factor, due in part to the relatively significant level of control that the owner has over this factor compared with the other two factors relevant to risk: threat and consequences. The *Handbook* can be (1) downloaded from the FEMA website (http://www.fema.gov/library), or (2) purchased for $60 through the ATC Online Store at www.atcouncil.org/Online-Store/vmchk.html.