Chapter 9

Earthquake

Introduction

The South Asian region has a history of catastrophic earthquakes that have occurred time and again, inflicting huge losses in terms of human lives and property in spite of low population density and level of development in the past (Tables 9.1 and 9.2). A great or major earthquake in recent times will cause devastation many more times than in the past due to high population density and developed infrastructure.[1,2] The following are the five deadliest earthquakes that have occurred in the region since the beginning of the last century; together they have claimed at least 222,500 lives and property and infrastructure worth billions of USD.

Table 9.1 The deadliest earthquakes in South Asia [3,4]

Year	Place	Deaths
2004	Sumatra	~55,000+
2005	Kashmir	~80,000
2001	Bhuj	~13,805
1935	Quetta	~35,000
1905	Kangra	~28,000
1934	Nepal-Bihar	10,653

Table 9.2. The strongest earthquakes in South Asia since 1900[3]

#	Date	Mw	Latitute	Longitude	Location
1	26 December 2004	9.1	03.29	95.98	Sumatra-Andaman arc
2	15 August 1950	8.6	28.38	96.76	Chayu (Zayu)-Upper Assam
3	15 January 1934	8.1	27.55	87.09	Eastern Nepal-Bihar border
4	27 November 1945	8.0	25.15	63.48	Makran Coast, Balochistan
5	30 May 1935	7.8	28.87	66.40	Quetta, Balochistan
6	4 April 1905	7.8	33.00	76.00	Kangra, Himachal Pradesh
7	26 June 1941	7.7	12.40	92.50	Middle Andaman Island
8	26 January 2001	7.7	23.44	70.31	Bhuj, Gujarat
9	8 October 2005	7.6	34.43	73.53	Kashmir-Kohistan
10	29 February 1944	7.4	00.30	75.30	Near the Maldive Islands

In the recent past, the region has been devastated by three major earthquakes:

(i) The Bhuj earthquake of 2001 left 13,805 dead in India (40 in Pakistan), 1,67,000 injured and 1,205,198 houses damaged;

(ii) The Indian Ocean earthquake of 26 December 2004 was the third largest seismic event on the earth with a magnitude of Mw 9.1 (the 1960 Chilean earthquake had a magnitude of Mw 9.5 and 1964 Prince William Sound, USA had a magnitude of Mw 9.2) and produced the most devastating tsunami in recorded history. It killed over 225,000 people in 11 countries and inundated large tracts of coastal land with waves up to 30 m (100 feet) high. Among SAARC countries, Sri Lanka and India were worst affected, followed by the Maldives;

(iii) The 2005 Kashmir earthquake with a magnitude of 7.6 on the Richter scale, similar to the 1935 Quetta earthquake and the 2001 Gujarat earthquake caused deaths of nearly 80,000 people in Kashmir and other adjoining areas of India, Pakistan and Afghanistan.

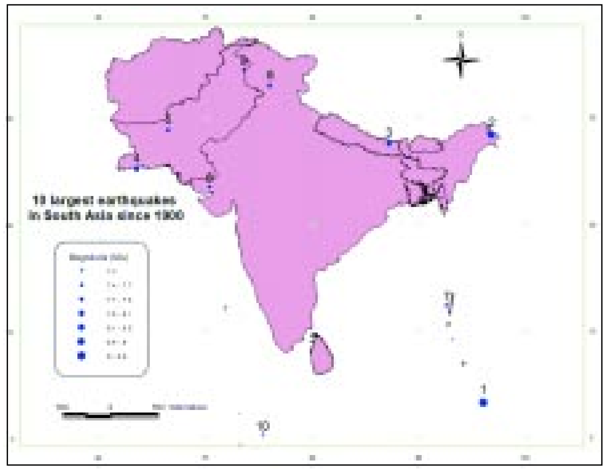


Figure 9.1. The strongest earthquakes in South Asia since 1900[3]

Seismotectonics of the region

The world's youngest mountain belt, the Himalaya and the Hindukush, envelope the SAARC region all along its northern fringe. These lofty mountain ranges spread from Afghanistan in the west to Bangladesh in the east. Six out of the eight SAARC countries, namely, Afghanistan, Pakistan, India, Nepal, Bhutan and Bangladesh are located within the seismically most active Himalayan-Hindukush belt of the world. The remaining two countries, the Sri Lanka and the Maldives, are vulnerable to a tsunamigenic earthquake in the Indian Ocean.

On a continental scale, the seismicity of central and eastern Asia is the result of northward convergence of the India plate against the Eurasia plate with a velocity of about 50 mm/y. The convergence of the two plates is broadly accommodated by the uplift of the Asian highlands and by the motion of crustal material to the east away from the uplifted Tibetan Plateau. As a result, the Himalayas have emerged as the largest active continent-continent collision zone on earth causing numerous major and great earthquakes.[5,6,7] The same process, though involving the Indian plate and the Burmese Micro-plate, results in deadly earthquakes in the Andaman and Nicobar Islands. The rate of convergence between the Indian plate and the Himalayas is 10-5mm/year.[8,9] This is only about one-fourth of the convergence rate between the Indian and Eurasian plates; a major fraction of the plate convergence is accommodated by the eastward escape of central Asia along large strike slip faults and by internal deformation accompanying uplift in Tibet and the Himalayas itself.[10,11]

The Indus suture (is this a technical term?) zone marks the beginning of the collision between the Indian subcontinent and Eurasia in early Tertiary times. This zone is marked by relict oceanic crust (ophiolite) that separated the two continents. With time, the collision boundary shifted southward, and the northern edge of the Indian plate was thrust back on to itself, first along the Main Central Thrust (MCT) and later along the Main Boundary Thrust (MBT).[12] Presently, the main tectonic displacement zone lies along the Himalayan Frontal Fault System, which comprises Himalayan Frontal thrust at the edge of the Indo-Gangetic plain, and several anticlines and synclines to the north, which are the surface expression of displacement on a buried decollement fault.[12,13,14]

The spatial distribution of earthquakes in this region is clustered around main tectonic discontinuities such as MCT, MBT and HFT in the Himalayan range. This high seismicity zone may mark the intersection of the top of basement with the decollement thrust fault. Most of the seismicity of the southern flank of the Himalayas is attributed to the decollement. At the outer fringe, three great earthquakes

(M=8) struck the foothills of the Himalayas in 1905, 1934 and 1950. These are the largest earthquakes that ever occurred on continental thrust faults and are comparable in scale to the great earthquakes of the subduction zones.

Intraplate earthquakes

Earthquakes that occur within a tectonic plate account for less than 1 per cent of the world's earthquakes, but they pose a significant seismic hazard and can be quite large. Intraplate earthquakes are not readily explained by plate tectonics. Some occur within broad plate boundary deformation zones, such as those across North America and South Asia within the Indian plate in the peninsula and in adjoining parts of the Arabian Sea or the Bay of Bengal. These are mainly due to localized systems of stress accumulation along mega structures and flexures as interpreted recently by Bilham et al.[15] The current study highlights an outer trough south of the flexural bulge in central India where surface stresses are double the contiguous compressional stresses to the north and south. The Bhuj, Latur and Koyna earthquakes and numerous other recent reverse faulting events occurred in this compressional setting.

2007 Seismicity in South Asia

At least 709 deaths resulted from earthquake activity worldwide in 2007, according to the U.S. Geological Survey (USGS) and confirmed by the United Nations Office for Coordination of Humanitarian Affairs (OCHA). This is the fewest number of casualties from earthquakes in a year since 2000, when only 231 people were killed. Most of the fatalities for the year, at least 514, occurred when an earthquake of magnitude 8.0 hit Pisco, Peru on August 15. An additional number of at least 4,256 people were injured by earthquakes during the year.

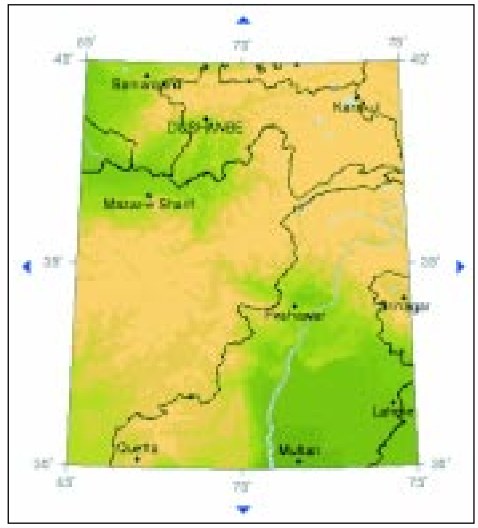
Earthquakes caused casualties or damage in 23 countries during 2007, including the United States. Other countries affected were Barbados, Brazil, Chile, China, Colombia, Ecuador, France (Martinique), Guatemala, India, Indonesia, Iran, Japan, New Zealand, Papua New Guinea, Peru, Russia, Solomon Islands, Tajikistan, Tanzania, Turkey, United Kingdom and Vanuatu.

Once again, the largest earthquake of the year was in Sumatra, Indonesia, where an event of magnitude 8.4 struck on September 12, causing 25 fatalities and severe damage. A quake of magnitude 8.1 hit the Solomon Islands on April 2 (April 1 UTC), causing 54 fatalities, and another event of magnitude 8.1 occurred east of the Kuril Islands (Russia) on January 13. Because of the sparse population on those islands, there were no casualties and only minor damage occurred, showing that the location of the earthquake is as important as magnitude in determining how destructive it might be.

In South Asia and adjoining regions, a total of 24 events have been recorded with magnitude more than 3.0 as per the records compiled by ASC. The earthquake data recorded by USGS and its subsidiary partners is presented in Appendix - IV D.

All earthquakes above magnitude 3.0, which occurred in South Asia in 2007, are included along with earthquakes from nearby regions due to possible impact of such earthquakes affecting countries in South Asia (Source: ASC[3], IMD[6]).

M6.2 Khaneqa-Hindukush Earthquake (Afghanistan), 3 April 2007



A strong earthquake occurred in the Hindukush mountains in Badakhshan, Afghanistan, on 3 April 2007 at 08:05 a.m. local time and was widely felt in north-east Afghanistan, northern Pakistan, north India and the central Asian republics. It had a magnitude of Mw=6.2 and resulted in several injuries in northern Pakistan and in Jammu and Kashmir, India.

The earthquake was centred 1.1 km south of Khaneqa (Badakhshan), Afghanistan,
262 km NNE of Kabul (Kabol), Afghanistan,
292 km NW of Peshawar (N.W.F.P.), Pakistan,
393 km NW of Rawalpindi (NCT), Pakistan,
463 km NW of Srinagar (Jammu and Kashmir), India.

This earthquake was felt over a wide area in Afghanistan, Pakistan and India. A child was injured while running out of his school in the village of Dherkot; another person was hurt after jumping out of an office building at Muzaffarabad. An unknown number of people were also injured in Kashmir Valley in Jammu and Kashmir, India, after jumping out of windows during the earthquake.

In Afghanistan, the earthquake was felt at Faizabad, Jalalabad and Kabul for close to 90-seconds. At Faizabad, the provincial police chief of Badakhshan province was quoted as saying, "My room was shaking and the light was swinging back and forth". Many people ran outdoors in Jalalabad and Kabul. In Kabul, loose items and furniture including television sets were seen shaking and some windows shattered.

In neighbouring Pakistan, it was felt at 08:25 a.m. PST at Chitral, Dera Ismail Khan, Dir, Hangu, Karak, Kohat, Parachinar and Peshawar in the N.W.F.P., at Lahore, Multan and Rawalpindi in Punjab and at Islamabad. Doors and windows rattled under the impact of the earthquake at Lahore, Islamabad and Peshawar sending people outdoors. Strong tremors have also been felt in parts of the Kashmir Himalayas including at Balakot, Daimer, Ghanchee, Ghizer, Gilgit, Muzaffarabad and Skardu. In Jammu &and Kashmir in India, the earthquake was felt at 09:05 a.m. IST at Doda, Jammu, Kathua, Kupwara, Poonch, Rajouri and Srinagar. In Srinagar, there were reports of minor damage and a brief power outage/shortage following the earthquake. The tremors lasted between 5-10 seconds in the city, rattling doors and windows. Many people panicked and ran outdoors when the earthquake struck. Several people were also injured in Kashmir Valley after jumping out of windows during the earthquake. In Jammu, there was minor panic and telephone services were temporarily disrupted.

Elsewhere in the state, all schools were closed at Rajouri following the earthquake while at Baramulla, people ran on to open spaces as the quake shook buildings and trees. Mild tremors were also felt in the Union Territory of Chandigarh, at Gurgaon and Faridabad in Haryana, at Chamba and Dharamsala in Himachal Pradesh, at Amritsar, Firozpur, Hoshiarpur, Jalandhar, Jhangran, Khanna, Ludhiana and Mullapur in Punjab, at Jaipur in Rajasthan and as far as Delhi. At Firozpur in Punjab, many people ran outdoors on experiencing the quake for close to 30 seconds. The earthquake was also felt in parts of the Central Asian republics including at Dushanbe and Khorog in Tajikistan as well as at Andizhan and Tashkent Uzbekistan. In Dushanbe, people ran out of apartment buildings as windows rattled and hanging lights shook.

Afghanistan is often hit by earthquakes, especially around the Hindukush mountain range that is near the collision of the Eurasian and Indian tectonic plates, where seismic activity is high. In 2002, a 7.6-magnitude quake in the Hindukush destroyed several villages and left more than 1,000 people dead.
(Source: ASC,[3] USGS,[17] AIMS[18])

M4.9 Akara Earthquake (Pakistan), 29 April 2007

An earthquake occurred in the Makran Coast of Pakistan on 29 April 2007 at 11:33 a.m. local time. It had a magnitude of Mb=4.9 and was felt strongly in parts of the region, including Gwadur. The earthquake was centred at:

5.4 km N of Akara (Balochistan), Pakistan,

19.2 km NNW of Gwadur (Balochistan), Pakistan,

31.6 km SE of Suntsar (Balochistan), Pakistan,

484 km WNW of Karachi (Sindh), Pakistan.

This earthquake was strongly felt at Gwadur where many people ran outdoors in panic. No damage occurred as a result of this earthquake. A small landslide occurred in the hills overlooking the new deep-water Gwadur Sea Port. Rock falls also occurred from Koh Batil to Koh Mehdi between Gwadur and Sur Banda.
(Source: ASC[3])

Other earthquakes that have been recorded at Peshawar by the Pakistan Meteorological Dept. are depicted in Appendix-IV B

In Nepal in year 2007, minor tremors were recorded at Kathmandu by the National Seismological Centre. These have been presented in Appendix-IV C.

Figure 9.2: Epicentre of 5.2 Magnitude earthquake of 11 August 2007 (Nepal). However, no major damage has been reported.

Mb5.2 Roninpara (Bangladesh) Earthquake, 7 November 2007

A moderate earthquake struck the Chittagong Hill Tracts in south-eastern Bangladesh, on 7 November 2007 at 13:10 p.m. local time. It had a magnitude of Mb=5.2 and was felt strongly in the region causing minor damage and some injuries. This is one of the strongest local events in the region since the Mw=5.7 Kolabunia earthquake in 2003 and the Mw=6.1 Bandarban earthquake in 1997.

The earthquake was centred at 2 km WSW of Roninpara (Chittagong), Bangladesh,

10.2 km NNE of Ruma Bazaar (Chittagong), Bangladesh,

39.8 km SW of Buntlang (Mizoram), India,

66.9 km ESE of Chittagong (Chittagong), Bangladesh,

90.8 km NNE of Cox's Bazaar (Chittagong), Bangladesh.

Tremors from this earthquake were felt in Bangladesh's southeastern Chittagong, Cox's Bazar, Bandarban, Khagrachhari, Comilla and Noakhali districts. At least 10 people were hurt as a result of this earthquake. Two of the injuries occurred when people jumped out of buildings at Bandarban and Rangamati. One person suffered a broken hand in an earthquake-related traffic accident in Chittagong. In Bandarban, several buildings developed cracks, including the courthouse, the Nilachal Parjatan Tower, the Press Club and the Sonali Bank. In Chittagong, where the earthquake was felt for close to 25 seconds, a newly constructed 5-storey building developed cracks on Rajakpukur Lane in the Andarkillah area. Plaster was dislodged from the walls and the ceiling of the city's Shah Amanat International Airport. It was also felt by people in moving vehicles and at least one injury was caused by an earthquake-related traffic accident in the city. Strong shocks were also felt in the city of Cox's Bazaar where hanging objects and furniture were violently shaken and outdoors, birds and animals were frightened. A fire broke out at the Bkahrabad Gas Systems Limited at Fauderhat in Sitakunda when a pipeline was fractured during the earthquake. Tremors from the earthquake were also felt at Comillah, Feni, Khagrachari and Noakhali. In neighbouring India, light tremors were felt in Agartala in Tripura and Guwahati in Assam.

Figure 9.3: Students at a girls' dormitory in Dhaka look at a ceiling damaged by the 26 July quake (Source: IRIN News[19])

Figure 9.4: Residents examine a cracked wall of a building following last month's quake

M4.6 Nambu Earthquake (India), 18 May 2007

A mild earthquake struck the Sikkim Himalayas on 18 May 2007 at 18:10 p.m. local time resulting in some panic in the state of Sikkim, India. It had a magnitude of Mb=4.6. The earthquake was centred in the vicinity of the village of Nambu (Sikkim), India,

NNE 5.7 km N of Dentam (Sikkim), India,

13.2 km WNW of Ringchingpong (Sikkim), India,

20.9 km E of Chyangthapu (Mechi zone), Nepal,

21.4 km NW of Naya Bazaar (Sikkim), India,

31.1 km NNW of Darjeeling (West Bengal), India,

40.5 km NW of Kalimpong (West Bengal), India,

45.3 km W of Gangtok (Sikkim), India.

Tremors from this earthquake were felt in many parts of Sikkim including the capital, Gangtok. The earthquake was felt at Ranka, Rangpo, Ranipool and Singtam. At Nam Nang many people ran outdoors in panic. In Gangtok, it was felt for 3-4 seconds and many people went outdoors. The earthquake was also felt in adjoining parts of West Bengal, including in Darjeeling and Mirik.

The strongest earthquake in this region since a Mw=6.3 earthquake in 1980 was the Mw=5.3 Mana earthquake on 14 February 2006 that killed 2 people and damaged many buildings across the state. The earthquake on 18 May 2007 was the second tremor within a short span of 48 hours to have occurred in this immediate region and followed a Mb=4.0 earthquake that occurred on 16 May 2007 in eastern Nepal, along the Nepal-Sikkim border. These two earthquakes were followed by the much stronger M5.0 Singyang earthquake that occurred on the evening of 20 May 2007. However, no major damage has been reported from the region as it is sparsely populated. It is important to note that such earthquakes in high mountainous terrain affect jointed rocks of steep hill slopes and at places develop fractures through which rainwater can percolate, leading to increase in pore water pressure and landslides in subsequent years. *(Source: ASC[3] and IRIN News[20])*

Mb 5.1 Uttarakhand Earthquake (India), 22 July 2007

On July 22 at 23 02 14.7 hrs, an earthquake occurred at 30.881° N and 78.239° E in Uttrakhand with a magnitude of mb 5.1. Three people injured and buildings damaged at Uttarkashi. Buildings were also damaged at Chamoli and Muzaffarnagar; in parts of the Dehra Dun District and in the Yamnotri Valley area. Rockfalls blocked National Highway 94 in the Dharasu-Phulchatti-Yamnotri area. Tremors were also felt at Almora, Badaun, Bharmaur, Chakrata, Chamba, Chandigarh, Dehradun, Didihat, Gopeshwar, Gurgaon, Haridwar, Haryana, Karnaprayag, Kinnaur, Manali, Meerut, Mussoorie, Muzaffarnagar, New Tehri, Pauri, Roorkee, Shimla, Srinagar and in the Lahul and Spiti Districts of J&K *(Source: USGS[17]).*

Tsunami due to 8.5 Mw Sumatra earthquake of 12 September 2007

In September 2007, three Sumatra earthquakes with magnitude greater than 7 struck the Java Trench off the coast of Sumatra, Indonesia. A series of tsunami bulletins was issued for the area. The first earthquake occurred at 11:10:26 UTC (18:10 local time) on 12 September 2007, with 8.5 Mw on the moment magnitude scale. It was centred about 34 km underground, at 4.520°S 101.374°E, about 130 km southwest of Bengkulu on the southwest coast of Sumatra, Indonesia, and some 600 km west-northwest of Indonesia's capital city, Jakarta. It was followed by several earthquakes of magnitude 5 through 6 along the same fault, west of Sumatra. The second largest earthquake, 7.9 Mw, occurred later the same day at 23:49:04 UTC (06:49:04 local time the following day). It was centred about 10 km underground, at 2.506°S 100.906°E, some 185 km (115 miles) south-southeast of Padang, Indonesia and about 205 km north-west of Bengkulu (about 225 km north-west of the magnitude 8.5 earthquake).

After further aftershocks above magnitude 5, a third earthquake, of 7.0 Mw, occurred at 03:35:26 UTC (10:35:26 local time) on 13 September. It was centred about 10 km underground, at 2.160°S 99.851°E, some 165 km south-southwest of Padang and 345 km west-northwest of Bengkulu. Aftershocks continued into 13 September and 14 September, with more earthquakes ranging up to magnitude 6.4. Most of the aftershocks were north-west of the original magnitude 8.4 earthquake.

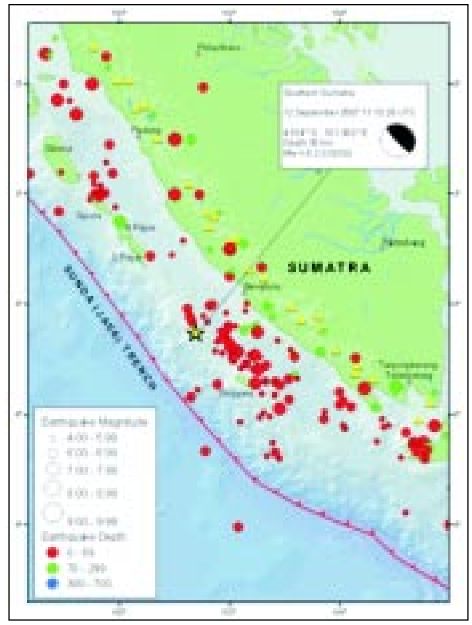


Figure 9.5: Epicentre of 8.5 Mw Sumatra earthquake 12 September 2007 along with aftershocks (USGS)

Tidal buoys positioned in the Indian Ocean and other seismic tools have led scientists to issue a series of tsunami bulletins. Sea-level readings indicated that a tsunami was generated. A total of 4 tsunami alerts were issued in 24 hours. After the first, and largest, earthquake, the Pacific Tsunami Warning Centre issued a tsunami alert for much of the Indian Ocean basin. Tsunami warnings were also issued in India as well and other countries around the Indian Ocean soon after the earthquake. The Government of India asked the states of Tamil Nadu, Kerala, Andhra Pradesh and the Union Territories of Andaman and Nicobar Islands and Puducherry to be on high alert. By late September 12, the tsunami warning was recalled.
(Source: USGS[17] and Wikipedia)

Gir Earthquakes (India), 6 November 2007

Two moderate earthquakes occurred in the vicinity of the Gir National Park and adjoining parts of Saurashtra in Gujarat, India, on 6 November 2007 at 05:58 a.m. and 15:08 p.m. local time. Both had preliminary magnitudes of Mb=5.1. They were felt in many parts of the state of Gujarat and resulted in at least one death.
The earthquake at 05:58:33 a.m. was centred around 21.28 N and 70.70 E **(insert sign of degree)** at
6.3 km SSE of Sarsai (Gujarat), India,
11.8 km SSE of Visavadar (Gujarat), India,

35.1 km ESE of Junagadh (Gujarat), India,

114 km S of Rajkot (Gujarat), India,

220 km W of Surat (Gujarat), India,

275 km SW of Ahmedabad (Gujarat), India.

The earthquake at 15:08 p.m. was centred around 21.181 N and 70.571 E at:

20.3 km SW of Sarsai (Gujarat), India,

22.2 km SW of Visavadar (Gujarat), India,

82 km WSW of Amreli (Gujarat), India,

175 km WSW of Bhavnagar (Gujarat), India,

234 km W of Surat (Gujarat), India,

293 km SW of Ahmedabad (Gujarat), India.

At least one person was in killed in a wall collapse at Hiranvel in Talala taluka in Junagadh district, Gujarat during the second earthquake. At least 5 other persons were injured. The strongest tremors were experienced in towns and villages located in the western reaches of the Gir National Park causing some panic. Several buildings were damaged at Hiranvel, including a school and a temple. Between seven to ten buildings collapsed in the nearby village of Haripur and many structures are also thought to have collapsed in the village of Chitravad Gir. Other villages that suffered various degrees of damage include Akolwadi, Amrutvel, Bhalachchel, Jalpar, Moruka, Rasulpara, Sasan and Surawa. Strong tremors were also felt in the town of Junagadh as well as other villages in the district of the same name, including Keshod, Maliya-Hariya, Mevarada, Veraval and Visavadar. Minor damage was also reported to buildings in the districts of Amreli and Porbandar.

The two earthquakes were felt in most parts of Saurashtra, including in the districts of Amreli, Bhavnagar, Jamnagar, Junagadh, Porbandar, Rajkot and Surendernagar. In Amreli district, it was felt at Amreli, Babra, Bagsara and Savarkundla. In Bhavnagar district it was felt at Bhavnagar, Botad, Gadhda, Mahuva, Palitana, Talaja, Umrala and Valbhipur. It was felt in many parts of the city of Bhavnagar itself, including at Bharatnagar, Kaliabeed and Motibagh. In Jamnagar it was felt in the towns of Bhagwad, Jamnagar, Jamjodhpur and Kalyanpur. It was also felt in Rajkot district, including at Dhoraji, Gondal, Jasdan, Jetpur, Morbi, Rajkot, Upleta and Wankaner. In the city of Rajkot it was felt at Dudh Sagar Marg, Kalavad Road, Karanpura and Ring Road, sending people running outdoors. In Surendernagar district, it was felt at Chotila.

Mild tremors were also felt as far as Ahmedabad, Navsari and Surat. In the Ahmedabad metropolitan area it was felt in several parts of the city, including at Bapunagar, Maninagar, Narangpura, Paldi, Sabarmati Ashram, Sardar Patel Colony, University, Vasna and Vastrapur. Some people went outdoors, windows rattled and in a few isolated instances, loose items were displaced.
(Source: USGS[17] and ASC[3])

M4.7 Delhi Earthquake (India), 26 November 2007

A light (M4.0-M4.9 range termed as 'light') earthquake was felt in the Delhi Metropolitan area as well as in adjoining parts of the states of Haryana, Rajasthan and Uttar Pradesh on the morning of 26 November 2007 at 04:42 a.m. IST. It had a magnitude of Mb=4.7 and was felt in Delhi, causing widespread panic as well as some minor damage in the region. The red star denotes the revised NEIC-PDE epicentre while the purple star shows the IMD epicentre.

This earthquake was centred (NEIC red star) 7.6 km SW of Chanakyapuri (Delhi), India,
11.2 km SSE of Paschim Vihar-Punjabi Bagh (Delhi), India,

13.4 km SW of Connaught Place (Delhi), India,

13.7 km SSW of Karol Bagh (Delhi), India,

14.1 km NE of Gurgaon (Haryana), India,

25.9 km NW of Faridabad (Haryana), India,

32.1 km WSW of Ghaziabad (Uttar Pradesh), India.

Tremors from this earthquake were felt strongly throughout the NCR and in parts of the adjoining states of Haryana, Rajasthan and Uttar Pradesh for 15-20 seconds. People were woken up by the tremor in many parts of Delhi and there was some panic and anxiety. The tremors were accompanied by a rumbling sound. The general observation includes rocking of beds and hanging objects, barking of dogs and chirping of birds. Many people, particularly those from higher storeys, came out in the open. The effect of the tremor was felt more on upper floors than at lower ones. Widening of some pre-existing cracks was reported in stray cases but no damage to structures as such was observed.

Tremors were also strongly felt in eastern Haryana. Buildings developed cracks at Balore while strong tremors were felt at Bahadurgarh, Charkhi Dadri, Jind, Faridabad, Gurgaon, Hissar, Panipat, Rewari, Rohtak and Sonepat. Windowpanes were broken at Rewari while it was widely felt in Gurgaon including at DLF, Jaikampuri, Miyawali Colony, Old Railway Road, Omnagar, Patel, Malibu Town, Nagar, Rajiv Nagar, Sadr Bazaar, Shivajinagar, Sector 2, Sector 5 and Sector 14. Power supply was also disrupted in Gurgaon temporarily. In neighbouring Uttar Pradesh, minor damage was reported to buildings at Bagpat, Badaut, Meerut and Noida. Some buildings developed cracks in Sectors 32 and 71 in Noida. In Ghaziabad, people ran outdoors in panic while in Meerut, parked cars were seen shaking. Tremors were also felt at Bulandshahr, Faridabad, Govardhan and Mathura. Tremors were also experienced in adjacent parts of Rajasthan including at Alwar, Chirawa, Jaipur, Jhunjhunu, Kaman, Sikar and Sikri Patti. In Jaipur, they were felt in several parts of the city including at Amera, Jawaharnagar, M.D. Road and Shriji Ki Mori.

Analysing the data obtained from different localities, the maximum intensity of the earthquake appears to be of the order of V on MSK-64 Intensity scale as per estimates of Geological Survey of India, encompassing areas south of Delhi and Gurgaon. Intensity IV appears to extend up to Meerut and includes places like Ghaziabad, Faridabad, West and North Delhi,. Chandigarh, located 200 km north of Delhi, seems to have been in intensity II.

Seismotetonics and Past Earthquakes in Delhi Region

The National Capital Region is located between the Mahendragarh-Dehradun fault in the west and Great Boundary fault in the east, at the junction of Aravalli Delhi fold belt and Indo-Gangetic foredeep (is this a technical term?). A few faults/lineaments of seismogenic nature have been inferred as

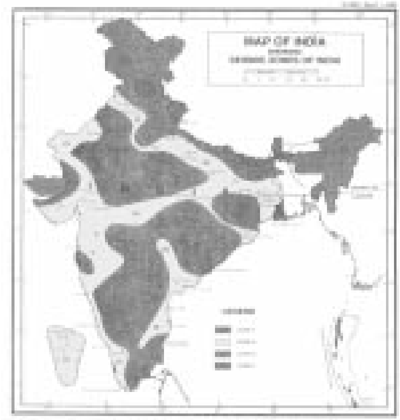


Figure 9.6: Seismic Zones of India showing Delhi in Zone-IV (High hazard category)

dissecting the fold belt. The present earthquake is one of the strongest earthquakes in the Delhi region since 2001 and the biggest since 1960. It is also the strongest earthquake to originate within or in the immediate vicinity of a city with a population over one million since the Mw=5.8 Jabalpur earthquake in 1997. Prior to this latest earthquake, the strongest local earthquakes to have originated within the Delhi metropolitan area since the 1960 Gurgaon earthquake was a Mb=4.3 earthquake in the Dwarka-Najafgarh area on 28 April 2001, which caused minor damage and widespread panic. The strongest known earthquakes in the Delhi region include the M6.0 Khurja-Bulandshahr earthquake on 10 October 1956, the M6.0 Gurgaon earthquake on 27 August 1960 and the Mb=5.6 Moradabad earthquake on 15 August 1966. Historically, the 15 July 1720 earthquake with epicentral intensity IX, in which some 1,000 people perished in the Delhi region caused the greatest damage including knocking down large parts of the Shaharepanah (city wall) in Old Delhi from Kabuli Gate to Lal Darwaza and the battlements of the Fatehpuri Masjid. Some of the damaging earthquakes originating in the north-west Himalayas have also affected the region. The Seismic Zone map of India, therefore, categorises NCR in Zone IV, that is of High Hazard category. *(Source: ASC,[3] GSI,[4] IMD,[16] USGS[17])*

Additional earthquakes that have been recorded by the Indian Meteorological Department (IMD) are presented in Appendix-IV A.

Rehabilitation and Response to 2005 Kashmir Earthquake

On October 8, 2005 at 08:52 hours a powerful earthquake of magnitude 7.6 on the Richter scale struck the Kashmir region causing major destruction and playing havoc with millions of lives in Pakistan, India and to some extent in Afghanistan. The severely affected areas include the eleven districts of North West Frontier Province, five districts of Azad Jammu and Kashmir, Punjab, Islamabad, three districts of Jammu and Kashmir, India. More than 70,000 people lost their lives, of which 17,000 (Source: UNICEF) were children. Most of the civil society infrastructure such as roads, schools, colleges and hospitals was destroyed and required immediate attention. It also caused large-scale landslides, blockade of streams in the region affecting villages and lifeline infrastructure.

Response, relief and rehabilitation in Pakistan

The magnitude of the devastation and overwhelming response by domestic as well as international communities, demanded harnessing and synchronisation of the national relief efforts. Govt. of Pakistan set up the Federal Relief Commission (FRC) to oversee the whole operation and provide necessary guidelines for effective management of the entire operation. Besides handling the enormous task of retrieving dead and injured persons and providing relief to people spread across 30,000 sq km in one of the most inaccessible regions, the FRC in collaboration with many international and local NGOs carried out the enormous task of reconstruction in the region in subsequent years. Th efollowing are some of the prominent ongoing reconstruction and rehabilitation measures in the region.

IFRC Initiatives[21]

Almost three years following the devastating earthquake, the recovery process is in full swing in Pakistan. Relief has given way to recovery with the focus now on activities to get people back on their feet. This involves 42 reconstruction projects with emphasis on earthquake-resistant designs, health and care programmes, livelihoods, continuing water and sanitation rehabilitation, and strengthening the disaster management of communities by IFRC and many other organisations. The relief effort was a success. A total of 1.1 million people received non-food emergency relief items during the emergency phase. Approximately half a million people received health care assistance while nearly 90,000 people now have improved access to water by efforts of IFRC. Recovery and rehabilitation activities will take until the end of 2009 to finish. The Pakistan Red Crescent, supported by the International Federation, will be rolling out earthquake recovery activities for another two years. The shock of the terrible death toll of 73,000 and massive damage to infrastructure has given way to hope.

Figure 9.7: Reconstruction delegate checks the positioning of steel for a concrete beam at Garhi Dupatta Boys College reconstruction site. "Concrete kills," he cautions, unless beams are properly tied together (Source: IFRC [21])

Figure 9.8: Girl students are excited about their new school being built in parts of Kashmir. Their remote village of Mera Bakot suffered the loss of over half its people, including 50 students in the 2005 earthquake.

Government Initiatives (World Bank supported)[22]

In addition to seismic-resistant construction now taking root in the mountainous region, owner-driven reconstruction and rehabilitation of some 560,000 damaged or destroyed homes in collaboration with World Bank initiatives in Pakistan is now in various stages of completion. The task has been very challenging as the area spreads over difficult terrain across 30,000 sq km. Despite those challenges, progress has proved far better than earlier perceived. This is being implemented by the Earthquake Relief and Reconstruction Authority (ERRA), which has launched this ambitious US$1.5 billion owner-driven rebuilding programme - largely suited to the mainly rural affected population. Beneficiaries are also provided with technical advice and assistance to follow construction standards needed for a high seismic-risk zone.

Figure 9.9: Under the government subsidy programme, home owners can rebuild their own homes either by themselves or by hiring trained artisans in the earthquake-affected area of Pakistan (IRIN).[23]

Under this programme, partially funded by the World Bank, homeowners are given over US$ 3,000 in instalments to build quake-resistant homes - with routine visits by inspection teams to ensure compliance to agreed seismic-resistant standards. According to ERRA, of the target of 463,000 homes to be reconstructed under the plan, significant progress has already been made. It has disbursed over $1.1 billion to programme beneficiaries or 75 per cent of the overall $1.5 billion estimated cost. As of December 2007, 99 per cent of the beneficiaries had received the second installment of the grant; 67 per cent the third; and 23 per cent the fourth and final instalment. Those who have received the full grant had completed 70,000-75,000 homes by end of 2007. According to the World Bank's latest formal assessment, 42 per cent of the houses to be reconstructed were now certified at the lintel level, and 80 per cent at the plinth level. Moreover, ERRA expects to complete - either through reconstruction or retrofitting - around 550,000 homes by the quake's third anniversary in 2008, with full completion by late 2009. Evidence is also emerging that a culture of seismic-resistant construction is gradually taking hold: The aggregate seismic compliance rates are 93 per cent for plinth level and 77 per cent for lintel level.

Figure 9.10: To date, some 75,000 rural homes have been reconstructed across the quake-affected area (IRIN).[23]

Additional reconstruction efforts include construction of a new high school by Mercy, located in the village of Shamdhara in the Mansehra District of NWFP, which will serve approximately 250 girls from this village and several surrounding villages. The campus will consist of a building with ten classrooms, another with an examination hall and laboratory and a third with administrative offices. All structures will be earthquake resistant, utilizing a light steel design. In addition to this, 150 houses were also constructed at village Anwar Sharif, Muzaffarabad by the donation of The International Association of Lions Clubs and Lions Club International Foundation.

Figure 9.11: To date, some 75,000 rural homes have been reconstructed across the quake-affected area (IRIN).[23]

Response, relief and rehabilitation in Jammu and Kashmir, India

The response in Jammu and Kashmir started with immediate search and rescue operations led by the army, air force and local volunteers from National Institute of Technology, Hazratbal and many NGOs and social organisations in Uri, Tangdhar, Baramulla and Kupwara, Srinagar, Jammu and Udhampur. The state government has opened relief centres at the Mirwaiz Manzil and Jamia Masjid. Army and Air force personnel have evacuated at least 274 persons from Baramullah, Tangdar and Uri; the injured persons were treated at Field Hospital, SMHS hospital Srinagar, Bone and Joint Hospital Srinagar, Sher-e-Kashmir Institute and in makeshift hospitals.

In a quick response, the state administration had mobilized all essential items such as tents, blankets, sleeping bags, kitchen sets, kerosene, drinking water, woollen clothes, medicines, sugar, and fresh milk. The Food Cooperation of India had also readied a stock reserve of 83,000 metric tonnes of foodgrains for distribution. The water and electricity supplies had also been restored in many parts of the quake-affected region.

For immediate relief work and assistance, Rs 1 billion (US$ 23.25 million) and an ex-gratia amount of Rs.100,000 (US$ 2325) to the next of kin of the deceased has been sanctioned from the Prime Minister's National Relief Fund. Additionally, the state government had sanctioned an ex-gratia amount of Rs. 5000 (US$ 111) per person. The central government has announced a package of central relief of Rs. 5 billion (US$ 116.27 million) for rehabilitation work. This is in addition to Rs.142 billion (US $31.646 million) relief already sanctioned by the central government for the quake affected. The state government has distributed Rs. 75,000 per family in earthquake-affected areas for complete reconstruction and rehabilitation.

Many International and local NGOs such as ActionAid had participated reconstruction programme in 24 villages covering around 30,000 people in Uri and Karnah districts. The reconstruction programme involves developing village amenities through cash-for-work programmes. All this work is being supervised and implemented by Village Committees made up of local people. USAID responded to relief/rehabilitation and their specialists were the first 'on the ground' from bilateral donors. Humanitarian assistance from the American people was directed towards providing shelter, warm clothing and blankets, easing psychological trauma, and modest cash-for-work to clear debris, construct interim shelter and restart livelihoods.

The HELP Foundation launched programmes of relief and rehabilitation in the affected areas with the objective of alleviating human sufferings and to rehabilitate the victims of the earthquake. It is interesting to note that in the initial phase of relief and rescue, most of the relief went to Tehsil Uri in Baramulla and Tangdar in Kupwara. In fact, the proportion of devastation in other parts of Baramulla and Kupwara districts was the same as in Uri and Tangdar. Hundreds of deaths were reported in these areas (Uri and Tangdar). Some areas like Chandoosa, Rafiabad of Baramulla district and tehsils of Kupwara district, like Handwara, Kupwara and Sogam were almost ignored as they didn't get media hype like Uri and Tangdar. Almost every organization - government or NGO - was highly active in Uri and Tangdar and according to some media report, very few were interested in working in these ignored parts of the valley due mainlyto lack of information regarding the destruction in these areas, security reasons; these areas being high security zones, low casuality and destruction as compared to Uri and Tangdar, and inaccessibility.

CASA[25] (Churches Auxiliary for Social Action), India has initiated efforts to continue rehabilitation assistance in the Pawadian village in Uri, Kashmir through the provision of permanent shelter for 38 targeted families and to enhance the capacities of 8 widows in the same village through livelihood support activities. In November 2006, the Indian Government allotted to CASA the village of Pawadian in Uri, Kashmir, just 14 km from Sokar Village in which CASA was carrying out rehabilitation activities earlier. Due to generous in-kind contributions from private individuals, savings were made in the reconstruction of housing in Sokar, enabling CASA to budget for further housing for 29 of the most needy families out of the 113 families in Pawadian village, almost all of whom had suffered loss/

Figure 9.12: Retrofitted hospital building at Kupwara (Jammu and Kashmir, India)

damage to property. In addition, CASA is proposing to take up reconstruction of an additional eight houses in Pawadian.

Some of the lifeline buildings such as Sub-District hospital in Kupwara, had suffered damage due to earthquake. Inspection by experts revealed that it had a number of deficiencies as far as safety against earthquake are concerned. Therefore, it was suggested that the hospital being a lifeline building could be taken for seismic strengthening by Building Materials & Technology Promotion Council (BMTPC)[26] to demonstrate the retrofitting techniques for safety against earthquakes. Accordingly, a study of the building for its seismic evaluation was undertaken with the help of National Centre for Peoples' Action in Disaster Preparedness (NCPDP), an NGO from Ahmedabad, Gujarat, which has undertaken similar works with BMTPC in post-earthquake rehabilitation programmes in Gujarat, and the hospital building was retrofitted.

In response to the Kashmir earthquake, Centre for Environment Education (CEE)[27] has put together a comprehensive rehabilitation programme, 'Rebuilding Trust' for the affected people, with the objectives of:

- offering relief to the communities affected by the earthquake
- providing shelter to the worst affected families through the winter months
- offering trauma relief to children affected by the earthquake and continuing their school programme
- building the foundation for undertaking an integrated rehabilitation programme in the long term.

In the first phase, Rebuilding Trust had focused on education, shelter and capacity building to meet the immediate rehabilitation needs. As most of the school buildings had collapsed, under an innovative programme called 'Umang' - school without walls, open air schools were organised for formal and informal learning and it reached out to more than 34,000 students in 470 schools in 139 villages of Baramulla district, including far-flung areas, hardly visited by outside agencies. Another initiative towards education interventions was to build the capacity of teachers to help children cope with stress, earthquake awareness and preparedness. Under this programme, more than 300 teachers were trained.

In order to facilitate interim construction, architects and students from the Centre for Environmental Planning and Technology (CEPT) had visited the damaged area and found that the construction technique of most of the houses in the village was very sustainable, and the damaged houses were mostly those that had not been built in the traditional style. A prototype was constructed for a beneficiary Zaman Khan of ward Daazan for demonstrating the construction of interim shelters. Initially, 128 interim shelters were constructed in village Lachhipora and subsequently nearby villages were also taken up for reconstruction with support from Oxfam GB (702 families), Plan India (250 families) and German Agro Action (128 families). A workshop for carpenters and local technicians from Lachhipora village was conducted to facilitate the shelter construction process.

Restoration of water supply was another initiative of CEE, and altogether 31 storage tanks with a total capacity of 20,000 litres were installed at different *chesmas* (springs) and at suitable locations at different *pattis* (wards) in the village. The Public Health Engineering Department provided technical support for layout, materials and deputing plumbers for the installation of tanks and pipes. Village Panchayat members and villagers contributed labour for carrying tanks and pipes to different *chesmas* and other locations.

Realising that economic rehabilitation is a prerequisite to stabilize any society after a disaster, livelihood support was provided by initiating economic activity based on traditional skills and local resources through Self-Help Groups (SHG), by restoration of livelihoods in agrarian communities through Cash for Work programmes and reclamation of land and water bodies, and by establishing alternate livelihoods.

CEE's interventions began immediately after the earthquake in Uri, where 29 villages were severely affected, with most houses fully or partly damaged. Shelter was the most urgent need as winter was approaching. CEE provided 1,537 interim shelters in 10 villages, helping around 15,000 victims to survive the severe cold. Oxfam GB, German Agro Action, Plan India and Care India supported the effort by providing shelter material. The community was motivated to build the shelters. Centre for Environmental Planning and Technology (CEPT), Ahmedabad helped in architectural assessment and designing prototypes for earthquake-resistant shelters suitable for the harsh weather and possible to build quickly

Figure 9.13: Opening of crossing points on the Line of Control between India and Pakistan (Source: *Terra Daily*[28])

Regional Cooperation to Reduce Grieve and Sorrow

In an unprecedented move, both Pakistan and Indian governments agreed to establish five crossing points on the Line of Control between India and Pakistan in the province of Kashmir. The first was opened at Chakan Da Bagh in Poonch, the second at Kaman Post in Uri (on the road between Srinagar and Muzaffarabad), and the third across the Neelum river between Chiliana in Pakistan and Tithwal in India. These facilitated the flow of relief goods and allowed divided Kashmiri families to meet relatives across the Line of Control and share their grief.

Seismic Hazard Mitigation Measures in SAARC region: Towards a Resilient Future

The seismicity in the South Asian region is characterized by the Himalayan seismic belt that constitutes one of the largest seismic belts of the world and brings several common elements related to the science of seismology, technology, policy, planning, experiences and lessons learnt to share with and work together in the framework of regional cooperation for seismic risk reduction. This may include, but is not limited to, the following issues for regional cooperation as envisaged by SDMC.

***Seismic Hazard Assessment of the SAARC Region*:** The regional efforts on earthquake hazard mitigation must focus on recent assessment of seismic hazard/vulnerability/risk in the region, networking of seismic stations, sharing pre-existing seismic data, exchange of scientific and technical know-how with regard to mitigation methods and adoption of state-of-the-art approach for mitigation. This is particularly so as the understanding of inter-plate as well as intra-plate seismicity has undergone a sea change in recent times due to advancement of geophysical observation and synthesis. Therefore, there is an urgent need to incorporate the results of advance research in mitigation measures so as to develop 'Resilience through Research'.

Updation of Seismic Hazard Maps: Country-specific as well as regional efforts are required for updation of Seismic Hazard Maps by incorporating the history of recent earthquakes, their damage and recently acquired scientific knowledge out of cutting edge research published in reputed scientific journals. This can be achieved by referring to updated seismo-tectonic map, active fault map and recent geomorphological changes, micro-seismicity, strain rates, geotechnical investigation and palaeo-seismicity of the region. Based on this updated hazard map, attempts must be made on development of vulnerability and earthquake risk maps.

***Risk and vulnerability assessment*:** Realistic risk and vulnerability assessment must be carried out for scenario earthquake events based on detailed socio-economic as well as infrastructure data. This can be possible only by fusion of geospatial technology including recently acquired satellite images for building footprint survey and infrastructure mapping.

***Liquefaction Susceptibility Analysis*:** Liquefaction is one of the most important potential seismic hazards already experienced during past earthquakes. Most recently, it caused maximum devastation during the Bhuj earthquake of 2001. Therefore, it needs to be analysed with respect to expected ground motion, geomorphological characteristics including age of the sediments and grain size, water table and past history of liquefaction. Already efforts are underway in Bangladesh for liquefaction hazard assessment of Dhaka and surrounding areas.

***Seismicity-Induced Landslides*:** Numerous seismicity-induced landslides have caused immense damage in the past, such as the 1998 Afghanistan earthquake, the 1991 Uttarkashi earthquake, the 1999 Chamoli earthquake, the 2005 Kashmir earthquake and more recently, the 2008 China earthquake. Landslides bury habitats, infrastructures, and can dam a river and form a reservoir that can be a potential danger in case of breach. Therefore, steep hill slopes of the Himalayas on fragile rocks must be assessed for potential landslides in the event of earthquakes. Towards this, global efforts have already been initiated and different types of slope maps have been prepared using SRTM data sets as a critical input to slope response models.

***Seismic Microzonation and Site Response Study*:** The damage pattern of some of the recent earthquakes demands that microzonation needs to be carried out at city level to determine the most vulnerable pockets of a city, so that suitable measures can be taken either for retrofitting of existing buildings or construction of new buildings. It will provide crucial information on seismic wave amplification and liquefaction. Efforts are underway in Gandhidham, Gujarat, India, Dhaka (Bangladesh), Karachi (Pakistan), and Kathmandu (Nepal), with the involvement of Oyo International Corporation, Japan.

***Fusion of advance technology*:** Predictive efforts through GPS and InSAR as well as several ground and satellite-based observation for thermal and other anomalies can be adopted to further enhance the capability of hazard assessment and preparedness.

***BuildingCcodes, Regulation and Enforcement*:** Review of existing building codes and improvement thereon and finalization of new building codes for construction of earthquake-resistant buildings in different zones as per the level of hazard is one of the most significant approaches to minimize the risk level. In the absence of appropriate building codes, new building codes need to be developed at the earliest. Care must be taken to ensure that the building codes are in coherence with the traditional architectural perception of the local population. Governments should establish necessary techno-legal mechanisms to ensure that all stakeholders both in the public and private domain, like builders, architects, engineers and government departments implement building codes for adequate seismic safety in all designs and construction activities.

***Promotion of Earthquake-resistant design and construction*:** Collapse of structures like houses, schools, hospitals, roads, dams, bridges and other buildings, causes huge loss of life and property. Past experiences show that a very high percentage (about 75) of lives is lost due to the collapse of buildings that were not earthquake resistant. Therefore, earthquake-resistant design and construction must be emphasised, promoted and integrated in infrastructure development.

***Retrofitting of Priority Structure*:** The requirement to improve the ability of an existing building to withstand the ground shaking due to earthquake requires retrofitting of the structure that must be carried out in a phased manner by drawing priorities, like buildings of national importance, lifeline buildings, public utility structures, multi-storied buildings, etc.

***Upgradation of seismic network*:** At the national level, the seismic networks need to be improved with respect to density and coverage in order to assess accurately damage potential at different locations. Efforts at the national level could lead to prioritization of areas for seismic microzonation and better urban planning.

Post-disaster management of earthquakes which are trans-boundary in nature, like the Pakistan earthquake of 2005, that affected severely both India and Pakistan, requires a synergy at the regional level for data generation, dissemination, response and recovery.

***Relief, Recovery and Rehabilitation*:** To share experiences related to relief, recovery, rehabilitation of devastated area and assistance to victims of the 1998 Afghanistan earthquake, the 2001 Bhuj earthquake (India) and the 2005 Kashmir earthquake. The relief, recovery and rehabilitation efforts need to focus on the following aspects:

- Target populations must be identified on the basis of actual need; beneficiary consultation and participation is essential for effective targeting. For example, the poor are disadvantaged in recovery, by limited access to resources, and fewer options for recovery, therefore the focus should be pro-poor and disadvantaged.
- Appropriate selection of relief material based on culture and need of target population.
- Monitoring of emergency responses and coordination between communities (to ensure community participation), NGOs, private sectors, international agencies and national authorities in relief and rehabilitation. Based on strength-weakness assessment, the right combination of

agencies must be identified for different tasks during different time periods for better delivery in a credible manner.

- Shelter and rebuilding should be linked to livelihood promotion and as far as possible, be provided closer to damaged shelter/home. Rebuilding should be linked to reduction in poverty as well as vulnerability by suitable site selection and appropriate construction with as far as possible locally available resources (manpower as well as material). Reconstruction should be envisaged as opportunity for building better and reviving the local economy. A suitable balance must be maintained between temporary and permanent shelter construction.
- Logistics arrangements need to be locale-specific, feasible, sensible, effective and operable.
- Institutional and financial mechanism for reconstruction.
- Linking relief, recovery to development.
- Psychosocial support after earthquakes.
- Advocacy and the media to play an important role in assessing the local need, adequacy, aspiration and educating the local population in mitigation measures.
- Prioritisation of a recovery plan to address livelihood of marginalized, underprivileged section, agricultural sector (seed and fertilizer support), health care and education system.
- Deployment of trained and committed staff at all levels of management by all stakeholders such as NGOs, government and international agencies.
- External audit, grievance-redressal mechanisms, and mechanism to guard against potential corruption.

Business Continuity Planning and Economy recovery: Revival or survival of business activity is the key to quick recovery of any region in the world after any major disaster. Communities cannot survive a disaster unless the economy survives. Small to medium-sized businesses are the backbone of the South Asian economy, but most do not plan for a major business interruption. Second, since it falls mainly in the private domain, it often remains excluded from the disaster mitigation strategy initiated by government agencies. Therefore, it is necessary to educate and motivate business owners as well government planners to develop plans, to recognize that business recovery is tied to community-wide disaster resistance and resilience, and to institutionalize business continuity planning into business practices and government planning process. Lessons must be learnt from what has made the difference between business survival and failure following a disaster. It is important to explore how business continuity planning, involvement with disaster-resistant and resilient community enhances its ability to survive, remain viable, and ultimately recover from a major disaster.

Awareness and Preparedness: Awareness of improved understanding of seismic hazard for better preparedness among communities and to invoke and share indigenous knowledge for mitigation based on success stories and lessons learnt from the region would be of immense value in any disaster mitigation strategy. The earthquake-vulnerable communities need to be educated in earthquake safety measures in the construction of residential structures at a nominal additional cost. It is envisaged that as a sense of security, the civil society would automatically incorporate seismic resistance measures for stronger residential complexes. Visual aids in earthquake safety must be prepared in local languages for the general public to increase awareness about earthquake safety and generate demand for earthquake safety standards. Video films may also be created for creating awareness about the seismic hazard and preparedness. Awareness programmes may be organized by Governmental and Non-Governmental Organizations for specific target groups of stakeholders on seismic hazard mitigation.

Capacity Building: To implement capacity-building measures through training and education at various levels by making use of the expertise and infrastructure available at national/international organisations. The earthquake education may be included in the educational curricula starting from school level and high quality educational material needs to be developed to address various aspects of earthquake management, like preparedness, mitigation and response. Training programmes may be developed carefully for capacity building of trainers and trained teachers. For capacity development, the target groups could be the public representatives, Government officials, urban planners, engineers, architects, masons, builders, NGOs, community-based organizations (CBOs), social activists, school teachers and schoolchildren.

***Possibility-Opportunity-Priority (POP) Analysis*:** A comprehensive literature survey on seismic hazard mitigation measures in different geological settings worldwide suggests numerous possibilities to minimize and reduce loss due to earthquake-related hazards. In South Asia, due to the unique geological and geographical set-up, a subset of those possibilities exists as opportunity that could be implemented for reducing loss and developing resilience of community. However, based on the resources and urgency to implement the measures that would bring maximum results in the shortest possible time in terms of building resilience, it is important to prioritize the efforts. Therefore, while developing different components of mitigation measures, Possibility-Opportunity-Priority (POP) analysis must be carried out to maximize the benefit.

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