1 Introduction

On January 26, 2001, one of the most destructive earthquakes ever to strike India occurred in the Kachchh region of Gujarat State in western India (Figure 1-1). The earthquake occurred at 8:46 am, local time on a Friday morning, during a national holiday in honor of India's Republic Day celebration—many businesses, schools and government offices were closed. Damage was spread over a radius of 400 kilometers from the earthquake epicenter (Figure 1-2).

Official magnitude estimate for the January 26, 2001 event from the U.S. Geological Survey is 7.7 on the moment (M_w) scale. The epicenter was located at 23.40° North, 70.34° East with a focal depth of approximately 18 kilometers, approximately 70 kilometers east of the city of Bhuj in the low foothills along the southern margin of the Banni Plains. The earthquake caused extensive liquefaction and slope failures over an area of tens of thousands of square kilometers, but produced no primary surface fault rupture. Minor ground cracks were observed, but these features are attributed primarily to liquefaction-induced lateral spreading and/or strong ground shaking, but not to primary slip on the main fault plane.

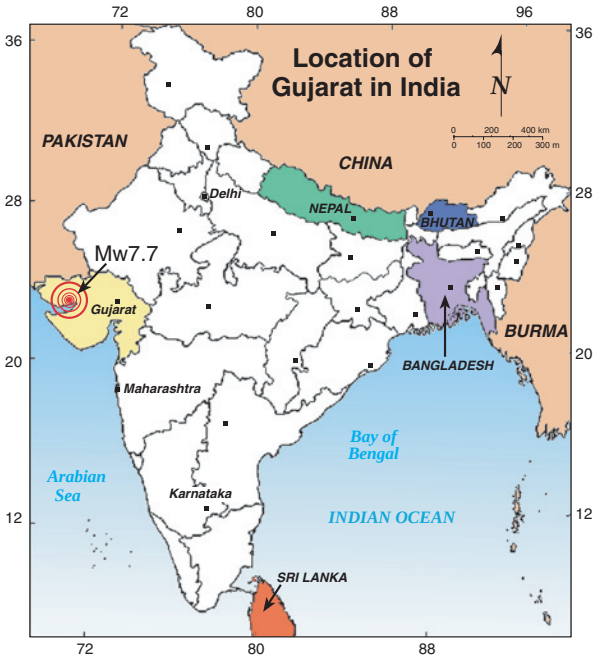

Figure 1-1. Location of the January 26, 2001 M_w 7.7 Bhuj earthquake in northwestern India.

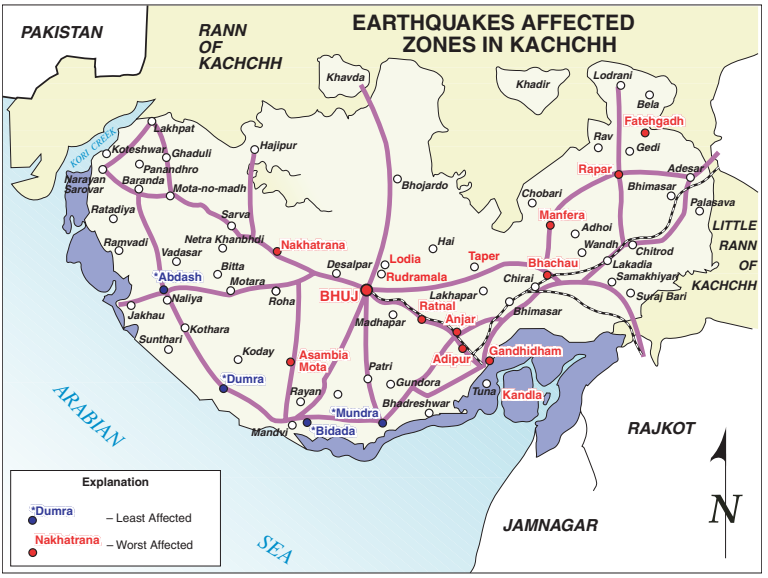

Figure 1-2. Detail map of the Kachchh district.

Over 13,800 human lives were lost, and over 167,000 persons were injured during the earthquake (Table1-1). About 90 percent of the deaths were in the largest district of Kachchh, the headquarters of which is Bhuj. (A district is the administrative sub-unit of the state, similar to a U.S. county.) One major city, Gandhidham, and four large towns, Bhuj, Anjar, Bhachau and Rapar, in the Kachchh district were devastated. Over 230,000 one- and two-story masonry houses collapsed, and over 980,000 more were damaged. Further, several hundred reinforced concrete frame buildings collapsed, including some 11-story buildings. While the quake was felt at far-off locations in the country (including Calcutta, about 1900 km east of the epicenter), the collapse of over 130 multistory reinforced concrete (RC) frame buildings in Ahmedabad city (~200 km from the epicenter), and collapse of a building in Surat city (~340 km from the epicenter) have stood out.

India has faced a number of major earthquakes in the past; e.g., 1897 Assam earthquake (M8.7; ~1,500 deaths), 1905 Kangra earthquake (M8.6; ~19,000 deaths), 1934 Bihar-Nepal earthquake (M8.4; ~11,000 deaths), 1935 Quetta earthquake (M7.6; ~30,000 deaths; in Baluchistan, now in Pakistan), and 1950 Assam-Tibet earthquake (M8.7; ~4,000 deaths). The area affected by the Bhuj earthquake also experienced a large earthquake in 1819 (~M8.0 Kachchh earthquake; ~1,500 deaths), and a moderate earthquake in 1956 (Anjar earthquake of M7.0; ~115 deaths). There have been several moderate earthquakes in India in the last 50 years (e.g., 1988 Bihar-Nepal: M6.6, ~1,004 deaths; 1991 Uttarkashi: M6.6, ~768 deaths; 1993 Latur: M6.4, ~8,000 deaths; 1997 Jabalpur: M6.0, ~38 deaths; and 1999 Chamoli: M6.5, ~100 deaths). However, these earthquakes occurred mostly in rural areas. The Bhuj earthquake is the first major earthquake to hit an urban area of India in the last 50 years. The net direct and indirect economic loss due to the damage and destruction is estimated to be about US$5 billion. The human deaths, destruction of houses, and direct and indirect economic losses during the 2001 Bhuj earthquake caused a major setback in the developmental process of the State of Gujarat.

Table 1-1. Human deaths due to the Bhuj earthquake in the affected districts of the State of Gujarat. (source: www.gsdma.org)

District	Men	Women	Children	Total
Ahmedabad	290	244	218	752
Anand	0	1	0	1
Banaskantha	9	13	10	32
Bharuch	3	4	2	9
Bhavnagar	2	1	1	4
Gandhinagar	2	0	6	8
Jamnagar	28	62	29	119
Junagadh	1	4	3	8
Kachchh	3,229	4,573	4,419	12,221
Navsari	7	6	4	17
Patan	11	13	14	38
Porbandar	4	3	3	10
Rajkot	106	204	119	429
Surat	25	9	12	46
Surendranagar	26	46	38	110
Vadodara	0	1	0	1
Total	3,743	5,184	4,878	13,805

LESSONS LEARNED

The Bhuj earthquake, like others in the past in India, produced ground deformation features and structural damages that will yield both scientific and practical lessons in earthquake engineering. The earthquake provided information on the seismotectonic setting of the Kachchh region and the behavior of man-made structures built with the prevalent state of knowledge and skill in India. Further, the emergency response of people and government in the aftermath of the disaster provided an evaluation of the earthquake preparedness of the State of Gujarat, in particular, and the country of India in general. Lessons provided by the Bhuj earthquake include:

Seismotectonics of the Western Corner of the Indo-Australian Plate

An event of this magnitude with no primary surface fault rupture provides important implications for seismic source characterization and seismic hazard analysis.

Geotechnical Engineering

Extensive liquefaction occurred in the affected area; numerous small- and medium-size earth dams and earthen embankments for roads and railways failed and will provide critical new data for benchmark analytical studies. In the soft soil deposits of ports, drilled shaft-supported berths responded to the earthquake better than those supported by hollow RC piles.

Structural Engineering

The collapse of modern multistory reinforced concrete buildings, elevated water tanks, and the failure of bridges, waterfront, and industrial structures all highlight the enormous vulnerability of man-made construction, particularly in regions of high seismicity. The earthquake brought into focus the fact that there is very poor compliance with building codes in India; moreover, the process needed to ensure compliance with building codes does not yet exist in the country.

Lifeline Engineering

The failure, and the consequences, of various lifelines—like power distribution facilities, telecommunications, highway links, and water supply services—was demonstrated for the first time in India and will have important implications for future design.

Earthquake Preparedness

The earthquake identified numerous areas that India can immediately build on—education on earthquakes and earthquake-resistant construction, application of appropriate technology in new construction, and preparedness to face the aftermath of such damaging earthquakes in the future.

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Figure Credits

Figures 1-1 and 1-2 by Jason Holmberg, William Lettis & Associates, Inc.