Chapter 31: Information on Some Disastrous Earthquakes

Introduction

Earthquakes are among the most devastating natural disasters, often leading to significant loss of life, destruction of property, and disruption of socio-economic systems. A clear understanding of the characteristics and impact of some of the most disastrous earthquakes in history is essential for civil engineers, especially those engaged in earthquake-resistant design and disaster management planning. This chapter explores major earthquakes from around the world, analyzing their causes, magnitudes, damage patterns, and lessons learned for future engineering practices.

31.1 The 2001 Bhuj Earthquake, India

Location and Magnitude

- **Date:** January 26, 2001
- **Magnitude:** 7.7 on the Richter Scale
- **Epicenter:** Near Bhuj, Gujarat, India
- **Depth:** 23 km

Damage and Impact

- Over 20,000 people killed, more than 167,000 injured
- Around 400,000 homes destroyed
- Infrastructure including roads, hospitals, and schools severely damaged
- Total economic loss estimated at $5 billion

Engineering and Geological Observations

- Soil amplification caused extensive damage in soft soil regions like Ahmedabad.
- Poor construction quality and lack of seismic detailing contributed to collapse of RCC buildings.
- Liquefaction observed in the Rann of Kutch region.

Lessons Learned

- Necessity for enforcing seismic codes and retrofitting vulnerable structures.
- Importance of soil-structure interaction studies in design.

31.2 The 2004 Indian Ocean Earthquake and Tsunami

Location and Magnitude

- **Date:** December 26, 2004
- **Magnitude:** 9.1–9.3 on the Richter Scale
- **Epicenter:** Off the west coast of northern Sumatra, Indonesia
- **Depth:** 30 km

Damage and Impact

- Triggered a massive tsunami affecting 14 countries
- Over 230,000 deaths globally
- Severe damage in coastal areas of India, Indonesia, Sri Lanka, and Thailand
- Indian state of Tamil Nadu was one of the worst hit

Engineering and Geological Observations

- Subduction of the Indian Plate beneath the Burma Plate caused vertical displacement.
- Coastal structures like sea walls failed; traditional wooden houses were swept away.
- Lack of early warning systems was a major factor in high casualties.

Lessons Learned

- Implementation of tsunami warning systems.
- Importance of coastal planning and resilient infrastructure near coastal zones.

31.3 The 2011 Tōhoku Earthquake, Japan

Location and Magnitude

- **Date:** March 11, 2011
- **Magnitude:** 9.0 on the Moment Magnitude Scale
- **Epicenter:** Off the Pacific coast of Tōhoku, Japan
- **Depth:** 29 km

Damage and Impact

- Over 15,000 people killed, thousands injured and missing
- Massive tsunami with waves up to 40 meters
- Fukushima Daiichi Nuclear Power Plant meltdown
- Economic losses exceeded $235 billion — the costliest natural disaster in history

Engineering and Geological Observations

- Advanced Japanese seismic design limited damage in newer buildings.
- Older infrastructure and coastal defense mechanisms proved insufficient.
- Extensive liquefaction in reclaimed lands around Tokyo Bay.

Lessons Learned

- Importance of redundancy in nuclear plant safety systems.
- Need for updating old infrastructure and elevating coastal protections.

31.4 The 2015 Gorkha Earthquake, Nepal

Location and Magnitude

- **Date:** April 25, 2015
- **Magnitude:** 7.8
- **Epicenter:** Near Barpak, Gorkha District, Nepal
- **Depth:** 15 km

Damage and Impact

- Over 9,000 deaths and more than 22,000 injured
- Massive destruction in Kathmandu Valley and surrounding rural areas
- Historic buildings and cultural heritage sites were reduced to rubble

Engineering and Geological Observations

- Unreinforced masonry structures and heritage buildings suffered the most damage.
- Landslides and avalanches triggered in mountainous regions, including Everest.
- Seismic gaps indicated long overdue release of tectonic stress.

Lessons Learned

- Need for integrating modern engineering with traditional architecture.
- Community awareness and emergency preparedness proved vital for reducing fatalities.

31.5 The 1976 Tangshan Earthquake, China

Location and Magnitude

- **Date:** July 28, 1976

- **Magnitude:** 7.5 (Some estimates suggest up to 8.2)
- **Epicenter:** Near Tangshan, Hebei Province, China
- **Depth:** 11 km

Damage and Impact

- Official death toll: over 240,000 (some estimates exceed 600,000)
- Almost 85% of buildings in Tangshan were destroyed
- Tremors felt as far as Beijing and Tianjin

Engineering and Geological Observations

- Strike-slip faulting along the Tangshan fault.
- Collapse of reinforced concrete and brick masonry structures due to lack of seismic design.
- Ground fissures, lateral spreads, and soil failures observed.

Lessons Learned

- Led to major reforms in Chinese seismic code and urban planning.
- Need for earthquake risk zoning and early warning systems emphasized.

31.6 The 1994 Northridge Earthquake, USA

Location and Magnitude

- **Date:** January 17, 1994
- **Magnitude:** 6.7
- **Epicenter:** Northridge, California
- **Depth:** 18.4 km

Damage and Impact

- 57 people killed, over 9,000 injured
- Economic losses estimated at $44 billion
- Major freeway overpasses and buildings collapsed

Engineering and Geological Observations

- Blind thrust faulting without surface rupture.
- Damage concentrated in soft-story buildings and welded steel moment-frame structures.
- Strong ground motions recorded exceeding design levels.

Lessons Learned

- Revised seismic codes to address vulnerability of soft-story and steel frame structures.
- New emphasis on retrofitting older buildings and infrastructure.

31.7 The 1906 San Francisco Earthquake, USA

Location and Magnitude

- **Date:** April 18, 1906
- **Magnitude:** 7.8
- **Epicenter:** Near San Francisco, California
- **Depth:** Shallow focus

Damage and Impact

- Estimated 3,000 deaths
- Over 28,000 buildings destroyed due to quake and ensuing fires
- Most of the city's central business district reduced to ashes

Engineering and Geological Observations

- Rupture along the San Andreas Fault
- Extensive lateral displacement of up to 6 meters
- No seismic design practices in place at the time

Lessons Learned

- Triggered the beginning of seismic studies and fault mapping in the U.S.
- Importance of fire-resistant construction and city planning recognized.

31.8 The 1985 Mexico City Earthquake, Mexico

Location and Magnitude

- **Date:** September 19, 1985
- **Magnitude:** 8.0
- **Epicenter:** Offshore, Pacific coast of Mexico
- **Depth:** 15 km

Damage and Impact

- Over 10,000 fatalities (official), some reports suggest over 30,000
- Thousands of buildings collapsed or were damaged
- Severe impact in Mexico City due to resonance effects

Engineering and Geological Observations

- Amplification of seismic waves in ancient lakebed sediments
- Resonance of ground motion with mid-rise buildings (~8–15 stories)
- Failure of non-ductile concrete frames and shear walls

Lessons Learned

- Emphasized the importance of soil-structure interaction in design.
- Building codes revised to account for local geological conditions.
