UNDERSTANDING EARTHQUAKE DISASTERS

AMITA SINVHAL

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Amita Sinvhal

Professor

Department of Earthquake Engineering,
Indian Institute of Technology, Roorkee
Uttarakhand, India

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To

Swapnil, Yash, Manya

Preface

Earthquakes take a heavy toll on human life and property as witnessed after the recent earthquakes, like the Kashmir earthquake of 2005, the Sumatra earthquake of 26 December 2004, the Kutch earthquake of 26 January 2001, and the Latur earthquake of 1993. This book is a consequence of the many lectures that followed these earthquakes. These lectures were for audience from diverse backgrounds—who were interested in and wanted to understand more about earthquakes and the disasters caused by them—such as planners, policy makers, decision makers, administrators, builders, teachers, technical institutions, researchers, and students of civil engineering, earthquake engineering, seismology, architecture, planning, management, geology and geophysics, and many others. Because of the diverse and complex nature of the subject, it was necessary to strike a fine balance between damage surveys, seismology and engineering aspects of earthquakes.

Some of the larger cities in India, with an increasingly large stock of brick masonry and multistory buildings, are at risk due to ground tremors from distant and near earthquakes. A distant and small earthquake is 'usually' less hazardous compared to a near and large one. The Kutch earthquake of 2001 was an eye-opener in this sense. Rural houses of random rubble stone masonry near the epicenter were as vulnerable as new multistory buildings at large epicentral distances in an urban landscape. What happened in a prosperous city like Ahmedabad, which is at an epicentral distance of more than 250 km, and Surat, which is even further away, serves as a lesson for making earthquake-resistant multistory buildings in future at other similar seismically vulnerable sites. The study of the damage inflicted by every earthquake, therefore, imparts important lessons, which if learnt, can go a long way in minimizing future human misery.

This book deals with elementary concepts of earthquakes, such as global seismicity, causes of earthquakes, plate tectonics, seismic waves, magnitude, intensity, faults in the earth, seismo-tectonics, seismicity, seismic zoning, how earthquakes are monitored and how data is used as a tool to understand the earth's interior. Further, it deals with several damaging effects of earthquakes, such as ground failure, landslides, tsunamis and the human habitat. Photographs accompanying the text tell their own stories. It is my sincere hope that this book will help the reader demystify earthquakes and the disasters they cause, which may lead to an urge to know more about how to minimize the disastrous effects of future earthquakes.

The subject has been given a simple treatment. Most terms used are defined in a glossary at the end of the book and mathematical treatment has been kept to a bare minimum. A reader interested in more rigorous treatment of any particular topic will find references and several online resources provided at the end of this book useful.

I acknowledge with deep gratitude, the facilities and continued support I received from the Head, Department of Earthquake Engineering and my colleagues at this Department. With some I had the opportunity to carry out fieldwork on various earthquakes, in difficult post-earthquake conditions, inhospitable and rugged terrain, inclement weather, and the threat from terrorists along the Line of Control (LoC). Learning from these experiences was adventurous, exciting and, at times, very disturbing and frightening.

For a stimulating interaction in course of my research, gratitude is due to many, especially to my colleagues at the Department of Earthquake Engineering, to the late Professors Jai Krishna and L.S. Srivastava; to Professors H.R. Wason, Ashwani Kumar, A.D. Pandey, A.K. Mathur, R.N. Dubey, Daya Shanker, D.K. Paul, M.L. Sharma, and G.I. Prajapati. I cherish my long association with Professors Pratima Rani Bose, Vipul Prakash, B.C. Mathur, V.H. Joshi, Sachin Pore and Sudarshan Singh, who were former colleagues at this Department; to late Professor K.N. Khattri and to Professors A.K. Awasthi, V.N. Singh, A.K. Jain, A. Joshi and S. Singh, from the Department of Earth Sciences; and to Professor Amit Bose, who was formerly at the Department of Architecture and Planning at IIT Roorkee. I am grateful to all individuals, establishments, and district administrations who helped me in field expeditions, gave their time freely to share their experiences, and provided relevant information. A special gratitude is also due to the Indian Army for their logistic support in several field investigations.

A special thanks to Mr. Subodh K. Saini who typed most drafts and made illustrations. Ms Swapnil Sinvhal, Mr. Manish Jain, Dr. Ila Gupta and Mr. Abhishek Singh helped in drawings in earlier drafts of the manuscript. Many thanks too to Professor M.P. Jain and Ms Revathi Bhaskar for their continued support and encouragement. Except for quoted matter, I take full responsibility for any errors and omissions in this manuscript.

Finally, Professor Harsha Sinvhal, my family, friends, and publishers, who believed in me and did not let me give up, deserve my thanks.

Amita Sinvhal

AMITA SINVHAL
email: amitafeq@iitr.ernet.in
amitafeq@gmail.com

List of Symbols

a	Ground amplitude in microns
g	Acceleration due to gravity
h	Focal depth
m_b	Body wave magnitude
p	Initial ascent of *P*-wave to the surface
s	Initial ascent of *S*-wave to the surface
A	Maximum trace amplitude of an event to be measured
A_0	Maximum trace amplitude of a zero-magnitude earthquake
c	Wave reflected at boundary of outer core
E	Epicenter
E	East
E	Energy in an earthquake
E_0	Energy released in earthquake of magnitude, zero, $= 2.5 \times 10^{11}$ ergs
E_M	Energy released in earthquake of magnitude M
FF	Fault (as shown in figure)
I	Intensity
I	Reflection of *P*-wave from boundary of inner core
J	Shear wave that travels through the inner core
k	Bulk modulus of elasticity of a medium
K	Compressional wave that comes from the outer core
L	Length of fault
M	Magnitude
M, M_L	Richter magnitude
M_0	Seismic moment
M_S	Surface wave magnitude
M_W	Moment magnitude

N	North
O	Centre of the earth
P	Longitudinal waves or compressional waves
P, *S*, *L*	These symbols are seismological shorthand for three successive group of waves recorded on seismograms of normal earthquakes
R	Radius of the earth
R	Hypocentral distance
S	Point of observation, station
S	Transverse waves
S	South
(*S*–*P*)	Time difference between arrival of *S*- and *P*-waves
T	Period of wave in seconds
T_P	Travel time of *P*-wave
T_s	Travel time of *S*-wave
V	Volume
V_P	Velocity of *P*-waves
V_S	Velocity of *S*-waves
W	West
W	Work done
Greek Characters	
α	Constant = 1.656, used in magnitude computation
β	Constant = (1.818 + C); C is station constant
Δ	Epicentral distance
μ	Rigidity
ρ	Density g/cc, kg/m^3
σ	Stress
λ	Wavelength
π	Pi
Conversion Factors	
1 micron, (μm)	0.001 mm, 10^{-4} cm, 10^{-6} m
1 megaton	1 million tons
1°	111 km
km	Kilometer
m	Meter

List of Acronyms

BIS	Bureau of Indian Standards
EMS	European Macro Seismic Scale
EQRD	Earthquake Resistant Design
FFT	Frontal Foothill Thrust
GMT	Greenwich Mean Time
GPS	Global Positioning System
GSI	Geological Survey of India
IMD	India Meteorological Department
ISI	Indian Standards Institution
IST	Indian Standard Time
ITSZ	Indus Tsangpo Suture Zone
MYA	Million years ago
MBT	Main Boundary Thrust
MCT	Main Central Thrust
MI	Mercalli Intensity Scale
MMI	Modified Mercalli Intensity Scale
MSK	Medvedev Sponhouer Karnik Intensity Scale
NEIC	National Earthquake Information Center
ONGC	Oil and Natural Gas Commission
RBC	Reinforced Brick and Concrete
RCC	Reinforced Cement and Concrete
RF	Rossi Forel Scale of Intensity
UCT	Universal Coordinated Time
USGS	United States Geological Survey
RRSM	Random Rubble Stone Masonry

Contents

1 CHAPTER

Global Seismicity

INTRODUCTION

Earthquakes are one of the most devastating natural phenomena. Every year thousands of people are rendered homeless, displaced, injured, or even killed all over the world due to earthquakes. Growing population and global urbanization is increasing the threat of earthquakes. Man from time immemorial has experienced earthquakes. It was generally believed that like all other natural phenomena, large animals like Sheshnag in Indian mythology or the catfish in its Japanese counterpart caused these. However, the common theme in all these explanations was that an earthquake occurred when the earth shook violently.

A very large number of earthquakes occur throughout the world every year; in fact earthquakes occur more often than one might tend to believe. However, spatial distribution of earthquakes shows that some regions have more earthquakes than other regions, while large areas are almost free of seismicity. Seismicity is the distribution of earthquakes in time and space. Any region, which has frequent earthquakes, is considered seismically active. Seismicity is concentrated along certain narrow, semicontinuous geographical regions called seismic belts. These are shown in Figure 1.1. Seismic belts are of particular interest as frequent earthquakes occur in these regions, induce large-scale damage repeatedly, and make large populations vulnerable. Two prominent seismic belts can be identified on the globe. These are the Circum Pacific Belt and the Alpine-Himalayan Belt, as discussed in the following sections.

THE CIRCUM PACIFIC BELT

The Circum Pacific belt, also known as the ring of fire, is long and narrow. It exists along the Pacific coast of North and South America and continues into

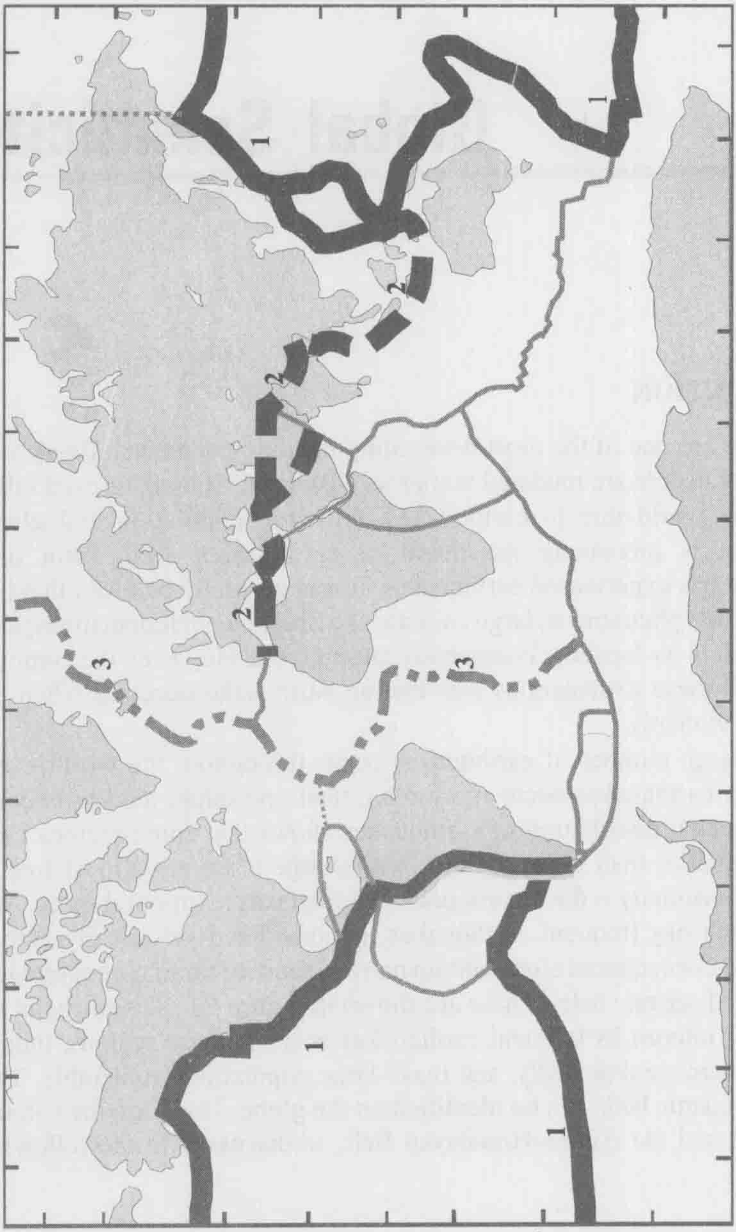

Fig. 1.1 The two main seismic belts are: (1) the Circum Pacific belt, and (2) the Alpine-Himalayan belt. (3) The Mid-Atlantic Ridge, forms a third, less active belt. (See color figure also.)

the Pacific coast of Asia. It is the most active of all seismic belts and has the largest concentration of devastating earthquakes. It contributed more than three quarters of world seismicity; in fact between 1904 and 1952, it gave off 75.6% of global seismic energy (Gutenberg and Richter, 1954).

This belt comprises of, starting from the 12 o'clock position assumed to be at the Bering Strait and going anticlockwise, the Aleutian Islands, Alaska (Good Friday earthquake of 1964, M = 8.6, 131 casualties); Canada; U.S.A., including the states of Washington and California (San Francisco earthquakes of April 18, 1906, M = 8.3, 700 dead; and February 1971, M = 6.6, 65 dead; Loma Prieta earthquake of 1989, M = 7.1, 63 dead; North Ridge earthquake of 1994, M = 6.7, 61 dead); Mexico (September 1985, M = 8.1, 9500+ dead); Central America; Columbia (January 25, 1999, M = 6.0, 1171 dead); Ecuador (January 31, 1906, M = 8.9); Nicaragua El Salvador (2001, M = 7.7, 700 dead); Guatemala and countries within the Andes Mountains of South America, e.g., Peru and Chile (January 24, 1939, M = 8.3, 128000 dead; May 22 1960, M = 8.5). Then on the east coast of Pacific Ocean are New Zealand, Kermadec, Tonga and Fiji islands (Samoa earthquake of June 26, 1917, M = 8.7); East Indies, Papua New Guinea, and Philippines; Japan (Kwanto earthquake of September 1, 1923, M = 8.3, 143,000 dead; Sanriku earthquake of March 2 1933, M = 8.9; Kobe earthquake of January 17, 1995, M = 7.2, 5000+ dead); Taiwan (September 1999, M = 7.6, 2400 dead); the Kamachatka peninsula (November 10, 1938, M = 8.7); and many other places in between.

The Circum Pacific belt is very complex and includes special topographic features such as island arcs, oceanic trenches, and mountain ranges. It has intermediate and deep focus earthquakes, together with shallow focus earthquakes.

THE ALPINE-HIMALAYAN BELT

The Alpine-Himalayan belt is the next most active belt. It contributed 22.1% of seismic energy given off on the globe between 1904 and 1954. This seismic belt is more diffused than the Circum Pacific belt. Topographic features associated with this belt are mountain ranges on continents and island arcs and deep trenches in oceans. It includes the mountainous regions of Alps in Europe, Zagros in Iran, Sulaiman and Kirthar ranges in Pakistan, Hindu Kush and Pamir regions, the Himalayas in Asia, and extends toward the East Indies, via the Arakan Yoma mountain ranges and continues eastward into Indonesia and Philippines. It includes the mountain ranges that radiate from the Pamir knot, such as Karakoram, Kunlun, Altyn Tagh, and those that stretch into Tibet, China, and Mongolia.