Earthquakes and Tsunamis: Fundamental Concepts

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Earthquakes and Tsunamis: Fundamental Concepts

Samir G. Khoury, Ph.D., P.G.

Introduction

Earthquakes, sometimes also referred to as quakes, shocks, seism or temblors, are one of the most alarming and destructive natural phenomena that people can experience. It is also known and well documented that these events are distressing to animals as well, although no one knows as yet what the animals' sense just before the occurrence of an earthquake. The occurrence of large earthquakes is often sudden, their duration is short (on the order of seconds or at most minutes) and the devastation they cause can be extensive or even total. Large earthquakes are often followed by aftershocks, which are tremors that follow a larger earthquake, or main shock. Aftershocks may be felt for several days after the main shock. The number and severity of the aftershocks contribute greatly to the sense of panic felt by the affected population.

The scientific study of earthquakes is relatively new, and a reasonable understanding of their occurrence can only be traced back for a couple of hundred years. Prior to that time, the early historical record of earthquakes is cryptic at best because people did not understand the reason for their occurrence. In fact, there are very few factual descriptions of earthquakes prior to the 18th century because before then, people believed that an earthquake was a massive punishment imposed by the gods to punish the sinners and warn the unrepentant. During these early times, the occurrence of strong earthquakes usually triggered passionate discussions between philosophers and theologians resulting in lengthy and convoluted explanations about a long overdue and deserved retribution by God in response to the pervasive problems of evil in the world. The few that looked for natural causes for these unexplained phenomena reached equally strange conclusions. For example, an early popular theory postulated that earthquakes were caused by strong winds blowing out of deep caverns within the earth.

A drastic change in attitude regarding this issue can be traced back to a strong earthquake that occurred on All Saints' Day, November 1, 1755, near Lisbon, Portugal. Just before 10 am, the city was shaken ferociously for several minutes. The convulsions were so great that the water was sucked out of the city's harbor and returned soon thereafter as a fifty-foot wave that contributed greatly to the destruction of the city. The survivors that had fled to the waterside were drowned by the great waves that raced on them from the Atlantic. The motion of this first earthquake had not ceased for more than a few minutes when a second shock came, only slightly less severe than the first. A third and less severe final shock occurred about two hours later. The end of this mayhem reduced virtually every building within miles of the city center to rubble. Over 60,000 people lost their lives.

For the first time in history, however, we have detailed descriptive information of what happened, soon after the earthquake struck. All over Portugal priests were asked by their bishops to document their observations in as much detail as they could. Their records are still preserved and represent the first systematic effort in history to describe the effects of an earthquake as, or soon after, it occurred. One of the many archived contemporary descriptions is given below:

“The sea rose boiling in the harbor and broke up all the crafts harbored there. The city burst into flames, and ashes covered the streets and squares. The houses came crashing down, roofs piling up on foundations, and even the foundations were smashed to pieces.”

Below is an artistic rendition of this destructive earthquake.

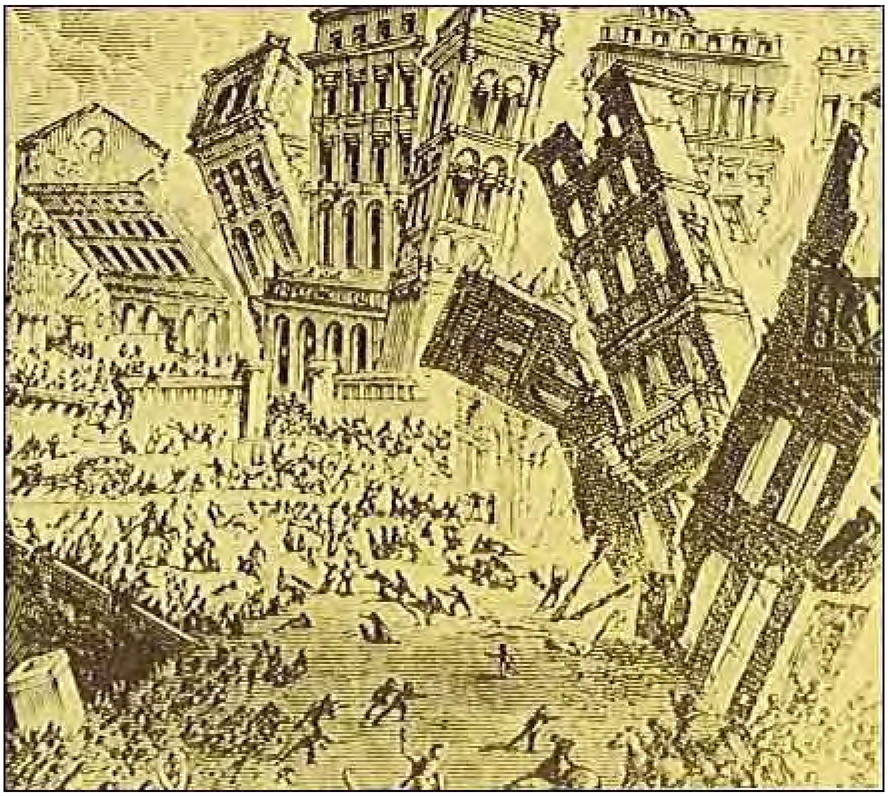


Figure 1. Artistic rendition of the effects of the 1755 Lisbon earthquake (Source: United States Geological Survey, initially published in Candide, by Voltaire).

Ever since that time detailed records have been made of the majority of large earthquakes that have occurred around the world. Today, however, our understanding of these phenomena has evolved beyond the purely descriptive realm of reciting their effects to the deeper understanding of the causes and mechanisms that trigger the occurrence of these events. In fact, it is now understood that earthquakes have punctuated the evolution of our planet since its inception, over 4 billion years ago.

This series of courses on earthquakes, of which this is the first, will explore the advances that have been made in this field and will bring you up-to-date with the knowledge that has been developed since these early days of pure speculations.

Measuring the size of Earthquakes

By the late nineteenth century, the new discipline of seismology, which deals with the methodical study of earthquakes, had accumulated sufficient empirical observations to allow the development of novel approaches to systematically estimate the size and tabulate the effects of earthquakes. It took another fifty years, with associated improvements in seismic instrumentation, to develop a scale to record the absolute size and associated energy released by earthquakes. The history of these developments is presented below:

Development of the Intensity Scale

Using the detailed descriptions that have been recorded for over a century after the occurrence of the 1755 Lisbon earthquake, attempts have been made at developing scales to characterize the shaking severity of earthquakes. Early efforts to describe the intensity of earthquake shaking were initially based on arbitrary scales that were developed independently in 1874 in Italy and in 1878 in Switzerland. This early Italian and Swiss work culminated soon afterward in the development of the standardized Rossi-Forel scale. This first ever scale combined the work and efforts of M. S. di Rossi, Director of the Geodynamic Observatory, near Rome, and F. A. Forel, a member of the Helvetic Society of Natural Sciences for the study of earthquakes. The Rossi-Forel Scale, with intensity levels of I to X, was widely used throughout the world for over half a century after its inception. A copy of this scale is presented below:

Rossi-Forel Intensity Scale

Intensity	Effects
I	Felt only by experienced observers at rest, and recorded by instruments.
II	Felt by a small number of persons at rest.
III	Felt by several persons at rest; strong enough for the duration or direction to be appreciable.
IV	Felt by several persons in motion; disturbance of movable objects, doors, windows; creaking of floors.
V	Felt generally by everyone; disturbance of furniture and beds; ringing of some bells (of schools and churches).
VI	General awakening of those asleep; general ringing of bells; oscillation of chandeliers;

	stopping of clocks; visible disturbance of trees and shrubs; some startled persons leave their dwellings.
VII	Overthrow of movable objects, fall of plaster, ringing of church bells, and general panic, without damage to buildings.
VIII	Fall of chimneys, cracks in the walls of buildings.
IX	Partial or total destruction of some buildings.
X	Great disaster, ruins, disturbance of strata, fissures in the earth's crust, rock falls from mountains.

With the passage of time, the study of earthquake intensity continued to be studied and refined. Between 1890 and 1901 Giuseppi Mercalli, an Italian geologist, made a new compilation of the shaking effects. His efforts led to the development of a standardized scale to document the variations in shaking between various locations and regions. Today, the Mercalli scale has been modified to adapt to local construction conditions and practices. In the United States it is called the "Modified Mercalli Scale", which is the most commonly used adaptation of this scale and covers the range from "I – Not felt except by a very few under especially favorable conditions", to "XII – Damage near total, lines of sight and level distorted". A copy of the Modified Mercalli Scale is presented below:

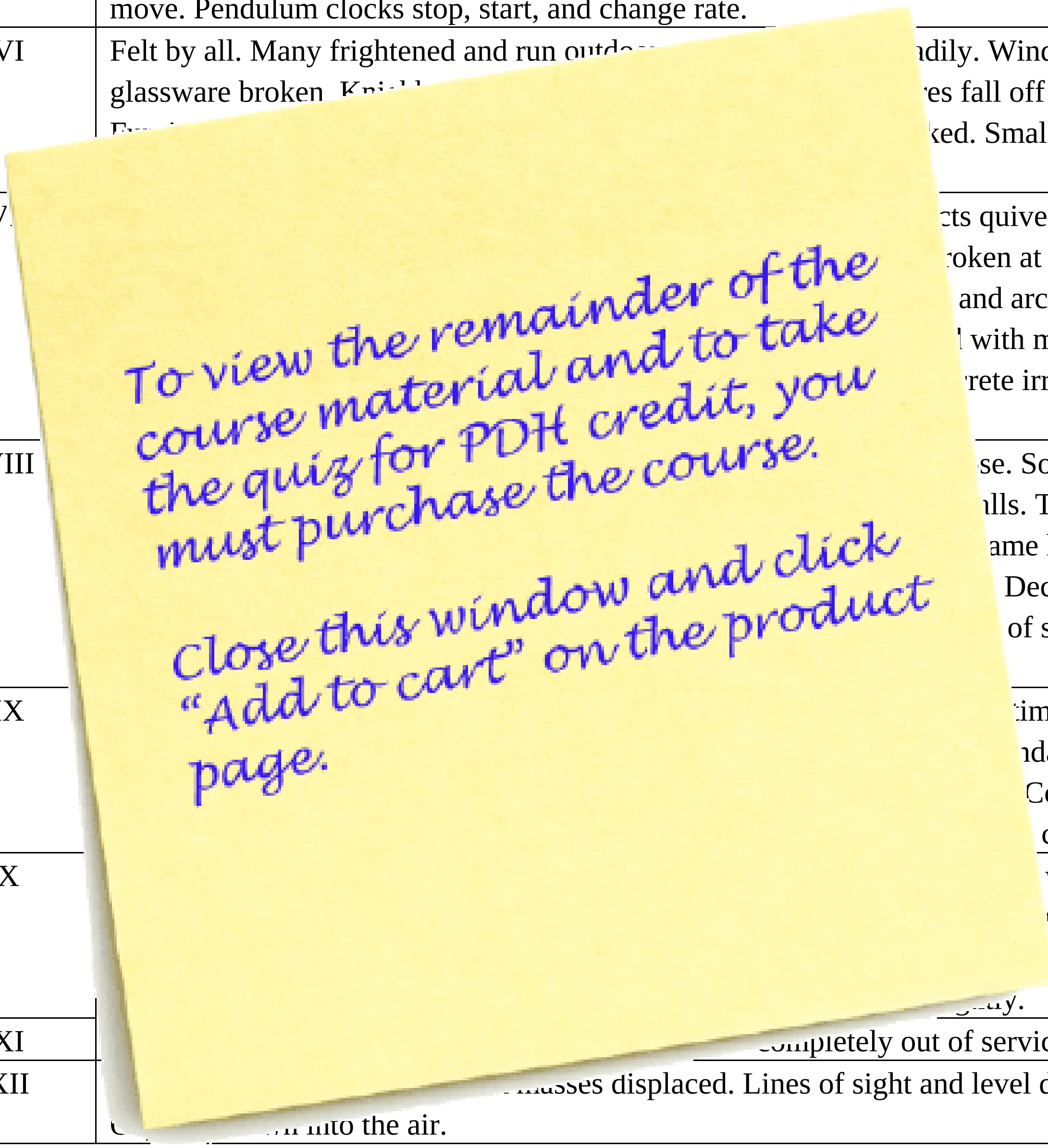
Modified Mercalli Intensity Scale*

Because the performance of masonry is such an important criterion for evaluating intensity, this intensity scale specifies four qualities of masonry, brick or other construction materials, as follows:

Masonry A	Good workmanship, mortar and design; reinforced, especially laterally, and bound together using steel, concrete, etc.; designed to resist lateral forces.
Masonry B	Good workmanship and mortar; reinforced, but not designed in detail to resist lateral forces.
Masonry C	Ordinary workmanship and mortar; no extreme weaknesses like failing to tie in at corners, but neither reinforced nor designed against horizontal forces.
Masonry D	Weak materials, such as adobe; poor mortar; low standards of workmanship; weak horizontally.

Intensity	**Effects**
I	Not Felt
II	Felt by persons at rest, on upper floors, or favorable places.
III	Felt indoors. Hanging objects swing. Vibrations like passing of light trucks. Duration estimated. May not be recognized as an earthquake.

IV	Hanging objects swing. Vibrations like passing of heavy trucks, or sensation of a jolt like a heavy bell striking the walls. Standing automobiles rock. Windows, dishes, and doors rattle. Glasses clink. Crockery clashes. In the upper range of IV, wooden walls and frame creak.
V	Felt outdoors, direction estimated. Sleepers wakened. Liquids disturbed, some spilled. Small unstable objects displaced or upset. Doors swing, close, open. Shutters, pictures move. Pendulum clocks stop, start, and change rate.
VI	Felt by all. Many frightened and run outd... ...dily. Windows, dishes, glassware broken. Kni... ...es fall off walls. F... ...ked. Small bells ring
V...	...cts quivers. Furniture ...oken at roof line. ...and architectural ...with mud. Small ...rete irrigation
VIII	...se. Some damage ...lls. Twisting, fall ...ame houses ...Decayed piling ...of springs and
IX	...times with ...ndations. ...Conspicuous ...craters.
X	...well-built ...nbankments. ...nd mud ...y.
XI	...ompletely out of service.
XII	...masses displaced. Lines of sight and level disturbed. ...n into the air.



*Reference: AGI Data Sheets, American Geological Institute, Alexandria, VA 22302

Although very useful, it is obvious that this kind of descriptive evaluation is subjective and can be made only after eyewitness reports are reviewed, interpreted and tabulated. Relying on the impressions