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MATHEMATICAL ASPECTS OF SEISMOLOGY

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Abstract:

Every day there are about fifty earthquakes worldwide that are strong enough to be felt locally, and every few days an earthquake occurs that is capable of damaging structures. Each event radiates seismic waves that travel throughout Earth, and several earthquakes per day produce distant ground motions that, although too weak to be felt, are readily detected with modern instruments anywhere on the globe. Seismology is the science that studies these waves and what they tell us about the structure of Earth. Seismology occupies an interesting position within the more general fields of geophysics and Earth sciences. It presents fascinating theoretical problems involving analysis of elastic wave propagation in complex media, but it can also be applied simply as a tool to examine different areas of interest. Applications range from studies of Earth's core, thousands of kilometers below the surface, to detailed mapping of shallow crustal structure to help locate petroleum deposits.

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Earthquake:

A sudden ground motion or vibration produced by a rapid release of stored up energy.

Epicenter:

The epicenter is the point on the earth's surface vertically above the focus/hypocenter or point in the crust where a seismic rapture begins.

Crust:

It is the outermost solid shell of a rocky planet/natural satellite which is chemically distinct from underlying mantle.

The crust of earth is compared of a great variety of igneous, metamorphic and sedimentary rocks.

Focus:

The location where the earthquake begins. The ground ruptures at this spot then seismic waves radiate outward in all directions.

Seismology:

It is the scientific study of earthquakes and propagation of elastic waves through the earth and is recorded on seismograph.

Seismograph:

An instrument that measures and records the details of earthquakes such as focus and direction.

Seismic waves:

These are the waves of energy caused by sudden breaking of rock within the earth or an explosion. These are the energy that travels through the earth and id recorded by seismograph.

Fault:

The surface where ruptures start is called fault or fault plane.

Aftershocks:

A smaller earthquake following the main shock of a large earthquake. These are earthquakes that follow the largest shock of an earthquake sequence. They are than the main shocks and within 1-2 rupture distance from the main shock. Aftershocks can continue over a period of week, months or years. Aftershocks decrease in magnitude and frequency over time.

Foreshocks:

It is an earthquake that occurs before a large seismic event and is related to it in both time and space. The designation of an earthquake as foreshocks, main shock or earthquake is only possible after the full sequence of events has happened. Foreshocks occur in the same area where main shock occurs. These may come in groups or be single events. The time between the last foreshock and main shock varies somewhat, but is typically less than a day. These may warn a big quake is coming.\

Difference between foreshock and aftershock:

A foreshock is an earthquake that occurs before seismic event and is related to it in both time and space whereas aftershocks are smaller quakes that occurs in same general area during the days to years following a larger event.

Earthquake Magnitude:

The magnitude is a number that characterizes the relative size of an earthquake. It is based on measurement of maximum motion recorded by a seismograph. It is measured on following scales,

1. 10 cal magnitude (Richter Magnitude) (ML)
2. Surface waves magnitude(MS)
3. Body waves magnitude(MB)
4. Moment magnitude(MW)

Earthquake Intensity:

Intensity is a number (written in Roman numeral) describing the severity of an earthquake in terms of its effects on the earth's surface and on humans and their structures. The most common scale used for its measurement is Modified Mercalli Scale and Rossi-Forel scale.

Differece between magnitude and intensity:

Magnitude measures the energy released at the source of earthquake measured by seismograph whereas intensity measures the strength of shaking produced by earthquake at certain location. Magnitude is determined from measurements on seismographs whereas intensity is determined from effects on people, human structures and the natural environment.

The table shows approximately how many earthquakes occur each year in each magnitude range and what might be the intensity:

Magnitude	**Average number per year**	**Modified Mercalli Intensity**	**Description**
0-1.9	>1 million	-	Micro -not felt
2.0-2.9	>1 million	I	Minor-rarely felt
3.0-3.9	About 100,000	II-III	Minor-noticed by few people
4.0-4.9	About 10,000	IV-V	Minor-felt by many people, minor damage possible
5.0-5.9	About 1,000	VI-VII	Moderate –felt by most people, possible broken plaster and chimneys
6.0-6.9	About 130	VII-IX	Strong- damage variable depending on building construction and substrate
7.0-7.9	About 15	IX-X	Major- extensive damage ,some buildings destroyed
8.0-8.9	About 1	X-XI	Great-extensive damage over broad areas, many buildings destroyed
9.0 and above	<1	XI-XII	Great-extensive damage over broad areas, most buildings destroyed

MAGNITUDE/ INTENSITY COMPARISION:

Magnitude	Intensity
1.0-3.0	I
3.0-3.9	II-III
4.0-4.9	IV-V
5.0-5.9	VI-VII
6.0-6.9	VII-VIII
7.0 and higher	IX or higher

Abbreviated Modified Mercalli Intensity Scale:

I. Not felt expect by few under especially favorable conditions.

II. Felt only by few persons at rest especially on upper floors of building.

III. Felt quite noticeably by persons indoors, especially on upper floors of buildings, most people do not recognize it as quake.

IV. Felt indoors by many, outdoors by few during day. At night some awakened. Dishes, windows, doors disturbed, wall cracking sound.

V. Felt by nearly everyone, many awakened, some dishes, windows broken, unstable objects overturned and pendulum clocks may stop.

VI. Felt by all, many frightened. Some heavy furniture moved, few instances of fallen plaster, slight damage.

VII. Slight damage in buildings of good design and construction. Slight to moderate in well built ordinary structures, considerably damage in poorly built or badly designed structures, some chimneys broken.

VIII. Damage slightly in specially designed structures, considerably damage in ordinary substantial buildings with partial collapse. Great damage in poorly built structures, fall of chimneys, factory, stack, columns, and monuments walls etc.

IX. Considerably damage in specially designed structures, well designed in frame structures thrown out of plumb , great damage in substantial buildings with partial collapse, buildings may shift from foundation.

X. Some well built wooden structures destroyed, most masonry and frame structure destroyed, rails bent.

XI. Few if any structures remain standing, bridges destroyed, rails bent greatly.

XII. Total damage

SEISMIC MOMENT:

It is measure of size of an earthquake based on the area of fault rupture. The average amount of slip and the forces that was required to overcome the friction sticking the rocks together that were offset by faulting.

Energy released by earthquakes:

Seismic moment is a measure of total amount of energy that is transformed during an earthquake. Usually only 1-10% or less of an earthquake's energy is released in form of radiated seismic waves.

$$\text{Log}(Es)=11.8+1.5m$$

where Es is energy and m is magnitude.

Conclusion:

Earthquakes shake the ground surface, can cause buildings to collapse, disrupt transport and services, and can cause fires. They can trigger landslides and Tsunami. Earthquakes occur mainly as a result of plate tectonics, which involves blocks of the Earth moving about the Earth's surface. The blocks of rock move past each other along a fault. Smaller earthquakes, called foreshocks, may precede the main earthquake, and aftershocks may occur after the main earthquake. Earthquakes are mainly confined to specific areas of the Earth known as seismic zones, which coincide mainly with ocean trenches, mid-ocean ridges, and mountain ranges.

The point of origin of an earthquake is called the focus. The epicenter is the point on the Earth's surface directly above the focus. Most earthquake foci are within a few tens of kilometers of the Earth's surface. Earthquakes less than 70 km deep are classified as shallow-focus. Intermediate-focus earthquakes are 70-300 km deep and deep-focus earthquakes more than 300 km deep. Shallow-focus earthquakes occur in all of the Earth's seismic zones, but intermediate- and deep-focus earthquakes are almost exclusively associated with seismic zones near ocean trenches.

The destructiveness of an earthquake depends on the size, the depth and the location. Earthquake size can be stated in terms of the damage caused (the intensity) or the amount of ground motion and the energy released by the earthquake (related to the Richter magnitude).

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