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Professional paper

FUNDAMENTALS OF EARTHQUAKE ENGINEERING AND ENGINEERING SEISMOLOGY

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Abstract

Purpose: Earthquakes as an unwanted phenomenon are a destructive force that causes thousands of deaths and severe material damage every year. Earthquakes as well as the sources of earthquakes, such as volcanic, tectonic, oceanic, atmospheric and artificial processes (explosions). Seismology helps in understanding the Earth's tectonic crust, the Earth's internal structures and the prediction of earthquakes.
Earthquakes are uncontrolled phenomena with negative effects expressed through the destruction of material goods and endangering people's lives. Many of the earthquakes have brought numerous disasters both in terms of taking human lives but also in material goods to the detriment of humanity by destroying infrastructure, buildings, etc. These disasters have also been influenced by poor construction techniques used in the construction of buildings with very weak materials, a non-serious approach to the definition of structural systems, as well as insufficient knowledge in the field of engineering geology, geomechanics and the lack of knowledge of contemporary techniques for mechanisms and materials that make structures more resistant to these phenomena such as earthquakes. The main factor that motivates us is to design buildings that will have high seismic safety with which there will be no major economic and human losses due to their premature collapse.
Method: Analysis of the earthquake resistance of building structures according to technical regulations: The action of high-intensity seismic energy on structures of all categories, especially multi-storey buildings, respecting the rules and standards that deal with the topic, using methods for calculating structures with European norms, international norms, respecting the statements given by the European committee, such as the many seismological institutes in the world that have perfect techniques and technology, first of all for detecting these phenomena - earthquakes, and up to the proposals offered by these institutions, the standards they propose for the many methods for calculation, adoption of constructive systems, proposals for the center of gravity and the center of inertia, types of supports, construction materials, etc.
Results: From the study of the structure of planet Earth, data on tectonic plates, their movement, the processes that occur in the earth's mantle and in other layers of the earth, it is found that the final results from the seismological phenomenon - earthquakes, unfortunately the results result in alarming numbers in terms of the loss of tens of thousands of lives of people of all age groups from different countries and peoples, material damage with significant amounts that bring the economies of countries around the world to their knees. Taking these scientists into consideration, legislators are giving their maximum by offering theoretical, experimental solutions and proposing materials, mechanisms of many types so that these results - damage to people and material goods are minimal.
Conclusions: In conclusion, earthquake-resistant systems and practices play a key role in protecting life, property and infrastructure in regions prone to seismic activity. Understanding earthquake hazards, geological processes, and seismic wave behavior has paved the way for innovative solutions aimed at reducing the destructive impact of earthquakes. This state of the art has explored key aspects of earthquake resilience, including monitoring and early warning systems, retrofitting existing structures, community preparedness, and future trends and challenges.

Keywords: Seismicity, earth, intensity, magnitude, tectonic plates, structures, seismic energy,dissipation systems.

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Earthquake engineering basics and engineering seismology

Seismology (Greek seismos: earthquake and logos: science) is a branch of geophysics that deals with the study of earthquakes, that is, the movement of elastic waves through the Earth and their associated phenomena. It observes and measures natural tectonic vibrations, studies the effects of earthquakes (mainly tsunami waves), as well as the sources of earthquakes, such as volcanic, tectonic, oceanic, atmospheric and artificial processes (eruptions). Seismology helps in understanding the Earth's tectonic crust, the internal structures of the Earth and the prediction of earthquakes.
The results of seismic research are applied in construction (earthquake engineering, engineering seismology, anti-seismic construction), urban planning and oil and natural gas exploration (applied geophysics). The work of experts in seismology includes recording earthquakes, their localization and cataloguing-mapping, data exchange with international institutions, macroseismic processing of the strongest earthquakes (mapping their effects) and the like. Scientific research includes studying the details of the rupture process at the focus (hypocenter) of the earthquake, modeling the propagation of elastic waves through the Earth and determining its internal structure, studying the effects of earthquake waves on buildings and assessing the seismic forces that will act on the object in the future (seismic hazard). Most of the knowledge about the structure of the Earth was discovered precisely through seismological methods. The scientific field also includes studies of the effects of earthquakes, such as tsunamis, and various seismic sources such as volcanic, tectonic, oceanic, atmospheric and artificial (such as explosions) processes. A related field that uses geology to draw conclusions based on information about past earthquakes is paleoseismology. The recording of ground motion as a function of time is called a seismogram.

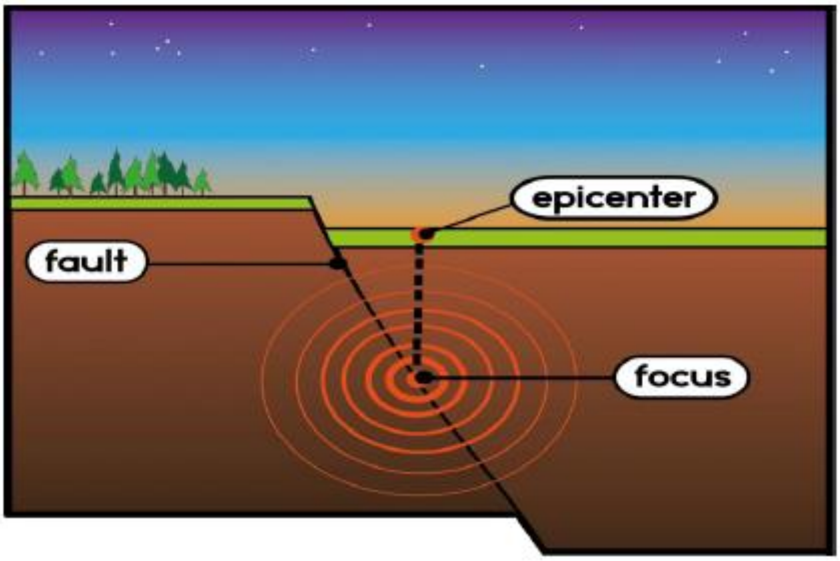
History

Seismology is a relatively new science that has developed rapidly since the early 20th century. The word seismology was first used in the mid-19th century by the Irish scientist Robert Malet (1810–1881), and the first useful seismographs (seismometers) were built shortly thereafter in Italy, Japan, and Germany. The development of the theory of elastic wave propagation preceded the development of measuring instruments, so the main types of earthquake waves in seismograms were determined many years after their existence was theoretically predicted. In 1828, the strength (intensity) of an earthquake was first taken into account to indicate damage to buildings.
In seismological practice, various macroseismic scales have been preserved to this day, which classify the observed effects of earthquakes on buildings, people, animals, objects and the environment into a certain number of scales, thus determining the strength of the earthquake in that country. At the end of the 19th century, the first national seismological societies and so-called commissions were founded (1878 in Switzerland, 1880 in Japan), and in 1905 the International Association for Seismology was founded, which in 1951 grew into the International Association for Seismology and the Physics of the Earth's Interior, which it is today. About 150 seismological stations were operating in the world in the 1920s, and the International Seismological Center was founded, which still collects data from seismological observatories around the world. A regional seismological organization has been operating in the Euro-Mediterranean area since 1975. In the 1950s, there were about 700 seismological stations in the world. Today there are more than 8,500 stations registered internationally. The rapid development of computers in the second half of the 20th century enabled the solution of complex numerical problems related to the theory of propagation and the modeling of elastic waves in a heterogeneous and anisotropic medium, but also significant progress in the

development of seismographs, which today are based exclusively on the collection of digital data. Seismology considers phenomena that are measured over extremely large ranges; the smallest measured ground displacements are about 10-8 meters in magnitude, while displacements in large earthquakes exceed ten meters, and their period is from one thousandth of a second to approximately 1 hour. Typical seismographs today collect between 60 and 600 data points per second in continuous operation, so each station collects an average of 12 Gb of data per year.

Earthquakes

An earthquake is a sudden and short-term shaking of the ground caused by the collapse of rocks (earthquake), magmatic activity (volcanic earthquake) or tectonic disturbances (tectonic earthquake) in the lithosphere and partly in the Earth's mantle. The study of earthquakes is carried out by seismology, a branch of geophysics. The place where earthquakes occur deep in the Earth is called the focus or hypocenter of the earthquake. It can be directly below the surface to a depth of 750 kilometers (so far, no earthquakes with deeper focal points have been recorded). If the hypocenter is at a depth of up to 70 kilometers, the earthquake is shallower, a medium-depth hypocenter is located between 70 and 300 kilometers, and a deep hypocenter is more than 300 kilometers below the Earth's surface.



Earthquake vibrations spread from the hypocenter in all directions by progressive elastic earthquake waves. The fastest are longitudinal waves (lat. undae primae or P waves), which oscillate in the direction of propagation, compressing and expanding the material through which they pass. Transverse waves (lat. undae secundae or S waves) vibrate perpendicular to the direction of propagation, are 1.7 times slower than P waves and propagate only through solid rocks. Long waves (lat. undae longae or L waves) are the slowest, they have a circular and horizontal component, and their action is weak. The earthquake is strongest at the epicenter (a place on the Earth's surface immediately above the hypocenter) and in its immediate vicinity (epicentral zone). The curve that depends on the duration of the travel of a seismic wave to a given place at the epicentral distance is called the hodochrone.
The strength of an earthquake depends on the depth of the hypocenter, the distance from the epicenter, the properties of the soil (in solid walls, the earthquake is weaker than in loose soil), the presence of groundwater, the strength of the building, etc. The strength of an earthquake (the measure of the effect of an earthquake on people, buildings and nature) is determined by experimental macroseismic scales that are valid only for certain areas. The first scale was made

by Giacomo Gastaldi in 1564. Since then, a number of scales have been created for determining and comparing the strength of earthquakes: the P. B. Egen scale of 6 degrees (1828), Michel Stefan de Rossi and François Alphonse Forel of 10 degrees (1900) and others. In 1917, the International Seismological Association proposed a Mercalli-Cancan-Sieberg scale. (MCS) of 12 degrees (Mercal scale) for general use. The Medvedev-Sponheuer-Karnikov (MSK) scale of 1964, also of 12 degrees, is based on it. The lines that separate areas of equal earthquake strength are called isoseisms.

*The magnitude of an earthquake is the relative measure of the energy released in an earthquake. It is an unnamed number, and common magnitude values are between 1 and 9, although the magnitude scale is open both at the top and bottom. Very weak earthquakes can also have negative magnitudes (since magnitude is defined by the logarithmic function). Thus, magnitude is the equivalent measure of the energy of an earthquake relative to its focal point, which means that it does not depend on the depth of the hypocenter. In honor of seismologist Charles Richter, who in 1935 mathematically defined magnitude as a measure of the energy of an earthquake, this earthquake parameter is also called the Richter magnitude.

*The intensity of an earthquake expresses the extent of the surface effects of the earthquake – on buildings, the ground, and people. It is expressed in degrees from I to XII on the so-called Mercalli Scale (Mercali – Cancani – Sieberg), or MCS for short, as well as equivalent, but much more detailed scales: EMS-98 (European Macroseismic Scale from 1998), or MSK-64 (Medvedev – Sponhauer – Karnik scale defined in 1964). The intensity scale in the range of degrees I-IX is the so-called Japanese Scale. Intensity scales are descriptive and express textually the effects of earthquakes on the earth's surface.

Here are the descriptions of all earthquake intensity scales:

Level I – Not felt by people, recorded only by seismographs;

Level II – Only very sensitive people react at rest;

Level III – Felt by more people inside the building;

Level IV – Most residents feel it at home and only individuals feel it outside. Dishes and windows shake. Individuals wake up from sleep;

Level V – Felt by many people even in open space. Freely hanging objects swing. Causes some panic in individuals;

Level VI – All people feel it and run away from home. Pictures fall from walls. The first damage occurs in poorly constructed buildings;

Level VII – Parts of furniture fall from homes. Damage occurs even in quality homes. Cracks appear in walls. Parts of chimneys in homes collapse, tiles fall from roofs. Greater damage is possible in weaker buildings;

Grade VIII – Most people have difficulty standing. 25% of houses are damaged, and some weaker ones collapse. Smaller cracks appear in the damp ground and on slopes;

Grade IX – General panic. About 50% of houses are significantly damaged, many are destroyed, and most are uninhabitable;

Grade X – Severe damage occurs in about 75% of buildings, and most of them collapse. Cracks up to several centimeters wide form in the ground. Rocks fall from the slopes and large landslides are created;

Grade XI – All brick buildings have collapsed. Wide cracks form in the ground, through which water with sand and mud penetrates. Large landslides occur;

Grade XII – No objects can survive. The ground and relief change their appearance, lakes break up, and rivers change their beds.

In instrumental seismology, the strength of an earthquake is determined by its magnitude (M), which is calculated from seismograph data. The magnitude scale was defined by C. F. Richter in 1935, hence its name. The magnitude M of an earthquake is the average energy of the earthquake waves E (expressed in joules) released at the focus of the earthquake and is the same at all seismological stations recording the earthquake in question. It depends directly on the energy released at the focus of the earthquake, according to the relationship:

$$\log E = 4.8 + 1.5 \cdot M$$

namely:

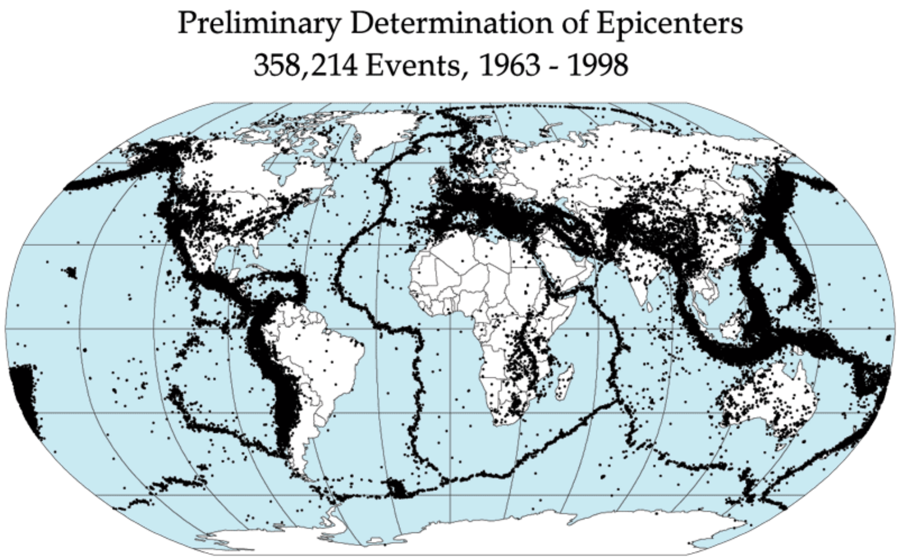
$$M = 2/3 \cdot (\log E - 4.8)$$

and allows a relatively accurate assessment of the effect of earthquakes at a distance, because for many areas on Earth the relationship between the magnitude of the magnitude and the damage from the earthquake, i.e. the MCS scale, has been established.

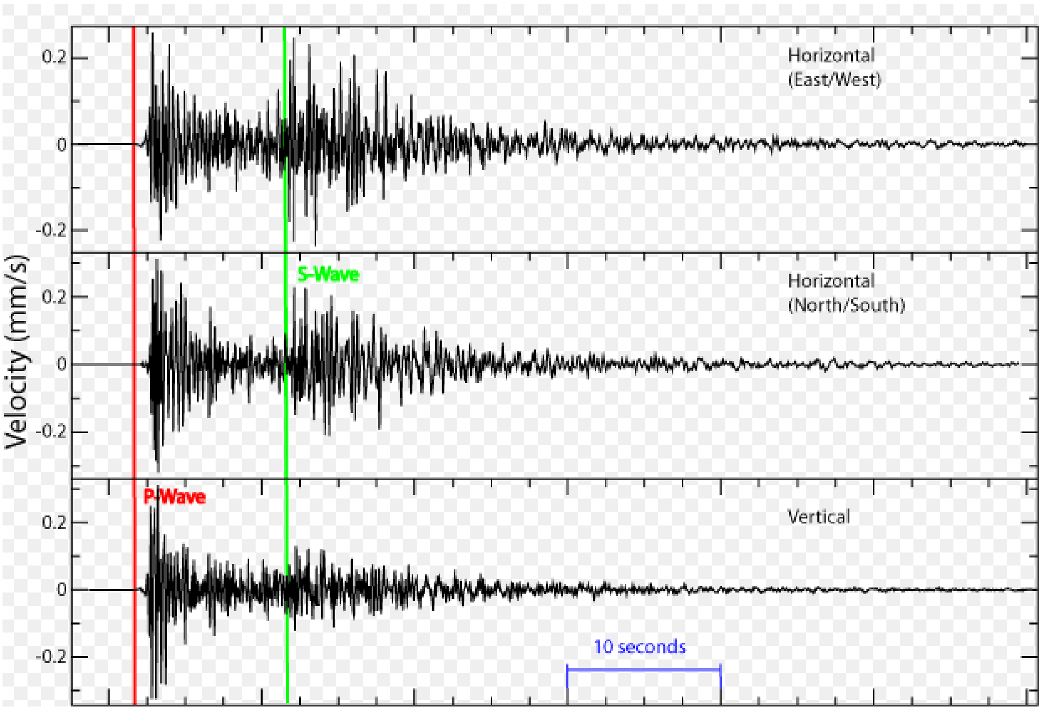
More than a million earthquakes are recorded on Earth every year, earthquakes that are mostly invisible to human senses. Only 20 to 30 earthquakes per year cause human casualties, sometimes hundreds of thousands of deaths. Almost 95% of earthquakes occur in two narrow belts: the circum-Pacific and the Mediterranean-trans-Asian. The first extends along the edge of the Pacific Ocean (the so-called Pacific Ring of Fire), and the second from the Azores through the Mediterranean Sea, Asia Minor, the Caucasus, the Armenian Highlands, the Pamirs and the Himalayas to Indonesia.

Types of Earthquakes

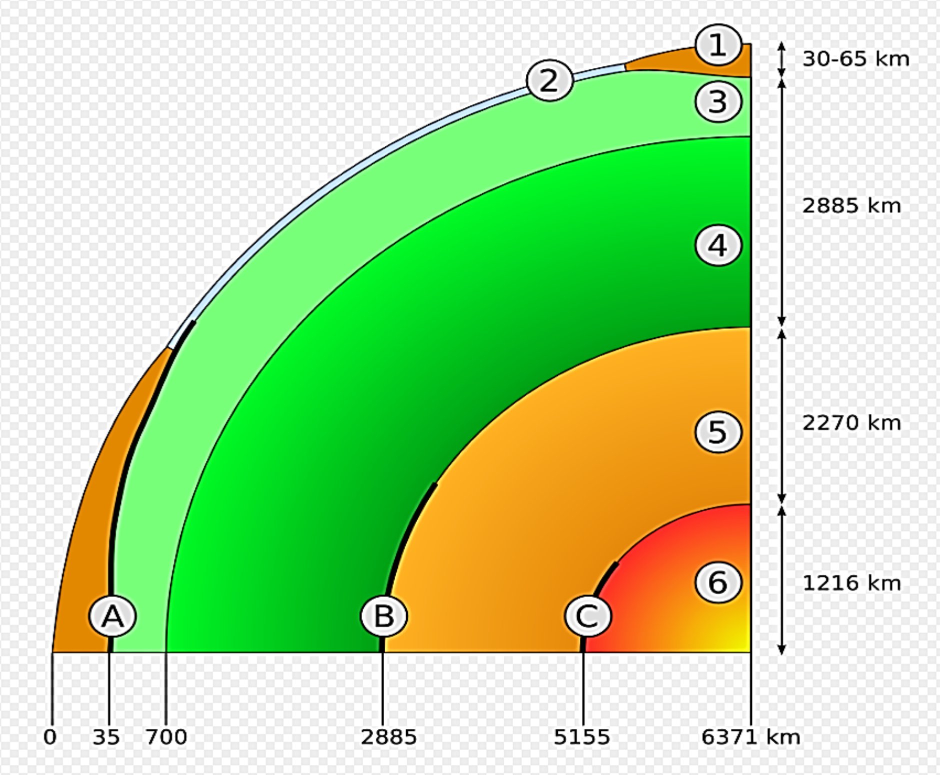
*According to the Richter Scale, we have these types of earthquakes;
Micro earthquakes - 2 Richter points (about 800 per day)
Very small - 2.0-2.9 points (about 1000 such per day)
Small - 3.0-3.9 points (about 49000 per year)
Light - 4.0-4.9 points (about 6200 per year)
Moderate / in all ways and times / - 5.0-5.9 points (about 800 per year)
Strong - 6.0-6.9 points (about 120 per year)
Large - 7.0-7.9 points (about 18 per year)
Giant - 8.0-8.1 points (about 1 in 20 years)
***Meteoric** (one in several thousand years, its power remains unknown, but the most similar phenomenon recorded is the fall of a meteor giant in Tunguska, Russia on June 30, 1908)
***According to the depth, earthquakes are classified as:**
Shallow- below 70 km of the focus
Medium- 70-300 km of the focus
Deep from 300 to 800 km of the focus
***According to the shaking, we have 3 types of earthquakes:**
Sliding when the ground moves sideways
Normal when the ground goes down
Uplift when the ground goes up (the most destructive type of all)



Map of global earthquake epicenters from 1963 to 1998.



The seismogram records 3 types of earthquake waves: the red line shows P waves, which are the fastest; the green line shows S waves, which are 1.7 times slower; Long waves or L waves are the slowest and their action is weak.



Schematic representation of the Earth's interior. 1. continental crust - 2. oceanic crust - 3. upper layer - 4. lower layer - 5. outer core - 6. inner core –
A: Mohorovič discontinuity - B: Gutenberg discontinuity - C: Lehmann discontinuity.

It is understood that in order to explain earthquakes, one must first understand the structure of the Earth. Based on the analysis of seismological observations, this picture of the composition of our planet is presented (Fig.-1). From the surface to a depth of 5÷60 km is the Crust. The Crust is separated from the Mantle by the Mohorovič boundary. The Mantle extends to a depth of 2900 km, thus constituting the largest part of the matter in the Earth's crust. The Mantle is divided into the upper mantle (60÷800km) and the lower mantle (800÷2900km). **The entire mantle is solid, and only in its upper part does the material soften and approach the melting point.** This softened layer of mantle material is called the asthenosphere (from the Greek: asthenes - weak; sphera - sphere) and extends to a depth of 700 km. Above the asthenosphere, including the crust, lies the lithosphere (lithosurge). This layer is up to 100 km thick in the regions of the continents, while in the oceans up to 50 km. The lithosphere includes the rocks of the Earth's crust and the rigid part of the upper mantle.

At a depth of 2900 km, the outer core begins, while inside it, at a depth of 1300 km from the center, is the inner core. The outer core is liquid (in a way, this matter
is a compressed plasma). Up to a depth of 6370 km, it is the center of the terrestrial sphere (the depth that constitutes the average radius of the Earth).

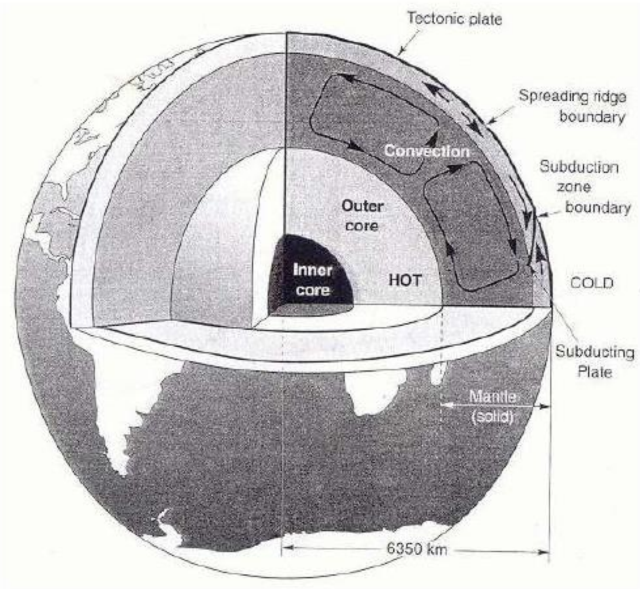


Figure 1. Earth based on analysis of seismological observations

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