ELASTIC REBOUND THEORY, SEISMIC HISTORY AND ZONES IN INDIA, SIGNIFICANCE OF SEISMIC STUDIES

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Elastic Rebound Theory

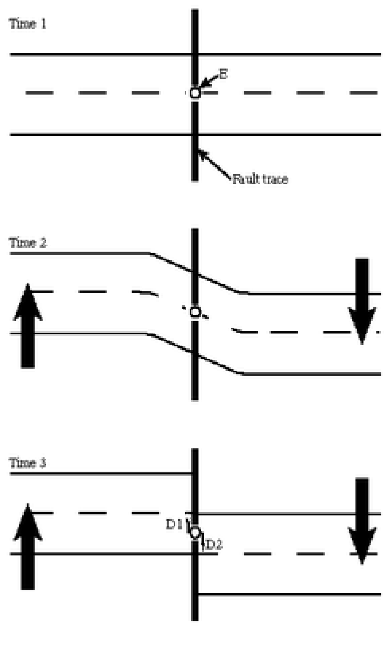
After the great 1906 San Francisco earthquake, geophysicist Harry Fielding Reid examined the displacement of the ground surface along the San Andreas Fault in the 50 years before the earthquake. He found evidence for 3.2 m of bending during that period. He concluded that the earthquake must have been the result of the elastic rebound of the strain energy stored in the rocks on either side of the fault.

In geology, the elastic-rebound theory is an explanation for how energy is released during an earthquake.

As the Earth's crust deforms, the rocks which span the opposing sides of a fault are subjected to shear stress. Slowly they deform, until their internal rigidity is exceeded. Then they separate with a rupture along the fault; the sudden movement releases accumulated energy, and the rocks snap back almost to their original shape. The previously solid mass is divided between the two slowly moving plates, the energy released through the surroundings in a seismic wave.

This gradual accumulation and release of stress and strain is now referred to as the "elastic rebound theory" of earthquakes. Most earthquakes are the result of the sudden elastic rebound of previously stored energy.

The two sides of an active but locked fault are slowly moving in different directions, where elastic strain energy builds up in any rock mass that adjoins them. Thus, if a road is built straight across the fault as in Time 1 of the figure panel, it is perpendicular to the fault trace at point E, where the fault is locked. The overall fault movement (large arrows) causes the rocks across the locked fault to accrue elastic deformation, as in Time 2. This deformation may build at the rate of a few centimeters per year. When the accumulated strain is great enough to overcome the strength of the rocks, the result is a sudden break, or a springing back to the original shape as much as possible, a jolt which is felt on the surface as an earthquake. This sudden movement results in the shift of the roadway's surface, as shown in Time 3. The stored energy is released partly as heat, partly in alteration of the rock, and partly as a seismic wave.



Seismology: - When an earthquake occurs, the elastic energy is released sending out vibrations that travel throughout the Earth. These vibrations are called seismic waves. The study of how seismic waves behave in the Earth is called ***seismology***.

Seismic waves emanating from the focus can travel in several ways, and thus there are several different kinds of seismic waves.

Body Waves - emanate from the focus and travel in all directions through the body of the Earth. There are two types of body waves: P -waves and S-waves.

P-Waves - are Primary waves. They travel with a velocity that depends on the elastic properties of the rock through which they travel.

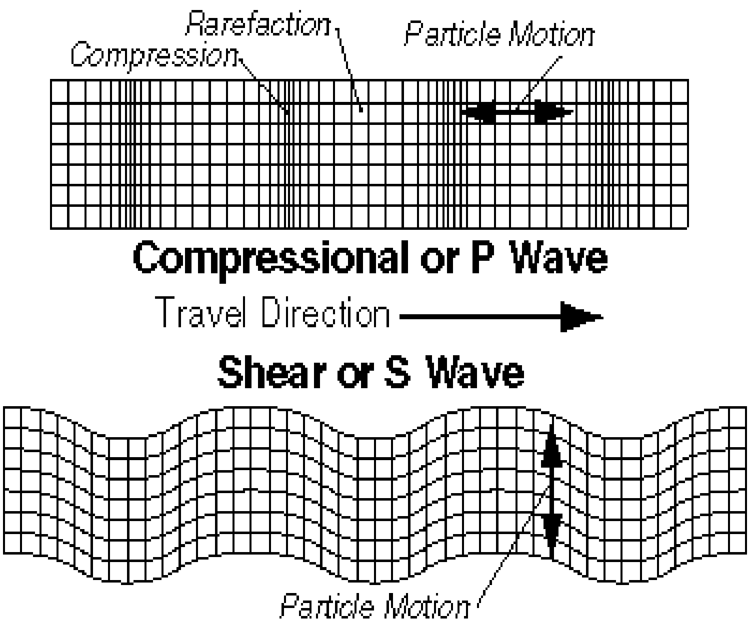
$$V_p = \sqrt{[(K+4/3\mu)/\rho]}$$

P-waves are the same thing as sound waves. They move through the material by compressing it, but after it has been compressed it expands, so that the wave moves by compressing and expanding the material as it travels. Thus, the velocity of the P-wave depends on compressibility (K), rigidity (μ), and the density(ρ) of the material. P-waves have the highest velocity of all seismic waves and thus will reach all seismographs first.

S-Waves - Secondary waves, also called shear waves. They travel with a velocity that depends only on the rigidity and density of the material through which they travel:

$$V_S = \sqrt{\mu/\rho}$$

S-waves travel through material by shearing it or changing its shape in the direction perpendicular to the direction of travel. The resistance to shearing of a material is the property called the rigidity. It is notable that liquids have no rigidity, so that the velocity of an S-wave is zero in a liquid. S-waves travel slower than P-waves, so they will reach a seismograph after the P-wave.



Surface Waves - Surface waves differ from body waves in that they do not travel through the Earth, but instead travel along paths nearly parallel to the surface of the Earth. Surface waves behave like S-waves in that they cause up and down and side to side movement as they pass, but they travel slower than S-waves and do not travel through the body of the Earth. Surface waves are often the cause of the most intense ground motion during an earthquake.

*<u>Seismology</u>

INTRODUCTION:-

Seismology is the scientific study of earthquakes and related phenomena, such as volcanic eruptions. Earthquakes occur when the tectonic plates that make up the Earth's crust shift and release energy in the form of waves.

•SEISMIC HISTORY OF INDIA

12 June 1897

The Assam earthquake of 1897 occurred on 12 June 1897, in Assam, India at 17:15 IST, and had an estimated moment magnitude of 8.0.

The regions of Kashmir, the Western and Central Himalayas, North and Middle Bihar, the North-East Indian region, the Rann of Kutch and the Andaman and Nicobar group of islands fall in this zone. Generally, the areas having trap rock or basaltic rock are prone to earthquakes.

Bhuj earthquake of 2001, massive earthquake that occurred on Jan. 26, 2001, in the Indian state of Gujarat, on the Pakistani border.

India has had a number of the world's greatest earthquakes in the last century. In fact,

more than 50% area in the country is considered prone to damaging earthquakes. The north-eastern region of the country as well as the entire Himalayan belt is susceptible to great earthquakes of magnitude more than 8.0.

•FEW MAJOR INDIAN EARTHQUAKES

Indian subcontinent has suffered some of the greatest earthquakes in the world with magnitude exceeding 8.0. For instance, in a short span of about 50 years, four such earthquakes occurred

- **ASSAM EARTHQUAKE**

Assam earthquake of 1897 (magnitude 8.7) (Oldham, 1899), Kangra earthquake of

1905 (magnitude 8.6) (Middlemiss, 1910), Bihar-Nepal earthquake of 1934 (magnitude 8.4) (GSI,

1939), and the Assam-Tibet earthquake of 1950 (magnitude 8.7) (CBG, 1953).

Another very interesting earthquake that took place about 180 years ago: the Cutch earthquake

of 1819(the most tragic earthquake of last 50 years in India which caused about 8000 deaths).

- **CUTCH EARTHQUAKE OF 1819**

This 8.3 magnitude earthquake took place on the west coast of India on June 16, 1819. It

caused ground motion which was perceptible as far as Calcutta. The earthquake caused a fault

scarp of about 16 mile long and about 10 foot high which was later named as "Allah Bund

- **ASSAM EARTHQUAKE OF 1897**

The Assam earthquake of June 12, 1897 (magnitude 8.7) caused severe damage in an area of

about 500 km radius (as against the area of about 10 km radius that sustained severe damage in

the Latur earthquake!). The earthquake caused extensive surface distortions in the area. There

were clear instances of upthrow of objects caused by the shaking this implied that the

maximum vertical acceleration during the earthquake exceeded 1.0g.

- **BIHAR - NEPAL EARTHQUAKE OF 1934**

This 8.4 magnitude earthquake occurred on January 15, 1934 at around 2:13 PM and caused

wide-spread damage in the northern Bihar and in Nepal (GSI, 1939). The number of deaths was

relatively low: about 7,253 in India and 3,400 in Nepal since most people are outdoors in the

winter afternoon.

Serious damage was caused in an area of about 300 km mean radius. The earthquake

caused a maximum intensity of X in 125 km long and 30 km wide area.

•SEISMIC ZONES OF INDIA

Seismic Zone	Intensity on M.M Scale
Zone-II (Low-Intensity Zone)	6 (or less)
Zone-III (Moderate Intensity Zone)	7
Zone-IV (Severe Intensity Zone)	8
Zone-V (Very Severe Intensity Zone)	9 (and above)

Zone-V covers entire northeastern India, some parts of Jammu and Kashmir, some parts of Ladakh, Himachal Pradesh, Uttarakhand, Rann of Kutch in Gujarat, some parts of North Bihar and Andaman & Nicobar Islands.

Zone-IV covers remaining parts of Jammu & Kashmir, Ladakh and Himachal Pradesh, Union Territory of Delhi, Sikkim, northern parts of Uttar Pradesh, Bihar and West Bengal, parts of Gujarat and small portions of Maharashtra near the west coast and Rajasthan.

Zone-III comprises of Kerala, Goa, Lakshadweep islands, remaining parts of Uttar Pradesh, Gujarat and West Bengal, parts of Punjab, Rajasthan, Madhya Pradesh, Bihar, Jharkhand, Chhattisgarh, Maharashtra, Odisha, Andhra Pradesh, Tamil Nadu and Karnataka.

Zone-II It contains all rest part of India .

SIGNIFICANCE OF SEISMIC STUDIES IN CIVIL ENGINEERING PROJECTS

- It helps in understanding the behaviour of structures of various types subjected to earthquake loads, and how we can protect the inhabitants of that structure in an event of an earthquake.

- The study of seismic activity of a particular zone helps in establishing minimum standards of safety for that zone, making life easier to continue post-earthquake.

- The importance of seismic wave research lies not only in our ability to understand and predict earthquakes and tsunamis, it also reveals information on the Earth's composition and features in much the same way as it led to the discovery of Mohorovicic's discontinuity.

- As our theoretical understanding of the physics behind seismic waves has grown, physical and numerical modelling have greatly advanced and now augment applied seismology for better prediction and engineering practices.

- This has led to some novel applications such as using artificially-induced shocks for exploration of the Earth's subsurface and seismic stimulation for increasing the productivity of oil wells.

- Its overall goal is to make such structures more resistant to earthquakes. An earthquake (or seismic) engineer aims to construct structures that will not be damaged in minor shaking and will avoid serious damage or collapse in a major earthquake. Earthquake engineering is the scientific field concerned with protecting society, the natural environment, and the man-made environment from earthquakes by limiting the seismic risk to socio-economically acceptable levels.
- **THE MAIN OBJECTIVES OF EARTHQUAKE ENGINEERING**:

    - Foresee the potential consequences of strong earthquakes on urban areas and civil infrastructure.

- Design, construct and maintain structures to perform at earthquake exposure up to the expectations and in compliance with building codes.

- A properly engineered structure does not necessarily have to be extremely strong or expensive. It has to be properly designed to withstand the seismic effects while sustaining an acceptable level of damage.

Seismic performance assessment

- Engineers need to know the quantified level of the actual or anticipated seismic performance associated with the direct damage to an individual building subject to a specified ground shaking. Such an assessment may be performed either experimentally or analytically. Seismic design is based on authorized engineering procedures, principles and criteria meant to design or retrofit structures subject to earthquake exposure. Those criteria are only consistent with the contemporary state of the knowledge about earthquake engineering structures. Therefore, a building design which exactly follows seismic code regulations does not guarantee safety against collapse or serious damage.
- Earthquake loss estimation is usually defined as a *Damage Ratio* (DR) which is a ratio of the earthquake damage repair cost to the total value of a building.

- An earthquake may be of very small magnitude and only detectable by instruments, but may be powerful enough to cause annoyance or alarm to people and to damage buildings. Seismic risk from ground movements must be foreseen, understood and dealt with in planning and design. Regions of high seismicity are often covered by building laws specified in terms of earthquake parameters.
- Seismic activity must be considered when certain engineering structures, particularly dams, are designed. Dams in earthquake zones will be designed with a capacity for resistance to the dynamic forces that can be applied during an earthquake.
- Before construction begins, past seismological records of the dam site or nearby areas should be checked and major fault lines located. An

instrumentation programme should be initiated on the actual site as soon as its location has been determined, particularly with regard to long-term seismic monitoring.

- The type of ground movements likely to occur should be predicted, and whether any earthquakes that may occur are likely to be of shallow depth, such as by slip along a fault plane, or of deep focus. Structural damage is likely to result from ground displacement, acceleration at low seismic frequencies and velocity from blast vibrations.
- Prediction of seismic risk can be assessed from general theory and from past records of an area. It is used for planning and for laying down building codes. Prediction of a specific, destructive earthquake is of greatest value only if it allows evacuation of a threatened city and deployment of emergency services a few days before the event.
- Prediction approaching this accuracy has been achieved in a few cases since 1973, and the Chinese claim to have successfully evacuated one of their towns in 1975. As elastic strain builds up within rocks close to the focus, over periods as long as decades, minute cracks in the rocks (microfractures) open and affect their physical properties. This dilatancy of the rocks increases their volume, and results in minor tilting of the ground surface from the active fault.
- Small quantities of the gas radon, trapped in some rocks, are released and can be detected by analysis of well water. The velocity of seismic waves changes, and V_p/V_s decreases by about 20%. This change can be monitored by local seismic surveys at daily intervals.
- A day or two before the earthquake, the seismic velocities revert to normal as water seeps into the microfractures. The fluid pressure within the voids of the rock (pore pressure) is increased, and by reducing effective pressures allows movement along the fault to take place.