MODULE 2
EARTHQUAKE AND LANDSLIDES

EARTHQUAKE

Although earthquakes have been reported from all parts of the world they are primarily associated with the edges of the plates that form the Earth's crust. The Earth's crust is being slowly displaced at the margins of the plates. Differential displacements give rise to elastic strains, which eventually exceed the strength of the rocks involved and faults then occur. The strained rocks rebound along the fault under the elastic stresses until the strain is partly or wholly dissipated.

Earthquake foci are confined within a limited zone of the Earth, the lower boundary of which is located at approximately 700 km, and they rarely occur at the Earth's surface. In fact, most earthquakes originate within the upper 25 km of the Earth. Because of its significance, the depth of focus has been used as the basis of a threefold classification of earthquakes: those occurring within the upper 70 km are referred to as shallow; those located between 70 and 300 km as intermediate; and those between 300 and 700 km as deep

Causes of Earthquake

The primary cause of an earthquake is fault on the crust of the earth. A fault is a break or fracture between two blocks of rock in response to stress.

Earthquakes are caused by tectonic movements in the Earth's crust. The main cause is when tectonic plates ride one over the other, causing orogeny (a process in which a section of the earth's crust is folded and deformed by lateral compression to form a mountain range), and severe earthquakes.

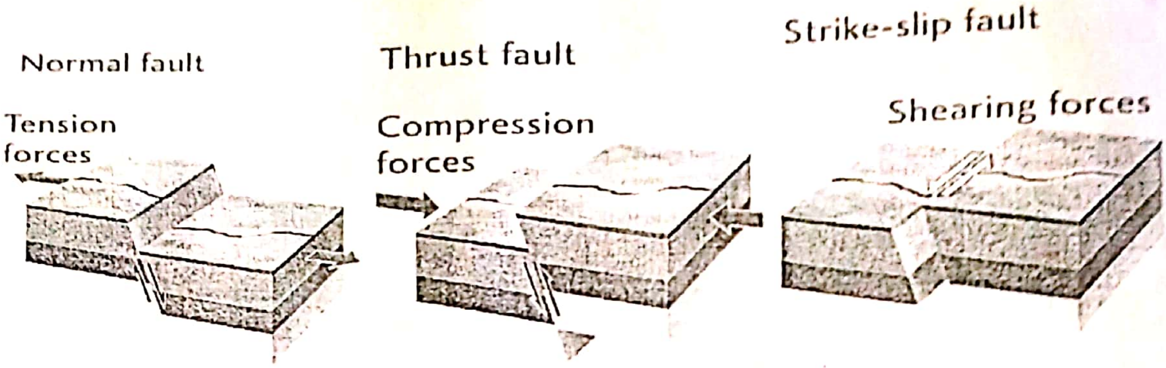
The boundaries between moving plates form the largest fault surfaces on Earth. The relative motion between the plates leads to increasing stress. This continues until the stress rises and breaks, suddenly releasing energy as shock waves. Earthquakes occur most often along geologic faults, narrow zones where rock masses move in relation to one another. The major fault lines of the world are located at the fringes of the huge tectonic plates that make up Earth's crust.

Faults

Faults are fractures in Earth's crust where rocks on either side of the crack have slid past each other.

There are three kinds of faults: **strike-slip, normal and thrust (reverse) faults.**

Each type is the outcome of different forces pushing or pulling on the crust, causing rocks to slide up, down or past each other.



A fault is a fracture or zone of fractures between two blocks of rock. Faults allow the blocks to move relative to each other. This movement may occur rapidly, in the form of an earthquake - or may occur slowly, in the form of creep. Faults may range in length from a few millimeters to thousands of kilometers. Most faults produce repeated displacements over geologic time.

TECTONIC PLATE

A tectonic plate (also called lithospheric plate) is a massive, irregularly shaped slab of solid rock, generally composed of both continental and oceanic lithosphere. Plate size can vary greatly, from a few hundred to thousands of kilometers across; the Pacific and Antarctic Plates are among the largest. Plate thickness also varies greatly, ranging from less than 15 km for young oceanic lithosphere to about 200 km or more for ancient continental lithosphere (for example, the interior parts of North and South America).

Plate tectonics is a scientific theory describing the large-scale motion of seven large plates and the movements of a larger number of smaller plates of the Earth's lithosphere. The model builds on the concept of continental drift, an idea developed during the first decades of the 20th century. The lithosphere, which is the rigid outermost shell of a planet (the crust and upper mantle), is broken into tectonic plates. The Earth's lithosphere is composed of seven or eight major plates (depending on how they are defined) and many minor plates.

Elastic Rebound Theory

- Rocks undergoing deformation bend and store energy
- When strength of rock is exceeded, they rupture and release energy – the earthquake
- Rocks rebound to original, un-deformed shape

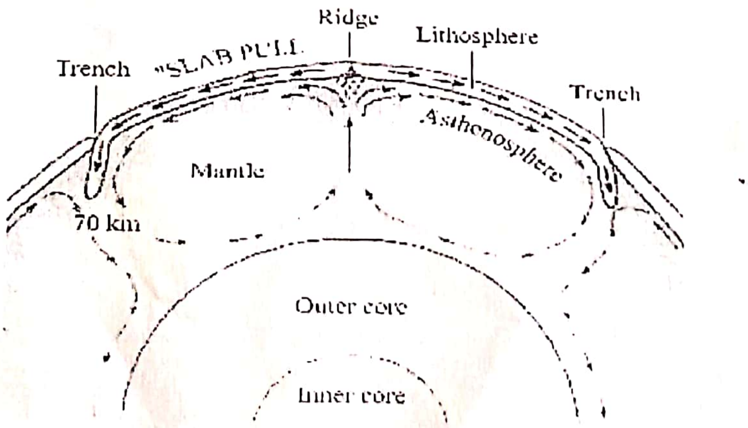


Fig. Tectonic Plates

SEISMIC WAVES

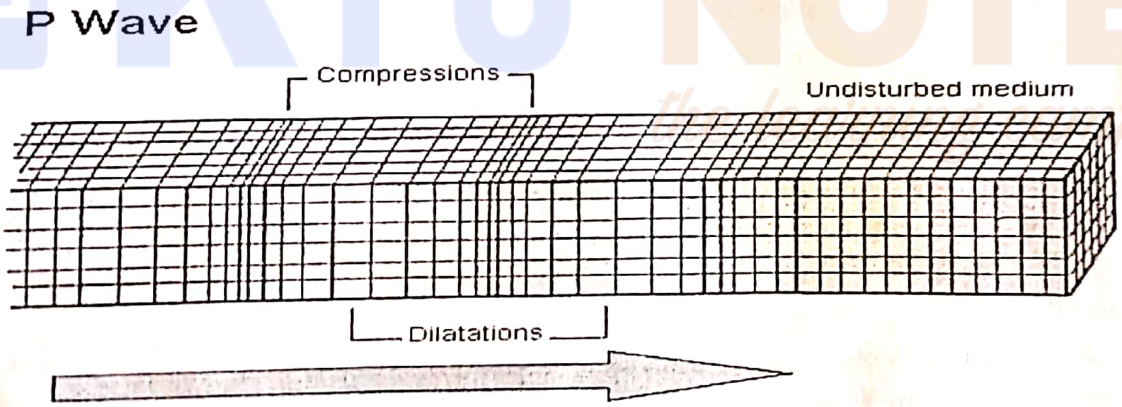
Seismic waves are the waves of energy caused by the sudden breaking of rock within the earth or an explosion. They are the energy that travels through the earth and is recorded on seismographs. An earthquake is caused by sudden movement on a sub-surface fault. The energy which is released (which was stored as strain in the rock) is converted to seismic waves which radiate from the earthquake focus. These seismic waves cause ground shaking and can be measured using seismometers.

Body Waves

Body waves are those which travel through the entire volume of the Earth. There are two types: P-waves (Primary, or first arriving) are the quickest and have a compressional particle motion parallel to the direction of travel. S-waves (Shear) are quicker than surface waves, and have a shearing particle motion perpendicular to the direction of travel.

P Waves (compression wave)

The first kind of body wave is the P wave or primary wave. This is the fastest kind of seismic wave. The P wave can move through solid rock and fluids, like water or the liquid layers of the earth. It pushes and pulls the rock it moves through just like sound waves push and pull the air.
P waves are pressure waves that travel faster than other waves through the earth to arrive at seismograph stations first, hence the name "Primary". These waves can travel nearly 1.7 times faster than the S waves. In air, they take the form of sound waves; hence they travel at the speed of sound. Typical speeds are 330 m/s in air, 1450 m/s in water and about 5000 m/s in granite.

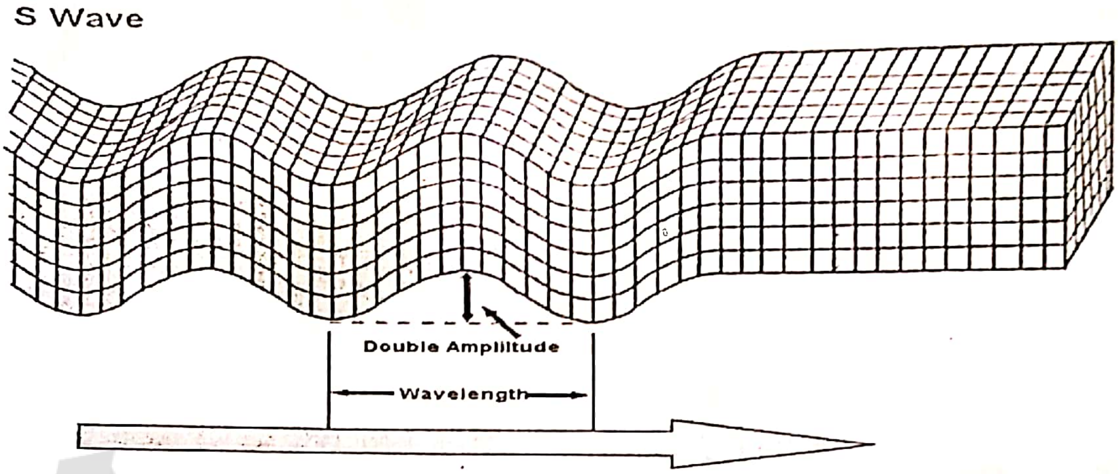


The windows after thunder rattle because the sound waves were pushing and pulling on the window glass much like P waves push and pull on rock. Sometimes animals can hear the P waves of an earthquake. Usually we only feel the bump and rattle of these waves.

S wave (transverse wave)

The second type of body wave is the S wave or secondary wave, which is the second wave you feel in an earthquake. An S wave is slower. Secondary waves (S-waves) are shear waves that are transverse in nature. Following an earthquake event, S-waves arrive at seismograph stations after the faster-moving P-waves and displace the ground perpendicular to the direction of propagation. Depending on the propagational direction, the wave can take on different surface characteristics;

for example, in the case of horizontally polarized S waves, the ground moves alternately to one side and then the other. S-waves can travel only through solids, as fluids (liquids and gases) do not support shear stresses. S-waves are slower than P-waves, and speeds are typically around 60% of that of P-waves in any given material.



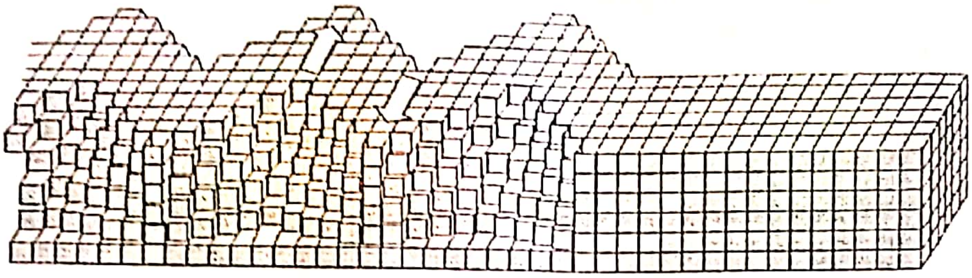
Surface Waves

Surface waves are those which are restricted to propagation close to the free surface. Seismic surface waves travel along the Earth's surface. They can be classified as a form of mechanical surface waves. They are called surface waves, as they diminish as they get further from the surface. They travel more slowly than seismic body waves (P and S). In large earthquakes, surface waves can have amplitude of several centimeters. There are two main types: Love waves have a shearing particle motion but only in the horizontal plane (parallel to the ground surface). Rayleigh waves have a reverse retrograde ellipse particle motion parallel to the direction of propagation.

Love Waves

The first kind of surface wave is called a Love wave, named after A.E.H. Love, a British mathematician who worked out the mathematical model for this kind of wave in 1911. It's the fastest surface wave and moves the ground from side-to-side. Love waves are horizontally polarized shear waves (SH waves), existing only in the presence of a semi-infinite medium overlain by an upper layer of finite thickness. They usually travel slightly faster than Rayleigh waves, about 90% of the S wave velocity, and have the largest amplitude.

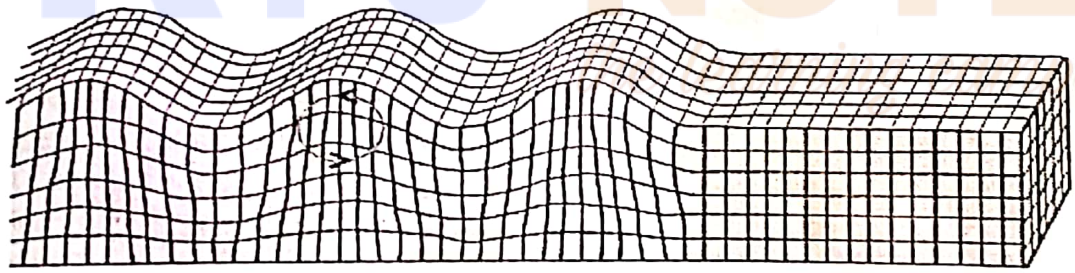
Love Wave



Rayleigh Waves

The other kind of surface wave is the Rayleigh wave, named for John William Strutt, Lord Rayleigh, who mathematically predicted the existence of this kind of wave in 1885. Rayleigh waves, also called ground roll, are surface waves that travel as ripples with motions that are similar to those of waves on the surface of water. They are slower than body waves, roughly 90% of the velocity of S waves for typical homogeneous elastic media. In a layered medium (like the crust and upper mantle) the velocity of the Rayleigh waves depends on their frequency and wavelength. A Rayleigh wave rolls along the ground just like a wave rolls across a lake or an ocean. Because it rolls, it moves the ground up and down and side-to-side in the same direction that the wave is moving. Most of the shaking felt from an earthquake is due to the Rayleigh wave, which can be much larger than the other waves.

Rayleigh Wave



Measuring Earthquakes

Earthquakes can be described by the use of two distinctively different scales of measurement demonstrating magnitude and intensity. Earthquake **magnitude** or amount of energy released is determined by the use of a ***seismograph'*** which is an instrument that continuously records ground vibration. The scale was developed by a seismologist named *Charles Richter*. An earthquake with a magnitude 7.5 on the Richter scale releases 30 times the energy than one with 6.5 magnitudes. An earthquake of magnitude 3 is the smallest normally felt by humans. The largest earthquake that has been recorded with this system is 9.25 (Alaska, 1969 and Chile, 1960).

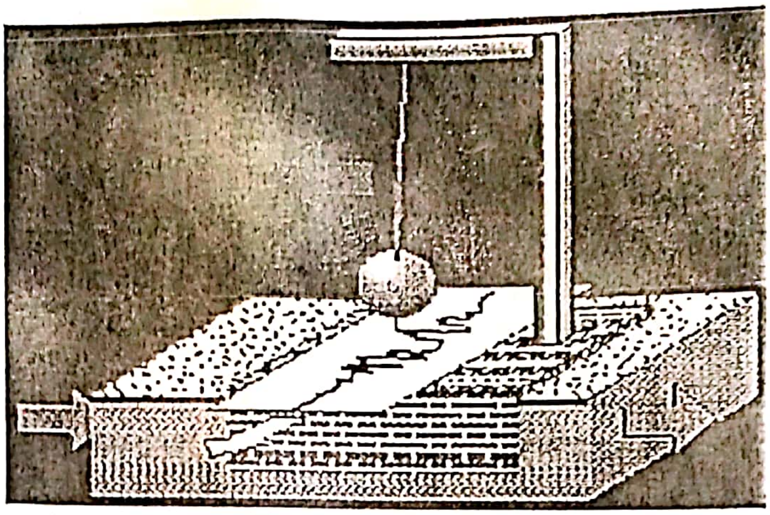


Fig : Seismograph

The **second type** of scale, the earthquake **intensity** scale measures the effects of anearthquake where it occurs. The most widely used scale of this type was developed in 1902 by *Mercalli* an Italian seismologist. The scale was extended and modified to suit the modern times. It is called the **Modified Mercalli Scale**, which expresses the intensity of earthquake effect on people, structure and the earth's surface in values from I to XII. With an intensity of VI and below most of the people can feel the shake and there are cracks on the walls, but with an intensity of XII there is general panic with buildings collapsing totally and there is a total disruption in normal life.

MAGNITUDE	TYPICAL MAXIMUM MODIFIED MERCALLI INTENSITY
$M \geq 8.0$	Great Earthquake
$7.0 \geq M < 8.0$	Major/ Large Earthquake
$5.0 \geq M < 7.0$	Moderate Earthquake
$3.0 \geq M < 5.0$	Small Earthquake
$1.0 \geq M < 3.0$	Micro earthquake
$M < 1.0$	Ultra Micro earthquake

The Richter scale

There are a number of ways to measure the magnitude of an earthquake. The first widely-used method, the Richter scale, was developed by Charles F. Richter in 1934. It used a formula based on amplitude of the largest wave recorded on a specific type of seismometer and the distance between the earthquake and the seismometer. That scale was specific to California earthquakes; other scales, based on wave amplitudes and total earthquake duration, were developed for use in other situations and they were designed to be consistent with Richter's scale.

The magnitude of an earthquake is determined from the logarithm of the amplitude of waves recorded by seismographs. Adjustments are included in the magnitude formula to compensate for the variation in the distance between the various seismographs and the epicenter of the earthquakes. On the Richter Scale, magnitude is expressed in whole numbers and decimal fractions. For example, a magnitude of 5.3 might be computed for a moderate earthquake, and a strong earthquake might be rated as magnitude 6.3. Because of the logarithmic basis of the scale, each whole number increase in magnitude represents a tenfold increase in measured amplitude; as an estimate of energy, each whole number step in the magnitude scale corresponds to the release of about 31 times more energy than the amount associated with the preceding whole number value.

Richter Magnitudes and Earthquake effects

Richter Magnitudes	Description	Earthquake Effects	Frequency of Occurrence
< 2.0	Micro	Micro earthquakes, not felt.	About 8,000 per day
2.0-2.9	Minor	Generally not felt, but recorded	About 1,000 per day
3.0-3.9	Minor	Often felt, but rarely causes damage	49,000 per year (est.)
4.0-4.9	Light	Noticeable shaking of indoor items, rattling noises. Significant damage unlikely	6,200 per year (est.)
5.0-5.9	Moderate	Can cause major damage to poorly constructed buildings over small regions. At most slight damage to well-designed buildings	800 per year
6.0-6.9	Strong	Can be destructive in areas up to about 160 kilometres (100 mi) across in populated areas.	120 per year
7.0-7.9	Major	Can cause serious damage over larger areas.	18 per year
8.0-8.9	Great	Can cause serious damage in areas several hundred miles across.	1 per year
9.0-9.9	Great	Devastating in areas several thousand miles across.	1 per 20 years
10.0+	Epic	Never recorded	Extremely rare (Unknown)

EARTHQUAKE PREDICTION

1 Animal Behavior

Animals are more sensitive than people in many ways, so they may start to feel the shaking from an earthquake before their human friends notice it. In 1835 dogs escaped from the city of Talcahuano in Chile before the earthquake struck the city. Flocks of birds flew inland before the Chilean earthquakes of 1822 and 1835. Monkeys became restless a few hours before the Managua earthquake of 1972 in Nicaragua.

Most animals show increased restlessness before an earthquake.

(ii) The precursor time varies from a few minutes to several days, with increased restlessness at 11 hours which becomes still more marked about 2 to 3 hours before the earthquake. In general precursor times of various animals are mostly within 24 hours before the earthquake.

Help your community get ready

- Publish a special section in your local newspaper with emergency information on earthquakes. Localize the information by printing the phone numbers of local emergency services offices and hospitals.
- Conduct week-long series on locating hazards in the home.
- Work with local emergency services and officials to prepare special reports for people with mobility impairment on what to do during an earthquake.
- Provide tips on conducting earthquake drills in the home.
- Interview representatives of the gas, electric, and water companies about shutting off utilities.
- Work together in your community to apply your knowledge to building codes, retrofitting programmes, hazard hunts, and neighborhood and family emergency plans.

What to Do During an Earthquake

Stay as safe as possible during an earthquake. Be aware that some earthquakes are actually foreshocks and a larger earthquake might occur. Minimize your movements to a few steps that reach a nearby safe place and stay indoors until the shaking has stopped and you are sure exiting is safe.

If indoors

- DROP to the ground; take COVER by getting under a sturdy table or other piece of furniture; and HOLD ON until the shaking stops. If there is no a table or desk near you, cover your face and head with your arms and crouch in an inside corner of the building.
- Protect yourself by staying under the lintel of an inner door, in the corner of a room, under a table or even under a bed.
- Stay away from glass, windows, outside doors and walls, and anything that could fall, (such as lighting fixtures or furniture).
- Stay in bed if you are there when the earthquake strikes. Hold on and protect your head with a pillow, unless you are under a heavy light fixture that could fall. In that case, move to the nearest safe place.
- Use a doorway for shelter only if it is in close proximity to you and if you know it is a strongly supported, load bearing doorway.
- Stay inside until the shaking stops and it is safe to go outside. Research has shown that most injuries occur when people inside buildings attempt to move to a different location inside the building or try to leave.

If outdoors

- Do not move from where you are. However, move away from buildings, trees, streetlights, and utility wires.
- If you are in open space, stay there until the shaking stops. The greatest danger exists directly outside buildings; at exits; and alongside exterior walls. Most earthquake-related casualties result from collapsing walls, flying glass, and falling objects.

If trapped under debris

- Do not light a match.
- Do not move about or kick up dust.
- Cover your mouth with a handkerchief or clothing.

- Tap on a pipe or wall so rescuers can locate you. Use a whistle if one is available. Shout only as a last resort. Shouting can cause you to inhale dangerous amounts of dust.

ADVANCED EARTHQUAKE RESISTANT DESIGN TECHNIQUES

1. Base Isolation

A base isolated structure is supported by a series of bearing pads which are placed between the building and the building foundation. A variety of different types of base isolation bearing pads are now developed. Most frequently used is lead rubber bearings.

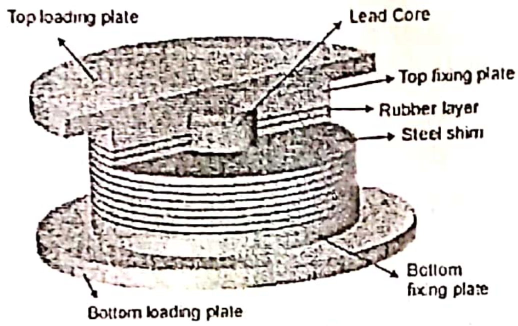


Fig :Lead rubber bearing

A lead rubber bearing is made from layers of rubber sandwiched together with layers of steel. In the middle of the bearing is a solid lead plug. On the top and bottom the bearing is fitted with steel plates which are used to attach the bearing to the building and foundation.

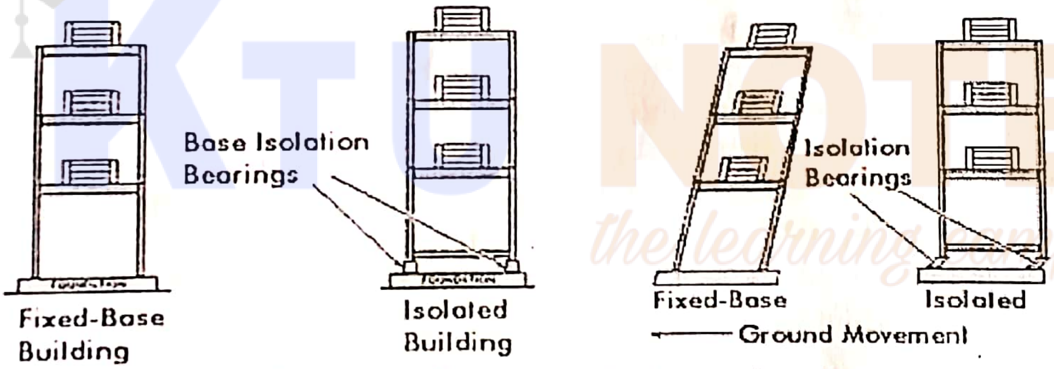


Fig:Movement of structures during earthquake

To get a basic idea of how base isolation works. Fig above shows earthquake acting on both a base isolation building and a conventional fixed base building. As a result of earthquake the ground beneath each building begins to move. Each building responds with movement which tends to move towards left and right. The building displaces in opposite to the ground motion.

In addition to displacement towards right the bearing changes the shape from rectangular toparallelogram and the deformations are not transferred to the building.

2. Spherical Sliding Bearing

Spherical bearing systems are another type of base isolation. The building is supported by bearing pads that have a curved surface and low friction. During the earthquake, the building is free to slide on the bearing. Since the bearing have a curved the building slides both horizontal and vertically.

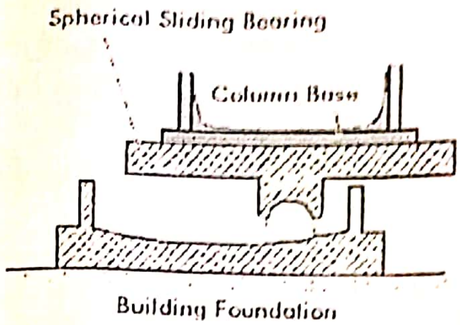


Fig: Spherical sliding bearing

3. **Energy Dissipation Devices**
   By equipping a building with additional devices which have high damping capacity, we can gently decrease the seismic energy entering the building and thus decrease building damage. Damping devices are usually installed as a part of bracing systems.

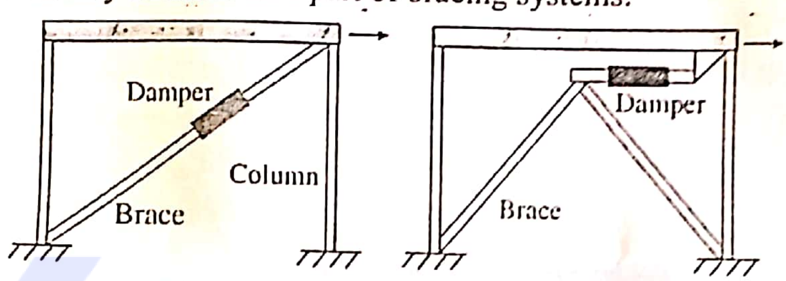
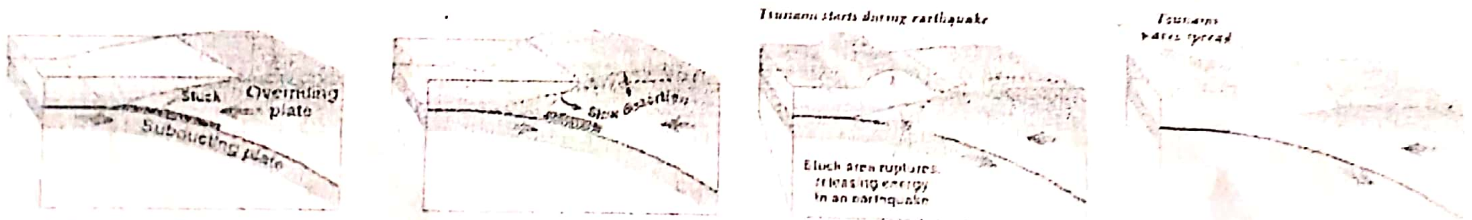


Fig: Dampers attached to frames

TSUNAMI FORMATION AS A RESULT OF EARTHQUAKE

Tsunami can be generated when the sea floor abruptly deforms and vertically displaces the overlaying water. Tectonics earthquakes are a particular kind of earthquake that are associated with earth's crustal deformation. When these earthquake occurs beneath the sea, the water above the deformed area is displaced from its equilibrium position.



Vertical Slice Through a Subduction Zone

One of the many tectonic plates that make up Earth's outer shell descends or "subducts" under an adjacent plate. This kind of boundary between plates is called a "subduction zone." When the plates move suddenly in an area where they are usually stuck, an earthquake happens.

Between Earthquakes

Stuck to the subducting plate, the overriding plate gets squeezed. Its leading edge is dragged down, while an area behind bulges upward. This movement goes on for decades or centuries, slowly building up stress.

During an Earthquake

An earthquake along a subduction zone happens when the leading edge of the overriding plate breaks free and springs seaward, raising the sea floor and the water above it. This uplift starts a tsunami. Meanwhile, the bulge behind the leading edge collapses, thinning the plate and lowering coastal areas.

Minutes Later

Part of the tsunami races toward nearby land, growing taller as it comes in to shore. Another part heads across the ocean toward distant shores.

A tsunami can be generated when the thrust faults associated with convergent or destructive plate boundaries move abruptly resulting in water displacement owing to vertical component of movement involved. Tsunami have a small amplitude at offshore and long wavelength. They grow in height when they reach shallower water.

LANDSLIDES

Landslides are among the many natural disasters causing massive destructions and loss of lives across the globe. According to a survey study by the International Landslide Centre at Durham University, UK, 2,620 fatal landslides occurred between 2004 and 2010. These landslides resulted in the death of over 32,322 people. The figure does not include landslides caused by earthquakes. This research result is astonishing considering the number of people killed by landslides. It is, thus, paramount to know the causes and warning signs of a potential landslide to minimize losses.

A landslide, sometimes known as landslip, slope failure or slump, is an uncontrollable downhill flow of rock, earth, debris or the combination of the three. Landslides stem from the failure of materials making up the hill slopes and are beefed up by the force of gravity. When the ground becomes saturated, it can become unstable, losing its èquilibrium in the long run. That's when a landslide breaks loose. When people are living down these hills or mountains, it's usually just a matter of time before disaster happens

1. INTRODUCTION

Landslides (landslips, the collapse and flow of earth, mud and rock falls) often occur in times of bad weather (heavy rain, storms), earthquakes, floods, avalanches or melting snow. It is thus as difficult to distinguish between their causes and effects as it is to differentiate between preventive and protective measures.

The damage caused by a landslide varies according to the phenomenon at the origin of the danger and can affect whole regions through, for example, flooding or rivers of mud, or very limited areas as when rock slides or falls occur.

A localised event can also have widespread consequences especially if it disrupts transport links (roads, rail, cable cars) or damages the infrastructure (important buildings, electricity grids, telecommunication networks, conduits, pipeworks and reservoirs for water, gas, toxic and polluting substances).

Landslides can also affect the safety of electricity generating dams and installations (power stations, transformers, etc.) or cause the build up of water behind unstable embankments thus threatening the population and infrastructure lower down in the valley.

Four Actions Meant to Increase Ground Stability and Prevent a Landslide

Landslides hazard can be reduced by avoiding new constructions on steep slopes or by stabilizing the slopes before beginning the actual construction works. When ground water cannot rise in the landslide mass, stability is increased. To achieve this result, some actions are required:

- Covering the land with impermeable membranes in order to prevent water infiltration in the landslide;
- Directing surface water sources away from the landslides;
- Draining ground water streams away from the landslides;
- Minimizing irrigation on the surface of the soil.

2. PREVENTIVE AND PROTECTIVE MEASURES

Landslides can occur slowly or rapidly. They can generally be predicted by observing areas known to be unstable and by taking into account the meteorological conditions (bad weather).

Preventive measures consist of developments and constructions intended to avoid or at least limit landslides through stabilising work: terracing, drainage anchoring, deep injections into the soil or by the construction of retaining dikes to hold back or divert landslides, tunnels, shafts, etc. Planting trees in unstable areas is also an efficient preventive measure.

As regards long term security measures it is important that legislation on land development requires a systematic appraisal of the potential natural dangers. Before establishing residential areas and granting planning permission for buildings the natural dangers must be taken into account.

These measures will be complemented by the constant monitoring of unstable areas and by an obligation to upkeep forests and vegetation and to maintain high altitude waterways (water falls, silting basins, dikes etc.).

The damaging effects of landslides will primarily be avoided or limited by taking the following preventive and protective measures:

- Monitoring (observatories or specialist institutes) constantly or randomly unstable areas representing a major threat.
- Establishing one or several information and alarm centres to inform the authorities and the public.
- Imposing building restrictions, forbidding people from staying in restricted areas and banning traffic on certain routes (road, rail, etc.)
- Erecting buildings and developing infrastructures that will prevent or limit landslides and protect the population.

3. INTERVENTION AND RESCUE MEASURES

As soon as a dangerous landslide is identified and after an assessment of its characteristics the local, regional or national authorities take the protective measures dictated by the situation (observation and warning services, sealing off the area at risk, warning the local population and eventually evacuating all or some of the inhabitants and their belongings). Consultation with experts (geologists, civil engineers) is very important as is knowledge of the damage caused in similar incidents in the past (historical studies of geological hazards). The political authorities and the governing bodies in charge of the coordinated deployment of civilian and military means of intervention are responsible for managing the protective, search, rescue and rehabilitation operations. If the national capacity for prevention and protection proves insufficient in the light of the probable evolution of the situation, the government of the stricken state can appeal for international emergency assistance. As far as possible, this assistance should be coordinated by the national department in charge of the operations and by non-governmental humanitarian organisations.

4. INSTRUCTIONS FOR THE POPULATION

4.1 In case of an imminent risk of landslides

- Respect the laws on land development and environmental protection especially with regard to building restrictions, living restrictions and closure of routes.
- Inform yourself of the protective measures in force, and especially know the alarm signals and evacuation procedures.
- Always keep an emergency kit ready for the family. This should include identity papers,

personal documents (medical certificates, vaccination papers, blood type details) and personal medicines. Also pack a portable radio and a torch.

4.2 During the disaster

- Keep calm. Warn the neighbours and help the handicapped, children and the elderly.
- Follow the instructions given by the authorities and rescue teams, especially those concerning the evacuation of people and livestock.
- Listen to the radio but do not use the telephone without good reason (do not overload the lines).
- Turn off the electricity, gas, and the central heating. If there is enough time move valuable objects to the highest and strongest parts of the building.
- Use private vehicles only with the authorisation of the rescue teams (evacuation of the sick and wounded, children and the elderly).
- Close doors, windows and shutters and, if possible, reinforce them.

4.3 After the disaster

- Keep calm, do not panic.
- Check to see if there are any injured people in the vicinity and if possible help them.
- Listen to the radio but do not use the telephone without good reason.
- Check to see if there are any fires in the building and try to put them out.
- Collaborate with the official rescue organs and with the services that are helping the homeless.
- Collaborate in the identification of bodies.

IMPACTS OF LANDSLIDES

Landslides affect the following elements of the environment: (1) **the topography of the earth's surface; (2) the character and quality of rivers and streams and groundwater flow; (3) the forests that cover much of the earth's surface; and (4) the habitats of natural wildlife that exist on the earth's surface, including its rivers, lakes, and oceans.** Large amounts of earth and organic materials enter streams as sediment as a result of this landslide and erosion activity, thus reducing the potability of the water and quality of habitat for fish and wildlife. Biotic destruction by landslides is also common; widespread stripping of forest cover by mass movements has been noted in many parts of the world. Removal of forest cover impacts wildlife habitat.

The ecological role that landslides play is often overlooked. Landslides contribute to aquatic and terrestrial biodiversity. Debris flows and other mass movement play an important role in supplying sediment and coarse woody debris to maintain pool/riffle habitat in streams. As disturbance agents landslides engender a mosaic of seral stages, soils, and sites (from ponds to dry ridges) to forested landscapes.

CAUSES OF LANDSLIDES

While landslides are considered naturally occurring disasters, human-induced changes in the environment have recently caused their upsurge. Although the causes of landslides are wide ranging, they have 2 aspects in common; they are driven by forces of gravity and result from failure of soil and rock materials that constitute the hill slope:

Natural Causes of Landslides

1. **Climate**
   Long-term climatic changes can significantly impact soil stability. A general reduction in precipitation leads to lowering of water table and reduction in overall weight of soil mass, reduced solution of materials and less powerful freeze-thaw activity. A significant upsurge in precipitation or ground saturation would dramatically increase the level of ground water. When sloped areas are completely saturated with water, landslides can occur. If there is absence of mechanical root support, the soils start to run off.
2. **Earthquakes**
   Seismic activities have, for a long time, contributed to landslides across the globe. Any moment tectonic plates move, the soil covering them also moves along. When earthquakes strike areas with steep slopes, on numerous occasion, the soil slips leading to landslides. In addition, ashen debris flows instigated by earthquakes could also cause mass soil movement.
3. **Weathering**
   Weathering is the natural procedure of rock deterioration that leads to weak, landslide-susceptive materials. Weathering is brought about by the chemical action of water, air, plants and bacteria. When the rocks are weak enough, they slip away causing landslides.
4. **Erosion**
   Erosion caused by sporadic running water such as streams, rivers, wind, currents, ice and waves wipes out latent and lateral slope support enabling landslides to occur easily.
5. **Volcanoes**
   Volcanic eruptions can trigger landslides. If an eruption occurs in a wet condition, the soil will start to move downhill instigating a landslide. Stratovolcano is a typical example of volcano responsible for most landslides across the globe.
6. **Forest fires**
   Forest fires instigate soil erosion and bring about floods, which might lead to landslides
7. **Gravity**
   Steeper slopes coupled with gravitational force can trigger a massive landslide.

Human causes of landslides

1. **Mining**
   Mining activities that utilize blasting techniques contribute mightily to landslides. Vibrations emanating from the blasts can weaken soils in other areas susceptible to landslides. The weakening of soil means a landslide can occur anytime.
2. **Clear cutting**
   Clear cutting is a technique of timber harvesting that eliminates all old trees from the area. This technique is dangerous since it decimates the existing mechanical root structure of the area.

EFFECTS OF LANDSLIDES

1. **Lead to economic decline**
   Landslides have been verified to result in destruction of property. If the landslide is significant, it could drain the economy of the region or country. After a landslide, the area affected normally undergoes rehabilitation. This rehabilitation involves massive capital outlay. For example, the 1983 landslide at Utah in the United States resulted in rehabilitation cost of about $500 million. The annual loss as a result of landslides in U.S. stands at an estimated $1.5 billion.

2. **Decimation of infrastructure**

The force flow of mud, debris, and rocks as a result of a landslide can cause serious damage to property. Infrastructure such as roads, railways, leisure destinations, buildings and communication systems can be decimated by a single landslide.

3. **Loss of life**

Communities living at the foot of hills and mountains are at a greater risk of death by landslides. A substantial landslide carries along huge rocks, heavy debris and heavy soil with it. This kind of landslide has the capacity to kills lots of people on impact. For instance, Landslides in the UK that happened a few years ago caused rotation of debris that destroyed a school and killed over 144 people including 116 school children aged between 7 and 10 years. In a separate event, NBC News reported a death toll of 21 people in the March 22, 2014, landslide in Oso, Washington.

4. **Affects beauty of landscapes**

The erosion left behind by landslides leaves behind rugged landscapes that are unsightly. The pile of soil, rock and debris downhill can cover land utilized by the community for agricultural or social purposes.

5. **Impacts river ecosystems**

The soil, debris, and rock sliding downhill can find way into rivers and block their natural flow. Many river habitats like fish can die due to interference of natural flow of water. Communities depending on the river water for household activities and irrigation will suffer if flow of water is blocked.

Types of Landslides

- **Falls**

  Falls are sudden movements of loads of soil, debris, and rock that break away from slopes and cliffs. Falls landslides occur as a result of mechanical weathering, earthquakes, and force of gravity.

- **Slides**

  This is a kind of mass movement whereby the sliding material breakaways from underlying stable material. The kinds of slides experienced during this type of landslide include rotational and transitional. Rotational slides are sometimes known as slumps since they move with rotation. Transitional slides consist of a planer or 2 dimensional surface of rupture. They involve landslide mass movement following a roughly planar surface with reduced rotation or backward slanting. Slides occur when the toe of the slope is undercut. They move moderately, and the consistency of material is maintained.

- **Topples**

  Topple landslides occur when the topple fails. Topple failure encompasses the forward spinning and movement of huge masses of rock, debris, and earth from a slope. This type of slope failure takes place around an axis near or at the bottom of the block of rock. A topple landslide mostly lead to formation of a debris cone below the slope. This pile of debris is known as a Talus cone.

- **Spreads**

  They are commonly known as lateral spreads and takes place on gentle terrains via lateral extension followed by tensile fractures.

- **Flows**

  This type of landslide is categorized into five; earth flows, debris avalanche, debris flow, mudflows, and creep, which include seasonal, continuous and progressive.

  Flows are further subcategorized depending upon the geological material, for example, earth, debris, and bedrock.

  The most prevalent occurring landslides are rock falls and debris flow.

The study of landslides is critical considering the annual economic losses they bring. Globally, landslides result in expenditure of billions of dollars towards rehabilitation of affected areas. Due to these astonishing annual losses, most governments have instituted bodies to deal specifically with landslides. For example, the U.S. government created the National Landslide Information Centre to collect and distribute all kinds of data related to landslides. The body is intended to cater to landslide researchers, geotechnical practitioners involved in landslide mobilization and other individuals and organizations focused on landslide hazard analysis and mitigation. The aim is to reduce the financial burden and deaths from landslides.