5.2 EARTHQUAKE GROUND MOTION

The terms earthquake motions, earthquake ground motion, or ground motion is the vibrational motion of the ground near the ground surface, which is caused by earthquake waves propagated away from the earthquake source. Earthquake ground motion is a complicated phenomenon which arises due to several factors such as (i) Dynamics of source breakage (ii) Details of the transmitting media. The ground motion varies from source to source, from path to path or from site to site and therefore introduce large scattering in numerical values of ground motion.

Earthquake ground motion – basic concepts

Ground motion at a particular site is influenced by four main elements; viz.

(i) Source, which describes how the size and nature of the earthquake source controls the generation of earthquake waves.

(ii) Directivity, which describes the direction at which the earthquake ground motion, is affected.

(iii) Travel path, which describes the effect of the earth on these waves as they travel from the source to a particular location.

(iv) Local site condition, which describes the effect of the uppermost several hundred meters of rock and soil and the surface topography at that location on the resultant ground motion produced by the emerging or passing earthquake waves.

Earthquake source

The earthquake source consists of a circular fault of radius 'r' that begins rupturing everywhere along the fault at the same time. After an earthquake begins, the accumulated strain resulting from tectonic stresses is too large for the rocks to bear.

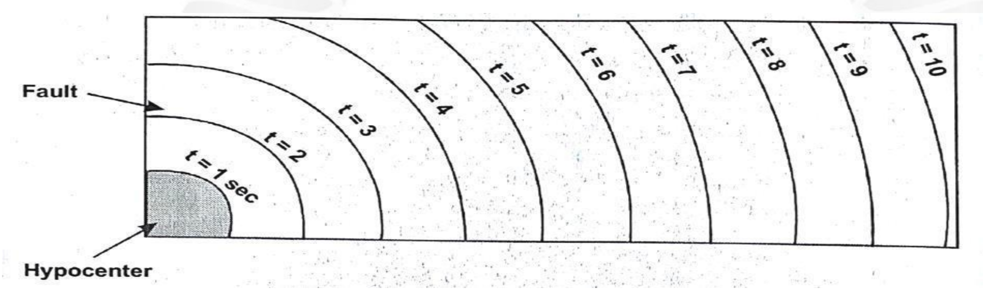

Fig 5.2.1- Earthquake source

The process of starting, propagation and ending of earthquake is as follows.

1. The hypocenter, is the point of rupture nucleation, where in which the earthquake starts and is shown near the lower left hand corner.
2. As the earthquake continues the rupture propagates away from the hypocenter to other parts of the fault.
3. The curved lines represent the locations of the rupture front, or boundary between the broken and unbroken parts of the fault, at different times after the initiation of rupture or origin time of the earthquake.
4. The rupture process stops at locations where it breaks the surface of the earth or where the rock is strong enough to bear the strain without breaking.
5. The rupture usually proceeds at a rupture velocity somewhat less than the velocity of S waves in the adjacent rock.
6. An increase in rupture velocity result in an increase in the amplitude of ground motion, particularly at high frequencies.
7. It is obvious that the rupture did not progress at the same velocity because of the heterogeneity in rock properties, fault geometry and stress release along the fault.

Faults consists of stronger parts [which are called barriers and asperities] and weaker parts, which rupture during an earthquake.

Barrier hypothesis

Before earthquake: The fault is in a state of uniform stress as shown Fig. (a).

During earthquake: The rupture propagates leaving unbroken stronger patches as shown in Fig.(b).

Asperities hypothesis

Before earthquake: The fault is not in a rate of uniform stress as shown in Fig (c) and hence having strong patches by the release of extensive stress.

During earthquake: The patches asperities are broken resulting in a smoothly slipped fault(bare land) as shown in Fig. (d).

Barriers and asperities are significant to earthquake ground motion because they represent locations of concentrated stress release and localized stopping.

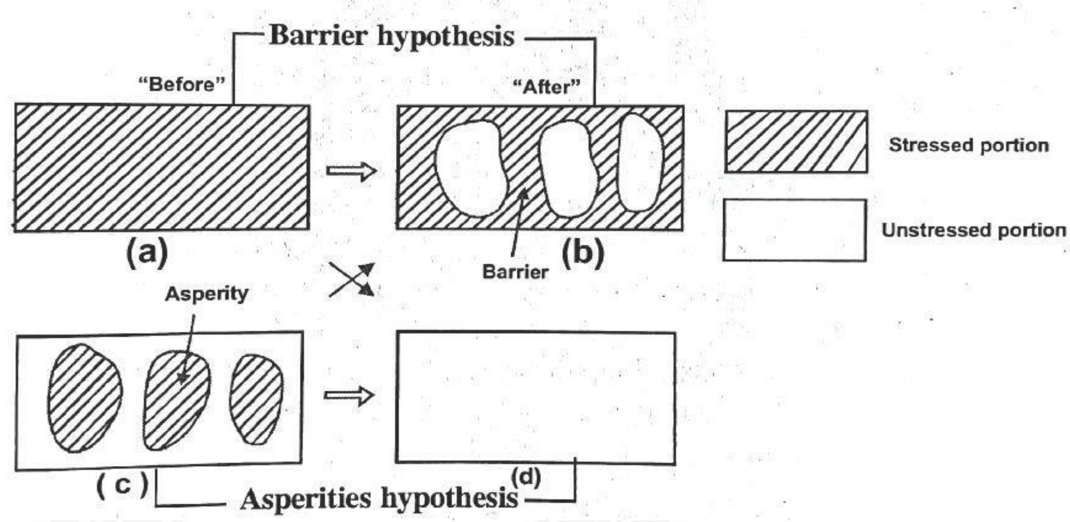

Fig:5.2.2- Barriers and Asperities

(ii) Directivity (or) focusing of Seismic energy

Another source characteristic which can affect earthquake ground motion is called directivity, also referred to as focusing. Directivity occurs because the source of seismic waves. Directivity occurs because the source of seismic waves (fault rupture) is a moving source travelling along a fault at a finite rupture velocity.

1. The propagation of 'seismic energy from the epicenter will have the following effects. The direction of fault rupture affects ground motion. Simply to say, if a fault rupture propagates towards a particular site the ground motion at that site will be greater than if a fault rupture propagates away from it as shown in Fig. (a)
2. Here, when the fault ruptures, or earthquake source moves, from right to left from the epicenter, it generates ground motion from each part of the fault.
3. The pulse which began the earliest, near the epicenter, has spread the farthest, while the pulse that began the latest at the end of the fault rupture has spread the least.
4. Although they originated at different times, the wave fronts, and therefore the pulses generated, tend to arrive close to the same time at receiver A (in the direction of rupture propagation) because the pulses that started the latest have the least distance to travel, as shown in Fig (b).

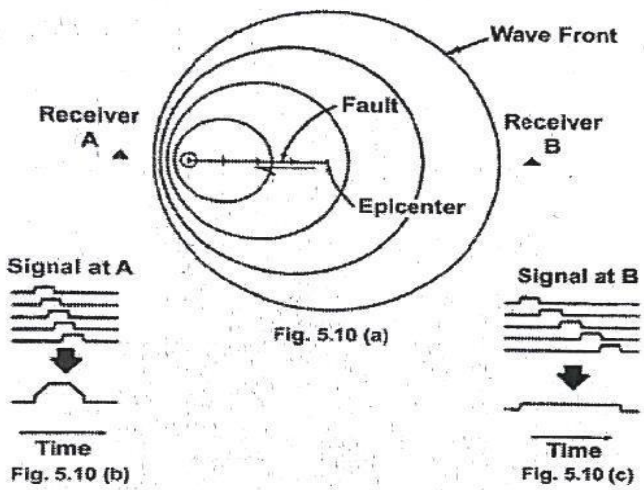

Fig:5.2.3- Directivity of seismic energy

5. At receiver B (opposite to the direction of rupture propagation) the pulses that started last have the greatest distance to travel, so that pulses originating from different parts of the fault tend to arrive spread out over time, as shown in Fig (c).
6. The constructive interference of the ground motion at receiver A results in high amplitude motion. Thus the effect of directivity is to yield the highest ground motion (and shortest total duration) in t] direction of rupture propagation and the lowest ground motion (at longest total duration) opposite to the direction of rupture propagation.
7. This effect increases as the rupture velocity approaches the seismic wave velocity and as the angle between the point of observation an: the direction of rupture propagation becomes smaller.

(iii)Travel path effects

The effects of the travel path on earthquake ground motion are primarily related to the attenuation of the propagating seismic waves.

Seismic wave attenuation consisting of two major element, viz., (a) Geometric spreading and (b) Absorption (sometimes called damping).

(a) Geometric spreading

Geometric spreading results from the conservation of energy as waves and wave fronts occupy more area as they spread out form the seismic source. If the earth were homogeneous and isotropic (the same properties in all directions) body waves would have spherical wave fronts and their amplitudes1 would decrease as E, where R is the distance to the earthquake source.

Similarly if the earth was both uniformly layered and flat, surface waves would have cylindrical wave fronts and their amplitudes would decrease as 1/ R The nonuniform, spherical nature of the earth modifies these factors

(b) Absorption

Absorption is a net loss of energy as seismic waves propagate. Absorption is caused due to intrinsic physical loss mechanisms such as sliding friction across cracks, internal friction, and grain boundary effects which occur, as a seismic wave passes through the rock. The rate at which seismic wave amplitude attenuates (due to absorption) with increasing distance, is given by

$$\tau = \frac{\pi f}{QV}$$

Where, f → Frequency,

V → Seismic wave velocity and

Q → Quality factor which varies with wave type and is a function of material.

Q increases with frequency and the relation between

them is given by $Q = Q_0 f$