**What is earthquake ?**

when rocks of the earth’s crust are suddenly disturbed , vibrations are caused

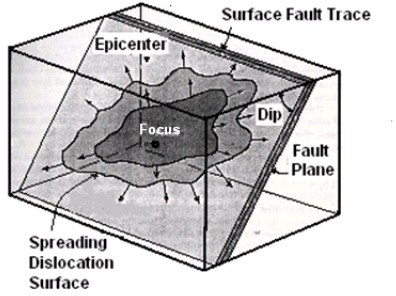
The effects of which spread in all direction form the place of disturbance.the passage of these vibration through the rocks may induce a local or regional shaking in them and this shaking movement may last for various fractions of time .The momentary shaking in the curst of the earth is called an earthquake .The effects of earthquakes on people and their environment and methods of reducing those effects are included in the earthquake engineering. Earthquake engineering is a very broad field drawing on aspects of

* Geology
* Seismology
* Geotechnical engineering
* Structural engineering
* Risk analysis
* other technical field Its practice also requires consideration of
* social factor
* economic factor
* political factor

**SEISMIC SOURCES**

* **NATURAL SOURCE MAN- MADE SOURCE**
* **Tectonic Earthquakes Controlled sources**
* **Volcanic Earthquakes Reservoir Induces**
* **Rock Falls/Collapse of cavity Mining Induces Earthquakes Microseism Cultural Noise (Industry, Traffic,etc)**

Terminology :- Earthquakes: Earthquakes are defined as, ‘Ground shaking and radiated seismic energy caused mostly by sudden slip on a fault, volcanic or any sudden stress change in the earth’.



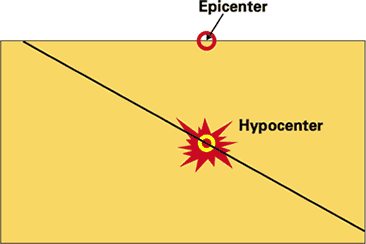
1.1 Origin of an earthquake

**Seismology:**

It is the study of the generation, propagation and recording of elastic waves in the earth and the sour that produce tham. The science dealing with the study of earthquakes in all their aspects is called Seismology. It is an interdisciplinary science which is partly geology and partly physics. The word seismic is commonly used to qualify anything related to an earthquake, such as seismic waves, seismic intensity, seismic zoning, seismic region and so on.

**Epicenter:**

The point or place on the surface vertically above the focus of a particular earthquake is termed as its epicentre as shown in Figure 1.1. It is that (geographical) place on the surface of the earth where the vibration from a particular earthquake reaches first of all. It is often the location of maximum damage in that event.

[](https://cdn.zmescience.com/wp-content/uploads/2018/11/EpicenterHypocenter.gif)

**Hypocenter or Focus**:

An earthquake is generally due to some disturbance or displacement in the rocks at some depth below the surface of the Earth. Shock waves originate from that place or point of disturbance and then travel in all directions causing the vibrations. The place or point of origin of an earthquake below the surface of the Earth is termed as its focus (or hypocenter). In modern seismology, focus signifies a zone rather than a point of origin. It may lie from a few hundred meters to hundreds of kilometres below the surface.

**Magnitude:**

It is the term expressing the rating of an earthquake on the basis of amplitude of seismic waves recorded as seismograms. The method (of determining rating of an earthquake) was first used by Charles F Richter in 1935 who developed a scale of magnitude for local use on the basis of study of records of earthquakes of California, USA. Subsequently that scale was improved upon and is presently used internationally for describing the size of an earthquake. In precise terms and as understood today, the Richter Magnitude is the logarithm to the base of 10 of the maximum seismic wave amplitude recorded on a seismograph at a distance of 100 km from the epicentre of a particular earthquake.

**Intensity:**

It is the rating of the effects of an earthquake at a particular place based on the observations of the affected areas, using a descriptive scale like Modified Mercalli Scale.

## What Causes Earthquakes?

Earthquake are caused by processes which fall into two distinct groups .Non technonic earthquake and tectonic earthquakes .The earth’s crust is composed of solid core, mantle (consists of molten magma) and tectonic plates. Tectonic plates are constantly moving due to convection currents triggered by molten lava inside the earth crust. This constant movement leads to either the plates sliding against each other or drifting away from each other. These interactions and drifting apart of tectonic plates underneath the earth are perceived by living organisms, humans included. The constant movements have even led to the formation of mountains and valleys. When these plates move against each other, there is a point where they interact. In geological terminology, this meeting point is known as fault line. This fault line is sometimes known as fracture in the earth’s crust. The moment the plates begin to move, the potential energy, commonly known as stored energy, is released from the meeting point, known as hypocenter. The outcome is an earthquake.

Tectonic plates found in ocean are called oceanic plates while those found in continents are continental plates. With the movement of these tectonic plates, energy is formed and can be released once these plates meet in the so called fault line. The intensity of this released energy will also determine that of the earthquake. One can feel the earth’s shaking once energy is released from earth’s crust.

In few occasions, earthquakes have foreshocks. Foreshocks are smaller version of earthquakes that occur in the same area as the bigger earthquakes that ensues. Up until now, scientists have not been able to tell whether an earthquake is a foreshock until the real earthquake occurs. The real or larger earthquake is known as the mainshock. Mainshocks, on numerous occasions, are followed by an aftershock. Aftershocks are a collection of small earthquakes that take place after the main earthquake. Depending upon the magnitude of the mainshock, aftershocks may continue to happen for weeks, months or even years.

## Types of Earthquakes(causes)

### 1 Tectonic Earthquakes

The earth’s crust is composed of loose, cracked fragments of lands referred to as tectonic plates. These plates are capable of moving slowly and gradually. The movement of these plates occurs in different forms; towards each other, away from each other, sliding past each other or colliding with each other. A huge tremor occurs when 2 moving tectonic plates slide over one another. This type of earthquake is known as tectonic earthquake. Tectonic earthquakes are the most prevalent kinds of earthquakes in the world. Its magnitude may be small or large. Tectonic earthquakes have caused most of the planet’s mass destruction. Tremors triggered by tectonic earthquakes are always severe, and if their magnitude is high, they are capable of bringing down an entire city in seconds.

### 2 , Volcanic Earthquakes

Compared to tectonic earthquakes, volcanic earthquakes are less prevalent. They typically take place before or after an eruption. Volcanic earthquakes come in two forms: long-period volcanic earthquakes and volcano-tectonic earthquakes. Volcano-tectonic earthquakes usually happen after a volcanic eruption. During an earthquake, magma erupts from inside the earth’s crust leaving a space behind. The space left after magma eruption must be filled. To fill it, rocks move towards the space resulting in severe earthquakes.On numerous occasions, magma blocks the vents during a volcanic activity. This means that the high pressure fails to be released. The buildup of pressure becomes unbearable and releases itself with a massive explosion. The massive explosion results in a ruthless earthquake. On the other hand, the long period volcanic earthquake takes place after a volcanic eruption. Some days prior to the massive explosion, the magma inside the earth’s crust experiences rapid changes in heat. The change in heat triggers seismic waves, resulting in an earthquake.

### 3, Explosion Earthquakes

These are caused by nuclear explosions. They are, essentially, man triggered kind of earthquakes and represent the biggest impact of modern day nuclear war. During the 1930s nuclear tests conducted by the United Sates, numerous small towns and villages were devastated as a result of this grave act.

### 4, Collapse Earthquakes

These kinds of earthquakes are generally smaller and most commonly occur near underground mines. They are sometimes referred to as mine bursts. Collapse earthquakes are instigated by the pressure generated within the rocks. This kind of earthquake leads to the collapse of the roof of the mine instigating more tremors. Collapse earthquakes are prevalent in small towns where underground mines are located.

## Effects of Earthquakes

**Damage to buildings**

High magnitude earthquakes can lead to complete collapse of buildings. Debris from collapsing buildings is the main danger in the course of an earthquake because the falling effects of huge, heavy objects can be deadly to humans. High magnitude earthquakes result in shattering of mirrors and windows, which also present danger to humans.

**Damage to infrastructure**

Earthquakes can cause electricity lines to fall. This is dangerous because the exposed live wires can electrocute humans or start fires. Major earthquakes can cause rupturing of roads, gas lines, and water pipelines. Broken gas lines can cause gas to escape. Escaping gas can result in explosion and fires, which may be difficult to contain.

**Landslides and rockslides**

When an earthquake occurs, large rocks and sections of earth located uphill can be dislodged, consequently, rolling rapidly down into the valleys. Landslides and rockslides can cause destruction and death to the people living downstream.

**Can result in floods**

High magnitude earthquakes can instigate cracking of dam walls, collapsing in the long run. This would send raging waters into nearby areas leading to massive flooding.

**Earthquakes can trigger tsunamis**

A tsunami is a series of long high sea tremors sparked by an earthquake or volcanic eruptions under the sea. A tsunami can wipe out an entire surrounding coastal area population. A typical example is the March 11, 2011, earthquake and tsunami that struck the coast of Japan leaving more than 18, 000 people dead in its wake.

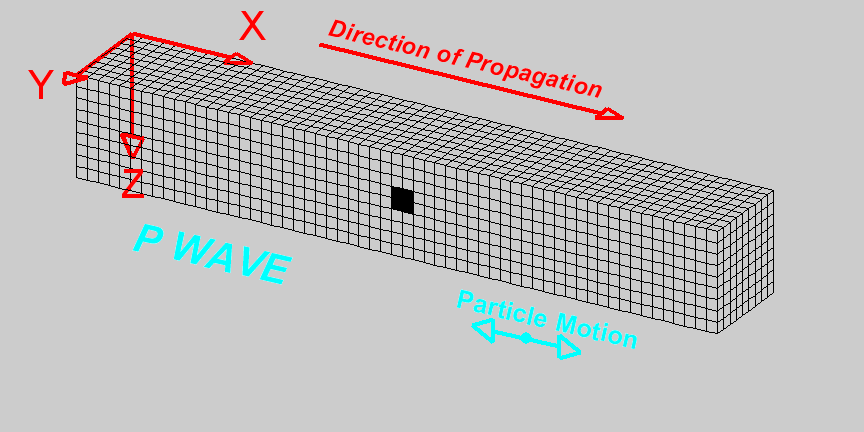
**Leads to liquefaction**

Liquefaction is a phenomenon where the soil becomes saturated and loses it strength. When sediments consisting of high water content are subjected to constant trembling, water pressure held in the sediment pores slowly increase. Ultimately, the sediments lose almost all cohesive strength and start acting like liquids. Buildings and other structures built on top of this liquefied soil overturn or sink into the ground. Earthquakes are responsible for most of the liquefaction occurring across the world. A typical example of liquefaction phenomenon is the earthquake of 1692 in Jamaica that resulted in the devastation of the town of Port Royal.

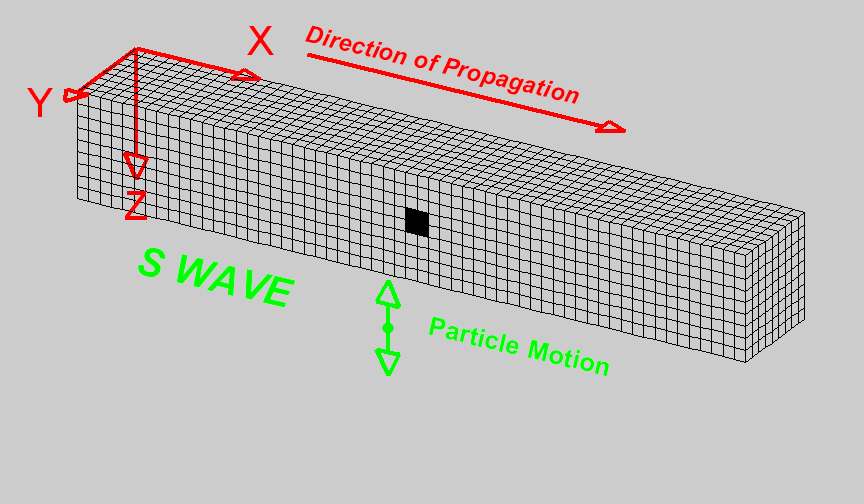
### Types of seismic waves

Seismologists like to split seismic waves into several categories, but the main types of seismic waves come in two categories — body waves (which move throughout entire bodies, such as the Earth), and surface waves )(which travel only on different surfaces, not through the whole body). The main types of seismic waves are the following:

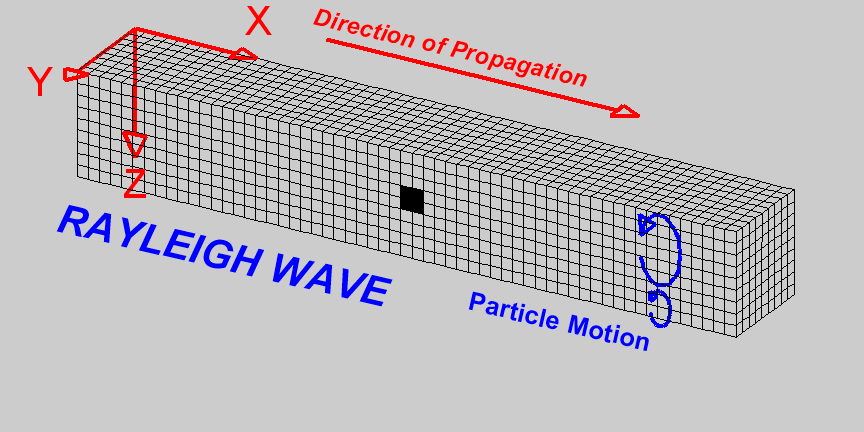
* **Primary waves (P-waves).**These are the “first” body waves — the ones that travel the fastest and through any type of medium (solid, liquid, gas). They propagate longitudinally on the propagation direction (think of an accordion) and are harmless in terms of earthquake damage.

[](https://cdn.zmescience.com/wp-content/uploads/2018/11/giphy.gif)

**Secondary (S-wave**). These are shear waves, which arrive after the P-waves. They’re also body waves but they only propagate through a solid medium. They also rarely do any significant damage.

[](https://cdn.zmescience.com/wp-content/uploads/2018/11/image001-1.gif)

**Surface waves — Rayleigh (R-wave).** Surface waves (Rayleigh and Love) do by far the most damage. As opposed to body waves (S and P waves), they propagate on the surface and carry the vast majority of the energy felt on the surface — in other words, these are what you feel when you experience an earthquake. This happens because although they move slower than body waves, their particle movement is much more pronounced (see below). In the case of Rayleigh waves, the motion is of a rolling nature, similar to an ocean surface wave.

[](https://cdn.zmescience.com/wp-content/uploads/2018/11/Rwave.gif)

**Surface wave — Love (L-wave).** Contrary to their name, there’s nothing really lovable about the Love waves — they were named thusly after Augustus Edward Hough Love, a Professor for Natural Philosophy at Oxford University who first described the movement of the waves named after him. Love waves have a transversal (perpendicular) movement and are the most destructive outside the immediate area of the epicenter. Love waves can be devastating

**Earthquake Location:-**

* The earthquake **hypocentre** or **focus** is the point on the fault plane where the rupture starts.
* The fault may rupture in one direction from the hypocentre, or in both directions. That is, the hypocentre may be at the edge of the rupture or within the rupture.
* The earthquake **epicentre** is the point on the earth’s surface vertically above the hypocentre.
* The earthquake **depth** is usually taken as that of the hypocentre, even if the fault ruptures to the surface.
* The **centroid** of an earthquake is located at the centre of energy release, usually near the centre of the rupture area.
* “Locating” an earthquake normally means determining the origin time, coordinates of the hypocentre, and the earthquake magnitude or size.
* The **origin time** of an earthquake was the precise time that the rupture commenced. The rupture duration then varies from a fraction of a second for a small earthquake to a few tens of seconds for a very large earthquake.
* The **longitude** and **latitude** of the hypocentre are, by definition, the same as those of the epicentre. They are usually given in degrees, although metric grid zone coordinates are sometimes used.
* The **depth** of an earthquake is usually given in kilometres below mean sea level.

## The Impact of Earthquakes on Buildings

## Impacts

## A major earthquake on the Teton Fault would have many serious impacts here in Teton County.

## Serious Injury & Death

## Most  importantly, there are going to be people who are injured or killed  during the earthquake. The shaking itself does not usually cause  injuries, but rather falling objects, shattering glass, and collapsing  structures are the culprit.

## Cascading Events

## When a large earthquake occurs, usually it is after the shaking stops that the major problems occur. Earthquakes are a type of disaster that can cause what are known as cascading events. Examples of cascading events would be broken gas lines fueling fires, loss of electricity, disrupted routes of transportation, landslides, dam ruptures, or any other secondary disaster caused initially by the earthquake.

### Isolated Communities Within Teton County Island

In Emergency Management, we refer to this as Teton County's "islands". An earthquake can collapse bridges, cause both landslides and avalanches, and damage roads making them impassable. This can easily isolate communities within Teton County not allowing the people already there to leave, and more importantly blocking emergency services from reaching them. Teton County has taken steps to alleviate the "island effect" by spreading out our emergency apparatus such as ambulances and fire trucks throughout the county. Emergency Management and Jackson Hole Fire/EMS have also placed mass casualty equipment caches in all of the fire stations located throughout the county so that major first aid supplies are available to communities even if routes are shut down to Jackson.

### Limited Resources Available for Response & Recovery

Due to Teton County's remote location, and the fact that an earthquake of the 7 magnitude range would be a regional event, there may be limited  outside resources initially available to assist us. Major emergency response teams from Idaho Falls, Salt Lake City, or Denver can generally  mobilize within half a day to a day. They may not be able to reach Teton County for days, however, due to collapsed bridges, damaged  airstrips, or ruptured roadways. That is why Teton County Emergency Management stresses that every family has at least a 72 hour preparedness kit, and preferably one that will last a week.

### Economic Impacts to Local Business

According  to a 2006 Small Business Administration study, up to 25% of small  businesses fail to reopen following a disaster. Most of this is due to  lack of planning, but some disasters are just too great to overcome. In  our community we depend on small businesses, and if 25% of them failed  to reopen it would be catastrophic for our economy.

What's a Seismograph?

Earthquakes are fascinating and frightening at the same time. Have you ever wondered how scientists study these earth-shaking events? They use what's called a **seismograph**, also called a seismometer, which is an instrument that measures and records seismic waves that move through the earth as the result of an earthquake.

A modern seismograph can help scientists detect earthquakes and measure several aspects of the event:

* The time at which the earthquake occurred
* The epicenter, which is the location on the surface of the earth below which the earthquake occurred
* The depth below the earth's surface at which the earthquake occurred
* The amount of energy released by the earthquake

Scientists measure and record this data to learn more about earthquakes, tectonic plates, and Earth's layers. Earthquakes are difficult to predict, but scientists studying them hope to use seismographic measurements to be able to make more accurate predictions.

## How a Seismograph Works

The idea behind a seismograph is fairly simple. A basic seismograph includes a solid base and a heavy weight suspended from a spring over the base. A pen hangs from the weight and a rotating drum with paper sits below it on the base. The tip of the pen touches the drum. When the earth shakes from an earthquake, the drum rotates, and the weighted pen moves back and forth due to the motion of seismic waves. The pen records the movement on the drum. The paper recording of an earthquake is called a **seismogram**.

|  |
| --- |
| https://study.com/cimages/multimages/16/seismographs.png |

The most high-tech seismographs used by scientists studying earthquakes today are sophisticated and precise. They are based on the same concept as a basic, simple seismograph, but make use of electronics, magnets, and amplifiers in order to accurately and precisely measure the smallest ripples in the earth caused by earthquakes.

|  |
| --- |
| https://study.com/cimages/multimages/16/seismogram_at_weston_observatory.png |

## Measurement Scales

You have probably heard of the **Richter scale**, a popular unit for measuring the magnitude of an earthquake. It was invented by Charles F. Richter of the California Institute of Technology in 1935 and uses a logarithmic scale to measure seismic wave magnitude. Because the scale is logarithmic, a difference of one unit represents a tenfold difference in the magnitude of a seismic wave. For instance, an earthquake measured as 6.0 on the Richter scale is 10 times more intense than a 5.0 earthquake. A 7.0 earthquake is 100 times more intense than the 5.0 earthquake.

The Richter scale is still often cited in news reports of earthquakes, but scientists studying these events use another scale that allows for more accurate measurements. This is called the **moment magnitude scale** and it can be applied to a wider range of types and sizes of earthquakes. It is logarithmic, like the Richter scale, and similar to the older scale for earthquakes up to about a magnitude of 8.0. For larger quakes, the moment magnitude scale begins to differ from the Richter scale and provides more accurate measurements.

**Unit 1 part 2 Theory of vibration :-**

**Single Degree of Freedom (SDOF) system**





k

F(t)

m

Figure 1: Undamped SDOF system

F(t)

M

u(t)

Figure 2: Example of overhead water tank that can be modeled as SDOF system

# 1. Equation of motion (EOM)

Mathematical expression defining the dynamic displacements of a structural sys- tem. Solution of the expression gives a complete description of the response of the structure as a function of time

# Derivation of EOM

1. Dynamic Equilibrium (Using D’Alembert’s principle)
2. Principle of Virtual Work
3. Hamilton’s principle (Using Lagrange’s equation)

# Dynamic Equilibrium

D’Alembert’s principle states that a mass develops an inertial force proportional to its acceleration and opposing its motion. (See Figure 3)

*mu*¨ + *ku* = *F* (*t*) Equation of Motion (1)

for *F* (*t*) = 0, the response is termed as free vibration and occurs due to initial excita- tion.

mu

ku

m

F(t)

Figure 3: Dynamic force equilibrium

# Free Vibration

*mu*¨ + *ku* = 0 linear,homogeneous second order differential equation

*k*

⇒ *u*¨ + *mu* = 0

*n*

*m*

2 2 *k*

⇒ *u*¨ + *ω u* = 0 *ω* = *, ω*

*n*

*n*

*m*

= . *k*

*ω* = natural frequency (2)

*n*

Solution of Equation 2 will be,

*u*(*t*) = *C*1*eıωnt* + *C*2*e−ıωnt*

= *C*1(cos *ωnt* + *ı* sin *ωnt*) + *C*2(cos *ωnt* − *ı* sin *ωnt*)

= (*C*1 + *C*2) cos *ωnt* + *ı*(*C*1 − *C*2) sin *ωnt* (3) Applying the initial conditions,

*u*(*t*)|@*t*=0 = *u*0 = *C*1 + *C*2

*u*˙(*t*)|@*t*=0 = *u*˙0 = *ıωn*(*C*1 − *C*2) (4) Substituting Equation 4 into Equation 3, we get,

Again, substituting,

*n*

*u*(*t*) = *u*0

cos *ωn*

*t* + *u*˙0 sin *ω ωn*

*t* (5)

*u*0 = *A* cos *φ*

into Equation 5, we get,

*u*˙0 *ωn*

= *A* sin *φ* (6)

*u*(*t*) = *A* cos *φ* cos *ωnt* + *A* sin *φ* sin *ωnt*

= *A* cos(*ωnt* − *φ*) (7)

where, *A* is the *amplitude* and *φ* is the *phase angle*

. Σ

*A* = ‚.,*u*2 +

0

*u*˙0 2

. Σ

*ωn*

and *φ* = tan

*−*1 *u*˙0*/ωn u*0

(8)

..

# Free vibration of damped SDOF system

Modeling of damping is perhaps one of the most difficult task in structural dynamics. It is still a topic of research in advanced structural dynamics and is derived mostly experimentally.

# Viscous Damping

The most common form of damping is viscous damping.

# Equation of Motion

..

u

k

F(t)

c

m

Figure 4: SDOF with viscous damping

*mu*¨ + *cu*˙ + *ku* = 0

*c k*

where, *ξ* = *c*

2*mω*

*n*

⇒ *u*¨ + *m u*˙ + *mu* = 0

⇒ *u*¨ + 2*ξωnu*˙ + *ωnu* = 0 (9)

2

is the *viscous damping factor*. Assuming a solution *u*(*t*) = *Cest* and

substituting in Equation 9, we get,

*s*2 + 2*ξωns* + *ω*2 = 0

*n*

−2*ξωn* ± .4*ξ*2*ω*2 − 4*ω*2

⇒

*n n*

*s* =

2

= .−*ξ* ± .*ξ*2 − 1Σ *ωn* (10)

Depending on the value of *ξ*, the nature of *s* and correspondingly *u*(*t*) will be deter- mined,

*u*(*t*) = *C e*(*−ξ*+√*ξ*2*−*1)*ωnt* + *C e*(*−ξ−*√*ξ*2*−*1)*ωnt*

1 2

= Σ*C e*√(*ξ*2*−*1)*ωnt* + *C e−*√(*ξ*2*−*1)*ωnt*Σ *e−ξωnt* (11)

1

2

**Case I** *Under-damped system*, 0 *< ξ <* 1

For *ξ <* 1, *s*1*, s*2 are complex numbers and given as,

*s*1 *s*2 = .−*ξ* ± *ı*.|*ξ*2 − 1|Σ *ωn*

(12)

Therefore,

*u*(*t*) = .*C eı*√*|ξ*2*−*1*|ωnt* + *C e−ı*√*|ξ*2*−*1*|ωnt*Σ *e−ξωnt* (13)

Considering .|*ξ*2 − 1|*ωn* = *ωd*, Equation 13 can be written as,

1

2

*u*(*t*) = .*C*1*eıωdt* + *C*2*e−ıωdt*Σ *e−ξωnt*

[(*C*1 + *C*2) cos *ωdt* + *ı*(*C*1 − *C*2) sin *ωdt*] *e−ξωnt* (14)

where, *ωd* is referred as *damped natural frequency*. Substituting (*C*1 + *C*2) = *A* cos *φ*

and *ı*(*C*1 − *C*2) = *A* sin *φ* into Equation 14, we get,

*u*(*t*) = *A* cos(*ωdt* − *φ*)*e−ξωnt* (15)

Applying initial conditions as, *u*(*t*)|@*t*=0 = *u*0 and *u*˙(*t*)|@*t*=0 = *u*˙0, we get,

*C* + *C* = *u* and *ı*(*C* − *C* ) = Σ *u*˙0 + √ *u*0*ξ* Σ

*ω*

1 2 0

1 2

*d*

1 − *ξ*2

Thus for these initial conditions, the response can be written as,

*u*(*t*) = .*u*

cos *ω t* + Σ *u*˙0 + √ *u*0*ξ*

*ω*

Σ sin *ω t*Σ *e−ξωnt* (16)

*d*

0 *d*

*d*

1 − *ξ*2

**Case II** *Critically-damped system*, *ξ* = 1

Critical damping is the minimum damping required to stop the oscillations.

*s*1*, s*2 = −*ωn*

The solution is of the form,

*u*(*t*) = (*C*1 + *C*2*t*)*e−ωnt* (17)

Even here, *C*1 and *C*2 can be obtained from the initial conditions given.

**Case III** *Over-damped system*, *ξ >* 1

There is no oscillatory motion in an over-damped system.

*u*(*t*) = (*C*1*eωdt* + *C*2*e−ωdt*)*e−ξωnt* (18)

For a over-damped system, higher the values of *ξ*, the slower the rate of the decay (See Figure 5).

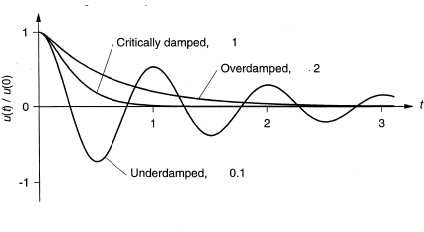


Figure 5: Free vibration of under-damped, critically damped and over-damped system

**UNIT –II**

**Seismic performance, repair and strengthening :-**

**Identification of seismic damage in RC Building**

The principal causes of damage to buildings soft stories, floating columns ,mass irregularities, poor quality of material, faulty construction practices, inconsistent seismic performance, soil and foundation effect , pounding of adjacent structure and inadequate ductile detailing in structural and inadequate ductile detailing in structural components .

**Soft storey**

It is the one which the lateral stiffness is less than 70 percent of that in the storey above or less than 80 percent of the average lateral stiffness of the three storeys above.

**Weak storey**

It is one in which the storey lateral strength is less than 80 percent of that in the storey above. The storey lateral strength is the total strength of all seismic forces resisting elements sharing the storey shear in the considered direction.

**Soft Storey Failure**

Multi-storey buildings in metropolitan cities require open taller first storey for parking of vehicle and/or for retail shopping, large space for meeting room or a banking hall owing to lack of horizontal space and high cost. Due to this functional requirement, the first storey has lesser strength and stiffness as compared to upper stories, which are stiffened by masonry infill walls. This characherics of building construction creates weak or soft storey problems in multi storey buildings. Increased flexibility of first storey results in extreme deflections, which in turn, leads to concentration of forces at the second storey connections accompanied by large plastic deformation. In addition, most of the energy developed during the earthquake is dissipated by the column of the soft stories. In this process the plastic hinges are formed at the ends of column, which transform the soft stories into a mechanism. In such cases the collapse is unavoidable.therefoere, the soft stories deserve a special consideration in analysis and design. It has been observed from the survey that the damages are due to collapse and buckling of columns especially where parking places are not covered appropriately. On the contrary, the damage is reduced considerably where the parking places are covered adequately. It is recognized that this type of failure results from the combination of several other unfavorable reasons, such as torsion,exceesive mass on upper floors, P-Δ effects and lack of ductility in the bottom storey. Figure shows some of the examples of soft storey. The soft storey concept has technical and functional advantages over the conventional construction. First, is the reduction in spectral acceleration and base shear due to increase of natural period of vibration of structure as in a base isolated structure. However, the price of this force reduction is paid in the form of an increase in structural displacement and interstorey drift, thus entailing a significant P-Δ effect, which is threat to the stability of the structure. Secondly taller first storey is sometimes necessitated for parking of vehicles and /or retail shopping, large space for meeting room or banking hall. Due to this, functional requirement, the first storey has lesser stiffness of columns as compared to stiff upper floor rooms, which are generally constructed with masonry infill walls.

**Causes of soft storey**

There are many practical reasons for having fewer walls at the ground level of a building. A building may have larger public spaces at this entry level, such as lobbies, large meeting rooms or open-plan retail space. In urban locations, residential buildings sometimes have fewer walls at the ground level to allow for parking underneath the building which is shown in figure below.

**Irregularity in strength and stiffness of weak and soft storey**

A weak storey is defined as one in which the storey’s lateral strength is less than 80 percent of that in the storey above. The storey’s lateral strength is the total strength of all seismic resisting elements sharing the storey shear for the direction under consideration i.e. the shear capacity of column or the shear wall or the horizontal component of the axial capacity of the diagonal braces. The deficiency that usually makes a storey weak is inadequate strength of frame columns. A soft storey is one in which late al stiffness is less than 70% of that in the storey immediately above, or less than 80% of the combined stiffness of the three stories above. The essential characherics of a weak or soft storey consist of a discontinuity of strength or stiffness, which occurs at the second storey connections. This discontinuity is caused by lesser strength, or increased flexibility, the structure results in extreme deflections in the first storey of the structure, which in turn results in concentration of forces at the second storey connection. The result is a concentration of inelastic action.

**Building With Soft Storey**

In case building with a flexible storey, such as the ground storey consisting of open spaces for parking that is stilt buildings. A special arrangement needs to be made to increase the lateral strength and stiffness of the soft/open storey. Dynamics analysis of building is carried out including the strength and stiffness effects of infills and inelastic deformations in the members’ .particularly, those in the soft storey, and the members designed accordingly.

**IS Code Provisions**

Alternatively, the following design criteria are to be adopted after carrying out the earthquake analysis. Neglecting the effect of infill walls in other storeys:

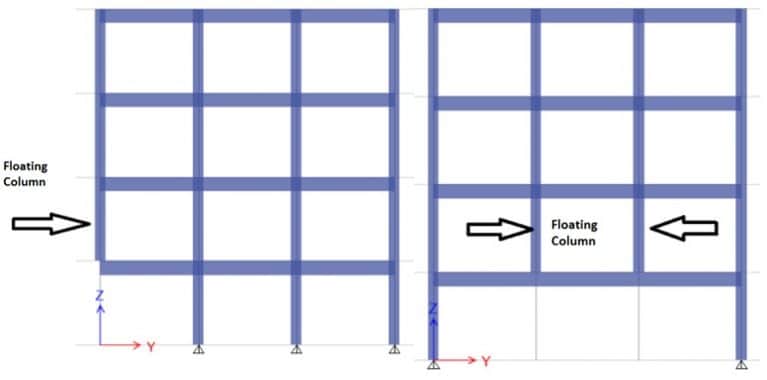
1. The column and beams of the soft storey are to be designed for 2.5 times the storey shears and moments calculated under seismic loads specified.
2. Besides the columns designed and detailed for the calculated storey shears and moments, shear wall placed symmetrically in both directions of the building as far away from the centers of the building as feasible: to be designed exclusively for 1.5 times the lateral storey shear force calculated as before.

**Conclusions**

RC frame buildings with open bottom storey are known to perform poorly during in strong earthquake shaking. Thus, it is clear that such buildings will exhibit poor performance during a strong shaking. This hazardous feature of Indian RC frame buildings needs to be recognized immediately and necessary measures taken to improve the performance of the buildings. The phenomena of soft story may arise due to many Different reasons such as change in load carrying and slab system between stories. The abrupt changes which take place in the amount of the infill walls between stories is also one of the frequent reasons of the soft storey behavior. Since infill walls are not regarded as a part of load carrying system, generally civil engineers do not consider its effects on the structural behavior.

**Floating Columns in Building Structures – Need and Uses**

A column is a vertical member which transfers the loads from beam to foundation whereas a floating column is a vertical member which transfers the load from beam to another beam. The load transfer in any building is usually from slab to beams to columns and then foundation. But a floating column, instead of transferring the load to foundation transfers the load on to the beam. The beam on which the floating column rests transfers the load to the columns below. The load is transferred in the form of a point load.



**Need of Floating Column**

Multi-storey building construction for residential, industrial or commercial purpose has become a common feature. These multi-storey building need ample of parking or open spaces below.

In multi-storey residential building to accommodate for the number of parking places and the turning radius, some of the columns from the floors above create a problem. In these cases, these columns are designed as floating columns.Even in commercial building there might be a need for conference hall or banquet hall on the lower floors. For these purposes we prefer to have a clear open space rather than having columns in between. This is where floating columns come into the picture. Floating columns gives the liberty to alter the floor plans above.

## **How are Floating Columns Incorporated in the structure?**

Like in any structure, the load from the floors above is transferred to the column. The entire load is then transferred to the beam on which the floating column is going to rest. The floating column is designed as regular column. The beam on which it rests is designed as a beam carrying all the load of the column as a single point load.This beam referred to as girder beam or transfer beam usually has a big cross section with heavy steel. This girder beam is also subjected to torsion. The design and detailing of this girder beam is very crucial in the construction of floating columns.

## **Floating Column and Earthquake**

The lateral forces due to earthquake need to be transferred to the foundation through clear force transfer path. This force transfer path is disrupted in case of floating columns. These floating columns attract a lot of seismic force, which is unfavorable in the high seismic zone.The floating columns act well when only vertical forces are considered. But they are highly undesirable for lateral forces such as earthquake. It is highly discouraged to have floating columns in high seismic zone regions.But even then, we see a lot of buildings be it residential, commercial or industrial using floating columns in their construction. And the only reason being the flexibility to alter the plan above or below to suit the client requirement. This is where our knowledge and art of structural engineering comes into play. So, in this situation, it is the job of structural engineers like us to ensure that such buildings are not only analyzed properly but the detailing of such buildings is also done properly. Detailing of the steel becomes a crucial part of floating column construction.Floating columns, though highly discouraged, are still an important part of the construction industry. It is in our hands to ensure correct analysis and design of this structural member. It is our responsibility to ensure that the detailing of this structural member and the girder beam supporting this floating column is done properly.With all its advantages and disadvantages, a floating column is one of the favorite structural elements in today's construction world.

**Stiffness Irregularity — Soft Storey-**A soft storey is one in which the lateral stiffness is less than 70 percent of the storey above or less than 80 percent of the average lateral stiffness of the three storeys above.

**1) Stiffness Irregularity** — Extreme Soft Storey-An extreme soft storey is one in which the lateral stiffness is less than 60 percent of that in the storey above or less than 70 percent of the average stiffness of the three storeys above.

**2) Mass Irregularity**-Mass irregularity shall be considered to exist where the seismic weight of any storey is more than 200 percent of that of its adjacent storeys. In case of roofs irregularity need not be considered.

**3) Vertical Geometric Irregularity-** A structure is considered to be Vertical geometric irregular when the horizontal dimension of the lateral force resisting system in any storey is more than 150 percent of that in its adjacent storey.

**4)In-Plane Discontinuity in Vertical Elements Resisting Lateral Force-**An in-plane offset of the lateral force resisting elements greater than the length of those elements.

**5) Discontinuity in Capacity —** Weak Storey-A weak storey is one in which the storey lateral strength is less than 80 percent of that in the storey above. As per IS 1893, Part 1 Linear static analysis of structures can be used for regular structures of limited height as in this process lateral forces are calculated as per code based fundamental time period of the structure. Linear dynamic analysis are an improvement over linear static analysis, as this analysis produces the effect of the higher modes of vibration and the actual distribution of forces in the elastic range in a better way. Buildings are designed as per Design Based Earthquake(DBE), but the actual forces acting on the structure is far more than that of DBE. So, in higher seismic zones Ductility based design approach is preferred as ductility of the structure narrows the gap. The primary objective in designing earthquake resistant structures is to ensure that the building has enough ductility to withstand the earthquake forces, which it will be subjected to during an earthquake.

**TYPES OF IRREGULARITIES**

There are two types of irregularities1. Plan Irregularities 2. Vertical Irregularities

Vertical Irregularities are mainly of five types)

**Stiffness Irregularity —**

a) **Soft Storey**-A soft storey is one in which the lateral stiffness is less than 70% of the storey above or less than 80% of the average lateral stiffness of the three storeys above.

b) **Extreme Soft Storey**-An extreme soft storey is one in which the lateral stiffness is less than 60 % of that in the storey above or less than 70 % of the average stiffness of the three storeys

**TYPE OF IRREGULARITIES**

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**TYPES OF SEISMIC ANALYSIS**

a. Equivalent lateral force

b. Response spectrum analysis

c. Elastic time history analysis

d. Push over analysis

e. Inelastic time history analysis

**a.Equivalent lateral force:** Seismic analysis of most of the structures is still carried out on basis of lateral force assumed to be equivalent to the actual loading. This method is usually conservative for low to medium height buildings with regular conformation.

**b.Response spectrum analysis**: This method is applicable for those structures where modes other than the fundamental one affect significantly the response of the structure. Modal analysis leads to the response history of the structures to a specified ground motion however; the method is usually used in conjunction with a response spectrum.

**c.Elastic time history analysis**: A linear time history analysis overcomes all the disadvantages of modal response spectrum analysis, provided non-linear behavior is not involved. This method requires greater computational efforts for calculating the response at discrete times.

**d.Push over analysis**: The push over analysis of a structure is a static non- linear analysis under permanent vertical loads and gradually increasing lateral loads. On a building

frame, load or displacement is applied incrementally; the formation of plastic hinges, stiffness degradation and plastic rotation are monitored. This type of analysis enables weakness in the structure to be identified.

**e.Inelastic time history analysis:** A seismically deficient building will be subjected to inelastic action during design earthquake motion. The inelastic time history analysis of the building under strong ground motions brings out the region of weakness and ductility demand in structure. This is most rational method available for assessing building performance.

***3.IRREGULARITIES IN A BUILDING***

**Irregularities are categorized in two types**

**I Vertical irregularities** referring to sudden change to strength, stiffness, geometry and mass results in irregular distribution of forces and deformation over the height of building

**II. Horizontal irregularities** which refer to asymmetrical plan shapes or discontinuities in the

horizontal resisting elements such as large openings, re-entrant corners and abrupt changes resulting in torsion, diaphragm deformation and stress concentration .

**i)Vertical Discontinuities in load path :-**

The structural should contain a continous load path for transfer of the seismic force, which develops due to acceleration of individual elements, to the ground .

failure to the individual element together can result in distress or complete collapse of the system. Therefore all the structural and non-structural elements must be adequately field to the structural system . the load path must be complete and sufficient strong .

The example of load path irregularities are, discontinuous columns, shear walls, bracing, frames that arise a floting box type situation. In the case of columns or shear walls that do not continue upto the ground but end at an upper level , shear is induced to overturning forces to another resisting element of a lower level. Therefore , the connecting element (link b\w discontinuous column to lover level column) and lower level columns.

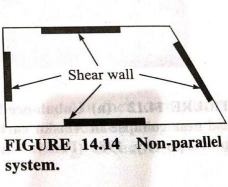
***soft story*** *:- a soft storey is one in which the lateral stiffness is less than 70% of that in the story above or less than 80% of the average lateral stiffness of the three story’s above*

***Extreme soft storey****:- an extreme softy story is one in which the lateral stiffness is less than 60% of that in the story above or less than 70% of the average stiffness of the three storey’s above eg:- building on slits will fall under this category****.***

***Proximity of Adjacent Buildings***pounding damage is caused by hitting of two buildings constructed in close proximity with each other. Pounding may result in irregular response of adjacent buildings of different heights

***PLAN* CONFIGURATION PROBLEMS   
*Torsion Irregularities***Torsion irregularity shall be considered when floor diaphragms are rigid in their own plan in relation to the vertical structural elements that resist the lateral forces. Torsion irregularity is considered to exist when the maximum storey *drift,* computed with design eccentricity, at one

***Re-entrant Corners***   
The re-entrant. lack of continuity or “inside” corner is the common characteristic of overall building configurations that, in plan, assume the shape of an L, T, H, +, or combination of these shapes occurs due to Jack of tensile capacity and force concentration (Vukazich, 1998). According to ***IS*** 1893 (Part 1): 2002, plan configurations of a structure and its lateral force resisting system contain re-entrant corners, where both projections of the structure beyond the re-entrant corner are greater than 15% of its plan dimension in the given direction. The re-entrant corners of the buildings are subjected to two types of problems. The first is that they tend to produce variations of rigidity, and hence differential motions between different parts of the building, resulting in a local stress concentration at the notch of the re-entrant corner (Figure 14.13a). The second problem is torsion. In Figure 14.13b, an L-shaped building is subjected to a ground motion of Alaska earthquake, 1964 in north-south direction; attempt to move differently at their notch, pulling and pushing each other. So the stress concentrations are high at the notch. The magnitude of the induced forces will depend on mass of building, structural system, length of the wings and their aspect ratios and height of the wings and their height/depth ratios. Examples of damage to re-entrant corner buildings are common and can be identified in Kanto earthquake 1923, Santa Barbara earthquake ***1925.*** To avoid this type of damage, either provide a separation joint between two wings of buildings or tie the building together strongly in the system of stress concentration and locate resistance elements the tensile capacity at re-entrant corner.

***Non-parallel Systems   
The*** vertical load resisting elements are **not parallel or** symmetrical about the major orthogonal axis of the lateral- force resisting system (Figure 14.14). These situations are often faced by architects. This condition results in a high probability of torsional forces under a ground motion, because the centre of mass and resistance does not coincide. This problem is often exaggerated in the triangular or wedge shape buildings resulting from street inter. 

***Diaphragm discontinuity***  
,1iaphragm is a horizontal resistance element that transfer force between vertical resistance elements The diaphragm discontinuity may occur with abrupt variations in stiffness, including having Cut-Out or Open areas greater than 50% of the gross enclose4 diaphragm area, or change in effective diaphragm stiffness of more than 50% from one storey to the next (Figure 14. 15a). The diaphragm acts as a horizontal beam, and its edge acts as flanges. It is obvious that opening cut in tension flange of a beam will seriously weaken its load carrying *capacity.* In a number of buildings there has been evidence of roof diaphragms, which is caused by tearing of the diaphragm

**Unit –III**

**Introduction to structural failures due to earthquake**

Introduction :-When a building is subjected to seismic forces is being opposed by horizontal inertia forces which are generated from the building.The resultant of these forces is assumed to act through the centre of mass (cm) of the building. The vertical members in the structure resist these forces and the total resultant of these systems of act through a point called as centre of stiffness. When the centre of mass and centre of stiffness does not coincide, eccentricities are developed in the building which further generate torsion. When the buildings are subjected to lateral then phenomenon of torisonal coupling occur. Due to interaction b/w lateral loads and resistant forces. Eccentrisity may occur due to presence of structural irregularities. Seismic analysis is adivision of structural analysis and itinvolves the calculation of the different response of a building irregularities.

**Failure Mode of Buildings**

**Out of Plane Failure** –The structural wall perpendicular to seismic motion are subjected to out of plane building results in out of plane failure featuring vertical cracks at the corners and in the middle of the walls.Inadequate anchourage of the wall into the roof diaphragm and limited tensile strength of masonry and mortar unitedly causes out of plane failure in unreinforced masonry building, which are the most vulunerable.

**In-Plane Failure –**The structure walls parallel to seismic motion are subjected to in plane force i.e, bending and shear causes horizontal and diagonal cracks in the wall. In plane failure of walls in un-reinforced masonry structures due to excessive bending or shear are must common as is evident from double diagonal shear cracking. This cracking pattern frequently found in cyclic loading indicates that the planes of principal tensile sites in the walls incapable of with standing repeated load reversals leading to total collapse.

**Diaphragm Failure**-Lack of tension anchoring producesa non-bending cantilever action at the base of the wall resulting from the push of diaphragm against the wall.

**Failure of Connection**-

-The general shakes simultaneously in the vertical and two horizontal directions during earthquakes.

-However the horizontal vibration are the most damaging to normal masonry buildings.

-To ensure good seismic performace, all wall must be jointed properly to the adjacent walls.

-If these connections are weak in shear case connection failure.

This type of failure is charactherized by diagonal cracks dispused on both the walls edges causing separation and collapse of corner zones.

**Non-Structural components-**

Non-structural elements fail because of either excessive inertial forces applied to them or excessive deflection caused by deformation of the structural system.

The following are some of the consequences of the failure of the non-structural elements.

1. Failling of debris ,ceilings, light fixtures, window glass and exterior wall panels, parapets and or namentation. These may not only injure or kill people inside and outside the building but may also damage critical mechanical and electrical components.
2. Collapse of stairways and elevators, and damage of exit doors,may prevent the escape of the people from the buildings.

c)Emergency lighting and exit signs may damage malfunction during and after earthquake disturbance.

d)The fire resistance system may collapse.

e)Furniture and equipment may overturn.

Pounding-When adjacent roof levels of two buildings and vertical brick work faces flish with one another, the pounding action causes structural distress due to out-of-plan vibrations.

TypesofSeismicAnalysis-

1. -Equivalent lateral force
2. -Response spectrum analysis
3. -Elastic time history analysis
4. -Push over analysis
5. -Inelatic time history analysis

1-Equivalent lateral force-Seismic analysis of most of the structures is still carried out on basis of lateral force assumed to be equivalent to the actual loading. This method is usually conservative for low to medium height buildings with oregular conformation.

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2. -Push over analysis –The push over analysis of a structure is a static non-linear analysis under permanent vertical loads and gradually increasing lateral loads. On a building frame, load or displacement is applied incrementally, the formation of plastic hinges, stiffness degradation and plastic relation are monitored. This type of analysis enables weakness in the structure to be identified.

5-Inelatic time history analysis –A seismically deficient building will be subjected to inelastic action during design earthquake motion. The in elastic time history analysis of the building under strong ground motions brings out the region of weakness and duatility demand is structure. This is most rational method available for assessing building performance.

Fundamental Natural Period:- First(longest) modal time period of vibration of structure.

-For a moment-resisting from building without bricks infill panch, Ta may be estimated by the empirical

Expressions Ta=0.075h^0.75 for RC frame building

Ta=0.085h^0.75 for steal frame building

-For all oth*er* buildings including moment resisting frame buildings with brick infills panels, Ta may be estimated by the empirical expression.

Ta=0.09h/

Where h = height of building in meters.

(this excludes the basement storeys, where basement walls are connected with the ground floor deck or fitted with the building columns) But it includes the basemen storeys whom they are not so connected.

D = base dimmension s b/w building at the plinth level in meters, along the considered direction lateral force.

Design Response Spectrum-

The design response spectrum is a smooth response spectrum specifying the level of seismic ressistance required for a design. The relation works well in SDOF system (sa/g) Spectral ordinates are used for the compution of inertia forces. Design response spectrum for rock and soil site for 5% damping.

Multipying factor for obtaining spectrual values for damping cother than 5% damping

Damping(%) 0 2 5 7 1 0 1 5 2 0 2 5 3 0

Factor 3.20 1.40 1.00 0.90 0.80 0.70 0.60 0.55 0.50

The design spectram ordinates are independent of the amount of damping and their variations from one material or one structural solution to another .When a building is subjected to seismic forces it is beung opposed by horizontal intertia forces which are generated from the building .

**Equivalent lateral force method**-This method of finding design lateral force is also known as the slatic method or the equivalent static method or the seismic coefficient method.The design base shear is computed for the building and it is then distributed along the height of the building. The lateral forces at each floor level thus obtained are distributed to individual lateral load resisting elements.

1. eismic Base Shear -

The total design lateral forceor design seismic base shear (Vb)

Vb = Ah W

Ah = Design horizontal acceleration spectrum value, using the fundamental natural period, T, in the considered direction of vibration.

**Ah=1/2.ZI/R.Sa/g**

W=seismicweightofbuilding

For any structure with T<0.1 the value of An will not be taken less then Z/2 whatever be the value of I/R.

Z is the zone factor given on table for the maximum considered earthquake (MCE).

The factor 2 in denominator is used so as to reduce the maximum considered earthquake (MCE).

Zone factor to the factor for design basic earthquake (DBE).

Sa/g is the response acceleration coefficient for 5% damping based on appropriate natural periods.

For Rocky or Hard soil sites -

Sa/g = [1+1.5T0.00<T<0.10]

[2.500.10<T<0.40]

[1.00/T0.40<T<4.00]

**For medium soil sites.**

Sa/g = [1+15T0.00<T<0.10]

[2.500.10<T<0.67]

[1.36/T0.55<T<47.00]

**For soft soil sites**

Sa/g = [1+1.5T0.00<T<0.10]

[2.50.10<T<0.67]

[1.67/T0.67<T<4.00]

**Seismic Weight(W) :-**

Seismic weight = full DL + Imposed load + weight of column and wall

While computing seismic weight of each floor, the weight of columns and wall sinany story should be equally distributed to floors above and below the storey.

As per IS 1893(Part1) the % of imposed load a given in table should be used. For calculating the design seismic forces of the structure, the imposed load on the roof need not be considered.

Distribution of Design Force:-

Vertical distribution of baes shear to different floor level as per the following expression-

**Qi=Vb WiHi^2/wihi^2**

Qi=Designlateralforceatfloori

Wi=theseismicweightoffloor

hi=heightoffloorimeasuredfromthebase

n=no.ofstoreysinthebuildings

UNIT-IV

**Seismoresistant Building Architecture**

Several studies and recommendations have been carried out to avoid situation affecting the buildings earthquake resistant behavior

These studies enable architects to develop a systematic study and a methodology to be applied to a architectural design of building to optimize earthquake resistant capacity. This study is called Seismoresistant building architecture.

The main objective of Seismoresistant building resistant architecture is to prevent stepping of Seismoresistant capacity of building and to optimize seismoresistance. The major aspects involved in Seismoresistant building construction are

1. Selection of loud resisting system
2. Its configuration system
3. Its basic dynamic characteristics
4. its construction capability
5. **Lateral load resisting system:**

The load resisting system must be of close loops so that it is able to transfer all the forces acting either vertically or horizontally to the ground.

BIS has approved three major types of lateral force resisting system in the code151893 (part 1): 2002

1. moment resisting frame system
2. building with shear wall (or bearing ball system)
3. Building with dual system.

These systems are further subdivided into types of construction material used table 7 of 151893 (part1) 2002.

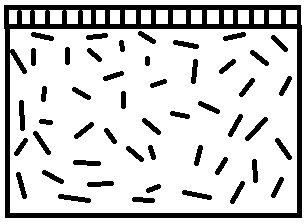
**Moment resisting frame**

In building frame system, the member shown in fig (Columns and beams) and joints of frame are resting the earthquake force primarily by flexure.This system is generally preferred by architects because they are relatively unobstrusive compared to the shear walls or braced frames but there may be poor economic risk unless special damage control measures are taken slabs column frames are not recommended as a lateral land resisting system.

## 

## Building with shear wall or bearing wall system

This system supports all or most of the gravity loads as well as lateral loads. In general a bearing ball system has a comparatively lower value for R since system looks redundancy has a poor inelastic response capacity .this system is not much preferred by the architects.



## Building with dual system

This system consists of shear wall and moment resisting frame such that

1. The two systems are designed to resist the total design forces in proportion to their lateral stiffness considering the interaction of the dual system of all floor levels
2. The moment resisting frames are designed to independently resist at least 25 % of design seismic phase shear.
3. In general , a dual system comparably has a higher value of R science a secondary lateral support system is available to assist the primary non bearing lateral support system as shown in figure . this system is somewhat less restricted architecturally.

### 

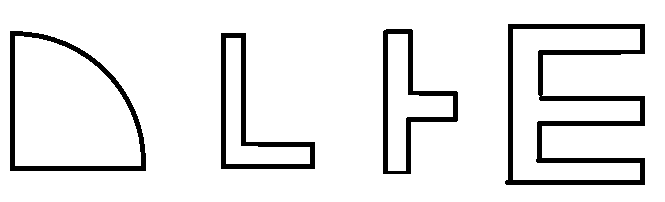
### 2) Building configuration

The configuration of load resisting system of building selected for the better performance of the building during earthquake .An important feature in building configuration is its regularity and symmetry in horizontal and vertical planes.

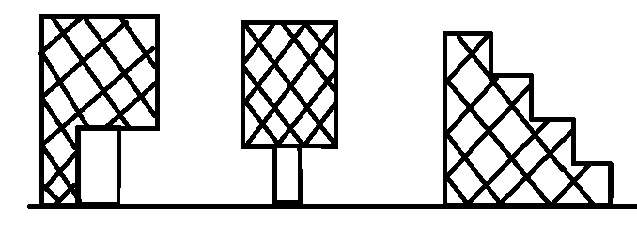
Seismic behavior of irregular shape of plan differs from regular shapes because the first can be subjected to their asymmetry and/or can present local deformations due to the presence of reentrant corners or excessive openings. Both give origin to undesired stress concentration in some resisting members of building.

On the contrary the ideal rectangular or square plan structurally symmetrical with enough in-plane stiffness in its diaphragm, presents an ideal behavior, because it has the same displacement at every point in the slab.

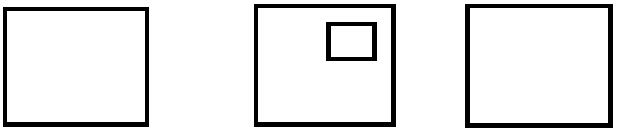
Therefore building shaped like a box such as rectangular, both in plan and elevation is inherently stronger than one that is L shaped or U shaped that is building with wings.



(Example of plan irregularity)



(Example of vertical irregularity)



(Example of highly torsional configuration)

### Building characteristics:

The seismic forces exerted on a building are not externally developed forces like wind instead they are the response of cyclic motions at the base of a building causing accelerated and hence inertia force .the response is therefore dynamic in nature.

The dynamic properties are:

Natural period, damping and mode shape, used to determine the response of the building

Other characteristics of the building also affect the seismic response such as ducfility, building foundation, response of non structural elements.

The effects of building characteristics on its seismic performance are defined as follows;

Made shapes and fundamental period: The elastic properties of mass of building causes to develop a vibratory motion when they are subjected to dynamic position The vibration of the building consist of fundamental mode of vibration and addition contribution of various modes which vibrates at higher frequencies the period of vibration of this mode expressed in seconds, is one of the most representative characteristic of the dynamic response of building

On the bases of time period building may be classified as rigid (t<0.3sec) , semi rigid( 0.3< t >1.0 sec) and flexible structure( T > 1.0 sec)

Building with higher nature frequency and short natural periods tends to suffer higher acceleration but small displacement and vice versa.

### Building frequency and ground period

Inertial forces generated in the building depend upon the frequencies of the ground on which the building is standing and the building is natural frequency when these are near or equal to one other the buildings is response reaches a perk level . Bui ding structures have fundamental periods of approximate 0.1.N (Where N is the no. of storeys).

If the foundation soil is firm rigid structure will have more unfavorable seismic response than flexible structures, whereas the seismic response of flexible structures on soft foundation sites will be less favorable than that of rigid structure

### Damping

Damping is the ability of the structural system to dissipate the energy of the earthquake ground shaking

There is no numerical method available for determining the damping .It is only obtained by experiments. In a structure, damping is due to internal friction and the absorption of energy by the building is structural and non-structural.

### Ductility

Ductility is defined as the capacity of the building materials, system or structure to absorb energy by deforming in the inelastic stage (range). The ductility of a structure depends on the type of material used and also the structural characteristics of the assembly.

It is possible to build ductile structures with reinforced concrete of care is taken during designing to provide the joints with sufficient ailments that can adequately confine the concrete , thus permitting it to deform plastically without breaking.

### Seismic weight

Seismic forces are proportional to the building weight and increase along the height of the building. Weight reduction can be obtained by using lighter materials, or by relocation of heavy weights such as file racks libraries swimming pools etc, at lower level.

### Hyperstaticity / Redundancy

In general, hyperstatic (statically indeterminate) structures have advantage because if primary system yields or fails, the lateral force can be redistributed to secondary elements or system to prevent progressive failure . Hyperstaticity of the structures causes the formation of plastic hinges that can absorb considerable energy without depriving the structure of its stability.

### Non-structural elements

Non-structural components remain uninvolved in the building design and become the source of damage. In general non-structural damage is caused in two ways:

The component may be directly affected by the ground motion transmitted by the main structure of the building and be subjected to accelerations and consequent inertial forces in similar way to the building structure.

Second: non-structural components may be affected by the movement or disportion in the structural elements that support or abet the element

These two causes can be summarized as acceleration or drift related damage

### Foundation soil/ liquefaction

Problems related to foundation soil can be classified in two groups

1. Influence of the subsoil on the characteristic of seismic moment, landslides and load of soil resistance , these problems are not significantly affected by the structures and therefore
2. Problems caused by loads transmitted to the soil by foundation and the settling of the foundation under seismic and static loads.

### Foundation

Foundations of the building are subjected to earthquake stress; the following major recommendation on structural design must be born in mind:

1. Foundation should be designed as continuous in order to avoid relative horizontal displacement.
2. In case of isolated footing, they should be joined to each other by means of foundations beams or ties. These ties should be designed such that it will bear tension and compression forces.
3. It is recommended that if different parts of the buildings are to be structurally independent because of the shape of their ground plan; their foundations should also be independent.

### Quality of construction and materials

One of the main factors responsible for stepping of Seismoresistant capacity of building is its quality of material and its workman ship of construction quality of concrete, faulty execution of construction joint, and detailing reinforcement are also affecting the performance of structure.

The factors affecting the Seismoresistant capacity of building are described as follows

1. Quality of concrete: grade of concrete specified in design documents may not be developed during construction mainly due to:

* Incorrect proportioning
* Insufficient mixing which causes segregation
* Aggregates with excessive impurities or improper grading
* Excessive high water/cement ratio

1. Construction joints: A defective concrete joint which contribute significantly to causing of failure of many buildings in past earthquake due to:

* Poor execution of construction joints/ discontinuity
* Not located at the points specified by the designer
* Accumulation of sawdust, dust and loose materials at surface of joints.

1. General detailing requirements:

Stepping of Seismoresistant capacity of building is due to:

* Amount of reinforcement is not placed as specified in design
* Insufficient concrete cover to reinforcement results resting in reinforcing bar and cracks in surface concrete
* Improper confinement and large tie spacing especially in plastic hinge region.
* Insufficient confinement and anchorage length of joints
* Insufficient splicing length of longitudinal reinforcement in columns or splicing of all bars at same cress-section
* Accumulation of splices just above a concrete joint or in plastic hinge zone
* The end of lateral reinforcement cause thrust in concrete when bar is subjected to tension and compression.

### Building configuration: problems and solutions:

|  |  |  |
| --- | --- | --- |
| Architectural problems | Structural problems | Remedial measures |
| 1. Extreme height/depth ratio | High overturning forces, large drift causing non-structural damage foundation stability. | Revise proportion or special structural system |
| 1. Extreme plan area | Built-up large diaphragm forces | Subdivide building by seismic joints |
| 1. Extreme length/depth ratio | Built-up of large lateral forces in parameter | Subdivide building by seismic joints. |
| 1. Variation in perimeter strength-stiffness | Torsion caused by extreme variation in strength and stiffness. | Add frames and disconnect walls or use frames and lightweight walls. |
| 1. False symmetry | Torsion cause by stiff asymmetric core. | Disconnect core, or use frame with non-structural core walls |
| 1. Re-entrant corners | Torsion, stress concentrations at the notches | Separate walls, uniform box, centre box, diagonal reinf. |
| 1. Mass eccentricities | Torsion, stress concentration | Reprogram, or add resistance around mass to balance resistance and mass. |
| 1. Soft storey frame | Causes abrupt changes of stiffness at point of discontinuity | Add bracing, add columns braced |
| 1. Variation in column stiffness. | Causes abrupt changes of stiffness, much higher forces in stiffer columns. | Redesign structured system balance stiffness. |
| 1. Discontinuous shear wall | Results in discontinuous in load path and stress concentration for most heavily loaded elements. | Primary concern over the strength of lower level columns and connecting beams that support the load of discontinuous frame. |

### Design of beam:

1s 13920 2016[EQ]

Q.1 L.L=20kN/M D.L= 25KN/m

Due to earthquake BM=60 KN/m and S.F(v)= 40KN

c/c distance b/w support =6m use M 20, Fe 415 steel

Sol=

Assume depth. D= **= =600 mm**

**and with= 300mm**

**Effective depth d= D – effective cover(40mm)**

**D=640mm**

**self weight= = 4.8 k N/m**

**total dead load = 4.8+25=29.8 k N/m**

**L.L = WL= 20 k N/m**

**Max. BM due to D.L = K N/m**

**Max. BM due to L.L= K N/m**

**Max. S.F due to D.L (Vd)= k N**

**Max. S.F due to L.L (Vv)= K** N

**seismic design shear, VL= 40 K N.**

**factored moment Mu = 1.5 (Md + Mc)**

**or**

**1.2( Md + Mc + Mc ) whichever is more**

**Mu=1.2(89.4+60+60)=251.28 k N/m**

**Factored shear force, Vu is given as**

**Vu= 1.5(Vd + Vl) or**

**1.2 (Vd + Vl + Vl) whichever is more**

**Vu= 1.2(89.4+60+40)= 227.28 K N/m**

**For Fe 415 steel and M 20 concrete :**

**Fe k = 20 N/ m Fy= 415 N/ m**

**R lim= 2.76**

**Mu= 0.138 ( for Fe 415)**

**0.138 (for Fe 500)**

**d= 640-30-20/2**

**d= 600mm**

**Area of steel required**

**=0**

**let 1380**

**no. of bar required =**

**provide= 5 bars**

**as per IS 13920, for ductility requirement**

**Maximum %of steel P max= 2.5 %**

**Steel provided =**

### Check for shear

Design shearing force Vu=227.8 k N

Nominal shear stress Zv=

Permissible shear stress, Tc = 0.589=0.5

Max. permissible shear stress= 2.8 N/

Zv < Zc safe

If Zv>ZC shear reinforcement will be required

Let, use 8-2- legged vertical shear stirrufy

Sv=

Sv= 177.9mm/c/c

Min spacing Sv=

Maximum spacing = Sv= 0.75d or 300mm (whichever is less)

450 or 300 =300mm

The spacing of shear stirrups should not be more than

1. d/4=600/4= 150mm
2. (smallest longitudinal bar)=

Provide 8 two legged vertical shear spacing

at 150mm c/c over length of 2d =1200mm at either end of beam