STRUCTURAL DYNAMICS AND EARTHQUAKE ENGINEERING

UNIT – I

THEORY OF VIBRATION

1. What is mean by Frequency?

Frequency is number of times the motion repeated in the same sense or alternatively. It is the number of cycles made in one second (cps). It is also expressed as Hertz (Hz) named after the inventor of the term. The circular frequency ω in units of sec-1 is given by 2π f.

2. What is the formula for free vibration response?

The corresponding equation under free vibrations can be obtained by substituting the right hand side of equation as zero. This gives

$$mu + Cu + Ku = 0$$

3. What are the effects of vibration?

i. Effect on Human Sensitivity.

ii. Effect on Structural Damage

4. What is mean by theory of vibration?

Vibration is the motion of a particle or a body or a system of concentrated bodies having been displaced form a position of equilibrium, appearing as an oscillation.

Vibration was recognized in mechanical systems first and hence the study of vibrations fell into the heading "Mechanical Vibrations" as early about 4700 years ago.

5. Define damping.

Damping is a measure of energy dissipation in a vibrating system. The dissipating mechanism may be of the frictional form or viscous form. In the former case, it is called dry friction or column damping and in the latter case it is called viscous damping. Damping in a structural system generally assumed to be of viscous type for mathematical convenience. Viscous damped force (Fd) is proportional to the velocity ( ) of a vibrating body. The constant of proportionality is called the damping constant (C). Its units are NS/m.

6. What do you mean by Dynamic Response?

The Dynamic may be defined simply as time varying. Dynamic load is therefore any load which varies in its magnitude, direction or both, with time. The structural response (i.e., resulting

displacements and stresses) to a dynamic load is also time varying or dynamic in nature. Hence it is called dynamic response.

7. What is mean by free vibration?

A structure is said to be undergoing free vibrations if the exciting force that caused the vibration is no longer present and the oscillating structure is purely under influence of its own inertia or mass(m) and stiffness (k). Free vibration can be set in by giving an initial displacement or by giving an initial velocity (by striking with a hammer) to the structure at an appropriate location on it.

8. What is meant by Forced vibrations?

Forced vibrations are produced in a structure when it is acted upon by the continuous presence of an external oscillating force acting on it. The structure under forced vibration normally responds at the frequency ratio, i.e. (fm/fn) where fm is the frequency of excitation and fn is the natural frequency of the structure.

9. Write a short note on Amplitude.

It is the maximum response of the vibrating body from its mean position. Amplitude is generally associated with direction – vertical, horizontal, etc. It can be expressed in the form of displacement (u), velocity ($\dot{u}$) or acceleration ($\ddot{u}$). In the case of simple harmonic motion, these terms are related through the frequency of oscillation (f).

If 'u' is displacement amplitude, then

$$\text{Velocity } (\dot{u}) = 2\pi \text{ f .u}$$

$$\text{Acceleration } (\ddot{u}) = (2\pi \text{ f}). \text{ (u)} = 4\pi 2f 2\text{u}$$

When acceleration is used as a measure of vibration, it is measured in terms of acceleration due to gravity, g (9.81 m/sec2).

10. Define Resonance.

This phenomenon is characterized by the build –up area of large amplitudes of any given structural system and as such , it has a significance in the design of dynamically loaded structures. Resonance should be avoided under all circumstances, whenever a structure is acted upon by a steady state oscillating force (i.e., fm is constant).

The presence of damping, however, limits the amplitudes at resonance. This shows the importance of damping in controlling the vibrations of structures. According to IS 1893 –1975-

Indian standard code of practice on Earthquake resistant design of structures, following values of damping are recommended for design purposes.

11. What is mean by Degrees of freedom?

The number of degrees of freedom of system equals the minimum number of independent co-ordinates necessary to define the configuration of the system.

12. Define static force.

A push or pull or a load or many loads on any system creates static displacement or deflection depending on whether it is a lumped system or a continues system; there is no excitation and hence there is no vibration.

13. Write a short note on simple Harmonic motion.

Vibration is periodic motion; the simplest form of periodic motion is simple harmonic. More complex forms of periodic motion may be considered to be composed of a number of simple harmonics of various amplitudes and frequencies as specified in Fourier series

14. What is the response for impulsive load or Shock loads?

Impulsive load is that which acts for a relatively short duration. Examples are impact of a hammer on its foundation. Damping is not important in computing response to impulsive loads since the maximum response occurs in a very short time before damping forces can absorb much energy from the structure. Therefore, only the undamped response to impulsive loads will be considered.

15. Write a short note on single degree of freedom (SDOF) systems.

At any instant of time, the motion of this system can be denoted by single co- ordinate (x in this case). It is represented by a rigid mass, resting on a spring of stiffness ‘k’ and coupled through a viscous dashpot (representing damping) having constant ‘C’. Here, the mass ‘m’ represents the inertial effects of damping (or energy dissipation) in the system. Using the dynamic equilibrium relation with the inertial force included, according to D’Alembert’s principle, it can be written as

$$\mathbf{FI + FD + FS = P(t)}$$

(Inertia Force)	(Damping force)	(Elastic force)	(Applied force)

This gives

$$mx + Cx + Kx = P$$

x, x, x respectively denote the displacement, velocity and acceleration of the system. P (t) is the time dependent force acting on the mass. The above equation represents the equation of motion of the single degree freedom system subjected to forced vibrations.

16. Define Cycle.

The movement of a particle or body from the mean to its extreme position in the direction, then to the mean and then another extreme position and back to the mean is called a Cycle of vibration. Cycles per second are the unit Hz.

17. Write short notes on D'Alembert's principle.

According to Newton's law F = ma

The above equation is in the form of an equation of motion of force equilibrium in which the sum of the number of force terms equal zero. Hence if an imaginary force which is equal to ma were applied to system in the direction opposite to the acceleration, the system could then be considered to be in equilibrium under the action of real force F and the imaginary force ma. This imaginary force ma is known as inertia force and the position of equilibrium is called dynamic equilibrium.

D'Alembert's principle which state that a system may be in dynamic equilibrium by adding to the external forces, an imaginary force, which is commonly known as the inertia force 18. Write the mathematical equation for springs in parallel and springs in series Springs in parallel

$$ke = k_1 k_2 k$$

ke is called equivalent stiffness

is called equivalent stiffness of the system e k

Springs in series

$$1/ke = 1/k1 + 1/k2$$

19. Define logarithmic decrement method.

Logarithmic decrement is defined as the natural logarithmic value of the ratio of two adjacent peak values of displacement in free vibration. It is a dimensionless parameter. It is denoted by a symbol δ

20. Write short notes on Half-power Bandwidth method.

Bandwidth is the difference between two frequencies corresponding to the same amplitude. Frequency response curve is used to define the half-power bandwidth. In which, the damping ratio is determined from the frequencies at which the response amplitude is reduced $1/\sqrt{2}$ times the maximum amplitude or resonant amplitude.

21. Define Magnification factor.

Magnification factor is defined as the ratio of dynamic displacement at any time to the displacement produced by static application of load.

22. What is the difference between a static and dynamic force?

In a static problem, load is constant with respect to time and the dynamic problem is the time varying in nature. Because both loading and its responses varies with respect to time Static problem has only one response that is displacement. But the dynamic problem has mainly three responses such as displacement, velocity and acceleration.

23. Define critical damping.

Critical damping is defined as the minimum amount of damping for which the system will not vibrate when disturbed initially, but it will return tot the equilibrium position. This will result in non-periodic motion that is simple decay. The displacement decays to a negligible level after one nature period T.

24. List out the types of damping.

(1) Viscous Damping,

(2) Coulomb Damping,

(3) Structural Damping,

(4) Active Damping,

(5) Passive Damping.

25. What is meant by damping ratio?

The ratio of the actual damping to the critical damping coefficient is called as damping ratio. It is denoted by a symbol ρ and it is dimensionless quantity.

It ca be written as $\rho = c/cc$ damping ratio.

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UNIT – II

MULTIPLE DEGREE OF FREEDOM SYSTEM

1. Define degrees of freedom.

The no. of independent displacements required to define the displaced positions of all the masses relative to their original position is called the no. of degrees of freedom for dynamic analysis.

2. Write a short note on matrix deflation technique.

Whenever the starting vector, the vector iteration method yields the same lowest Eigen value. To obtain the next lowest value, the one already found must be suppressed. This is possible by selecting vector that is orthogonal to the eigen values already found, or by modifying any arbitrarily selected initial vector form orthogonal to already evaluated vectors. The Eigen vectors XL2 computed by iteration as in the previous example X1 would be orthogonal to the XL1. the corresponding frequency will be higher than λL1 but lower than all other Eigen values.

3. Write the examples of multi degrees of freedom system.

4. What is mean by flexibility matrix?

Corresponding to the stiffness (k), there is another structural property known as flexibility which is nothing but the reciprocal of stiffness. The flexibility matrix F is thus the inverse of the stiffness matrix, [F] = [K]-1.

5. Write a short note on Jacobi's Method.

While all other enable us to calculate the lowest Eigen values one after another, Jacobi's method yields all the Eigen values simultaneously. By a series of transformations of the classical form of the matrix prescribed by Jacobi, all the non diagonal terms may be annihilated, the final diagonal matrix gives all the Eigen values along the diagonal.

6. What are the steps to be followed to the dynamic analysis of structure?

The dynamic analysis of any structure basically consists of the following steps.

1. Idealize the structure for the purpose of analysis, as an assemblage of discreet elements which are interconnected at the nodal points.

2. Evaluate the stiffness, inertia and damping property matrices of the elements chosen.

3. By supporting the element property matrices appropriately, formulate the corresponding matrices representing the stiffness, inertia and damping of the whole structure.

7. Write a short note on Inertia force – Mass matrix [M]

On the same analogy, the inertia forces can be represented in terms of mass influence co efficient, the matrix representation of which is given by $\{f1\} = [M] \{Y\}$

Mij a typical element of matrix M is defined as the force corresponding to co – ordinate i due as the force corresponding to coordinate i due to unit acceleration applied to the co ordinate

j. $[M]\{Y\}+[C]\{Y\}+[K]\{Y\} = \{P(t)\}$

8. What are the effects of Damping?

The presence of damping in the system affects the natural frequencies only to a marginal extent. It is conventional therefore to ignore damping in the computations for natural frequencies and mode shapes

9. Write a short note on damping force – Damping force matrix.

If damping is assuming to be of the viscous type, the damping forces may likewise be represented by means of a general damping influence co efficient, Cij. In matrix form this can be represented as

$$\{fD\}= [C] \{Y\}$$

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11. What are normal modes of vibration?

If in the principal mode of vibration, the amplitude of one of the masses is unity, it is known as normal modes of vibration.

12. Define Shear building.

Shear building is defined as a structure in which no rotation of a horizontal member at the floor level. Since all the horizontal members are restrained against rotation, the structure behaves like a cantilever beam which is deflected only by shear force.

13. What is mass matrix?

The matrix $\begin{bmatrix} m1 & 0 \\ 0 & m2 \end{bmatrix}$

is called mass matrix and it can also be represented as [m]

14. What is stiffness matrix?

The matrix $\begin{bmatrix} k1+k2 & -k2 \\ -k2 & k2 \end{bmatrix}$

is called stiffness matrix and it also denoted by [k]

15. Write short notes on orthogonality principles.

The mode shapes or Eigen vectors are mutually orthogonal with respect to the mass and stiffness matrices. Orthogonality is the important property of the normal modes or Eigen vectors and it used to uncouple the modal mass and stiffness matrices.

$\therefore \{\phi\}[k]\{\phi\}j = 0$, this condition is called orthogonality principles.

16. Explain Damped system.

The response to the damped MDOF system subjected to free vibration is governed by

$[M]\{\ddot{u}\}+[c]\{\dot{u}\}+[k]\{u\}=0$

In which [c] is damping matrix and $\{\dot{u}\}$ is velocity vector.

Generally small amount of damping is always present in real structure and it does not have much influence on the determination of natural frequencies and mode shapes of the system.

∴The naturally frequencies and mode shapes for the damped system are calculated by using the same procedure adopted for undamped system

17. What is meant by first and second mode of vibration?

The lowest frequency of the vibration is called fundamental frequency and the corresponding displacement shape of the vibration is called first mode or fundamental mode of vibration. The displacement shape corresponding to second higher natural frequency is called second mode of vibration.

18. Write the equation of motion for an undamped two degree of freedom system.

$$[m]\{\ddot{u}\}+[k]\{u\}=0$$

This is called equation of motion for an undamped two degree of freedom system subjected to free vibration.

19. What is meant by two degree of freedom and multi degree of freedom system?

The system which requires two independent coordinates to describe the motion is completely is called two degree of freedom system. In general, a system requires n number of independent coordinates to describe it motion is called multi degree of freedom system

20. Write the characteristic equation for free vibration of undamped system.

$$|[k]-\omega 2[m]|=0$$

This equation is called as characteristic equation or frequency equation.

UNIT – III

ELEMENTS OF SEISMOLOGY

1. Define Seismology. And Earthquake

Seismology is the study of the generation, propagation generation and recording of elastic waves in the earth and the sources that produce them.

An Earthquake is a sudden tremor or movement of the earth's crust, which originates naturally at or below the surface. About 90% of all earthquakes results from tectonic events, primarily movements on the faults.

2. What are the causes of Earthquake?

Earthquake originates due to various reasons, which may be classified into three categories. Decking waves of seashores, running water descending down waterfalls and

movement of heavy vehicles and locomotives, causes feeble tremors these earthquakes are feeble tremors, which don't have disastrous effects.

Contrary to the volcanic earthquake and those due to superficial causes, which can be severe, only locally, the more disastrous earthquakes affecting extensive region are associated with movements of layers or masses of rocks forming the crust of the earth. Such seismic shocks, which originate due to crustal movements, are termed as tectonic earthquakes.

3. What is mean by Epicenter and focus?

The point at which the rupture begins and the first seismic wave originates is called focus or hypocenter. The point on the ground directly above the focus is called epicenter.

4. Write a short note on Plate Tectonic Theory

Tectonic is the study of deformations of earth materials that result from deformation. Plate tectonics refers to deformation on a global scale. The basic hypothesis of plate tectonics is that the surface of the earth consists of a number of large plates. These plates move relative to one another. The present six important plates are namely

1. African plate
2. American plate
3. Antarctic plate
4. Australian – Indian plate
5. Eurasian plate
6. Pacific plate

5. Write a short note on Seismic waves.

Large strain energy released during an earthquake travel as seismic waves in all directions through the earth's layers, reflecting at each interface. These waves area of two types, body waves and surface waves

6. Write a short note on Magnitude.

The magnitude of an earthquake is a measure of the amount of energy released. The earthquake scale is devised by Charles F. Richter, an American seismologist be based on the total amount of energy released during an earthquake be called magnitude.

7. What is mean by seismogram?

A seismogram is the graph output by a seismograph. It is a record of ground motion at a measuring station. The energy measured in a seismogram may result from earthquake or from some other source.

8. Write a note on Intensity.

Intensity indicates the intensity of shaking or extent of damage at a given location due to particular earthquake. Thus the intensity of some earthquake will be different at different places. Intensity is a measure earthquake in qualitative way by judging what actually happens on the ground, the damage to the buildings and other structures caused by earthquake waves.

9. What is Elastic rebound theory?

The concept of possible mode of origin of tectonic earthquakes is known as Elastic Rebound theory.

10. Name the types of fault.

(i) Dip-Slip fault

(ii) Strike-Slip fault

(iii) Oblique-Slip fault

11. What are the types of Dip-Slip fault?

Dip-Slip fault having two types they are

(i) Normal fault

(ii) Reverse fault

12. What are the types of Body waves and surface waves?

Body waves are mainly of two types, they are

(i) Primary waves (or) P-waves

(ii) Secondary waves (or) S-waves

Surface waves also having two types, they are

(i) Love waves

(ii) Rayleigh waves

13. Compare: Magnitude and Intensity of an earthquake.

Sl.No	Magnitude	Intensity
1.	Magnitude measures the energy release at the source of the earthquake. It is determined from measurements on seismographs.	Intensity measures the strength of shaking produced by the earthquake at a certain location. It is determined from the effects on people, structure and natural environment.
2.	Magnitude of an earthquake is a quantitative measure of its size. Thus the magnitude of the earthquake is a single number which does not vary from place to place.	Intensity is a qualitative measure of an earthquake, based on the damage caused by them.
3.	Bhuj earthquake of January 2001 had a magnitude of 7.7 on Richter scale. The earthquake was felt over a large part of the state such as Bhuj, Ahmedabad etc. Magnitude of the earthquake of all the places remains same, i.e. 7.7.	The intensity of the same earthquake at Bhuj is different from the intensity at Ahmedabad vice-versa.

14. How the earthquakes are classified?

Earthquake can be classified into the following types.

(a) According to plate boundaries

(b) According to its depth of focus

(c) According to its origin of the earthquakes

(d) Based on magnitude (M).

15. What is the difference between Inter plate earthquakes and Intra plate earthquakes?

(i) Inter plate earthquakes: The earthquake occurring along the boundaries of the tectonic plates are called as inter plate earthquakes.
Example: 1987, Assam Earthquake

(ii) Intra plate earthquakes: The earthquakes occurring within a plate are called as intra plate earthquakes.

Example: 1993, Latur Earthquake

16. What are the factors influences the ground motion?

The factors which influence the ground motion are:

(i) Magnitude of earthquake

(ii) Epicentral distance

(iii) Local soil conditions

17. What is the difference between shallow, intermediate and deep focus earthquake?

(i) Shallow-focus earthquake: In this case, the seismic shocks originate at a depth of about less than 70 km. Nearly 80% of the world's earthquakes are shallow-focus earthquakes.

(ii) Intermediate-focus earthquake: In this case, the seismic waves originate at a depth between 70 km to 300 km.

(iii) Deep-focus earthquake: Here, the point of origin of the seismic wave is at a depth of greater than 300 km.

18. What is Seismograph?

Seismograph is an instrument used to recording motions of the earth's surface caused by seismic waves, as a function of time. A modern seismograph includes five basic parts: a clock, a sensor called a seismometer that measures intensity of shaking at the instruments location, a recorder that traces a chart or seismogram, of the seismic arrivals, an electronic amplifier and a data recorder that stores the information for later analysis.

19. Explain volcanic Earthquake?

Earthquakes associated with volcanoes are more localized both in the extent of damage and in the intensity of the waves produced in comparison to those which are associated with faulting motions. Deep below the centre of volcano, hot magma moves slowly through underground passages under pressure, as its makes it ways towards the earth's surface. As this happens, the surrounding rock is put under pressure as the magma pushes against it. This causes the rock to fracture and small earthquakes to occur.

20. What are the basic difference between Focus and Epicentre?

Focus is the location within the earth where fault rupture actually occurs whereas the epicentre is the location on the surface above the focus.

21. What is hypocenter?

Focus is an exact location within the earth where seismic waves are generated by sudden release of stored elastic building. It is called as hypocenter.

22. What is accelerogram?

A graph plotted between acceleration of ground and time is called accelerogram. The nature of accelerogram's may vary depending on energy released at focus, type of faults, geology along the fault plane and local soil.

23. Explain Uttarkashi earthquake of 1991?

An earthquake of magnitude 6.6 struck the districts of Uttarkashi, Tehri and Chamoli in the state of Uttar Pradesh on October 20, 1991. About 768 persons lost their lives, with about 5,066 injured. Maximum peak ground acceleration of about 0.31g was record at Uttarkashi. Many four-storey buildings in Uttarkashi with RC frame and infill walls sustained the earthquake. Howe ever, some of the ordinary RC buildings collapsed.

24. Enumerate TSUNAMI.

A tsunami is a wave train or series of waves, generated in a body of water by an impulsive disturbance that vertically displaces the water column. Tsunami is a Japanese word with the English translation, "harbour wave". The term "tsu" means harbour and "nami" means wave.

Tsunami can be generated when the sea floor abruptly deforms and vertically displaces the overlaying water. Tectonic earthquakes are a particular kind of earthquakes that are associated with the earth's crustal deformation; when these earthquakes occur beneath the sea, the water above the deformed area is displaced from the equilibrium position. Waves are formed as the displaced water mass, which acts influence of gravity. When large areas of the sea floor elevate or subside, a tsunami can be created.

25. What is Focal depth and Epicentral distance?

(i) Focal depth: The distance between the epicentre and the focus is called focal depth.

ii) Epicentral distance: The distance from epicentre to any of interest is called epicentral distance.

UNIT – IV

RESPONSE OF STRUCTURES TO EARTHQUAKE

1. What do you understand by response spectrum?

A Response spectrum is the plot of the maximum response (maximum displacement, velocity, acceleration or any other quantity of interest) to a specified load function Xa (t) for all possible SDOF systems (having different natural frequencies or time periods T and a constant damping ratio).

2. What is mean by soil liquefaction?

Soil liquefaction during an earthquake is a process that leads to loss of strength or stiffness of the soil. This could result in the settlement of structures, cause landslides, precipitates failures of earth dams or cause other types of hazards. Soil liquefaction has been observed to occur most often in loose saturated sand deposits.

3. Write a short note on liquefaction of clay soil.

Certain clayey soils are vulnerable to serve strength loss due to earthquake shaking. A clayey soil would be considered liquefiable if all of the following criteria are met:

i. The weight of the soil particles finer than 0.005mm is less than 15% of the dry weight of the soil.

ii. The liquid limit of the soil is less 35%.

iii. The moisture content of the soil is less than 0.9 times the liquid limit.

4. How the liquefaction – induced Ground failures?

If a soil becomes liquefied and loses its shear strength, ground failures may result. When structures are founded over or near these soil deposits, they may get damaged. The ground failures caused by liquefaction may be classified into the following categories:

i. Lateral Spreading

ii. Flow Failures

iii. Loss of Bearing Capacity

5. What do you understand by lateral spreading?

Lateral spreading is the movement of surfacial soil layers, which occur there is a loss of shear strength in a subsurface layer due to liquefaction. Lateral spreading usually occurs on very

gentle slopes (< 6%). If there is differential lateral under a structure, there could be sufficient tensile stresses developed in the structures that it could literally tear apart. Flexible buildings have been observed to better withstand extensional displacement than more stiff or brittle buildings.

6. What are the methods available on site Modification?

Several site modification methods have been devised and adopted to reduce the potential or susceptibility of the soils beneath a site to liquefy. Some of them include

i. Excavation and Replacement of liquefiable soils

ii. Densification of in – situ soils

iii. In –stu improvement of soils by alteration

iv. Grouting or chemical Stabilization.

7. Write a short note on Soil Alteration?

The third major category of site improvement methods is alteration of the soil to reduce the potential for liquefaction. The soil may be made more resistant by the construction of mixed – in place solidified piles or walls to provide shear resistance which would confine an area of liquefiable soils to prevent flow.

8. What is mean by Grouting?

The fourth category of soil improvement methods is soil grouting or chemical stabilization. These would improve the shear resistance of the soils by injection of particulate matter, resins or chemicals into the voids. Common applications are jet grouting and deep soil mixing.

9. What is mean by Structural Damping?

Damping of structural systems plays a major role in determining the response of the structure for ground motions induced by earthquakes. The actual stiffness of foundation and damping co – efficient are dependent on the frequency of vibration.

10. What are the effects of Damping on soil – structure interaction?

Simple single degree of freedom (SDOF) system is considered for the analysis. The system is mounted on a rigid, mass-less and L-Shaped foundation which in turn is supported on an elastic foundation.

11. Define Ductility.

The ability of a structure or its components or of the materials used to offer resistance in the inelastic domain of response in described by the term ‘ Ductility”. It includes the ability to sustain large deformations, and a capacity to absorb energy hysteretic behavior.

12. What are the basic concepts for ductile performance structures?

i. Selection of sound structural configuration with a well defined lateral load resisting system.

ii. Systematic placement of stiff elements with a view to minimize increase in member forces due to torsion.

iii. Availability of direct load path for force transfer from superstructure to soil medium.

iv. Proper detailing of members and joints is very much necessary

13. Write a short note on Push over analysis.

Pushover analysis is a static analysis procedure for assessing the capacity of structural members against seismic forces. A number of widely used procedures (FEMA 273, ATC – 40) compare these demands with the recommended values of member capacities varying with the level of the performance objectives employed. Each member is classified as either force based or displacement based, depending on its mode of behavior.

14. Mention the different Variable affecting sectional ductility.

The variables that affect sectional ductility include,

i. Material variables such as the maximum usable compressive strain in concrete and grade of reinforcement.

ii. Geometric variables such as the amount of tension and compression reinforcement and the shape of the section.

iii. Loading variables such as the level of axial load accompanying shear.

15. What do you understand by Response reduction factor (R)?

It is the factor by which the actual base shear force, that would be generated if the structure were to remain elastic during its response to design basis Earthquake shaking, shall be reduced to obtain the design lateral force. Ductile buildings are designed for seismic forces that are R times lower than the elastic behavior would require.

16. Write a Short notes on the Analysis of structural Response Based on Soil properties.

Analysis of soil structure interaction can be either using the direct method or the multiple – step method. In the direct method, finite element model of the soil – foundation system is generated and solved in a single step. Multi – step method of analysis uses the principle of superposition to isolate the two primary causes of soil – structure interaction, a) the inability of the foundation to match free field deformation; b) the effect of dynamic response of foundation – structure system on the movement of the supporting soil.

17. What is zero period acceleration?

Zero period acceleration implies maximum acceleration experienced by a structure having zero natural period (T =0). An infinitely rigid structure has zero natural period (T = 0). It doesn't deform. Thus relative motion between its mass and its base, Mass has same acceleration as of the ground. Hence ZPA is the same as peak ground acceleration.

18. What is a design spectrum?

Response spectrum developed for displacement, pseudo-velocity and pseudo acceleration in a combined manner for elcentro earthquake (1940) for various damping ratios. This type of spectrum called tripartite response spectrum. For design purpose, local peaks and valleys should be ignored, since natural period can't be calculated with accuracy. Hence smooth cure plotted by considering the average number of elastic response spectrums corresponding to various possible earthquakes at particular site. It is known as design spectrum.

19. What is peak ground acceleration (PGA)?

PGA is a measure of earthquake acceleration. Unlike Richter scale, it is not a measure of the total size of the earthquake, but rather how hard the earth shakes in a given geographical area. PGA is what is experienced by a particle on the ground.

20. Enumerate site specific response spectrum.

A site specific response spectrum is plotted by taking the average of each record of site specific ground motions. This results in smooth means spectrum. The recorded earthquake motions clearly show that response spectrum shape differs for different types of soil profile at the site. Seed, Ugas and Lysmer (1985) plotted the average shape of response of spectrum.

21. What are the methods to reduce liquefaction?

(a) Avoid liquefaction-susceptible soils

(b) Build liquefaction-resistant structures

(c) Shallow foundation aspects

(d) Deep foundation aspect

(e) Improve the soil

(f) Drainage techniques

(g) Verification of improvement

22. List out the effects of liquefaction.

(a) Loss of bearing strength

(b) Lateral spreading

(c) Sand boils

(d) Flow failures

(e) Ground oscillation

(f) Flotation

(g) Settlement.

23. Name two type of liquefaction.

Liquefaction has two types they are

(i) Flow liquefaction

(ii) Cyclic mobility.

24. What is pounding?

Pounding is another important issue in the construction of multistory frame in urban areas. That is when two multistory frames are constructed too close to each other; they may pound on each other during strong ground motion which leads to collision. To avoid collection, adjacent buildings should be separated by minimum gab. These factors imply that nowadays there is a need of earthquake resistance architecture in highly seismic areas.

25. Name the four techniques of aseismic design.

The following four techniques of aseismic design or earthquake resistant building are:

(a) Structural configuration

(b) Lateral strength

(c) Good ductility

(d) Light weight mass.

UNIT – V

DESIGN METHODOLOGY

1. What is the formula to find the load factors for plastic design of steel structures?

In plastic design of steel structures, the following load combinations shall be accounted for

1. 1.7(DL+IL)
2. 1.7(DL+EL)
3. 1.3(DL+IL+EL)

When Earthquake forces are considered on a structure, these shall be combined as per Load combination for plastic design of steel structures and partial safety factor for limit state deign of RC and PSC structures.

2. What are the methods of improving element level Ductility?

Ductility in element level is generally with reference to the displacement and moment curvature relationship of a section. This can be generally improved by

i. Decreasing the tension steel area, yield stress and strain of the tension steel increasing the ultimate compressive strain of concrete.

ii. Increasing the area of compression steel.

iii. Reduction in the axial compression on the section.

iv. Provision of effective confinement stirrups, hoops or ties such that compressive steel does not buckle and concrete is led into three dimensional state of stress such that its ultimate compressive strain increases.

3. Write the IS 13920 provisions for flexural members.

The provisions apply to frame members resisting earthquake induced forces and designed to resist flexure. These members shall satisfy the following provisions

(a) The factored axial stress on the member under earthquake loading shall not exceed 0.1fck.

(b) The member shall preferable have a width to depth ratio more than 0.3

(c) Width of the member shall not be less than 200mm.

(d) The depth D of the member shall preferably be not more than ¼ of clear span.

4. What is the formula for finding out the Base shear using seismic co efficient method?

$$VB = K C\alpha h W$$

Where, VB = is base shear, K is performance factor

C is a co – efficient depending on the flexibility of the structure

αh is design seismic co – efficient.

5. Write a short notes on Review of Indian Code IS 1893 (1984)

IS 1893 (1984) gives the Necessary criteria for the earthquake resistant design of structures. This code states that structures should withstand without structural damage, moderate earthquakes and withstand without total collapse, heavy earthquakes.

This code specifies two methods of analysis

i. Seismic co-efficient method

ii. Modal analysis or Response Spectrum method.

6. What are the structural protective systems?

Modern protective system is based on (i) Seismic base isolation (ii) Passive energy dissipaters (iii) Semi active and active systems. Passive energy dissipaters are classified as hysteric, design seismic co – efficient design seismic co – efficient Visco – elastic and others based on the devices used. Eg yielding of metals through sliding friction

7. Write a short note on Mechanism of Base isolation.

The Mechanism of base isolation subjected to ground motion. The isolation reduces the fundamental lateral frequency of the structure from its fixed base frequency and thus shifts the position of structure in the spectrum from peak plateau region. Also it brings forth additional damping due to the increased damping introduced at the base level and thus reduction in the spectral acceleration is achieved.

8. Write down the steps to improve Global level Ductility?

(a) Increasing the redundancy of the structure

(b) Weak bam and strong column approach.

(c) Avoiding soft first storey effects

(d) Avoiding Non – ductile failure modes like shear, bond and axial compression at the element level

9. Define lateral load analysis of building system.

Earthquake force is an inertia force which is equal to mass times acceleration. Mass of the building is mainly located at its floors. Transferring the horizontal component of seismic force safely to the ground is the major task in seismic design. The floors should transfer the horizontal force to vertical seismic elements viz., columns, frames, walls and subsequently to the foundation finally to the soil.

10. Write a short note on Indian seismic codes.

The codes ensure safety of buildings under earthquake excitation IS 1893 – 1962, recommendations for earthquake resistant design of structures. IS 1893 – 1984 the country has divided into five zones in which one can reasonably forecast the intensity of earthquake shock which will occur in the event of future earthquake.

11. Define the term DBE, MCE and MMI.

DBE: Design Basics Earthquake

MCE: Maximum Considered Earthquake

MMI: Mercalli Intensity Scale

12. What is the design philosophy adopted for earthquake resistant structure?

The extreme loading condition caused by an earthquake and also the low probability of such an event occurring within the expected life of a structure, the following dual design philosophy is usually adopted

i. The structure is designed to resist the expected intensity of ground motion due to a moderate earthquake so that no significant damage is caused to the basic structure and

ii. The structure should also be able to withstand and resist total collapse in the unlikely event of a severe earthquake occurring during its lifetime. The designer is economically justified in this case to allow some marginal damage but total collapse and loss of life must be avoided.

13. Write down the formula to find out the Magnitude as per the IS code.

The amount of strain energy released at the source is indicated by the magnitude of the earthquake.

$$\text{Magnitude} = \text{Log10 (Amax)}$$

Where A is the maximum aptitude in microns (10-3m) recorded by Wood – Anderson seismograph. If E is the energy released, then

$$\text{Log } E = 11.8 + 1.5\ M$$

14. What do you understand by response spectrum?

A Response spectrum is the plot of the maximum response (maximum displacement, velocity, acceleration or any other quantity of interest) to a specified load function Xa (t) for all possible SDOF systems (having different natural frequencies or time periods T and a constant damping ratio).

15. Why is base isolation effective?

The base isolation systems reduce the base shear primarily because the natural vibration period of the isolation mode, providing most of the response, is much longer than the fundamental period of the fixed base structure, leading to a much smaller spectral ordinate. The higher modes are essentially not excited by the ground motion; although their pseudo acceleration is large their modal static responses are very small.

The primary reason for effectiveness of base isolation in reducing earthquake induced forces in a building is the lengthening of the first mode period. The damping is the isolation system and associated energy dissipation is only a secondary factor in reducing structural response.

16. Explain two cases of design horizontal earthquake load.

(a) When the lateral resisting elements are oriented along orthogonal horizontal direction, the structure shall be designed for the effects due to full design earthquake load in one horizontal direction at time.

(b) When the lateral load resisting elements are not oriented along the orthogonal horizontal directions, the structure shall be designed for the effect due to full design earthquake load in one horizontal direction plus 30% of the design earthquake load in the other direction.

17. Write the formula for modal mass (Mk).

The modal mass Mk of mode k is given by:

$$Mk = [\Sigma Wini=1 \phi ik]2 \ / \ g\Sigma Wini=1(\phi ik)2$$

18. Explain design eccentricity.

The design eccentricity, edi to be used at floor I shall be taken as:

$edi = \{1.5\ esi + 0.05bi$

$ores - 0.05bi\}$

Whichever of these gives the more severe effect in the shear of any frame

Where edi = Static eccentricity

esi = defined as the distance between centre of mass and centre of rigidity

bi = floor plan dimension of floor

19. What is additive shear?

Additive shear will be super-imposed for a statically applied eccentricity of $\pm 0.05bi$ with respect to centre of rigidity.

20. Name types of damper's.

(i) Metallic dampers or yielding dampers

(ii) Friction dampers

(iii) Viscous dampers.