**Chapter -1**

**Introduction to Seismic Design Parameter**

**1.1 INTRODUCTION**

Deformation results from plate tectonic forces and gravitational forces. The type of deformation that takes place during an earthquake generally occurs along zones where rocks fracture to produce faults. Before we can understand earthquakes, we first must explore deformation of rocks and faulting.

Within the earth rocks are constatly subjected to forces that tend to bend, twist or fracture them. When rocks bend, twist or fracture they are said to deform or strain (change shape or size). The forces that cause deformation are referred to as stresses. To understand rock deformation we must first explore stress and strain.

Stress is a force applied over an area. One type of stress that we are all used to is a uniform stress, called pressure. A uniform stress is where the forces act equally from all directions. In the earth the pressure due to the weight of overlying rocks is a uniform stress and is referred to as confining stress, if stress is not equal from all directions then the stress is a differential stress. Three kinds of differential stress occur.

**WHAT IS EARTHQUAKE**

When rocks of the earth's crust are suddenly distrubed, vibrations are caused which spread in all directions from the place of disturbance. The passage of these vibrations 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 crust of the earth is called an earthquake.

**CAUSES OF EARTHQUAKES**

Earthquake are caused by processes which fall into two distinct groups Now tectonic earthquake and tectonic earthquake

**Non-Tectonic Earthquakes** The non-tectonic earthquakes are caused either by volcanic eruptions ow collapse of ground. Both of these typon are generally only locally folt. The collapse earthquakes are another example of non-teotonio type.

The volcanic, earthquakes are caused due to jerkn or vibration induced in ground of a volcanic vents. Sinco the upward panaago of the lawn is invariably nchi under great pressure from below nuch jorku or vibrations are almost natural. canes, the volcano eruption Itel may be of an lava suddenly and with great promu The volcanic earthquake are a feature of common experience.

**Tectonic Earthquakes** The Tectonic Earthquakes are the most destructive ovents. Their origin is n yot an unsolved geological problem. It is broadly groped that these aro caused by displacement of blocks of the rock making the body of the earth, and that the focus of an earthquake indicates the depth at which the displacement takes place. But as to how and why the displacement occura below the surface is not clearly understood Many theories have been forwarded from time to time to explain the rupture and displacement of the blocks of rocks below the surface, but none has been accepted universally. The Elastic Rebound Theory Theory of H. Roid is presently the most popular theory in explaining the mechanism of tectonic earthquakes.

According to this theory any block of the earth that is under the influence of unequal forces would withstand the forces in the initial stages by undergoing elastic deformation. The forces get stored in the rock as elastic strain till a limit is reached when the elasticity of the rock block in question is exceeded by the operating forces. A fracture is caused at that stage in the block and under the influence of those forces the blocks so created by fracturing move past each other. This is called faulting.

**EPICENTER** The point or place on the surface vertically above the focus of an earthquake is termed as epicentre of that particular earthquake. It is a place on the earth where the earthquake disturbances reach first of all and do the maximum damage. The effects of particular earthquake will apear diminishing away from the epicenter.

**FOCUS OR HYPOCENTRE**

The earthquakes are mostly due to some disturbance in the rocks below the surface. This disturbance is commonly in the form of displacement or faulting of rocks at any depth. Such a displacement, however, always has a beginning at a certain point or narrow zone. This is the place or point of origin of a particular earthquake and is commonly termed as focus or sometimes as epicentre. In modern semiological science it is becoming more conventional to interpret the term focus as a zone rather than a point.

**EARTHQUAKE WAVES**

During each earthquake of any origin elastic waves are generated at the place of origin and these waves spread in cell directions. It is now well established that during on earthquake three well defined types of waves are produced. These are briefly termed as P S, L waves.

(a) The P waves or Primary waves (also termed "Push and pull" waves) are the fastest of the seismic waves. These are longitudinal waves in character, that is, the particles vibrate in the direction of propagation. In this aspect the P. waves are similar to sound waves. The velocity of P-waves is controlled the relationship.

(b) The S-waves or secondary waves are like light waves in which the particles vibrate at right angles to the direction of propagation. Their vel. is controlled by the relationship :

Where, and p is the density of the medium. It is obvious that these waves would travel faster in more rigid rocks. are elastic constants related to the rigidity of the medium and Suppose through the medium at all.

**THE SEISMIC ZONES OF INDIA**

It has been seen that earthquake occur frequentely and repeatedly in those parts of the earth's crust which have a marked instability, where certain adjustments and ro-adjustments under the effect of stored strain keep on taking place. Such areas are the mountain belts of geologically young age, where the crustal rocks are still giving way to the stored strains and heading for the state of stability. In addition,

In view of these points, India can be divided into three parts of different seismic activity, viz, highly seismic, moderately seismic, and poorly seismic-zones.

**1. Moderately Seismic Zone** : Leaving aside the zones of the great boundary fault and the syntaxial bends, the other parts of the Himalaya ranges, and the Indo Gangetic planes are moderately seismic areas. A study about the formation of Indo-Gangetic planes indicates that these are made of alluvial deposits laid into a vast tectonic depression present in front of the foot-hills of the Himalayan range. The base of these large basin and the alluvial sediments are still in an unstable condition. Earthquakes are common in this zone.

**2. Poorly Seismic Zone** : The peninsular India which is a region of remarkable stability, comprises the zone. Since mountain building in this part ceased lonta is in a geologically static condition. Though there are several faults, but these are used long ago, it quite inactive. Very feeble earth-quakes, sometimes occur along the marginal area.This indicates that faults along these border areas have not yet reached the state of equilibrium. Also sometimes, mild shocks are felt in this zone, whenever the major earthquake in the northen parts of the country.

**INTENSITY OF EARTHQUAKES**

As it has been experienced from time to time earthquakes have a highly variable intensity. Some of the earthquakes are so strong that they cause a great damage while there are some which are hardly felt. For a comparative study of earthquakes and demarcation of the area of known earthquake intensities. It is essential to have a measure or a scale of reference. Available data for this purpose is the acceleration produced. Sensation of people and the extent of damage caused to the building and ground surface. Initially a scale of earthquakes intensity with ten divisions was given by Rassi and force which was based entirely an the sensation of people and damage caused. However it has been modified by Mercalli and further by wood and Neumann in 1931, which is, in present day use. Scale is given below.

Introduction to Seismic Design Parameters 1 9 Strong - Minor damage to the buildings.

Particularly to their over hanging and projecting parts.

Very strong - Damage to the building, such as cracks in the walls etc.

Destructive - Grater damage to the building involving over drawing of over hanging and projecting portions like chimneys Ruinous Severe damage to the buildings, involving their over drawing Disasterous - With a severe, general destruction of building Very disastrous Severe destruction of building and cracking of the ground Catastrophic - Large scale to complete destruction of building and ground

MAGNITUDE OF AN EARTHQUAKE

Whenever the train energy held capture The real displacement of th is small, while in a function of the If 'a' is the relationship M energy released Though in remains the sar as it does not Richter h

damage. Houses not bolted down move off foundations. Some underground pipe broken. Ground cracks. Serious damage to Well built buildings suffer considerable reservoirs, Most buildings and their foundations destroyed. Dams damaged. Large landslides occur. Water thrown on the banks of canals, rivers, lakes. Ground cracks in large areas,

**Magnitude**

The magnitude of earthquake is a number, which is a measure of energy released in an earthquake. It is defined as logarithm to the base 10 of the maximum trace amplitude, expressed in microns, which the standard short-period torsion seismometer (with a period of 0.8s, magnification 2800 and damping nearly critical) would register due to the earthquake at an epicentral distance of 100 km.

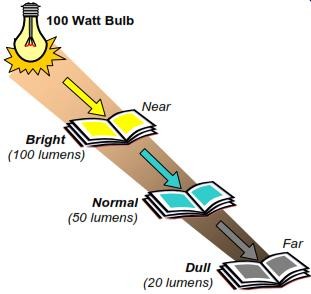
**Intensity**

The intensity of an earthquake at a place is a measure of the strength of shaking during the earthquake, and is indicated by a number according to the modified Mercalli Scale or M.S.K. Scale of seismic intensities.

**Basic difference between Magnitude and Intensity**

Magnitude of an earthquake is a measure of its size, whereas intensity is an indicator of the severity of shaking generated at a given location. Clearly, the severity of shaking is much higher near the epicenter than farther away.

This can be elaborated by considering the analogy of an electric bulb. Here, the size of



**Fig. 2.2 Reducing illumination with distance from an electric bulb**

the bulb (100- Watt) is like the magnitude of an earthquake (M), and the illumination (measured in lumens) at a location like the intensity of shaking at that location (

**Liquefaction**

Liquefaction is a state in saturated cohesion-less soil wherein the effective shear strength is reduced to negligible value for all engineering purpose due to pore pressure caused by vibrations during an earthquake when they approach the total confining pressure. In this condition, the soil tends to behave like a fluid mass.

**Tectonic Feature**

The nature of geological formation of the bedrock in the earth’s crust revealing regions characterized by structural features, such as dislocation, distortion, faults, folding, thrusts, volcanoes with their age of formation, which are directly involved in the earth movement or quake resulting in the above consequences.

**Seismic Mass**

It is the seismic weight divided by acceleration due to gravity.

**Seismic Weight**

It is the total dead load plus appropriate amounts of specified imposed load.

**Base**

It is the level at which inertia forces generated in the structure are transferred to the foundation, which then transfers these forces to the ground.

**Centre of Mass**

The point, through which the resultant of the masses of a system acts, is called Centre of Mass. This point corresponds to the centre of gravity of masses of system.

**Centre of Stiffness**

The point, through which the resultant of the restoring forces of a system acts, is called Centre of stiffness.

**Box System**

Box is a bearing wall structure without a space frame, where the horizontal forces are resisted by the walls acting as shear walls.

**Band**

A reinforced concrete, reinforced brick or wooden runner provided horizontally in the walls to tie them together, and to impart horizontal bending strength in them.

**Ductility**

Ductility of a structure, or its members, is the capacity to undergo large inelastic deformations without significant loss of strength or stiffness.

**Shear Wall**

Shear wall is a wall that is primarily designed to resist lateral forces in its own plane.

**Ductile Detailing**

Ductile Detailing is the preferred choice of location and amount of reinforcement in reinforced concrete structures to provide adequate ductility. In steel structures, it is the design of members and their connections to make them adequate ductile.

**Elastic Seismic Acceleration Co-Efficient A**

This is the horizontal acceleration value, as a fraction of acceleration due to gravity, versus natural period of vibration *T* that shall be used in design of structures.

**Natural Period *T***

Natural period of a structure is its time period of undamped vibration.

1. Fundamental Natural Period *T*l: It is the highest modal time period of vibration along the considered direction of earthquake motion.
2. Modal Natural Period *T*k: Modal natural period of mode *k* is the time period of vibration in mode *k*.

**Normal Mode**

Mode of vibration at which all the masses in a structure attain maximum values of displacements and rotations, and also pass through equilibrium positions simultaneously.

**OverstrengthStrength**

considering all factors that may cause its increase e.g., steel strength being higher than the specified characteristic strength, effect of strain hardening in steel with large strains, and concrete strength being higher than specified characteristic value.

**ISOSEISMALS**

These are lines passing through values of same intensity in a particular earthquake record. Thus, while using Mercalli scale, for instance, at ten different places of a region almost similar effects are observed during an earthquake. A line joining all these ten points will be an isoseismal. Similarly, in four places lying outside the first ten places effects of lesser nature are observed during the same earthquake. These four points, when joined together, make another isoseismal. The exact value of these two lines or isoseismal would be assigned by company them with the Mercalli Scale effects and may be any numbers between 1 to 10.

The isoseismal record of an earthquake may show lines that are closely or widely spaced any may from a regular and even pattern or they may be irregular in nature.

1**. Nature of the shocks:** Thus a shallow shock (with focus not very deep) may give rise to high isoseismal (above values VI) in a small area, whereas a deep shock m produce moderate isoseismals spread broadly over a much large area.

**2. Nature of the rocks** : The petrological and structural variations in the rock When a number of isoseismal of a particular earthquake are properly plotted, the focus of shock will ordinarily lio beneath the centre of the highest isoseismal. The rule, however, is not applicable universally and exceptions are numerous

**RECORDING OF AN EARTHQUAKE**

During an earthquake, vibration are transmitted over variable distances. These variations or surface displacement are recorded by instrument called seismographs. The record of an earthquake, thus obtained is culled seismograph.

Fixed on the ground. A weighted horizontal beam is loosely supported against it with the help of a wire. On the free end of the horizontal beam is a small mirror to reflect light. There is a revolving drum to which a photographic paper is wrapped.

The drum is mounted on a screw so that the paper once exposed moves farward. These are the essential parts of a seismograph.

Whenever there are vibration, the vertical support and the drum, being rigidly fixed in the ground, also move simultaneously. The weighted horizontal beam tending to remain in stationary position, records the vibration. A beam of light threwn over the mirror is reflected on to the photographic paper fixed on the revolving drum. Earthquake Resistant Building Construction A seismograph is muitable only when the vibration are not of a very high intense drawing the instrument out of balance For recording higher intensities, special stro matrix instruments are used

**Seismogram Measuring Instruments**

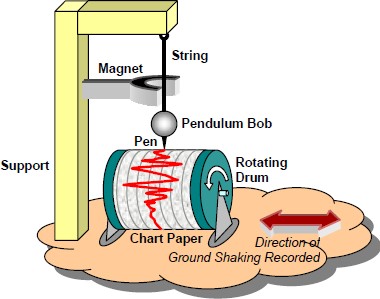
**Seismograph:** The instrument that measures earthquake shaking is known as a seismograph (Fig. 4.4). It has three components –

* + **Sensor –** It consists of pendulum mass, string, magnet and support.
  + **Recorder –** It consists of drum, pen and chart paper.
  + **Timer –** It consists of the motor that rotates the drum at constant speed.

**Seismoscopes:** Some instruments that do not have a timer device provide only the maximum extent (or scope) of motion during the earthquake.

**Digital instruments:** The digital instruments using modern computer technology records the ground motion on the memory of the microprocessor that is in-built in the instrument.

In a histogram the earthquake waves are recorded.



**Fig. 4.4 Schematic of Early Seismograph**

**Scale of Measurement**

The Richter Magnitude Scale (also called Richter scale) assigns a magnitude number to quantify the energy released by an earthquake. Richter scale is a base 10 logarithmic scale, which defines magnitude as the logarithm of the ratio of the amplitude of the seismic wave to an arbitrary minor amplitude.

The magnitude M of an Earthquake is defined as

M = log10 A - log10 A0

Where,

A =Recorded trace amplitude for that earthquake at a given distance as written by a standard type of instrument (say Wood Anderson instrument).

A0 = Same as A, but for a particular earthquake selected as standard.

This number M is thus independent of distance between the epicentre and the station and is a characteristic of the earthquake. The standard shock has been defined such that it is low enough to make the magnitude of most of the recorded earthquakes positive and is assigned a magnitude of zero. Thus, if A = A0,

M = log10 A0 - log10 A0 = 0

**Standard shock of magnitude zero**: It is defined as one that records peak amplitude of one thousandths of a millimetre at a distance of 100 km from the epicentre.

1. Zero magnitude does not mean that there is no earthquake.
2. Magnitude of an earthquake can be a negative number also.
3. An earthquake that records peak amplitude of 1 mm on a standard seismograph at 100 km will have its magnitude as

M = log10 (1) - log10 (10-3)= 0 – (-3) = 3

**Magnitude of a local earthquake:** It is defined as the logarithm to base 10 of the maximum seismic wave amplitude (in thousandths of a mm) recorded on Wood Anderson seismograph at a distance of 100 kms from the earthquake epicentre.

**GLOSSARY OF EARTHQUAKE**

**1. Earthquake**: This term is used to describe both sudden slip on a fault and the resulting ground shaking and radiated seismic energy caused by the slip or by volcanic or magnatic activity or other sudden stress changes in the earth.

**2. Earthquake risk:** The probable building damage and number of people that are expected to be hurt or killed if a likely earthquake an a particular fault occurs. Earthquake risk and earthquake hazard are occasionally used interchangeably

**3. Earthquake hazard** : Anything associated with an earthquake that may affect the normal activities of people. This includes surface faulting, ground shaking. landslides, liquefaction, tectonic deformation, tsunamies and seiches.

**4.Epicentre**: The point on the earth's surface vertically above the paint in the crust where seismic rupture begins.

**5. Alluvium** : Loose gravel, sand, silt or clay disposited by streams.

**6. Seismic moment**: A measure of the size of an earthquake based on the area of fault rupture, the average amount of slip and the force that was required to overcome the friction sticking the racks together that were offset by faulting, seismic moment can also be calculated from the amplitude spectra of seismic waves.

**7. Seismic zone**: An area of seismicity probably sharing a common cause. Example "The Himalayan Zone."

**8. Seismogenic** : Capable of generating earthquake.

**9. Seismogram**: A record written by a seismograph in response to ground motions produced by an earthquake, explosion or other ground motion sources.

**10. Seismology**: The study of earthquake and the structure of the earth, by both naturally and artificially generated seismic waves.

**11. Lithosphere**: The outer salid part of the earth including the crust and uppermost The lithosphere is about 100 km thick although its thickness is age dependent.

**12. Mantle** : The part of the earth's interior between the metallic outer care and the crust.

**13. Love wave:** A type of seismic surface wave having a horizontal motion that is transverse to the direction the wave is travelling.

**14. Oceanic spreading ridge:** A fracture zone along the ocean bottom where malten mantle material cames to the surface, thus creating new crust. This fracture can be seen beneath the ocean as a line of ridges that form as molten rock reaches the ocean bottom and solidifies.

**15. Plate tectonics**: A theory supported by a wide range of evidence that considers the earth's crust and upper mantle to be composed of several large. Then, relatively rigid plates that move relative to one another. Slip on faults that define the plate boundaries commonly results in earthquake.

Several styles of faults sound the plates including thrust faults along which plate material is subjected or consumed in the mantle oceanic spreading ridges along which new crystal material is produced and transform faults that accommodates horizontal slip between adjoining plate.

**16. Rayleigh wave:** A seismic wave causing the ground to shake in an elliptical ation with no transverse or perpendicular motion.

**17. Fault** : A fracture along which the blocks of crust an either side have moved relative to one another parallel to the fracture. Stripe-slip faults are vertical (or nearly vertical) fractures where posite to an observer looking across the fault move to the right, the slip style is termed right lateral, if the block moves to the left, the motion is termed left lateral. the blocks have mostly moved horizontally. If the block

**18. Dip-slip Faults** : are inclined fractures where the blocks have mostly shifted vertically. If the rock mass above an inclined fault moves down, the fault is termed normal whereas. If the rock above the fault moves up, the fault is termed reverse (or thrust) oblique-slip faults have significant components of bath slip styles.

**19. Hypocentre**: The point within the earth where an earthquake rapture starts.Also commonly termed the focus.

**20. Intensity**: A number describing the severity of an earthquake in terms of its effect on the earth's surface and an humans and their structure. There are many intensity values for an earthquake, depending on where you are unlike the magnitude, which is one number for each earthquake.

**21. Active Fault** : A fault that is likely to have another earthquake same time i the future. Faults are commonly considered to be active. If they have moved one more times in the past Earthquake Resistant Building Construction the aftershocks and the longer they will continue

**22. After shock :** Earthquake that follow the largest shock of an earthquake equence. They are smaller than the main shock and continue over a period of week months, or years. In general the larger the mainshock, the larger and more numerou

**23. A seismic**: This term describe a fault on which no earthquakes have been observed sediment or soil, a subset of the basement, 24, Bedrock : Relatively hard, solid rock that commonly underlies softer rock

**25. Benioff zone** : A dipping planner zone of earthquake that is produced bu 4 interaction of a down going accanic crystal plate with a continental plate. The earthquake can be produced by slip along the subduction thrust fault on iction thrust fault or by slip on faults within the downgoing plate as result of bending and extension as the plate pulled into the mantle. Also known as the Wadati - Benioff zone.

**26.body waves:-:** A seismic wave that moves through the interior of the earth. opposed to the surface waves that travel near the earth's surface P and S waves are boby wave.

**27. Crust:** The outermost major layer of the earth, ranging from about 10 to 13 km in thickness worldwide. The uppermost 15 to 35 km of crust produce earthquake. brittle enough to

**28. Core**: The innermost part of earth. The outer core extends from 2500 to 3500 miles below the earth's surface and is liquid metal. The inner core is the central 500 miles and is solid metal.

**29. S-Wave**: A seismic body wave that shapes the ground back and beneath perpendicular to the direction the wave is moving also called a shear wave.

**30. Sand boil**: Sand and water that comes out onto the ground surface during an earthquake as a result of liquefaction at shallow depth.

**31. Seismic gap**: A section of a fault that has produced earthquakes in the past but is now quiet.

**32. Seismicity** : The geographic and historical distribution of earthquake.

**33. Reflection**: The energy or wave from an earthquake that has been reflected rom a boundary between two different material within the earth just as a mirror eflects light.

**34. Refraction**: The deflection or bending of the ray path of a seismic wave caused its passage from one material to another having different elastic properties. Bending a tsunami wave front away to variations in the water depth along a coastline.

**Types of Earthquake Magnitude Scales**

Several scales have historically been described as the “Ritcher Scale”. The Ritcher local magnitude (*ML*) is the best known magnitude scale, but it is not always the most appropriate scale for description of earthquake size. The Ritcher local magnitude does not distinguish between different types of waves.

At large epicentral distances, body waves have usually been attenuated and scattered sufficiently that the resulting motion is dominated by surface waves.

Other magnitude scales that base the magnitude on the amplitude of a particular wave have been developed. They are:

Surface Wave Magnitude (*M*S)

Body Wave Magnitude (*M*b)

Moment Magnitude (*M*w)

**Surface Wave Magnitude (*M*S)**

The *surface wave magnitude* (Gutenberg and Ritcher, 1936) is a worldwide magnitude scale based on the amplitude of Rayleigh waves with period of about 20 sec. The surface wave magnitude is obtained from

*M*S = log *A* + 1.66 log Δ + 2.0

Where A is the maximum ground displacement in micrometers and Δ is the epicentral distance of the seismometer measured in degrees (3600 corresponding to the circumference of the earth).

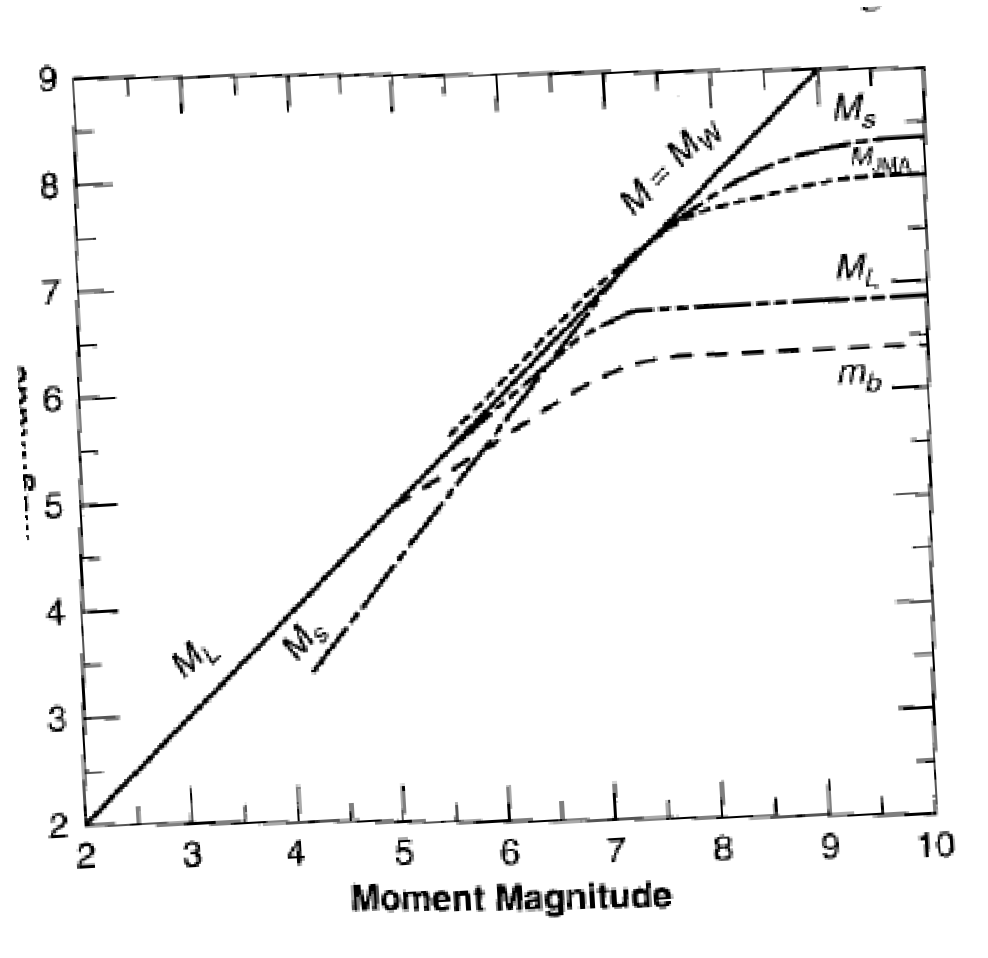
The surface wave magnitude is most commonly used to describe the size of shallow (less than about 70 km focal depth), distant (farther than about 1000 km) moderate to large earthquakes.

**Body Wave Magnitude (*M*b)**

For deep-focus earthquakes, surface waves are often too small to permit reliable evaluation of the surface wave magnitude. The *body wave magnitude* (Gutenberg, 1945) is a worldwide magnitude scale based on the amplitude of the first few cycles of p-waves which are not strongly influenced by the focal depth (Bolt, 1989). The body wave magnitude can be expressed as

*Mb* = log *A* – log *T* + 0.01Δ + 5.9

Where, A is the p-wave amplitude in micrometers and T is the period of the p-wave (usually about one sec).



**Fig. 4.5 Saturation of various magnitude scale: *Mw* (Moment Magnitude), *ML* (Ritcher Local Magnitude), *MS* (Surface Wave Magnitude), *mb* (Short-period Body Wave Magnitude), *mB* (Long-period Body Wave Magnitude), and *MJMA* (Japanese Meteorological Agency Magnitude).**

###### Saturation

For strong earthquakes, the measured ground-shaking characteristics become less sensitive to the size of the earthquake than the smaller earthquakes. This phenomenon is referred to as *saturation* (Fig. 4.5)*.*

The body wave and the Ritcher local magnitudes saturate at magnitudes of 6 to 7 and the surface wave magnitude saturates at about *Ms* = 8.

To describe the size of a very large earthquake, a magnitude scale that does not depend on ground-shaking levels, and consequently does not saturate, would be desirable.

**Moment Magnitude (*Mw*)**

The only magnitude scale that is not subject to saturation is the moment magnitude.

The moment magnitude is given by:

*Mw* = [(log *M0*)/1.5] – 10.7

Where, *M0* is the seismic moment in dyne-cm.

**Earthquake Intensity**

Earthquake magnitude is simply a measure of the size of the earthquake reflecting the elastic energy released by the earthquake. It is usually referred by a certain real number on the Ritcher scale (e.g. magnitude 6.5 earthquake).

On the other hand, earthquake intensity indicates the extent of shaking experienced at a given location due to a particular earthquake. It is usually referred by a Roman numeral on the Modified Mercalli Intensity (MMI) scale as given below:

|  |  |
| --- | --- |
| I | Not felt except by a very few under especially favourable circumstances. |
| II | Felt by only a few persons at rest, especially on upper floors of buildings; delicately  suspended objects may swing. |
| III | Felt quite noticeably indoors, especially on upper floors of buildings, but many people do not recognize it as an earthquake; standing motor cars may rock slightly; vibration  like passing of truck; duration estimated. |
| IV | During the day felt indoors by many, outdoors by few; at night some awakened;  dishes, windows, doors disturbed; walls make cracking sound; sensation like heavy truck striking building; standing motor cars rocked noticeably. |
| V | Felt by nearly everyone, many awakened; some dishes, windows, etc., broken; a few  instances of cracked plaster; unstable objects overturned; disturbances of trees, piles, and other tall objects sometimes noticed; pendulum clocks may stop. |
| VI | Felt by all, many frightened and run outdoors; some heavy furniture moved; a few  instances of fallen plaster or damaged chimneys; damage slight. |
| VII | Everybody runs outdoors; damage negligible in buildings of good design and construction, slight to moderate in well-built ordinary structures, considerable in poorly built or badly designed structures; some chimneys broken; noticed by persons  driving motor cars. |
| VIII | Damage slight in specially designed structures, considerable in ordinary substantial buildings, with partial collapse, great in poorly built structures; panel walls thrown out of frame structures; fall of chimneys, factory stacks, columns, monuments, walls; heavy furniture overturned; sand and mud ejected in small amounts; changes in well  water; persons driving motor cars disturbed. |
| IX | Damage considerable in specially designed structures; well-designed frame structures  thrown out of plumb; great in substantial buildings, with partial collapse; buildings shifted off foundations; ground cracked conspicuously; underground pipes broken. |

|  |  |
| --- | --- |
| X | Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations; ground badly cracked; rails bent; landslides considerable  from river banks and steep slopes; shifted sand and mud; water splashed over banks. |
| XI | Few, if any (masonry) structures remain standing; bridges destroyed; broad fissures in ground; underground pipelines completely out of service; earth slumps and land slips  in soft ground; rails bent greatly. |
| XII | Damage total; practically all works of construction are damaged greatly or destroyed; waves seen on ground surface; lines of sight and level are destroyed; objects thrown  into air. |

**MSK Intensity Scale**

The MSK intensity scale is quite comparable to the Modified Mercalli intensity scale but is more convenient for application in field and is widely used in India. In assigning the MSK intensity scale at a site, due attention is paid to:

Type of Structures (Table – A)

Percentage of damage to each type of structure (Table – B)

Grade of damage to different types of structures (Table – C)

Details of Intensity Scale (Table – D)

The main features of MSK intensity scale are as follows:

###### Table – A : Types of Structures (Buildings)

|  |  |
| --- | --- |
| **Type of**  **Structures** | **Definitions** |
| A | Building in field-stone, rural structures, unburnt – brick houses, clay houses. |
| B | Ordinary brick buildings, buildings of large block and prefabricated type, half  timbered structures, buildings in natural hewn stone. |
| C | Reinforced buildings, well built wooden structures. |

**Table – B : Definition of Quantity**

|  |  |
| --- | --- |
| **Quantity** | **Percentage** |
| Single, few | About 5 percent |
| Many | About 50 percent |
| Most | About 75 percent |

**Table – C : Classification of Damage to Buildings**

|  |  |  |
| --- | --- | --- |
| **Grade** | **Definitions** | **Descriptions** |
| G1 | Slight damage | Fine cracks in plaster; fall of small pieces of plaster. |
| G2 | Moderate damage | Small cracks in plaster; fall of fairly large pieces of plaster;  pantiles slip off cracks in chimneys parts of chimney fall down. |
| G3 | Heavy damage | Large and deep cracks in plaster; fall of chimneys. |
| G4 | Destruction | Gaps in walls; parts of buildings may collapse; separate parts of  the buildings lose their cohesion; and inner walls collapse. |
| G5 | Total damage | Total collapse of the buildings. |

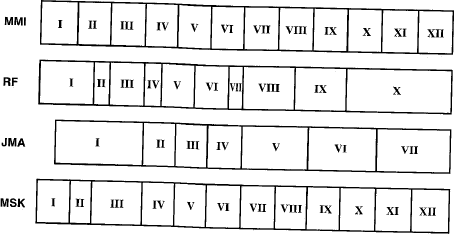
**Table – D : Details of Intensity Scale**

|  |  |  |
| --- | --- | --- |
| **Intensity** | | **Descriptions** |
| **I** | Not noticeable | The intensity of the vibration is below the limits of sensibility;  the tremor is detected and recorded by seismograph only. |
| **II** | Scarcely noticeable  (very slight) | Vibration is felt only by individual people at rest in houses,  especially on upper floors of buildings. |
| **III** | Weak, partially observed only | The earthquake is felt indoors by a few people, outdoors only in favourable circumstances. The vibration is like that due to the passing of a light truck. Attentive observers notice a slight  swinging of hanging objects, somewhat more heavily on upper floors. |
| **IV** | Largely observed | The earthquake is felt indoors by many people, outdoors by few. Here and there people awake, but no one is frightened. The vibration is like that due to the passing of a heavily loaded truck. Windows, doors, and dishes rattle. Floors and walls crack. Furniture begins to shake. Hanging objects swing slightly. Liquid in open vessels are slightly disturbed. In standing motor cars, the  shock is noticeable. |
| **V** | Awakening | 1. The earthquake is felt indoors by all, outdoors by many. Many people awake. A few run outdoors. Animals become uneasy. Buildings tremble throughout. Hanging objects swing considerably. Pictures knock against walls or swing out of place. Occasionally pendulum clocks stop. Unstable objects overturn or shift. Open doors and windows are thrust open and slam back again. Liquids spill in small amounts from well-filled open containers. The sensation of vibration is like that due to heavy objects falling inside the buildings. 2. Slight damages in buildings of Type A are possible. 3. Sometimes changes in flow of springs. |
| **VI** | Frightening | 1. Felt by most indoors and outdoors. Many people in buildings are frightened and run outdoors. A few persons loose their balance. Domestic animals run out of their stalls. In few instances, dishes and glassware may break, and books fall down. Heavy furniture may possibly move and small steeple bells may ring. 2. Damage of Grade 1 is sustained in single buildings of Type B and in many of Type A. Damage in few buildings of Type A is of Grade 2. 3. In few cases, cracks up to widths of 1cm possible in wet ground; in mountains occasional landslips; change in flow of   springs and in level of well water are observed. |
| **VII** | Damage of buildings | 1. Most people are frightened and run outdoors. Many find it difficult to stand. The vibration is noticed by persons driving motor cars. Large bells ring. 2. In many buildings of Type C damage of Grade 1 is caused; in many buildings of Type B damage is of Grade 2. Most |

|  |  |  |
| --- | --- | --- |
|  |  | buildings of Type A suffer damage of Grade 3, few of Grade  4. In single instances, landslides of roadway on steep slopes; crack inroads; seams of pipelines damaged; cracks in stone walls.  c) Waves are formed on water, and is made turbid by mud stirred up. Water levels in wells change and the flow of springs changes. Sometimes dry springs have their flow resorted and existing springs stop flowing. In isolated instances parts of sand and gravelly banks slip off. |
| **VIII** | Destruction of buildings | 1. Fright and panic; also persons driving motor cars are disturbed. Here and there branches of trees break off. Even heavy furniture moves and partly overturns. Hanging lamps are damaged in part. 2. Most buildings of Type C suffer damage of Grade 2, and few of Grade 3. Most buildings of Type B suffer damage of Grade   3. Most buildings of Type A suffer damage of Grade 4. Occasional breaking of pipe seams. Memorials and monuments move and twist. Tombstones overturn. Stone walls collapse.   1. Small landslips in hollows and on banked roads on steep slopes; cracks in ground up to widths of several centimetres. Water in lakes becomes turbid. New reservoirs come into existence. Dry wells refill and existing wells become dry. In many cases, change in flow and level of water is observed. |
| **IX** | General damage of buildings | 1. General panic; considerable damage to furniture. Animals run to and fro in confusion, and cry. 2. Many buildings of Type C suffer damage of Grade 3, and a few of Grade 4. Many buildings of Type B show a damage of Grade 4 and a few of Grade 5. Many buildings of Type A suffer damage of Grade 5. Monuments and columns fall. Considerable damage to reservoirs; underground pipes partly broken, In individual cases, railway lines are bent and roadway damaged. 3. On flat land overflow of water, sand and mud is often observed. Ground cracks to widths of up to 10 cm, on slopes and river banks more than 10 cm. Furthermore, a large number of slight cracks in ground; falls of rock, many landslides and earth flows; large waves in water. Dry wells renew their flow and existing wells dry up. |
| **X** | General destruction of building | 1. Many buildings of Type C suffer damage of Grade 4, and a few of Grade 5. Many buildings of Type B show damage of Grade 5. Most of Type A have destruction of Grade 5. Critical damage to dykes and dams. Severe damage to bridges. Railway lines are bent slightly. Underground pipes are bent or broken. Road paving and asphalt show waves. 2. In ground, cracks up to widths of several centimetres, |

|  |  |  |
| --- | --- | --- |
|  |  | sometimes up to 1m. Parallel to water courses occur broad fissures. Loose ground slides from steep slopes. From river banks and steep coasts, considerable landslides are possible. In coastal areas, displacement of sand and mud; change of water level in wells; water from canals, lakes, rivers. etc.  thrown on land. New lakes occur. |
| **XI** | Destruction | 1. Severe damage even to well built buildings. bridges, water dams and railway lines. Highways become useless Underground pipes destroyed. 2. Ground considerably distorted by broad cracks and fissures, as well as movement in horizontal and vertical directions. Numerous landslips and falls of rocks. The intensity of the earthquake requires to be investigated specifically. |
| **XII** | Landscape changes | 1. Practically all structures above and below ground are greatly damaged or destroyed. 2. The surface of the ground is radically changed. Considerable ground cracks with extensive vertical and horizontal movements are observed. Falling of rock and slumping of river banks over wide areas, lakes are dammed; waterfalls appear and rivers are deflected. The intensity of the earthquake requires to be investigated specially. |

**4. Comparison of Intensity Values of Different Scales**



**Fig. 4.5 Comparison of Intensity Values of Different Scales**

**4. Effect of Earthquake of various Magnitude and Intensity**

The following describes the typical effects of earthquakes of various magnitudes near the epicenter. The values are typical only. They should be taken with extreme caution, since intensity and thus ground effects depend not only on the magnitude, but also on the distance to the epicenter, the depth of the earthquake's focus beneath the epicenter, the location of the epicenter and geological conditions (certain terrains can amplify seismic signals).

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Magnitude** | **Description** | **Mercalli intensity** | **Average earthquake effects** | **Average frequency of occurrence**  **(estimated)** |
| 1.0-1.9 | Micro | I | Micro earthquakes, not felt, or felt rarely.  Recorded by seismographs. | Continual/several  million per year |
| 2.0-2.9 | Minor | I to II | Felt slightly by some people. No damage to  buildings. | Over one million  per year |
| 3.0-3.9 | III to IV | Often felt by people, but very rarely causes  damage. Shaking of indoor objects can be noticeable. | Over 100,000 per year |
| 4.0-4.9 | Light | IV to VI | Noticeable shaking of indoor objects and rattling noises. Felt by most people in the affected area. Slightly felt outside. Generally causes none to minimal damage. Moderate to significant damage very unlikely. Some objects may fall off shelves  or be knocked over. | 10,000 to 15,000  per year |
| 5.0-5.9 | Moderate | VI to VIII | Can cause damage of varying severity to poorly constructed buildings. At most, none to slight damage to all other buildings. Felt  by everyone. | 1,000 to 1,500 per year |
| 6.0-6.9 | Strong | VII to X | Damage to a moderate number of well-built structures in populated areas. Earthquake- resistant structures survive with slight to moderate damage. Poorly designed structures receive moderate to severe damage. Felt in wider areas; up to hundreds of miles/kilometers from the epicenter.  Strong to violent shaking in epicentral area. | 100 to 150 per year |
| 7.0-7.9 | Major | VIII or Greater | Causes damage to most buildings, some to partially or completely collapse or receive severe damage. Well-designed structures are likely to receive damage. Felt across  great distances with major damage mostly limited to 250 km from epicenter. | 10 to 20 per year |
| 8.0-8.9 | Great | Major damage to buildings, structures likely to be destroyed. Will cause moderate to heavy damage to sturdy or earthquake- resistant buildings. Damaging in large  areas. Felt in extremely large regions. | One per year |
| 9.0 and greater | At or near total destruction – severe damage or collapse to all buildings. Heavy damage  and shaking extends to distant locations. Permanent changes in ground topography. | One per 10 to 50 years |

**FUNDAMENTAL PERIOD**

The flexibility of a building (elastic property), and its mass, causes to develop a ibratory motion. When they are subjected to dynamic action such as earthquake.

During seismic shock, the base of a building moves with the ground and the building swings back-and-forth (vibratory motion). The building oscillate back-and- forth horizontally and after sometime comes back to its true position. This vibratory motion of a building depends upon fundamental period, which is an inherent property

**Definition :** The time taken by a building structure in seconds for one complete ile of oscillation (i.n. one complete back-and-forth movement) during the effect of mic loading is termed as fundamental period or natural period. It is generaly hy To Fundamental period T' is always same for a building and any structural Donations made to the building will change value of 'T'. More of mass and flexibility building, longer is the value of "T'. Thus taller buildings have more value of T as compared to low to medium rise buildings.

On the basis of T, building may be classified as :

1.Rigid (T will be less than 0.3 seconds)

2. Semi rigid (t lies 0.3-0.1 seconds)

3. Flexible (T > 1.0 seconds).

Fundamental period T' usually varies from 0.05 seconds to 2.00 seconds. Fundamental period of some important building structure is

**Chapter 2**

**Performance of Buildings Under Past Earthquakes**

The seismic performance of masonry buildings during the earthquakes is documented in reconnaissance reports (EERI, 2002, DEQ, 2000, DEQ, 1997) from which number of observations are summarized as follows.

**BHUJ EARTHQUAKE, JANUARY 26, 2001**

A massive earthquake of magnitude ML = 6.9 on richter scale, M = 7.0, Mg = M = 7.7 occurred on the morning of January 26, 2001, Friday at 08:46:42.9

**Types of Construction**

Different types of masonary constructions have been observed in the affected areas, from which summarized that, (shown in figure 2.2 and (b)

(a) Traditional earthen houses (Kachn houses) reinforced with wooden stick and sun-dried clay brick construction. In both the construction plan circular and about 4-8 m in diameter, which is also called Bhunga in locally language. The walls of this types of buildings raised on a shallow foundation with a conical roof on top tied with ropes to form a thatch roof.

(b) Village houses made up from random rubble masonry laid in lime or other mortar like mud cement ete. The roof was covered with Mangalore clay tiles In urban areas houses were constructed with dressed stone or concrete block, in cement mortar.

**2.1.2 Different types of damages and non damages** Typical features of damages and non damages in masonry buildings during Bhuj earthquake 26 January, 2001 and from which we summarized that:

(a) Houses built with stone masonry in mud mortar without any earthquake resistant feature as per IS 4326, is mostly used in rural area. These houses were mostly damaged during earthquake due to:

i)Structural integrity (No bands)

ii) Positive mechanism of roofing systems No bottom tie member

(iii) Connection between wall to roof lie

iv) Connection between wall to wall and within the two wythes of wall i.e.

no through stone.

b) In single or two storeyed residential building random rubble masonry in cement mortar with reinforced concrete slab used in construction with plinth and lintel band performed very well. The wall roof interface had nominal sliding and separation, and the wall between plinth and lintel bands sustained shear cracks.

c)The seismic performance of clay brick masonry and cement block masonry have depended upon the earthquake resistant features. Bentonite factory building and stone block masonary with lintel bands, near Bhuj, escaped from damages.

(d) The main cause of failure of masonry buildings was recycled construction materials and the structures without earthquake resistant features.

**CHAMOLI EARTHQUAKE, MARCH 29, 1999**

A moderate earthquake of magnitude 6.8 on richter scale occurred on Chamoli area of Kumaon Garhwal Himalayan region on March 29, 1999, at 00: 35 hrs. The epicentre of this earthquake was near to Chamoli and the maximum intensity of ys VIII on MSK scale. Chamoli and Rudraprayag district was mostly affected by the earthquake shown in fig. 9.4. The houses in mud mortar with slate tar with slate roofs of bamboo trusses suffered maximum damage as compared to the other ty construction

**Types of Construction** Different typical features of masonry constructed have been observed in earthquake affected areas shown in fig. 2.5, from which we summarized that:

(a) Old stone masonry houses were constructed in mud mortar with large sire of stone blocks sandwiched between many thin wafers of 2 to 5 mm thick slates arranged in layers. The resulting stone masonry is different from typical random rubble masonry. The wall thickness varied about 45 cm to 75 cm, consisting of two wythes each of 20 to 30 cm thick by filler materials The filler material were slates and small stone embeded in mud mortar.

b)Random rubble stone masonry without layers of thin slates were laid im myd mortar and plaster in cement-sand mortar to provide finish surfare The walls were composed of two watches with total wall thickness varying from 75 cm The usage of burnt-clay brick masonry construction in cement od mortar has also been seen in the recent years after Killari and Uttarkashi carthquakes. These constructions have generally lintel and roof band.

**Different Types of Damages and Non-damages** Typical features of damages and non-damages in masonry buildings during Chamoli earthquake, 1999, are shown in figure 2.6 and from which we summarized that

a) Random rubble stone masonry with a thicker slates or without any layer of slates has suffered maximum damage in comparison to stone masonry with multi-layers of thin-slates in mud mortar. It is mainly due to energy dissipation through friction.

(b) Mostly damage may be due to inferior construction material, bad workmanship. poor wall-to-wall connections. Due to improper support to the roof and roof trusses, ageing, lack of integrity or robustness, poor detailing work, weak in plane wall due to large openings.

(c) The majority of structural damage was due to non-compliance to the earthquake resistant construction features, as well as poor construction practices and use of material local available.

**JABALPUR EARTHQUAKE, MAY 22, 1997**

A moderate earthquake of magnitude M, 6.0 on Richter Scale occurred at 421 hrs on May 22, 1997. The maximum intensity VIII on MMI scale was recorded around Jabalpur City in are Sconi, mandal and other towns in Narmada belt of Madhya Pradesh and adjoining was near to Jabalpur City. The cities mostly affected by earthquake was Jabalpur. district of Uttar Pradesh and Maharashtra. Houses, which were damaged in earthquake bamboo grid. were mud houses having thick mud wall with tile roof and supported on or rest on a

**Types of Construction**

The non-earthquake resistant buildings, which have suffered maximum damage, were either constructed with lime mortar or mud mortar. Roof were constructed of clay tiles or RBC (Reinforced Brick Concrete). The old house in which stone and bricks used for walls and tiles, reinforced concrete and reinforced brick concrete (RBC)

**Different types of damages and non-damges** Typical features of damages and non-damages in masonry buildings during Jabalpur earthquake 1997, are shown in fig. 2.9 and from which we summarized that:

(a) Largly damage to a very large number of two or three storey brick masonry buildings which is constructed by different government agencies.

(b) Unreinforced brick walls cracked at relatively small deformation and they would also have suffered failure if their slenderness ratio (height to thickness) would have been large.

c) Buildings which is constructed without engineering specification suffered Earthquake Resistant Building Construction more damage due to going poor wall-to-wall joint, lack of integrity, ou plan instability poor workmanship, inadequate support to the roof and trunnion, poor detailing work

(d) One and two storey unreinforced masonry buildings perform satisfactorily, especially those which did not suffer layout or plan, deficiencies and where the quality of workmanship and material were

(e) The extent of damage would have been reduced, is modern earthquake resistant design procedure and construction practice had been followed.

(f) Frequent failtures of the walls enclosing the stairs at the roof love.

**KILLARI EARTHQUAKE, SEPTEMBER 30, 1993**

An earthquake of magnitude 6.3 occurred on September 30, 1993. The epicenter of earthquake was close to the Killari. There was a heavy damage in the area of 15km close to Killari on the north side of river Tama. The maximum intensity was VI on MMI This earthquake occurred in carly hours of morning when pe were fast asleep strong ground Gulbarga.

**Types of Construction**

Tunical features of masonry construction have been observed in the earthquake ated area near Killari from which we summarized that

(a) The locally available stone mostly rounded and smooth were used in building

Earthquake Resistant Building Construction construction. The walls 700 mm to 1800 mm thick were made of rand rubble stone Masonry Laid in mud mortar. The depth of foundation va from 600 mm to 2500 mm below the top surface of black cotton soil. The consisted of timber rafters running in two perpendicular direction over whi wooden planks and a thick layer of mud is laid, for making the root hen compact Inyer of mud, whose thickness 300 mm to 600 mm used.

b) The timber beams and frames bounded by stone wall had been used in ma of old house. The roofs of much houses were also heavy due to use of this laser of mud The distance between vertical posts of wood about 1.0 m to 1

c) The mixed form of construction, such as stored of brick masonry or stone blocks in cement mortar has been added over storey of tradional random rubble masonry construction. The building of stone masonry employee, earthquake resistant measures though few in number were also existing i the earthquake affected area.

**Different types of damage and non damage** Typical features of damages and non-damages in masonry buildings durini Killari earthquake, 1993 are shown in figures 2.11 from which

(a) Mostly houses which were damage in earthquake built in stone masonry The masonry with mud and other organic material used for binding ha deteriorated in strength over the years. summarized the

(b) There were very few cases of collapse of reinforced concrete roof, which were rested on dressed stone masonry or brick masonry. The failure masonry wall caused falling of roofs like a sheet.

**UTTARKASHI EARTHQUAKE (UTTARANCHAL OCTOBER 20, 1991**

A earthquake of magnitude 6.6 occurred in the early hours on October 20, 1991 Cn 45 seconds and caused enormous destruction of houses and loss of life. The los of life were more because of its occurrence in the night when people were sleeping and buildings collapsed on them. The area which was largly affected by the earthquake is shown in figure 2.13, which includes Uttarkashi, Chamoli regions. The epicentre of earthquake was at a place called Agora. The maximum intensity at epicentral track was VIII+ on Modified Mercalli Intensity scale (MMI) Gwana steel bridge located about 6 km from Uttarkashi on road to Gangotri collapsed, cutting of hundreds of village. There were only some eases of non-damage of buildings only those which was earthquake resistant features. The power supply and telecommunication and power supply were completely cut off due to broken telephone and electric poles.

**Types of construction** :-typical features of masonry construction have been observed in the earthquake affected area

a) Most of the houses made up of locally available material such as stone and mud.consisted of CGI sheets which is laid on wooden planks and rafters New the construction. The stone wall thickness ranges from 30 em to 45 em There is use of wood has rapidly reduced due to its non availability for building ne proper joint between the corners of the walls

b)The buildings using cement concrete blocks of single or double store boaring walls, 200 mm thick were also constructed in these districts Mail. blocks were laid in 1:6 cement sand mortar Due to heavy snow falls, the roots were made sloping or in RC slab construction. Of buildings had earthquake resistant provision of IS. 4326 in the form of gable band, roof band, lintel etc.

c)In the rural area mostly mud masonry buildings were constructed. The houses were plastered with mud inside and outside. The one or two storey houses were generally very old. The above in mud buildings was mostly self made without any earthquake resistance.

**Different types of damages and non-damages**

Typical features of damages and non-damages

(a) The widespread damage, in most of cases resulting in collapse, occurred to old stone masonry buildings of random rubble construction in mud mortar or no mortar

(b) The damages were more where undressed or round stone or round stone is used in construction as compare to constructed with half dressed flats

(c) In cement concrete block construction wide spread damages wer but no complete collapse was seen.

(d) The earthen building made in mud masonry suffered wide cracks in wall complete collapse of wall, roof and floors. More than one-storey building in adobe suffered more damage than single-storey buildings.

(e) The stone masonry houses of traditional construction using wooden beam and planks were not damaged.

**BIHAR-NEPAL EARTHQUAKE, AUGUST 21, 1988**

A strong earthquake of magnitude 6.6 on Richter Scale occurred on August 21, The epicentre of this earthquake was near to the Bihar-Nepal border. The maxim Seule (MMI). 1 Panchthar, Dh Nalanda, Saha Kutcha house the earthquake and darkness such a morde of buildings Under Past Earthquakes that sand ratio and poor workmanship

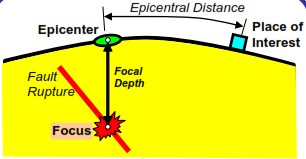
**Different types of damages and non-damages** Nepal earthquake, 1988 have been shown in fig. 2.18 and from which we summarized Typical feature of damages and non-damages in masonry building during Bihar

1. Spreading of roof rafter had caused separation at corners of wall false ceiling action.
2. Mostly vertical cracking of brick masonry arches were near the Crown Wedige action
3. Government buildings performed well which constructed according to 1S code
4. The framed construction has st better performance than the load bearing
5. Horizontal shear cracks were produced due to the pour strength of cement send.
6. In old buildings, there was a deterioration of strength and poor workmanship has been the causes of failure in many cases
7. the arch construction has been found to be weak and are failure in most cases.

(i) Some failure at the corners of openings.

j) Absence of horizontal band in bricks and stone masonry houses

**Terminology for Earthquake Engineering**



**Fig. 2.1Basic terminology**

* 1. **Focus or Hypocenter**

In an earthquake the waves emanate from a finite area of rocks. However, the point from which the waves first emanate or where the fault movement starts is called the earthquake focus or hypocenter.

**Epicentre**

The point on the ground surface just above the focus is called the epicentre.

* 1. **Shallow Focus Earthquake**

Shallow focus earthquake occurs where the focus is less than 70 km deep from ground surface.

* 1. **Intermediate Focus Earthquake**

Intermediate focus earthquake occurs where the focus is between 70 km to 300 km deep.

* 1. **Deep Focus Earthquake**

Deep focus earthquake occurs where the depth of focus is more than 300 km.

* 1. **Epicentre Distance**

Distance between epicentre and recording station in km or in degrees is called epicentre distance.

**Foreshocks**

Fore shocks are smaller earthquakes that precede the main earthquake.

**Aftershocks**

Aftershocks are smaller earthquakes that follow the main earthquake.

**Response Reduction Factor *R***

The factor by which the actual lateral force that would be generated, if the structure were to remain elastic during the most severe shaking that is likely at that site, shall be reduced to obtain the design lateral force.

**Response Spectrum**

The representation of the maximum response of idealized single degree freedom system having certain period and damping, during that earthquake. The maximum response is plotted against the undamped natural period and for various damping values, and can be expressed in terms of maximum absolute acceleration, maximum relative velocity or maximum relative displacement.

**Soil Profile Factor *S***

A factor used to obtain the elastic acceleration spectrum depending on the soil profile below the foundation of structure.

Chapter 3

Introduction to Provisions of IS 1893:2002

Following are the major and important modifications made in the fifth revision (a) The seismic zone map is revised with only four zones, instead of five. Erstwhile Zone 1 has been merged to Zone II. Hence, Zone I does not appear in the ne zoning only Zones II, III, IV and V do.

b)The values of seismic zone factors have been changed: these now reflect mon realistic values of effective peak ground acceleration considering Maximum Considered Earthquake (MCE) and service life of structure in each seismic zone

(c) Response spectra are now specified for three types of founding strata, namely rock and hard soil, medium soil and soft soil.

(d) Empirical expression for estimating the fundamental natural period T, of multi-storeyed buildings with regular moment resisting frames has been revised

(e) This revision adopts the procedure of first calculating the actual force that may be experienced by the structure during the probabe maximum earthquake, if it were to remain elastic. Then, the concept of response reduction due to ductile deformation or frictional energy dissipation in the cracks is brought into the code explcitly, by introducirg the response reduction factor in place of the earlier performance factor.

(f) A lower bound is specified for the design base shear of buildings, based on empirical estimate of the fundamental natural eriod T..

(g) The soil-foundation system factor is dropped. Instead, a clause is introduced to restrict the use of foundations vulnerable to differential settlements in severe seismic zones.

(h) Torsional eccentricity values have been revised damages observed n buildings with irregular with plans.

(j) Modal combination rule in dynamic analysis of buildings has been revised.

(k) Other clauses have been redrafted where necessary for more effective implementation

**Indian Seismic Codes**

In India, the first ever code related to seismology was introduced, by Bureau of Indian Standard, was IS: 1892 in the year 1962). With the advancement n technology and time to time upgradation of available information, Bureau of Indian Standard BIS) has introduced the following Seismic design codes for practice :

1. IS: 1893 (Part - 1), 2002 : Criteria for Earthquake Resistant Design of Structures (Vth Revision).

2. IS : 43262002 : Code of Practice for Earthquake Resistant, Design of Structures of Building (Ind Revision).

3. 1S : 139201993 : Ductile Detailing of Reinforced Concrete Structures subjected to Seismic Forces.

4.IS: 138271993 : Guidelines for Improving Earthquake Resistance of Earthern Buildings

5. IS: 138281993 : Guidelines for Improving Earthquake Resistance of Low Strength Masonry Building Construction.

6 IS 139351993 : indian Standard Guidelines for Repair and Seismic Strengthening of Buildings.

7. SP: 22 (S&T), 1982 : Explanatory Handbook on Codes for Earthquake Engineering (Special Publications).

**Scope**

This standard (Part Id us with assessment of seismic loads on various structures and earthquake Is an design of buildings. Its basic provisions are applicable to buildings; elevated structures: industrial and stack like structures; bridges; concrete masonry and earthen dam; embankments and retaining walls and other structures.

Temporary elements such as scaffolding, temporary excavations need not be designed for earthquake forces.

This standard does not deal with the construction features relating to earthquake resistant design in buildings and other structures. For guidance on earthquake resistant construction of buildings, reference may be made to the following Indian standards :

IS 4326, IS 13827, IS 18328, IS 13920 and IS 13935.

1.

**Terminology for Earthquake Engineering**

Closely-Spaced Modes

1.**Closely-spaced modes** of a structure are those of its natural modes of vibration

whose natural frequencies for Groom each other by 10 percent or less of lower frequency. than

2.**Critical Damping** The damping beyond which the free vibration motion will not be scillatory

**3.Damping** The effect of internal Friction, imperfect elasticity of material, slipping, m ete in reducing the amplitude of vibration and in e Corbed as a percent 14. critical damping

**4.Design Acceleration Spectrum**

Design acceleration spectrum refers to an average smoothened plot of maxi acceleration as a function of frequency or time period of vibration for a spe damping ratio for earthquake excitations at the base of a single degree of free system.

**5.Design Basis Earthquake (DBE)** It is the earthquake which can reasonably be expected to occur at least during the design life of the structure.

**6.Design Horizontal Acceleration Coefficient (Ah)** It is a horizontal acceleration coefficient that shall be used for design structures.

**7.Design Lateral Force** It is the horizontal seismic force prescribed by this standard, that to design a structure.

**8 Ductility** Ductility of a structure, or its members, is the capacity to undergo largo iwa deformations without significant loss of strength or stiffness

**9. Epicentre** The geographical point on the surface of earth vertically above the focus

earthquake.

**10. Effective Peak Ground Acceleration (EPGA)** It is 0.4 times the 5 percent damped average spectral acceleration between 0.1 to 0.3 s. This shall be taken as Zero Period Acceleration ( ZPA).

**11. Floor Response Spectra** Floor response spectra is the response spectra for a time history motion 20.floor. This floor motion time history is obtained by an analysis of multi-ste building for appropriate material damping values subjected to a specil earthquake motion at the base of structure.

**11.Focus** The originating earthquake source of the elastic waves inside the earth will.

cause shaking of ground due to earthquake.

**13. Importance Factor (I)**

Ti is a factor used to obtain the design seismic force depending on the functional of the structure, characterised by hazardous consequences of its failure. La st-earthquake functional food, history value, or economic importance.

**14. Intensity of Earthquake** The intensity of an earthquake at a place is a measure of the strength of nanking during the earthquake, and is indicated by a number according to the modified Mercalli Scale or M.S.K. Scale of seismic intensities.

**15. Liquefaction** Liquefaction is a state in saturated cohesionless soil wherein the effective shear strength is reduced to negligible value for all engineering purpose due to pore pressure caused by vibrations during an earthquake when they approach the total confining pressure. In this condition the soil tends to behave like a fluid mass.

**16. Lithological Features**

The nature of the geological formation of the earth's crust above bed rock on the basis of such characteristics as colour, structure, mineralogical composition and grain size.

**17. Magnitude of Earthquake (Richter's Magnitude)** The magnitude of earthquake is a number, which is a measure of energy released in an earthquake. It is defined as logarithm to the base 10 of the maximum trace amplitude, expressed in microns, which the standard short-period torsion seismometer with a period of 0.8 s, magnification 2800 and damping nearly critical) would register due to the earthquake at an epicentral distance of 100 km.

**18. Maximum Considered Earthquake (MCE)** The most severe earthquake effects considered by this standard.

**19. Modal Mass (MK)** Modal mass of a structure subjected to horizontal or vertical, as the case may be, ground motion is a part of the total seismic mass of the structure that is effective in mode k of vibration. The modal mass for a given mode has a unique value irrespective of scaling of the mode shape.

**20. Modal Participation Factor (PK)** Modal participation factor of modes of vibration is the amount by which mode k contributes to the overall vibration of the structure under horizontal and vertical earthquake ground motions. Since the amplitudes of 95 percent mode shapes can be scaled arbitrarily, the value of this factor depends on the scaling

**21. Mode Shape Coefficient ()** When a system is vibrating in normal mode k, at any particular instant of time,

| Earthquake Resistant Building Construction the amplitude of mass i expressed as a ratio of the amplitude of one of the system, is known as mode shape coefficient

**22. Natural Period (T)** Natural period of a structure is its time period of undamped free vibration

**23.Fundamental Natural Period (T1)** It is the first longest) modal time period of vibration.

.**24. Modal Natural Period (Tk)** The modal natural period of mode k is the time period of vibration in mode k.

**25.Normal Mode** A system is said to be vibrating in a normal mode when all its masse maximum values of displacements and rotations simultaneously, and through equilibrium positions simultaneously.

**26. Response Reduction Factor (R)** It is the factor by which the actual base shear force, that would be generous the structure were to remain elastic during its response to the Design u7 Earthquake (DBE) shaking, shall be reduced to obtain the design lateral

forces

**27.Response Spectrum** The representation of the maximum response of idealized single degree.

**28. Base**

Ti is the level at which inertia forces generated in the structure are transferred in the foundation. which then transfers these forces to the ground. IS 1893 (Part : 1): 2002

**29. Base Dimensions (d)**

Base dimension of the building along y direction is the dimension at its base, in metre, along that direction.

**Centre of Mass**

The point through which the resultant of the masses of a system acts. This point corresponds to the centre of gravity of masses of system.

**Centre of Stiffness**

The point through which the resultant of the restoring forces of a system acts.

**Design Eccentricity (edi)** It is the value of eccentricity to be used at floor i in torsion calculations for design.

**Design Seismic Base Shear (VB**) It is the total design lateral force at the base of a structure.

**Diaphragm** It is a horizontal, or nearly horizontal system, which transmits lateral forces to the vertical resisting elements, for example, reinforced concrete floors and horizontal bracing systems.

**Dual System** Buildings with dual system consist of shear walls (or braced frames) and moment resisting frames such that:

(a) The two systems are designed to resist the total design lateral force in proportion to their lateral stiffness considering the interaction of the dual system at all floor levels; and (b) The moment resisting frames are designed to independently resist at least 25 percent of the design base shear.

**Height of Floor (hi)** It is the difference in levels between the base of the building and that of floor i.

**Height of Structure (h)** It is the difference in levels, in metres, between its base and its highest level

**Horizontal Bracing System** It is a horizontal truss system that serves the same function as a diaphragm.

**Joint** It is the portion of the column that is common to other members beam, framing into it.

**Lateral Force Resisting Element** It is part of the structural system assigned to resist lateral forces

**Moment-Resisting Frame** It is a frame in which members and joints are capable of resisting force by feure.

**Ordinary Moment-Resisting Frame** It is a moment-resisting frame not meeting special detailing require ductile behaviour.

**. Special Moment-Resisting Frame** It is a moment-resisting frame specially detailed to provide ductile beba and comply with the requirements given in IS 4326 or IS 13920 or SP 6 5 3231

**Number of Storeys (n)** Number of storeys of a building is the number oflevels above the base excludes the basement storeys, where basement walls are connected to ground floor deck or fitted between the building columns. But, it includes basement storeys, when they are not so connected.

**Principal Axes** Principal axes of a building are generally two mutually perpendicular horiam directions in plan of a building along which the geometry of the building oriented

**. P-A Effect** It is the secondary effect on shear and moment of frame members due to actie of the vertical loads, interacting with the lateral displacement of building resulting from seismic forces.

**Shear Wall** It is a wall designed to resist lateral forces acting in its own plane.

**Soft Storey** It is one in 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.

**Static Eccentricity (e)** It is the distance between centre of mass and centre of rigidity of floor i

**Storey**. It is the space between two adjacent floors.

**Storey Drift** It is the displacement of one level relative to the other level above or below.

**Story Shear (Vi)**

Ti is the sum of design lateral forces at all levels above the storey under consideration

**Weak Story**

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 force resisting elements sharing the storey shear in the considered direction.

Coefficient used in the Complete Quadratic Combination (CQC) method while combining responses of modes i andj

Circular frequency in rad/second in the ith mode

**General Principles and Design Criteria**

**General Principles**

**1. Ground Motion**

The characteristics intensity, duration, etc) of seismic ground vibrations expected at any location depends upon the magnitude of earthquake, its depth of focus, distance from the epicentre, characteristics of the path through which the seismic waves travel, and the soil strata on which the structure stands. The random earthquake ground motions, which cause the structure to vibrate, can be resolved in any three mutually perpendicular directions. The predominant direction of ground vibration is usually horizontal.

Earthquake-generated vertical inertia forces are to be considered in design unless checked and proven by specimen calculations to be not significant. Vertical acceleration should be considered in structures with large spans, those in which stability is a criterion for design, or for overall stability analysis of structures.

Reduction in gravity force due to vertical component of ground motions can be particularly detrimental in cases of prestressed horizontal members and of cantilevered members. Hence, special attention should be paid to the effect of vertical component of the ground motion on prestressed or cantilevered beams; girders and slabs.

2.The response of a structure to ground vibrations is a function of the nature of foundation soil; materials, form, size and mode of construction of structures; and the duration and characteristics of ground motion.

This standard specifies design forces for structures standing on rocks or soils which do not settle, liquefy or slide due to loss of strength during ground

vibrations.

3.The design approach adopted in this standard is to ensure that structures possess at least a minimum strength to withstand minor earthquakes (<DBE), which occur frequently, without damage; resist moderate earthquakes (DBE) without significant structural damage though some non-structural damage may occur; and aims that structures withstand a major earthquake (MCE) without collapse.

Actual forces that appear on structures during earthquakes are much gr than the design forces specified in this standard. However, ductility, arising from inelastic material behaviour and detailing, overstrength, arising from the additional reserve strength in structures nd above the design strength, are relied upon to account for this differene actual and design lateral loads Reinforced and prestressed concrete members shall be suitably designed to en that premature failure due to shear or bond does not occur, subject to provisions of IS 456 and IS 1343. Provisions for appropriate ductile detailing reinforced concrete members are given in IS 13920. ature fall

In steel structures, members and their connections should be so proporti that high ductility is obtained, vide SP 6 (Part 6), avoiding premature due to elastic or inelastic buckling of any type.

The specified earthquake loads are based upon post elastic energy dissipation the structure and because of this fact, the provision of this standard for des detailing and construction shall be satisfied even for structures and memb for which load combinations that do not contain the earthquake effect indir larger demands than combinations including earthquake.

4.Soil-Structure Interaction The soil - structure interaction refers to the effects of the supporting foundation medium on the motion of structure. The soil-structure interaction may not b considered in the seismic analysis for structures supported on rock or rock-like material.

5.The design lateral force specified in this standard shall be considered in each of the two orthogonal horizontal directions of the structure. For structures which have lateral force resisting elements in the two orthogonal directions only, the design lateral force shall be considered along one direction at a time, and not in both directions simultaneously. Structures, having lateral force resisting elements (for example frames, shear walls) in directions other than the two orthogonal directions, shall be analysed considering the load combinations specified in 6.3.2.

Where both horizontal and vertical seismic forces are taken into account, load combinations specified in 6.3.3 shall be considered.

6.Equipment and other systems, which are supported at various floor levels of the structure, will be subjected to motions corresponding to vibration at their support points. In important cases, it may be necessary to obtain floor response spectra for design of equipment supports. For detail reference be made to IS 1893 (Part

7 Additions to Existing Structures Additions shall be made to existing structures only as follows

(a) An addition that is structurally independent from an existing structures shall be designed and constructed in accordance with the selfie Requirements for new structures.

b)An addition that is not structurally independent from an existinitu re shall be designed and constructed surah that the entire structure conforama to the seismic force resistance requirements for now structures unlean the following three conditions are complied with

1.The addition shall comply with the requirements for new structures

2.The addition shall not increase the seismic forces in any structural elements of the existing structure by more than 5 percent unless the capacity of the element subject to the increased force is still in compliance with this standard, and

3. The addition shall not decrease the seismic resistance of any structural element of the iating structure unless reduced resistance is equal to or greater than that required for new structures.

**Change in Occupancy**

When a change of occupancy results in a structure being reclassified to a higher importance factor (I), the structure shall conform to the seismic requirements for a new structure with the higher importance factor.

**Assumptions**

The following assumptions shall be made in the earthquake resistant design of structures

1. Earthquake causes impulsive ground motions, which are complex and juegular in character, changing in period and amplitude each lasting for a small duration. Therefore, resonance of the type as visualized under steady state sinusoidal excitations, will not occur as it would need time to build up such amplitude
2. Earthquake is not likely to occur simultaneously with wind or maximum flood or maximum sea waves.
3. The value of elastic modulus of materials, wherever required, may be taken as for static analysis unless a more definite value is available for use in such condition ( see IS 456, IS 1343 and IS 800)

**Load Combination and Increase in Permissible Stresses**

1. **Load Combinations**

When earthquake forces are considered on a structure these shall be combined as per (b) and (c) where the terms DL, IL and EL stand for the response quantities due to dead load, imposed load and designated earthquake load respectively.

1. **Load factors for plastic design of steel structures** In the plastic design of steel structures, the following load combination shall be accounted for:

(1)1.7 DL+IL)

(2) 1.7( DL = E  
 (3) 1.3 DL + IL +EL)

**C)**Partial safety factors for limit state design of reinforced concrete prestressed concrete structures In the limit state design of reinforced and prestressed concrete structures the following load combinations shall be counted for

(1) 1.5 (DL + IL)

2 12(ĐL +IL+-EL)

(3) 1.5( DL +-EL)

(4) 0.9DL =1.5EL

**Design Horizontal Earthquake Load**

1. When the lateral load resisting elements are oriented along orthogonal horizontal direction, the structure shall be designed for the effects full design earthquake load in one horizontal direction at time
2. When the lateral load resisting elements are not oriented along the orthogonal horizontal directions, the structure shall be designed for the effects due to fall design earthquake load in one horizontal direction plus 30 percent ofthe design earthquake load in the other direction.
3. **Vertical Earthquake Load** When effects due to vertical earthquake loads are to be considered, the design vertical force shall be calculated **(d) Combination for Two or Three Component Motion**

(i)When responses from the three earthquake components are to be considered the responses due to each component may be combined using the assumption that when the maximum response from one component occurs, the responses from the other two component are 30 percent of their maximum. All possible combinations of the three components Elox, ELy and ELZ including variations in sign (plus or minus) shall be considered. Thus, the response due earthquake force (EL) is the maximum of the following three cases.

(1) + ELX: 0.3 ELy = 0.3 ELz

(2) ELy +0.3 ELx 0.3 ELX

(3) ELZ: 0.3ELX=0.3ELY

where x and y are two orthogonal directions and z is vertical direction.

(ii)As an alternative to the procedure in 6.3.4.1, the response (EL) due to the combined effect ofthe three components can be obtained on the basis of square root of the sum of the square (SRSS) that is

EL = ELa -(ZL) -(BL2

(iii)Wher two component motions (By one horizontal and one vertical, or only two horizontal) are combined, the equations in 6.3.4.1 and 6.3.4.2 should be modified by deleting the term representing the response due to the component of motion not being considered.

**Increase in Permissible Stresses**

* Increase in permissible stresses in materials
* Increase in allowable pressure in soils

**Design Spectrum**

(a)For the purpose of determining seismic forces, the country is classified into four seismic zones as shown in Fig. 1.

(b) The design horizontal seismic coefficient A for a structure shall be determined by the following expression:

Ah=ZISa/ 2Rg

Provided that for any structure with T < 0.1 s, the value of A, will not be taken less than 2/2 whatever be the value of I/R

Z = Zone factor given in Table 2, is for the Maximum Considered Earthquake (MCE) and service life of structure in a zone. The factor 2 in the denominator of 2 is used so as to reduce the Maximum Considered Earthquake (MCE) zone factor to the factor for Design Basis Earthquake (DBE).

I= Importance factor, depending upon the functional use of the structures, characterised by. hazardous conselluences of its failure, post-earthquake functional needs, historical value, or economic importance (Table 1).

R = Response reduction factor, depending on the perceived seismic damage performance of the structure, characterised by ductile or brittle deformations. However, the ratio (fiR) shall not be greater than 10 (Table 2). The values of R for buildings are given in Table 2.

Sa/g = Average response acceleration coefficient.

Table 1. Response Reduction Factor 1), R, for Building Systems

|  |  |  |
| --- | --- | --- |
| S.No | Structure | Importance Factor |
| (i)  (ii) | Important services and community buildings such as hospitals school, large community all power stations  All other buildings | 1.5  1.0 |

Table 2. Response Reduction Factor 1), R, for Building Systems

|  |  |  |
| --- | --- | --- |
| S.No.  (1) | Lateral Load Resisting System  (2) | R  (3) |
| (1)  (ii)  (iii)  (iv)  (v)  (vi) (vii)  (vii)  (ix)  (x)  (xi) | Building Frame System Ordinary RC moment-resisting frame (OMRF)2)  Special RC moment resisting frame ( SMRF )3)  Steel frame with  a Concentric braces  (b) Eccentric braces  Steel moment resisting frame designed as per SP 6 (6) Building with Shear Walls  Load bearing masonry wall buildings (5) (a)Unreinforced  (b) Reinforced with horizontal RC bands (c)Reinforced with horizontal RC bands and vertical bars at corners of rooms und jambs of openings  Ordinary reinforced concrete shear walls Ductile shear walls?  Buildings with Dual Systems)  Ordinary shear wall with OMRF Ordinary shear wall with SMRF  Ductile shear wall with OMRF  Ductile shear wall with SMRF | 3.0  5.0  4.0  5.0  5.0  1.5  2.5  3.0  4.0  3.0  4.0  4.5  5.0 |

**Design Lateral Force**

(a) Buildings and portions thereof shall be designed and constructed, to resist the effects of design lateral force specified in (c) as a minimum.

(b)The design lateral force shall first be computed for the building as This design lateral force shall then be distributed to the various floor

The overall design seismic force thus obtained at each floor level, shall then be distributed to individual lateral load resisting elements depending on the floor diaphragm action.

**c)Design Seismic Base Shear** The total design lateral force or design seismic base shear (VB) along any principal direction shall be determined by the following expression:

Vb = AhW

Where

Ah = Design horizontal acceleration spectrum value as per 6.42, using the fundamental natural period Ta as per 3 10 in the considered direction of vibration; and

W = Seismic weight of the building as per

**Fundamental Natural Period**

**(a)** The approximate fundamental natural period of vibration (Ta), in seconds, of a moment-resisting frame building without brick infill estimated by the empirical expression: may be

Ta = 0.075 h0 75 for RC frame building

= 0.085 h0.75 for steel frame building

Where

h=Height of building, in m. This excludes the basement storeys, where basement walls are connected with the ground floor deck or fitted between the building columns. But, it includes the basement storeys, when they are not so connected.

b)The approximate fundamental natural period of vibration (Ta), in seconds, of all other buildings, including moment-resisting frame buildings with brick infil panels, inay be estimated by the empirical expression:

T = 0.09/D

where

h = Height of building, in m, as defined in 7.6.1; and

d = Base dimension of the building at the plinth level, in m, along the considered direction of the lateral force.

**Distribution of Design Force**

**(a) Vertical Distribution of Base Shear Different Floor Levels** The design base shear (VB) computed in (c) shall be distributed along the height of the building as per the following expression:

Q1=Vb bwihi/wjhj\*2

where

Q-Design lateral force at floor i

, w - Seismic weight of floor.i

Hi=height of floor i measured from base and

n=Number of storeys in the building is the number of levels at wheh the masses are located.

b)Distribution of Horizontal Design Lateral Force to Different Lateral Foro Resisting Elements

c)In case of buildings whose doors are capable of providing rigid hori diaphragm action, the total shear in any horizontal plane shall be distributed to the various vertical elements of lateral force resisting system, assuming the floors to be infinitely rigid in the horizontal plane.

d)In case of building whose floor diaphragms can not be treated as infinite rigid in their own plane, the lateral shoar at each floor shall be distribut to the vertical elements resisting the lateral forces, considering the in plane flexibility of the diaphragms.

**NOTES** ( A floor diaphragm shall be considered to be flexible, if it deforms such that the maximum lateral displacement measured from the chord of the deformed shape any point of the diaphragm is more than 1.5 times the average displacement of the entire diaphragm.

(2) Reinforced concrete monolithic slab-beam floors or those consisting of prefabricated precast elements with topping reinforced screed can be taken a rigid diaphragms.

**Dynamic Analysis** (a) Dynamic analysis shall be performed to obtain the design seismic force, and its distribution to different levels along the height of the building and to the various lateral load resisting elements, for the following buildings:

1. Regular buildings : Those greater than 40 m in height in Zones IV and V, and those greater than 90 m in height in Zone II and III.
2. Irregular buildings (as defined in 7.1) All framed buildings higher than 12 m in Zone IV and V, and those greater than 40 min height in Zone II and

The analytical model for dynamic analysis of building with unusual configuration should be such that it adequately models the types of irregularities present in the building configuration. Buildings with plan irregularities, as defined in Table 4, cannot be modelled for dynamic analysis by the method.

**NOTE**: For irregular buildings, less than 40 min height in Zones II and III, dynamic analysis, even though not mandatory, is recommended.

(b) Dynamic analysis may be performed either the Time History Method or bu

the Response However, in either method, the design be whenr(w whall be compared with n baso shear (VS calculated using a fundamental period Ta

where is as per 3.10. Where V in low than III the response quantition (for example member force, displacement, storey forces, storey hear and bse reactions) shall be multiplied by Vb/ve

c)The value of damping for buildings m3 be taken ns 2 and 5 percent of the critical, for the purposes of dynamic analysis of steel and reinforced concrete buildings, respectively.

**(d) Time History Method**

Time history method of analysis, when used, shall be based on an appropriate ground motion and shall be performed using accepted principles of dynamics.

**(e) Response Spectrum Method** Response spectrum method of analysis shall be performed using the design spectrum specified in 3.8 , or by a site-specific design spectrum.

**(f) Modes to be considered** The number of modes oto be used in the analysis should be such that the sum total of modal masses of all modes considered is at least 90 percent of the total seismic mass and missing mass correction beyond 33 percent. If modes with natural frequencies beyond 33 Hz are to be considered, modal combination shall be carried out only for modes upto 33 Hz. The effects of higher modes shall be included by considering missing mass correction following well established procedures.

**Buildings with Soft Storey**

(a) In case buildings with a flexible storey, such as the ground storey consisting of open spaces for parking that is Stilt buildings, special arrangement needs to be made to increase the lateral strength and stiffness of the soft/open storey.

(b) Dynamic analysis of building is carried out including the strength and stiffness effect of infills and inelastic deformation in the members, particularly, those in the soft storey, and the members designed accordingly.

(c) Alternatively, the following design criteria are to be adopted after carrying out the earthquake analysis, neglecting the effect of infill walls in other storeys:

i)the columns and beams of the soft storey are to be designed for 2.5 times the storey shears and moments calculated under seismic loads, specified in the other relevant clauses: or,

ii)besides the columns designed and detailed for the calculated storey shears and moments, shear walls placed symmetrically in both directions of the building as far away from the centre of the building feasible to exclusively for 1.5 times the lateral storey shear force calculator m lateral to

**Storey Drift Limitation** The storey drin in an storey due to the minimum specified design la with partial load factor of 1.0, shall not exceed 0.004 times the storey For the purposes of displacement requirements only, it is permissible iod of the build noemie force obtained from the computer fundamental period of the without the lower bound limit on design seismic force.There shall be no drift limit for single storey building which has been des to accommodate storey drin.mations que

**Deformation Compatibility of Non-Seismic Members** For building structural components, that are not a part of the seismic force resisting in the direction under consideration, do not lose their vertical load-car located in seismic Zones IV and V. it shall be ensured that t cupacity under the induced moments resulting from storey deformations to R times the storey displacements.

**Separation Between Adjacent Units** Two adjacent buildings, or two adjacent units of the same building with separati times the sum. in between shall be separated by a Distance equal to the amount R times the of the calculated storey displacement as per 7.11.1 of each of them, to ay damaging contact when the two units deflect towards each other. When levels of two similar adjacent units or buildings are at the same elevation level factor R in this requirement may be replaced by R/2.

**Foundations** The use of foundations vulnerable to significant differential settlement due to ground shaking shall be avoided for structures in seismic Zones III, IV and V In seismic Zones IV and V. individual spread footing or pile caps shall be interconnected with ties Except when individual spread footings are directly supported on rock. All ties shall be capable of carrying, in tension and in compression, an axial force equal to A, 4 times the larger of the column or pile cap load, in addition to the otherwise computed forces. Here, A, is as per 3.8(b).

**Cantilever Projections**

(a) Vertical projections Tower, tanks, parapets, smoke stacks (chimneys) and other vertical cantilever projections attached to buildings and projecting above the roof, shall be designed and checked for stability for five times the design horizontal seismic coefficient As specified in 3.8

(b). In the analysis of the building, the weight of these projecting alerts will he lumped with roof weight.

(c)Horizontal projection All horizontal projection like cornices and balconies shall be designed and chocked for stability for five times the design vertical coefficient specified in 6.4.5 (that is = 10/3 A) The increased deisgn forces specified in (a) and (b) are only for designing the projecting parts and their connections with the main structure. For the design of the main structure, such incrense need not be considered.

(d) Compound Walls Compound walls shall be designed for the design horizontal coefficient A with importance factor 1 = 1.0 specified in 3.8(b).

Connection between Parts All parts of the building, except between the seperation sections, shall be tied together to act as integrated single unit. All connections between different parts, such as beams to columns and columns to their footings, should be made capable of transmitting a force, in all possible directions, of magnitude (Q/W) times but not less than 0.05 times the weight of the smaller part or the total of dead and imposed load reaction. Frictional resistance shall not be relied upon for fulfilling these requirements.

**Chapter 4**

**Ductility Detailing of Seismic Resistance Practices**

I**NTRODUCTION**

per IS 1893: (Part I) 2002, clause 6.1.3 "Actual forces that appear on ures during earthquakes are much higher than the design forces specified in code" It is recognized that neither the complete protection against earthquakes all sizes is economically feasible nor design alone based on strength criteria is satisfied. The basic approach of earthquake resistant design should be based on steel strength as well as formability and ductility capacity of structure with mite damage but no collapse. The code IS 13920 : 1993 entitled "Ductile detailing f reinforced concrete structure subjected to seismic forces-code of practices is bused on this approach. This standard covers the requirements of lateral strength designing detailing of monolithic reinforced concrete building to as to give them adequate toughness and ductility to resist severe earthquake shocks without collapse.

Thus, the ductility of a structure is in fact one of the most important factors affecting its seismic performance and it has been clearly observed that the well designed and detailed reinforced structure behave well during earthquakes and the gap between the actual and design lateral forces is narrowed down by providing

**IMPACT OF DUCTILITY**

The structural engineer must have to understand the impact of ductility o building response when it is subjected to earthquake forces. For example con a single degree freedom system consisting of a metal rod and a weight as show fig. 4.1. As the ground moves or displaces, the characteristics of the grou weight connection will play a vital role. If this connection is very rigid, the will experience the same or larger forces but if the connection is very flexible in case of metal rod, it will bend or deform and the weight will subjected to forces because some of the energy will be consumed to displace the system. Mo the building response under earthquakes are within these two extremes.

Inertial force

Ground motion

From this example we can easily conclude that ductility, properly induced the building system, will improve the behaviour of the building primarily by reducin the forces in the structure Ductility is an essentially attribute of an earthquake resistant design structure that serves as a shock absorber in a structure and reduces the transmitte force to one that is sustainable.

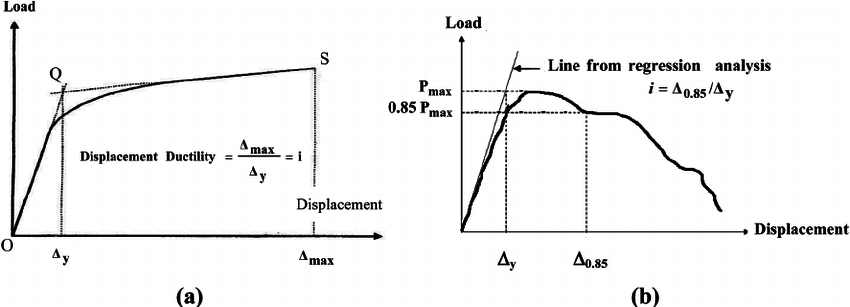
**REQUIREMENT FOR DUCTILITY**

In order to achieve a ductile structure we must give stress on three key a during the design process. Firstly, the whole design concept for the building configuration must be sound. Secondly, individual member must be designed ductility and finally connection and other structural details meet careful attent It is well recognized and accepted analysis of experimental results and analyt studies, that in earthquake resistant design of structure, all structural member and their connection and supports i.e. all critical regions whose yielding stress may be reached and increases by a severe earthquake, should be designed with ductility and stable hysteresis behaviour so that the entire structure will re ductile displaying stable hysteresis behaviour. There are two main reasons for

**Assessment of ductility** : Ductility is the capability of a mponent or entire structure to undergo deformation after its initial yield without ible as to lease Most Ay significant reduction in yield strength. Ductility is measured in term of ductility ratis, which is the ratio of the maximum deformation that a structure or element an undergo without significant loss of initial yield deformation.

**DISPLACEMENT DUCTILITY MEMBER/ELEMENT DUCTILITY**

In order to determine the ductility ratio of an element, yield displacement and ultimate displacement must be defined clearly. Yield load is defined as the load when forcement at the centre of the resultant of tensile forces in the reinforcement the reinforcement some iterative calculations are needed to determine the yield yields. if the yield load is defined as described, the yield displacement can be load, but if yield inted the displacement when the load reaches the yield load. At same time, computed as



1. Fig. 4.2 (a) Yield criterion; (b) Definition of ductility ratio Ductility ratio is influenced by various factors and must be evaluated properly calyie considering all the factors according to design structures. The ductility ratio embe becomes around 10 when the axial compressive stress, compressive strength of conc, and yield strength of reinforcement are in the range of 1MPa, 20-30 MPa, 300- h lar 400 MPa, respectively.

in order to evaluate the ductility of a structure, curvature ductility ratio or Rotation angle ductility ratio of each element is needed. The rotational ductility factor is often expressed max. plastic hinge rotation, y, = yield rotation in case beam is loaded by two antisymmetrie end moments, y= M yL/ 6EI

Where

M,, L, l and E are yield moment, length. Moment of Inertia and modulus of elasticity of the beam respectively. There is no unique yield rotation that col be used in the definition of ductility factor. This definition applies for antisymmetric deformation of beam members that occurs in beam laterally loaded fram Curvature ductility is the ratio of curvature at the ultimate strength of to the curvature of first yield of tension steel in the section. It is defined for biline max -1 + by where Op = plastic pune

Bilinear moment curvature relationship for beams (Macaida, 1999) The rotational ductility are better measures of flexural damage than curve ductility. It is the simple index to characterize the severity of inelastic ties deformation. True curvature ductility are substantially large than rat ductility. Comparing the member rotational ductility factor H. In a building global ductility Hb, the former is typically larger.

**The JSCE code**, the EC 8 and NZ code are proposing methods methods to calculate ductility factor of member or to express the relation between the amount of sh 6 reinforcement in the plastic hinge region and the ductility factor are to JSCE Code

Evaluation of ductility Factor (Fig.)

Hr = [Ho + (1 - Ho) (0/0)

Detailing and Seismic Resistance Practice

**STRUCTURAL DUCTILITY** coral Structure ductility in a global sense depends on the displacement ductility of with mom mombora boonuse remponge displacement of each member can be evaluated even Matic analysis. Its quantification requires a relationship between lateral loads ulat displacement of whole building. This may be obtained by a pushover analysis ho " plotting total base shear vorgus the top storey displacement or preferably versus.

The displacement at the level where the resultant force QbX Ft is applied. Then ub

determined from the worth of lateral force Ft at follows ub=FiUi/Qb

**DUCTILITY FACTOR**

The displacement ductility ratio are used in the reduction of required elastic strength of structure. In actual, the need for incorporation of respo reduction factor (R) in base shear formula in IS 1893 (Past 11 : 2002 is an atte to consider the structural ductility in addition to over strength, energy dissip capacity, the stability of vertical load carrying system at max. induced in deformation. The value of R is prescribed in table 7 of IS 1893 (Part 1): 200 different types of building system. It shows a low value of R approaching 1.5 65 to an extremely brittle building i.e. unreinforced masonry wall building and value of R = (5) is assigned to a more ductile structure like special moment to frame reinforced concrete or shear wall building.

The response reduction factor may be same as ductility factor of structures with a very long period with respect to the period of the press frequency content of the earthquake ground motion. Some times the ome times the resp reduction factor may be equal to R = iR li which is only applicable itt cable if the str is subjected to relatively very short acceleration pulse (with respect to its)

**DUCTILE DETAILING CONSIDERATION AS PER IS 13920:1993**

Provision for ductile detailing in the members of reinforced concrete te and splices are given in IS 13920 : 1993. These provision are for the anchorage and al reinforcem longitudinal reinforcement, spacing, anchorage and splices of lateral reinfo at the problem and joint of member. It is often observed in part earthquakes that the pro The discussion structural detailing may also be a significant cause of damage. The dise herein focus on the provision of ductile detailing provision for RC building possible reasons for providing structure ACI 3181999 co code 8, 2002), whin 1. SH be helpful to understand the importance of ductile detailing for earthquake res What design of structure.

**GENERAL SPECIFICATIONS**

The design and construction of reinforced concrete buildings shall governed by the provision of IS 453 : 1978 (now IS : 456 : 2000): except as modir by the provisions of this code.

For all buildings which are more than 3 stories in height, the minimi grade of concrete shall be M 20 (F = 20 MPa)

**Possible explanation** : The concrete strength below M 20 may not have the requie strength in bond or shear to take full advantage of design provisions. Bend strength of a reinforced concrete member is relatively insensitive to concrete compressive tensile and shear strength and durability, which are adversely affe by weak concrete.

**INDIAN STANDARD I.S. 13920: 1993**

**DUCTILE DETAILING OF REINFORCED CONCRETE STRUCTURE SUBJECTED TO SEISMIC FORCES - CODE OF PRACTICE**

**SCOPE**

(a) This standard covers the requirements for designing and detailing monolithic reinforced concrete buildings so as to give them adequ toughness and ductility to resist severe earthquake shocks without com

(b) Provisions of this code shall be adopted in all reinforced concrete structures which are located in seismic zone III, IV or V.

(c) The provisions for reinforced concrete construction given here specifically to monolithic reinforced concrete construction. Precast on. Precast as prestressed concrete members may be used only if they can pre can provide same level of ductility as that of a monolithic reinforced construction during or after an earthquake.

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**Chapter 5**

**INDIAN STANDARD**

**EARTHQUAKE RESISTANT DESIGN OF MASONRY BUILDINGS**

EARTHQUAKE RESISTANT DESIGN OF MASONRY BUILDINGS

Introduction

Masonry construction is the oldest and most common building technique, together with timber construction. The word “masonry” actually encompasses techniques which may differ substantially depending on type and shape of materials and construction methods. In general, masonry may be defined as a structural assemblage of masonry units (such as stones, bricks and blocks) with a binding material known as mortar. A vertical two-dimensional structure of such an assemblage is known as masonry wall. The walls of a masonry building and the building itself are designed to be stable, strong and durable to withstand a combination of design loads.

The basic advantage of masonry construction is that it is possible to use the same element to perform a variety of functions, which in a framed building, for example, have to be provided for separately, with consequent complication in detailed construction. Thus masonry may, simultaneously, provide structure, subdivision of space, thermal and acoustic insulation as well as fire and weather protection. As a material, it is relatively economical, durable and produces external wall finishes of acceptable appearance. Masonry construction is flexible in terms of building layout and can be constructed without very large capital expenditure on the part of the builder.

In India, at present, IS-1905 (1987, reaffirmed 1998) is the code of practice for “Structural Use of Un-reinforced Masonry”. A detailed hand book on Masonry Design and Construction is published by Bureau of Indian Standards in the form of SP-20 (S&T, 1991). An IS code for Structural Use of Reinforced Masonry is under preparation.

There are some guidelines for construction of reinforced masonry in IS-4326 (1993, reaffirmed 1998), mainly for earthquake resistant design and construction of masonry buildings. Guidelines for improving earthquake resistance of low-strength masonry buildings are covered separately in IS-13828 (1993, reaffirmed 1998).

This chapter contains the following;

Terminologies in structural masonry

Basics of design of load bearing masonry

Concepts for reinforced masonry and earthquake resistant masonry

Terminologies in Structural Masonry

Table 1: Terminologies and abbreviations commonly referred in Structural Masonry

|  |  |  |
| --- | --- | --- |
| Sl.  No. | Terminology | Definition and remarks |
|  | Bed Block | A block bedded on a wall, column or pier to disperse a concentrated  load on a masonry element. |
|  | Cross-Sectional Area of Masonry Unit | Net cross-sectional area of a masonry unit shall be taken as the gross cross-sectional area minus the area of cellular space. Gross cross- sectional area of cored units shall be determined to the outside of the coring but cross-sectional area of grooves shall not be deducted from the gross cross-sectional area to obtain the net cross sectional area Remark: Net section area is difficult to ascertain especially in hollow masonry units. In case of full mortar bedding as shown in Fig 10.1 it is the gross sectional area based on the out-to-out dimension minus hollow spaces. Often alignment of cross webs is not possible while laying hollow units and the load transfer takes place through mortars on the face shells only. In such cases, it is conservative to base net cross-sectional area on the minimum face shell thickness.    Net cross sectional area = shaded area or gross area if the block is more than 75% solid    Net area = shaded area = full-mortar bedding area |

|  |  |  |
| --- | --- | --- |
|  |  | Net area = shaded area if face-shell bedding is adopted (provided alignment of cross webs is ensured) |
|  | Grout | A mixture of cement (or any binding material), sand and water of pourable consistency for filling small voids.  Remark: used extensively for filling the surrounding the reinforcement in masonry |
|  | URM | Un-reinforced masonry |
|  | RM | Reinforced masonry |
|  | MI | Masonry In-fill, the masonry wall between the columns and beams of  a frame structure |
|  | EMU | Engineered Masonry Unit – engineered for architectural (colour, shape, texture etc), physical (density) and structural requirement  (strength, elasticity and durability) |
|  | HCB | Hollow concrete block (A masonry unit of which net cross-sectional area in any plane parallel to the bearing surface is less than 75 percent  of its gross cross-sectional area measured in the same plane) |
|  | ECB | Engineered Concrete Block |
|  | SMB | Stabilized Mud block |
|  | SCB | Solid Concrete Block |
|  | TMB | Table Moulded Brick |
|  | WCB | Wire-cut Brick |
|  | Grouted Hollow  Masonry Unit | That form of grouted masonry construction in which certain  designated cells of hollow units are continuously filled with grout. |
|  | Grouted Multi-  Wythe Masonry | That form of grouted masonry construction in which the space  between the wythes is solidly or periodically filled with grout. |
|  | Wythe | A continuous vertical tie of masonry one unit in thickness. |
|  | Grouted Multi-  Wythe Masonry | That form of grouted masonry construction in which the space  between the wythes is solidly or periodically filled with grout. |
|  | Joint Reinforcement | A prefabricated reinforcement in the form of lattice truss which has been hot dip galvanized after fabrication and is to be laid in the mortar bed joint.    Ladder type reinforcement Truss type reinforcment |
|  | Prism | An assemblage of masonry units bonded by mortar with or without grout used as a test specimen for determining properties of masonry.  (preferably with a height/thickness ratio between 2 to 5) |
|  | Grouted Cavity | Two parallel single leaf walls spaced at least 50 mm apart, effectively |

|  |  |  |
| --- | --- | --- |
|  | Reinforced Masonry | tied together with wall ties. The intervening cavity contains steel  reinforcement and is filled with infill concrete so as to result in common action with masonry under load. |
|  | Pocket type Reinforced Masonry | Masonry reinforced primarily to resist lateral loading where the main reinforcement is concentrated in vertical pockets formed in the tension face of the masonry and is surrounded by in situ concrete. |
|  | Quetta Bond Reinforced Masonry | Masonry at least one and half units thick in which vertical pockets containing reinforcement and mortar or concrete infill occur at intervals along its length.    Quetta bond |
|  | Specified Compressive Strength of Masonry | Minimum Compressive strength, expressed as force per unit of net cross- section area, required of the masonry used in construction by the contract document, and upon the project design is based.  Remark: Whenever the quantity fm is under the radical sign, the square root of numerical value only is intended and the result has units of MPa. |
|  | Wall Tie | A metal fastener which connects wythes of masonry to each other or  to other materials. |
|  | Bond | Arrangement of masonry units in successive courses to tie the masonry together both longitudinally and transversely; the arrangement is usually worked out to ensure that no vertical joint of one course is exactly over the one in the next course above or below  it, and there is maximum possible amount of lap. |
|  | Column | An isolated vertical load bearing member, width of which does not  exceed four times the thickness. |
|  | Pier | It is an isolated vertical member whose horizontal dimension measured at right angles to its thickness is not less than 4 times its  thickness and whose height is less than 5 times its length. |

|  |  |  |
| --- | --- | --- |
|  |  | Column and pier |
|  | Buttress | A pilaster of masonry built as an integral part of wall and projecting from either or both surfaces, decreasing in cross-sectional area from base to top.    Buttress |
|  | Curtain Wall | A non-load bearing wall subject to lateral loads. It may be laterally supported by vertical or horizontal structural members, where necessary    Curtain wall |
|  | Effective  Height | The height of a wall or column to be considered for calculating  slenderness ratio. |

|  |  |  |
| --- | --- | --- |
|  | Effective  Length | The length of a wall to be considered for calculating slenderness ratio. |
|  | Effective  Thickness | The thickness of a wall or column to be considered for calculating  slenderness ratio. |
|  | Joint | A junction of masonry units Remark:  Horizontal joints are known as bed joints  Vertical joints are known as perpends, and if they are perpendicular to the plane of the wall they are known as cross joint  Vertical joints are known as collar joints if they are parallel to the plane of the wall  Wall joints are the junctions of walls    Joints |
|  | Leaf | Inner or outer section of a cavity wall. |
|  | Lateral Support | A support which enables a masonry element to resist lateral load and/or restrains lateral deflection of a masonry element at the point of support.  Remark: Lateral support is a primary requirement in structural design of masonry. A lateral support may be provided along either a horizontal or a vertical line, depending on whether the slenderness ratio is based on a vertical or horizontal dimension. Horizontal or vertical lateral supports should be capable of transmitting design lateral forces to the elements of construction that provide lateral stability to the structure as a whole. |

|  |  |  |
| --- | --- | --- |
|  |  | RC slab as a lateral support at the top of wall in the horizontal plane    Cross walls as lateral support in the vertical plane    Pilasters as lateral supports in the vertical plane |
|  | Load Bearing  Wall | A wall designed to carry an imposed vertical load in addition to its  own weight, together with any lateral load. |
|  | Masonry Unit | Individual units which are bonded together with the help of mortar to  form a masonry element, such as wall, column, pier and buttress. |
|  | Partition Wall | An interior non-load bearing wall, one storey or part storey in height. |
|  | Panel Wall | An exterior non-load bearing wall in framed construction, wholly supported at each storey but subjected to lateral loads in out-plane  direction such as wind loads, earthquake loads etc. |
|  | Shear Wall and Cross wall | A wall designed to carry horizontal forces acting in its plane with or without vertical imposed loads. The walls normal to shear walls are  known as cross walls. |

|  |  |  |
| --- | --- | --- |
|  |  | Cross Wall  Earthquake Motion  Cross Wall  Shear walls and cross walls |
|  | Slenderness  Ratio (SR) | Ratio of effective height or effective length to effective thickness of a  masonry element. |
|  | Cavity Wall | A wall comprising two leaves, each leaf being built of masonry units and separated by a cavity and tied together with metal ties or bonding units to ensure that the two leaves act as one structural unit, the space  between the leaves being either left as continuous cavity or filled with a non-load bearing insulating and waterproofing material. |
|  | Faced Wall | A wall in which facing and backing of two different materials are bonded together to ensure common action under load backing shall be  provided by toothing, bonding or other means. |
|  | Veneered Wall | A wall in which the facing is attached to the backing but not so  bonded as to result in a common action under load. |
|  | Ks | Stress reduction factor |
|  | Ka | Area reduction factor |
|  | Kp | Shape modification factor |
|  | Pilaster | A thickened section forming integral part of a wall placed at intervals along the wall, to increase the stiffness of the wall or to carry a vertical concentrated load. Thickness of a pilaster is the overall thickness including the thickness of the wall or when bonded into a leaf of a cavity wall, the thickness obtained by treating that leaf as an independent wall |



Shear Wall

Shear Wall

|  |  |  |
| --- | --- | --- |
|  |  | Pilasters |
|  | Jamb | Side of an opening in wall.    Jamb (example: door jamb) |
|  | Non-Load Bearing Wall | A wall that is not resisting or supporting any loads such that it can be removed with the approval of a structural engineer without  jeopardizing integrity of the remaining structure |
|  | Partition Wall | An interior non-load bearing wall, one storey or part storey in height. |
|  | Veneered Wall | A wall in which the facing is attached to the backing but not so  bonded as to result in a common action under load. |
|  | Wall Tie | A metal fastener which connects wythes of masonry to each other or  to other materials. |

Masonry reinforcement

For the purpose of general load bearing construction, Fe 415 grade steel is acceptable, with the generic requirements as given in Table 2. However, for the purpose of earthquake resistant masonry, a variety of reinforcement can be used, typically the ones which impart to the system ductility.

Table 2: Specification for reinforcement in load bearing masonry

|  |  |
| --- | --- |
| Tensile strength | |
| MS Bars confirming to IS 432 (Part I) | 140 MPa for diameter ≤20 mm  130 MPa for diameter >20 mm |
| HYSD Bars (IS 1786) | 230 MPa |
| Compressive strength | |
| MS Bars confirming to IS 432 (Part I) | 130 MPa |
| Size and spacing of reinforcement | |
| The maximum size of reinforcement used in masonry shall be 25 mm diameter bars and  minimum size shall not be less than 5 mm. | |

The diameter of reinforcement shall not exceed one-half the least clear dimension of the cell, bond beam, or collar joint in which it is placed.

Clear distance between parallel bars shall not be less than the diameter of the bars, or less than 25 mm. In columns and pilasters, clear distance between vertical bars shall not be less than 1.5 times the bar diameter, nor less than 35 mm.

Basics of Load Bearing Masonry

It is very important to note that the first step in masonry building design is to ensure a stable configuration. Masonry structures gain stability from the support offered by cross walls, floors, roof and other elements such as piers and buttresses Load bearing walls are structurally more efficient when the load is uniformly distributed and the structure is so planned that eccentricity of loading on the members is as small as possible. Avoidance of eccentric loading by providing adequate bearing of floor/roof on the walls providing adequate stiffness in slabs and avoiding fixity at the supports etc., is especially important in load bearing walls in multistory structures. These matters should receive careful consideration during the planning stage of masonry structures.

In order to ensure uniformity of loading, openings in walls should not be too large. and these should be of 'hole in wall' type as far as possible; Bearings for lintels and bed blocks under beams should be liberal in sizes; heavy concentration of loads should be avoided by judicious planning and sections of load bearing members should be varied where feasible with the loadings so as to obtain more or less uniform stress in adjoining parts of members. One of the commonly occurring causes of cracks in masonry is wide variation in stress in masonry in adjoining parts.

Achieving lateral stability through lateral supports

Lateral support may be in the vertical or horizontal direction, the former consisting of floor/roof bearing on the wall ‘or properly anchored to the same and latter consisting of cross walls, piers or buttresses. These can be achieved by;

In case of a wall, where slenderness ratio is based on effective height, any of the following constructions are provided:

RCC floor/roof slab (or beams and slab), irrespective of the direction of span, bears on the supported wall as well as cross walls to the extent of at least 9 cm;

RCC floor/roof slab not bearing on the supported wall or cross wall is anchored to it with non-corrodible metal ties of 60 cm length and of section not less than 6 x 30 mm, and at intervals not exceeding 2 m as shown in Fig. 1;

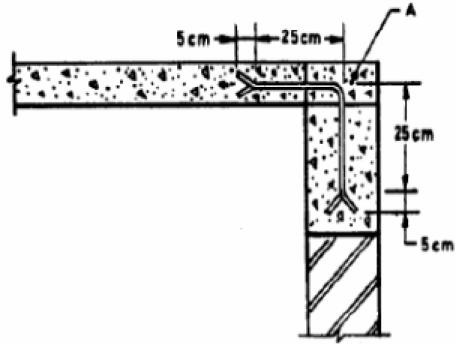


Fig 1: Anchoring a slab when it is not bearing on the wall

Timber floor/roof and pre-cast floor/roof require special connection details (not covered in this part)

In case of a wall, when slenderness ratio is based on its effective length; a cross wall/pier/buttress of thickness equal to or more than half the thickness of the supported wall or 90 mm, whichever is more, and length equal to or more than one-fifth of the height of wall is built at right angle to the wall (Fig 2) and bonded to it according to provision of 4.2.2.2 (d) of IS 1905 (1987)

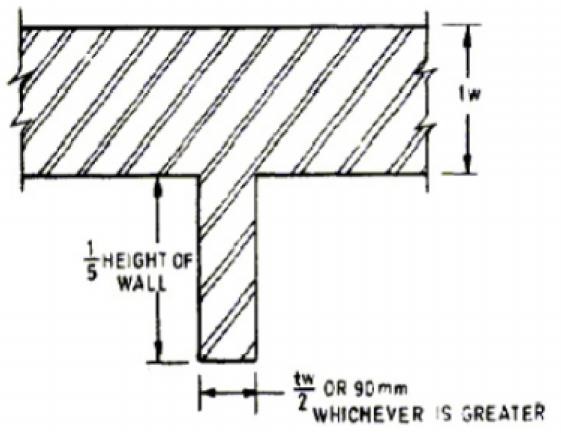


Fig 2: Minimum dimensions for masonry wall/buttress providing effective lateral support

In case of a column, an RCC or timber beam/R S joist/roof truss is supported on the column. In this case, the column will not be deemed to be laterally supported in the direction right angle to it; and

In case of a column, an RCC beam forming a part of beam and slab construction is supported on the column, and slab adequately bears on stiffening walls. This construction will provide lateral support to the column in the direction of both horizontal axes.

Achieving stability – general

A wall or column subjected to vertical and lateral loads may be considered to be provided with adequate lateral support from consideration of stability, if the construction providing the support is capable of resisting the following forces:

Simple static reactions at the point of lateral support to all the lateral loads; plus

2.5 percent of the total vertical load that the wall or column is designed to carry at the point of lateral support.

In case of load bearing un-reinforced buildings up to four storeys, stability requirements of may be deemed to have been met with if:

Height to width ratio of building does not exceed 2;

Cross walls acting as stiffening walls continuous from outer wall to outer wall or outer wall to a load bearing inner wall, and of thickness and spacing as given in Table 10.7 are provided. If stiffening wall or walls that are in a line, are interrupted by openings, length of solid wall or walls in the zone of the wall that is to be stiffened shall be at least one-fifth of height of the opening as shown in Fig 10.8;

Floors and roof either bear on cross walls or are anchored to those walls as stated earlier, such that all lateral loads are safely transmitted to those walls and through them to the foundation;

And cross walls are built jointly with the bearing walls and are jointly mortared, or the two interconnected by toothing. Alternatively, cross walls may be anchored to walls to be supported by ties of non-corrodible metal of minimum section 6 x 35 mm and length 60 cm with ends bent up at least 5 cm; maximum vertical spacing of ties being 1.2 m).

Table 3: General guidelines for geometry of stiffeners

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Thickness (m) of load  bearing wall to be stiffened | Height (m) of storey not to exceed | Stiffening wall | | |
| Thickness (m) not less than | | Maximum spacing (m) |
| 1 to 3 storey | 4 storey |
| 0.1 | 3.2 | 0.1 | - | 4.5 |
| 0.2 | 3.2 | 0.1 | 0.2 | 6.0 |
| 0.3 | 3.4 | 0.1 | 0.2 | 6.0 |
| Above 0.3 | 5.0 | 0.1 | 0.2 | 8.0 |

Remark

In case of halls exceeding 8.0 m in length, safety and adequacy of lateral supports shall always be checked by structural analysis.

Trussed roofing may not provide lateral support, unless special measures are adopted to brace and anchor the roofing. However, in case of residential and similar buildings of conventional design with trussed roofing having cross walls, it may be assumed that stability requirements are met with by the cross walls and structural analysis for stability may be dispensed with.

Capacity of a cross wall and shear wall to take horizontal loads and consequent bending moments, increases when parts of bearing walls act as flanges to the cross wall. Maximum overhanging length of bearing wall which could effectively function as a flange should be taken as 12 t or H/6, whichever is less, in case of T or I shaped walls and 6 t or H/6, whichever is less, in case of L or U shaped walls, where t is the thickness of bearing wall and H is the total height of wall above the level being considered.

The connection of intersecting walls shall conform to one of the following requirements:

c) Providing proper masonry bonds such that 50% of masonry units at the interface shall interlock.

Connector or reinforcement extending in each of the intersecting wall shall have strength equal to that of the bonded wall

Requirements of section 8.2.4 of IS: 4326.

Effective overhanging width of flange = 12 t or H/6 whichever is less, H being the total height of wall above the level being considered. Effective overhanging width of flange = 6 t or H/6 whichever is less, H being the total height of wall above the level being considered In case of external walls of basement and plinth stability requirements may be deemed to have been met with if:

bricks used in basement and plinth have a minimum crushing strength of 5 MPa and mortar used in masonry is of Grade Ml or better;

clear height of ceiling in basement does not exceed 2.6 m;

walls are stiffened according to provisions of 4.2.2.1;

in the zone of action of soil pressure on basement walls, traffic load excluding any surcharge due to adjoining buildings does not exceed 5 kN/m2 and terrain does not rise; and

Minimum thickness of basement walls is in accordance with Table 4. In case there is surcharge on basement walls from adjoining buildings, thickness of basement walls shall be based on structural analysis.

Table 4: Minimum thickness of basement walls

|  |  |  |
| --- | --- | --- |
| Height of the ground above basement floor level with  wall loading (permanent load) | | Minimum thickness (m) of basement walls |
| More than  50 kN/m | Less than  50 kN/m |
| 2.75 | 2.0 | 0.4 |
| 1.75 | 1.4 | 0.3 |

Structural design

The building as a whole shall be analyzed by accepted principles of mechanics to ensure safe and proper functioning in service of its component parts in relation to the whole building. All component parts of the structure shall be capable of sustaining the most adverse combinations of loads, which the building may be reasonably expected to be subjected to during and after construction.

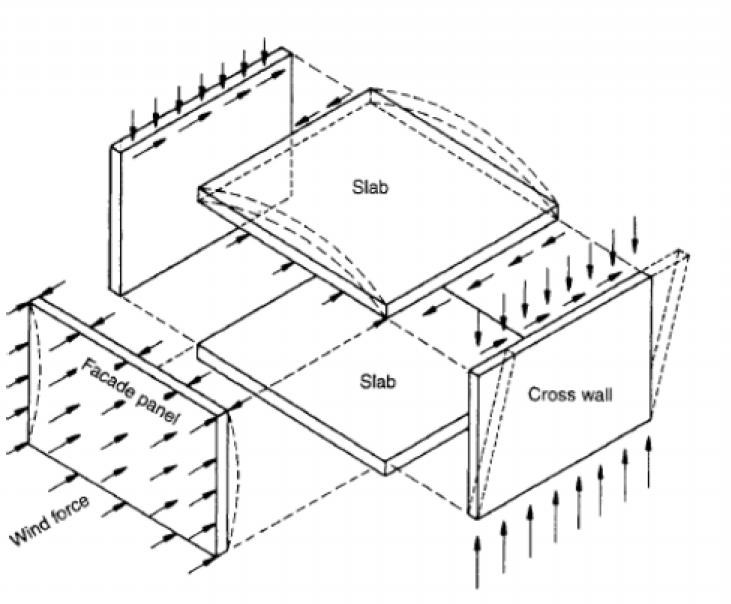
Some general guidance on the design concept of load bearing masonry structures is given in the following paragraphs.

A building is basically subjected to two types of loads, namely:

vertical loads on account of dead loads of materials used in construction, plus live loads due to occupancy; and

lateral loads due to wind and seismic forces.

While all walls in general can take vertical loads, ability of a wall to take lateral loads depends on its disposition in relation to the direction of lateral load. The lateral loads acting on the face of a building are transmitted through floors (which act as horizontal beams) to cross walls which act as shear walls. From cross walls, loads are transmitted to the foundation. This action is illustrated in Fig. 3. Wind load on the facade wall is transferred via floor slabs to the cross walls and thence to the ground. The strength and stiffness of floors as horizontal girders is vital; hence floors/roofs of lightweight construction should be used with care.



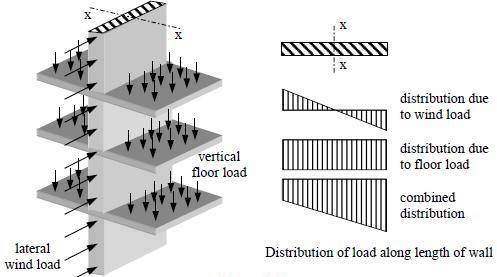


Fig 3: Lateral force (eg. wind force) is resisted by the facade panel owing to bending, and transferred via floor slabs to the cross or shear wall and finally to the ground.

As a result of lateral load, in the cross walls there will be an increase of compressive stress on the leeward side, and decrease of compressive stress on the wind-ward side. These walls should be designed for 'no tension' and permissible compressive stress. It will be of interest to note that a

wall which is carrying greater vertical loads will be in a better position to resist lateral loads than the one which is lightly loaded in the vertical direction. This point should be kept in view while planning the structure so as to achieve economy in structural design.

A structure should have adequate stability in the direction of both the principal axes. The so- called 'cross wall' construction may not have much lateral resistance in the longitudinal direction. In multi-storeyed buildings, it is desirable to adopt 'cellular' or 'box type' construction from consideration of stability and economy.

Size, shape and location of openings in the external walls have considerable influence on stability and magnitude of stresses due to lateral loads.

If openings in longitudinal walls are so located that portions of these walls act as flanges to cross walls, the strength of the cross walls get considerably increased and structure becomes much more stable.

Ordinarily a load-bearing masonry structure is designed for permissible compressive and shear stresses (with no tension) as a vertical cantilever by accepted principles of engineering mechanics. No moment transfer is allowed for, at floor to wall connections and lateral forces are assumed to be resisted by diaphragm action of floor/roof slabs, which acting as horizontal beams, transmit lateral forces to cross walls in proportion to their relative (moment of inertia).

Design Loads

Loads to be taken into consideration for designing masonry components of a structure are:

dead loads of walls, columns, floors and roofs;

live loads of floors and roof;

wind loads on walls and sloping roofs and

seismic forces.

Note - When a building is subjected to other loads, such as vibration from railways and machinery, these should be taken into consideration according to the best engineering judgment of the designer.

Dead loads

Dead loads shall be calculated on the basis of unit weights taken in accordance with IS:875 –

part I (1987).

Live Loads and Wind Loads

Design loads shall be in accordance with the recommendations of IS: 875- (1987) or such other loads and forces as may reasonably be expected to be imposed on the structure either during or after construction.

Note - During construction, suitable measures shall be taken to ensure that masonry is not liable to damage or failure due to action of wind forces, back filling behind walls or temporary construction loads.

Seismic loads

Seismic loads shall be determined in accordance with the IS 1893- Part 1:2002.

Load combinations

In the allowable stress design method followed for the structural design of masonry structures as outlined in this code, adequacy of the structure and member shall be investigated for the following load combinations:

DL + IL

DL + IL + (WL or EL)

DL + WL

0.9 DL +EL

Note: The four load combinations given are consistent with those in other BIS codes. In case of wind and earthquake loads, the reversal of forces needs to be considered. The structure is to be designed for the critical stresses resulting from these load combinations.

Permissible stresses and loads

Permissible stresses and loads may be increased by one-third for load case b, c, & d when wind or earthquake loads are considered along with normal loads.

As an alternative of using an increased permissible stress value when checking safety of structural components, one can use a 25% reduced load for load combinations involving wind or earthquake forces and compare with full permissible stress values. Thus, the modified load combinations b, c and d will be:

a) 0.75 [DL + IL + (WL or EL)]

b) 0.75 [DL + WL]

c) 0.75 [0.9DL +EL]

Vertical load dispersion

Generally, it is accepted, based on experiments, that dispersion of axial loads does not take place at an angle 45° to vertical as assumed in previous codes. An angle of distribution for axial loads not exceeding 30° is more realistic and is recommended by various other masonry codes.

In case of buildings of conventional design with openings of moderate size which are reasonably concentric, some authorities on masonry recommend a simplified approach for design. In simplified approach, stress in masonry at plinth level is assumed to be uniformly distributed in different stretches of masonry, taking loadings in each stretch of masonry walls without making any deduction in weight of masonry for the openings. It is assumed that the extra stresses obtained in masonry by making no deduction for openings, compensates more or less for concentrations of stresses due to openings. This approach is of special significance in the design of multi-storeyed load-bearing structure where intervening floor slabs tend to disperse the upper storey loads more or less uniformly on the inter-opening spaces below the slabs and thus at plinth level stress in masonry, as worked out by the above approach is expected to be reasonably accurate.

Lintels

Lintels, that support masonry construction, shall be designed to carry loads for masonry (allowing for arching and dispersion, where applicable) and loads received from any other part of the structure. Length of bearing of lintel at each end shall not be less than 9 cm or one-tenth of the span, whichever is more, and area of the bearing shall be sufficient to ensure that stresses in the masonry (combination of wall stresses, stresses due to arching action and bearing stresses from the lintel) do not exceed the stresses permitted.

When location and size of opening is such that arching action can take place, lintel is designed for the load of masonry included in the equilateral triangle over the lintel. In case floor or roof slab falls within a part of the triangle in question or the triangle is within the influence of a concentrated load or some other opening occurs within a part of the triangle, loading on the lintel will get modified as discussed earlier.

Lateral load distribution

Lateral loads from the wind or earthquakes are generally considered to act in the direction of the principal axes of the building structure. The distribution of lateral loads to various masonry wall elements depends on the rigidities of the horizontal floor or roof diaphragm and of the wall elements. If a diaphragm does not undergo significant in-plane deformation with respect to the supporting walls, it can be considered rigid and lateral loads are distributed in various lateral load

resisting wall elements in proportion to their relative stiffness. Horizontal torsion developed due to eccentricity of the applied lateral load with the plan centre of the rigidity can cause forces in the wall parallel and perpendicular to load direction. In-plane rigidities are considered in the analysis, which includes both shearing and flexural deformations. Generally rigidities of transverse walls in direction perpendicular to the direction of lateral force, is usually disregarded. However, stiffening effect of certain portion of such walls as permitted by the code, when the stiffening action is significant, i.e. when the method of connection between the intersecting walls and between walls and diaphragms is adequate for the expected load transfer. On the other hand, flexible diaphragms change shape when subjected to lateral loads and are incapable of transmitting torsional forces. The distribution of lateral loads to vertical wall elements takes place in proportion to the tributary area associated with each wall element for vertical loads distribution.

Basic Compressive Strength of Masonry

The basic compressive strength of masonry fm shall be determined by the (a) unit strength method or by the (b) prism test method. The unit strength method eliminates the expense of prism tests but is more conservative than the prism test method.

Unit strength method

The basic compressive strength of masonry shall be four times of the basic compressive stress which based on the strength of the units and the type of mortar. Unit strength method is based on the compressive strength of masonry units and mortar type, and is developed by using prism test data.

Prism strength method

Basic compressive strength of masonry shall be determined by prism test on masonry made from masonry units and mortar to be actually used in a particular job. This is a uniform method of testing masonry to determine its compressive strength and is used as an alternative to the unit strength method.

Permissible stresses

Permissible compressive stress in masonry shall be based on the value of basic compressive stress (fb) which is based on two approaches, (i) when prism is not tested and (ii) when prism is tested.

Prism not tested/Unit Strength Method:

Values of basic compressive stress given in Table 5 which are based on the crushing strength of masonry unit and grades of mortar, and hold good for values of SR not exceeding 6, zero eccentricity and masonry unit having height to width ratio (as laid) equal to 0.75 or less.

Prisms tested:

The basic compressive stress can be obtained by multiplying the specified compressive strength obtained from prism test with a factor of 0.25.

Permissible Compressive Stress

Permissible compressive stress in masonry shall be based on the value of basic compressive stress (fb) as given in Table 4 and multiplying this value by factor known as stress reduction factor (ks), Area reduction factor (ka) and shape modification factor (kp). Amongst these, the stress reduction factor plays a very important role. It can be explained with the help of fig. 4 and to fig. 5. When the prism (or a short wall) is axially loaded, it can withstand maximum load. As the wall becomes slender, the load carrying capacity reduces and when the loads are eccentric, the load carrying capacity becomes even lesser. Thus the slenderness ratio (SR) and the eccentricity of load (or e/t ratio) plays an important role is the estimation of load capacity of walls. This is presented in Table 6. In the present Indian code, the stress reduction factors are unity for SR=6 and all values of e/t, this is not the case in the other masonry codes. Also the stress reduction factors are to be taken for any type of masonry, but current literature indicates clearly that both, the strength and elasticity of masonry play a role in the reduction factors.

Area reduction factor due to 'small area' of a member is based on the concept that there is statistically greater probability of failure of a small section due to sub-standard units as compared to a large element. However some codes do not include any provision for smallness of area. In view of the fact that strength of masonry units being manufactured at present in our country can appreciably vary, the necessity for this provision is justified in our code. This factor is applicable when sectional area of the element is less than 0.2 m2. The factor ka=0.7 + 1.5 A, A being the area of section in m2.

Shape modification factor is based on the general principle that lesser the number of horizontal joints in masonry, greater its strength or load carrying capacity. This is presented in table 5. Here also there is a need for further studies.

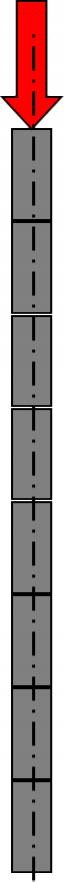
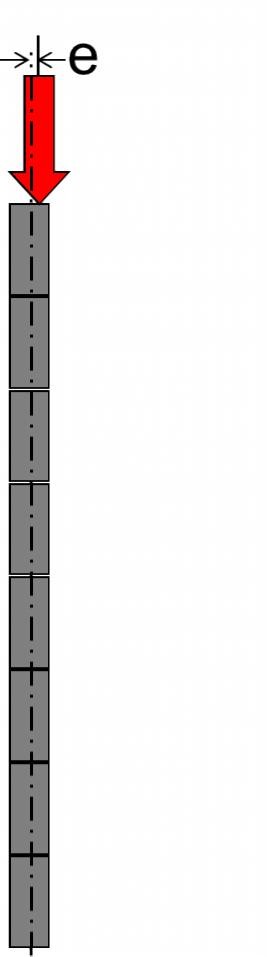
 

Fig. 4: (a) Short and axially loaded wall (capacity 100%) (b) Slender and axially loaded wall (capacity < 100%)



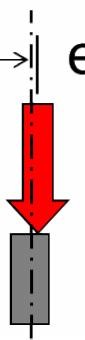


Fig. 5: (a) Short and eccentrically loaded wall (capacity < 100%) (b) Slender and eccentrically loaded wall (capacity << 100%)

Table 5: Basic Compressive strength (in MPa)

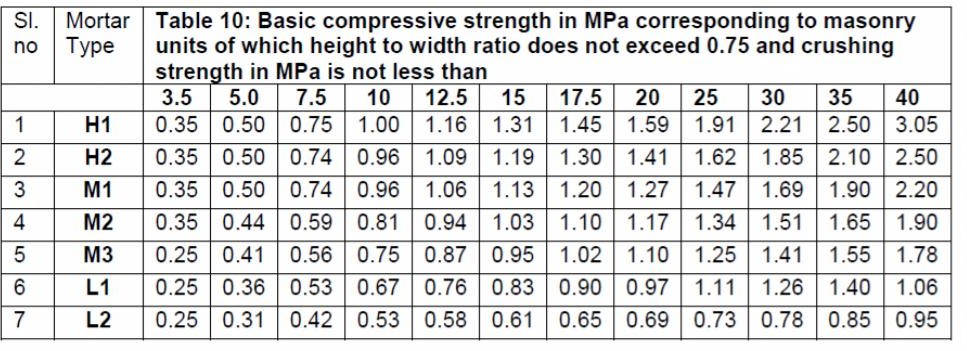
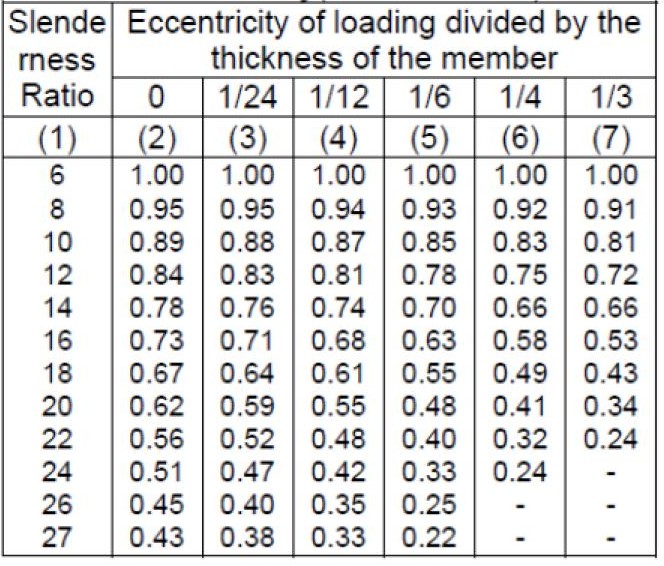
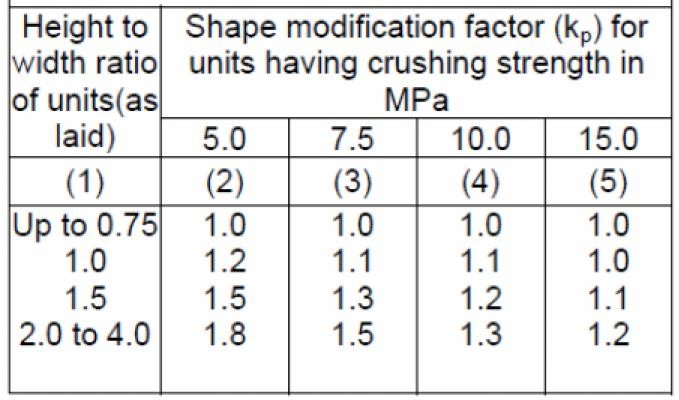


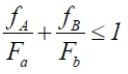
Table 6: Stress reduction factors (ks)



Table. 7: Shape modification factor

Combined Permissible Axial and Flexural Compressive Stress

Members subjected to combined axial compression and flexure shall be designed to satisfy the following:



Where,

fa= Calculated compressive stresses due to axial load only fb= Calculated Compressive stresses due to flexure only Fa = Allowable axial compressive stress

Fb = Allowable flexural compressive stress = 1.25 Fa

The unity equation assumes a straight line interaction between axial and flexural compressive stresses for unreinforced masonry sections. This is simple portioning of the available allowable stresses between axial and flexure loads, which can be extended for the biaxial bending, by using the bending stress quotients for both axes. In this interaction formula, the secondary effect of moment magnification for flexure term due to axial loads is not included, which is an error on the unsafe side. However, this error for practical size of walls will be relatively small and large overall safety factor of about 4 is adequate to account for this amplification of flexure term. The code allows 25% increase in allowable axial compressive stress, if it is due to flexure. The permissible flexural compressive stress can be expressed as a function of masonry prism strength as follows:

Fb = 1.25 Fa = 1.25 x 0.25 fm = 0.31 fm

Permissible Tensile Stress

As a general rule, design of masonry shall be based on the assumption that masonry is not capable of taking any tension. However, in case of lateral loads normal to the plane of the wall, which causes flexural tensile stress, as for example, panel, .curtain partition and freestanding walls, flexural tensile stresses as follows may be permitted in the design for masonry:

Grade M1 or Better mortar

0.07 MPa for bending in the vertical direction where tension developed is normal to bed joints.

0.14 MPa for bending in the longitudinal direction where tension developed is parallel to bed joints provided crushing strength of masonry units is not less than 10 MPa.

Grade M2 mortar

0.05 MPa for bending in the vertical direction where tension developed is normal to bed joints.

0.10 MPa for bending in the longitudinal direction where tension developed is parallel to bed joints provided crushing strength of masonry units is not less than 7.5 MPa.

Important note:

No tensile stress is permitted in masonry in case of water-retaining structures in view of water in contact with masonry. Also no tensile stress is permitted in earth-retaining structures in view of the possibility of presence of water at the back of such walls.

Permissible shear stress

In-plane permissible shear stress (Fv )shall not exceed any of :

0.5 MPa (b) 0.1+ 0.2fd

(c) 0.125 (fm)1/2

Where,

fd = compressive stress due to dead loads in MPa.

Unreinforced masonry in shear fails in one of the following mode (a) Diagonal tension cracking of masonry generally observed when masonry is weak and mortar is strong, (b) Sliding of masonry units along horizontal bed joint, especially when masonry is lightly loaded in vertical

direction and (c) Stepped cracks running through alternate head and bed joints, usually observed in case of strong units and weak mortars. Permissible shear stress for unreinforced masonry is based on experimental research for various failure modes. At low pre-compression (<2 MPa), for sliding type of failure mode, a Mohr-Coulomb type failure theory is more appropriate and shear capacity is increased due to increase in the vertical load. The coefficient of friction of 0.2 has been long used in the masonry codes, however, the recent research indicate that a higher value (about 0.45) is more appropriate. At large pre-compression (> 2 MPa), tensile cracking of masonry is more likely which are expressed in terms of square root of compressive strength of masonry.

Wall Thickness (Cross-Section and Dimensions)

Walls and Columns Subjected to Vertical Loads: Walls and columns bearing vertical loads shall be designed on the basis of permissible compressive stress. Design involves in determining thickness in case of walls and the section in case of columns in relation to strength of masonry units and grade of mortar to be used, taking into consideration various factors such as slenderness ratio, eccentricity, area of section, workmanship, quality of supervision, etc.

Solid Walls

Thickness used for design calculation shall be the actual thickness of masonry computed as the sum of the average dimensions of the masonry units specified in the relevant standard, together with the specified joint thickness. In masonry with raked joints, thickness shall be reduced by the, depth of raking of joints for plastering/pointing. Brick work is generally finished by either pointing or plastering and with that in view, it is necessary to rake the joints while the mortar is green, in case of plaster work raking is intended to provide key for bonding the plaster with the background. Strictly speaking, thickness of masonry for purposes of design in these cases is the actual thickness less depth of raking. However in case of design of masonry based on permissible tensile stress (as for example, design of a free standing wall), if walls are plastered over (plaster of normal thickness i.e. 12 to 15 mm) with mortar of same grade as used in the masonry or M2 grade whichever is stronger or if walls are flush pointed with mortar of M1 grade or stronger, raking thickness can be ignored.

Concepts for earthquake resistant masonry

The basic principles of design and detailing, as outlined in the codes of practice, of earthquakes resistant structures are intentionally simple and generally easy to adopt. Essentially the principles are focused on,

Achieving strength and ductile behaviour

Maintaining structural integrity

This means that the primary requirement is ‘prevention of catastrophic collapse of buildings or their components’. It is also the intention of the codes of practice to achieve this in relatively simple and cost effective manner.

The level of resistance aimed for in earthquake resistant design is based on the concept of

‘acceptable risk’, with the following objectives;

To resist minor earthquakes without damage

To resist moderate earthquakes without significant structural damage, but with some non- structural damage

To resist major (or severe) earthquake without major failure of the structural framework of the building or its components, to prevent loss of life and to allow safe escape passage for the inmates of the building.

However, certain important critical structures hospitals, power generating units, communication set-ups etc., shall be designed to remain operational during and after an earthquake event.

Un-reinforced masonry buildings are very common in rural and semi-urban area of India. A variety of load bearing masonry units such as adobe, stone, burnt brick, concrete blocks and stabilized mud blocks are commonly used along with a variety of mortars such as mud mortar, cement mortar, lime mortar and composite mortar. Normally these buildings are designed for vertical loads and since masonry has adequate compressive strength, the structure behaves well as long as the loads are vertical.

The behaviour of a masonry building during ground motion can be understood by analysing the nature of stress distribution in the walls of the masonry building. When dominant ground motion is along one axis of the building, the walls parallel to the direction of ground motion are known as ‘shear walls’ and those orthogonal to it are known as ‘cross walls’.

Shear walls are predominantly subjected to in-plane shear stresses and in-plane bending stresses. The in-plane bending stresses in shear walls are normal-to-bed joints. The in-plane shear stresses are responsible for the typical X-type of cracking in the shear walls, while the in-plane bending stresses in the shear walls tend to cause separation of cross walls and shear walls at the junction. Although severe cracking could be caused, the walls may not readily collapse unless a component of ground motion is normal to it. The stress concentration near the openings in shear walls adds to the vulnerability.

The failure pattern of such masonry structures during earthquake can be classified as under (shown in plates 1 to 7);

Out-of-plane flexural and/or out-of-plane shear failure

In-plane shear and/or in-plane flexure failure

Separation of walls at junction

Failure of masonry piers between openings

Local failures

Buckling of wythes

Separation of roof from walls



Plate 1: Out-of-plane flexure failure



Plate 10.6: In-plane shear failure



Plate 2: Separation of wall at junctions



Plate 3: Failure of masonry piers between openings



Plate 4: Local failures



Plate 5: Buckling of wythes



Plate 6: Separation of roof from walls Concept of ‘Containment Reinforcement’

The pattern of failure of masonry buildings during an earthquake makes it clear that the prevention of sudden flexural failure of masonry wall is critical to ensure an earthquake resistant masonry structure. Since flexural tension can occur on both the faces of the wall due to reversal of stresses during an earthquake, there is a need to provide ductile reinforcement on both the faces. This can be accomplished by placing vertical reinforcement either on the surface or close to the surface and surrounding the wall, which is termed as “containment reinforcement”. For the containment reinforcement to be effective, it is essential for it to remain hugged to the wall all times during an earthquake. In order to meet this objective and to prevent buckling of the reinforcement on the compression side of the wall, the vertical reinforcement on either face of the wall to be connected to each other, through horizontal ties/links passing through the bed joint of masonry. Containment reinforcement is intended to permit large ductile deformation and avoid total collapse. In other words, containment reinforcement will act as main energy absorbing element of the wall which otherwise is poor energy absorbing capacity. Fig 6 shows a schematic diagram of containment reinforcement for a typical masonry wall with ties at bed joints. The complete scheme of vertical and horizontal reinforcement is shown in Fig 7.

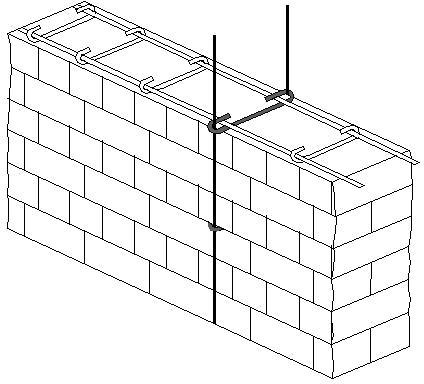


Fig 6: Containment reinforcement scheme integrated with horizontal bed reinforcement

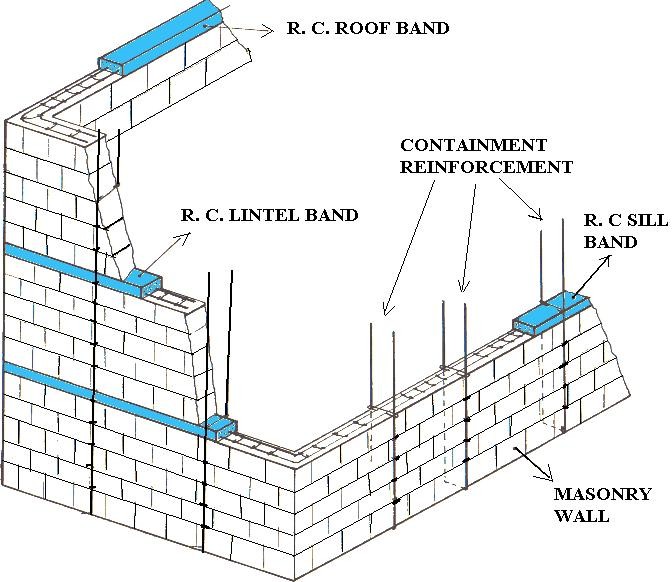


Fig 7: Schematic diagram of vertical and horizontal reinforcement in a masonry building

Specification for vertical ‘containment reinforcement’

It is recommended that containment reinforcement may be provided for low-rise (up to 3 storey load bearing) masonry buildings in earthquake zones III, IV, and V. This is in addition to horizontal bands.

In case of buildings with heavy roofs/floors (mass of the floor more than 200kg/m2), if height of the wall is 3.0m or less and the length of the wall is less than or equal to 3.0m containment reinforcement need not be provided if there are no openings in the wall.

Masonry buildings with light roofs (tiled roof, asbestos or zinc sheet roofs) must have containment reinforcement on all walls irrespective of the aspect ratio of the wall.

Walls with height greater than 3.0m must invariably have containment reinforcement.

All door and window jambs must have containment reinforcement on either sides of the opening at a distance of 150.0mm to 200.0mm from the jamb. Masonry piers between door and window openings or between two window openings should not be less than 0.75m in width. This is a modification of clause 8.3.1 in IS: 4326 (1993). Other provision in this clause may not be changed.

The wires/rods of containment reinforcement must be tied to the steel in the horizontal band to form a coarse two-dimensional cage holding the masonry in place.

Normally, the horizontal spacing between two sets of containment reinforcement should be between 0.75m to 1.25m.

A variety of reinforcing materials can be used as containment reinforcement. The details are presented in Table 8.

Table – 8: Different materials for ‘containment reinforcement’

|  |  |
| --- | --- |
| Reinforcing material | Remarks |
| Mild steel rods/flats | 6mm rods available, very ductile, liable to corrosion if exposed and hence has to be either coated with non-corrosive paints or covered with plaster.  20-25mm wide, 3mm thick MS flats could also be used, holes could be  made at regular intervals to insert links/bolts to tie the flats provided on both faces of the wall. |
| Galvanized Iron (GI) wires/flats | Any diameter wire available, easy for handling, good ductility, liable to corrosion and hence has to be protected.  20-25mm wide, 3mm thick GI flats could be used as mentioned above. |
| Stainless steel | Ideal material for containment reinforcement, 3mm to 4mm wires at  1.0m spacing, no need of coating, plastering etc. |
| Timber battens | Good quality battens (teak wood, sal wood etc.) of size 50mm x 25mm at 1.0m spacing, the pair of batten on either face of the wall to be tied together at two points at the base and two points at the top by boring a hole and inserting a bolt; needs regular maintenance to prevent rotting;  care to be taken to prevent it from catching fire. |
| Bamboo/split bamboo | Pairs of bamboo or split (half) bamboos at about 1.0m to 1.5m interval;  the poles to be tied at two points at the base and two points at top by using GI wires; less life; can catch fire, hence has to be protected |
| Ferro-cement strips | Thin ferro-cement strips (about 150.0mm wide) with sufficient amount |

|  |  |
| --- | --- |
|  | of reinforcing material such as chicken mesh, expanded metal, weld  mesh etc. at 1.2m spacing; the strips have to be bonded to the masonry wall by using grouted hooks. |
| Aluminum | Wires, rods and flats readily available, durable and have good resistance to corrosion, strength and modulus is less and hence large quantity is needed. |

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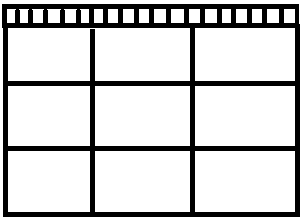
**Chapter 6**

**Planning, Designing and Construction of Earthquake Resistant Buildings**

**PLANNING OF EARTHQUAKE RESISTANT BUILDING**

First step in architectural planning of a building in to nolect the lateral load ing system. The load resisting system must be of cloned loop, wo that it in able transfer all the forces acting either vertically or horizontally to the ground. Bureau af Indian Standards (BIS) han approved three major types of lateral force resisting m in the code IS 1893 (Part1) 2002. ngint of moment resisting building frame system, bearing wall system These consist mon stem. These symptoms are further subdivided into types of construction dual system. The ed Table 7 of IS 1893 (Part1):2002 lints the different framing nystem and cara sed. Table 7 reduction factors. Response reduction factor (R) is banically an indicator of daemance of the structure in earthquakes. A low value of R(L5) Indicates an sly earthquake prone building i.e, unreinforced masonry wall buildings and ch ralue of R (5) indicates an earthquake resistant type building like special ant resistant reinforced concrete frame or shear wall building

1. Moment Resisting Frame



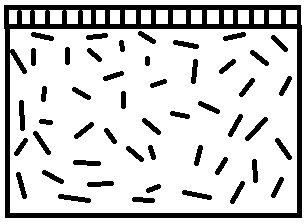
In building frame system, the member shown in fig

(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.

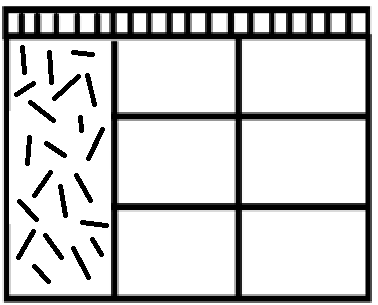
2.Building with shear wall or bearing wall system

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.

3.Building with dual system

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

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

The moment resisting frames are designed to independently resist at least 25 % of design seismic phase shear.

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.

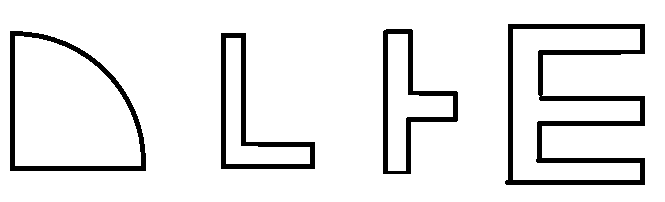
Building configuration

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.

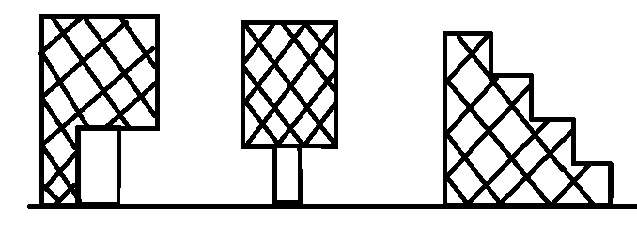
Seismic behavior of irregular shape of plan differs from regular shapes because the first can be subjected to their asymmetry and/or can present local deformations due to the presence of reentrant corners or excessive openings. Both give origin to undesired stress concentration in some resisting members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

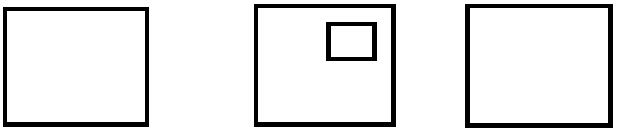
On the contrary the ideal rectangular or square plan structurally symmetrical with enough in-plane stiffness in its diaphragm, presents an ideal behavior, because it has the same displacement at every point in the slab.

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

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

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:

Foundation should be designed as continuous in order to avoid relative horizontal displacement.

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.

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

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

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.

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 |
| Extreme height/depth ratio | High overturning forces, large drift causing non-structural damage foundation stability. | Revise proportion or special structural system |
| Extreme plan area | Built-up large diaphragm forces | Subdivide building by seismic joints |
| Extreme length/depth ratio | Built-up of large lateral forces in parameter | Subdivide building by seismic joints. |
| 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. |
| False symmetry | Torsion cause by stiff asymmetric core. | Disconnect core, or use frame with non-structural core walls |
| Re-entrant corners | Torsion, stress concentrations at the notches | Separate walls, uniform box, centre box, diagonal reinf. |
| Mass eccentricities | Torsion, stress concentration | Reprogram, or add resistance around mass to balance resistance and mass. |
| Soft storey frame | Causes abrupt changes of stiffness at point of discontinuity | Add bracing, add columns braced |
| Variation in column stiffness. | Causes abrupt changes of stiffness, much higher forces in stiffer columns. | Redesign structured system balance stiffness. |
| 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. |

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.

2-Response spectrum analysis-THis method is applicated for these structure where made other than fundamental one affect significantly the response of the structure. Modal analysis leads to the response history of the structure to a specific round motion however, the method is usually used in conjuction woth a response spectrum.

3-Elastic time history analysis-A linear time history analysis overcomes all the disadvantages of modal response spectrum analysis provided non linear behaviour is not involved. This method requires greater computional efforts for calculating the response at discrate times.

4-Push over analysis-The push over analysis of a structure is a startic non-linear analysis under permanent vertical loads and gradually incresing lateral loads. On a building frame, load or displacement is applied incrementally, the formation of plastic hinges, stippress degradation and plastic relationare monitored. This type of analysis enables weakness in the structure to be identified.

5-Inelatic time history analysis-A sesmically deficient building willbe 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 duatility demand is structure. This is most

rational method avaliable for assesing building performance.

6.Equivalent lateral force method-THis method of finding design lateral force is also known as the slatie method or the equivalent spectrum method fo the seismic cofficient method.THe design base shear is computed for the building and it is then distributed along the height of the building. The lateral force at each floor level thus obtained are distributed to individual lateral load resisting elements.

SOME ADVANCED TECHNIQUES OF EARTHQUAKE RESISTANT

DESIGN CONSTRUCTION ARE:

Base inflation

Energy Dissipation devices

1 Base Isolation

Ti is easiest to see the principle at work by referring directly to the most widely used of these advanced techniques, which is known as base isolation.

A base islated structures is supported by a series

of bearing pads which are placed between the building and the building's foundation. A variety of different types of base isolation bearing pads have now been developed.

2. Earthquake Generated Forces

To get a basic idea of how base osolation works, an earthquake acting on both a base isolated building and a conventional,fixed base building. As a result of an earthquake, the ground beneath each building begins to move in figure. It is shown moving to the left Each building respond with movement which tends towards the right We say that the building undergone displacement in the direction opposite the ground motion is actually due to interia The inertial forces acting on a building are the most important of all those generated during an earthquake

It is important to know that the inertial forces which the building undergoes proportional to the buildings acceleration during ground motion. It is also importa to realize that the building doesn't actually shift in only one direction. Because of the complex nature of earthquake ground motion, the building actually tends to vibra back and forth in varying direction To figure is really a kind of Snapshot of the building at only one particular point of its earthquake response.

3 Deformation and Damages

In addition to displacing towards right, the unisolated building is also show be changing its shape from a rectangle to a parallelogram We say that the builder deforming. The primary cause of earthquake damage to buildings is the deforma

which the building undergoes as a result of the inertial forces acting upon it. different types of damage which buildings can suffer are quite varied upon a large number of complicated factors. But to take one simple exam an easily imagine what happens to two pieces of wood joined at a right angle ails, when the very heavy building containing them suddenly starts to. This make the nails pull out and the connection fails. 4.Response of Base Isolated Building

By contrast, even though it too is displacing, the base-isolated building retains its original, rectangular shape. It is the lead-rubber bearings supporting the bui

Lat are deformed. The base-isolated building itlsef escapes the deformation and dan which implies that the internal forces acting on the base-isolated building have reduced. Experiments and observations of base-isolated buildings in earthquake

been shown to reduce building accelerations to as little as Y of the accelerate comparable fixed-base buildings, which each building undergoes as a percenta poverty. As we noted above, internal forces increase, and decrease, proportional acceleration increases or decreases.

Acceleration is decreased because the base isolation system lengthens a builPeriod of vibration, the time it takes for the building to rock back and forth and mn. And in general, structures with longer periods of vibration tends to lon, while those with shorter periods tend to increase or amplify

Earthquake Resistant Building Construction

5 A second type of Base Isolation

Spherical sliding isolation systems

As we said earlier, lead-rubber bearings are just one of a number of differ types of base isolation bearings. Which have now been developed. Spherical Isolation systems oro another type of base isolation. The building is supported bearing pads that have a cureved surface and low friction. During an earthquake building in free to slide on the bearings, Since the buildings have a curved sur the building slides both horizontally and vertically (See figure 6.7). The force not to move the building upwards limits the horizontal or lateral forces which would otherwise causo building deformations. Also, by adjusting the radius of the building curved surface, this property can be used to design bearings that also lengthen

building period of vibration. The article below describes one particular type of spherical sliding system, ita successful use in making some structure more earthquake resistant.

The large number of damping devices that have been developed pain be grouped into three broad categories:

Friction Dampers :Utilize frictional forces to dissipate energy

viscous Dampers : Utilized the force movement (orificing) of Nudes within the damper

Metallic Dampers: Utilize the deformation of metal elements within the

Viscoelastic Dampers : Utilize the controlled shearing of solids.

7 Fluid Viscous Dampers

Once again, to illustrate some of the general principles of damping devices, we'll look more closely at one particular type of damping device, the fluid viscous damper, which is one variety of viscous damper that has been widely utilized and has proven to be very effective in a wide range of applications

The article below, describes the basic characteristics of fluid viscous dampers the Process of developing and testing them, and the installation of fluid viscous dampers an actual building to make it more earthquake resistant.

8 Applications of Fluid Viscous Dampers to Earthquake Resistant Design

Damping devices and bracing systems: Damping devices are usually installed as part bracing systems. Figure shows one type of damper-brace arrangement, with one end attached to a column with additional support Most earthquake ground motion in azontal direction. So, it is a buildings columns which normally undergo the most displacement relative to the motion of the ground. Figure 6.8 also shows that damping device as part of the bracing system and gives some idea of its action.

ROOF

The roofing structure must be light, well connected and adequately the walls. Trusses are superior to sloping roofs consisting of only refer frames,

The roof covering should preferably be a light material, like sheetin type. Heavy roofs consisting of wood joints and earth topping are and should not be used in zone V and IV. Tiled and slate roofs a heavier and shall be avoided in zone V and IV.

If thatch is used for roof covering, it should better be made waterproof and Ore renistant by applying waterproof mud plaster.

The roof beams rafters or truman should preferably be rested on longitudinal wooden elements for distributing the loads on walls

The slopes and the overhanging will depends on local climatic conditons In zones subjected to rain and snow, walls protection must be ensured by projecting roof by about 500mm beyond the walls

The roof beams or rafters should be Located to avoid their position above door or window lintel. Otherwise, the lintel should be reinforced by an additional lumber.

|  |  |
| --- | --- |
| Description | Causes |
| Cracking  Disintegration  Straining  Scaling  Spalling  Honey combing | Plastic shrinkage, Expansion, Corrosion of reinforced  concrete, shrinkage.  Sulphate attack, chemical attack, frozen concrete, low strength.  Curing, finishing. Non-uniform absorption, Aggregates, calcium chloride, finishing  Finishing problems, freeze-than cycling  Aggregate reaction, Poor construction joints corrosion, construction problem  Congested reinforcement, Poor consolidation |

(Table 6.1) Concrete Distress other than Earthquake

NON DESTRUCTIVE TESTS

1 Impact Echo

2 Penetrating radar

3Rebound hammer

4. Ultrasonic pulse velocity

5 Penetration resistance method

Brief of these methods are given below

1) Impact Echo : It is mainly used for concrete structures. It consists of three ponents a la for detecting discontinuities within the thickness of a wall.

2) Penetrating radar : It is used for detecting surface condition of slab-on grade to detect the location of reinforcing bars, cracks, voids or other material discontinuities.

(3)Rebound hammer : It is also known as Swiss hammer. It is a non-destructive device .Ti does not give precise value of compressive strength It provides estimate strength for comparison. It does not one reading at the same spot Earthquake Resistant Building Construction the quality of concrete. It does not give precisen vale

(4) Ultrasonic pulse velocity : It is used for determining the model and Poisson's ratio and density The pulse may propagate through the be in an apparent pulse velocity that is higher than that propagating throoh These measurements cannot determine the depth of the words

(5) Penetration resistance method : This provides a measure of the penetration probe Probe text may be the cause of minor cracking in concrete Probe penetration results are more meaningful than the real of resistance of the material. It is based on the determination hammer.

EFFECT OF EARTHQUAKE ON CODE DESIGNED STRUCTURES

Two Government buildings sustained minor or changes in the form of cracking of infill brick wall and non-functioning of lift. Both the buildings were condition after the earthquake The government buildings follows the a mandatory requirement IS 1993 Part) 2002 and IS 139201998 The performance of

Ends of wellne government buildings in the earthquake has been relatively better on account of code of compliance .

**CHAPTER 7**

**Disaster Risk Management**

**DISASTER MITIGATION**

Mitigation is a Corner stone of disaster or emergency management. It is defined as "sustained actions that reduce or eliminate long term risks to people and property from natural phenomenon like earthquakes, cyclones, floods etc. and even causes like highway/railway accidents, industrial accidents etc. It is an on going ef to lessen the impact that the hazards have in national economy and its develop including people, their property and infrastructure. The mitigation strategy has to be different in pre and post disaster scenario. Different professionals have on active role in such mitigation exercise.

The prevention and preparedness are the pre-disaster activities of mitigation The response is a post-disaster mitigation exercise. Besides other measures like rescue medical, relief etc. these include repairs and restoration of built infrastructure and housing constructed without structural safety features. The cost of repair, strengthening and restoration is many times after these are hit by an earthquake and get damaged

In this chapter details of disaster management rescue plan, different types kits etc. are discussed.

**DISASTER MANAGEMENT**

**DISASTER RISK MANAGEMENT (DRM)**

The overall goal of the programme is "Sustainable Reduction in Disaster Risk some of the most hazard-prone districts in the selected States of India."

**Part A: Situation Analysis** Disaster risk management is essentially a development problem and thus any Preparedness and mitigation planning will have to be taken up in tandem with fundamental concerns that the country is facing today. The Government of India - set up a National Committee on Disaster Management (NCDM) under the I the Prime Minister. The recommendations of this National Committee would form the of na orm the basis of national disaster risk management programme and "gthening the natural disaster management and response meer Powered Committee [HPC] on Disaster Management was earlier constituted in August 1999. The mandate of the HPC was to prepare Disaster Management Plans at National, State and District level

**Part I B: Programme Strategy** United National Development programme intends to support national and state efforts in disaster management with emphasis on the most multi-hazard prone districts by strengthening the capacities of the communities, local-self governments and districts to deal with future disasters. This programme design is based on UND? support to the states of Orissa and Gujarat after the two disasters these stale experienced.

Maharashtra, Delhi, Uttar Pradesh, Uttaranchal, Assam, Meghalaya and Sikkim for a comprehensive programme on disaster risk management. In this programme, a multi- nged strategy would be adopted :

* Support to Ministry of Home Affairs for ensuring adminstrative, institutional, financial and legal mechanisms for disaster risk management.
* Support National Government (MHA] efforts in strengthening its role in • Support National De nunity and local self-government's preparedness and response, including ort to National Civil Defense College (NCDC] and National Fire Service College [NFSC).
* comprehensive disaster risk management programme in the selected 125 most vulnerable districts falling in Gujarat, Orissa, Bihar, Tamil Nadu, West Bengal, Maharashtra, Delhi, Uttar Pradesh, Uttaranchal, Assam, Meghalaya and Sikkim two phases. These states are exposed to various natural disasters and strengthening disaster prevention, response and recovery in all multi-hazard prone districts would minimize disaster risk. The programmed components would include the following:
* Development of state and district disaster management plans
* Development of disaster risk management and response plans at Village/ Ward, Gram Panchayat, Block/Urban Local Body levels.
* Constitution of Disaster Management Teams and Committees at all levels with adequate representation of women in all committees and team. (Village/ Ward, Gram Panchayat, Block/Urban local body, District and State)
* Capacity building of Disaster Management Teams at all levels. Special training for women in first aid, shelter management, water and sanitation, rescue and evacuation, etc.
* Capacity building in cyclone and earthquake resistant features for houses in disaster-prone districts, training in retrofitting and construction of technology demonstration units.
* Integration of disaster management plans with development plans of local self-government.

**The project envisages the following:**

* Appropriate specialized support to Ministry of Home Affairs (MHA) fo setting up the system and framework for disaster risk management. Glity, disaster risk
* Development of national/state database on vulnerability, disaster management and sustainable recovery.
* Strengthening National and State Governments through support fe it and capacity building hardware and software for disaster risk management and capacity of institutions.
* Awareness campaign disaster mitigation and preparedness programme state.
* Support to include disaster management in school curriculum and to drill in disaster prevention and response for schools.
* Promoting partnerships with academic institutions and private se development of disaster risk management plans.
* Development of training manuals in Disaster Management for District Rl.- Gram Panchayat, Villages/Wards for each State in vernacular languages Capacity building activities for all stakeholders including civil sori organizations in the rescue, relief and restoration in disaster situation and the use of equipment involved.
* District multi-hazard preparedness and mitigation plans integrating Blo ULB, Gram Panchayat, Village/Ward plans which would involve vulnerabil mapping, risk assessment and analysis, hazard zoning, resource inventory response structure, etc.
* Strengthening disaster management information centres in programme sta and districts for accurate dissemination of early warning and flow information for preparedness and quick recovery operations.
* Dissemination of cost effective alternative technologies for hazard resist housing including retrofitting/roof top rainwater harvesting features as lo tern mitigation measures.
* Developing vulnerability and Risk Indices and annual Vulnerability and Reduction Reports for creating benchmarks to measure disaster management.

The entire programme would be divided into two phases for 2004], it is proposed to provide support to Ministry of Home Affairs as Nation six years. In Phase-T Agency and intensive natural disaster risk management activities in vulnerable districts of Orissa, Gujarat and Bihar.

**PARTIC: GOALS AND OBJECTIVES**

Goal: Sustainable Reduction in Disaster Risk in some of the most hazard prone Districts dected States of India

**Indicators** : The indicators of achievement of this goal would be :

* Risk reduction factor in rapid disaster recovery.
* Disaster mitigated and development gains protected.
* Disaster risk considerations mainstreamed into development.
* Gender equity in disaster preparedness.

**PSO-I** National capacity building to institutionalize the system for natural disaster risk management in Ministry of Home Affairs.

**PSO-II** Environment building, education, awareness programmes and strengthening capacities at all levels in natural disaster risk management and sustainable recovery. [Development of manuals and training modules, information, education and communication materials and their dissemination, awareness campaign strategy and implementation for disaster reduction and recovery.]

**PSO-III** Multi-hazard preparedness, response and mitigation plans for disaster risk management at state, district, block, village and ward level in 125 most multi-hazard prone districts of 12 selected states.

**PSO-IV** Networking knowledge on effective approaches, methods and tools for disaster risk management, developing and promoting policy framework at State and National levels.

**The activities envisaged are as follows**:

**Activities under PSO I**:

* Supporting the Miniso oporting the Ministry of Home Affairs for establishment of institutional, administrative, financial and legal systems for disaster risk man mechanisms to ensure adequate representation of women at community level.
* capacity building of functionaries at National level to sustain the programme.
* Support to NCDC and NFSC to strengthen them as resource centres for disaster management.
* Exposure visits to understand the best practices in the area of disaster ri management and sustainable recovery.
* Support for outlining the development of policy initiatives for disaster r management in the country, building on the work of High Powered Committee report, and with a conscious effort to mainstream gender (by giving space thought to the needs of women and disabled persons in policy, in preparedness all levels of disaster mitigation as well as response) and decentralization management.

**Activities under PSO II :**

* Consultations with National and State Governments, NGO institutions, private sector etc., at state, district and sub-district area specific disaster reduction and recovery strategies.
* Finalization of districts for the programme in the selected States.
* Sensitization of all stakeholders, including women representatives and on the need for disaster risk management and mitigation.
* Formulation of state specific awareness compaigns and strategies f implementation for disaster risk management in the seleted districts have specific Do's and Don'ts, checklist for preventive measures, etc.)
* Awareness generation programmes at all levels including all villages/wanie in selected districts through workshops/seminars/training, posters leaflets wall painting, and observation of disaster risk management day/week. A the community level, women volunteers, village level functionaries and PRL would be used to organize the events.
* Development of school primers on disaster management, training of teachers in curricula, preparedness and response activities, mock drills in schools etc.
* Development of manuals for District, Block, Gram Panchayat, Community and Ward level for preparing disaster risk management and response plans
* Development of manuals for design and construction of hazard resistant houses in the selected districts.
* Development of user-friendly manuals for retrofitting, roof top harvesting features etc.
* Training of all stakeholders on the process based disaster risk management and response plans.
* Manuals for training and orientation of Disaster Management "gement Teams (DMT all levels in dissemination of accurate warning, search and rescue operations first aid , water and sanitation, shelter management,counseling and damage. All manuals would address disaster response and recovery needs of special groups such as disabled persons, children, elderly people, pregnant women, etc.

**Activities under PSO III** :

* Geographical Information System (GIS) based hazard and vulnerability Iness mapping along with risk modeling of the 125 multi-hazard prone districts in the 12 programme states.
* Identification and establishment of working networks of nodal agencies and partners at different levels of implementation of the programme. Formations committees to look at gender mainstreaming.
* Formation of State, District, Block, Gram Panchayat, Village/Ward Disaster Formation of State, Dist Management Committees (DMC), which would include all concerned government Departments/functionaries, Senior Citizens, National Cadet Corps (NCC), National Social Service (NSS), Nehru Yuva Kendra Sangathan NYKS), Zilla Sainik Board, civil society response groups. Each DMC would have equal representation of women, and at community level, would include school teacher, disabled persons, village volunteers and members of isolated rds hamlets.
* Vulnerability mapping and risk assessment in all the multi-hazard prone At districts with special emphasis on vulnerability and risk of women, disabled persons and children, to help in formulating gender equitable and sustainable community plans for disaster preparednes
* Development of disaster management plans at district, block, municipality gram panchayat, village/ward levels. Women and disabled persons, socially marginalised sections, etc. would be an integral part of the plan preparation activity.
* Development of inventory of resources at all levels for speedy response during emergencies – use of GIS to project the resources on the maps for immediate decision-making.
* Development of disaster response structure from village/ward to district level.
* Formation and training of Disaster Management teams [DMT] at all levels. Each DMT would ensure adequate representation of women. Members of DMTS at all levels would be sensitised to response and recovery needs of special groups.
* Identification aprons and emergency response kits for DMT members.
* Disaster Response Mock drills at all levels - National, State, District, Block, Gram Panchayat

**Activities under PSO IV:**

* National database on disaster risk management and disaster response plan n for natural disaster
* Capability assessment and national training plan for natural management.
* Capacity building of State Administrative Training Institutions AT National and State levels for development of disaster risk management ni Research and documentation on disaster risk management indices for each State.
* Development of Risk and Vulnerability Reduction Indices and annual report
* Documentation and sharing of best practices in India in disaster ri management for wider circulation as part of training curriculum.
* Development and use of a web-site linking DRM Programme implementation partners (National and State Governments, UNDP, etc.) to share act approaches, methods to mainstream disaster management, decentralization etc. and exchange best practices and lessons lear nd lessons learnt between states:
* Consultations and studies in disaster risk management and global cima change linkage.
* Development of GIS based disaster vulnerability database for States and use to generate risk and vulnerability reports, to be

**MANAGEMENT ARRANGEMENTS**

**A.Execution arrangements**.

**ministry of Home Affairs, Govt of India would execute this programme under National dion [NEX] guidelines**. The programme involves partnerships at different levels with different stakeholders. It aims to reach most multi-hazard prone states and ts and thus it has a multi-state focus. The programme seeks to establish close with communities and civil society organizations. Programme demands ent Carship er flexibility, creativity and innovative approaches for natural disaster risk ction gement. In view of the complexities involved in the implementation.

**institutional arrangements**

* **coordinations at the National level :** The Ministry of Home Affairs, Government f India will be the nodal agency at central level for smooth execution of the programme supported out of Country Cooperation Framework resources.There would be a Programme Management Board (PMB) headed by the Secretary, MHA to provide overall guidance to the programme. Programme Steering Committee (PSC) headed by the Joint Secretary would be constituted, it will meet in every quarter to review the progress of the programme.ane Ti
* Monitoring at the State level : In each state, a State Steering Committee (SSC) headed by Chief Secretary will review the programme at periodic intervals. The committee may consist of executing agencies, implementing agency and UNDP. A joint UNDP-Govt of India assessment would be carried out ot examine the effectiveness of the programme at the end of each programme year.
* The financial arrangement and audit would as per the guidelines of Department of Economic Affairs, UNDP guidelines and procedures established for Country Office Support agreements.

The UNDP Country Office. Delhi would liaise with central government for smooth on implementation of the programme and provide effective backstopping to the state es, lices for planning, implementation, resource, mobilization and financial

**Implementation Arrangements**

The programme would be implemented by UNDP in partnership with the state odal institutions and NGOS in Programme states and districts. The national nodal agency, Ministry of Home Affairs would be provided support o develop national disaster risk management framework, strengthen the institutional, administrative, techno-legal and legal systems for disaster risk management. Nodal agencies in each of

State Project Officer specialist on Community Based Disaster Risk Management development of disaster risk management plans. For smooth execution. sustainability, State nodal agencies will take support of the existing training institutions/resource units in the state for up gradation of the disaster ri management plan and the training capabilities of the different stakeholders. In addition to this an Engineer specialist on disaster resistant/cost effective technology (Nationa cict to strengthen the levels UN Volunteer would be provided to each programme district to str technology transfer in housing sector training of masons and engineers resistant housing programme, model retrofitting initiates and rooftop stem would be put in harvesting features. Appropriate programme management system would place for effective implementation of the programme.

Village/ward based multi-hazard preparedness and response plans would a prepared by the local institutions and linkages with the existing development programme would be established to address the causes of vulnerabilities. Localsak government at all levels would be directly involved in these exercises for sustainability of the programme in long term. Disaster Management Specialists and experienced project management professionals, who have expertise in disaster risk management at the community lives in post-disaster situations would work with state and district government, civil society partners and communities.

**C. Implementation Process**

The disaster management plan would start from the village/ward level and would be consolidated through similar planning at the Panchayat, Block, District and Urban Local Bodies levels in the selected districts. A cadre of village volunteers would be created to cary out the village based natural disaster risk management programmer in the select programme districts. These Village Volunteers will be drawn from the community with the help of civil society organizations such as NCC, NSS, NI Scouts and Guides and Civil Defence etc. The plans would focus on the disaster risk prevention and early recovery through community-based preparedness and plans, skill development for construction of hazard-resistant housing and enhane access to information as per the need of the community. Information Technology o Specialists would be responsible for development

**Phase 1:** The programme will strengthen the disaster risk reduction initiatives the Ministry of Home Affairs (Govt. of India). the states of Orissa, Gujarat and and 28 districts from these three states in first two years. Environment building initiation of the natural disaster risk management programme will be also part he programme and initiated in all levels simultaneously in these three states along Ich national and state consultation for strategy development for sustainable recovery massive awareness campaign, transformation of technology, database etc. Some the activities will be taken up in the third year of the programme implementation depending on the availability of resources.

**Phase II:** Remaining 97 most vulnerable districts in nine states of India would be Bered in Phase II depending on the availability of resources under and resources obliged from donors for disaster risk management programme.

The State offices would provide required specialized programme implementation rs in the support to strengthen the state nodal agencies and civil society partners Programme states for implementation of this programme. National Institute of administrative Institute would be Industrial Security, Hyderabad State Administrative Training Institute unctionaries, Civil Society response groups entrusted to train the State government functionaries, Civil Society nd state task force on disaster management. Research centers and non ups stitutions in different states would be engaged to carry out studies of existing system or disaster response and recovery in the state along with traditional coping mechanism the communities for development of appropriate strategies and would be followed

1. **Awareness Campaign Strategy:**

An effective disaster risk management campaign strategy will be developed in consultation with all stakeholders of the selected states for public education to take the wake of natural hazards to minimize the loss. The state preventive measures in nodal

1. **Gender equity in disaster preparedness and mitigation**

Special training shall be provided to women for enhancement of their capacities to carry out the activities effectively. Capacity building of women groups will include skill upgradation in use of the latest know-how for effective response and sustainable recovery in disaster situations.

1. **Manuals and standard operating guidelines:**

Based on the experience of Orissa and Gujarat disaster preparedness programmes the state nodal agencies and research units will develop training manuals for Village Gram Panchayat, Block, District and State disaster management team, manuals for development of contingency plans for different hazards and Standard Operating Procedures [SOPS] for all levels. The manuals would be printed in easy languages after field-testing. Training will be provided to the stakeholders to use the manuals and widely circulated for replication of the programme. In all manuals special column shall be there for coping mechanism of women in disaster situations.

4**. Formation of Disaster Management Team/Committees :**

Disaster Management Teams (DMT) would be formed at different levels to carry out the activities during emergency for sustainable recovery from disaster such as State, District, Municipality, Block, Gram Panchayat, Community and Ward. DMT al village/ward level would comprise of a group of 10-15 people in task-based groups such as Early Warning (EW), Search and Rescue Operation (SRO), First Aid and Water and Sanitation (FAWA), Shelter Management (SM), Trauma Counseling and Damage Assessment (DA) groups. Similarly, DMT at Gram Panchayat, Murid and Block level may be formed with the involvement of people representatives, me from local administrative system like local police, Medical Officer, Junior Eng

**5.Training Capacity Building**

State nodal agency and UNDP will organize the "Training of trainers' at state, district and block levels to enhance the capacity of disaster management committees and prepare a core team to trainers and training Training would be a continuous process on disaster risk management programme. The trained cadre will facilitate the process of contingency plan development at diferent levels.

**6. Development of disaster risk management plan**

The trained volunteers, government functionaries, CBO:/NGOs and facilitate the process of development of Contingency Plan based on the vulnerability or the need at village of the areas and available resources and form the DMT as per need lan respectively, Palle ward, Gram Panchayat and Blocks disaster risk management plan respective Sabha, Gram Sabha and Panchayat Samitis will approve all the plans respect make it as a part of the ongoing programme.

**7. Demonstration Unit**

Construction of demonstration unit on disaster resistant and cost effective technology in housing sector would be done through trained masons and engineers for wider dissemination and adoption of the technology selected districts, which enable the communities to adopt disaster-resistant and cost-effective technologies.

**8. Emergency Rescue Kits**

Support will be provided to the district administration for having an emergency kits with some essential equipments like a boat, portable power generator set, eu warning equipments, tents, power saw etc to meet the emergency need at the ti natural disasters like cyclone or flood or earthquake. Each selected district provided the equipment kit as per their need. Equipments will procure in consult

**9. Resource Inventory data base**

Support will be provided to each state to have a web enabled resource inventory mobilization of resources and volunteers for emergency. It facilitators will support state government for development of a resource database, which will updated gularly by the nodal agency to know the status of the resource availability. Similarly, ch state will have a list of volunteers with specific skill set-those who can be utilized e the state nodal agencies during emergencies.

**10. Vulnerability and risk indexing and Report**

Benchmarking of vulnerability and risk would be attempted through national level research on the subject. Vulnerability and Risk Index would evolve through a consultative process. A national database would also be developed for assessment of preparedness and Risk Vulnerability Reports.

**(D) Sustainability**

Village disaster preparedness and response plans will be approved by the Palli Sabha/Village meeting/assembly to make it a public document. It will establish linkages with the existing development programmes to reduce the vulnerability of the areas.Similarly, the Gram Panchayat disaster management plans will be the compilation of all village plans, which will be approved by the Gram Sabha and Panchayat will endeavor to support mitigation plans under the annual development plans. The Gram Panchayat mitigation plan will be reflected in the Panchayat Samiti plan and in the Zilla Parishad plan. This will be an ongoing process at all levels and district mitigation plan would be a sub-set of district annual development plan. Disaster preparedness and mitigation planning will be an integral part of all development planning process. Specifically, the following will be the measurable indicators of success of the programme :

* Preparedness, response and mitigation planning becomes an integral

part of Annual Development Planning process at all levels.

* Disaster Management Committees and Disaster Management Teams conduct regular mock drills to enhance preparedness.
* Well equipped and functional state and district disaster management information system.
* Specific modification in building codes and techno-legal systems for risk reduction.
* Adequate human resource capacity for training and capacity building in disaster preparedness and response functions
* Manuals and guidelines will be available for all operations for pre, during and post emergencies.
* Trained masons available at village level on alternate and cost ofr technology for building a safer habitat,

**12. Strengthening state and District Disaster Management Information Center**

Necessary support will be provided in terms of equipments like advance communication equipments such as computer with internet facilities, equipments, FAX etc to the district control room and state control room and trai to the functionaries to handle the equipments during emergency. Thus there will be well-equipped control room at state and district levels to disseminate accurate war for advance action. These control room will also provide plateform for the coordination during and post emergencies.

**E. Exit Strategy**

The exit strategy would be based on strengthening local capacities for development and upgradation of disaster preparedness and response plans along with regular mock drills. With trained human resource made available in the state and district and the entire planning process linked to development plans, UNDP programme implementation support could be withdrawn gradually from all programme districts. UNDP implementation strategy is based on partnerships with local institutions and empowering District Disaster Management Committees and Disaster Management Teams at all levels. Mainstreaming risk management and vulnerability reduction activities in the development plans and enhancing capacities of Government functionaries would ensure that the achievements of the programme are sustained even after the programme duration

**F. Transparency and Accountability**

UNDP will ensure quarterly reporting to the nodal agency in order to maintain better coordination and accountability. There will be review committees at state as well as national level to review the implementation of the programme. Progress report along with financial report will be shared with all for better understanding and transparency. Utilization of resources under the programme would be based on decisions of the Programme Steering Committee.

**LEGAL CONTEXT**

This project documents shall be instrument referred to as such in Aricle, Paragraph I. of the Standard Basic Assistance Agreement between the Government of India and the United National Development Programme on signature by the concept persons.

The following types of revisions may be made to this programme document with

* Revision in, or addition of any of the annexes of the Project Document:
* Revisions which do not involved significant changes in the Immediate Objectives, Outputs or Activities of a project, but are caused by the rearrangement of inputs agreed to or by cost increases due to inflation, and
* Mandatory annual revisions that rephrase the delivery of the agreed project inputs or increased expert of other costs due to inflation or which take into account agency expenditure flexibility,

**EARTHQUAKE UNIQUE PLANNING CONSIDERATIONS**

This section contains a listing of the functional annexes that typically would require the preparation of a hazard-specific appendix for earthquakes. It also identifies the unique and/or regulatory planning considerations that should be examined by the planning team and used, as appropriate, when preparing earthquake-specific

1. **Direction and Control**

For this hazard it is essential for emergency response personnel to take immediate action to gather damage assessment information. This information is needed to determine the severity and extent of injuries and damages. Further, this data gathering effort should provide much of the information decision makers will need to implement and prioritize response actions for : activities, access control re-entry to the impacted area, debris clearance, restoration of utilities and lifeline repairs, and the inspection, condemnation, and or demolition of buildings and other structures.

Therefore, provisions should be made, as appropriate, to address the following planning considerations in one or more appendices to a direction and control annex :

1. **Damage Assessment**

Conduct of ground and aerial surveys to determine the scope of the damage, casualties and the status of key facilities.

1. **Search and Rescue**

Removal of trapped and injured persons from landslides, building collapse, and other structural collapses, administering first aid, and assisting in transporting the seriously injured to medical facilities. This activity involves the use of professional and volunteer search teams including the use of dog teams. Consideration should be

1. **Access Control and Re-Entry**

This section deals with the immediate actions to be taken, as soon as conditions permit, in the area that was severely impacted by an earthquake. Relevant considerations include

* Control of access to the area until it is safe. Only those people directly involved in emergency response operations should be allowed to enter
* Establishing a protocol for determining the appropriate time to allow evacuees and the general public to re-enter the area that was severely impacted.

1. **Debris Clearance**

The identification, removal, and disposal of rubble, landslides, wreckage, and other material which block or hamper the performance of emergency response functions should be a high priority action. Activities may include:

* Demolition and other actions to clear obstructed roads.
* Repair or temporary reinforcement of roads and bridges.
* Construction of emergency detours and access roads.

1. **Inspection, Condemnation, Demolition**

Inspection of buildings and other structures to determine whether it is safe to inhabit or use them after an earthquake has occured. Activities may include :

* Inspection of buildings and structures which are critical to emergency service operations and mass care activities. Designate those that may be occupied and identify/mark those that are unsafe.
* Inspection of buildings and structures that may threaten public sau Identify/mark those that are unsafe and may not be occupied.
* Inspection of dams and leves
* Inspection of less critical damping structures. Designate those that may be cupid and identity mark those that are unsafe to occupy.
* Arrangements for the demolition of condemned structures

**7.Utilities and Lifeline Repairs**

Restoration and repair of electrical power, natural gas, water, sewer and telephone other communications systems to minimize the impact on critical services are the public

**8.Emergency Public Information**

The flow of accurate and timely emergency information is critical to the protection lives and property in the wake of a catastrophic earthquake. This section deals with the provisions that should be included in the plan for the preparation and insemination of notifications, updates, warnings, and instructional messages. The Bowing planning considerations should be examined and addressed, if appropriate, one or more appendices to an EPI annex:

* Survival tips for people on what to do during and immediately after an earthquake
* Warnings and advice on the continuing threat of fire, unsafe areas, building collapse, aftershocks, and other hazards.

**9. Evacuation**

Immediately following an earthquake people may need to be evacuated. People should be evacuated from structures that have been damaged and are likely to receive more damage when hit by one or more of the aftershocks. An appendix to an evacuation annex should address special provisions for moving the residents of custodial facilities hospitals, jails, mental health facilities, nursing homes, retirement homes, etc.) following an earthquake.

**10. Mass Care**

The information gained from the vulnerability assessment should be used to ensure the following needs are addressed, if appropriate, in one or more appendix to a mass care annex.

**11. Safe Location of Facilities**

If possible, identify mass care facilities in low seismic risk areas that are also out of the way of secondary effect threats (eg, flooding from a damaged dam).

**12. Structural Safety**

If the facilities selected for use are located within the earthquake hazard area, ensure that a structural engineer, knowledgeable of the earthquake hazard:

**DISASTER MITIGATION TOOL KIT**

Kits to Sustain Everyday Life in the event of a disaster : We are giving information for an ideal kit that might be useful to disaster affected people. However preparation for this should be done beforehand. The following kits are suggested in places where people might not have ready access to many essential supplies for everyday life as preparation to a disaster:

1. **Health Kit** •

* 1 hand towel
* 1 wash cloth
* 1 hair comb, regular size (not pocket)
* 1 nail file or nail clipper
* 1 bath-size bar of soap in wrapper
* 1 toothbrush in sealed package
* 1 large tube of toothpaste
* 6 adhesive bandages (such as Band-aids)

Wrap the brand new items in the new hand towel, tie it with string or yar place inside a sealed, one plastic bag with a zipper closure.

**2. First Aid Medicine Kit**

**1. Sterile Gauze Pads** (4X4) 50 pads

2. Adhesive Tape 6 Rolls, 1/2" or 1" x 10 yds. or more

3. Triple Antibiotic Topical Ointment 4 Tube (1 oz tubes) Example : Neosporin Ointment

4. Aspirin 325 mg (5 gr) tablets

1. Ferrous Sulfate Tablets 500 Tablets of 325 mg

2. Children's Multivitamins with Iron Chewable Tablets 500 Tablets

3. Children's Acetaminophen Chewable Tablets 300 Tablets of 80 mg.

Where possible, purchase tablets in bottles of 100 or more. No samples are permitted. For example, if the required number of tablets is 1,000, then collect :

1 bottle of 1,000 tablets each, or

1. bottles of 500 tablets each, or
2. bottles of 300 or 250 tablets each, or
3. bottles of 130 tablets each, or
4. Acetaminophen for Adults - pain reliever

6. Antacid - for treatment of upset stomach/heartburn

7. Mebendazole or Thiabendazole - for intestinal worm infection

8. Sulfamethoxazole Trimethoprim - antibacterial for adults and children

9. Tetmosol Soap - for treatment of scabies for adults and children

10. Oral Rehydration Salts - to combat dehydration for adults and children

11. Promethazine - for treatment of nausea

12. Metronidazole - for treatment of intestinal amebiasis (amebic dysentery)

13. Chlorhexidine - antiseptic for adults and children

14. Tolnaftate 1% Antifungal Cream - for skin infections for adults and children

15. Rolled Bandages - for first aid applications

**School Kit**

In many countries, there are no books, or even classrooms. Classes are mobile or held in the open air. School kits may be the only educational resources available.

Often students must write down everything the teacher says or writes on a board.

Their teachers knowledge and their own notes are their only textbooks. They have difficulty learning without the basic tools in this kit, which is designed for a variety of ages. It is includes:

* 1 blunt scissors
* 2 pads of 8" x 11" ruled paper •
* 1 30 centimeters ruler
* 1 pencil sharpener
* unsharpened pencils with erasers
* 1 eraser, 24"
* 12 sheets of construction paper

1 box of 8 crayons Prepare a 12" x 14" (finished size) cloth bag with handles and a closure (Velcro, snap, or button) and place the items in the bag.

**Kit for Kids** Kits with the basic supplies every baby needs. Please be sure that all items are

NEW!

* + 6 cloth diapers
  + 2 shirts
  + 2 baby wash cloths
  + 2 gowns
  + 1 sweater
  + 2 receiving blankets

Bundle the items inside one of the receiving blankets and secure it with diaper

**Domestic Kit**

The following kits are recommended following a natural disaster.Bedding Pack

* 2 flat double-bed sheets
* 2 pillow cases
* 2 pillows

Other necessities :

**Linen (new only)**

* Sheets
* Towels
* Blankets
* Pillows
* Sewing Kit

Sewing kits foster interdependence rather than dependance. Women can make clothing in their own size and in the style of their culture. Cottage industries ofter grow out of the sewing classes where women use these kits to practice valuable income generating skills.

* 3 yards of cotton or cotton-blend solid-color or print fabric (there must be 3 uncut yards of fabric or the kit is not usable)
* 1 pair of sewing scissors
* 1 package of needles
* 1 spool of thread
* 6 matching buttons

Wrap sewing notions in the fabric and tie it with a string or strip of cloth. Place items in a sealed plastic bag with zipper closure.

**Cleaning and Utilities**

These resources enable people to begin the overwhelming job of cleaning up after a flood or hurricane.

* gal, bucket with reseal able lid
* Bleach gallon
* Scouring pads, 5
* Scrub brush
* Cleaning towels, 18 each
* Sponges, assorted size - 7 pack
* Laundry detergent, 10 oz.
* Household cleaner, 12 oz.
* Disinfectant dish soap, 28 oz.
* Clothes pins (50)
* Clothesline, 100 f.t x 3/16
* Dust masks, 5 packs
* Latex gloves, package of 2 pairs
* Work gloves, 1 pair
* Trash bags, 24 roll
* Insect repellant, 14 oz.
* Air freshener, 9 o

Please purchase all liquids in plastic bottles. Be sure to send all new materials that are unopened when they are sealed or in packages. Put all items in the plastic bucket and seal lid.

Though all of the following items are needed at some time, some are in heavier demand than others.

**Baby Items**

* Disposable diapers
* Baby wipes

**Cleaning Supplies**

* Dry laundry detergent
* Dish detergent
* Dry disinfectant
* Mops
* Shovels
* Rubber gloves
* Buckets
* Plastic garbage bags (30 gallon)
* Squeegees
* Pressure water sprayers
* Power scrubbers
* Scoop shovel

**Miscellaneous**

* Generators
* Tarps
* Tents
* Cots

**Paper Products**

* Paper plates
* Paper cups
* Paper towels
* Toilet paper
* Send all new paper goods that are unopened.

**Personal Items**

* Soap
* Toothbrushes
* Hand lotion
* Feminine hygiene products
* Large (adult) diapers
* Insect repellent
* Surgical masks and gloves
* Sun block (rated 15 or higher)
* Cream

**Chapter 8**

**Retrofitting of Buildings**

**INTRODUCTION**

A large number of existing buildings in India are severely deficient against earthquake forces and number of such buildings is growing very rapidly. This can be highlighted in the past earthquakes. The experience during last earthquake of Bhuj has been particularly alarming as not only Rural "non-engineered" houses suffered large scale devastation, but also a large number of so-called "engineered buildings have collapsed, even at a distance of more than 200 km from the epicenter

**Methods for Seismic Retrofitting**

* + - Retrofit Procedure
    - Global
    - Retrofit techniques
    - Adding shear wall
    - Adding Infill wall
    - Adding Bearing
    - Wall thickening
    - Mars reduction in storeys
    - Suplemental damping and base insalation
    - Local
    - Jacketing of beams
    - Jacketing of columns
    - Jacketing of beam-column oints
    - Strengthening individual fastings
    - Detailed Seismic evaluation
    - Seisme capacity assessment
    - Selection of Retrofit scheme
    - Design of Retrofit scheme and detailing
    - Re-evaluation of retrofit structure

**EVALUATION AND RETROFITTING PROCESS**

Evaluation of an existing structure is an essential part of its retrofitting. A proper retrofitting scheme can not be visualized without a detailed investigation and evaluation of weaknesses and deficiencies. A detailed evaluation aims at dentifying weak members, which need to be strengthened. Evaluation is also required cor retrofitted structure to assess the adequacy of the retrofitting. Different steps evaluation and retrofitting process are shown in fig.

Safety of a building during earthquake does not depend only on the strength Wferent members but also on their ductility or the ability to deform plastically, without loosing the vertical load carrying capacity. Therefore the ductility of the existing and retrofitted components is also required. A considerable research has been focused to this task in the past few decades and significant developments have taken place.

Setting of goals and performance level of building and estimation of seismic hazard

Systematic visual inspection and study of available drawings and documents

In-situ investigation for strength and degradation of material and preparation of as built drawings

Preliminary evaluation : Identification of potential deficiencies and need and scheme for detailed investigation.

Detailed evaluation of strength, ductility and deterioration.

Design of Retrofitting scheme based on the evaluated deficiencies

Evaluation of the retrofitted building.

**EVALUATION METHODS**

Evaluation of existing building has attracted significant research efforts across the globe, particularly in the last 2-3 decades. A number of techniques have been developed for insitu assessment of strength, integrity and durability of concrete list of these techniques is given in Table.

|  |  |  |  |
| --- | --- | --- | --- |
| Sr.No. | Property under Investigation | Test | Equipment type |
| 1.  2.  3.  4.  5.  6.  7.  8. | Concrete Strength | Cores  Pull-out  Pull-off  Break-off  Internal fracture  ESCOT  Maturity  Temperature  matched curing |  |
| 9.  10.  11  12.  13.  14.  15.  16.  17.  18.  19.  20.  21.  22.  23.  24.  25.  26.  27.  28. |  | Surface hardness Ultrasonic pulse Radiography  Radiometry  Neutron  Absorption  Relative humidity  Permeability  Absorption  Petrographic  Sulphate content  Expansion  Air content  Cement type and  Abrasion resistance  Half-cell potential  Resistivity  Cover depth  Carbonation  depth Chloride  concentration | Mechanical  Mechanical Mechnical Mechanical Mechnical Mechnical Penetration resistance MechanicalElectrical  MechanicalElectrical  Chemical/microscopic Chemical/electrical |

**Table 8.3 List of insitu test for reinforced concrete**

**RETROFITTING TECHNIQES** A number of alternative techniques are available in the literature for retrofitting of RC buildings. These techniques are based on four basic principles of miami safety and retrofitting :

**(i) Completion of load path and removal of structural irregularity** : It has been observed that symmetric and regular buildings are subjected to lesser damage than asymmetric and irregular buildings. Buildings with floating columns and soft storeys can be asymmetric configuration, retrofitted using these techniques.

**(ii) Strengthening of structure** : A structure, which is deficient in original design can be retrofitted by strengthening of the structure. This strengthening can be achieved either by adding new lateral load resisting members or by strengthening the existing members. This is the most common and feasible alternative for seismic strengthening and a large number of techniques based on conventional strengthening methods, such as, RC jacketing, steol ch as FRP have been jacketing, as well as, based on advance materials such FRP developed

**(iii) Enhancing deformation capacity of structure**: The seismic force on a varies inversely with its ductility or post yield deformation can Concrete being a brittle material, requires special reinforcement detailing for confinement resulting in ductility. Most of the existing buildings lack this ductile detailing of reinforcement. By providing external confinement and by mechanically anchoring or welding splices, the ductility can be enhanced to some extent.

**(iv) Reducing earthquake demand** : Earthquake demand on a structure can be reduced by reducing mass, by increasing damping or by de-tuning the structure using base isolation. There are practical limits on reduction of mass, but is some cases it may be feasible. Damping of the existing structure is enhanced by providing supplemental damping through viscous, frictional or yielding type Energy Dissipation Units (EDUs).

Table gives a list of available techniques. A detailed description of these techniques is beyond the scope of this paper and can be found in literature

|  |  |  |
| --- | --- | --- |
| Sr.No. |  | Retrofitting technique |
| 1  2  3  4  5  6  7  8  9  10  11  12  13  14  15  16  17  18  19  20  21  22  23  24  25 | Complation of load path  Removal of irregularity  Strengthening of structure Strengthening of existing members  Enhancing deformation capacity of structure  Earthquake demand reduction | Addition of missing parts of columns, beams and shear walls.  Addition of columns and shear walls to remove in-plane and out-of-plane irregularity  Addition of columns and shear walls to stiffen the flexible side of building  Separation of asymmetric building into symmetric parts.  Increasing the size of the members on flexible side of the building.  Reduction of change of usage at heavily loaded floors.  Strengthening of slabs by overlaying and underlaying RC jacketing of beams and columns.  Steel jacketing of beams and columns,  FRP or steel plate bonding of slabs and beams.  Wrapping of columns  RC jacketing of masonry partition walls.  Strengthening of infills by diagonal FRP strips.  RC, ferro-cement or steel jacketing of joints.  Prestressing of joints using collars and diagonal braces.  Foundation strengthening with or without increasing the bearing area.  Detailing enhancement by mechnical or welded connection of splices.  Provision of additional confining reinforcement near joints in beams.  Avoiding storey failure mechanism by strengthening columns or by providing shear walls.  Reduction of local stiffness.  Provision of supplemental support at members, not designed for lateral loads.  Seismic Base Isolation.  Supplemental damping using EDU's. |

**Table 8.4**

**RETROFITTING MATERIALS**

Considerable research has taken place In Hw view material and a large variety within the m ain en w in available. Out of the material are plant and avallahie in Petrofac engineer need to have information about the material for down retrofit scheme

The repair and retrofit materials can be broadly drained into th te

Grouts for repair of cracks, strengthening of masonary and honeycombed concrete.

Bonding agents for enhanced bonding between old and new concrete and concrete reinforcement

Replacement and jacketing material for replacing the damaged portions, increasing the size of members, enhancing the confinement and external reinforcement of the member .

Names of different materials available under these categories is given below .

1. INJECTION GROUT

2. CEMENT SAND GROUTS

3. GAS FORMING GROUTS

4 SULFOALUMINATE GROUTS

5. FIBRE REINFORCED GROUTS

6. POLYMER GROUT

7. INJECTION PROCEDURE

8. BONDING AGENT

9. REPLACEMENT AND JACKETING MATERIALS

10. ORDINARY PORTLAND CEMENT CONCRETE AND MORTAR

11. SHOTCRETE

12. POLYMER MODIFIED CONCRETE AND MORTAR

13. STEEL PLATE BONDING

14. FIBRE REINFORCED PLASTICS (FRP)