EARTHQUAKE DYNAMICS OF STRUCTURES

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Abstract: This Paper contains dynamic behaviour of structures. To study properties and analysis of structures like High raise structures, Off-shore structures and other huge structures need dynamic analysis. This paper contains mainly guideline, methods and approximate methods to evaluate load and displacement of the structures. It is useful to evaluate elastic and plastic properties of materials and structures. During natural disaster like Earthquake, Tsunami and blast etc. structures withstand against these. This paper is specifically for the structural Engineering design to provide design guidance for engineers to design structures to resist earthquake dynamics for several types of dynamic loadings.

Keywords: dynamics, earthquake, tsunami, loadings design, structure, resistance

Introduction : As per new mapping (zoning) of India, the entire coastal belt of Andhra Pradesh falls under seismic zone III (as per BIS). Hence it is necessary to focus our attention on the safety of our constructions. After every damaging earthquake in India, a lot of coverage is given in newspapers and on TV to the issues of earthquake safety. Different government agencies announce plans towards this. Many experts are interviewed on TV channels to share their wisdom on ways to mitigate such disasters. Numerous conferences are held all over the country. And, the public feels reassured that the problem of earthquake safety will now be taken care of, until the next such earthquake when we realize that not much really got done since the last event. An earthquake is the motion produced when stress within the earth built up over a long period of time until it exceeds the strength of the rock which then fails by breaking along a fault.

Earthquake Motion: The Earthquake motion can be considered in two parts

1) Transient vibrations 2) permanent deformation

1) Transient vibrations:

a) The movement during rupture produces range of vibrations, or seismic waves, that are radiated outwards.

b) The motion can be measured as displacement, velocity and acceleration.

2) Permanent deformation:

a) An earthquake produces a permanent displacement across the fault displacements vary from a few millimeters in very small earthquakes to a few meters in very large earthquakes.

b) Once a fault produced, it is a weakness within the rock, and is the likely locations for future earthquakes.

Earthquake Size: The size of earthquakes: Earthquakes vary enormously in the amount of energy released, over a range exceeding a million million. It is not possible to measure the energy released directly, so it must be computed from measurements of the ground vibrations.

Earthquake magnitude: The most common method of describing the size of an earthquake is the Richter magnitude scale, ML. This takes the logarithm of the ground displacement as measured by a seismograph, and applies a correction, which varies with the distance from the earthquake to the seismograph. The Richter magnitude scale can only be used when seismographs are within 600km of the earthquake. For greater distances, other magnitude scales have been defined. The most modern scale is the moment magnitude scale MW, which can be used for a wide range of magnitudes and distances.

Earthquake Intensity: The most common intensity scale in Australia is the 12-point modified Mercalli scale on this scale, intensities up to 5 are felt but cause no damage, while intensities from 6 to 12 because increasing amounts of damage. A modified Mercalli intensity of six is abbreviated as MMI 6.

Earthquake Effects and Design of Structures:

In buildings, earthquake damage can be divided in to two categories; structural damage and non-structural damage, both of which can be hazardous to buildings occupants. Structural damage means degradation of the building's structural support system. Such as the building frames and walls. Non-structural damage refers to any damage that does not affect the integrity of the structural support system. Examples of non-structural damage are a chimney collapsing, windows breaking or ceilings falling, etc.

How do Earthquakes Effect RC Buildings:

A typical RC building is made of horizontal members and vertical members, and supported by foundations that rest on ground. The RC frame participates in resisting the earthquake forces. Earthquake shaking generates inertia forces in the building, which are proportional to the building mass is present at floor levels, earthquake-induced inertia forces primarily develop at the floor levels. These forces travel downwards-through slab and beams to columns and walls, and then to foundation from where they are disperse to the ground. As inertia forces accumulate downwards from the top of the building, the column and walls at lower storey experience higher earthquake-induced forces and are therefore designed to be stronger than those in storey above.

In residential multi-story buildings, thickness of slabs is only about 110-150mm. When beams bending the vertical direction during earthquakes, these thin slabs bend along with them and when beams move in the horizontal direction, the slab usually forces the beam to move together with it. In most buildings, the geometric distortion of the slab is negligible in the horizontal plane, this behaviour is known as the rigid diaphragm action structural engineers must consider this during design.

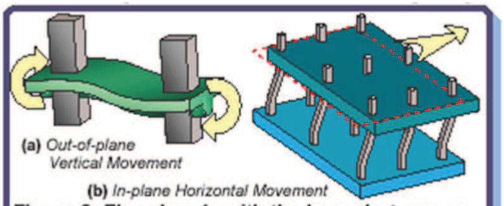


Figure 2: Floor bends with the beam but moves all columns at that level together.

After columns and floors in a RC Buildings are cast and the concrete hardens, vertical spaces between columns and floors are usually filled-in swith masonry walls to demarcate a floor area in to functional spaces. Normally these masonry walls also called infill Walls, are not connected to surrounding RC columns and beams. When columns receive horizontal forces at floor levels, they try to move in the horizontal direction, but masonry walls tend to resist this movement. Due to their heavy weight and thickness, these walls attract rather large horizontal forces. However, since masonry is a battle material, these walls develop cracks once their alibi to carry horizontal load is exceeded. Thus, infill walls act like sacrificial fuses in buildings, they develop cracks under severe ground shaking but help share the load of the beams and columns until cracking earthquake performances of infill walls in enhanced by mortars of good strength, making proper masonry courses, and proper packing of gaps between RC farms and masonry infill walls.

Figure 1: Total horizontal earthquake force in a building increases downwards along its height.

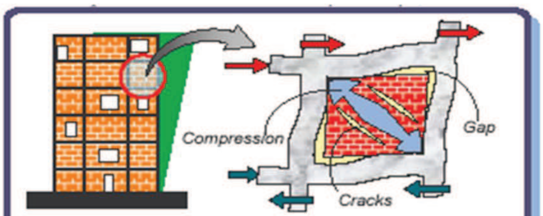


Figure 3: Infill walls move together with the columns under earthquake shaking.

However, an infill wall that is unduly tall or long in comparison to its thickness can fall out-of-plane, which can be life threatening. Also placing infill irregularly in the building causes ill effects like short-column effect and torsion.

Making of RC Buildings as Earthquake Resistance:

A) Beams: Beams in RC buildings have two sets of steel reinforcement, namely a) long straight bars placed along its length and b) closed loops of small diameter steel bars (called stirrups). Beams may fail in two types

1) Flexural failure 2) shear failure.

Design Strategy:

Designing a beam involves the selection of its material properties (i.e., grades of steel bars and concrete) and shape and size; these are usually selected as a part of an overall design strategy of the whole building. And, the amount and distribution of steel to be provided in the beam must be determined by performing design calculations as per is: 456-2000 and IS: 13920-1993.

Longitudinal bars are provided to resist flexural cracking on the side of the beam that stretches. Since both top and bottom faces stretch during strong earthquake shaking, longitudinal steel bars are required on both faces at the ends and on the bottom face at mid-length. The Indian Ductile Detailing Code IS 13920-1993 prescribes that:

a) At least two bars go through the full length of the beam at the top as well as the bottom of the beam.

b) At the ends of beams, the amount of steel provided at the bottom is at least half that at top.

B) Columns:

The vertical members in RC buildings, contain two types of steel reinforcement, namely: (a) long straight bars (called longitudinal bars) placed vertically along the length, and (b) closed loops of smaller diameter steel bars (called transverse ties) placed horizontally at regular intervals along its full length. Columns are sustaining two types of damage. Namely axial-flexural (or combined compression bending) failure and shear failure. Shear damage is brittle and must be avoided in column by providing transverse ties at close spacing.

Design Strategy:

Designing a column involves selection of materials to be used choosing shape and size of the cross-section, and calculation amount and distribution of steel reinforcement. The first two aspects are part of the overall design strategy of the whole building. The Indian Ductile Detailing Code IS: 13920-1993 requires column to be at least 300mm wide. A column width of up to 200mm is allowed if unsupported length is less than 5m. Columns that are required to resist earthquake forces must be designed to prevent shear failure by a skillful selection of reinforcement.

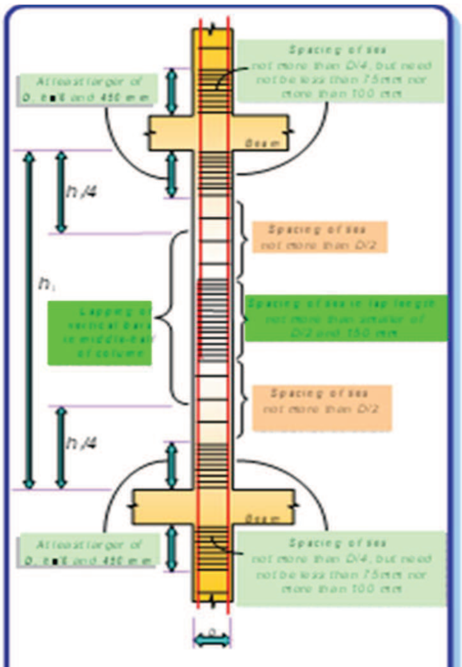


Figure 4: Placing vertical bars and closed ties in columns – column ends and lap lengths are to be protected with closely spaced ties.

C) Providing Shear Walls: RC buildings often have vertical plate-like RC wall called shear walls. In addition to slabs, beams and columns. These walls generally stand at foundation level and are continuous throughout the building height. Their thickness can be as low as 150mm, or as high as 400mm in high rise building. Shear walls are usually provided along both length and width of buildings. Shear walls are like vertically-oriented wide beams that carry earthquake loads downwards to the foundation.

Shear walls are easy to construct, because reinforcement detailing of walls is relatively straight-forward and therefore easily implemented at site. Shear walls are effectiveness in minimizing earthquake damage in structural and non-structural elements.

D) Strengthening Beam-Column Joints:

In RC buildings, portions of columns that are common to beams at their intersections are called Beam-Column Joints. Under earthquake shaking, the beams adjoining a joint are subjected to moments in the same direction.Under these moments the top bars in the beam-column joint are pulled in one direction and bottom once in the opposite direction.

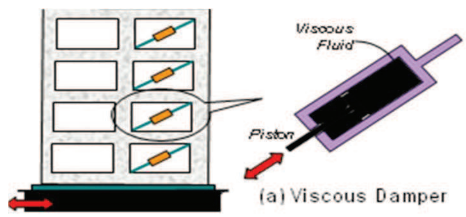
Anchoring Beam Bars:

The gripping of beam bars in the joint region is improved first by using columns of reasonably large cross-sectional size requires building columns in seismic zones 3,4and 5 to be at least 300mm wide in each direction of the cross-section when they support beams that are longer than 5m or when these columns are taller than 4m between floors (or beams). In exterior joints where beams terminate at columns, longitudinal beam bars need to be anchored into the column to ensure proper gripping of bar in joint. The length of anchorage for a bar of grade Fe415 is about 50times its diameter. In interior joints, the beam bars (both top and bottom) need to go through the joint without any cut in the joint region. Also, these bars must be placed within the column bars and with no bends.

E) By Base Isolation: The foregoing discussion of Earthquake Resistant Design emphasizes the traditional approach of resisting the forces an earthquake imposes on a structure. An alternative approach which is presently emerging is to avoid these forces partially or fully, by isolation of the structure from the ground. When an earthquake occurs, the surface of the earth fractures and moves. This makes the soil around the fracture vibrate. These vibrations radiate from the fracture zone in all directions. As these vibrations reach a structure, they shake the foundation which in turn shakes the structure supported on it. The idea behind base isolation is to separate the foundation from the structure so that the vibrations are not transmitted to the structure.

The concept of base isolation is resisting the building on frictional rollers when the ground shakes, the rollers freely roll, but the building above does not move. Thus no force is transformed to the building due to shaking of the ground simply the building does not experience the earthquake. In other words, the building will not experience the earthquake.

F) Providing Seismic Dampers: Another approach for controlling seismic damage in buildings and improving their seismic performance is by installing seismic dampers in place of structural elements such as diagonal braces. These dampers act like the hydraulic shock absorbers in cars-much of the sudden jerks are absorbed in the hydraulic fluids and only little is transmitted above to the chassis of the car. When seismic energy is transmitted through them,



dampers absorb part of it, and thus damp the motion of building. Commonly used type of seismic dampers includes viscous dampers, friction dampers and yielding dampers.

Types of Seismic Dampers:

Structural Damping:Structural damping occurs in a system due to the internal molecular friction of the material of the structure, or due to the connections inherent in a structural system.

Viscous Damping:Viscous damping occurs in a system vibrating in a fluid. The damping force in this case is proportional to the velocity.

Coulomb Damping:Coulomb damping or dry friction occurs when the motion of the body is on a dry surface.

G) Quality Control in Construction:

The capacity design concept in earthquake-resistant design of buildings will fail if the strength of the brittle links falls below their minimum assumed values. The strength of the building construction materials, like masonry and concrete is highly sensitive to the construction materials, workmanship, and supervision and construction methods. Similarly special care is needed in construction to ensure that the elements meant to be ductile or indeed provided with features that give adequate ductility. Thus, strict headrace to prescribed standards of construction materials and construction process is essential in assuring an earthquake-resistant building. Regular testing of construction materials at qualified laboratories, periodic training of workman at professional training houses, and on site evaluation of the technical work is elements of good quality control.

Conclusions

1. Special design is needed to make the elements to absorb dynamic loads of structure.
2. The effects of the earthquake dynamics on buildings can be reduced by providing shear walls and strengthening beam-column joints and the application of Base Isolation on the structures, etc.
3. The effects of earthquake can be reducing by using dampers in seismic region.
4. The whole structure is designed so that it should act as a single unit

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