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EFFECT ON BUILDING STRUCTURES IN EARTHQUAKE

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Abstract
As we know that earthquake is the shaking of the surface of the Earth, which can be violent enough to destroy any building which is not constructed as per norms for earthquake resist structure and kill thousands of people. The severity of the shaking can range from barely felt to violent enough to toss people around. Earthquakes can destroy whole cities. They result from the sudden release of energy in the Earth's crust that creates seismic waves. The seismicity, seismic or seismic activity of an area refers to the frequency, type and size of earthquakes experienced over a period of time. In this paper we will focus on the occurrence of earthquake, how it affect a building, types of forces acting on a structure and their magnitudes.

Keywords:
buildings, forces, earthquake, safety

Introduction

Tectonic earthquakes occur anywhere in the earth where there is sufficient stored elastic strain energy to drive fracture propagation along a fault plane. The sides of a fault move past each other smoothly and a seismically only if there are no irregularities or asperities along the fault surface that increase the frictional resistance. Most fault surfaces do have such asperities and this leads to a form of stick-slip behaviour. Once the fault has locked, continued relative motion between the plates leads to increasing stress and therefore, stored strain energy in the volume around the fault surface. This continues until the stress has risen sufficiently to break through the asperity, suddenly allowing sliding over the locked portion of the fault, releasing the stored energy.[2] This energy is released as a combination of radiated elastic strain seismic waves, frictional heating of the fault surface, and cracking of the rock, thus causing an earthquake. This process of gradual build-up of strain and stress punctuated by occasional sudden earthquake failure is referred to as the elastic-rebound theory. It is estimated that only 10 percent or less of an earthquake's total energy is radiated as seismic energy. Most of the earthquake's energy is used to power the earthquake fracture growth or is converted into heat generated by friction. Therefore, earthquakes lower the Earth's available elastic potential energy and raise its temperature, though these changes are negligible compared to the conductive and convective flow of heat out from the Earth's deep interior.

1. Inertia Forces in Structures

The principle cause of damage due to Earthquake is shaking. All buildings on earth surface vibrates as the earth vibrates but in varying degrees. The accelerations, velocities and displacements are induced by the earthquake, unless the construction is earthquake resist. The superstructure including its components tends to shake and vibrate from the position of rest, in a very irregular manner due to inertia of the masses.
As we know from Newton's First Law of Motion, the base of the building (foundations) moves with the shaking ground but the roof is at rest position. But, since the structure is monolithic, the wall columns are connected with the roof and drag the roof with them.
When the base of the building suddenly moves to the left, the building moves to the right, as the building being pushed to the left by an unseen force called as 'Inertia Force. 'Actually, there is no push at all but, because of its mass, the building resists some motion.
Consider a building whose roof is supported on columns.

If the roof has a mass M, experiences an acceleration a, then from Newton's Second Law of Motion, the inertia force F is mass M times acceleration a, and its direction is opposite to that of the acceleration. It is clear that more mass means higher inertia force. Therefore, the buildings lighter in weight shakes well and sustain the earthquake.

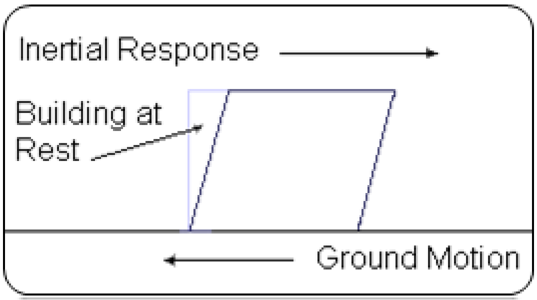

Fig 1 Showing ground motion during earthquake

A. Effects of Deformation in Structures

The inertia forces which are acting on the roof are transferred to the columns and columns experienced some forces. The relative moments are developed at the ends of the columns due to the shaking of the ground and the forces in can be explained in some another way.

Apart from gravity loads, the structure will experience dominant lateral forces of considerable magnitude during earthquake shaking .During continuous process of shaking of ground and columns, the columns always tries to come back to its original position to resist deformations. The resultant lateral force or seismic loads (F) is distinctly different from the dead load, live load, snow load, wind load, and impact loads. The horizontal ground motion action is similar to the effect of horizontal force acting on the building. Greater the mass of building, more lateral force is exerted on buildings, and this alone is the major component behind building damages. If the joints of the buildings are not strong like joints of beam, column, walls, roof etc. the buildings move on their own direction and results in the separation of the building. Separation of the building components and fails in designed force is called as building failure.

The reversible forces cause the building to move and sustain damage or collapse. Columns develop internal forces when forced to bend, in the straight vertical position, the columns carries no horizontal earthquake force. The larger is the relative horizontal displacement between the top and bottom of the column, the larger this internal force in columns. Also, the stiffer the columns are (i.e., bigger is the column size), larger is this internal force. These internal forces in the columns are called stiffness forces.

B. Horizontal and Vertical Shaking

During earthquake ground shakes in all the three directions .i.e. along the X and Y, two horizontal directions, and the vertical direction Z (Figure 2). Also, during the earthquake, the ground shakes randomly back and forth (- and +) along each of these X, Y and Z directions. All structures are primarily designed to carry the structural loads and gravity loads, i.e., they are designed for a force equal to the mass M (which includes mass of its own weight and imposed loads) times the acceleration due to gravity g acting in the vertical downward direction (-Z). The force acting downward Mg is called the gravity load. The vertical acceleration during ground shaking either adds to or subtracts from the acceleration due to gravity.

However, horizontal shaking of the structure along X and Y directions (both + and – directions of each) remains a concern. The Structures which are designed for gravity loads are not able to safely sustain the effects of horizontal earthquake shaking. Hence, it is necessary to ensure adequacy of the structures against horizontal earthquake effects also.

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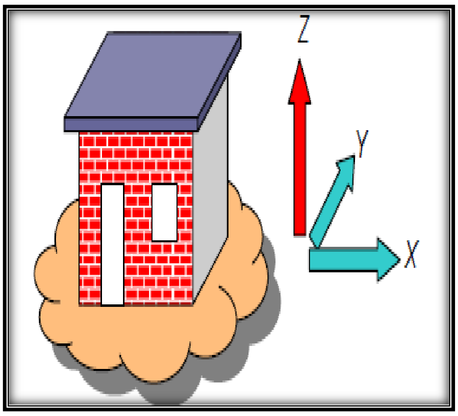

Fig. 2 Principle directions of a building

C. Flow of Inertia Forces to Foundations

During horizontal shaking of the ground, horizontal inertia forces are generated at level of the mass of the structure. These lateral inertia forces are transferred from the floor slab to the walls or columns, to the foundations, and finally to the soil system underneath the structure. So, each of these structural elements (floors slabs, walls, columns, and foundations) and the connections between them must be designed to safely transfer these inertia forces through them. Walls or columns are the most critical elements in transferring the inertia forces. The consequences of failure of the structure may also be of concern in the reliable estimation of design lateral forces. Resist minor earthquake shaking without damage. Resist moderate earthquake shaking without structural damage but possibly with some damage to non-structural members.

Resist major levels of earthquake shaking with both structural and non-structural damage, but the building should not collapse thus endangerment of the lives of occupants is avoided.

But, in traditional construction, more attention is given for the design and construction of floors, slabs and beams than walls and columns. Walls are of brittle material like masonry and relatively thin. They are poor in carrying horizontal earthquake inertia forces along the direction of their thickness. Failures of masonry walls structures have been observed in almost all of the earthquakes causalities in the past. Similarly, poorly designed and constructed reinforced concrete columns can be disastrous. The failure of the ground storey columns resulted in numerous building collapses during the 2001 Bhuj (India) earthquake.

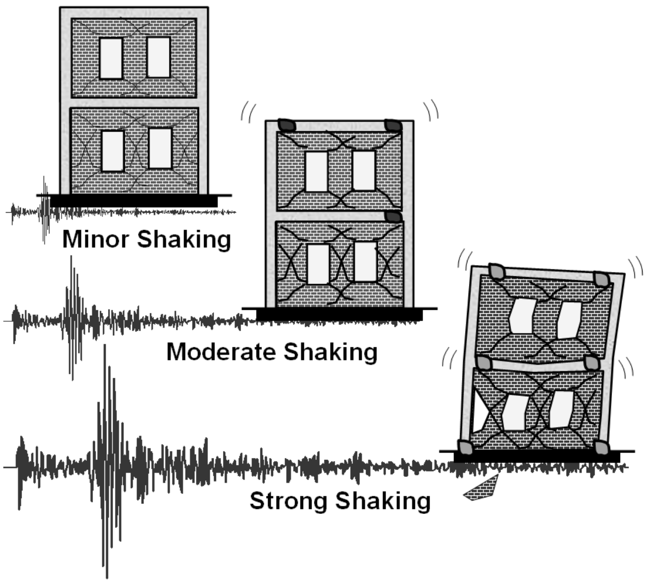

Fig. 3 Schematic diagram depicting earthquake resistant design philosophy for different levels shaking

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D. Time Period and Frequency

The time period required in seconds to complete one cycle of a seismic wave and the number of cycles that occur in one second is called as the Frequency, it is the inverse of Time Period and is measured in "Hertz". One Hertz is equal to one cycle per second.

A four-story building will sway at about a 0.5 second period, and taller buildings between about 10 and 20 stories will swing at periods of about 0.2 seconds and Comparative building periods, determined by height. These values are only the approximations: the structural system of the building, materials used and geometric proportions l also affect the period.

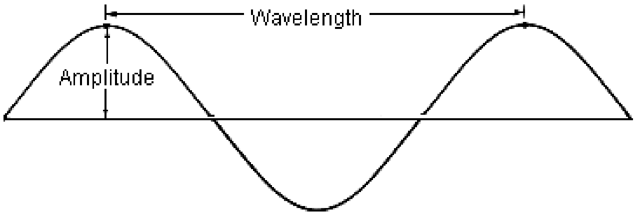

Fig. 4 Showing the wavelength and amplitude

Natural periods vary from about 0.05 seconds for a piece of equipment, such as a filing cabinet, to about 0.1 seconds for a one-story building. Period is the inverse of frequency, so the cabinet will vibrate at 1 divided by 20 cycles a second or 20 Hertz.

E. Resonance

When a vibrating or swinging object is given further pushes that are also at its natural period, its vibrations increase dramatically in response to even rather small pushes and, in fact, its accelerations may increase as much as four or five times. This phenomenon is called resonance.

Taller buildings also will undergo several modes of vibration so that the building will wiggle back and forth like a snake.

2. BUILDING PERFORMANCE AND DAMAGE

- Shape (configuration) of building:
  – Square or rectangular usually perform better than L, T, U, H, +, O, or a combination of these.
- Construction material: steel, concrete, wood, brick.
  – Concrete is the most widely used construction material in the world.
  – Ductile materials perform better than brittle ones. Ductile materials include steel and aluminium. Brittle materials include brick, stone and un-strengthened concrete.
- Load resisting system.
- Height of the building: (i.e. natural frequency)
- Previous earthquake damage
- Intended function of the building (e.g. hospital, fire station, office building)
- Proximity to other building.
- Soil beneath the building.
- Magnitude and duration of the earthquake.
- Direction and frequency of shaking

A. Proximity to other Buildings:

When two buildings are too close to each other, they may pound on each other during strong shaking. With increase in building height, this collision can be a greater problem. During earthquakes this problem occurs when building heights do not match, the roof of the shorter building may pound at the mid-height of the column of the taller one; this can be very dangerous.

Fig. 5 Pounding can occur between two buildings during horizontal shaking.

B. Size of the Building

In tall buildings with large height-to-base size ratio (Figure 4a), the horizontal movement of the floors during ground shaking is large. In short but very long buildings (Figure 4b), the damaging effects during earthquake shaking are many. And, in buildings with large plan area like warehouses), the horizontal seismic forces can be excessive to be carried by columns and walls.

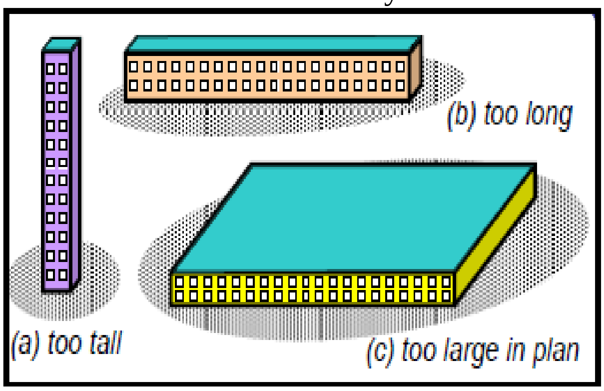

Fig.6 Different sizes of the buildings which do not perform well during earthquake.

C. Building Frames

Frame structures are the structures having the combination of beam, column and slab to resist the lateral and gravity loads. These structures are usually used to overcome the large moments developing due to the applied loading.

Frames structures can be differentiated into:

1. Rigid Frame Structure

The word rigid means ability to resist the deformation. Rigid frame structures can be defined as the structures in which beams & columns are made monolithically and act collectively to resist the moments which are generating due to applied load.

Rigid frame structures provide more stability. This type of frame structures resists the shear, moment and torsion more effectively than any other type of frame structures. That's why this frame system is used in world's most astonishing building Burj Al-Arab.

Which are further sub divided in two types-

- Pin Ended
- Fixed Ended

2. Braced Framed Structure

In this frame system, bracing are usually provided between beams and columns to increase their resistance against the lateral forces and sideways forces due to applied load. Bracing is usually done by placing the diagonal members between the beams and columns.
This frame system provides more efficient resistance against the earthquake and wind forces. This frame system is more effective than rigid frame system.

D. Shear Walls

In structural engineering, a shear wall is a structural system composed of braced panels (also known as shear panels) to counter the effects of lateral load acting on a structure. Wind and seismic loads are the most common loads that shear walls are designed to carry. Under several building codes, including the International Building Code (where it is called a **braced wall line**) and building code, all exterior wall lines in wood or steel .Frame construction must be braced. Depending on the size of the building some interior walls must be braced as wells hear walls resist in-plane loads that are applied along its height. The applied load is generally transferred to the wall by a diaphragm or collector drag member. They are built in wood, concrete, and CMU (masonry).
Plywood is the conventional material used in shear walls, but with advances in technology and modern building methods, other prefabricated options have made it possible to inject shear assemblies into narrow walls that fall at either side of an opening. Sheet steel and steel-backed shear panels in the place of structural plywood in shear walls has proved to provide stronger seismic resistance.
Generally shear walls are either plane or flanged in section, while core walls consist of channel sections.
In many cases, the wall is pierced by openings. These are called coupled shear walls because they behave as individual continuous wall sections coupled by the connecting beams or slabs.
Normally the walls are connected directly to the foundations. However, in a few cases where the lateral loads are relatively small and there no appreciable dynamic effects, then they can be supported on columns connected by a transfer beam to provide clear space.

3. POSITIONING OF SHEAR WALLS

The shape and plan position of the shear wall influences the behavior of the structure considerably. Structurally, the best position for the shear walls is in the centre of each half of the building. This is rarely practical, however, since it dictates the utilization of the space, so they are positioned at the ends.
This shape and position of the walls give good flexural stiffness in the short direction, but relies on the stiffness of the frame in the other direction. This arrangement provides good flexural stiffness in both directions, but may cause problems from restraint or shrinkage. As does this arrangement with a single core, but which does not have the problem from restraint of shrinkage. However, this arrangement lacks the good torsional stiffness of the previous arrangements due to the eccentricity of the core. If the core remains in this position then it must be designed explicitly for the torsion. It is far preferable to adopt a symmetrical arrangement to avoid this.
Architectural features that are detrimental to earthquake response of buildings should be avoided. If not, they must be minimized. When irregular features are included in buildings, a considerably higher level of engineering effort is required in the structural design and yet the building may not be as good as one with simple architectural features. Decisions made at the planning stage on building configuration are more important, or are known to have made greater difference, than accurate determination of code specified design forces.

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