A Study on Earthquake Resistant Building

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Abstract— An earthquake is the vibration, sometimes violent to the earth's surface that follows a release of energy in the earth's crust. This energy can be generated by a sudden dislocation of segments of the crust, by a volcanic eruption or even by a manmade explosion. The dislocation of the crust causes most destructive earthquakes. The crust may first bend and then the stresses exceed the strength of rocks, they break. In the process of breaking, vibrations called seismic waves are generated. These waves travel outward from the source of the earthquake along the surface and through the earth at varying speeds depending on the material through which they move. These waves can cause disasters on the earth's surface. Whenever a building project is prepared and designed, the first and the most important aspect of design is to know the zone to which this structure is likely to rest. Depending upon these, precautionary measures in structural design calculation are considered and structure can be constructed with sufficient amount of resistance to earthquake forces. Various measures to be adopted are explained pointwise, giving emphasis to increase earthquake resistance of buildings.
Keywords: Earthquake Resistant Building, RC Building

I. Introduction

An earthquake is the vibration, sometimes violent to the earth's surface that follows a release of energy in the earth's crust. This energy can be generated by a sudden dislocation of segments of the crust, by a volcanic eruption or even by a manmade explosion. The dislocation of the crust causes most destructive earthquakes. The crust may first bend and then the stresses exceed the strength of rocks, they break. In the process of breaking, vibrations called seismic waves are generated. These waves travel outward from the source of the earthquake along the surface and through the earth at varying speeds depending on the material through which they move. These waves can cause disasters on the earth's surface.

No structure on the planet can be constructed 100% earthquake proof; only its resistance to earthquake can be increased. Treatment is required to be given depending on the zone in which the particular site is located. Earthquake occurred in the recent past have raised various issues and have forced us to think about the disaster management. It has become essential to think right from planning stage to completion stage of a structure to avoid failure or to minimize the loss of property. Not only this, once the earthquake has occurred and disaster has taken place; how to use the debris to construct economical houses using this waste material without affecting their structural stability.

II. Methodology

Since the magnitude of a future earthquake and shaking intensity expected at a particular site cannot be estimated with a reasonable accuracy, the seismic forces are difficult to quantify for the purposes of design. Further, the actual forces that can be generated in the structure during an earthquake are very large and designing the structure to respond elastically against these forces make it too expensive. Therefore, in the earthquake resistant design post yield inelastic behavior is usually relied upon to dissipate the input seismic energy. Thus the design forces of earthquakes may be only a fraction of maximum (probable) forces generated if the structure is to remain elastic during the earthquake. For instance, the design seismic for buildings may at times be as low as one tenths of the maximum elastic seismic force. Thus, the earthquake resistant construction and design does not aim to achieve a structure that will not get damaged in a strong earthquake having low probability of occurrence; it aims to have a structure that will perform appropriately and without collapse in the event of such a shaking.

Ductility is the capacity of the structure to undergo deformation beyond yield without loosing much of its load carrying capacity. Higher is the ductility of the structure; more is the reduction possible in its design seismic force over what one gets for linear elastic response. Ensuring ductility in a structure is a major concern in a seismic construction.

III. Effect of Earthquake on Reinforced Concrete Buildings

In recent times, reinforced concrete buildings have become common in India. A typical RC building is made of horizontal members (beams and slabs) and vertical members (columns and walls) and supported by foundations that rest on the ground. The system consisting of RC columns and connecting beams is called a RC frame.

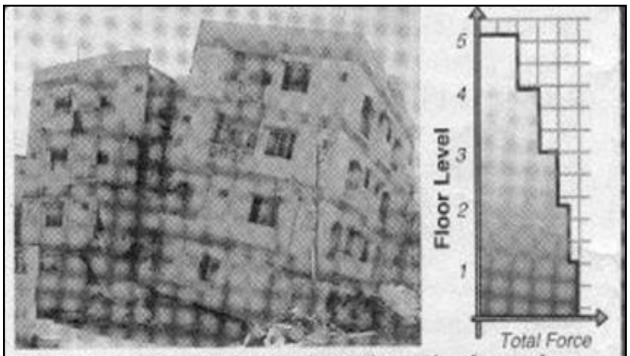


Figure 1: Total horizontal earthquake force in a building increases downwards along its height.

The RC frame participates in resisting earthquake forces. Earthquake shaking generates inertia forces in the building, which are proportional to the building mass. Since most of the building mass is present at the floor levels, earthquake induced inertia forces primarily develop at the floor levels. These forces travel downward through slabs to beams, beams to columns and walls and then to foundations from where they are dispersed to the ground. As the inertia forces accumulate downward from the top of the building (as shown in fig3.1) , the columns and walls at the lower storey experience higher earthquake induced forces and are therefore designed to be stronger than the storey above.

1) Roles of Floor Slabs and Masonry Walls:

Floor slabs are horizontal like elements, which facilitates functional use of buildings. Usually, beams and slabs at one storey level are cast together. In residential multistoried buildings, the thickness of slab is only about 110mm-150mm. when beams bend in vertical direction during earthquakes, these thin slabs bend along with them. When beams move in horizontal direction, the slab usually forces the beams to move together with it.

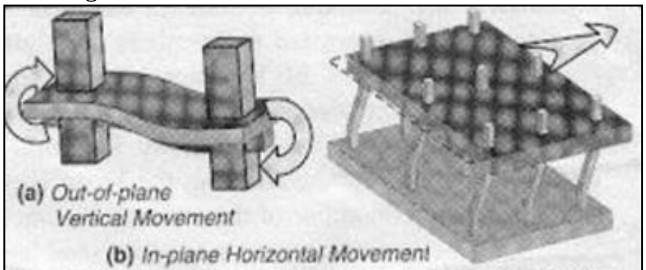


Figure 2: Floor bends with the beam but moves all columns at that level together.

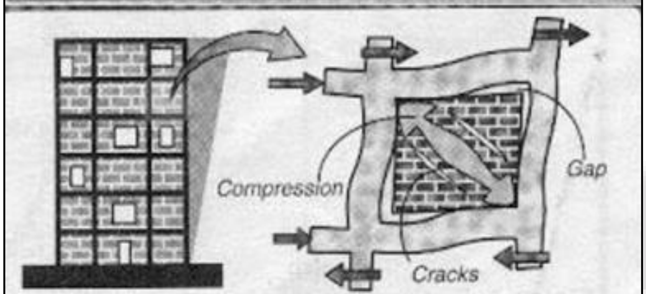


Figure 3: Infill walls move together with the columns under earthquake shaking.

In most of the buildings, the geometric distortion of the slab is negligible in the horizontal plane; the behavior is known as rigid diaphragm action. After columns and floors in a RC building are cast and the concrete hardens, vertical spaces between columns and floors are usually filled in with masonry walls to demarcate a floor area into functional spaces. Normally, these masonry walls are called infill walls, are not connected to surrounding RC beams and columns. When the columns receive horizontal forces at floor levels, they try to move in the horizontal direction, but masonry wall tend to resist this movement.

Due to their heavy weight and thickness, these walls develop cracks once their ability to carry horizontal load is exceeded. Thus, infill walls act like sacrificial fuses in the buildings, they develop crack under severe ground shaking but help share the load the load of beams and columns until cracking.

B. Strength Hierarchy:

For a building to remain safe during earthquake shaking columns (which receive forces from beams) should be stronger than beams and foundations (which receive forces from columns) should be stronger than columns. Further the connections between beams and columns, columns and foundations should not fail so that beams can safely transfer forces to columns and columns to foundations.

When this strategy is adopted in the design, damage is likely to occur first in beams. When beams are detailed properly to have large ductility, the building as a whole can deform by large amounts despite progressive damage caused due to consequent yielding of beams.

If columns are made weaker, localized damage can lead to the collapse of building, although columns at storey above remain almost undamaged.

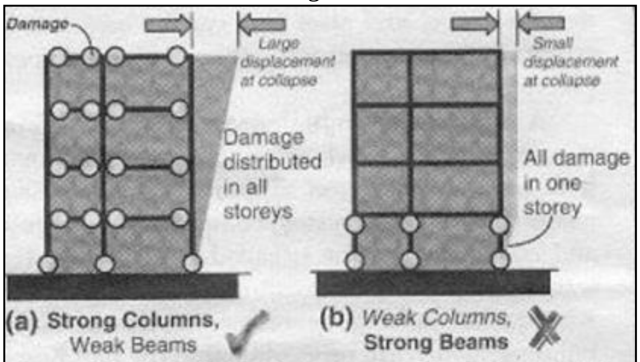


Figure 5: Two distinct designs of buildings that result in different earthquake performances – columns should be stronger than beams.

C. Earthquake Resistant Building:

The engineers do not attempt to make earthquake proof buildings that will not get damaged even during the rare but strong earthquake; such buildings will be too robust and also too expensive. Instead, engineering intention is to make buildings earthquake resistant, such building resists the effects of ground shaking, although they may get damaged severely but would not collapse during the strong earthquake. Thus, safety of peoples and contents is assured in earthquake resistant buildings and thereby, a disaster is avoided. This is a major objective of seismic design codes through the world.

D. Earthquake Design Philosophy:

The earthquake design philosophy may be summarized as follows:

- Under minor, but frequent shaking, the main members of the building that carry vertical and horizontal forces should not be damaged; however the building parts that do not carry load may sustain repairable damage.
- Under moderate but occasional shaking, the main member may sustain repairable damage, but the other parts of the building may be damaged such that they may even have to be replaced after the earthquake.
- Under strong but rare shaking, may sustain severe (even irreparable) damage, but the building should not collapse.

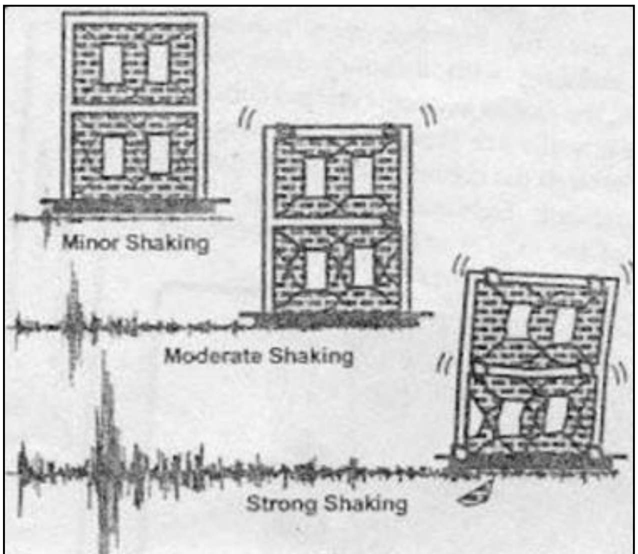


Figure 2: Performance objectives under different intensities of earthquake shaking – *seeking low repairable damage under minor shaking and collapse-prevention under strong shaking.*

Thus after minor shaking, the building will be operational within a short time and repair cost will be small and after moderate shaking, the building will be operational once the repair and strengthening of the damaged main members is completed. But, after a strong earthquake, the building may become disfunctional for further use, but will stand so that people can be evacuated and property recovered.

The consequences of damage have to be kept in view in the design philosophy. For example, important buildings like hospitals and fire stations play a critical role in post-earthquake activities and must remain functional immediately after earthquake. These structures must sustain very little damage and should be designed for a higher level of earthquake protection. Collapse of dams during earthquake can cause flooding in the downstream reaches, which itself can be a secondary disaster. Therefore, dams and nuclear power plants should be designed for still higher level of earthquake motion.

IV. REMEDIAL MEASURES TO MINIMIZE THE LOSSES DUE TO EARTHQUAKES

Whenever a building project is prepared and designed, the first and the most important aspect of design is to know the zone to which this structure is likely to rest. Depending upon these, precautionary measures in structural design calculation are considered and structure can be constructed with sufficient amount of resistance to earthquake forces. Various measures to be adopted are pointwise, giving emphasis to increase earthquake resistance of buildings.

- Building planning
- Foundation
- Provision of band
- Arches and domes
- Staircases
- Beam column joints
- Masonry building
- Using slurry infiltrated mat concrete (simcon)

V. MID-LEVEL ISOLATION

This includes mid-level isolation system installed while the buildings are still being used. This new method entails improving and classifying the columns on intermediate floors of an existing building into flexible columns that incorporate rubber bearings (base isolation systems) and rigid columns which have been wrapped in steel plates to add to their toughness.

This is the first method of improving earthquake resistance in Japan that classifies the columns on the same floor as flexible columns and rigid columns, and it is the first case in west Japan (the Kansai region) of attaching rubber bearings by cutting columns on the intermediate floors an existing building. This method involves improving earthquake resistance while the buildings are still being used as normal operations.

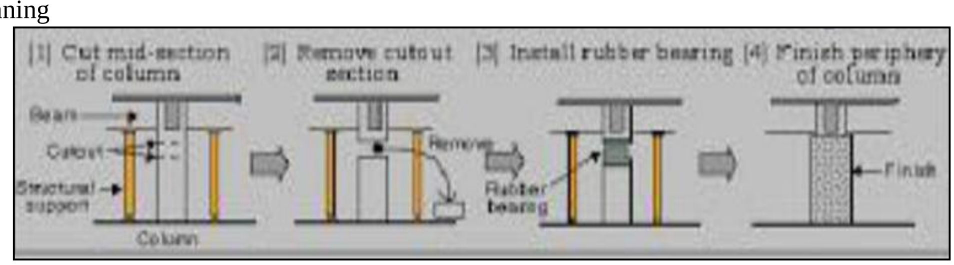
There are three types of base isolation systems, depending on the location where rubber bearings are incorporated:

- Pile head isolation
- Foundation isolation
- Mid-level isolation

By cutting horizontally all columns and walls on a specific intermediate floor and installing rubber bearings in the columns that have been cut, that floor becomes extremely flexible, and the building will sway horizontally with the large sway amplitude of 40-50 centimeters under maximum level earthquakes. It therefore becomes possible that the finishing materials, piping and existing elevators may not be able to keep pace with the deformations and break, perhaps resulting in their protruding from the site of the building.

In the head office of Himeji Shinkin Bank, columns with rubber bearings incorporated in them to allow them to move flexibly and rigid columns which were made tougher by wrapping steel plate were placed effectively, thereby suppressing horizontal deformation and improving the earthquake resistance of the building as a whole.

Vibration control units incorporating viscous materials with high energy absorption performance were installed in walls, to play the role of dampers. This reduced the swaying of the building. Mid-level isolation procedure is shown in the fig.



VI. TRADITIONAL EARTHQUAKE RESISTANT HOUSING

Earthquakes are not common phenomena in most parts of the world. Hence, houses in most rural areas are not built to withstand seismic forces, resulting in heavy causalities even in moderate quakes. In some parts of the world, however, where earthquakes are common, people have incorporated the critical elements of quake-resistance in their traditional construction method. Traditional house building techniques have successfully demonstrated, during past earthquakes in the Himalayan region, that there is inherent after component associated with the constructional design. This was found during the 1905 Kangra earthquake, the traditional Kat-Ki Kunni houses in Kullu valley made up of timber remained unaffected. The Dhajji-Diwari buildings remained intact in the 1885 Srinagar earthquake. Similarly, in Uttarkashi the traditional 100 years old multistoried buildings called Pherols have incorporated basic features of earthquake resistance.

- The Pherols of Uttarkashi
- The Dhajji-Diwari buildings of Kashmir
- The Kat-Ki- Kunni Buildings of Kulu Valley
- Quincha earthquake resistant buildings

VII. CONCLUSIONS

- Due to lack of awareness in earthquake resistant structures a lot of money is wasted on skilled labor which could otherwise be done with help of unskilled labor. Avoiding skilled labor in not so important parts of an earthquake resistant structure can bring down the expense on the project.
- A state wise program needs to be run depending on Earthquake Zone of the area to fully exploit the advancements in earthquake resistance in a cost-effective manner.
- There is an urgent need to revise the codal provisions regarding earthquake resistant structures.
- These updated codal provision shall be used by builders and contractors in future designs. Using these codal provisions regarding earthquake resistant structure would only incur a 2% to 6% increase in existing project cost.
- Techniques like SIMCON and RHCBM do not only mitigate the effect of earthquake but are also cost-effective.
- Working on energy dissipation devices would reduce the effect caused by the shock waves and hence reduce cost of repair works.

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