ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

# Earthquake Resistent Building Construction

**M Murali Krishna**
B.Tech Scholar,
Department of Civil Engineering,
Siddhartha Institute of Engineering and Technology,
Vinobha Nagar, Ibrahimpatnam, Hyderabad,
Telangana-501506.

**A Rama Mohana Chary**
Assistant Professor,
Department of Civil Engineering,
Siddhartha Institute of Engineering and Technology,
Vinobha Nagar, Ibrahimpatnam, Hyderabad,
Telangana-501506.

## 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.

## Introduction
No structure on the planet can be constructed 100% earthquake proof; only its resistance to earthquake can be increased [1]. 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 [2-4]. 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. 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 [5-7].

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 [8-9]. 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.

## 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.

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

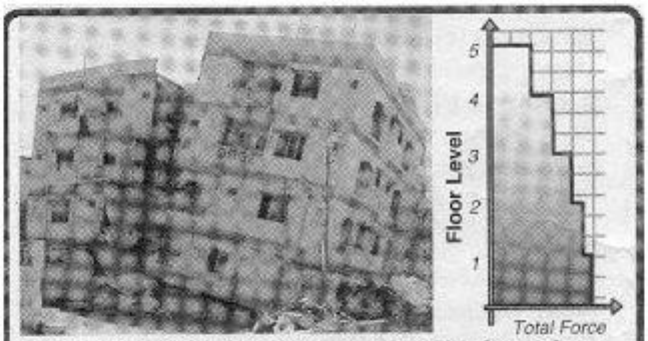

Figure 1: Total horizontal earthquake force in a building increases downwards along its height.

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.

**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.

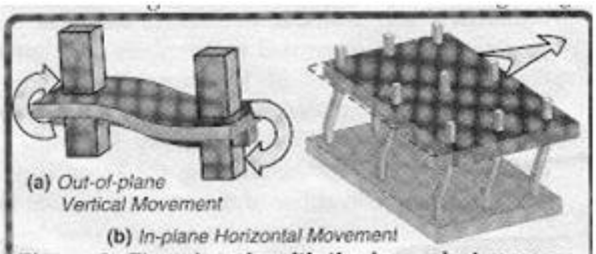

Figure 2: Floor bends with the beam but moves all columns at that level together.

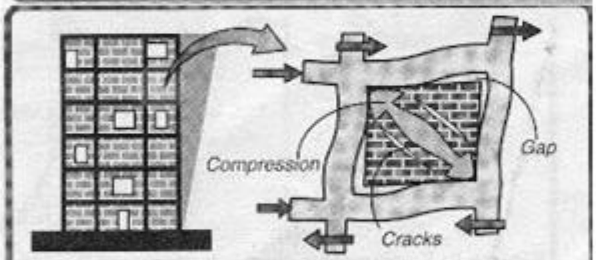

Figure 3: Infill walls move together with the columns under earthquake shaking.

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.

**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

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

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.

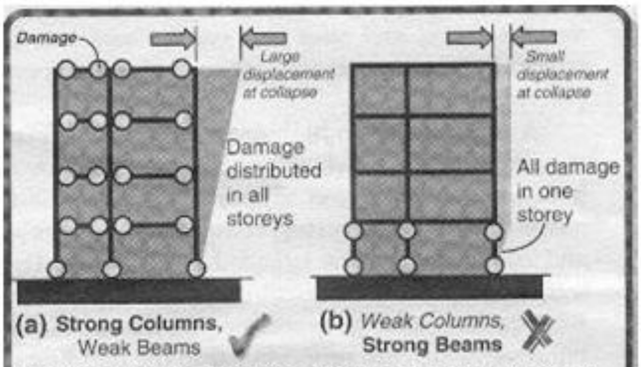


Figure 5: Two distinct designs of buildings that result in different earthquake performances – *columns should be stronger than beams.*

## SEISMIC DESIGN PHILOSOPHY

Severity of ground shaking at a given location during earthquake can be minor, moderate and strong. Relatively speaking, minor shaking occurs frequently; moderate shaking occasionally and strong shaking rarely. For instance, on average annually about 800 earthquakes of magnitude 5.0-5.9 occurs in the world, while the number is only 18 for the magnitude ranges 7.0-7.9. Since it costs money to provide additional earthquake safety in buildings, a conflict arises 'should we do away with the design of buildings for earthquake effects? Or should we design the building to be earthquake proof wherein there is no damage during strong but rare earthquake shaking. Clearly the formal approach can lead to a major disaster and second approach is too expensive. Hence the design philosophy should lie somewhere in between two extremes.

## 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.

## 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.

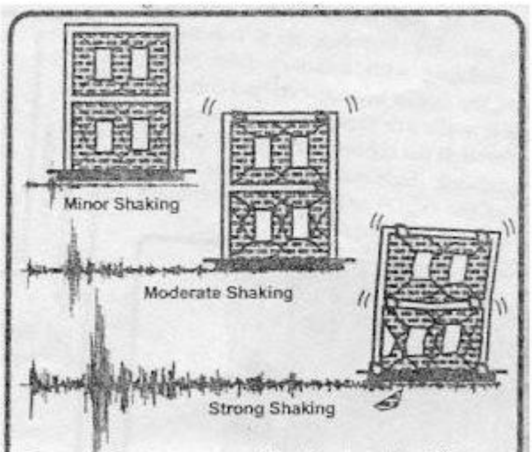


Figure 2: Performance objectives under different intensities of earthquake shaking – *seeking low repairable damage under minor shaking and collapse-prevention under strong shaking.*

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.

## REMEDIAL MEASURES TO MINIMISE 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 explained pointwise, giving emphasis to increase earthquake resistance of buildings.

### Building planning:

The records of various earthquake failures reveal that unsymmetrical structure performs poorly during earthquake. The unsymmetrical building usually develops torsion due to seismic forces, which causes development of crack leading to collapse of a structure. Building therefore should be constructed rectangular and symmetrical in plan. If a building has to be planned in irregular or unsymmetrical shape, it should be treated as the combination of a few rectangular blocks connected with passages. It will avoid torsion and will increase resistance of building to earthquake forces.

### Foundation:

IS code recommends that as far as possible entire building should be founded on uniform soil strata. It is basically to avoid differential settlement. In case if loads transmitted on different column and column footing varies, foundation should be designed to have uniform settlement by changing foundation size as per code conditions to have a loading intensity for uniform settlement.

Raft foundation performs better for seismic forces. If piles are driven to some depth over which a raft is constructed (raft cum pile foundation), the behaviour of foundation under seismic load will be far better. Piles will take care of differential settlement with raft and resistance of structure to earthquake forces will be very large.

### Provision of band:

IS code recommends construction of concrete band at lintel level to resist earthquake. The studies revealed that building with band at lintel level and one at plinth level improves load carrying of building to earthquake tremendously. It is suggested here that if bands are plinth level, sill level, lintel level and roof level in the case of masonry structure only, the resistance of building to earthquake will increase tremendously. Band at sill level should go with vertical band and door openings to meet at lintel level. Hold fast of doors can be fitted in their sill band. In case of earthquake of very high intensity or large duration only infill wall between walls will fail minimizing casualties and sudden collapse of structure. People will get sufficient time to escape because of these bands.

### Arches and domes:

Behavior of arches has been found very unsatisfactory during earthquake. However domes perform very satisfactory due to symmetrical in nature.

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

Arches during earthquake have tendency to separate out and collapse. Mild steel ties if provided at the ends, their resistance can be increased to a considerable extent.

### Staircases:

These are the worst affected part of any building during earthquake. Studies reveal that this is mainly due to differential displacement of connected floors. This can be avoided by providing open joints at each floor at the stairway to eliminate bracing effect.

### Beam column joints:

In framed structures the monolithic beam column connections are desirable so as to accommodate reversible deformations. The maximum moments occur at beam-column junction. Therefore most of the ductility requirements should be provided at the ends. Therefore spacing of ties in column is restricted to 100mm centre and in case of beam strips and rings should be closely spaced near the joints. The spacing should be restricted to 100mm centre to centre only near the supports. In case of columns, vertical ties are provided; performance of columns to earthquake forces can be increased to a considerable extent.
Steel columns for tall buildings ie buildings more than 8 storey height should be provided as their performance is better than concrete column due to ductility behavior of material.

### Masonry building:

Mortar plays an important role in masonry construction. Mortar possessing adequate strength should only be used. Studies reveal that a cement sand ratio of 1:5 or 1:6 is quite strong as well as economical also. If reinforcing bars are put after 8 to 10 bricklayers, their performance to earthquake is still better. Other studies have revealed that masonry infill should not be considered as non-structural element. It has been seen that in case of column bars are provided with joints at particular level about 600-700mm above floor level at all storey should be staggered. It may be working as a weak zone at complete floor level in that storey.

As such if few measures are adopted during stages of design and construction of building their resistance to earthquake forces can be improved considerably. Though buildings cannot be made 100% earthquake proof but their resistance to seismic forces can be improved to minimize loss of property and human life during the tremors.

## 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.

## EARTHQUAKE RESISTANCE USING SLURRY INFILTRATED MAT CONCRETE (SIMCON)

Following the devastating earthquakes in Turkey this summer that killed as many as 20,000 people and injured another 27,000, images of survivors trapped beneath the rubble of collapsed buildings appeared daily in news reports worldwide. Now a North Carolina State University engineer is developing a new type of concrete to help prevent such scenes from happening again. Because it's reinforced with mats made of thousands of stainless steel fibers injected with special concrete slurry, the new material, called Slurry Infiltrated Mat Concrete (SIMCON), can sustain much higher stress loads and deformations than traditional concrete. Tests show that concrete buildings or bridges reinforced with SIMCON are far more earthquake resistant and less likely to break apart in large chunks that fall off and cause injury to people below.

If extreme stresses cause SIMCON to fail, its mass of fibers and concrete doesn't collapse in the same way traditional concrete does. Instead of large chunks breaking and falling from a structure, the material crumbles into small, harmless flakes. This controlled form of failure is a key advantage of SIMCON. Because failure is inevitable in all structures, engineers must design buildings and bridges to fail in the safest way. In conventional concrete structures, this is achieved through the use of steel reinforcing bars -- rebars -- that give the concrete tensile strength it would otherwise lack. For safety and design reasons, the concrete is designed so that the rebars will fail before the concrete does.

Unfortunately, many structures have not been designed to sustain the powerful stresses caused by earthquakes. When such extreme stresses occur, the concrete can crack, explode and break away from the rebars, causing the structure to collapse. By contrast, failure of SIMCON would present little danger to people or property below.

## CONCLUSIONS

There is a lack of awareness in the earthquake disaster mitigations. Avoiding non-engineered structures with unskilled labour even in unimportant temporary constructions can help a great way. Statewide awareness programmes have to be conducted by fully exploiting the advancement in the information technology. Urgent steps are required to be taken to make the codal provisions regarding earthquake resistant construction undebatable. The builders and constructors should adopt the codal provisions in all the future construction, as prevention is better than cure. On the light of avoiding the risk, this may not be an impossible task as earthquake resistant measures in building involves only 2%6% additional cost depending on the type of building. Using construction techniques like SIMCON and RHCBM can not only mitigate earthquake effects but also are cost effective.

## Reference:

[1] Marulanda M, Carreño M, Cardona O, Ordaz M, Barbat A (2013) Probabilistic earthquake risk assessment using CAPRA: application to the city of Barcelona, Spain. Nat Hazards. doi: 10.1007/s11069-013-0685-z

[2] Tsai, C. H., & Chen, C. W. (2010). An earthquake disaster management mechanism based on risk assessment information for the tourism industry-a case study from the island of Taiwan. Tourism Management, 31, 470e481.

[3] Lester JR, Brown AG, Ingham JM. Stabilisation of the Cathedral of the Blessed Sacrament following the Canterbury earthquakes. Eng Failure Analysis, this issue.

[4] Dizhur D, Ingham J, Moon L, Griffith M, Schultz A, Senaldi I, et al. Performance of masonry buildings and churches in the 22 February 2011 Christchurch earthquake. Bull New Zealand Soc Earthq Eng 2011;44(4):279–96.

[5] Galli P, Castenetto S, Peronace E. Terremoti dell'Emilia – Maggio 2012. Rilievo Macrosismico MCS Speditivo, Final Report. Rome: Italian Civil Protection Department; 2012 [in Italian].

[6] Daniell JE, Khazai B, Wenzel F, Vervaeck A. The CATDAT damaging earthquakes database. Nat Hazards Earth Syst Sci 2011;11:2235–51.

[7] Daniell JE, Vervaeck A. CEDIM earthquake loss estimation series research report 2012-01. Karlsruhe: CEDIM; 2012.

[8] Cavallo, E., Galiani, S., Noy, I., Pantano, J., 2013. Catastrophic natural disasters and economic growth. Review of Economic and Statistics 95, 1549–1561.

[9] Aldrich, D., 2012. Building Resilience: Social Capital in Post-disaster Recovery. University of Chicago Press.