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Design Principles for Earthquake Resistant Buildings and Post Earthquake Study by Structural Engineering Perspectives

Two major earthquakes hit India in last eight years. The first in Killari (Latur) Maharashtra on 30th September 1993(Magnitude 6.4,deaths about 10,000) and the second recently at Bhuj Gujrat on 26th January 2001(Magnitude 8.1,deaths more than 35000).In USA two earthquakes took place one in California on 17th January 1994(Magnitude 6.6,deaths 57) and second in Ciatel near Canada on 1st March 2001(Magnitude 6.8,death 1).It shows clearly that the damage to structures and loss of life is more in developing countries like India as compared to developed countries like USA,Japan etc. This is due to lack of awareness in adopting Indian Standard codal provisions for earthquake resistant design. It is highly expensive to construct structure 100% earthquake proof. This paper aims to highlight design principles for earthquake resistant buildings which should be compulsorily adopted during the construction. In this paper, post earthquake effects on buildings from structural point of view are also highlighted.

Keywords: *post earthquake, building, structural, engineering*

1. Introduction

Earthquake Magnitude-

Magnitude of a local earthquake is defined as the logarithm to the base of 10 of the maximum seismic wave amplitude (in thousands of mm) recorded at a distance of 100 Kms from the earthquake epicenter. With increase in magnitude of 1.0,the energy released by the earthquake increases by a factor of about 30.Thus, magnitude 8.0 earthquake releases about 30 times energy released by a magnitude 7.0 earthquake or about 900 times energy released by a 6.0 earthquake.

Lateral analysis and design of RCC structures-

To transfer lateral load from floor diaphragm to the foundation suitable vertical elements are required. They may be moment resisting frames, shear walls, bearings or a combination of these. Shear wall is essentially a column with large depth and small width. In general shear wall tend to be laterally much stiffer than moment resisting frames. It is necessary to design the frame for at least 25% of design force in case of structure having a combination of shear wall and moment resisting frame. This is essential because if shear wall fails, there may be sudden collapse of building.

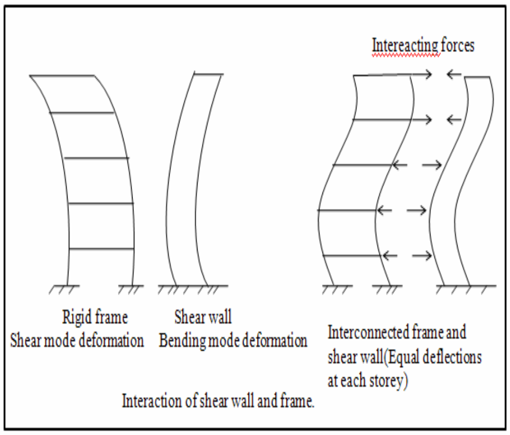

Figure 1.

If some of the storey is going to have sudden reduction in stiffness such as parking floor without walls, it is referred as soft storey. Soft storey attracts plastic deformation resulting in the collapse of the building. Many such failures due to soft storey were observed in Ahmedabad.For a good seismic performance it is necessary to have high redundancy, thus even after failure of one of the member the structure may not fail. If they are monolithically connected to each other and if yielding takes place in one of them then redistribution of forces takes place.

Ductility-

It is the capacity of the structure or a member to undergo deformation beyond yield without losing much of the load carrying capacity. The design philosophy for frames is to avoid failure of columns, from both axial load and bending moment consideration. Lack of stiffness or strength in the column will lead to formation of plastic hinge in them. Under such condition it is preferred to have a formation of moment hinge in the beams instead of column. Column failure may lead to collapse of the building but beam failure will be a localized failure. This philosophy of design is called as strong column and weak beam philosophy. This can be achieved by designing section as under-reinforced and providing limits on minimum and maximum reinforcement thus improving the ductility.

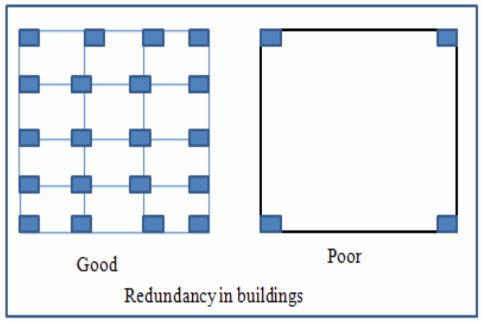

Figure 2.

To behave in ductile manner, the member shall not fail in diagonal shear before formation of plastic hinge.So,most seismic codes impose restriction on maximum tension reinforcement in flexural member(Beam) and require closely spaced stirrups at ends of beams.

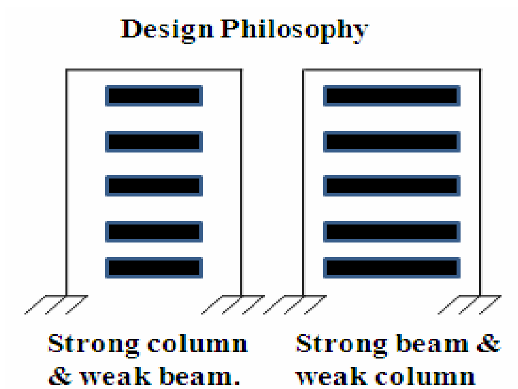

Figure 3.

Building/Structural shapes and configuration-

Buildings with simple and regular configuration with direct load transfer path perform much well during earth quake. In buildings with plan irregularity, the load distribution to different vertical elements becomes complex and require three dimensional dynamic analysis. So the seismic configuration is an important consideration at the stage of architectural planning of a building. In seismic design of building, architect and structural engineers need to actively interact with each other to arrive at a structural system, which is necessarily a seismic resistant. If we have a poor configuration to start with, all the engineers can do is to provide a band-aid to improve a basically poor solution as best as he can. Conversely, if we start with a good configuration and a reasonable framing system, even a poor engineer can't harm its ultimate performance too much. A slenderness ratio (Height/Least lateral dimension) and aspect ratio (Length/Width) of a building are measures of relative proportions in plan and in elevation. Slenderness ratio must be restricted to small value as possible and it is ideal to keep aspect ratio as close to unity.

Building geometries in plan-

A corner column in frame system must be designed conservatively from seismic consideration. In Ahmadabad, it was observed that many of the building corner columns were severely damaged.

Infill wall stiffness-

It is common practice to ignore the strength and stiffness contributed by them. Thus ignoring stiffness of infill walls may lead to calculate higher fundamental period (T) and decrease in the design force. So, the revised IS-1893 suggests using the expression for calculating T as

$T= (0.09)\ H / (D)^{1/2}$ and not as $T= (0.1)\ n$ as per old code.

Behavior of Buildings in past earthquakes-

Failures can be categorized as follows-

- Failure due to building structure.
  - -Building as a whole.
  - -Individual members.
- Failures due to soil conditions.

Structural collapse may occur at any level and may be due to lateral or torsional displacements, local failure of supporting members, excessive foundation movement and it may also be due to impact of very close adjoining structure which collapse during the earthquake. Some building may not collapse entirely but they do suffer extensive structural damage and thus become unsafe and hence are required to be demolished at any cost. Some structures which receive minor damage can be strengthened or retrofit and can be made reasonably fit for human living. Typical damage can be categorized as follows-

(a) Masonry part of the structures-

-Damage to the plaster and veneer tiles which are recognized as minor damage which might be dangerous.

-Masonry crushing as a result of strut-action.

-Masonry shear (bed-joint) and tensile (diagonal) cracks. Separation between the masonry infill and the frame.
-Masonry out-of-plane collapse.

(b) RC components-
-Cracks at the connection between two perpendicular beams.
-Crushing of the concrete core in RC columns/tiles.
-Spalling of the concrete cover/core in RC frame members (mostly columns).
-Buckling of longitudinal reinforcing bars as the result of either no/little concrete cover or inadequate stirrup spacing.
-Shear cracks/failures of RC columns and beams.
-Failure of beams/horizontal ties supported by masonry bearing walls due to inadequate supporting length.
-Foundation failure due to punching.
-Failure of concrete due to inappropriate material (such as using stones instead of appropriate aggregates).
-Column buckling.
-Flexural failure of beams/slabs.
-Non-uniform settlement of columns (Bridges and Buildings).

(c) Roads and other structures-
-Cracks in the road pavements.
-Land sliding.
-Collapse of transmission towers.
-Failure of retaining walls.
Here are some do's and don'ts to be followed for analysis and design of multi-storied buildings.

Planning stage-

Do's-

a)Simple planning.
b) Involve structural engineer.
c) Convex shapes.
d) Less slenderness ratio.
e) Aspect ratio near unity.
f) Proper placement of core shaft.

Don'ts-

a) Irregular shapes L,T and H .
b) Long cantilevers, overhangs.
c) Concave shapes.
d) Abrupt change in plan/elevation.
e) Plaza type planning.
f) Heavy malls at roof.

Structural design stage-

Do's-

a)Conduct soil investigations.

b) Moment resisting frame.

(Combination of MRF with wall/bearing/ shear walls).

c) Strong column and weak beam.

d) Minimum column size.(230 mm).

e)Ductile detailing is essential.

Don'ts-

Simply supported beams.

a) Parking floor without any shear Wall/bracing.
b) Floating columns.
c) Neglect effect of infill walls.
d) Lift shaft with masonry.

Construction stage-

Do's-

a) Proper testing of all materials.

b) Vibrated concrete for column. near column –beam junction.

c) Grade of concrete in column – beam junction has to be that of column.

Don'ts-

a) Lapping of column/beam bars

b) Never hide any construction defect.

4. Conclusion

Over 60% of the country's land area is under the threat of moderate to high seismic activity. It is very well acknowledged that earthquake engineering has progressed more from the experienced gained from actual earthquakes than from laboratory tests. In particular, efforts are required towards enforcing design codes by instituting a techno-legal regime. Providing education(teaching and research) in technical colleges and institutes along with schools. Continuously developing and updating seismic design provisions towards improving earthquake safety. Understanding and estimating seismic activity across the country.This paper will only help us to correct our knowledge in the design process. If structural engineers follow the provisions of the relevant I.S. codes then many of the failures of buildings can be avoided,if not at least the damages and loss of lives can be minimized.We shall always be well prepared to face earthquakes.

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