# COMPARATIVE STUDY ON COLLAPSE RESISTANCE OF RC BUILDING STRUCTURE HAVING PLAN IRREGULARITY

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***Abstract****: In this article, an attempt has been made to study the assessment of collapse resistance of RC building structures having plan irregularity. Moment resisting frame have been considered for the collapse analysis and the same have been designed as per IS:456-2000, IS:1893-2016 & IS:13920-2016. The Structure have been design using linear static method as mentioned in IS codes, and the same have been checked against collapse resistance using nonlinear static pushdown analysis. The models considered for studied are rectangular & L-shape in the plan. Typical three buildings are considered namely G+4 storey, G+7 storey & G+10 storey. For both rectangular and L-shape building, floor plate area has been maintaining same for better comparison on collapse load carrying capacity. Nonlinear behaviour of the elements is modelled using plastic hinges based on moment-curvature relationship as described in ASCE-41/FEMA 356 guidelines. The structure is pushed down monotonically to monitored failure behaviour. Four columns removal are considered for collapse assessment, potentially critical as defined in GSA guidelines. Column removal are considered on a time only, and the response of structure have been noted by pushdown curves.*

***Keywords:*** **Asymmetric Plan, Irregularities, Collapse Assessment, Design Eccentricity, Torsion**

## 1. Introduction

A Special Moment resisting frame structures form the space frame which cause the flexural deformation as they carry the lateral loads and gravity loads. Progressive collapse is the phenomena when one or more primary load carrying structure elements fails by means of any abnormal loading to the structure and eventually whole structure leads to the collapse. In present study, rectangular shape building & L-shape building have been considered for collapse assessment with different fourcolumn removal cases/locations at the plinth level of structure. Buildings structures of G+4, G+7 & G+10 have been design considering linear static method cum seismic co-efficient method, the considered structures have been assessed for collapse resistance by removal of one column at a time, and the response of structure have been evaluated. For, L-shape building there is difference in center of mass and center of stiffness, hence design eccentricity are calculated as per IS:1893- 2016 and same have been considered at designing stage too. All the four column removal cases for all the buildings undergoes with non-linear static pushdown method to evaluate the results as base reaction vs. displacement.

## 2. Modal Parameters

In this sections the Structural model details are described as below:

*A. Description of structural model & design parameters*

The considered models in the present study is rectangular and L-shape in plan with height of each storey as 3.0m. Spacing of bay in X-direction is 5.0m and in the Y-direction is 3.0m. A sample of typical plan and 3-D model of the structural models

are as shown in Figure 1 & Figure 2 for rectangular & L-shape respectively. The structure have been analysed and design for Gravity and Lateral load as per IS Code. The structural member sizes of beams, columns & slabs are mention in the table-1 in detail and Loading parameters are mentioned in table-2. The structure is considered as situated in seismic zone III founded on a medium soil in accordance with IS 1893:2016.

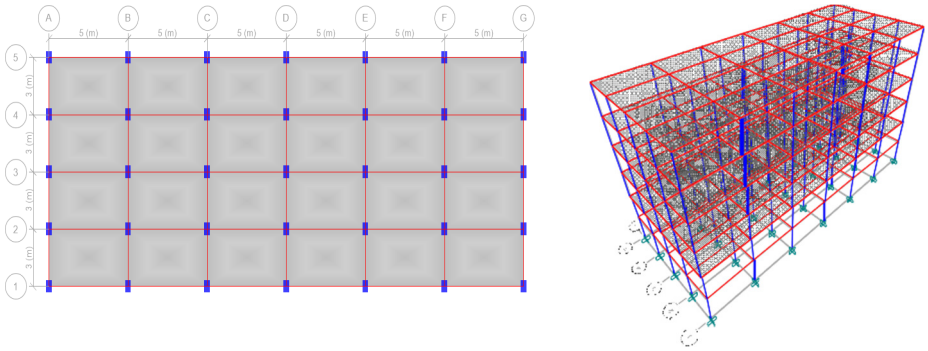

**Figure 1. Plan and 3D model of Rectangular Building Structure**

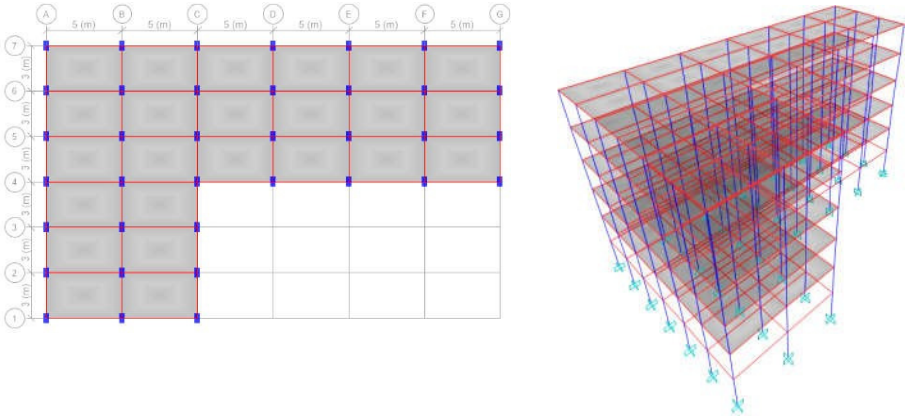

**Figure 2. Plan and 3D model of L-shape Building Structure**

**Table 1. Geometrical Parameters**

| Structure | Storey of Building | Height of Building (m) | Plan Dimension at Plinth Level (m) | Column Sizes (mm) | Beam Sizes (mm) | Slab Thk. (mm) |
|---|---|---|---|---|---|---|
| Rectangular Shape | G+4 | 15.00 | Dx=30.00m Dy=12.00m | 350x650 | 230x600 | 150 |
| | G+7 | 24.00 | | | | |
| | G+10 | 33.00 | | | | |
| L-Shape | G+4 | 15.00 | Dx=30.00m Dy=18.00m | 375x900 | 230x600 | 150 |
| | G+7 | 24.00 | | | | |
| | G+10 | 33.00 | | | | |

*Concrete Grade M30, Steel Grade Fe500 for all structural members

**Table 2. Loading Parameters**

| Structure | Storey of Building | Height of Building | Natural Period of Building as Per IS Code |
|---|---|---|---|

| | | (m) | (sec) |
|---|---|---|---|
| Rectangular Shape | G+4 | 15.00 | Tx=0.25, Ty=0.39 |
| | G+7 | 24.00 | Tx=0.39, Ty=0.62 |
| | G+10 | 33.00 | Tx=0.54, Ty=0.86 |
| L-Shape | G+4 | 15.00 | Tx=0.25, Ty=0.32 |
| | G+7 | 24.00 | Tx=0.39, Ty=0.51 |
| | G+10 | 33.00 | Tx=0.54, Ty=0.70 |

- Gravity Loadings as, Dead Load (Self Weight), LL=4.0kN/m2, SDL=1.2kN/m2, Wall Load = 6.9kN/m (UDL on Beams)
- Seismic & Wind Loading as, Seismic Zone – 3 (Z=0.16), Soil Type -2 (Medium Soil), I=1.2 (Importance Factor), R=5.0 (SMRF). Basic wind speed = 39m/s, Terrine Category=3, Risk & Topography factor = 1.0.

*B. Collapse Loading and Column Removal Cases*

For Design of Structure, load combination mentioned in IS:456-2000 & IS:1893-2016 have been considered. Collapse loading have been adopted from reference of GSA guidelines and modified accordingly as per Indian Codal Provision. Collapse load is considered as 2.4DL+2.0LL at & above all floors for particular column removal location, whereas 1.2DL+1.0LL at other than removal locations. Marked four columns locations are considered for column removal cases one at a time. Figure 3 shows the schematic column removal cases with circle marks for present study.

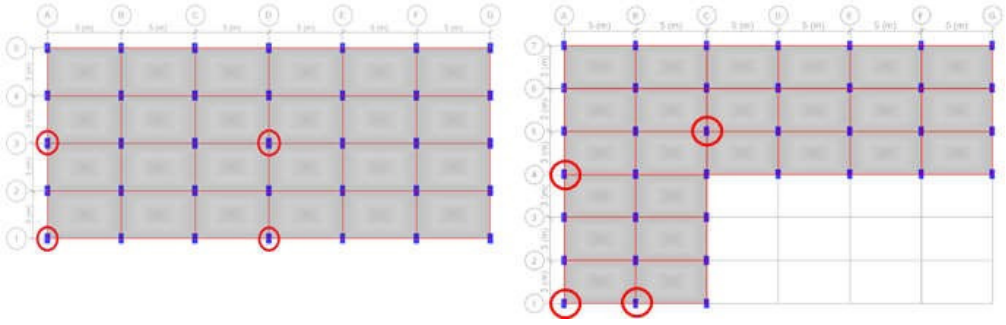

**Figure 3. Plan and 3D model of L-shape Building Structure**

*C. Modelling details*

ETABS has been used for modelling, analysis & design. Collapse assessment by Nonlinear static analysis, a 3D computer model is created and user defined plastic hinges are incorporated. For user defined hinges and moment-rotation data was generated using the XTRACT tool for reinforcement arrangements in cross section and presence of axial loads. A set of moment-rotations relationships have been calculated for beams and columns considering the basics of cross section properties as $\theta y=(My/EI)*Lp$ and $\theta p=(Mp/EI)*Lp$, where $(M/EI)=\emptyset$ and $Lp=0.08L+0.022dfy$ (Paulay and Priestley, 1992). Assigning the Collapse load to the structure, ultimate and plastic rotation are calculated for individual members. The results are calculated as maximum collapse load attempt by structure at failure of any structural member and load vs. displacement curve are generated for comparison.

## 3. Results and Discussions

Figure 4 shows pushdown curves for all four column removal cases for rectangular & L-shaped building together. The curves are superimposed for comparison of collapse load attempted by structure. It can be observed from pushdown curves that among all four column removal cases the long bay column removal & center column removal cases the structures under goes elastoplastic range before failure because of the catenary, double span effect after removal of column. For all the curves initial displacement have been observed at the starting point of curve and these is because of the initial stressed condition due to presence of gravity load. The dotted line in represent the L-shape building, where as full line represents rectangular shape building for pushdown curves. Based on the pushdown curves it can be shown that, there is marginal difference for collapse load attempting by rectangular & L-shape structure. As L-shaped building have been designed with additional design eccentricity recommended by IS codes, thus the capacity of the members is little more than the rectangular structure. Majority of column removal cases, L-shape building having more resistance as compare to rectangular building. Irregularities mentioned in the IS codes are most affected by the lateral loading, thus the code have mandates the same to address at design level to strengthen the structures one in other way. For Collapse assessment or pushdown analysis, gravity loads are more predominate rather than the lateral ones. As a result, the vertical irregularities and plan irregularities have not much influence on collapse resistance, only the alternate path for re-distribution of the loads by missing members shall be there for effective resistance towards collapse.

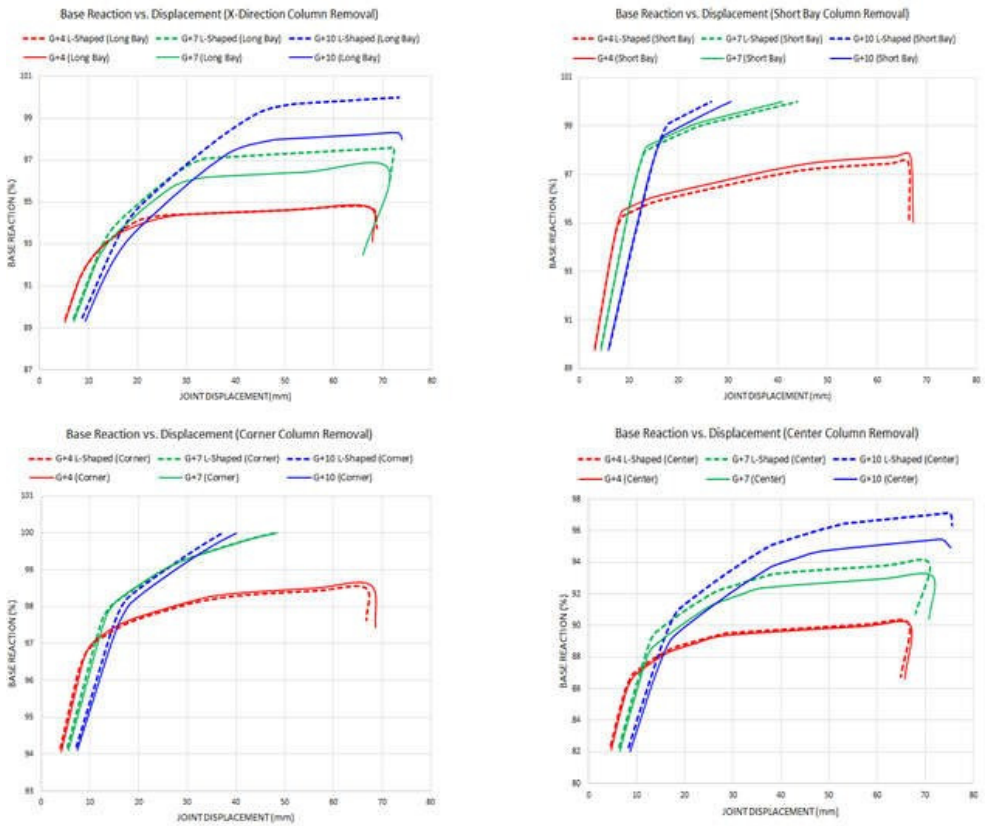


**Figure 4. Pushdown curve for Rectangular & L-shape Building (i) Long Bay Column Removal (ii) Short Bay Column Removal (iii) Corner Column Removal (iv) Center Column Removal**

## 4. Conclusion

In present study an attempt has been made on collapse assessment of reinforced concrete frame structure having the plan irregularity. The structure has been design & detail as per Indian codes and relevant clauses to address irregularity have been followed. Based on the study it can be conclude that, even if the structure having the irregularities as codify in the standards, and have been address properly than there will be not such noticeable difference on collapse resistance with respect to regular building. As the recommendations describe by the code to account for irregularities increase the strength of structural members which could help to resist the collapse loads.

## REFERENCES

***5.1. Book***

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