# STUDY OF SEISMIC BEHAVIOUR OF VERTICAL ASYMMETRIC MULTI-STORIED BUILDING

**Shantanu S. Magdum[1], Dr.P.S.Patil[2]**

*[1] Student, [2]Professer, Civil Department*
*Rajarambapu Institute of Technology, Islampur- 415414(India)*

**ABSTRACT**

*Seismic Behaviour of asymmetric building may cause interruption of force flow and stress concentration. Due to this, there is produce of torsion in the building which leads to increase in shear force, lateral deflection and ultimately causes failure. Asymmetry can be reason for a buildings poor performance under sever seismic loading. The building with vertical setbacks and L, H, U or T shaped in plans which built as unit are more affected during seismic event. There is horizontal torsional effect on each arm arising from the differential lateral displacement of two ends of each arm. In this paper, inelastic seismic behaviour of multistoried building with vertical setbacks are analyzed by IS code approach .The effect of torsion on building are analyzed. Designs of asymmetric multistoried building are studied. Study shows that there is increase in shear force due to torsion in column and increase in area of steel reinforcement in column particularly at the edge member of the building.*

***Keywords: Center Of Mass, Center Of Stiffness, Seismic Analysis, Shear Force, Torsion etc.***



## I. INTRODUCTION

### 1.1 General

To perform well in an earthquake, a building should possess four main attributes, mainly having simple and regular configuration, adequate lateral strength, stiffness and ductility. Buildings having simple regular geometry and uniformity distributed mass and stiffness in plan as well as in elevation, suffer much less damage than the irregular configuration. A building shall be considered as irregular as per IS 1893-2002, if it lacks symmetry and has discontinuity in geometry, mass or load resisting elements. These irregularities may cause problem in continuty of force flow and stress concentrations. Asymmetrical arrangement of mass and stiffness of elements have increase in shear forces on lateral force resisting elements resulting from the horizontal torsional moment arising due to eccentricity between centers of rigidity.

The study of dynamic torsional effects in buildings, particularly in multi-storey structures where this effect is more pronounced has been possible only with the recent development of programme for the dynamic analysis of three dimensional frame structures. Torsion occurs when the centre of mass does not coincide with the centre of rigidity in a story level. This can be a result of a lack of symmetry in the building plan or random disposition of live loads in an otherwise symmetrical structure. Torsion can also be included in symmetrical structures by the rotational components of ground motions.

Structural symmetry can be a major reason for buildings poor performance under severe seismic loading, asymmetry contributes significantly to the potential for translational-torsional coupling in the structures dynamic behaviour which can lead to increased lateral deflections, increased member forces and ultimately the buildings collapse.

Yielding in corner column or end shear wall in buildings due to torsional stresses tends to destroy the symmetry in an originally symmetrical building or increase the eccentricity in an unsymmetrical building, as the centre of resistance moves away from the yielding member. The increase in the eccentricity causes yielding to develop further. This tendency towards magnification of torsional effects by yielding in corner or at end elements suggests that such elements should be designed more conservatively than other member where torsional vibrations can be significant.

Horizontal twisting occurs in buildings when centre of mass and centre of rigidity do not coincide. The distance between these two is called eccentricity (e). Lateral force multiplied by this 'e' cause a' torsional moment which must be resisted by the structure in addition to the normal seismic force. Therefore, the Code stipulates that provision shall be made for increase in shear forces acting on particular elements resulting from the horizontal torsion due to an eccentricity between the centre of mass and the centre of rigidity. It is desirable to plan structural elements of the building in such a way that there is no eccentricity or the building is symmetrically planned with respect to the mass centre. However, it is very difficult to do so in practice and some provision has to be made for it.

Since there could be quite a bit of stiffness's of the variation in computed value of e, it is recommended by the Code that design eccentricity shall be 1.5 e. The net effect of this torsion is to increase shear in certain structural elements and reduction in certain others. The Code recommends that reduction in shear on account of torsion should not be applied and only increased shears in the elements be considered.

**Types of Irregularities:**

These irregularities are categorized as follows:

1. Vertical Irregularity
   a. Stiffness Irregularities – Soft Storey:
   b. Mass Irregularities:
   c. Vertical Geometric Irregularity
2. Horizontal/Plan Irregularity
3. Torsion Irregularities:
4. Re-entrant Corners:
5. Diaphragm. Discontinuity:

## 1.2 General terms

### 1.2.1 Centre of Mass (C.M)

According to IS: 1893-2002, centre of mass is the point through which resultant of the masses of a system acts. This point corresponds to centre of gravity of masses of system.

Earthquake induced lateral force on the floor is proportional to mass. Hence, resultant of this force passes through the centre of mass of the floor. Entre of the mass can be located by using method of statics. For floor having uniform distribution of mass, the C.M coincides with geometric centre of building. [7]

$$X=\frac{\sum Mi.Yi}{\sum Mi.} \qquad Y=\frac{\sum Mi.Xi}{\sum Mi.}$$

Where,

X, Y= Location of centre of mass

Mi = Lumped mass at $i^{th}$ floor

### 1.2.2 Centre of Stiffness or centre of rigidity (C.S):

According to IS1893-2002, centre of stiffness, for a one story building can be defined as the point on the floor through which lateral force should pass in order that floor undergoes only rigid body translation, with no rigid body rotation. In case of multi-story buildings, the concept of centre of stiffness is more complex. In general, for multi-story building C.S at each floor can be defined as-

a. A lateral load applied at that floor and passing through that point does not cause rotation of that floor (even though it may cause rotation of other floor).

b. Centre of stiffness of different floors of a building is obtained as these points at which the vertical seismic load profile should be applied such that none of floor undergoes any rotation. According to this definition of C.S, the location of C.S may depend on the vertical load profile for the building.

According to SP-22, the location of centre of stiffness is computed as follows- [7]

$$X_r=\frac{\sum Ky.X}{\sum Ky} \qquad Y_r=\frac{\sum Kx.Y}{\sum Kx.}$$

Where,

Xr and Yr = Location of centre of stiffness

X and Y = Distance of column line from centre of stiffness

Kx and Ky = Stiffness of the various elements in two directions respectively.

## II. MODELING

Data-

- Slab Thickness = 125 mm
- Size of Beam = 230 mm x 600 mm
- Size of Column = 350 mm x 350 mm
- Height of floor = 3m
- Live load on floors = 3 $kN/m^2$
- Floor Finish = 1.0 $kN/m^2$

- Grade of Concrete = 20 N/mm$^2$
- Grade of Steel = 415 N/mm$^2$
- EI = Constant
- Seismic zone = III
- Zone Factor (Z) = 0.16
- Importance Factor (I) = 1.0
- Response Reduction Factor (R) = 5.0
- Type of Soil = Medium
- Damping = 5%

### 2.1 Design of Members

Following loads have been considered for the design of the structure

Dead Load (DL)

Live Load (LL)

Earthquake Load (EQ)

- Load combinations:

  According to IS 1893:2002, following load combinations have been considered,

I. 1.5 DL + 1.5 LL

II. DL + 1.2 LL + 1.2 EQ

III. DL + 1.2 LL - 1.2 EQ

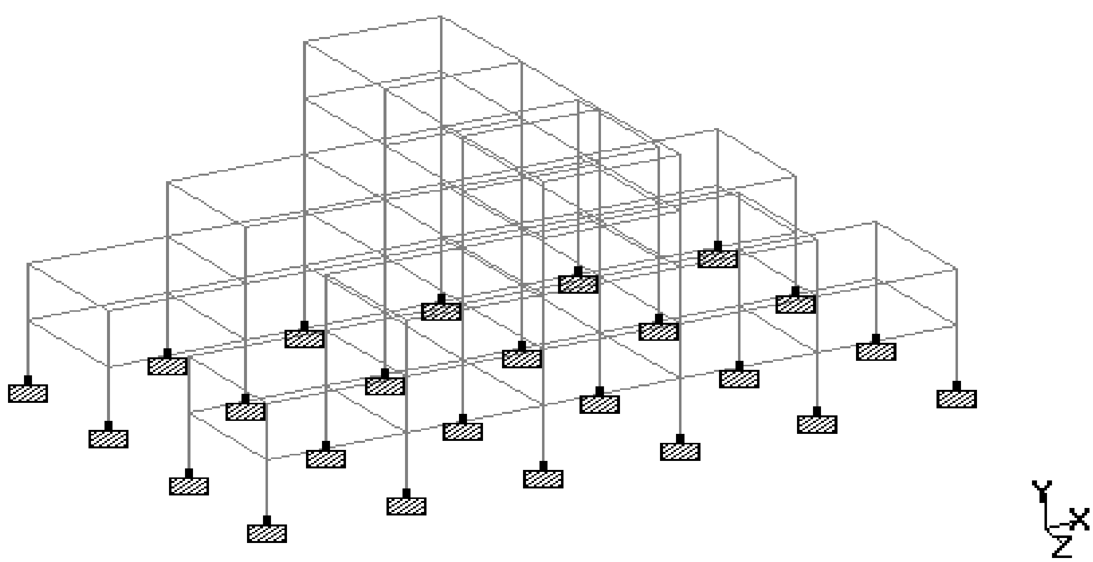


**Fig.1- Building Frame with Irregular Profile**

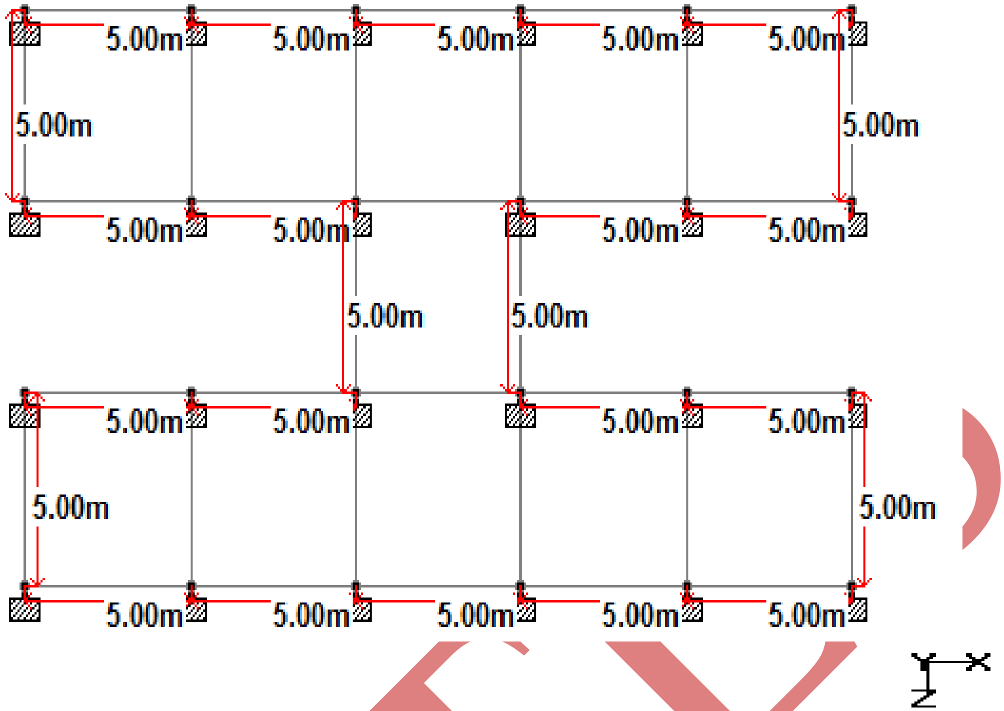


**Fig.2- Building Plan**

## III. RESULTS AND DISCUSSION

### 3.1 Comparative Results of Displacement -

**Table.1Comparative Results of Displacement without and With Considering Torsion.**

| NODE NO. | MAXIMUM DISPLACEMENT WITHOUT CONSIDERING TORSION (MM) | MAXIMUM DISPLACEMENT WITH CONSIDERING TORSION (MM) |
|---|---|---|
| 101 | 12.185 | 12.430 |
| 102 | 12.185 | 12.393 |
| 103 | 9.337 | 10.010 |
| 104 | 9.299 | 9.972 |

Comparative Results of maximum displacements in the building are studied in number Table.1, which shows that there is increase in the displacement due to torsion than that of without torsion and similarly Comparative Results of Shear force in column when earthquake force in X and Z direction are studied in Table.2, which shows that there is increase in the Shear force due to torsion than that of without torsion.

### 3.2 Comparative Results shear force in column

**Table.2 Comparative result of Shear in column without considering Torsion and Shear in column with considering Torsion (X and Z direction)**

| NODE NO. | EARTHQUAKE FORCE IN X DIRECTION | | EARTHQUAKE FORCE IN Z DIRECTION | |
|---|---|---|---|---|
| | SHEAR IN COLUMN WITHOUT TORSION(KN) | SHEAR IN COLUMN WITH TORSION (KN) | SHEAR IN COLUMN WITHOUT TORSION(KN) | SHEAR IN COLUMN WITH TORSION (KN) |
| 1 | 18.472 | 18.958 | 9.338 | 8.253 |
| 2 | 8.61 | 7.554 | 28.087 | 24.96 |
| 3 | 15.007 | 13.375 | 53.862 | 53.222 |
| 4 | 21.514 | 19.088 | 45.028 | 46.23 |
| 5 | 5.714 | 4.956 | 26.785 | 30.238 |
| 6 | 13.981 | 14.343 | 13.33 | 13.961 |
| 7 | 22.045 | 22.337 | 9.647 | 8.705 |
| 8 | 10.678 | 10.145 | 27.659 | 24.698 |
| 9 | 23.435 | 22.755 | 7.375 | 7.043 |
| 10 | 30.477 | 29.438 | 8.891 | 9.443 |
| 11 | 7.209 | 6.811 | 26.135 | 29.632 |
| 12 | 16.252 | 16.487 | 12.952 | 13.78 |
| 13 | 22.045 | 21.756 | 9.647 | 8.705 |
| 14 | 10.678 | 11.214 | 27.659 | 24.698 |
| 15 | 23.435 | 24.169 | 7.375 | 7.043 |
| 16 | 30.477 | 31.542 | 8.891 | 9.443 |
| 17 | 7.209 | 7.614 | 26.135 | 29.632 |
| 18 | 16.252 | 16.019 | 12.952 | 13.78 |
| 19 | 18.472 | 17.995 | 9.338 | 8.253 |
| 20 | 8.61 | 9.678 | 28.087 | 24.96 |
| 21 | 15.007 | 17.052 | 53.862 | 53.222 |
| 22 | 21.514 | 24.119 | 45.028 | 46.23 |
| 23 | 5.714 | 6.494 | 26.785 | 30.238 |
| 24 | 13.981 | 13.625 | 13.33 | 13.961 |

### 3.3 Comparative study of Column design when earthquake force in X-direction

**Table.3 Comparative Results of Column Design when Earthquake force in X–Direction.**

| COLUMN NO. | DESIGN OF COLUMN WITHOUT TORSION | | | DESIGN OF COLUMN WITH TORSION | | | VARIATION IN % OF STEEL |
|---|---|---|---|---|---|---|---|
| | $A_{st}$ ($mm^2$) | Main Rein. | Lateral Ties | $A_{st}$ ($mm^2$) | Main Rein. | Lateral Ties | |
| 48 | 1372 | 4-20 dia. | 8mm dia. @300mm c/c | 1405 | 12-12 dia. | 8mm dia. @300mm c/c | 2.41 |
| 54 | 1372 | 8-16 dia. | 8mm dia. @190mm c/c | 1448.50 | 12-16 dia. | 8mm dia. @190mm c/c | 5.58 |
| 106 | 1431.23 | 8-16 dia. | 8mm dia. @255mm c/c | 1490.73 | 8-16dia. | 8mm dia. @255mm c/c | 4.16 |
| 124 | 1488.76 | 8-16 dia. | 8mm dia. @190mm c/c | 1478.73 | 12-16 dia. | 8mm dia. @190mm c/c | 0.69 |
| 174 | 1561.71 | 8-16dia. | 8mm dia. @255mm c/c | 1583.81 | 8-16 dia. | 8mm dia. @255mm c/c | 1.41 |
| 178 | 1318.86 | 4-25 dia. | 8mm dia. @300mm c/c | 1380.47 | 20-12 dia. | 8mm dia. @190mm c/c | 4.67 |
| 228 | 1636.06 | 16-12dia. | 8mm dia. @190mm c/c | 1720.98 | 16-12dia. | 8mm dia. @190mm c/c | 5.19 |

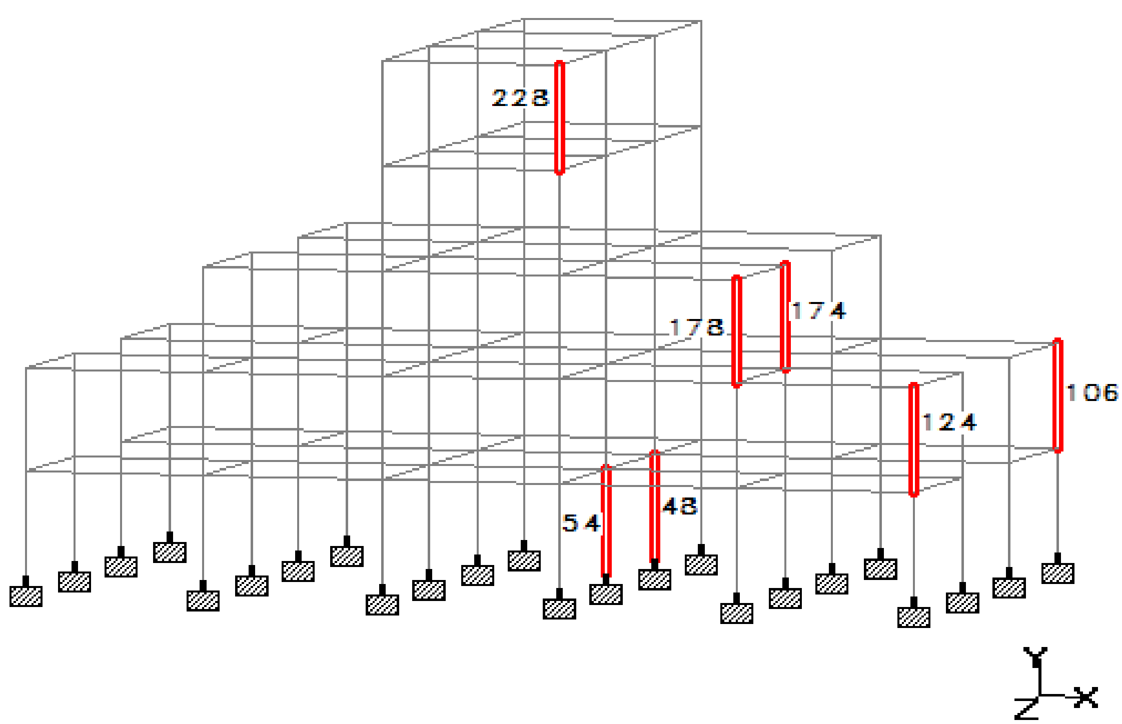


**Fig.3 - Column which are affected due to earthquake force in X- direction**.

### 3.4 Comparative study of Column design when earthquake force in Z-direction

**Table.3 Comparative Results of Column Design when Earthquake force in Z–Direction.**

| COLUMN NO. | DESIGN OF COLUMN WITHOUT TORSION | | | DESIGN OF COLUMN WITH TORSION | | | VARIATION IN % OF STEEL |
|---|---|---|---|---|---|---|---|
| | $A_{st}$ ($mm^2$) | Main Rein. | Lateral Ties | $A_{st}$ ($mm^2$) | Main Rein. | Lateral Ties | |
| 48 | 1470 | 8-16 dia. | 8mm dia. @255mm c/c | 1568 | 8-16 dia. | 8mm dia. @255mm c/c | 6.67 |
| 54 | 1470 | 8-16 dia. | 8mm dia. @255mm c/c | 1568 | 8-16 dia. | 8mm dia. @255mm c/c | 6.67 |
| 112 | 1371.26 | 8-16 dia. | 8mm dia. @255mm c/c | 1400 | 8-16dia. | 8mm dia. @255mm c/c | 2.09 |
| 124 | 1380.90 | 4-20 dia. | 8mm dia. @300mm c/c | 1498.32 | 8-16 dia. | 8mm dia. @255mm c/c | 8.50 |
| 170 | 1234.69 | 4-20 dia. | 8mm dia. @255mm c/c | 1303.52 | 12-12 dia. | 8mm dia. @190mm c/c | 5.57 |
| 178 | 1088.30 | 4-20 dia. | 8mm dia. @300mm c/c | 1172.38 | 4-20 dia. | 8mm dia. @300mm c/c | 7.73 |
| 206 | 1560.28 | 8-16- dia. | 8mm dia. @255mm c/c | 1670.99 | 8-16 dia. | 8mm dia. @255mm c/c | 7.09 |

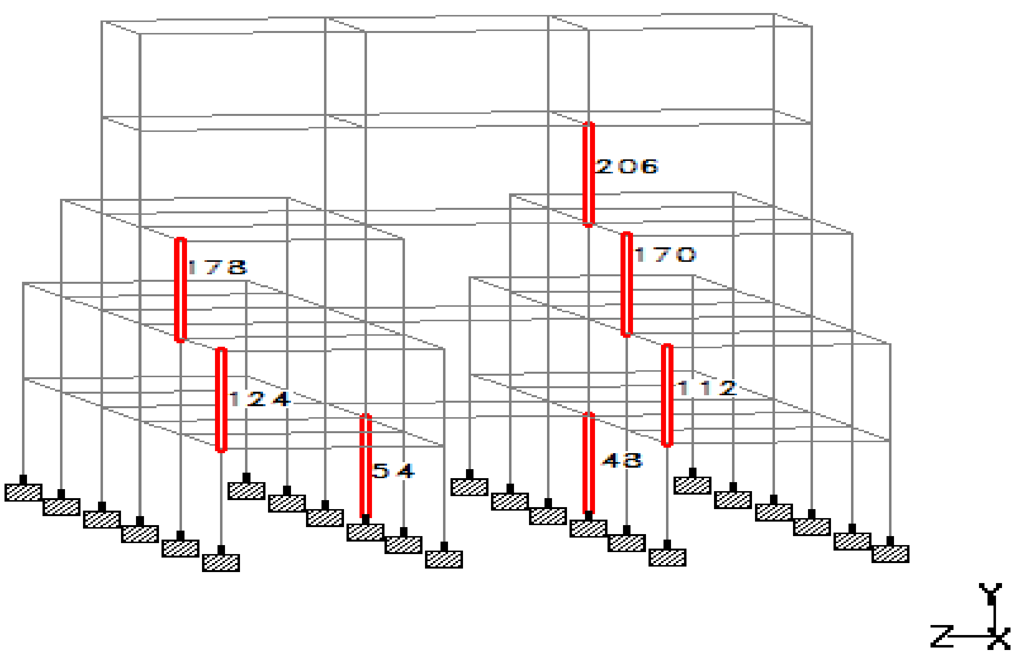


**Fig.4 - Column which are affected due to earthquake force in Z- direction.**

## IV. ACKNOWLEDGEMENTS

I would like to extend my deepest gratitude to my supervisor **Dr. P. S. Patil** for giving me the opportunity to do an M-Tech. at the Rajarambapu Institute of Technology, Rajaramnagar**.** I am greatly indebted to him for his continuing confidence in me as well as for giving me constant support throughout these years. It was a great experience to work with him and his valuable suggestions made me to have deep interest and knowledge of the topic. I have learnt many things from his rich academic and practical experience.

## V. CONCLUSION

The following Conclusions were made from this study.

1. Study shows that there is increase in shear force due to torsion produces in column by irregularity.
2. There is 4.53 % increase in the displacement due to torsion.
3. There is increase in steel reinforcement in some of the columns particularly at the corners due to asymmetry of building.
4. There is increase in reinforcement due to torsion when earthquake force in Z direction than Earthquake force in X direction.

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