Seismic Performance of Multi Storey RC Buildings with Horizontal
Irregularities

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Abstract— Multi storey reinforced concrete frame with horizontal irregularities are becoming common day by day. Site dimensions, architectural requirements and sometimes client requirements generally force the designer to adopt horizontal irregular buildings. In a city like Visakhapatnam which is highly vulnerable to wind forces, there is a need to study the effect of wind on horizontal irregular buildings. Although some literature available in this area. The conclusions are specific to a fixed wind speed and building height. Further the studies do not include the combined effect of wind and earth quake forces. The recent tremors in ad around Visakhapatnam there is a possibility that Visakhapatnam may be placed in earth quake zone-3 in near future. Hence this study aims at evaluating the performance of horizontal irregular buildings in earth quake zone -3 and earth quake zone -2 subjected to wind speeds ranging from 0-200 kmph. Here one regular building and 4 irregular buildings of same base area, same number of columns, and same spacing of columns are considered for this study.

Key words: Earthquakes, Multi Storey RC Buildings

I. INTRODUCTION

Earthquakes are the most unpredictable and devastating of all natural disasters, which are very difficult to save over engineering properties and life, against it. Hence in order to overcome these issues we need to identify the seismic performance of the built environment through the development of various analytical procedures, which ensure the structures to withstand during frequent minor earthquakes and produce enough caution whenever subjected to major earthquake events. So that can save as many lives as possible. There are several guidelines all over the world which has been repeatedly updating on this topic. The behaviour of a building during an earthquake depends on several factors, stiffness, and adequate lateral strength, and ductility, simple and regular configurations. The buildings with regular geometry and uniformly distributed mass and stiffness in plan as well as in elevation suffer much less damage compared to irregular configurations. But nowadays need and demand of the latest generation and growing population has made the architects or engineers inevitable towards planning of irregular configurations. Hence earthquake engineering has developed the key issues in understanding the role of building configurations.

A. Structural Irregularities

There are various types of irregularities in the buildings depending upon their location and scope, but mainly, they are divided into two groups—plan irregularities and vertical irregularities.

1) Vertical Irregularities
   - Stiffness Irregularity

2) Soft Storey
A soft storey is one in which the lateral stiffness is less than 70% of that in the storey above or less than 80% of the average lateral stiffness of the three storeys above.

3) Extreme Soft Storey
An extreme soft storey is one in which the lateral stiffness is less than 60% of that in the storey above or less than 70% of the average stiffness of the three storey’s above. For example, buildings on stilts will fall under this category.

4) Mass Irregularity
Mass irregularities are considered to exist where the effective mass of any storey is more than 150% of effective mass of an adjacent storey.

5) Vertical Geometric Irregularity
Geometric irregularity exists, when the horizontal dimension of the lateral force resisting system in any storey is more than 150% of that in an adjacent storey.

6) Discontinuity in capacity - Weak Storey
A weak storey is one in which the storey lateral strength is less than 80% of that in the storey above, the storey lateral strength is the total strength of all seismic force resisting elements sharing the storey shear in the considered direction.

7) In-Plane Discontinuity in Vertical Elements Resisting Lateral Force
An in-plane offset of the lateral force resisting elements greater than the length of those elements.

8) Plan irregularities

9) Torsion Irregularity
Torsional irregularity to be considered to exist when the maximum storey drift, computed with design eccentricity, at one end of the structures transverse to an axis is more than 1.2 times the average of the storey drifts at the two ends of the structure.

10) Re-entrant Corners
Plan configurations of a structure and its lateral force resisting system contain re-entrant corners, where both projections of the structure beyond the re-entrant corner are greater than 15 % of its plan dimension in the given direction.

11) Diaphragm Discontinuity
Diaphragms with abrupt discontinuities or variations in stiffness, including those having cut-out or open areas greater than 50 %of the gross enclosed diaphragm area, or changes in effective diaphragm Stiffness of more than 50 % from one storey to the next.

12) Out-of-Plane Offsets
Discontinuities in a lateral force resistance path, such as out-of-plane offsets of vertical elements.
13) Non-parallel Systems
The vertical elements resisting the lateral force are not parallel to or symmetric about the major orthogonal axes or the lateral force resisting elements

B. Objective of the Work
The main objective of this work is to reduce the Displacements, Shear Forces, Bending Moments, Axial Force, and Torsional Moment of the structure in the event of combined earth quake and wind load effects by considering different horizontal irregularities. By Evolution of response of the structure with various irregularities subjected to seismic loads and wind loads to identify the suitable horizontal irregularity structure for resisting selected seismic loads and wind loads; which give way in the reduction of human loss and property loss in the event of earth quake and wind loads.

C. Scope of the work
In this work 1 regular frame and 4 irregular frames which are un-symmetric in plan with same column numbers (27 columns), with same base area (1200Sft), which are subjected to wind loads like 50Kmph, 100Kmph, 150Kmph, 200Kmph and subjected to seismic loads such that these structures located in zone-2 and zone-3. Analysis has been done in STAAD Pro to find out the better and suitable irregular structure to these wind speeds and seismic loads by comparing various parameters between these 40 models.

Fig. 1: Regular model (R)  
Fig. 2: Irregular model (I-1)  
Fig. 3: Irregular model (I-2)  
Fig. 4: Irregular model (I-3)  
Fig. 5: Irregular model (I-4)

Totally 40 structures were modelled to analyse for different wind speeds and seismic zones to find out the better performance of horizontal irregularity

D. Description of the Model

<table>
<thead>
<tr>
<th>No of Stories</th>
<th>G+9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Storey Height</td>
<td>3m</td>
</tr>
<tr>
<td>Height of the Building</td>
<td>30 m</td>
</tr>
<tr>
<td>Type of Building</td>
<td>Residential</td>
</tr>
<tr>
<td>Wind load</td>
<td>50Kmph, 100Kmph, 150Kmph, 200Kmph</td>
</tr>
<tr>
<td>Earthquake zones</td>
<td>Zone-2, Zone-3</td>
</tr>
<tr>
<td>Live Load</td>
<td>4kN/m²</td>
</tr>
<tr>
<td>Grade of Concrete</td>
<td>M30</td>
</tr>
<tr>
<td>Grade of Steel</td>
<td>Fe415</td>
</tr>
<tr>
<td>Young’s modulus of M30 Grade Concrete</td>
<td>30 x 10⁶ kN/m²</td>
</tr>
<tr>
<td>Density of Reinforced Concrete</td>
<td>25 kN/m³</td>
</tr>
<tr>
<td>cross of the Beam</td>
<td>9¹¹ x 18¹¹</td>
</tr>
<tr>
<td>cross of the Column (1st-5 floors)</td>
<td>12¹¹ x 18¹¹</td>
</tr>
</tbody>
</table>

Table 1: Description of the Model

II. LITERATURE REVIEW
ASHVIN G. SONI, D. G. AGRAWAL, (2013) have opined that Earthquakes are the most unpredictable and devastating of all natural disasters, which are very difficult to save over engineering properties and life, against it. Hence in order to overcome these issues we need to identify the seismic performance of the built environment through the development of various analytical procedures, which ensure the structures to withstand during frequent minor earthquakes and produce enough caution whenever subjected to major earthquake events. So that can save as many lives as possible. The results are presented and discussed Considering the storey displacement, the frame with frame carries heavier loading on the top storey (frame-2) & frame has its 4th and 5th storeys soft (frame-5) is the weakest since it suffers the maximum displacement while the base frame exhibits the least displacement. As far as storey drift is concerned, frame-3 (with heavy loading on 4th and 7th storeys) is the weakest since it has the maximum storey drift which changes abruptly. Frame-4 & Frame-5 also shows similar pattern for bottom two storeys & middle storeys. In this paper, various frames with different irregularities, but with same dimensions have been analysed to study their behaviour when subjected to lateral loads.

Hirani Pravin, K.C. Koradia (2016) Said that the behaviour of a multi-storey framed building during strong earthquake motions depends on the distribution of stiffness, mass and strength in both the vertical and horizontal planes of the building. In multi-storeyed framed buildings, damage from earthquake ground motion generally occurs at locations of structural weaknesses present in the Reframes. These weaknesses may be created by discontinuities in stiffness, strength or mass between adjacent storeys. Such discontinuities between storeys are often associated with sudden variations in the frame geometry along the height. There are many examples of failure of buildings in past earthquakes due to such vertical discontinuities. On Study of Effect of Column Discontinuity on Behaviour of Structure Carried out Following Conclusions Is Derived: 1) Storey Displacement Increase in A Structure As Number Of Column Discontinuity Increase. 2) When Column Discontinuity Provided At A First Floor We Got A Maximum Displacement. 3) Storey Drift Is Also Increase In Structure As Column Discontinuity Increase. 4) Storey Drift Is In Structure At Which Floor Column Discontinuity Provided 5) Base Shear Decrease In Structure As Column Discontinuity Is Increase 6) From Nonlinear Analysis It Is Concluded That Failure Hinge Will Generated At Position of a Discontinuous Structural Member.

Dileshwar Rana, Juned Raheem (2015) Concluded that the performance of a multi-storey framed building during steady earthquake motions depends on the distribution of mass, stiffness, and strength in both the horizontal and vertical planes of the building. In multi-storeyed framed buildings, smash up from earthquake ground motion generally initiates at locations of structural weaknesses present in the lateral load resisting frames. In some cases, these weaknesses may be produced by...
discontinuities in stiffness, strength or mass between adjoining storeys. This study demonstrated that with the increase in number of bays the seismic performance of both regular and setback building improves. 5) The seismic performance of regular frame is found to be better than corresponding irregular frames in nearly all the cases. Therefore it should be constructed to minimize the seismic effects. Among setback frames, Type V1 building configuration is found superior than others.

Gowthami Satheesh, Suresh Babu. (2016) said that most iconic structures reduced to heaps of rubble, homes that collapsed, storefronts toppled over into the streets. These buildings were the earthquake's most deadly weapons. Earthquake don’t kill people building do” Many buildings in the present scenario have irregular configurations both in plan and elevation. This in future may subject to devastating earthquakes. In case, it is necessary to identify the performance of the structures to withstand against disaster for both new and existing one However, there is no general purpose computer programme which is able to account for the design eccentricity, because there is no direct method to compute the centre of Rigidity or Shear centre at each floor/storey of a building. This is the main reason as to why most designers adopt approximate methods for the torsional analysis of buildings. Some designers consider a torsional analysis to be a secondary analysis. However, this may be an inaccurate assessment. Several studies of structural damages during the past wind storms and earthquakes reveal that torsion is the most critical factor leading to major damage or complete collapse of buildings. It is, therefore, necessary that irregular buildings should be carefully analysed for torsion. Different irregularities are overviewed this overview method. Many literatures would have been studied that either any one problem will be solved. This will concentrated on a particular region. When 3D plan irregularities leads to study if the irregularity in X-direction and Z-direction and concentrates at the same time in Z-direction also. If irregularity in Y-direction which in account too Z-direction. Siva Bhanu Sai Kumar, Rama Rao and Markandeya Raju (2016) analysed the Seismic Fragility of Regular and Setback RCC Frames. Markandeya Raju (2015) studied the Effect of Column Spacing on Economy of G+5 RC Moment Resisting Frame using STAAD.Pro.

III. MODELLING OF STRUCTURE

(G+9) multistorey buildings with different plan irregularity structures have been modelled and designed for earthquake zones 2, 3 and wind loads ranging from 50kmph, 100kmph, 150kmph, 200kmph, dead load and live load using STAAD.Pro V.8i.The following procedure will shows the brief example of modelling the simple regular structure.

A. Assigning Loads

1) Wind Loads

Click on load and definitions ➔ definitions ➔ select wind definitions and click on add ➔ wind type definition dialog box opens click on add ➔ now click on wind 1 definitions, wind definitions dialog box opens ➔ click on calculate as per ASCE-7 ➔ enter basic wind speed as 50kmph and click on apply, add ➔ Give exposure as 1 ➔ now select exposure and click on assign to view

2) Seismic Loads

Now click on seismic definition say add ➔ seismic definitions dialog box will opens ➔ select code type as IS-1893-2002 and click on generate ➔ give self-weight factor as 1 ➔ now go to load case details click on add ➔ load cases dialog box will opens ➔ select loading type and give required file name as per our convenient and click on add ➔ now select seismic load and click on add ➔ load items dialog box will opens in that select seismic load give factor as 1 in X-direction and Z-direction and click on add ➔ now click on wind load ad add ➔ load items dialog box will opens and click on wind load ➔ select X-wind ward and Z-wind ward factor as 1 and click on add ➔

3) Dead and Live load

Now select dead load and click on add make assign to view ➔ select live load to open load items dialog box and click on floor load give pressure as -4kN/m² and give Y-range value as 30m, X-range value as 24m Z-range value as 18m ➔ click on add.

Fig. 6: seismic parameters for selecting zone

Fig. 7: Assigning wind load as 50kmph

Fig. 8: Wind Load in X And Z Direction
4) **Design**  
Click on design→concrete, select current code as IS-456→click on define parameters→select Fc, FY main, FY sec, Max main, Max sec, click on Track and select all these parameters to make assign to view→now click on commands→design command dialog box will open→click on design→design column, and take off→now click on design beam and select all the beams in the structure and make assign→click on design column and select all the columns in the structure and make assign→click on take off add.

5) **Analysis and Post Processing**  
Click on analysis / print option and click on all→go to analyse and run analysis→click on post processing→select all the loads and click on apply→here we can find out displacements, Shear force, bending moment, axial force, torsional moment etc to record the values as per our requirement.

Here onwards the same procedure will be repeated for remaining 39 models with change in earth quake zones and wind loads as well as plan irregularity. The result values will be recorded for comparing various with selected paramaeters to find out the better performance of irregular model.

### IV. RESULTS AND DISCUSSIONS

#### A. Displacement Earth Quake Zone-3, Wind Speed-50,100,150,200 (X)

![Fig. 9: Displacement Earth Quake Zone-3, Wind Speed-50,100,150,200 (X)]()

1) **Irregular - 1**
- 26% of displacement has been increased to the structure with Horizontal Irregularity -1 for earth quake zone-3 at wind speed 50Kmph.
- 26% of displacement has been increased to the structure with Horizontal Irregularity -1 for earth quake zone-3 at wind speed 100 Kmph.
- 23% of displacement has been increased to the structure with Horizontal Irregularity -1 for earth quake zone-3 at wind speed 150 Kmph.
- 23.3% of displacement has been increased to the structure with Horizontal Irregularity -1 for earth quake zone-3 at wind speed 200 Kmph.

2) **Irregular - 2**
- 60.8% of displacement has been decreased to the structure with Horizontal Irregularity -2 for earth quake zone-3 at wind speed 50Kmph.
- 60.8% of displacement has been decreased to the structure with Horizontal Irregularity -2 for earth quake zone-3 at wind speed 100 Kmph.

#### B. Shear Force (Earth Quake Zone-3, wind speeds 50,100,150,200)

![Fig. 10: Shear Force (Earth Quake Zone-3, wind speeds 50,100,150,200)]()

1) **Irregular - 1**
- 18.2% of Shear Force has been increased to the structure with Horizontal Irregularity -1 for earth quake zone-3 at wind speed 50Kmph.
- 18.2% of Shear Force has been increased to the structure with Horizontal Irregularity -1 for earth quake zone-3 at wind speed 100Kmph.
- 18.2% of Shear Force has been increased to the structure with Horizontal Irregularity -1 for earth quake zone-3 at wind speed 150Kmph.
- 24.3% of Shear Force has been increased to the structure with Horizontal Irregularity -1 for earth quake zone-3 at wind speed 200Kmph.
2) **Irregular - 2**
- 18.2% of Shear Force has been reduced to the structure with Horizontal Irregularity -2 for earth quake zone-3 at wind speed 50Kmph.
- 18.2% of Shear Force has been reduced to the structure with Horizontal Irregularity -2 for earth quake zone-3 at wind speed 100Kmph.
- 17% of Shear Force has been reduced to the structure with Horizontal Irregularity -2 for earth quake zone-3 at wind speed 150Kmph.
- 1.2% of Shear Force has been increased to the structure with Horizontal Irregularity -2 for earth quake zone-3 at wind speed 200Kmph.

3) **Irregular - 3**
- 6.09% of Shear Force has been increased to the structure with Horizontal Irregularity -3 for earth quake zone-3 at wind speed 50Kmph.
- 6.09% of Shear Force has been increased to the structure with Horizontal Irregularity -3 for earth quake zone-3 at wind speed 100Kmph.
- 6.09% of Shear Force has been increased to the structure with Horizontal Irregularity -3 for earth quake zone-3 at wind speed 150Kmph.
- 15.85% of Shear Force has been increased to the structure with Horizontal Irregularity -3 for earth quake zone-3 at wind speed 200Kmph.

4) **Irregular - 4**
- 19.5% of Shear Force has been increased to the structure with Horizontal Irregularity -4 for earth quake zone-3 at wind speed 50Kmph.
- 19.5% of Shear Force has been increased to the structure with Horizontal Irregularity -4 for earth quake zone-3 at wind speed 100Kmph.
- 21.9% of Shear Force has been increased to the structure with Horizontal Irregularity -4 for earth quake zone-3 at wind speed 150Kmph.
- 34.1% of Shear Force has been increased to the structure with Horizontal Irregularity -4 for earth quake zone-3 at wind speed 200Kmph.

C. **Bending moment (Earth Quake Zone-3, wind speeds 50,100,150,200)**

![Fig. 11: Bending moment (Earth Quake Zone-3, wind speeds 50,100,150,200)](image1)

1) **Irregular - 1**
- 5.45% of Bending Moment has been reduced to the structure with Horizontal Irregularity -1 for earth quake zone-3 at wind speed 50Kmph.
- 1% of Bending Moment has been reduced to the structure with Horizontal Irregularity -1 for earth quake zone-3 at wind speed 100Kmph.
- 19% of Bending Moment has been increased to the structure with Horizontal Irregularity -1 for earth quake zone-3 at wind speed 150Kmph.
- 104.4% of Bending Moment has been increased to the structure with Horizontal Irregularity -1 for earth quake zone-3 at wind speed 200Kmph.

2) **Irregular - 2**
- 15.4% of Bending Moment has been reduced to the structure with Horizontal Irregularity -2 for earth quake zone-3 at wind speed 50Kmph.
- 10% of Bending Moment has been reduced to the structure with Horizontal Irregularity -2 for earth quake zone-3 at wind speed 100Kmph.
- 6.36% of Bending Moment has been increased to the structure with Horizontal Irregularity -2 for earth quake zone-3 at wind speed 150Kmph.
- 46.4% of Bending Moment has been increased to the structure with Horizontal Irregularity -2 for earth quake zone-3 at wind speed 200Kmph.

3) **Irregular - 3**
- 10.9% of Bending Moment has been reduced to the structure with Horizontal Irregularity -3 for earth quake zone-3 at wind speed 50Kmph.
- 10.9% of Bending Moment has been reduced to the structure with Horizontal Irregularity -3 for earth quake zone-3 at wind speed 100Kmph.
- 19% of Bending Moment has been increased to the structure with Horizontal Irregularity -3 for earth quake zone-3 at wind speed 150Kmph.
- 108% of Bending Moment has been increased to the structure with Horizontal Irregularity -3 for earth quake zone-3 at wind speed 200Kmph.

4) **Irregular - 4**
- 1.8% of Bending Moment has been reduced to the structure with Horizontal Irregularity -4 for earth quake zone-3 at wind speed 50Kmph.
- 1% of Bending Moment has been reduced to the structure with Horizontal Irregularity -4 for earth quake zone-3 at wind speed 100Kmph.
- 36.3% of Bending Moment has been increased to the structure with Horizontal Irregularity -4 for earth quake zone-3 at wind speed 150Kmph.
- 66.9% of Bending Moment has been increased to the structure with Horizontal Irregularity -4 for earth quake zone-3 at wind speed 200Kmph.

D. **Steel quantity (Earth Quake Zone-3, wind speeds 50,100,150,200)**

![Fig. 12: Steel quantity (Earth Quake Zone-3, wind speeds 50,100,150,200)](image2)
1) Irregular - 1
- 6.6% of Steel quantity has been increased to the structure with Horizontal Irregularity -1 for earthquake zone-3 at wind speed 50Kmph.
- 6.6% of Steel quantity has been increased to the structure with Horizontal Irregularity -1 for earthquake zone-3 at wind speed 100Kmph.
- 6.4% of Steel quantity has been increased to the structure with Horizontal Irregularity -1 for earthquake zone-3 at wind speed 150Kmph.
- 12.9% of Steel quantity has been increased to the structure with Horizontal Irregularity -1 for earthquake zone-3 at wind speed 200Kmph.

2) Irregular - 2
- 3.3% of Steel quantity has been increased to the structure with Horizontal Irregularity -2 for earthquake zone-3 at wind speed 50Kmph.
- 3.3% of Steel quantity has been reduced to the structure with Horizontal Irregularity -2 for earthquake zone-3 at wind speed 100Kmph.
- 3.3% of Steel quantity has been reduced to the structure with Horizontal Irregularity -2 for earthquake zone-3 at wind speed 150Kmph.
- 6.4% of Steel quantity has been reduced to the structure with Horizontal Irregularity -2 for earthquake zone-3 at wind speed 200Kmph.

3) Irregular - 3
- 23.3% of Steel quantity has been increased to the structure with Horizontal Irregularity -3 for earthquake zone-3 at wind speed 50Kmph.
- 23.3% of Steel quantity has been increased to the structure with Horizontal Irregularity -3 for earthquake zone-3 at wind speed 100Kmph.
- 25.8% of Steel quantity has been increased to the structure with Horizontal Irregularity -3 for earthquake zone-3 at wind speed 150Kmph.
- 32.2% of Steel quantity has been increased to the structure with Horizontal Irregularity -3 for earthquake zone-3 at wind speed 200Kmph.

4) Irregular - 4
- 3.3% of Steel quantity has been increased to the structure with Horizontal Irregularity -4 for earthquake zone-3 at wind speed 50Kmph.
- 3.3% of Steel quantity has been increased to the structure with Horizontal Irregularity -4 for earthquake zone-3 at wind speed 100Kmph.
- 22.5% of Steel quantity has been increased to the structure with Horizontal Irregularity -4 for earthquake zone-3 at wind speed 150Kmph.
- 38.7% of Steel quantity has been increased to the structure with Horizontal Irregularity -4 for earthquake zone-3 at wind speed 200Kmph

V. CONCLUSIONS
Displacement in X direction has been reduced by 85.6%, displacement in Z-direction reduced by 31.5%, for earthquake zone 2 when compared with regular structure. In zone -3 displacement reduced by 76.7% in X-direction and 17.4% in Z-direction for Irregular-2 when compared with regular structure. Axial force has been reduced by 44% in earthquake zone-2 and zone-3 with the usage of irregular structure-3 when compared with regular structure. Shear force has been reduced by 18% in zone 2 and 3 with the usage of irregular structure-2 when compared with regular structure. Bending moment has been reduced by 9.1% in earthquake zone-2 and 15% in earthquake zone -3 for irregular structure-2 when compared with regular structure. Torsional moment has been reduced by 54% in earthquake zone-2 and zone-3 with the usage of irregular structure-2 when compared with regular structure. Concrete quantity has been increased by 1% in earthquake zone-2 and zone-3 with the usage of irregular structure-3 when compared with regular structure. Steel quantity has been reduced by 14.6% in earthquake zone-2 and zone-3 with the usage of irregular structure-2 when compared with regular structure.

There fore if the irregularity is mandatory to the client or designer than it will be better if they opt irregular-2 i.e rectangular plan, to reduce the percentage of various parameters which leads to safety of structure as well as people in the event of earth quakes or wind disasters like Hud-Hud.

A. Summary of Results
- With respect to displacement in X- directions I-2 (<85.6%) followed by I-1 (>25.7%), I-3 (<26%), I-4 (<5.8%) have shown better performance with respect to R in the event of earthquake zone-2 and wind loads ranging from 50kmph to 200kmph.
- With respect to displacement in Z- directions I-3 (<42.9%) followed by I-1 (>68.3%), I-2 (<31.5%), I-4 have shown better performance with respect to R in the event of earthquake zone-2 and wind loads ranging from 50kmph to 200kmph.
- With respect to displacement in X- directions I-2 (<76.7%) followed by I-1 (>23.8%), I-3 (<25.6%), I-4 (>66%) have shown better performance with respect to R in the event of earthquake zone-2 and wind loads ranging from 50kmph to 200kmph.
- With respect to displacement in Z- directions I-3 (<17.4%) followed by I-1 (>53%), I-2 (>22%), I-4 (<3%) have shown better performance with respect to R in the event of earthquake zone-3 and wind loads ranging from 50kmph to 200kmph.
- With respect to displacement in Z- directions I-3 (<18%) followed by I-1 (>53%), I-2 (>22%), I-4 (<3%) have shown better performance with respect to R in the event of earthquake zone-3 and wind loads ranging from 50kmph to 200kmph.
- With respect to Axial force I-3 (<43.21%) followed by I-1 (>18%), I-2 (>10%), I-4 (<19%) have shown better performance with respect to R in the event of earthquake zone-2 and wind loads ranging from 50kmph to 200kmph.
- With respect to Axial force I-3 (<44%) followed by I-1 (>18%), I-2 (>29%), I-4 (<19%) have shown better performance with respect to R in the event of earthquake zone-3 and wind loads ranging from 50kmph to 200kmph.
- With respect to shear force I-2 (<18%) followed by I-1 (>17%), I-3 (>6%), I-4 (>20%) have shown better performance with respect to R in the event of earthquake zone-2 and wind loads ranging from 50kmph to 200kmph.
- With respect to shear force I-2 (<18%) followed by I-1 (>18%), I-3 (>7.3%), I-4 (>21%) have shown better performance with respect to R in the event of earthquake zone-3 and wind loads ranging from 50kmph to 200kmph.
with respect to Torsional Force $I_2(<53.7\%)$ followed by $I_1(>25.9\%), I_3(<39.4\%), I_4(<7.9\%)$ have shown better performance with respect to $R$ in the event of earthquake zone-2 and wind loads ranging from 50kmph to 200kmph

- With respect to Torsional Force $I_2(<53.7\%)$ followed by $I_1(>25.9\%), I_3(<39.4\%), I_4(<7.9\%)$ have shown better performance with respect to $R$ in the event of earthquake zone-3 and wind loads ranging from 50kmph to 200kmph

REFERENCES


