Static Linear and Non-Linear (Pushover) Analysis of Multi Storey RC Frame with and without Vertical Irregularities

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Abstract—Earthquakes are most devastating natural hazards in terms of property loss and life of any region. The response of structure during earthquake greatly depends on size, geometry and shape of the structure. The Indian code IS-1893: 2002 (Part-I) has pointed out a variety of structural irregularities like plan irregularity and vertical irregularity. The study focuses on the seismic performance of G+6 storey regular and irregular Reinforced Concrete (RC) buildings. For this purpose, a finite element computer software ETABS (V. 9.7.1) has been used. The study as a whole makes an attempt to evaluate the impact of vertical irregularity on RC buildings in terms of static linear-Equivalent Static Lateral force Method (ESLM) and nonlinear analysis (PUSHOVER). Base shear, Lateral displacement, Storey drift and Performance points are the response parameters used to quantify the performance of the structure. The analysis has been carried out for zone II and zone V of India and soil type III (soft soil) condition. Based on the above response parameters, the results and conclusions are drawn.

Key words: Equivalent Static Lateral Force Method (ESLM), Pushover analysis, SMRF, OMRF etc

I. INTRODUCTION

Earthquake is a phenomenon related to violent shaking that takes place underneath the earth. Massive strain energy discharged at the time of an earthquake and travels as unstable waves called as seismic waves in every directions through the Earth’s layers, which refracting and reflecting at every interface. The destruction to structures because of earthquake depends on the stuff that the structure is formed out of, the sort of earthquake wave (motion) that is distressing the structure, and also the ground on that the structure is constructed. Therefore the dynamic loading which acts on the structure throughout an earthquake is not only external loading, but also inertial effect caused by motion of support. The different factor that causes damage to the structure throughout earthquake are mass irregularity, vertical irregularities, torsional irregularity, irregularity in strength and stiffness, etc. In multi-storied RC framed buildings, destruction from earthquake ground motion usually starts at locations of structural weaknesses there in buildings. In some of the cases, these weaknesses are also developed by discontinuities in stiffness, strength or mass between adjacent stories.

Over the past decades it has been recognized that destruction control has become a more specific design consideration which will also be carried out most effectively, by the way of introducing some kind of nonlinear analysis into the seismic design methodology. Following this pushover analysis has been developed during past years and has end up with the preferred method of analysis for performance-based seismic design (PBSD). It is the approach by which the ultimate strength and the limit state can be quite simply investigated after yielding, which has been researched and utilized in practice for earthquake engineering and seismic design.

II. IRREGULARITIES IN BUILDINGS

There are two types of building irregularities, they are
- Plan Irregularities.
- Vertical Irregularities.

In plan regular building there are of five types, they are
- Torsion Irregularity.
- Re-entrant Corners.
- Diaphragm Discontinuity.
- Out-of-Plane Offsets.
- Non-parallel Systems.

In vertical irregularity buildings there are also five types, they are
- Stiffness Irregularity.
  - Soft Storey.
  - Extreme Soft Storey.
- Mass Irregularity.
- Vertical Geometric Irregularity.
- In-Plane Discontinuity in Vertical Elements Resisting Lateral Force.
- Discontinuity in Capacity - Weak Storey.

III. OBJECTIVE OF THE WORK

The main objectives of this work includes the following.
1) To determine the response of 7 storey RC frame structure i.e., base shear and lateral displacement by Equivalent static lateral force method and performance point by pushover analysis. Modeling and analysis are achieved using ETABS a finite element software.
2) Equivalent static lateral force method is conducted for zone-II and zone-V according to IS 1893 2002 (Part 1) for soft soil type (type III).
3) All the six models are studied and analyzed using pushover analysis.

IV. PARAMETRIC STUDY

A reinforced concrete frame with 7(G+6) storey of dimension 19mx31m, has been taken for seismic analysis. Six building models with different types of irregularities are considered for comparison:
- Model-1: Regular building.
- Model-2: Stiffness (Soft storey) irregularity.
- Model-3: Mass irregularity.
- Model-4: Vertical geometric irregularity.
− Model-5: In-Plane Discontinuity in Vertical Elements Resisting Lateral Force.
− Model-6: Combination of all the above irregularities.
These six building models are analyzed for the following cases
− Using equivalent static lateral force method for zone-II and zone-V for soil type-III (soft soil) as per IS 1893(part 1):2002.
− Using Pushover analysis.

V. METHOD OF ANALYSIS
The study undertakes the following analysis
− Equivalent Static Lateral Force Method (ESLM).
− Pushover Analysis.

VI. DESCRIPTIONS OF BUILDING

<table>
<thead>
<tr>
<th>Description of building</th>
<th>Ordinary Moment Resisting Frame[OMRF] &amp; Special Moment Resisting Frame[SMRF]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Structure type</td>
<td>Plan dimension: 19x31m</td>
</tr>
<tr>
<td></td>
<td>Storey height: 3.5m</td>
</tr>
<tr>
<td></td>
<td>Height of building: G+6=7 storeys</td>
</tr>
<tr>
<td></td>
<td>Grade of concrete: M35(beams and slabs) &amp; M40 (columns)</td>
</tr>
<tr>
<td></td>
<td>Grade of steel: Fe500</td>
</tr>
<tr>
<td></td>
<td>Beam sizes: 500x850mm</td>
</tr>
<tr>
<td></td>
<td>column sizes: 600x1200mm</td>
</tr>
<tr>
<td></td>
<td>slab thickness: 150mm</td>
</tr>
<tr>
<td></td>
<td>Live load: 2.0kN/m²</td>
</tr>
<tr>
<td></td>
<td>Floor finish: 1.0kN/m²</td>
</tr>
<tr>
<td></td>
<td>Swimming pool load for mass and combination of irregular building: 10kN/m²</td>
</tr>
<tr>
<td></td>
<td>Zone factor: II and V</td>
</tr>
<tr>
<td></td>
<td>Soil type: Soft soil</td>
</tr>
<tr>
<td></td>
<td>Importance factor: 1</td>
</tr>
<tr>
<td></td>
<td>Response reduction factor: 3.0(OMRF) and 5.0(SMRF)</td>
</tr>
</tbody>
</table>

Table 1: Description

Figure 1: plan of regular building

![Fig 1: plan of regular building](image1)

![Fig 2: Elevation of stiffness irregular building](image2)

![Fig 3: Elevation of mass irregular building](image3)

![Fig 4: Elevation of vertical irregular building](image4)

![Fig 5: Elevation of in-plane discontinuity building](image5)

![Fig 6: Elevation of combination of irregular building](image6)

VII. RESULTS AND DISCUSSION

A. Base Shear

<table>
<thead>
<tr>
<th>MODELS</th>
<th>Base shear in kN</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>zone II</td>
</tr>
<tr>
<td></td>
<td>X-X</td>
</tr>
<tr>
<td>REGULAR</td>
<td>1572.82</td>
</tr>
</tbody>
</table>
Table 1: Base Shear of OMRF and SMRF building models in Zone-II and Zone-V along both x-x and y-y direction

Table 2: Lateral displacement of OMRF and SMRF building models in Zone-II and Zone-V along both x-x and y-y direction

C. Pushover Results

Fig 9: Capacity spectrum curve for regular building in zone II

Fig 10: Capacity spectrum curve for stiffness irregular building in zone II

Fig 11: Capacity spectrum curve for mass irregular building in zone II

Fig 12: Capacity spectrum curve for vertical geometric irregular building in zone II

Fig 13: Capacity spectrum curve for in-plane discontinuity irregular building in zone II
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Fig 13: Capacity spectrum curve for regular building in zone V

Fig 14: Capacity spectrum curve for combination of irregular building in zone II

Fig 15: Capacity spectrum curve for mass irregular building in zone V

Fig 16: Capacity spectrum curve for vertical geometric irregular building in zone V

Fig 17: Capacity spectrum curve for in-plane discontinuity irregular building in zone V

Fig 18: Capacity spectrum curve for combination of irregular building in zone V

D. Performance Point

<table>
<thead>
<tr>
<th>Performance point of base shear</th>
<th>Models</th>
<th>Zone II</th>
<th>Zone V</th>
</tr>
</thead>
<tbody>
<tr>
<td>REGULAR</td>
<td>10576.67</td>
<td>10712.06</td>
<td></td>
</tr>
<tr>
<td>STIFFNESS</td>
<td>10149.12</td>
<td>10279.11</td>
<td></td>
</tr>
<tr>
<td>MASS</td>
<td>10723.91</td>
<td>8436.621</td>
<td></td>
</tr>
<tr>
<td>VERTICAL</td>
<td>7973.329</td>
<td>8086.673</td>
<td></td>
</tr>
<tr>
<td>IN-PLANE</td>
<td>11309.64</td>
<td>11574.07</td>
<td></td>
</tr>
<tr>
<td>COMBI</td>
<td>9949.022</td>
<td>10389.48</td>
<td></td>
</tr>
</tbody>
</table>

Table 3: Comparison of base shear for all models in zone II and V
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(IJSRD/Vol. 3/Issue 06/2015/057)

VII. Discussion

- Base shear and displacement is more in mass irregular building for both zone II and V from ESLM analysis.
- Capacity spectrum curves are obtained from Pushover analysis and it is shown in above figs.
- At performance point base shear is more in in-plane discontinuity building and displacement is more in mass irregular building for both zone II and zone V.

Table 4: Comparison of displacement for all models in zone II and V

<table>
<thead>
<tr>
<th>Models</th>
<th>Zone II</th>
<th>Zone V</th>
</tr>
</thead>
<tbody>
<tr>
<td>REGULAR</td>
<td>69</td>
<td>69</td>
</tr>
<tr>
<td>STIFFNESS</td>
<td>76</td>
<td>76</td>
</tr>
<tr>
<td>MASS</td>
<td>82</td>
<td>95</td>
</tr>
<tr>
<td>VERTICAL</td>
<td>59</td>
<td>58</td>
</tr>
<tr>
<td>IN-PLANE</td>
<td>62</td>
<td>60</td>
</tr>
<tr>
<td>COMBI</td>
<td>64</td>
<td>60</td>
</tr>
</tbody>
</table>

Fig 19: Comparison of base shear for all models in zone II and V

Fig 20: Comparison of displacement for all models in zone II and V

VIII. Conclusions and Future Scope

A. Conclusions

1) Maximum base shear occurs in the mass irregularity building when compared to other models because of heavy mass are provided in mass irregularity building along X-X and Y-Y direction considering zone II and zone V.

2) Maximum lateral displacement is obtained mass irregular building and less in vertical geometric irregularity building shows less displacement. Hence vertical irregularity building shows better performance in zone II and zone V.

3) Performance point of base shear is more in in-plane discontinuity building when compared to all models both zone II and zone V.

4) Performance point of displacement is more in mass irregular building and less in vertical geometrical buildings when compared to other models in both zone II and zone V.

B. Future Scope

- Similar studies can be carried out for lateral load resisting systems like masonry infill and bracings.
- In the present study fixed base is considered for the structure, further study can be carried out for using soil structure interaction.

REFERENCES


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Codes:

