Comparative Study of Seismic Analysis of RC Building in Vertical Mass Irregularities

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Abstract: In this research paper, we studied about the mass irregularities in the RC building; here we created three models, in which heavy mass is provided at the storey-05 (model-1), at storey-10 (model-2), and storey-15 (model-3). These three models are analyzed with the help of the Etabs software by using the Indian Standard Code 1893-part-1:2016. According to the Indian Standard code 1893 part-1:2016, from the clause number 7.1, the mass irregularities will be considered when the seismic weight of the floor should be exceeded than 150% to above or below the floor. The method is used for analyzing these three models is Time History method and data for this methods is “ElCENTRO”, after completion of the analysis of these model, we will compare the result based on the seismic parameter such as base shear, maximum storey displacement, storey stiffness, natural period, and storey overturning moment. After comparing the result, we will conclude that which model is more stable as compared to other models.

Key Word: Mass irregularities, RC building, Asymmetrical, Dynamic Analysis, Etabs, Time History Analysis

1. INTRODUCTION
Nowadays the construction of the asymmetrical building increasing day by day because most of the hotel building have different height of the floor, re-entrant corner, heavy mass on some floor, etc. The mass irregularities have taken in the building when we assume to provide the water tank or swimming pool. In the past, several major earthquakes have exposed the shortcomings in buildings, which lead to damage or collapse. It has been found that regular-shaped buildings perform better during earthquakes. The structural irregularities cause non-uniform load distribution in various members of a building. There must be a continuous path for these inertial forces to be carried from the ground to the building weight locations. A gap in this transmission path fails the structure at that location.

1.1. Mass Irregularities
According to the IS Code 1893 part-1:2016, from the clause number 7.1, the mass irregularities will be considered on the building when the seismic weight of the floor is 150% exceed than the top or below the floor concerning that floor and the structure should exist in the seismic zone 3rd, 4th and 5th. The figure of the mass irregularities on the building is given below:

![Figure-1: Mass Irregularities](image)

2. METHODOLOGY
In the methodology, we will study the method which is used for the analysis, software, IS code, load combination, details of the model, etc.

2.1. Etabs
Etabs is a software, which created by CSI company. The innovative and revolutionary new ETABS is the ultimate integrated software package for the structural analysis and design of buildings. Incorporating 40 years of continuous research and development, this latest ETABS offers unmatched 3D object based modeling and visualization tools, blazingly fast linear and nonlinear analytical power, sophisticated and comprehensive design capabilities for a wide range of materials, and insightful graphic displays, reports, and schematic drawings that allow users to quickly and easily decipher and understand analysis and design results.

2.2. Time History Analysis
The method is used for the analysis in this paper is Time History Analysis. According to the Indian standard code 1893 part-1:2016, from the clause number 7.7.4, the time history is defined as the method shall be based on the appropriate ground motion and shall be performed using the accepted principles of earthquake structural dynamics. The data of the time history is taken as “EL CENTRO”.

© 2020 IJRAR August 2020, Volume 7, Issue 3 www.ijrar.org (E-ISSN 2348-1269, P-ISSN 2349-5138)
2.3. Indian Standard Code
In this paper, we used some Indian standard code for taking the value of the unit weight of the material, live load and seismic parameter. Here we used IS code 875 part 1 used for taking the unit weight of the RCC work, rebar, etc, and 875 part 2 for live load for the structure, and 1893 part 1:2016 for the seismic parameter based on the models.

2.4. Load Combination
In the analysis of these three models, we took as automatically load combination. It is easily created on the basis on the defined load and IS code.

2.5. Details of the Model
In this topic, we studied the models such as type of material used, load on the structure, seismic parameter which was considered, etc.

2.5.1. Material Parameter
In these three models, we used concrete of M25 grade for the beam, column and slab, and M30 for the heavy mass on the slab. The details of the material which are used in these model given below in the form of the table:

<table>
<thead>
<tr>
<th>S.No</th>
<th>Material</th>
<th>Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Concrete</td>
<td>M25 and M30</td>
</tr>
<tr>
<td>2.</td>
<td>Longitudinal reinforcement</td>
<td>Fe415</td>
</tr>
<tr>
<td>3.</td>
<td>Transverse reinforcement</td>
<td>Fe250</td>
</tr>
</tbody>
</table>

2.5.2. Building Parameter
In this topic, we gave the details about the building geometry such as the size of the beam, column and slab, etc. These data are given below in the form of the table:

<table>
<thead>
<tr>
<th>S.No</th>
<th>Building Parameter</th>
<th>Dimension</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Beam</td>
<td>350 mm wide and 450 mm depth</td>
</tr>
<tr>
<td>2.</td>
<td>Column</td>
<td>400 mm wide and 500 mm depth</td>
</tr>
<tr>
<td>3.</td>
<td>Slab</td>
<td>150 mm thickness</td>
</tr>
<tr>
<td>4.</td>
<td>Heavy mass</td>
<td>300 mm</td>
</tr>
<tr>
<td>5.</td>
<td>Height of ground floor</td>
<td>3.5 meter</td>
</tr>
<tr>
<td>6.</td>
<td>The total height of the building</td>
<td>45.5 meter</td>
</tr>
<tr>
<td>7.</td>
<td>Plan area of the building</td>
<td>27 m X 27 m</td>
</tr>
<tr>
<td>8.</td>
<td>The span of the beam</td>
<td>3 meter</td>
</tr>
</tbody>
</table>

2.5.3. Load Parameter
In the models, we applied the load on the structure such as live load, dead load, seismic load and other. The numerical value of the load is given below in the form of the table which was used on the models:

<table>
<thead>
<tr>
<th>S.No</th>
<th>Load Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Live load</td>
<td>3 KN/m2</td>
</tr>
<tr>
<td>2.</td>
<td>Partition wall</td>
<td>7 KN/m</td>
</tr>
<tr>
<td>3.</td>
<td>Load Bearing Wall</td>
<td>14 KN/m</td>
</tr>
<tr>
<td>4.</td>
<td>EX</td>
<td>Seismic Force in X-direction</td>
</tr>
<tr>
<td>5.</td>
<td>EY</td>
<td>Seismic Force in Y-direction</td>
</tr>
</tbody>
</table>

2.5.4. Seismic Parameter
These models are analyzed with the help of the seismic analysis, for the seismic analysis we need some seismic parameter and IS code based on which we analyzed the models and compare the result.

<table>
<thead>
<tr>
<th>S.No</th>
<th>Seismic Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Importance factor</td>
<td>1.2</td>
</tr>
<tr>
<td>2.</td>
<td>Seismic Zone</td>
<td>0.24</td>
</tr>
<tr>
<td>3.</td>
<td>Response Reduction factor</td>
<td>5</td>
</tr>
<tr>
<td>4.</td>
<td>Soil Type</td>
<td>2</td>
</tr>
<tr>
<td>5.</td>
<td>IS Code</td>
<td>1893 part-1:2016</td>
</tr>
<tr>
<td>6.</td>
<td>Time History Data</td>
<td>EL CENTRO</td>
</tr>
</tbody>
</table>
2.6. View of the Model
The plan, elevation, and 3D view of these three models is the same. There is only one difference that heavy mass is placed on a different floor. In the model-01, we placed the heavy mass at storey-5, and in model-02 the heavy mass is placed at the storey and model-01 the heavy mass is placed at the storey-15.

2.6.1. Plan, Elevation and 3D View of Model-01

![Figure 2: Plan and Elevation of Model-1](image1)

![Figure 3: 3D View of Model-1](image2)

In the model-1, the heavy mass is placed at the storey-5.
2.6.2. Plan, Elevation and 3D View of Model-02

In the model-2, the heavy mass is placed at the storey-10

2.6.3. Plan, Elevation and 3D View of Model-03

Figure-4: Plan and Elevation of Model-2

Figure-5: 3D View of Model-2

Figure-6: Plan and Elevation of Model-3
In the model-3, the heavy mass is placed at the storey-15.

3. ANALYSIS AND RESULT
In this topic, we studied about the result which comes out after the analysis of these three models. Here we selected some important parameter based on which we will compare the result:

1. Base Shear
2. Natural Period
3. Maximum Storey Displacement
4. Storey Stiffness
5. Storey Overturning Moment

3.1. Base Shear
From the clause 7.2.1 in Indian Standard code 1893 part-1: 2016, the base shear is defined as the lateral forces which act at every floor due to seismic effect on the structure. The following graph represents the base shear of all models in the X direction due to applying the seismic effect in EX direction:

![Chart-1: Base Shear Due to EX](image)

From the above graph of the base shear, we can analyze that the value of the base shear of the model-03 where the heavy mass is placed at the storey-15 is maximum as compared to other models (model-1 and model-2).

3.2. Natural Period
From clause 3.18 the natural period in the mode of oscillation is defined as the time (in second) taken by structure to complete one cycle of the oscillation in its natural mode of oscillation. The following graph represents the variation of the natural period:
From the above graph of the natural periods, the numerical value of the base shear of the model-03 is maximum as compared to other models.

3.3. Maximum Storey Displacement

Maximum storey displacement is defined as the maximum displacement of the floor from the ground surface due to lateral force which acts at the structure. The value of the maximum storey displacement does not measure concerning floor level. The graph of displacement of all models is given below due to load case EX:

From the above graph of the maximum storey displacement due to load case EX, the numerical value of model-1 and mode-3 is almost the same but increase at the storey-15.
3.4. Storey Stiffness

Storey stiffness is defined as the ratio of the storey shear to the storey drift of the structure. The value of the storey stiffness is given due to load case EX1, and the graph of the storey stiffness of all models is given below:

![Chart 4: Storey Stiffness](chart4.png)

From the above graph of the storey stiffness, we can see that the sudden variation take place at that storey of the building where the heavy mass is placed.

3.5. Storey Overturning Moment

The storey overturning moment is defined as the moment which is produced due to applying the lateral load at each floor of the structure, the multiplication of the lateral load or base shear into the height of the floor concerning the ground surface is converted into the overturning moment. The graph the storey overturning moment of these models is given below at the load case EX:

![Chart 5: Storey Overturning Moment Due to EX](chart5.png)

From the above graph of the storey overturning moment due to load case EX, the minimum value of the overturning moment is low in the model-2 as compared to the other models.
4. CONCLUSION

After analyzing these models in the mass irregularities with the help of the time history method, the following conclusion out:

1. According to the Indian Standard Code 1893 part-1: 2016, the seismic weight of the floor should be more than 150% concerning above or ground floor and structure should exist in the seismic zone 3rd, 4th or 5th. In the model-01 we provide the heavy mass at storey-5, where the base shear is 220% as compared to storey-4, in the model-2 the base shear 178% more as compared to storey-9, and in model-3 the base shear is 151% more than storey-14. From these three models, the value of the base shear in the model-2 is low as compared to the other models.

2. According to the Indian Standard 1893 part-1, the value of the maximum storey displacement should not be exceeding than H/250, where H is the total height of the building. Where the total height of the building is 45500 mm so 45500/250= 182mm. With reference from the graph of the maximum storey displacement due to EX-load case is 32.046 mm in the model-3 where the heavy mass is placed at the storey-15. The variation of the maximum storey displacement depends upon the position of the heavy mass either it is at the top or bottom of the building. The model-02 has low storey displacement as compared to other models.

3. According to the Earthquake tips of the Indian Institute of Technology Kanpur, the numerical value of the natural period of the building which has storey-1 to storey-20 should be existing between the 0.05 second to 2.00 second. Concerning this value, we can see that these models are safe in the natural period. The numerical value of the natural period in the model-3 is about 3.18% and 31.7% as compared to model-1 and model-2 respectively. When the heavy mass is placed at the top storey of the building then the value of the natural period gets an increase. The better ways to place the heavy mass at the mid height of the building.

4. The simple way to understand the value of the overturning moment, we should need the concept of the cantilever beam at a different position. In the model-1, the height of the floor where heavy mass is placed is at the 15.5 m so overturning moment is low as compared as model-3. The maximum value for the storey overturning moment in the model-03 and minimum value of the overturning moment in the model-2.

5. According to the Indian standard code 1893 part-1, the storey stiffness is defined as the ratio of the base shear to the storey drift of the model. Concerning the graph of the storey stiffness, the value of the storey stiffness of the model-3 is maximum and minimum for the model-2.

6. From the above conclusion, we can say that the model-2 is more stable as compared to another model because when the heavy mass is placed at the mid-height of the building then its balance the structure.

REFERENCES