THE RESPONSE SPECTRUM ANALYSIS OF MULTISTOREYED BUILDING BY STAADPRO SOFTWARE

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Abstract: A Reinforced Cement Concrete framed structure is a formation of multiple building components such as slabs, beams, columns, and foundations into a single unit. In this type of structure, the transfer of weight occurs sequentially; the beams receive a load from the slabs, then beams give it to the columns, then received it to the lower columns, and ultimately to the foundation. The foundation then transfers the load to the soil. The analysis outputs are applied to validate the structure's accuracy for future use. Nowadays, all types of forces can be calculated by using analysis software. The principal objective of this project is "The Response Spectrum Analysis of Multi-storeyed Commercial Building (G+7) by STAADPRO Software". To design the structure, designers highly recommended the STAADPRO software. In this project, to develop the economic design of the G+7 building through response spectrum analysis Staadpro software is used. Staadpro is the leading design software in present days used by many structural designers. According to the design of IS: 1893 (Part III) seismic design is used to perform the analysis of this structure. The results observed that the multi-storeyed buildings are stiff for earthquake excitation as modal participation.

Index Terms - RCC, Staadpro, G+7 Storey, Software, Analysis.

I. INTRODUCTION
An earthquake can vary in magnitude, ranging from imperceptible tremors to violent events capable of launching objects and people into the air, causing widespread devastation in cities. Seismicity, or the seismic activity of a region, is determined by the frequency, type, and size of earthquakes experienced over time. With rapid urbanization leading to the construction of numerous multi-storeyed buildings, many existing reinforced concrete (RC) structures in seismic zones are ill-equipped to withstand earthquakes. A significant portion of India is susceptible to high levels of seismic hazards, highlighting the importance of seismic safety in building design, especially for high-rise structures. Seismic loads must be carefully accounted for during the design process to accurately assess the behavior of structures. Past major earthquakes have exposed the shortcomings of buildings, resulting in damage or collapse. Research has shown that buildings with regular shapes tend to perform better during earthquakes. As earthquakes cause the ground to vibrate, structures supported on the ground experience induced motion and inertia forces. Therefore, analyzing and designing structures according to the Indian seismic code IS 1893 (Part 1) 2002 is crucial. The objective is to design buildings that can withstand earthquakes with an acceptable level of damage without collapsing and impacting lives and livelihoods. Response spectrum analysis, which considers the interaction between ground acceleration and the structural system based on multiple ground motion records, is employed. The design spectrum of IS 1893 (Part 1): 2002 is used for seismic analysis, and the building model is analyzed using STAADPRO software. The lateral loads generated by STAADPRO correspond to seismic zone III and the 5% damped response spectrum specified in IS 1893 (Part 1): 2002.
II. RESEARCH METHODOLOGY

The first stage in the structural design process involves the design of the building structure using specialized software such as ETABS and STAADPRO. In this research, a symmetrical plan for a 7-story reinforced concrete structure is being considered. The design process follows the guidelines provided by the IS1893-2002, Part-1 code for Zone II, which governs earthquake loads. Dynamic analyses are conducted using the response spectrum method, with a damping ratio of 3% and scale factors as specified in the IS code. The material properties are assumed to be linear static, and response spectrum analysis is performed.

2.1 Model Generation:
To create an accurate representation of the building structure, the model is generated using one of three methods: the snap node method, the coordinate method, or copy-paste method. In this research, the copy-paste method is used, as it is the most commonly employed technique for creating structures of any geometry.

2.2 Modeling the Building:
The objective of the model design is to faithfully capture the characteristics of high-rise buildings. Several buildings with the same floor plan dimensions but varying numbers of stories (in this case, 7 stories) are considered for the study. The floor plans are divided into six by four bays, with a center-to-center distance of 3 meters by 3 meters. The height of each floor is assumed to be 3 meters, while the plinth height is 5 meters above the foundation base.

2.3 Assigning Property:
To accurately represent the structural elements, such as beams, columns, and slabs, property dimensions such as width and thickness are assigned using the Property page in the software's toolbar.

2.4 Supports:
There are three types of supports provided to a structure: fixed support, pinned support, and roller support. In the software, options for pinned and fixed supports are available, while roller support can be created by releasing the Fx and Mz components using fixed support.

2.5 Assigning Loads:
The structure is subjected to two main types of loads: dead load and live load. The dead load includes the self-weight of the structure, while the live load consists of superimposed loads. Additionally, wind and seismic forces are taken into account. Definitions for wind and seismic loads are provided, and various load cases are assigned to the structure. These load cases should be entered after the necessary definitions have been provided.

By following this procedure, the structural design process is carried out, ensuring an accurate representation of the high-rise building. The resulting model and analysis can be used to study the behavior and response of the structure under various loads, providing valuable insights for the design and safety assessment of similar structures.
Figure 3. Assigning Columns

Figure 4. Assigning Beams

Figure 5. Assigning Plate

Figure 6. Assigning Fixed Supports

Figure 7. Response Spectrum Analysis

Figure 8. Shear Force Diagram
III. RESULT
The response spectrum analysis in STAAD.Pro yielded the following natural frequencies and corresponding mode shapes for Load Case.

<table>
<thead>
<tr>
<th>MODE</th>
<th>FREQUENCY (CYCLES/SEC)</th>
<th>PERIOD (SEC)</th>
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<td>1.162</td>
<td>0.86061</td>
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<tr>
<td>2</td>
<td>1.239</td>
<td>0.80726</td>
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<tr>
<td>3</td>
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<td>0.78621</td>
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<tr>
<td>4</td>
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<td>0.27374</td>
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<tr>
<td>5</td>
<td>3.902</td>
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<td>6</td>
<td>3.921</td>
<td>0.25504</td>
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Table No.1 Natural Frequencies

Table No.2 Peak storey shear calculation

<table>
<thead>
<tr>
<th>STORY</th>
<th>LEVEL IN METRE</th>
<th>PEAK STORY SHEAR IN KN</th>
</tr>
</thead>
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<tr>
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<td></td>
<td></td>
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<tr>
<td>7</td>
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<td>5268.27</td>
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<td>15206.77</td>
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<tr>
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<td>18735.38</td>
</tr>
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<tr>
<td>BASE</td>
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<td>24392.97</td>
</tr>
</tbody>
</table>
IV. VALIDATION

Peak storey shear calculation

To calculate base shear, we have considered the following data:
Type of structure- High rise RCC frame structure
Occupancy- office building
Number of storeys-7 Intermediate storey height-3m
Type of soil- medium soil
Length of Building- 18m
Height of Building-24m
No. of bays along the length- 6
No. of bays along width - 4
Column Size-0.50m × 0.50m
Beam Size-0.35m × 0.35m
Slab Thickness-0.125 m
Dead Load-1 kN/m²
Live Load-3.125 kN/m²
Zone Factor-V (Z=0.36)
Damping Ratio-0.5%

Table No.3 Base shear calculation

<table>
<thead>
<tr>
<th>STORY</th>
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<th>PEAK STOREY SHEAR IN KN</th>
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</table>

Figure 9. Plan of building
Wall Thickness= 0.23 m
Design life= 50 years
Base Shear= \( V_b = W \times A_h \)
Where \( W = \) Seismic Weight of building
\( A_h = Z/2 \times I/R \times S_a/g \)

**To calculate \( W \): Dead load + Live Load (Slab+Beams+Columns+Wall)**

1. **Slab:** Dead Load= Area*Density*thickness
   \[ = (18 \times 12) \times 25 \times 0.25 \]
   \[ = 675 \text{ kN} \]

   Therefore, Total DL for roof slab=675+86.4=761.4 kN

2. **Beams:**
   - **Size of beam=0.35m*0.35m**
   - **Self-weight of beam=0.35*0.35*1(per unit length) *25**
   \[ = 3.0625 \text{ kN/m} \]

   Length of beam:
   - **Transverse beam:**
     - Length of transverse beam=3-(0.25)2=2.9375m
   - **Length of longitudinal beam:**
     - Length of longitudinal beam=3(0.25)2=2.9375m

   There are 28 beams in the transverse direction and 30 beams in the longitudinal direction. Therefore, the length of the beam along the transverse direction = 28*2.9375=82.25 m

   Similarly, the length of the beam along longitudinal direction=30*2.9375=87.9m

   Therefore, self-weight of transverse beam=82.25*3.0625=251.89 kN.

   Similarly, the length of the beam along longitudinal direction=30*2.9375=87.9m

   Therefore, self-weight of longitudinal beams=87.9*3.0625=269.19 kN.

   So, the total self-weight of beam=251.89+269.19=521.08 kN

3. **Wall:**
   - **Self-weight= Thickness*Density*1 (Considering unit height)**
   \[ = 0.23 \times 20 \times 1 \]

   Length of a wall along the transverse and longitudinal directions.

   **For transverse direction:**
   - **For one wall:**3-(0.25)2=2.9375m
   - **For total wall:**2.9375*28=82.25m

   Therefore, self-weight of transverse wall=4.6*82.25=378.35 kN/m for per meter height

   **For Longitudinal direction:**
   - **For one wall:**3-(0.25)2=2.9375m
   - **For total wall:**2.9375*30=88.125m

   Therefore, the self-weight of the longitudinal wall=4.6*88.125=405.375 kN/m per meter height.

4. **Columns:**
   - **Self-weight= Size of column* Density * No. of columns**
   \[ = 0.50 \times 0.50 \times 25 \times 35 \]

   Therefore, the load=218.75 kN/m

   **To calculate seismic load**

   - **Live load on the roof= 0**
   - **Live load on floor slab=50% (L.L.>3 kN/m2)**

   Therefore, Live load = 0+0.5*(3.125)

   LL on roof slab=1.5625 kN/m2
5. **To calculate seismic load**

Live load on the roof= 0

Live load on floor slab=50% (LL.>3 kN/m²)

Therefore, Live load = 0+0.5*(3.125)

LL on roof slab = 1.5625 kN/m²

6. **Lumped mass**:

![Lumped mass](image)

**Figure 10. Lumped mass: transfer of seismic weight from center to center of storey**

7. **The total load on the roof slab**

= DL on the roof slab + LL on the roof slab

= Weight on roof slab + Self weight of beam + self-weight of column + Self weight of wall + LL on roof

Here, For column height: storey height/2 = 3/2 = 1.5 m

For the height of the wall: (Storey height-half width of beam-half width of the beam)/2

= (3-0.35/2-0.35/2)/2

= 1.325 m

Therefore, TL on the roof slab=

761.4 + 521.08 + (218.75*3/2) + [(378.35 + 405.375) * 1.325] + 0

= 2649.04 kN

8. **Also, total load for floor slab**

= DL on the floor slab + LL on the floor slab

= Weight on floor slab + Self weight of beam + self-weight of column + Self weight of wall + LL on floor

Here, For column height: storey height/2 = 3/2 = 1.5 m

For the height of the wall:

For height of wall: (Storey height-half width of beam-half width of the beam)/2

= (3 - 0.35/2) * 2 = 2.65 m

Total load for floor slab = 847.8 + 521.08 + (218.75*3) + [(378.35 + 405.375) * 2.65] + 1.5625

= 4103.56 kN

Therefore, the total seismic weight of each floor = 6752.60 + (4103.56*5)

= 27270.4 kN

Now to calculate Ah,

Ah = Z/2 * I/R * Sa/g

Where, Z = Zone factor = 0.36 (Building is in V zone)

I = Importance factor = 1

R = Response reduction factor = 5

According to the table

Sa/g = T = 0.09h/√d

Where h = height of building = 24 m

d = length of direction along which seismic effect occurs

Therefore, for x direction: d = 18 m

Therefore, time period T = 0.09*24/√18 = 0.509

From the spectral acceleration coefficient graph value of Sa/g for 0.509 time period = 2.5

Ah = Z/2 * I/R * Sa/g

= 0.36/2 * 1/5 * 2.5

Ah = 0.9

Therefore, base shear force along x direction Vb = W*Ah

= 27270.4 * 0.9

Vb = 24543.36 kN

Similarly, for z-direction: d = 12 m

Therefore, time period T = 0.09*24/√12 = 0.623

From spectral acceleration coefficient graph value of Sa/g for 0.623 time period = 1.36

Therefore, base shear force along z direction Vb = W*Ah
Ah = \frac{Z/2*I/R*Sa/g}{0.36/2*1/5*2.18} = 0.78

Therefore, base shear force along z direction \( V_b = W*Ah \)
= 27270.4*0.78

\( V_b = 21270.912 \text{ kN} \)

Now comparing with base shear values from staadpro software calculation, it is observed that the values for both x and z directions are approximately the same as the values calculated manually. It states that the results from staadpro are validated with manual calculation.

V. CONCLUSION

The reinforced concrete structure of the building is designed, and a response spectrum analysis is conducted. The analysis provides us with information about the displacement, shear force, and bending moment at each story of the structure.

Figure 11 illustrates a graph depicting the relationship between frequency and period. It can be observed that as the time increases, the frequency decreases. This indicates an inverse proportionality between frequency and time. The building R.C.C. structure is designed and Response Spectrum analysis is performed.
VI. ACKNOWLEDGMENT

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REFERENCES


