Seismic Analysis of Multistoried Building
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Abstract—The effective design and the construction of earthquake resistant structures have much greater importance in all over the world. In this paper, the earthquake response of symmetric multistoried building is studied by manual calculation and with the help of ETABS 9.7.1 software. The method includes seismic coefficient method as recommended by IS 1893:2002. The responses obtained by manual analysis as well as by soft computing are compared. This paper provides complete guideline for manual as well as software analysis of seismic coefficient method.

Index Terms—earthquake, manual calculation, ETABS 9.7.1, IS 1893:2002

I. INTRODUCTION
ETABS is the present day leading design software in the market. Many design company’s use this software for their project design purpose. So, this paper mainly deals with the comparative analysis of the results obtained from the analysis of a multi storey building structure when analyzed manually and using ETABS software separately. In this case, a 22.5m x 22.5m, 8 storey structure is modeled using ETABS software. The height of each storey is taken as 3 meter making the total height of the structure 24 meter. Analysis of the structure is done and then the results generated by this software are compared with manual analysis of the structure using IS 1893:2002.

II. PROBLEM DEFINATION
A. Case
A 22.5m x 22.5 m, 8 storey multi storey regular structure is considered for the study. Storey height is 3m. Modeling and analysis of the structure is done on ETABS software.

B. Preliminary Data

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length x Width</td>
<td>22.5m x 22.5m</td>
</tr>
<tr>
<td>No. of Storey’s</td>
<td>8 (G+7)</td>
</tr>
<tr>
<td>Beam</td>
<td>250 mm x 400 mm</td>
</tr>
<tr>
<td>Columns</td>
<td>400 mm x 500 mm</td>
</tr>
<tr>
<td>Slab thickness</td>
<td>150 mm</td>
</tr>
<tr>
<td>Support Condition</td>
<td>Fixed</td>
</tr>
<tr>
<td>Thickness External Wall</td>
<td>120mm</td>
</tr>
<tr>
<td>Grade of Concrete and steel</td>
<td>M20 and Fe415</td>
</tr>
<tr>
<td>Length of each bay</td>
<td>7.5m</td>
</tr>
</tbody>
</table>

C. Loading Consideration
Loads acting on the structure are dead load (DL), Live Load (LL) and Earthquake Load (EL). DL: Self weight of the structure, Floor load and Wall loads

- LL: Live load 3KN/m² is considered
- Seismic: Zone: III
- Zone Factor: 0.16
- Soil type: II
- Response reduction factor: R=3
- Importance factor: 1
- Damping: 5%
- Time period: 0.427 sec (calculated as per IS 1893: 2002)

III. ACTUAL ANALYSIS

Fig 1: Plan of the structure (ETABS model) (Ref.6)

Fig 2: Elevation of structure (ETABS model)
A. Dead Load (D. L.) per floor

<table>
<thead>
<tr>
<th>Items</th>
<th>SIZE (L x B x H) m&lt;sup&gt;3&lt;/sup&gt;</th>
<th>No.</th>
<th>Density (kN/m&lt;sup&gt;3&lt;/sup&gt;)</th>
<th>Dead Load (kN)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beam</td>
<td>0.25 x 0.4 x 7.5</td>
<td>24</td>
<td>24</td>
<td>432</td>
</tr>
<tr>
<td>Column</td>
<td>0.5 x 0.4 x 3</td>
<td>16</td>
<td>24</td>
<td>230.4</td>
</tr>
<tr>
<td>Slab</td>
<td>22.5 x 22.5 x 0.15</td>
<td>1</td>
<td>24</td>
<td>1822.5</td>
</tr>
<tr>
<td>Wall</td>
<td>22.5 x 0.12 x 3</td>
<td>4</td>
<td>20</td>
<td>648</td>
</tr>
<tr>
<td>SUM</td>
<td></td>
<td></td>
<td></td>
<td>3132.9</td>
</tr>
</tbody>
</table>

B. UDL due to wall:
Wall is not modulated only UDL is due to wall on beam is considered.

UDL OF WALL = 0.12 (thickness) x 3 (height of wall) x 20 (brick density) = 7.2 kN/m

C. Live load on floor area
As mentioned in ILC, Live load is considered 3kN/m<sup>2</sup> on each floor. Each floor has dimension 22.5m x 22.5m.
Live load on each floor is
3 x 22.5 x 22.5 = 1518.75 KN
As per IS 1893:2002 (pg no. 24) Clause no. 7.3.1, Table no.8, only 25% live load is considered in seismic weight calculations.
25% of live load = 0.25 \times 1518.75 = 379.6875 \text{ KN}.

Fig 6: 7.2kN/m UDL applied to beam on each floor

Fig 7: Procedure to assign live load on floor

Fig 8: Applied live load on each floor (3 kN/m²)

IS 1893 (Part 1) : 2002

Table 8: Percentage of Imposed Load to be Considered in Seismic Weight Calculation (Clause 7.5.1)

<table>
<thead>
<tr>
<th>Height of Building (m)</th>
<th>Percentage of Imposed Load</th>
</tr>
</thead>
<tbody>
<tr>
<td>Up to and including 3.0</td>
<td>15</td>
</tr>
<tr>
<td>Above 3.0</td>
<td>10</td>
</tr>
</tbody>
</table>

7.6.2 The approximate fundamental period of vibration ($T_f$), in seconds, of the building may be estimated by the expression:

$$T_f = \frac{0.90}{\sqrt{a}}$$

where $a = \text{Height of building, in m}$ and $d = \text{Base dimension of the level, in m, along the direction of the lateral force.}$

7.7 Distribution of Design Force

7.7.1 Vertical Distribution of Base Shear Forces

D. Load Combination

As per IS 1893:2000, the load combination Dead load + Live Load becomes,

$$DL + 25\% \text{ LL} = 3132.9 + 25\% \times 379.687 = 3572.5875 \text{ kN per each floor}.$$ 

This live load reduction is defined by a command mass source in ETABS 7.1.

Fig 9: Live load reduction clause as per IS 1893:2000 (Ref.5)

Fig 10: Procedure to define Mass Source (ETABS model) (Ref.6)
E. Seismic weight calculation of building

As per III, C

W1=W2=W3=W4=W5=W6=W7= 3512.5875 kN.

Lumped mass at roof floor.

In the calculation of seismic weight, for the terrace floor 50% of the weight is considered for walls and columns.

W8 = 432 + (230.4 / 2) + 1822.5 + (648 / 2)

= 2693.7 kN.

Total weight (W) = (3512.587 x 7) + 2693.7

= 27281.8125 kN.

Now the seismic weight obtain in ETABS software is as shown below.
IV. ANALYSIS FOR BASE SHEAR

A. Design Seismic Base Shear

As per IS 1893:2002, Page No. 24, The total design lateral force or design seismic base shear (VB) along any principal direction shall be determined by the following expression:

\[ V_B = A_h x w \]

Where,

\[ A_h = \frac{Z}{2} x x \frac{R}{R} \times \frac{S_a}{g} \]

Where,

\[ Z = 0.16, \text{ As per IS 1893:2002, Table No.2 and ANNEX E, Zone Factor for IIIrd zone.} \]

\[ I = 1, \text{ As per IS 1893:2002, Table No.6, Importance factor, It is depends on the functional use of the structure.} \]

\[ R = 3, \text{ As per IS 1893:2002, Table No.7, Response reduction factor.} \]

\[ S_a/g = \text{Average response acceleration coefficient.} \]

The value of average response acceleration coefficient is determined from the graph given on page no.16 of IS 1893:2002.

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Seismic weight obtained from ETABS = 27281.8 kN.
For determination of average response acceleration coefficient, it is required to calculate time period.

As per IS 1893:2002, Page No.7, time period T is given by

\[ T_a = \frac{0.09H}{\sqrt{d}} \]

Where,

\[ H = \text{Height of the building in meter} = 24 \text{ m} \]

Note: As per IS 1893:2002 for the terrace floor, half of the total load is considered for walls and columns. So while modeling in ETABS, top story height is modeled 1.5m while height of other stories is 3m. So in ETABS model H = 22.5m

\[ d = \text{Base dimension of the building in meter} = 22.4 \text{ m} \]

\[ T_a = 0.455 \text{ sec.} \]

\[ T_a = 0.427 \text{ sec. (In case of ETABS)} \]

From the graph as shown in Fig. 12.

\[ S_a/g = 2.5. \]

Now Design horizontal acceleration spectrum Value can be calculated.

\[ A_k = \frac{0.16}{2} \times 1.5 \times 2.5 = 0.0667 \]

Now base shear

\[ V_B = A_h \times w = 0.0667 \times 27281.8125 \]

\[ V_B = 1819.696 \text{ kN}. \]

Fig 16: Window of ETABS showing IS 1893:2000 inputs Time Period, Zone factor, Soil factor, response reduction factor.

(Ref.6)

B. Vertical Distribution of Base Shear to Different Floor Levels:

The design base shear \( V_B \) shall be distributed long the height of the building as per following equation

\[ Q_i = V_B \times \frac{W_i h_i^2}{\sum_{j=1}^{n} W_j h_j^2} \]

Where,

\[ Q_i = \text{Design lateral force at floor } i, \]

\[ W_i = \text{Seismic weight of floor } i, \]

\[ h_i = \text{Height of floor } i \text{ measured from base, and} \]

\[ n = \text{Number of storeys in the building is the number of levels at which the masses are located.} \]

<table>
<thead>
<tr>
<th>Floor</th>
<th>Height (Meter)</th>
<th>Wi h_i^2</th>
<th>Q</th>
<th>Base Shear</th>
</tr>
</thead>
<tbody>
<tr>
<td>W1</td>
<td>3</td>
<td>31613.29</td>
<td>9.624</td>
<td>1819.69</td>
</tr>
<tr>
<td>W2</td>
<td>6</td>
<td>126453.15</td>
<td>38.5</td>
<td>1810.07</td>
</tr>
<tr>
<td>W3</td>
<td>9</td>
<td>284519.59</td>
<td>86.62</td>
<td>1771.57</td>
</tr>
<tr>
<td>W4</td>
<td>12</td>
<td>505812.6</td>
<td>153.98</td>
<td>1684.95</td>
</tr>
<tr>
<td>W5</td>
<td>15</td>
<td>790332.19</td>
<td>240.6</td>
<td>1530.97</td>
</tr>
<tr>
<td>W6</td>
<td>18</td>
<td>1138078.3</td>
<td>346.46</td>
<td>1290.37</td>
</tr>
<tr>
<td>W7</td>
<td>21</td>
<td>1549051</td>
<td>471.57</td>
<td>943.91</td>
</tr>
<tr>
<td>W8</td>
<td>24</td>
<td>1551571.2</td>
<td>472.34</td>
<td>472.34</td>
</tr>
</tbody>
</table>

\[ \sum W_i h_i^2 = 5977431.9 \]
C. Vertical Distribution of Base Shear to Different Floor Levels from ETABS

![Fig 18: Vertical Distribution of Base Shear to Different Floor Levels.]

Fig 18: Vertical Distribution of Base Shear to Different Floor Levels.

![Fig 19: Procedure to display base shear of each story (ETABS model) (Ref.6)]

Fig 19: Procedure to display base shear of each story (ETABS model) (Ref.6)

![Fig 20: Vertical Distribution of Base Shear to Different Floor Levels (Out put from ETABS) (Ref.6)]

Fig 20: Vertical Distribution of Base Shear to Different Floor Levels (Out put from ETABS) (Ref.6)

V. CONCLUSION

From the data revealed by the manual as well as software analysis for the structures with seismic coefficient method using various loading combinations tried following conclusions are drawn:

1. Seismic analysis was done by using ETABS software and successfully verified manually as per IS 1893-2002.
2. There is a gradual increase in the value of lateral forces from bottom floor to top floor in both manual as well as software analysis.
3. Calculation of seismic weight by both manual analysis as well as software analysis gives exactly same result.
4. There is slight variation in the values of base shear in manual analysis as well as software analysis.
5. Base shear values obtained by manual analysis are slightly higher than software analysis.
6. Results as compared and approximately same mathematical values are obtained for 8-story building.
7. Complete guideline for the use of ETABS 7.1 for seismic coefficient analysis is made available by this paper.
8. To conclude a complete design involving several parameters so as to result the earthquake has been done and a 3D prospective is shown for easy understanding and use.

VI. FUTURE ENHANCEMENT

1. Any structural engineer can use this paper as a guide line for seismic analysis of any multistoried building.
2. The results obtained by this method can be compared with results of Response Spectrum Method and Time History Method.

REFERENCES

[7] ETABS Non linear version 9.7.1
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