Response spectrum analysis of irregular shaped high rise buildings under combined effect of plan and vertical irregularity using csi etabs

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Abstract: In this research work several high rise buildings were analyzed using CSI ETABS under the influence of the response spectrum analysis over it. Several different shaped high rise buildings such as H shaped, O shaped and C shaped buildings were taken into consideration for carrying out the research work. All three shaped buildings were of different storey that is of 12 storey and of 16 storey. For proper seismic analysis of all the above discussed buildings, response spectrum method of seismic analysis were taken into consideration. The results of all the buildings for response spectrum analysis were quite different from one another and it was found that the H-shaped building showed better results as compared to the other shaped buildings. It was also seen that the 12 storey building results were quite impressive as compared to the results of the 16 storey building. With the transference of heavy mass, very little effect was seen in latera sway i.e. variation in maximum displacement was negligible. Again, for 16 storey building, maximum displacement was found in the case L-Shaped 16 storey building with the value of 87.804 mm. Again, the transference of heavy masses had a minimal effect on total quantity and cost of the 16 Storey building. In the gist, it was concluded that, bending moments and shear forces were increased from 1.17% to 1.84%. Maximum variation in B.M and S.F. can be seen in O-shaped Building. L-shaped Building produces maximum displacement from all the three irregular shapes i.e. H-shape, L-shaped and O-shaped.

Keywords: Static and Dynamic Seismic Analysis, CSI ETABS, CSI SAP2000, Response spectrum analysis, seismic analysis

1. INTRODUCTION

1.1 SEISMIC ANALYSIS

Afterwards the Gujarat chronological Earthquake ‘BHUJ’ 2001, researchers and designers started captivating earthquakes truly and commence to design our structures seismic resilient so that they will be non-vulnerable to the seismic activity as BHUJ generated so much destruction to constructions and social life. Nowadays, numerous investigational research are being carried out every day to project new equipment relate to it so that our constructions will not surrender at that moment. Seismic activity are twisted due to the movement of rock-strewn surface within the earths inner that produces earth motion in numerous procedures [1–3].
1.2 IRREGULAR STRUCTURES

Today, most of the infrastructures are being widely constructed as irregular structures. A structure is a regular structure when its configurations (dimensional parameters) are almost symmetrical about all the axis. Regular buildings are those buildings which have same appearance either from plan or elevation [4–6].

1.3 PRACTICAL APPLICATIONS

- The current research work can easily be utilized for designing other similar kinds of irregular shaped high rise as well as low rise structures at different kinds of construction sites and the similar kinds of load combinations can also be used for designing the structure with broader aspects.
- The practical applications of all the proposed and well-designed irregular shaped structures can be achieved using the current research work and can be used as the basis of the construction of similar kinds of irregular and regular shaped structures.
- The present research work mainly compares the overall cost effectiveness of similar kind of irregular shaped structures so therefore it will be very much useful to construct the most cost effective building considering numerous number of factors that affect the construction and design of a structural component over a proposed site [4–6].
2. LITERATURE REVIEW

2.1 GENERAL

Various variations and enhancement in the Seismic activity resistant design of building is done in previous latest years. It outcomes in the fluctuations in the Indian standard code IS 1893 which is reviewed and conscripted in year 2016, subsequently a time forgotten of approximately fourteen years. In this research study, the author symbolizes the seismic load calculation for high-rise structure as per Indian standards: 1893-2016 references. Bearing in mind and examining the 4 storey RC framed multistory structure. It was determined that such education work is prepared on separate R-C framed construction building that is designed by means of previous code [7–9]. To forecast the seismic susceptibility of construction building and to check the amendments and variations in the IS code comestibles that the construction is safe or unsafe. In this venture, a private structure of G+10, G+15, G+20 and G+25, Special RC minute resting outline (SMRF) is taken for study. Displaying of the structure is done according to CSI ETABS V8i programming. Timespan of the structure in both the heading is taken from the product and according to the three norms 12 models are made for example 4 models for each code. The explanatory consequences of the model structures are then spoken to graphically and in forbidden structure, it is thought about and broke down observing any huge contrasts. This examination centers around investigating varieties in the outcomes acquired utilizing the three codes for example IS code, IBC and Canada code. A near examination is performed regarding base shear, relocation and story float. Some elevated structures are planned with storm cellar. As a rule, we expect that a structure is fixed at the ground level. In this manner, the storm cellar of the structure is excluded in the investigation and just gravity loads are considered in planning the cellar. In any case, the storm cellar may acquaint adaptability with the structure bringing about bigger horizontal removals and longer vibration periods. The seismic burdens connected to a structure will influence the part powers in the storm cellar. Along these lines, it is prescribed to incorporate the storm cellar in the examination of elevated structure structures. The impact of the storm cellar is examined dependent on the seismic reaction of elevated structures and a productive investigation technique to represent the impact of the cellar was proposed in this examination [10–12].

3. RESEARCH METHODOLOGY

3.1 OBJECTIVE OF STUDY

- To analyze the different storey buildings (with plan and vertical irregularity) with dynamic seismic analysis in zone V as per the new earthquake code IS: 1893-2016.
- To find all the structural parameters like axial force, displacement, bending moment etc. in a scrutinized way and comparison shall be made.
• To compare the effect of mass irregularity and V-bracing at different floors of same building in terms of Displacement and cost analysis [10–14].
• To draw the final conclusions towards the behavior of irregular structures under seismic forces as per the new code IS: 1893-2016 for RCC framed structures.

3.2 Research methodology
3.2.1 Modeling various irregular structures
Models that have been prepared for the present investigational study is being represented in the Table 1 to 5. As there were 12 models were made, 6 for 16 storey building and 6 for 12 storey building as shown below:

| Type | Floors      | Shape | Heavy Mass Floor | Type of Bracing |
|------|-------------|-------|-----------------|-----------------|
| 1    | 12 Storey   | H     | 6th floor       | V Type          |
| 2    | 12 Storey   | H     | 9th floor       | V Type          |
| 3    | 12 Storey   | L     | 6th floor       | V Type          |
| 4    | 12 Storey   | L     | 9th floor       | V Type          |
| 5    | 12 Storey   | O     | 6th floor       | V Type          |
| 6    | 12 Storey   | O     | 9th floor       | V Type          |
| 7    | 16 Storey   | H     | 9th floor       | V Type          |
| 8    | 16 Storey   | H     | 12th floor      | V Type          |
| 9    | 16 Storey   | L     | 9th floor       | V Type          |
| 10   | 16 Storey   | L     | 12th floor      | V Type          |
| 11   | 16 Storey   | O     | 9th floor       | V Type          |
| 12   | 16 Storey   | O     | 12th floor      | V Type          |

• Storey height in all the models is taken as 3.2 m.
• Size of each bay is taken as 5 m x 5 m

| Floors | Column (mm) | Beam (mm) | Bracing (mm) |
|--------|-------------|-----------|--------------|
| 1 to 4 | 750 x 750   | 550 x 450 | 450 x 450    |
| 5 to 8 | 650 x 650   | 450 x 350 | 350 x 350    |
| 9 to 12| 550 x 550   | 355 x 300 | 300 x 300    |

| Floors | Column (mm) | Beam (mm) | Bracing (mm) |
|--------|-------------|-----------|--------------|
| 1 to 4 | 900 x 900   | 600 x 550 | 550 x 550    |
| 5 to 8 | 800 x 800   | 550 x 450 | 450 x 450    |
| 9 to 12| 700 x 700   | 450 x 400 | 350 x 350    |
| 13 to 16| 600 x 600  | 400 x 350 | 300 x 300    |
| Floors | Column (mm) | Beam (mm) | Bracing (mm) |
|--------|-------------|-----------|--------------|
| 1 to 4 | 900 x 900   | 600 x 600 | 550 x 550    |
| 5 to 8 | 800 x 800   | 550 x 550 | 450 x 450    |
| 9 to 12| 600 x 600   | 450 x 450 | 350 x 350    |
| 13 to 16| 500 x 500  | 350 x 350 | 300 x 300    |

Table 5. Sectional Properties for O-Shaped 16 Storey Building

| Floors | Column (mm) | Beam (mm) | Bracing (mm) |
|--------|-------------|-----------|--------------|
| 1 to 4 | 900 x 900   | 550 x 550 | 450 x 450    |
| 5 to 8 | 800 x 800   | 450 x 450 | 400 x 400    |
| 9 to 12| 600 x 600   | 400 x 400 | 350 x 350    |
| 13 to 16| 500 x 500  | 350 x 350 | 300 x 300    |

**Dead Load:**
- External Wall Loading: 12.5 kN/m
- Interior Wall Loading: 6.5 kN/m
- Parapet wall loading: 3 kN/m²

**Live Load:**
- Floor load: 3.2 kN/m²
- Heavy Mass Floor Load: 12 kN/m²

Figure 1. Plan of H-Shaped Building.
3.2.2 RESPONSE SPECTRUM ANALYSIS

After modeling all the structures with various parameters, seismic analysis was carried out with Response Spectrum Method (dynamic seismic analysis). For this purpose, various seismic parameters were defined in CSI ETABS as shown below and in figure 1, 2 & 3.

3.2.3 COLLECTING AND SCRUTINIZING THE RESULTS

After analyzing the structures, a careful study was carried for various members and components. Therefore, the post-processing of CSI ETABS software were scrutinized and results were recorded for different parameters and were interpreted. Comparison charts, graphs and tables were developed which will be represented in the Chapter- IV. Cost analysis was also done for the purpose of better comparison so that final outcome of the study is achieved. For this, following material rates were assumed:

Rate of Concrete per cumec: Rs. 4000/.
Rate of steel per kg: Rs. 40/.
4. Results and Discussions

4.1 Results

Present investigational study of irregular structure for 12 storey and 16 storey buildings has been successfully done. All the types of irregularities of the structure have been explored during the study with V-type of Bracing (located at the edges) and the performance of the structure is noticed and structural members were evaluated in terms of displacement axial force, bending moment, shear force, % of steel etc. from the CSI ETABS result [15–17]. The results, collected from CSI ETABS, were tabulated and represented in figures and then they were studied very carefully with the help of tables and comparative figures. Following sections will discuss the results of 16 storey (H, L and O Shaped) buildings and 12 storey (H, L and O Shaped) buildings which were analyzed with earthquake loads.

4.1.1 Results of CSI Etabs for 12 Storey Irregular Shaped Building

The results of 12 storey irregular building i.e the Shear force and bending moment in beams, were recorded and are represent as under table 6 to 8:

Table 6. Displacement (Mm) In Column of 12 Storey H-Shaped Building

| Floor | Corner Column | Inner column |
|-------|---------------|--------------|
|       | Type 1  | Type 2  | Type 1  | Type 2  |
| 1     | 2.172   | 2.08    | 2.081   | 2.11 |
| 2     | 3.695   | 3.546   | 5.95    | 6.017 |
| 3     | 5.298   | 5.094   | 10.242  | 10.329 |
| 4     | 7.101   | 6.838   | 14.628  | 14.727 |
| 5     | 9.294   | 8.964   | 20.339  | 20.51 |
| 6     | 11.667  | 11.277  | 26.519  | 26.94 |
| 7     | 14.086  | 13.639  | 32.493  | 33.177|
| 8     | 16.496  | 15.993  | 38.217  | 39.06 |
| 9     | 19.066  | 18.487  | 46.181  | 46.7 |
| 10    | 21.605  | 20.951  | 54.171  | 54.376|
| 11    | 24.014  | 23.292  | 60.192  | 60.33 |
| 12    | 26.271  | 25.489  | 63.687  | 63.865|

Table 7. Displacement (Mm) In Column of 12 Storey L-Shaped Building

| Floor | Corner Column | Inner column |
|-------|---------------|--------------|
|       | Type 3  | Type 4  | Type 3  | Type 4  |
| 1     | 4.256   | 4.278   | 2.446   | 2.485 |
| 2     | 7.534   | 7.586   | 7.077   | 7.17  |
| 3     | 11.122  | 11.214  | 12.252  | 12.368|
| 4     | 15.212  | 15.351  | 17.569  | 17.684|
| 5     | 20.279  | 20.486  | 24.422  | 24.597|
| 6     | 25.866  | 26.158  | 31.888  | 32.421|
| 7     | 31.65   | 32.028  | 39.262  | 40.282|
Table 8. Displacement (Mm) In Column of 12 Storey O-Shaped Building

| Floor | Corner Column | Inner column |
|-------|---------------|--------------|
|       | Type 5        | Type 6       | Type 5        | Type 6       |
| 1     | 2.815         | 2.817        | 1.985         | 1.989        |
| 2     | 5.355         | 5.377        | 5.727         | 5.735        |
| 3     | 8.258         | 8.311        | 9.92          | 9.923        |
| 4     | 11.536        | 11.631       | 14.228        | 14.225       |
| 5     | 15.579        | 15.739       | 19.843        | 19.88        |
| 6     | 20.014        | 20.257       | 25.976        | 26.238       |
| 7     | 24.554        | 24.884       | 31.889        | 32.448       |
| 8     | 29.107        | 29.51        | 37.465        | 38.283       |
| 9     | 34.071        | 34.517       | 44.98         | 45.789       |
| 10    | 39.015        | 39.484       | 52.629        | 53.31        |
| 11    | 43.637        | 44.122       | 58.566        | 59.164       |
| 12    | 47.898        | 48.401       | 62.161        | 62.753       |

4.1.2 Results of CSI Etabs for 16 Storey Irregular Building

The results of 16 storey irregular building i.e. the Shear force and bending moment in beams, were recorded and are represent as under table 9 to 11:

Table 9. Displacement (Mm) In Column Of 16 Storey H-Shaped Building.

| Floor | Corner Column | Inner column |
|-------|---------------|--------------|
|       | Type 7        | Type 8       | Type 7        | Type 8       |
| 1     | 1.46          | 1.465        | 1.404         | 1.399        |
| 2     | 2.814         | 2.826        | 4.152         | 4.143        |
| 3     | 4.353         | 4.374        | 7.31          | 7.3          |
| 4     | 6.165         | 6.197        | 10.611        | 10.6         |
| 5     | 8.488         | 8.536        | 14.828        | 14.811       |
| 6     | 11.141        | 11.209       | 19.758        | 19.715       |
| 7     | 13.979        | 14.071       | 24.783        | 24.705       |
| 8     | 16.951        | 17.07        | 29.706        | 29.651       |
| 9     | 20.229        | 20.385       | 34.951        | 35.134       |
| 10    | 23.629        | 23.825       | 40.016        | 40.528       |
| 11    | 27.058        | 27.291       | 44.807        | 45.557       |
| 12    | 30.477        | 30.739       | 49.329        | 50.067       |
| 13    | 34.07         | 34.357       | 55.212        | 55.832       |
| Floor | 14  | 37.592 | 37.902 | 61.151 | 61.708 |
|-------|-----|--------|--------|--------|--------|
| 15    | 40.96 | 41.292 | 65.973 | 66.522 |
| 16    | 44.159 | 44.512 | 68.94  | 69.489 |

Table 10. Displacement (mm) In Column of 16 Storey L-Shaped Building

| Floor | Corner Column | Inner Column |
|-------|---------------|--------------|
|       | Type 9        | Type 10      | Type 9 | Type 10 |
| 1     | 2.563         | 2.57         | 1.532  | 1.537   |
| 2     | 4.897         | 4.909        | 4.493  | 4.503   |
| 3     | 7.549         | 7.562        | 7.911  | 7.925   |
| 4     | 10.589        | 10.603       | 11.5   | 11.521  |
| 5     | 14.364        | 14.376       | 15.702 | 15.732  |
| 6     | 18.482        | 18.492       | 20.126 | 20.165  |
| 7     | 22.809        | 22.82        | 24.58  | 24.635  |
| 8     | 27.35         | 27.369       | 29.042 | 29.133  |
| 9     | 32.667        | 32.719       | 35.411 | 35.673  |
| 10    | 38.422        | 38.515       | 42.968 | 43.438  |
| 11    | 44.307        | 44.436       | 50.395 | 50.992  |
| 12    | 50.223        | 50.362       | 57.433 | 57.936  |
| 13    | 56.614        | 56.745       | 66.841 | 67.103  |
| 14    | 62.954        | 63.068       | 76.203 | 76.258  |
| 15    | 68.951        | 69.05        | 83.419 | 83.352  |
| 16    | 74.563        | 74.648       | 87.804 | 87.685  |

Table 11. Displacement (mm) in Column of 16 Storey O-Shaped Building

| Floor | Corner Column | Inner Column |
|-------|---------------|--------------|
|       | Type 11       | Type 12      | Type 11 | Type 12 |
| 1     | 2.002         | 2.015        | 1.386   | 1.387   |
| 2     | 4.388         | 4.417        | 4.113   | 4.117   |
| 3     | 7.187         | 7.236        | 7.308   | 7.315   |
| 4     | 10.436        | 10.511       | 10.767  | 10.783  |
| 5     | 14.634        | 14.745       | 15.558  | 15.595  |
| 6     | 19.487        | 19.645       | 21.493  | 21.563  |
| 7     | 24.64         | 24.852       | 27.693  | 27.814  |
| 8     | 29.956        | 30.234       | 33.839  | 34.051  |
| 9     | 35.736        | 36.104       | 40.685  | 41.128  |
| 10    | 41.65         | 42.114       | 47.361  | 48.072  |
| 11    | 47.521        | 48.07        | 53.62   | 54.514  |
| 12    | 53.309        | 53.919       | 59.382  | 60.258  |
| 13    | 59.281        | 59.938       | 66.38   | 67.178  |
| 14    | 65.079        | 65.777       | 73.068  | 73.872  |
| 15    | 70.492        | 71.229       | 78.283  | 79.156  |
5. Conclusion and Future Scope

All the results have been represented and after evaluating all the irregular structure i.e. 12 storey building and 16 storey building. And final conclusions of the present thesis, which were drawn from results after a scrutinized study, have been concluded in the following section:

- There was very little variation in total quantities and total cost of the building. Therefore, it can be concluded that when the heavy mass is transferred from 6th floor to 9th floor in 12 storey building, it had negligible effect on the quantity and cost of the building.

- In 16 storey irregular building, when the heavy masses were introduced to 9th floor and 12th floor, then the maximum bending moment varies from 1.26% to 1.75%. Like bending moment, shear force also shows great variation as it varies from 1.17% to 1.84%.

- With the transference of heavy mass, very little effect was seen in lateral sway i.e. variation in maximum displacement was negligible. Again, for 16 storey building, maximum displacement was found in the case L-Shaped 16 storey building with the value of 87.804 mm.

- Again, the transference of heavy masses had a minimal effect on total quantity and cost of the 16 Storey building.

- In the gist, it was concluded that, bending moments and shear forces were increased from 1.17% to 1.84%. Maximum variation in B.M and S.F. can be seen in O-shaped Building. L-shaped Building produces maximum displacement from all the three irregular shapes i.e. H-shape, L-shaped and O-shaped.

This research work mainly deals with the seismic analysis of high rise buildings using STAAD.Pro, it can also be done using similar other kinds of software, but at the time of the research work it was very much limited for the whole seismic analysis of the similar other shapes structures as it was beyond the limits of the software although it can be resolved if some other kind of software was used [18,19]. At the time of the research work it was proposed to consider base isolation, hydraulic jacks and distemper kinds of aspects for performing the research work in a better and broader way, but still due to the absence of advanced aspects in the software, limited research work was performed. It was found that the existing practical applications of the similar kinds of irregular shaped buildings was unable to locate due to certain number of aspects and if found at the research work location, the research work might be performed in a broader way or detailed manner.

5.1. Future Scope

Present thesis work was carried out in the seismic zone V with V-type bracing for 16-storey building and 12 storey building with plan and mass irregularities. In future, many Research work shall be carried out from this manuscript includes: : As the variation in displacement was negligible when the heavy mass was transferred from 6th floor in 12 storey building and 9th floor in 16 storey building to three storey above. Therefore, the gap in transference of heavy mass shall be at least 5 Storey for next research. As H-shape, L-shape and O-shape buildings were chosen for present study, different shaped building such as U-shape, plus shape etc. shall be adopted for new study. Another study shall be carried out by changing the seismic zone of seismic analysis. New research study shall be conducted if the type of bracing (i.e. cross bracing, zigzag bracing) and the location of bracing is changed. Different design software like e-tabs, if used, can also generate new research work as it may produce different result. A good comparative study shall be conducted in this case.
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