ANALYZING THE EFFECT OF MASS IRREGULARITY AND FLOATING COLUMN ON HIGH-RISE STEEL FRAMED STRUCTURE WITH WIND ANALYSIS

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ABSTRACT

The analysis and design of the structures have become a difficult task now days due to presence of different kinds of irregularities in it. To make this as a simple task, the evaluation of performance of these structures is carried out in the professional analysis and designing tool such as Bentley's Staad. Pro, e-tabs, SAP etc. Out of all the irregularities of structures, Mass irregularities and elevation irregularities (having floating column) have become the most common one. Therefore, in present study, 15 and 20 Storey buildings were adopted while introducing floating columns at the upper floors and Mass irregularity at different floor throughout its height. Various vertical loads were taken from the IS codes and along with it, wind forces were applied on the structures. From the results, it has been concluded that the forces and moments increases when the heavy mass is introduced, but if the heavy mass is placed in the upper storeys, the forces and moments becomes higher than that of a building having heavy mass in the lower floors. Displacement of the column decreases as heavy mass increases the lateral capacity of the structure by giving the addition stability due to increase in total vertical load.

KEYWORDS: Extension of Building, RCC Frame Building, Staad. Pro

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INTRODUCTION

It is important to evaluate the complex structures subjected to strong lateral forces as being the developing nation, more and more complex structures with numerous storeys are being built in India. This is due to the advancement in design and construction technologies, architectural appearance and increasing population. One of the main processes in all this is analysis and design of structures and their structural members. On the basis of previous research works by eminent researchers, some standards were published which provides basic and professional guidelines for construction and design. Every situation was depicted by the researchers and numbers of investigational studies were carried out so that the behavior of the structure and its component can be observed.

Steel structure, as shown in figure 1, plays an impeccable part in modern infrastructures as it entails less self-weight than RCC structures and requires less time to erect. But due to its less self-weight, the lateral stability of the structure is compromised and special care is to be taken while designing such structures having large number of storeys. Various cross-sectional conventional shapes of steel (like T-Shape, I-shape, C-Shape, L-Shape etc) and modern shapes (like tubular hollow sections) are connected together in the form of columns and beams with different connecting methods so that members act as a monolithic unit. The design of such building is to be taken as per the IS 800:1984- "For steel structures".

Figure 1: Steel Structure.

Irregularity in a structure simply means that the structure is not symmetrical at its principle axis. Various kinds of irregularities can be introduced in the structure such as vertical irregularity, plan irregularity or both. Most common types of irregularity in high rise structures are the mass irregularity and irregularity in elevation. Floating column is a column which rests on beams and not on column. See figure 2.

Figure 2: Structure having Mass Irregularity and Floating Column.

RESEARCH METHODOLOGY

Geometry of Steel Framed Structure & Introduction of Mass Irregularity and Floating Column

Various models were modeled using staad.pro software with having different building heights with and without heavy mass entailing floating column.

Specifications of the model are as under:

- Each structure had 6 bays.
- Each bay was 6 m x 6 m in size.
- Each storey was 3.3 m in height.
- For steel sections, both (conventional and tubular) sections were chosen, whichever is suitable.
- All the models were regular and symmetrical in shape.

Table 1 show the various types of models which were generated under present study.

Table 1: Description of Various Models

Structural Type	Description	Mass Irregularity
Type 1	15Storey Building With Floating Columns (FC)	None
Type 2	15Storey Building With Floating Columns (FC)	On 2 nd Floor
Type 3	15 Storey Building With Floating Columns (FC)	On 7 th Floor
Type 4	15 Storey Building With Floating Columns (FC)	On 13 th Floor
Type 5	20Storey Building With Floating Columns (FC)	None
Type 6	20 Storey Building With Floating Columns (FC)	On 4 th Floor
Type 7	20 Storey Building With Floating Columns (FC)	On 10 th Floor
Type 8	20 Storey Building With Floating Columns (FC)	On 16 th Floor

Figure 3: Plan of Structure.

Figure 4: Elevation & Rendered View of 15 Storey Building with Floating Columns at 14th Floor.

Figure 5: Elevation & Rendered View of 20 Storey Building with Floating Columns at 19th Floor.

Wind Analysis as per IS: 875 (Part 3)

The behavior of wind in steel structures is very crucial due to its less self-weight and its analysis plays an impeccable role in designing the steel framed structures. Therefore, for the present study, wind analysis was carried out and various parameters of wind were considered for the analysis as per the codal specification of IS: 875 (Part 3).

Table: 2: Input Parameters for Wind Analysis

Parameter	Value
Basic Wind speed	47 m/sec
k1, Probability factor	1
k2, Terrain, height and structure size factor	1
k3, Topography factor	1
Therefore, Design Wind Speed (V_z)	47 m/sec
Wind Pressure ($P=0.6V_z^2$)	1325 N/m ² = 1500 N/m ²

The wind pressure of 1.5 kN/m^2 was calculated as above and applied directly on columns as uniformly distributed load (UDL) as mentioned in figures below. The wind was applied from different directions (i.e. from 'X' direction, from '-X' direction, from 'Z' direction and from '-Z' direction) in order to generate different load cases. In this case, the behavior of column was carefully observed and difference was noted. The deflection of column in case of wind along with the mass irregularity was determined as this is the ultimate aim of the study.

Figure 6: Wind Load Acting as UDL on Columns of 15 Storey Building.

Figure 7: Wind Load Acting as UDL on Columns of 20 Storey Building.

RESULTS OF 15 STOREY BUILDING

The results of various parameters have been represented below:

The maximum bending moment in the 2nd floor beams with and without heavy mass was recorded as 204.365 kN-m and 172.084 kN-m respectively. But if the same mass is shifted to 7th floor of the building, then the maximum bending moment in 7th floor beams with and without the heavy mass becomes 258.338 kN-m and 225.663 kN-m respectively. Again after shifting the heavy mass onto the 13th floor, the value of maximum bending moment in 13th floor beams with and without the heavy mass comes out to be 191.386 kN-m and 152.218 kN-m respectively. Therefore, from the figures 8, 9 and 10, it was concluded that when the heavy mass was placed at 2nd floor, the value of bending moment increases approximately 26% whereas, when the heavy mass is shifted to 7th floor, the increase in bending moment was found out to be 31%. And if the heavy mass is placed at 13th floor, then the approximate increase in bending moment comes out to be 36%.

Figure 8: Bending Moment of 2nd Floor Beam with and without Heavy Mass of 15 Storey Building.

Figure 9: Bending Moment of 7th Floor Beam with and without Heavy Mass of 15 Storey Building.

Figure 10: Bending Moment of 13th Floor Beam with and without Heavy Mass of 15 Storey Building.

The maximum shear force in the 2nd floor beams with and without heavy mass was recorded as 148.444 kN and 118.639 kN respectively. But if the same mass is shifted to 7th floor of the building, then the maximum shear force in 7th floor beams with and without the heavy mass becomes 165.759 kN and 135.653 kN respectively. Again after shifting the heavy mass onto the 13th floor, the value of maximum shear force in 13th floor beams with and without the heavy mass comes out to be 142.705 kN and 110.693 kN respectively. Therefore, from the figures 11, 12 and 13, it was concluded that when the heavy mass was placed at 2nd floor, the value of shear force increases approximately 29% whereas, when the heavy mass is shifted to 7th floor, the increase in shear force was found out to be 31%. And if the heavy mass is placed at 13th floor, then the approximate increase in shear force comes out to be 34%.

Figure 11: Shear Force of 2nd Floor Beam with and without Heavy Mass of 15 Storey Building.

Figure 12: Shear Force of 7th Floor Beam with and without Heavy Mass of 15 Storey Building.

Figure 13: Shear Force of 13th Floor Beam with and without Heavy Mass of 15 Storey Building.

As the beam beneath the floating column act as a cantilever beam, the bending moment and shear force value comes out to be huge. Maximum bending moment and shear force value comes out to be 454 kN-m and 207 kN respectively as shown in figure 14 and 15.

Figure 14: Bending Moment of End Beams where Floating Columns are Placed.

Figure 15: Shear Force of End Beams where Floating Columns are Placed.

Due to increase in the total weight of the building (having heavy mass) which increases the lateral stability, the displacement of the columns decreases. Maximum decrease in the column displacement was calculated as 4%, 6% and 7% approximately when the heavy mass was placed at 2nd floor, 7th floor and 13th floor respectively when compared to the building having no heavy mass. Whereas, the bending moment increases with the introduction of heavy masses at different floors. Maximum increase in the value of bending moment of column was calculated as 15.7%, 15.8% and 15.8% approximately when the heavy mass was placed at 2nd floor, 7th floor and 13th floor respectively when compared to the building having no heavy mass. See figure 16, 17, 18 and 19.

Table 3: Description of Displacement and Bending Moment in Column

Floor	Maximum decrease in the column Displacement	Maximum increase in the value of Bending moment of column
2 th floor	4 %	15.7 %
7 th floor	6 %	1.5 %
13 th floor	7 %	1.7 %

Figure 16: Maximum Displacement of Columns in 15 Storey Building.

Figure 17: Maximum Bending in Columns (Kn-m) in 15 Storey Building.

As the cross-sectional properties were revised after adding the heavy mass, the total quantity of the building changes as shown in figure 22, 23, 24 and 25. Maximum steel quantity for type 1, type 2, type 3 and type 4 buildings is 20050 kN, 20597 kN, 20928 Kn and 21156 Kn respectively. The percentage increase in the quantity of building is 2.7%, 4.4% and 5.5% in type 2, type 3 and type 4 buildings.

Table 4: Description of Total Percentage Increase in Quantity

Building Type	Total Quantity	Total Percentage Increase
Type 1	20050 kN	-
Type 2	20597 kN	2.7 %
Type 3	20928 kN	4.4 %
Type 4	21156 kN	5.5 %

RESULTS OF 20 STOREY BUILDING

The results of various parameters have been represented below:

The maximum bending moment in the 4th floor beams with and without heavy mass was recorded as 299.86kN-m and 262.37kN-m respectively. But if the same mass is shifted to 10th floor of the building, then the maximum bending moment in 10th floor beams with and without the heavy mass becomes 311.99kN-m and 272.309kN-m respectively. Again after shifting the heavy mass onto the 16th floor, the value of maximum bending moment in 16th floor beams with and without the heavy mass comes out to be 286.956kN-m and 241.944kN-m respectively. Therefore, from figure 26, 27 and 28, it was concluded that when the heavy mass was placed at 4th floor, the value of bending moment increases approximately 25% whereas, when the heavy mass is shifted to 10th floor, the increase in bending moment was found out to be 35%. And if the heavy mass is placed at 16th floor, then the approximate increase in bending moment comes out to be 33%.

Figure 18: Bending Moment of 4th Floor Beam with and without Heavy Mass of 20 Storey Building.

Figure 19: Bending Moment of 10th Floor Beam with and without Heavy Mass of 20 Storey Building.

Figure 20: Bending Moment of 16th Floor Beam with and without Heavy Mass of 20 Storey Building.

The maximum shear force in the 4th floor beams with and without heavy mass was recorded as 180.289kN and 148.68kN respectively. But if the same mass is shifted to 10th floor of the building, then the maximum shear force in 10th floor beams with and without the heavy mass becomes 183.704kN and 151.356kN respectively. Again after shifting the

heavy mass onto the 16th floor, the value of maximum shear force in 16th floor beams with and without the heavy mass comes out to be 174.993kN and 140.365kN respectively. Therefore, from figure 29, 30 and 31, it was concluded that when the heavy mass was placed at 4th floor, the value of shear force increases approximately 28% whereas, when the heavy mass is shifted to 10th floor, the increase in shear force was found out to be 33%. And if the heavy mass is placed at 16th floor, then the approximate increase in shear force comes out to be 32%.

Figure 21: Shear Force of 4th Floor Beam with and without Heavy Mass of 20 Storey Building.

Figure 22: Shear Force of 10th Floor Beam with and without Heavy Mass of 20 Storey Building.

Figure 23: Shear Force of 16th Floor Beam with and without Heavy Mass of 20 Storey Building.

As the beam beneath the floating column act as a cantilever beam, the bending moment and shear force value comes out to be huge. Maximum bending moment and shear force value comes out to be 441.011 kN-m and 202.942 kN respectively. See figure 32 and 33.

Figure 24: Bending Moment of End Beams where Floating Columns are Placed.

Figure 25: Shear Force of End Beams where Floating Columns are Placed.

Due to increase in the total weight of the building (having heavy mass) which increases the lateral stability, the displacement of the columns decreases as shown in figure 34, 35, 36 and 37. Maximum decrease in the column displacement was calculated as 0.4%, 1.2% and 2.6% approximately when the heavy mass was placed at 4th floor, 10th floor and 16th floor respectively when compared to the building having no heavy mass. Whereas, the bending moment increases with the introduction of heavy masses at different floors. Maximum increase in the value of bending moment of

column was calculated as 2.1%, 1.5% and 1.7% approximately when the heavy mass was placed at 4th floor, 10th floor and 16th floor respectively when compared to the building having no heavy mass.

Table 5: Description of Displacement and Bending Moment in Column

Floor	Maximum decrease in the column displacement	Maximum increase in the value of bending moment of column
4 th floor	0.4 %	2.1 %
10 th floor	1.2 %	1.5 %
16 th floor	2.6 %	1.7 %

Figure 26: Maximum Displacement of Columns in 20 Storey Building.

Figure 27: Maximum Bending in Columns (kN-m) in 15 Storey Building.

As the cross-sectional properties were revised after adding the heavy mass, the total quantity of the building changes. Maximum steel quantity for type 5, type 6, type 7 and type 8 buildings is 29137 kN, 29360kN, 29691kN and 30040 kN respectively. The percentage increase in the quantity of building is 0.8 %, 1.9 % and 3.10 % in type 6, type 7 and type 8 buildings.

Table 6: Description of Total Percentage Increase in Quantity

Building Type	Total Quantity	Total Percentage Increase
Type 5	29137 kN	-
Type 6	29360 kN	0.8 %
Type 7	29691 kN	1.9 %
Type 8	30040 kN	3.10 %

CONCLUSIONS

The comparison work between these aforementioned building were carried out and the final conclusions were drawn from the results of 15 storey buildings. They are as follows:

- When the heavy mass was placed at 2nd floor, the value of bending moment increases approximately 26% whereas, when the heavy mass is shifted to 7th floor, the increase in bending moment was found out to be 31%. And if the heavy mass is placed at 13th floor, then the approximate increase in bending moment comes out to be 36%.
- When the heavy mass was placed at 2nd floor, the value of shear force increases approximately 29% whereas, when the heavy mass is shifted to 7th floor, the increase in shear force was found out to be 31%. And if the heavy mass is placed at 13th floor, then the approximate increase in shear force comes out to be 34%.
- As the beam beneath the floating column act as a cantilever beam, the bending moment and shear force value comes out to be huge. Maximum bending moment and shear force value comes out to be 454 kN-m and 207 kN respectively.
- Due to increase in the total weight of the building (having heavy mass) which increases the lateral stability, the displacement of the columns decreases. Maximum decrease in the column displacement was calculated as 4%, 6% and 7% approximately when the heavy mass was placed at 2nd floor, 7th floor and 13th floor respectively when compared to the building having no heavy mass. Whereas, the bending moment increases with the introduction of heavy masses at different floors. Maximum increase in the value of bending moment of column was calculated as 15.7%, 15.8% and 15.8% approximately when the heavy mass was placed at 2nd floor, 7th floor and 13th floor respectively when compared to the building having no heavy mass.
- As the cross-sectional properties were revised after adding the heavy mass, the total quantity of the building changes. Maximum steel quantity for type 1, type 2, type 3 and type 4 buildings is 20050kN, 20597 kN, 20928 kN and 21156 kN respectively. The percentage increase in the quantity of building is 2.7%, 4.4% and 5.5% in type 2, type 3 and type 4 buildings.

The comparison work between these aforementioned building were carried out and the final conclusions were drawn from the results of 20storey buildings. They are as follows:

- When the heavy mass was placed at 4th floor, the value of bending moment increases approximately 25% whereas, when the heavy mass is shifted to 10th floor, the increase in bending moment was found out to be 35%. And if the heavy mass is placed at 16th floor, then the approximate increase in bending moment comes out to be 33%.

- When the heavy mass was placed at 4th floor, the value of shear force increases approximately 28% whereas, when the heavy mass is shifted to 10th floor, the increase in shear force was found out to be 33%. And if the heavy mass is placed at 16th floor, then the approximate increase in shear force comes out to be 32%.
- As the beam beneath the floating column act as a cantilever beam, the bending moment and shear force value comes out to be huge. Maximum bending moment and shear force value comes out to be 441.011kN-m and 202.942kN respectively.
- Due to increase in the total weight of the building (having heavy mass) which increases the lateral stability, the displacement of the columns decreases. Maximum decrease in the column displacement was calculated as 0.4%, 1.2% and 2.6% approximately when the heavy mass was placed at 4th floor, 10th floor and 16th floor respectively when compared to the building having no heavy mass. Whereas, the bending moment increases with the introduction of heavy masses at different floors. Maximum increase in the value of bending moment of column was calculated as 2.1%, 1.5% and 1.7% approximately when the heavy mass was placed at 4th floor, 10th floor and 16th floor respectively when compared to the building having no heavy mass.
- As the cross-sectional properties were revised after adding the heavy mass, the total quantity of the building changes. Maximum steel quantity for type 5, type 6, type 7 and type 8 buildings is 29137 kN, 29360kN, 29691Kn and 30040 kN respectively. The percentage increase in the quantity of building is 0.8 %, 1.9 % and 3.10 % in type 6, type 7 and type 8 buildings.

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