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Seismic Evaluation of Irregular Multi Storey Buildings Using Bracing In Zone V

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ABSTRACT

There are primarily two distinct kinds of irregularities present inside the building; the first of these is known as plan irregularity, and the second is known as vertical irregularity. Because irregular structures operate differently than regular structures, the introduction of irregularity into a structure results in difficult design and construction challenges. These issues are caused by the difference in behavior between the two types of structures. The reaction of such a building under seismic stress is dependent on a number of different parameters, and it is of the utmost importance to understand the behavior of such an irregular structure in order to establish a new method of design and construction through which the performance of the same shall be assessed. Because of this, the current research was carried out in order to get an understanding of the behavior of irregular structures that have bracing systems. In order to do this, three distinct kinds of irregularities were selected for the 12-story building: an H-shape, an L-shape, and an O-shape. In light of the findings of this research, the use of a V-bracing configuration is of particular importance. Heavy stuff was loaded onto the sixth floor and the ninth floor, but not at the same time. It was decided to do the dynamic seismic study in seismic zone V at Staad, and the analysis was carried out there.Professional software. Finding out how effective the bracing was, in addition to doing an analysis of the irregular structure, was the primary focus of this particular research endeavor, which led to its successful completion.

I. INTRODUCTION

Seismic evaluation and design of multi-story buildings are of utmost importance in regions prone to earthquakes, particularly in Zone V in India. The irregularities present in building configurations can significantly impact their response to seismic events. Irregularities can arise from variations in floor plans, vertical setbacks, or inconsistencies in vertical stiffness, posing challenges for the structural integrity and safety of buildings during earthquakes. To address these concerns, various structural mitigation strategies are employed, including the use of bracing systems. Bracing systems, such as diagonal or eccentric braces, play a vital role in improving the seismic performance of buildings. These systems help redistribute seismic forces and enhance the overall structural stiffness, thereby reducing the vulnerability of buildings to damage and collapse. However, the effectiveness of bracing systems in irregular multi-storey buildings in seismic Zone V, India, needs to be thoroughly evaluated to ensure their suitability for local conditions. The objective of this study is to conduct a comprehensive seismic evaluation of irregular multi-storey buildings in Zone V, India, with a specific focus on the effectiveness of bracing systems. By incorporating different bracing configurations into the building models, we aim to assess their impact on the structural response and performance during seismic events. This evaluation will contribute to a better understanding of the seismic behavior of irregular buildings in Zone V and provide insights into the efficacy of bracing systems as a mitigation strategy.

To achieve our goal, we will employ structural analysis software to model the irregular multi-storey buildings, considering various irregularities commonly observed in practice. Dynamic analysis will be conducted by subjecting the building models to

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ground motion records representative of seismic activity in Zone V. The analysis will provide valuable information on the building's response parameters, such as base shear, inter-story drift, and floor accelerations, under different bracing configurations.

Evaluation criteria based on relevant seismic codes and standards will guide the assessment of the building's seismic performance. By comparing the response parameters for different bracing configurations, we will identify the most effective bracing system in mitigating seismic forces in irregular multi-storey buildings in Zone V, India. The findings of this study will contribute to the body of knowledge on seismic evaluation and design practices for irregular buildings in high seismic zones. The outcomes will assist structural engineers and designers in making informed decisions regarding the use of bracing systems to enhance the seismic performance and safety of multi-storey buildings in Zone V, India.

II. RELATED WORK

Agarwal & Shrikhande (2019) provides an overview of the challenges associated with the seismic design of irregular buildings. It discusses various types of irregularities and their impact on the structural response. The paper also presents current design practices for mitigating the effects of irregularities, including the use of bracing systems. It highlights the importance of considering irregularities in the design process to ensure the safety and performance of buildings during earthquakes.

Ghosh & Dey (2018) focuses on the seismic performance evaluation of irregular multi-storey buildings with different bracing configurations. It investigates the effectiveness of various bracing systems, such as diagonal braces and eccentric braces, in improving the structural response during seismic events. The study includes numerical simulations and analyses of building models under earthquake excitations. The findings provide valuable insights into the performance of bracing systems and their influence on the overall seismic behavior of irregular buildings.

Vyas (2017) presents a seismic analysis of irregular multi-storey buildings with bracing systems. The study utilizes finite element analysis to evaluate the structural response of buildings under seismic loads. Different bracing configurations, including diagonal and eccentric braces, are considered, and their effects on the building's behavior are assessed. The paper provides useful information on the benefits and limitations of bracing systems in mitigating seismic forces in irregular buildings.

Shakya & Sriramula (2016) focuses on the seismic performance evaluation of irregular multi-storey buildings using different bracing systems. The research includes numerical analysis of building models with various irregularities, such as vertical setbacks and variations in floor plans. The effectiveness of bracing systems, including diagonal braces and eccentric braces, is investigated through performance parameters such as inter-story drift and base shear. The findings highlight the significance of proper bracing configuration in improving the seismic response of irregular buildings.

Ahmed & Khan (2014) examines the seismic response of irregular buildings with different bracing configurations. The study employs numerical analysis to evaluate the behavior of building models under seismic loads. The effectiveness of various bracing systems, including diagonal, concentric, and eccentric braces, is assessed in terms of structural performance measures. The paper provides insights into the seismic behavior of irregular buildings and the role of bracing systems in improving their performance.

Overall, the literature review indicates that the seismic evaluation of irregular multi-storey buildings using bracing systems is a well-studied topic. Previous studies have focused on investigating different types of irregularities and their effects on structural response. The effectiveness of various bracing configurations, including diagonal braces, eccentric braces, and concentric braces, has been assessed in terms of performance parameters such as inter-story drift, base shear, and floor accelerations. These studies contribute to the understanding of seismic design practices for irregular buildings and emphasize the importance.

III. RESEARCH METHODOLOGY

Various steps were taken for completing the project titled "**DYNAMIC SEISMIC**

EVALUATION OF IRREGULAR MULTI-STOREY BUILDINGS USING BRACING IN ZONE V AS PER IS: 1893-2016" and they are discussed as under:

Modeling Various Irregular
↓
Structures Response Spectrum
↓
Analysis Collecting and
↓
Scrutinizing the Results

Final Conclusion

A. Modeling Various Irregular structures

Models that have been prepared for the present investigational study is being represented in the Table 1. As there were 12 models were made, 6 for 16 storey building and 6 for 12 storey building as shown below:

Table 1. Different Models for Present Study

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 m.
- No. of bays are as per plan.
- Size of each bay is taken as 5 m x 5 m.

Table 1 shows different models for this work. Two kinds of floors exist. One has 12 stories from types 1 to 6, and the other has 16 stories from types 7 to 12. Here, all of the support is of the V type. The Type 1 is shaped like an H, and the floor with the most weight is the 6th floor. Type 2 is also in the shape of an H, and the heavy-mass floor is on the 9t floor. Both Type 3 and Type 4 have an L shape, and the floors with the most weight are on the 6th and 9th, respectively. In the same way, both Type 5 and Type 6 have an O shape, with the heavy mass floor on the 6th and 9th. Types 7 and 8 have an H shape, and the floors with the most weight are 9th and 12th floors, respectively. Type 9 and Type 10 have an L shape, and the floors with the most weight are on the ninth and twelfth floors, respectively. Type 11 and Type 12 are both in the shape of an O, with the heavy mass floor on the 9th and 12th floors, respectively.

Table 2. Sectional Properties for H, L and O Shaped 12 story Building.

Floors	Column (mm)	Beam (mm)	Bracing (mm)
1 to 4	750 x 750	525 x 450	450 x 450
5 to 8	600 x 600	450 x 375	375 x 375
9 to 12	450 x 450	375 x 300	300 x 300

Table 2 contains the sectional properties for a 12-story H, L, and O-shaped building. Floors 1 to 4 have a 750 x 750 (mm) column, a 525 x 450 (mm) beam, and a 450 x 450 (mm) bracing. Similarly, Floors 5 to 8 have a 600 x 600 (mm) column, a 450 x 375 (mm) beam, and a 375 x 375 (mm) bracing. Likewise Floors 9 to 12 have a 450 x 450 (mm) column, a 375 x 300 (mm) beam, and a 300 x 300 (mm) bracing.

Table 3. Sectional Properties for H-Shaped 16 Storey Building.

Floors	Column (mm)	Beam (mm)	Bracing (mm)
1 to 4	900 x 900	600 x 450	575 x 575
5 to 8	750 x 750	450 x 450	450 x 450
9 to 12	600 x 600	450 x 375	375 x 375
13 to 16	450 x 450	375 x 375	300 x 300

Table 3 contains the sectional properties for a 16-story H-shaped building. Floors 1 to 4 have a 900 x 900 (mm) column, a 600 x 450 (mm) beam, and a 575 x 575 (mm) bracing. Similarly, both floors 5 to 8 have a 750 x 750 (mm) column and have a 450 x 450 (mm) beam and bracing. Likewise floors 9 to 12 have a 450 x 450 (mm) column, a 375 x 375 (mm) beam, and a 300 x 300 (mm) bracing.

Table 4. Sectional Properties for L-Shaped 16 Storey Building.

Floors	Column (mm)	Beam (mm)	Bracing (mm)
1 to 4	900 x 900	600 x 600	575 x 575
5 to 8	750 x 750	575 x 575	450 x 450
9 to 12	600 x 600	450 x 450	375 x 375
13 to 16	450 x 450	375 x 375	300 x 300

Table 4 contains the sectional properties for a 16-story L-shaped building. Floors 1 to 4 have a 900 x 900 (mm) column, a 600 x 600 (mm) beam, and a 575 x 575 (mm) bracing. Similarly, both floors 5 to 8 have a 750 x 750 (mm) column and have a 575 x 575 (mm) beam and 450 x 450 (mm) bracing. Likewise floors 9 to 12 have a 600 x 600 (mm) column, a 450 x 450 (mm) beam, and a 375 x 375 (mm) bracing. The floors 13 to 16 have a 450 x 450 (mm) column, a 375 x 375 (mm) beam, and a 300 x 300 (mm) bracing.

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

Floors	Column (mm)	Beam (mm)	Bracing (mm)
1 to 4	900 x 900	575 x 575	450 x 450
5 to 8	750 x 750	450 x 450	375 x 375
9 to 12	575 x 575	450 x 375	375 x 300
13 to 16	450 x 450	375 x 375	300 x 300

Table 5 contains the sectional properties for a 16-story O-shaped building. Floors 1 to 4 have a 900 x 900 (mm) column, a 575 x 575 (mm) beam, and a 450 x 450 (mm) bracing. Similarly, both floors 5 to 8 have a 750 x 750 (mm) column and have a 450 x 450 (mm) beam and 375 x 375 (mm) bracing. Likewise floors 9 to 12 have a 575 x 575 (mm) column, a 450 x 375 (mm) beam, and a 375 x 300 (mm) bracing. The floors 13 to 16 have a 450 x 450 (mm) column, a 375 x 375 (mm) beam, and a 300 x 300 (mm) bracing.

Dead Load:

External Wall Loading:

12.4 kN/m Interior Wall
Loading: 6.2 kN/m
Parapet wall loading: 2.9
kN/m^2 **Live Load:**
Floor load: 3 kN/m^2
Heavy Mass Floor Load: 10 kN/m^2

IV. RESULTS AND EXPLANATION

Table 6. Displacement (mm) in Column of 16 story 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

Table 6 contains the displacement (mm) in column of 16 story H-Shaped Building. The inner column and corner column principles apply to both type 7 and type 8. As can be seen in the table, the maximum displacement for a corner column for type 7 is reached at 10th (23.629mm), followed by 9th (20.229mm), which is the second largest, and so on. The first floor yields the lowest displacement measurement (1.46mm). The maximum displacement for type 8 for a corner column is similarly attained at the 10th (23.825mm), followed by the 9th (20.385mm), which is the second highest, and so on. The first floor yields the lowest displacement measurement (1.465mm).

The largest displacement for type 7 found for an inner column is at the 10th (40.016mm), followed by the 9th (34.951mm), which is the second highest, and so on. The lowest displacement value (1.404mm) is obtained on the 1st floor. In a comparable manner, the maximum displacement obtained for type 8 is at the 10th (40.528mm), then followed by the 9th (34.951mm), which is the second highest, and so on. The 1st floor has the lowest displacement value (1.399mm).

Table 7. Displacement (mm) in Column of 16 Storey L-Shaped Building.

[illegible]

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 7 contains the displacement (mm) in column of 16 story L-Shaped Building. The inner column and corner column principles apply to both type 9 and type 10. As can be seen in the table, the maximum displacement for a corner column for type 9 is reached at 16^{th} (74.563mm), followed by 15^{th} (68.951mm), which is the second largest, and so on. The 1^{st} floor yields the lowest displacement measurement (2.563mm). The maximum displacement for type 10 for a corner column is similarly attained at the 16^{th} (74.648mm), followed by the 15^{th} (69.05mm), which is the second highest, and so on. The 1^{st} floor yields the lowest displacement measurement (2.57mm).

The largest displacement for type 9 found for an inner column is at the 16^{th} (87.804mm), followed by the 15^{th} (83.419mm), which is the second highest, and so on. The lowest displacement value (1.532mm) is obtained on the 1^{st} floor. In a comparable manner, the maximum displacement obtained for type 10 is at the 16^{th} (87.685mm), then followed by the 15^{th} (83.352mm), which is the second highest, and so on. The 1^{st} floor has the lowest displacement value (1.537mm).

Table 8. 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
16	75.549	76.327	81.526	82.464

Table 8 contains the displacement (mm) in column of 16 story O -Shaped Building. The inner column and corner column principles apply to both type 11 and type 12. As can be seen in the table, the maximum displacement for a corner column for type 11 is reached at 16^{th} (75.549mm), followed by 15^{th} (70.492mm), which is the second largest, and so on. The 1^{st} floor yields the lowest displacement measurement (2.002mm). The maximum displacement for type 12 for a corner column is similarly attained at the 16^{th} (76.327mm), followed by the 15^{th} (71.229mm), which is the second highest, and so on. The 1^{st} floor yields the lowest displacement measurement (2.015mm).

The largest displacement for type 11 found for an inner column is at the 16^{th}

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(81.526mm), followed by the 15th (78.283mm), which is the second highest, and so on. The lowest displacement value (1.386mm) is obtained on the 1st floor. In a comparable manner, the maximum displacement obtained for type 12 is at the 16th (82.464mm), then followed by the 15th (79.156mm), which is the second highest, and so on. The 1st floor has the lowest displacement value (1.537mm).

Table 9. Total Cost of 16 Storey building.

Type	Total Cost (Lakhs)
Type 7	330.9
Type 8	331.1
Type 9	258.9
Type 10	259.2
Type 11	314.2
Type 12	315.4

COMPARATIVE FIGURES FOR 12 STOREY BUILDING

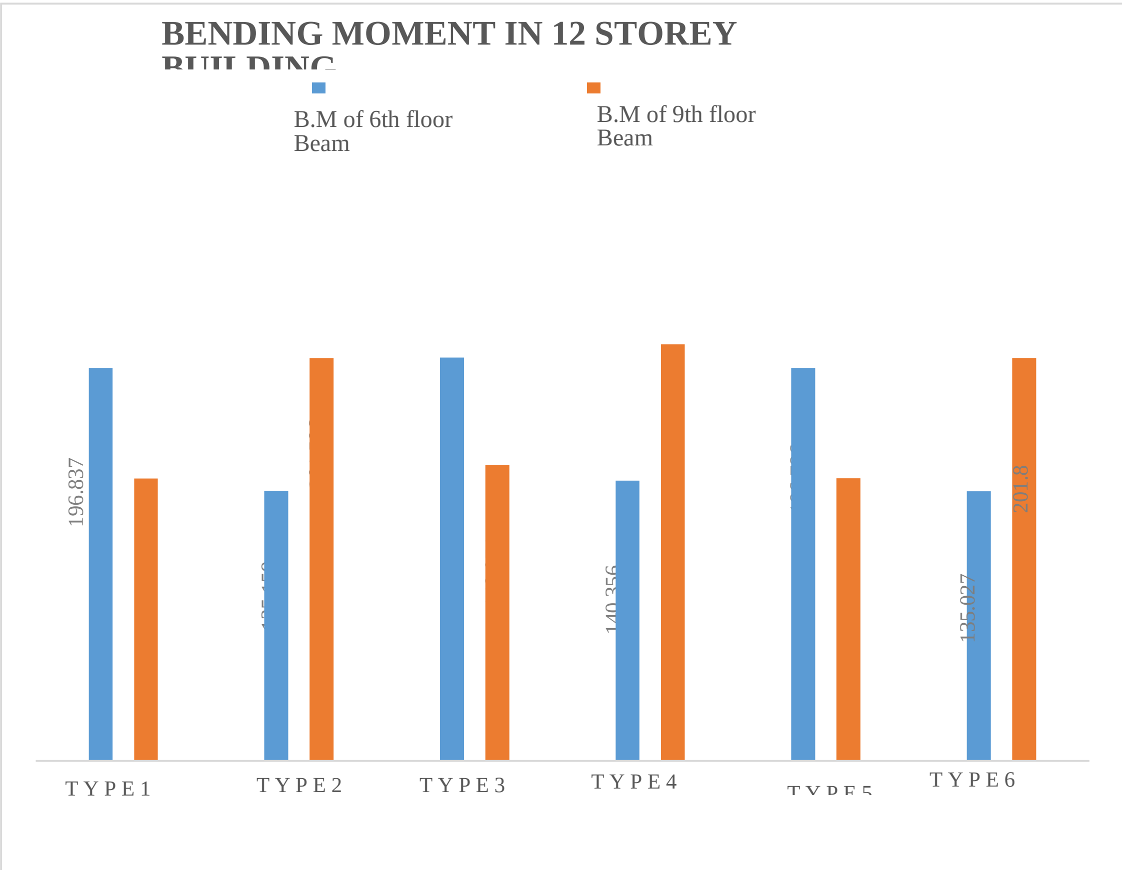

Figure 1. Maximum Bending Moment (kN-m) in Beams for 12 Storey Building.

Figure 1 depicts the maximal bending moment (kn-m) for a 12-story building's beams. In Type 1, the B.M values for the 6th and 9th floor beams are 196.837 and 141.36, respectively. In Type 2, the B.M values for the 6th and 9th floor beams are 135.159 and 201.596, respectively. Similarly, for Type 3, the obtained B.M for the 6th and 9th floors is 202.035 and 148.074. The B.M of the 6th and 9th floors for Type 4 are 140.356 and 208.611. Similarly, the B.M of the 6th and 9th floors for Type 5 and Type 6 is 196.786, 141.444, and 135.027, and 201.8 respectively.

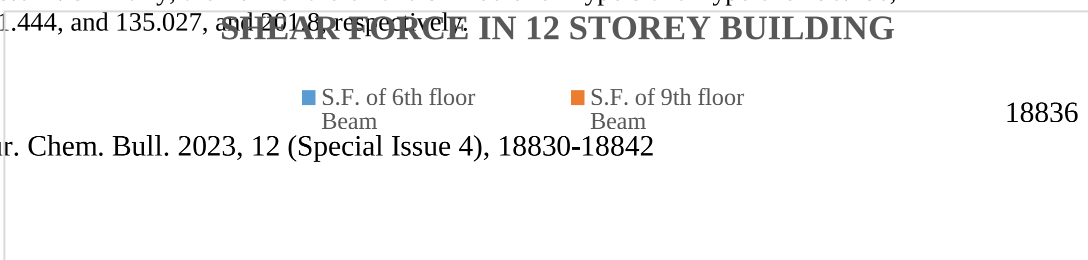

Figure 2. Maximum Shear Force (kN) in Beams for 12 Storey Building.

Figure 2 depicts the maximal shear force (kn) for a 12-story building's beams. In Type 1, the S.F values for the 6th and 9th floor beams are 190.19 and 129.442, respectively. In Type 2, the S.F values for the 6th and 9th floor beams are 126.622 and 192.772, respectively. Similarly, for Type 3, the obtained S.F for the 6th and 9th floors is 192.239 and 132.067. The S.F of the 6th and 9th floors for Type 4 are 128.671 and 195.515. Similarly, the S.F of the 6th and 9th floors for Type 5 and Type 6 is190.193, 129.569, and 126.607, and 192.927, respectively.

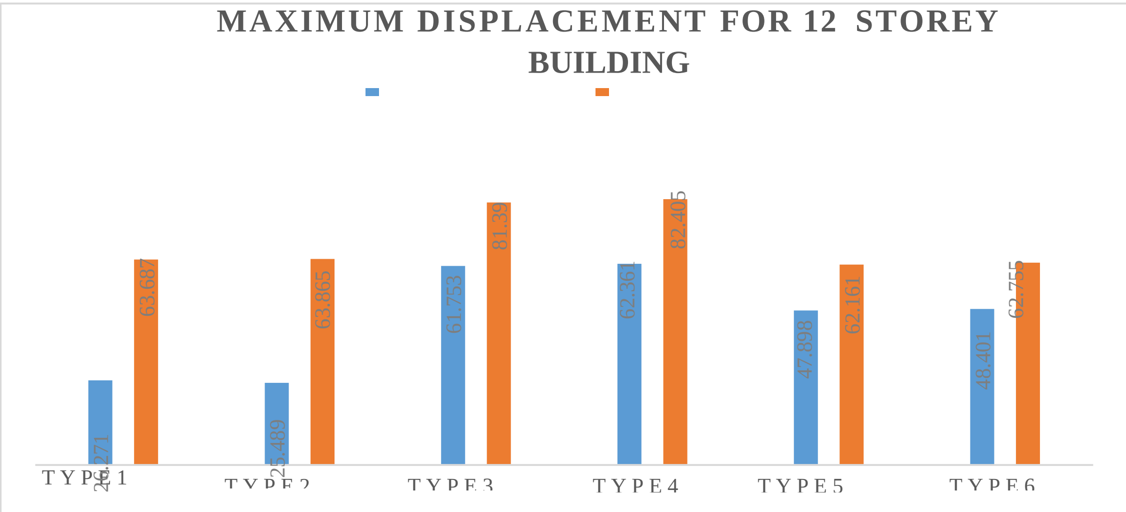

Figure 3 depicts the maximal displacement (mm) for a 12-story building's beams. In Type 1, the maximal displacement values for the 6th and 9th floor beams are 261.271 and 63.687, respectively. In Type 2, the maximal displacement values for the 6th and 9th floor beams are 25.489 and63.865, respectively. Similarly, for Type 3, the obtained maximal displacement for the 6th and 9th floors is 61.753 and 81.39. The maximal displacement of the 6th and 9th floors for Type 4 are 62.361 and 82.405. Similarly, the maximal displacement of the 6th and 9th floors for Type 5 and Type 6 is 47.898, 62.161, and 48.401, and 62.755, respectively.

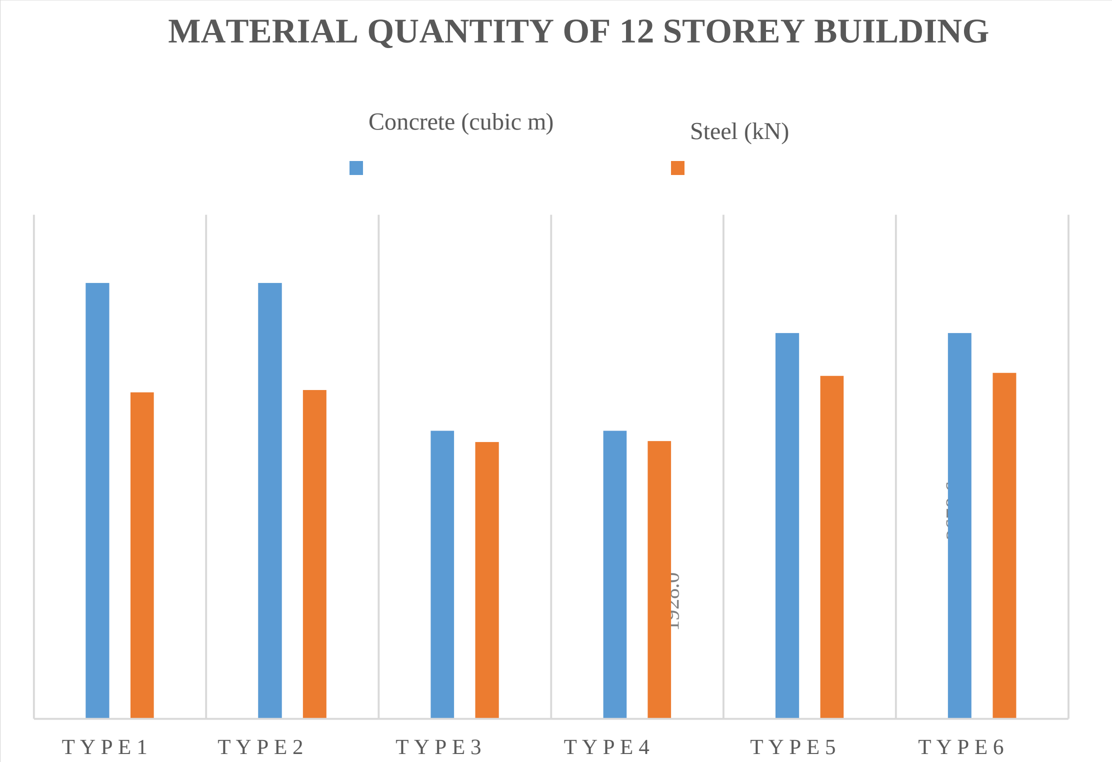

Figure 4. Total Material Quantity for 12 Storey Building.

Figure 4 depicts the material quality for concrete (cubic m) and steel (kN) for a 12-story building's beams. In Type 1, the material quality for concrete and steel are 3027.3 cubic m and 2267.8 kN, respectively. In Type 2, the material quality for concrete and steel are 3027.3 cubic m and 283.7 kN. Similarly, for Type 3, the material quality for concrete and steel is 1998.8 cubic m and 1922.2 kN. The material quality for concrete and steel in case of Type 4 are 1998.8 cubic m and 1928.0 kN. Similarly, the for Type 5 and Type 6 is 2678.6 cubic m, 2381.9 kN, and 2678.6 cubic m, and 2402.9 kN, respectively.

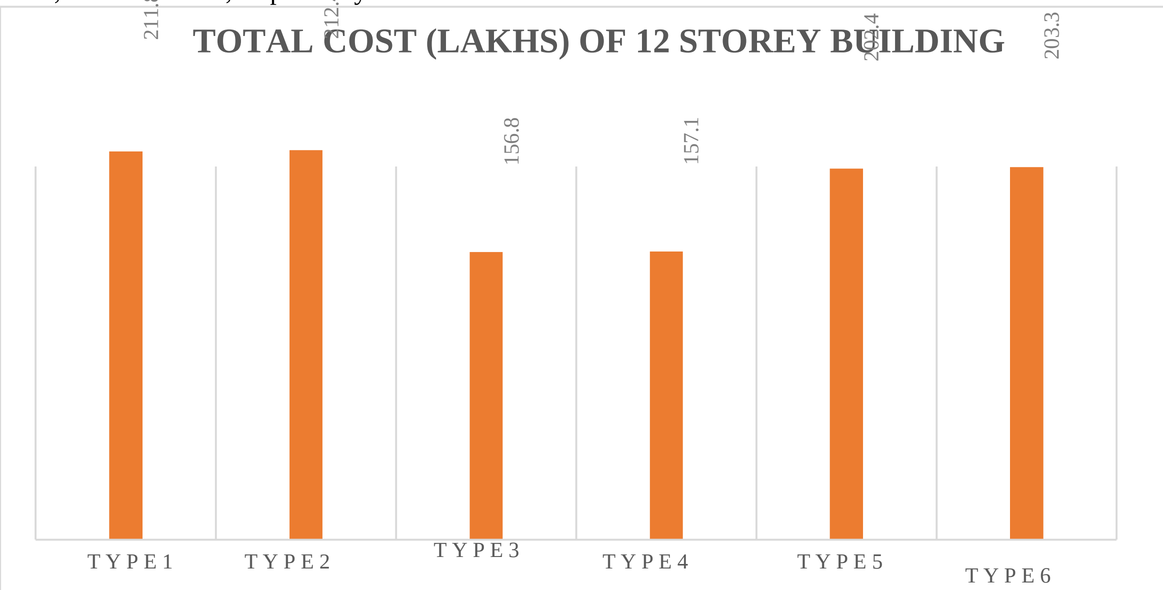

Figure5. Total Cost of 12 Storey Building.

Figure 5 depicts the total cost for a 12-story building's beams. In Type 1, the material quality for concrete and steel are 3027.3 cubic m and 2267.8 kN, respectively. In Type

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2, the material quality for concrete and steel are 3027.3 cubic m and 283.7 kN. Similarly, for Type 3, the material quality for concrete and steel is 1998.8 cubic m and 1922.2 kN. The material quality for concrete and steel in case of Type 4 are 1998.8 cubic m and 1928.0 kN. Similarly, the for Type 5 and Type 6 is 2678.6 cubic m, 2381.9 kN, and 2678.6 cubic m, and 2402.9 kN, respectively.

COMPARATIVE FIGURES FOR 16 STOREY BUILDING

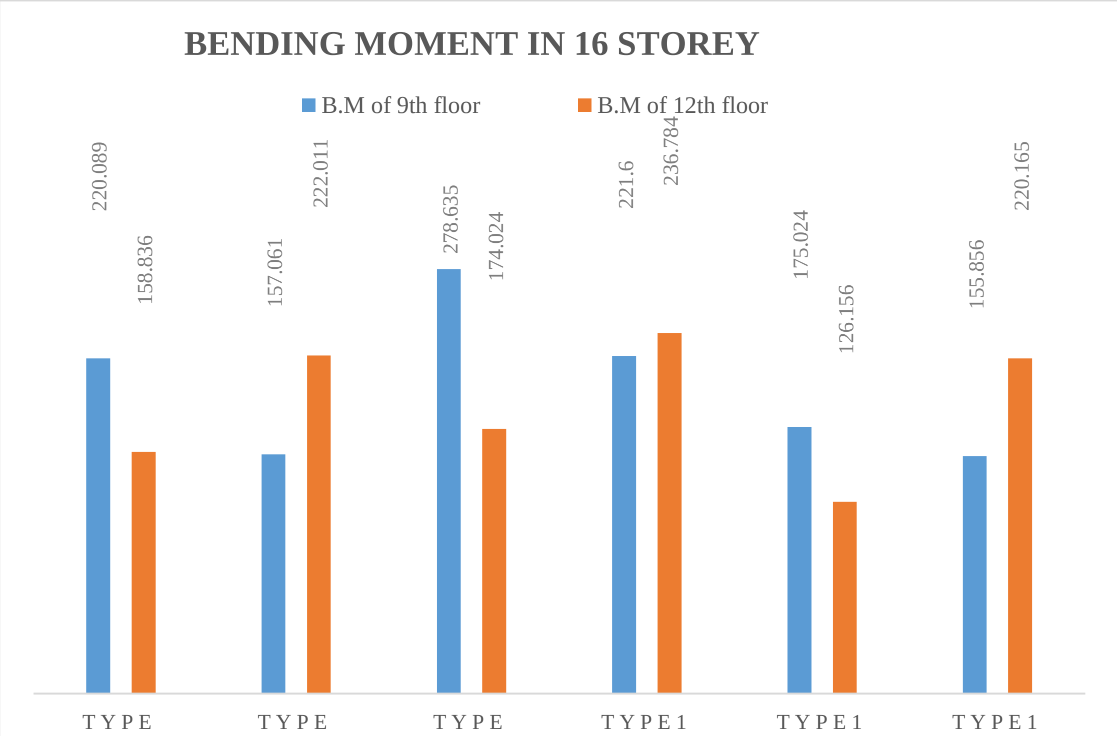

Figure 6. Maximum Bending Moment (kN-m) in Beams for 16 Storey Building.

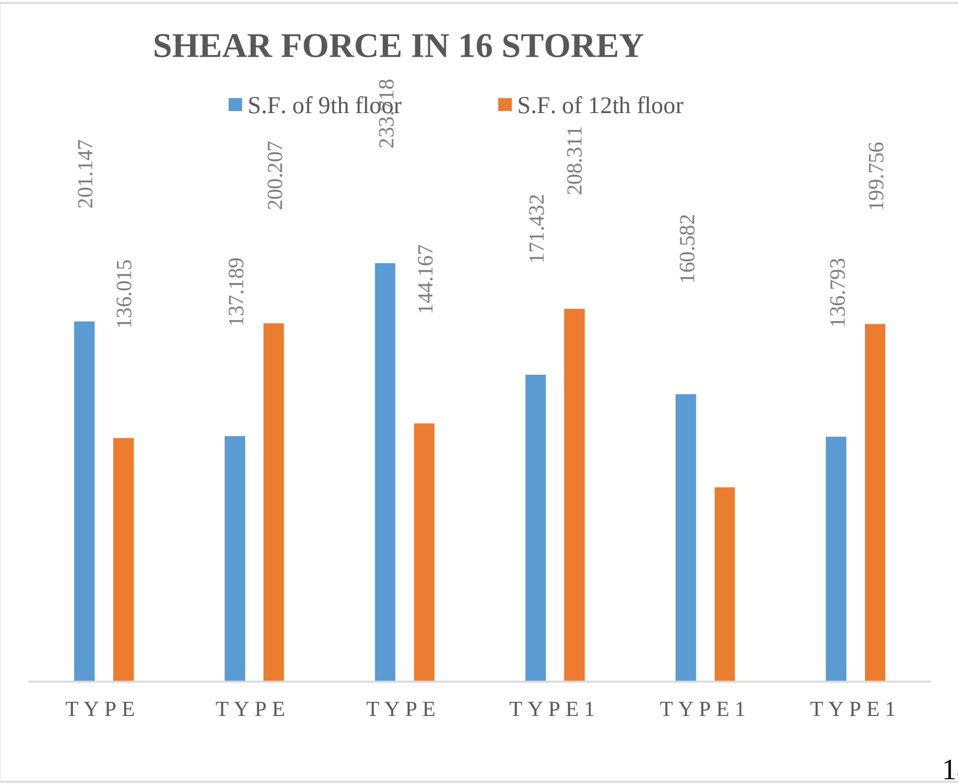

Figure 7. Maximum Shear Force (kN) in Beams for 16 Storey Building.

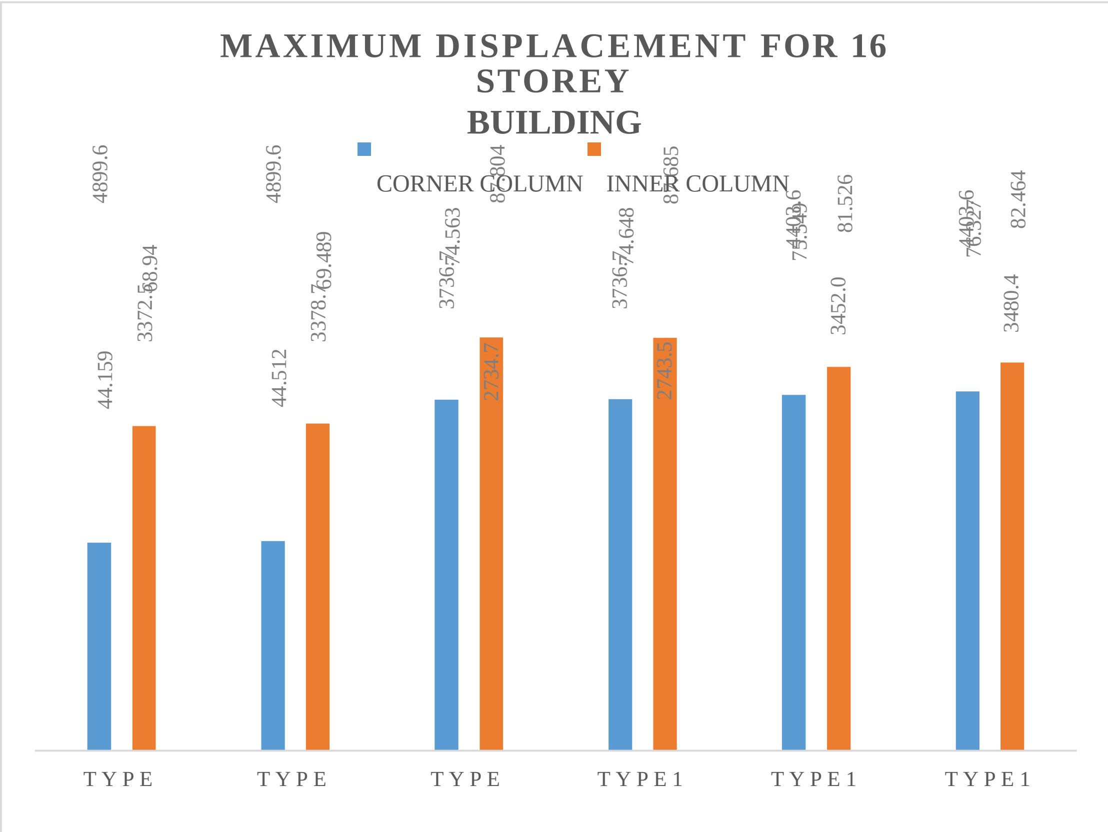

Figure 8. Maximum Displacement (mm) in Columns for 16 Storey Building.

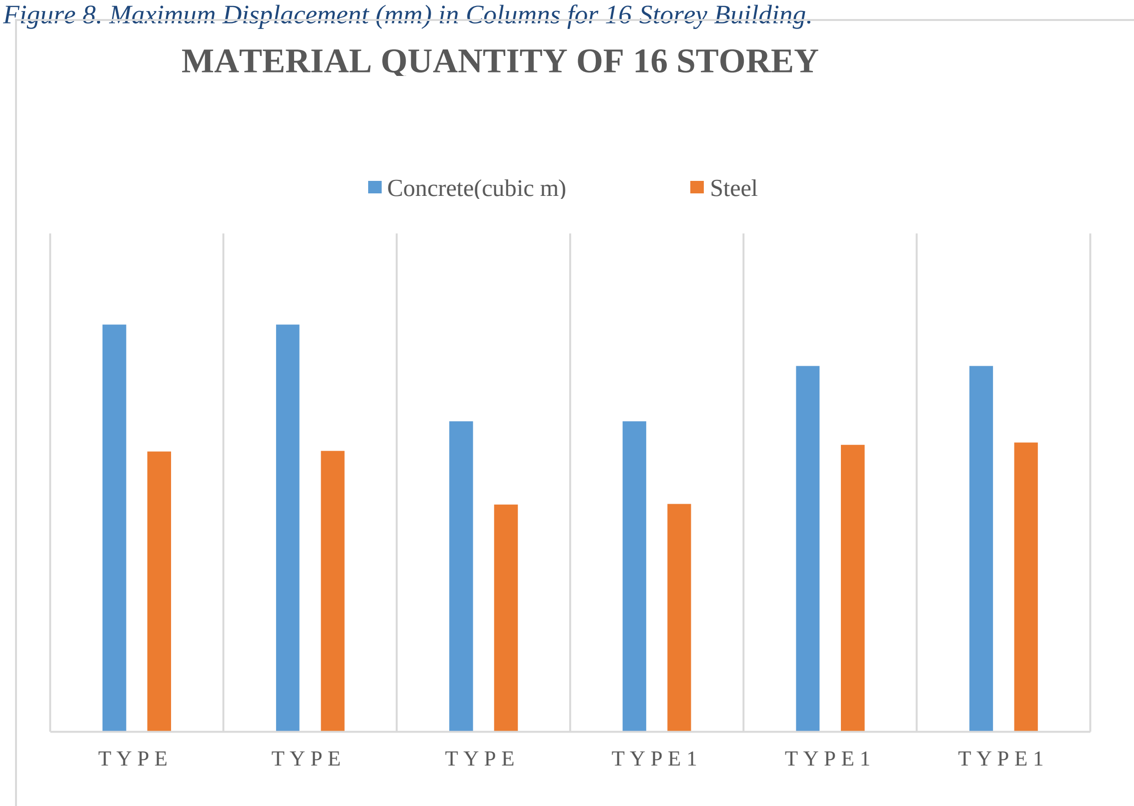

Figure 9. Total Material Quantity for 16 Storey Building.

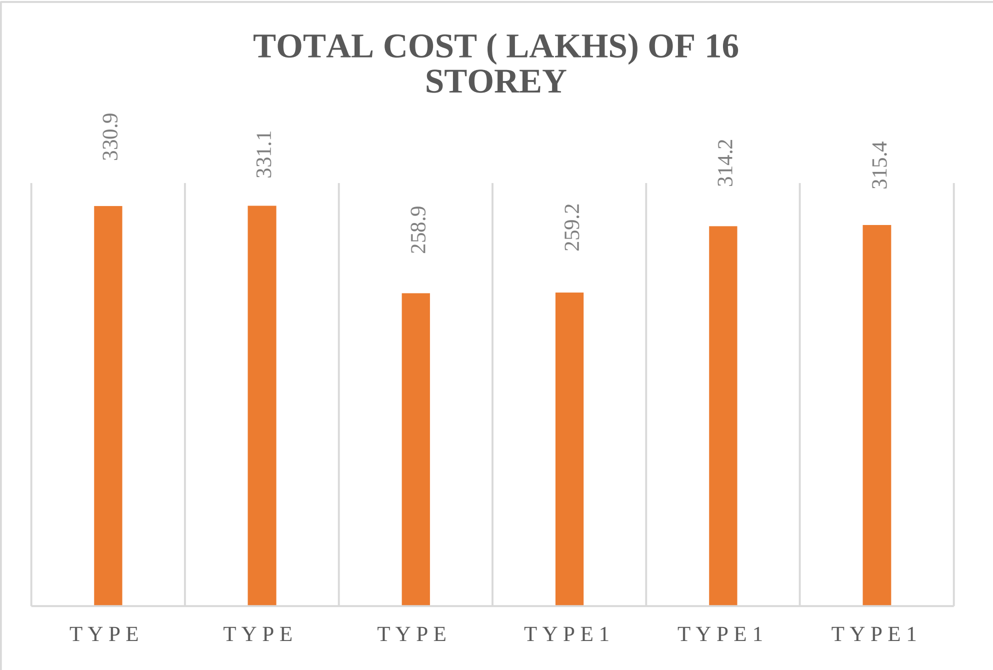

Figure10. Total Cost of 16 Storey Building

V. CONCLUSION

After analysing both the 12- and 16-story buildings, the findings may be found in the tables and figures of Section 4.1. The next part presents the concluding remarks of the current thesis, which are based on the findings of a well conducted investigation. The bending moment and shear force on a 12-story irregular structure have grown by 1.46 and 1.50 times, respectively, due to the addition of heavy loads on the floor. When a heavy object is moved from one level to another, the lateral sway of the column seldom changes since the displacement value is almost the same. When tested against lateral pressures, however, a 12-story L-shaped structure performs poorly because to the high amount of displacement it experiences (in this case, 82.405 millimetres). Total quantities and construction costs varied by just a small margin. Therefore, it may be stated that the quantity and cost of the building were not significantly affected when the heavy mass was relocated from the sixth to the ninth level of a 12-story structure. When large masses are put on the 9th and 12th floors of a 16-story irregular structure, the maximum bending moment ranges between 1.26 and 1.75 percent. Shear force, like bending moment, has substantial variance, with values ranging from 1.17 to 1.84 percent. Latera sway, measured as a change in maximum displacement, hardly budged when a big load was moved. Once again, the example of an L-shaped 16-story structure had the most displacement, measuring in at 87.804 mm. 90 Again, the transportation of heavy loads had little impact on the overall volume and price of the 16-story structure. Overall, it was determined that there was a rise from 1.17 percent to 1.84 percent in bending moments and shear forces. The B.M and S.F. of O-shaped buildings vary the most. The L-shaped building causes the most disruption of the three non-rectangular buildings.

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