Comparative Study of Diagrid Structures with and without Corner Columns

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Abstract: ***Construction of multi-storey building is rapidly increasing throughout the world. Advances in construction technology, materials, structural systems, analysis and design software facilitated the growth of these buildings. Recently the diagrid structural system has been widely used for tall buildings due to the structural efficiency and aesthetic potential provided by the unique geometric configuration of the system. In present work, concrete diagrid structures with and without corner columns were analysed and compared. Due to inclined columns, lateral loads are resisted by axial action of the diagonal in diagrid structure compared to buckling of vertical columns. A regular five storey RCC building with plan size 15 m × 15 m located in seismic zone V is considered for analysis. STAAD.Pro software is used for modelling and analysis of structural members. Load combinations of seismic forces are considered as per IS 1893(Part 1): 2002. Comparison of analysis results in terms of storey drift, lateral displacement, bending moment, shear forces and axial forces are presented. In diagrid structure, the major portion of lateral load is taken by external diagonal members which in turn release the lateral load in inner columns. Here, the value of axial force on interior columns for diagrid with corner column is two times more than the diagrid without corner columns. The axial force carried by the diagonal member get reduced due to the presence of corner column. Hence, the interior column has to take more axial force. Thus, the study can be concluded as the behaviour of structure without corner column is more effective than with corner columns.***

Keywords: diagrid, corner columns, storey drift, displacement, lateral forces

1. Introduction

Tall building development involves various complex factors such as economics, aesthetics look, technology, municipal regulations, and politics. Among these, economics has been the primary governing factor. For a very tall building, its structural design is generally governed by its lateral stiffness. Comparing with conventional orthogonal structures for tall buildings such as framed tubes, diagrid structures carry lateral wind loads much more efficiently by their diagonal member's axial action. Diagrid structure provides great structural efficiency without vertical columns have also opened new aesthetic potential for tall building architecture. Diagrid has a good appearance and it is easily recognized. The configuration and efficiency of a diagrid system reduces the number of structural element required on the facade of the buildings, therefore less obstruction to the outside view. The structural efficiency of diagrid system also helps in avoiding interior and corner columns, and therefore allowing significant flexibility with the floor plan. "Diagrid" system around perimeter saves approximately 20 percent of the structural steel weight when compared to a conventional moment-frame structure. The diagonal members in diagrid structural systems carry gravity loads as well as lateral forces due to their triangulated configuration. Diagrid can save upto 20% to 30% the amount of structural steel in a high-rise building.

The term "diagrid" is a combination of the words "diagonal" and "grid" and refers to a structural system that is single-thickness in nature and gains its structural integrity through the use of triangulation. Diagrid systems can be planar, crystalline or take on multiple curvatures, they often use crystalline forms or curvature to increase their stiffness. Perimeter diagrids normally carry the lateral and gravity loads of the building and are used to support the floor edges.

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There are engineering–based reasons that would suggest the use of a diagrid. Some of them are:
- Increased the stability due to triangulation.
- Combination of the gravity and lateral load-bearing systems, potentially providing more efficiency.
- Provision of alternate load paths (redundancy) in the event of a structural failure (which lacks in case of conventional framed building).
- Reduced weight of the super structure can translate into a reduced load on the foundations.

The distribution of load in diagrid structure are shown below:

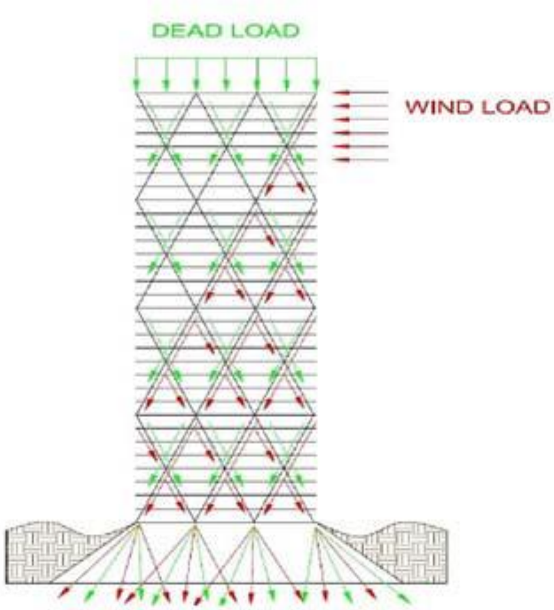

Figure 1: Load Distribution of Diagrid Structure

2. Methodology

In this study comparison of diagrids with and without corner columns under seismic forces is done. Here G+ 4 storey is taken and same live load is applied in both the buildings for its behaviour and comparison. The framed buildings are subjected to vibrations because of earthquake and therefore seismic analysis is essential for these building frames. The fixed base system is analyzed by employing in both building frames in seismic zone V by means of Staad.Pro software. The response of both the building frames is studied for useful interpretation of results.

A comparison of results in terms of moments, displacements, shear force, axial force and drift has been made. Following steps are adopted in this study:-

Step-1: Selection of building geometry and Seismic zone: The behaviour of both the models is studied for Zone V of Seismic zones of India as per IS code 1893 (Part 1):2002 for which zone factor (Z) is 0.36. Five storey building is taken. Each storey is of 3m height. Depth of foundation is taken as 1.5 m.
Step-2: Formation of load combination: load combinations are formulated as per IS code 1893 (part 1):2002.
Step-3: Modelling of building frames using STAAD.Pro software
Step-4: Analysis of both the building frames is done under seismic zone v and each load combination.
Step-5: Comparative study of results in terms of maximum moments in columns and beams, storey displacement, shear force, axial force and drift.

3. Structural Modeling

The following are the specification of G+4 storied commercial building located in seismic zone V. A regular plan of 15m x 15m is considered in both buildings. Storey height is 3m.the angle of inclination is 45º and kept it constant throughout the height. The design dead load is calculated and live load is taken as 4 kN/m^2. Exterior wall load is taken as negligible in both the buildings. Both the building frames are analysed for seismic zone V. seismic parameters are taken as per code IS 1893 (Part 1):2002. Here two structural diagrid models are created, one with 4 corner columns and other without corner columns.

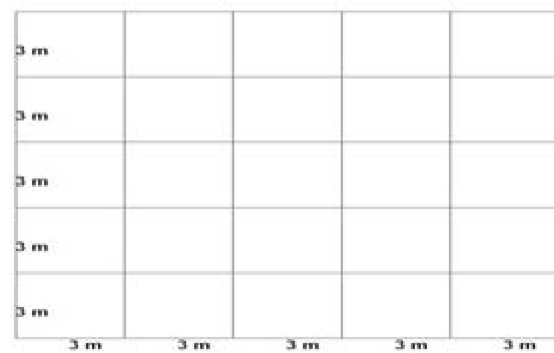

Figure 2: Plan of the Building Frame

The three dimensional regular frames of G+4 storied building with and without corner columns were considered in this study. Figure 2 shows the plan of the building representing the X and Z direction used for analysis. Figure 3 shows a configuration model of frame with corner column. Figure 4 shows a configuration model of frame without corner column.

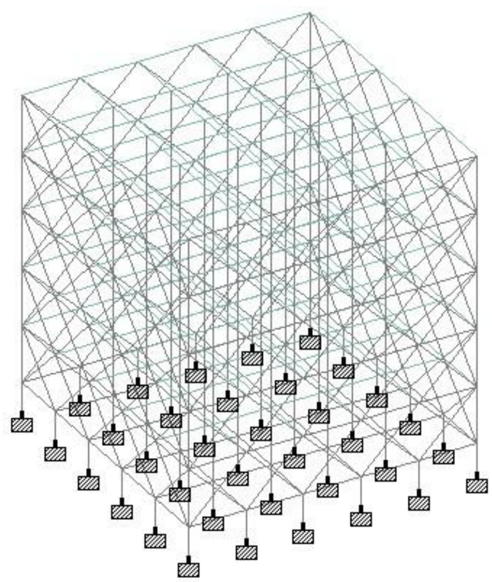

Figure 3: Building Frame with Corner Columns

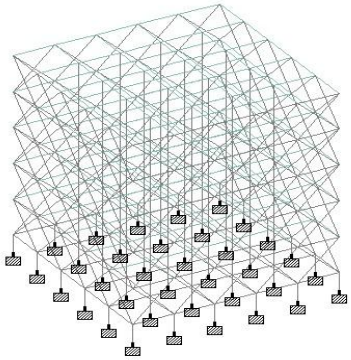

Figure 4: Building Frame without Corner Columns

4. Analysis

4.1 Beam Analysis

Size of beam is taken as 200 x 400 mm for both buildings. The shear force and bending moment in beams for different floors are compared between diagrids with and without corner columns.

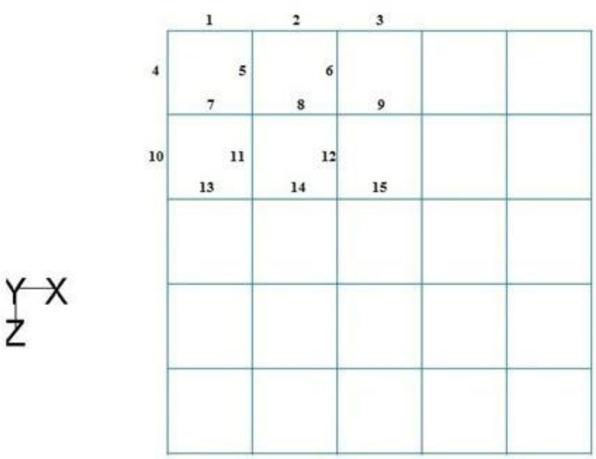

Figure 5: Plan of Building Showing the Selected Beam Numbering

Table 1: Comparison of Maximum Shear Forces and Bending Moments in Ground Floor Beams

Beam No.	*With corner columns*		*Without corner columns*		*Ratio*	
	F_Y (kN) (1)	M_Z(kNm) (2)	F_Y(kN) (3)	M_Z(kNm) (4)	(3/1)	(2/4)
1	18.179	12.65	18.66	13.507	1.026	1.06
2	18.460	12.963	18.25	12.743	0.988	0.983
3	17.741	10.824	17.740	12.133	0.999	1.12
4	18.179	11.470	18.660	13.574	1.026	1.183
5	32.177	18.744	32.014	18.603	0.995	0.992
6	31.537	19.376	31.619	19.153	1.0026	0.988
7	32.177	18.744	32.014	18.603	0.995	0.992
8	33.17	14.984	32.246	16.914	0.972	1.128
9	31.241	18.883	31.241	18.955	1	1.003
10	18.460	12.963	18.250	12.743	0.988	0.983
11	33.174	14.984	30.236	16.914	0.911	1.128
12	32.910	15.604	32.015	17.436	0.977	1.117
13	31.537	19.376	31.619	19.153	1.003	0.988
14	32.910	15.604	32.015	17.436	0.977	1.117
15	31.241	18.863	31.241	18.947	1	1.004

4.2 Interior Column Analysis

The analysis of the interior column is carried out at each floor in terms of axial force bending moment in y and z direction. The plan of the selected location for analysis is shown in fig. The behaviour of the rest of interior column is shown by symmetry. The selected location of the column to be analysed.

The size of the column is taken as 300 x 300 mm throughout the structure (interior vertical column as well as exterior diagonal column).

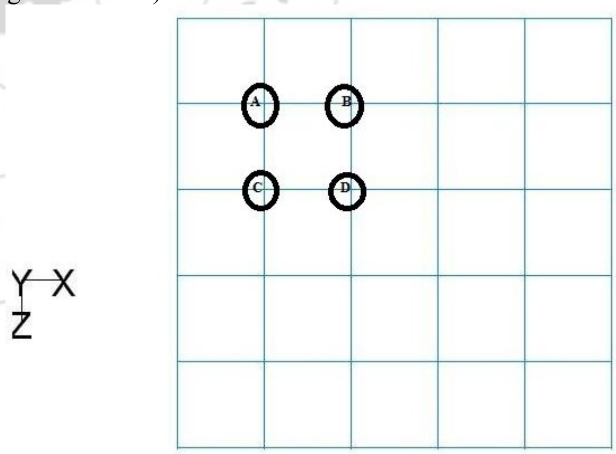

Figure 6: Selected Location of the Column for Result Discussion

Table 2: Comparison of Axial Forces and Bending Moments (y and z direction) in Interior Column Analysis for Location A

Location A	*With corner columns*			*Without corner columns*			*Ratio*		
	F_X(kN) (1)	M_Y(kNm) (2)	M_Z(kNm) (3)	F_X(kN) (4)	M_Y(kNm) (5)	M_Z(kNm) (6)	(4/1)	(5/2)	(6/3)
0	217.08	1.701	0.465	117.13	1.824	0.898	0.5	1	1.93
1	137.20	1.898	1.898	69.031	1.129	1.116	0.5	0.6	0.6
2	101.19	2.563	2.563	47.88	1.476	1.473	0.5	0.6	0.6
3	70.178	2.569	2.804	34.537	1.722	1.722	0.5	0.7	0.6
4	48.045	3.933	3.933	30.495	2.509	2.509	0.6	0.6	0.6

5. Results and Discussion

From the output of STAAD.Pro, various results are obtained. And these results are evaluated by preparing various tabular columns and graphs.

From shear force and bending moment diagram, the corner beams having the values half of the interior beams. For both structures, shear force and bending moment are approximately same.

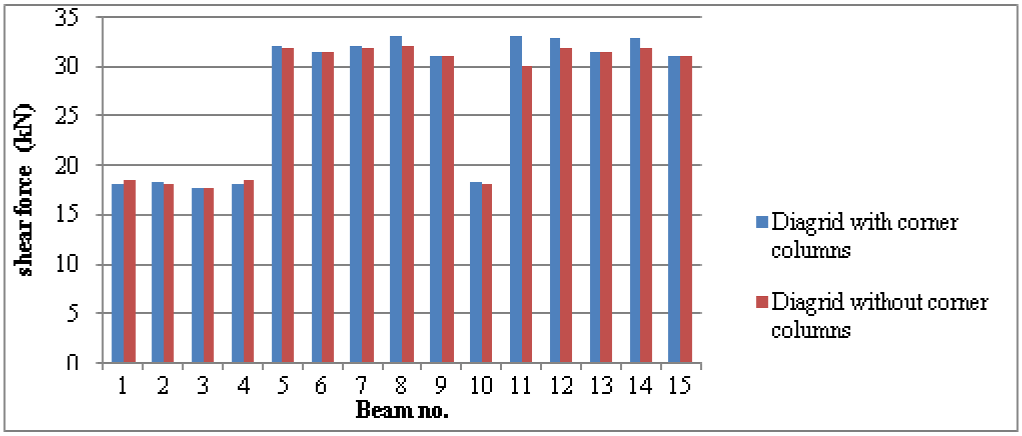

Figure 7: Comparison of Shear Force in Ground Floor

From the obtained results, the shear forces for both diagrids with and without corner columns are approximately same. Therefore, there no effect on shear force by corner columns in diagrid structure. From the obtained results, the bending moments for both diagrids with and without corner columns are approximately same. Therefore, there no effect on bending moment by corner columns in diagrid structure.

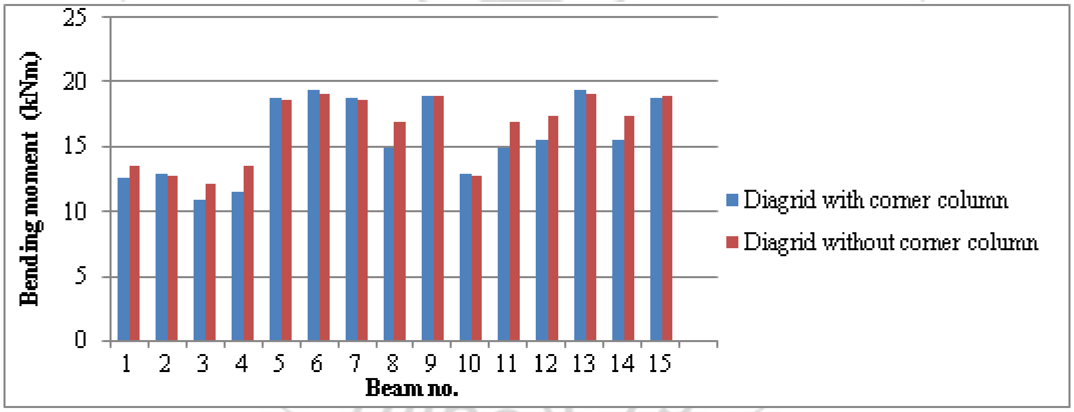

Figure 8: Comparison of Bending Moment in Ground Floor

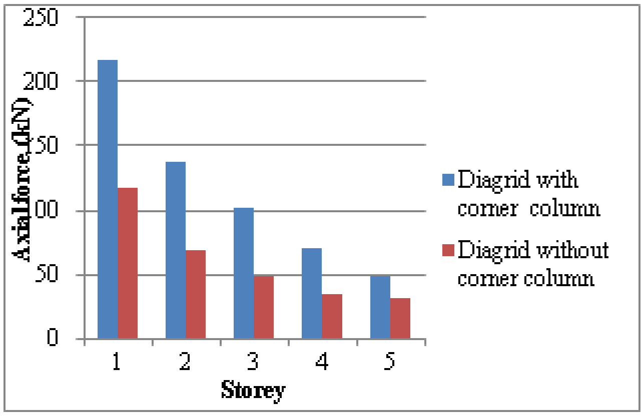

Figure 9: Comparison of Axial Force in Columns at Location A

From this, it is clear that value of axial forces in the interior column in the diagrid with corner columns is half of that without corner column. Similar behaviour is seen in location at B, C and D.

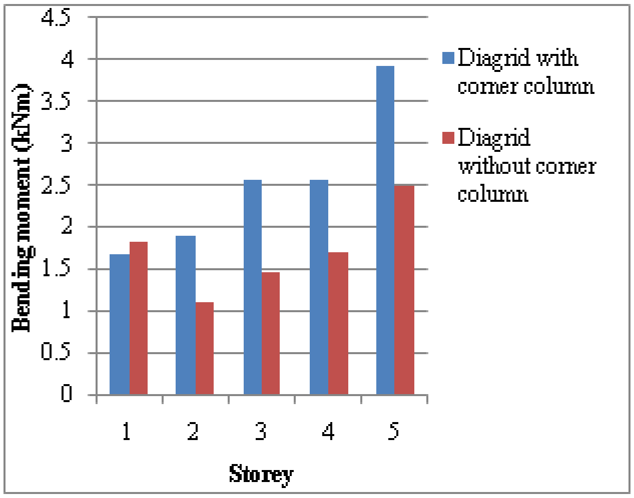

Figure 10: Comparison of Bending Moment in Columns at Location A

From the results, the value of bending moment in interior columns are 0.6 times for diagrids without corner column than in diagrid with corner columns.

4.1 Lateral Displacement and Storey Drift

Lateral displacement means the total displacement of the floor with respect to the ground. It is caused due to the lateral forces (wind or seismic) acting on building.

Table 3: Comparison of Lateral Displacement

Floor	*Diagrid without corner column (mm)*	*Diagrid with corner column (mm)*
Ground floor	0.165	0.147
First floor	0.305	0.288
Second floor	0.473	0.475
Third floor	0.657	0.641
Fourth floor	0.841	0.824
Fifth floor	1.007	0.987

The graphs of lateral displacement versus number of storey are plotted for diagrids with and without corner columns.

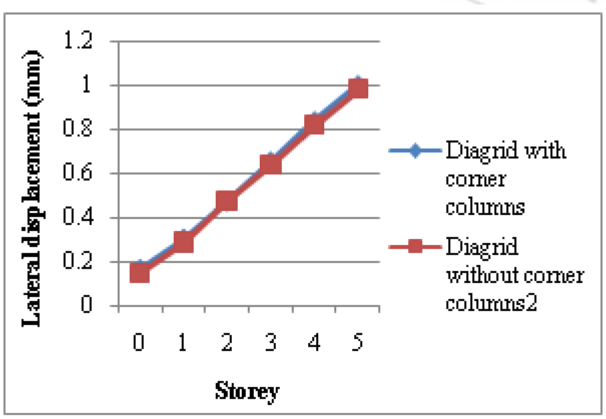

Figure 11: Lateral Displacement at Each Floor

Lateral displacement for both diagrids with and without corner columns has approximately same value. Then there is no effect of corner columns in lateral displacement. Drift means the relative displacement of floor with respect to lower one. The graphs of storey drift versus number of storey are plotted for diagrids with and without corner columns.

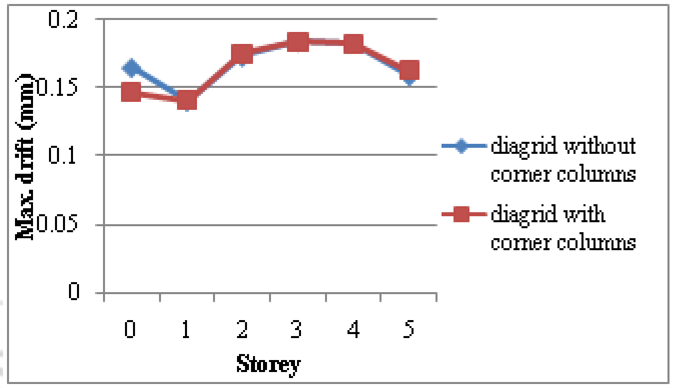

Figure 12: Maximum Drift of Floor with Respect to Adjacent Floor

Storey drift for both diagrids with and without corner columns has approximately same value. Then there is no effect of corner columns in storey drift.

6. Conclusions

The main conclusions obtained from the analysis of building frame are summarized below

- The values of shear force, bending moment, lateral displacement and storey drift are approximately same for the diagrids with and without corner columns.
- When considering axial forces in the interior columns, the value for diagrid with corner column is two times more than the diagrid without corner columns.
- The axial force carried by the diagonal member get reduced due to the presence of corner column. Hence, the interior column has to take more axial force.
- Thus, the study can be concluded as the behaviour of structure without corner column is more effective than with corner columns.

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