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Behaviour of Multistory Steel Structure with Different Types of Bracing Systems (A Software Approach)

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Abstract:- Steel has some important physical properties like the high strength per unit weight and ductility as compare to reinforced cement concrete structure. Due to high yield and ultimate strength member sizes comprising the structure are slender sections. Structural steel special moment frames often are used as part of the seismic force-resisting systems in buildings designed to resist seismic loads. Bracings are required to inhibit lateral buckling the members.

Keywords:- Bracing, Lateral Buckling, Moment Frames, Seismic Loads, Steel Structure

I. INTRODUCTION

Steel braced structural frame is one of the structural systems used to resist earthquake loads in multistoried buildings. In the present study, the seismic performance of steel buildings under braced and unbraced system is investigated. The bracings are provided in the peripheral columns. A fourteen story building is analyzed for seismic zone IV as per IS 1893:2002 using STAAD V8i software. The performance of different types of bracing system has been examined. Steel bracing for steel frames is used to reduce drift demands. Bracing can either be implemented from inside the frame or applied from outside of the system. Although its application inside the building is not easy for those buildings with small openings, it particularly allows easy installation across the axes on external facades. Architectural characteristics and functionality can be less disturbed by using an appropriate bracing style

II. OBJECTIVE OF THIS PAPER

The objective of this paper is to evaluate the response of braced and unbraced structure subjected to seismic loads and to identify the suitable bracing system for resisting the seismic load efficiently.

III. MODELLING AND ANALYSIS OF BUILDING

TABLE 1. MODELLING DATA

Structure	**SMRF**
No. of stories	G+14
Type of building use	Residential
Young's modulus, E	2.05×10^5 N/mm^2
Density of Steel	76.8 kN/m^3
Beam Size	0.18x0.26x0.006m
Column Size	0.25x0.25x0.012m
Dead Load Intensity	5 kN/m^2
Live Load Intensity	3.0 kN/m^2
Seismic Zone, Z	IV
Importance Factor, I	1
Response Reduction Factor, R_F	5

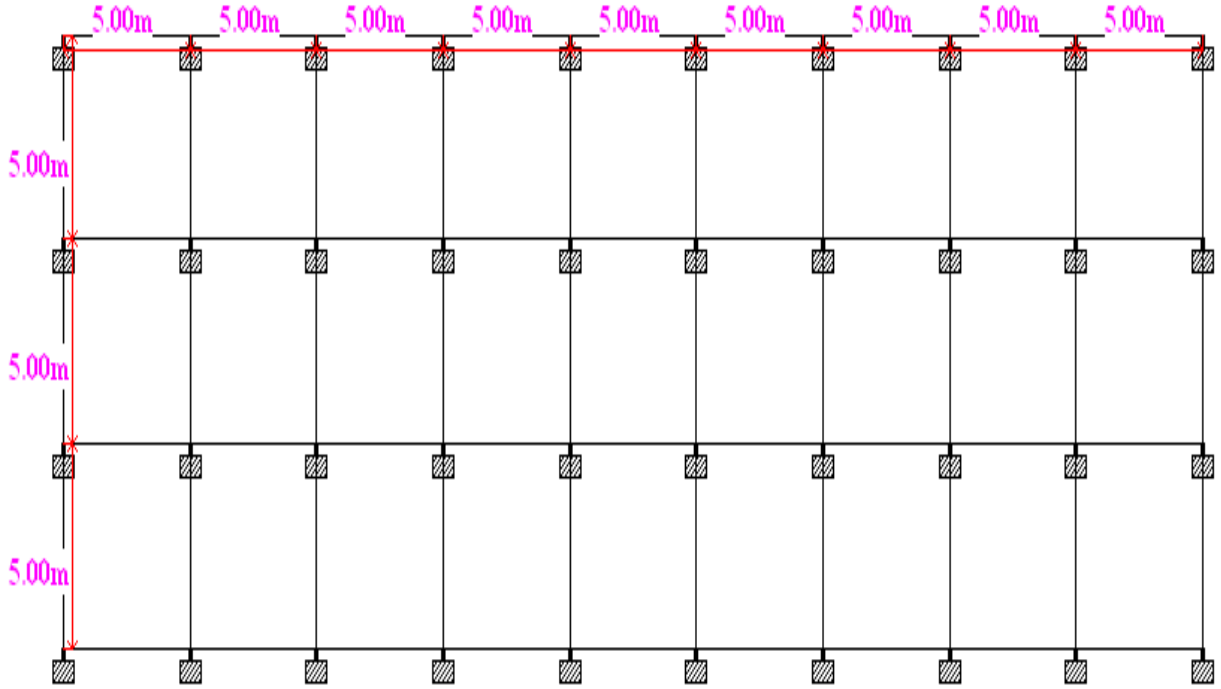

Fig. 1 Plan of a structure

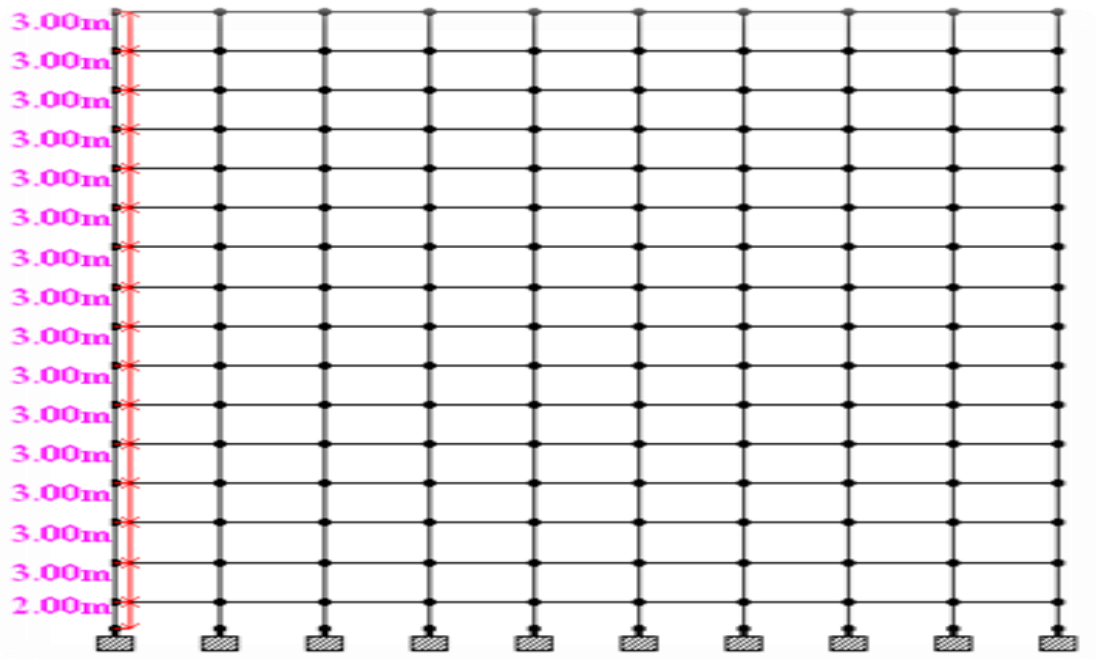

Fig. 3 Elevation of Unbraced Structure

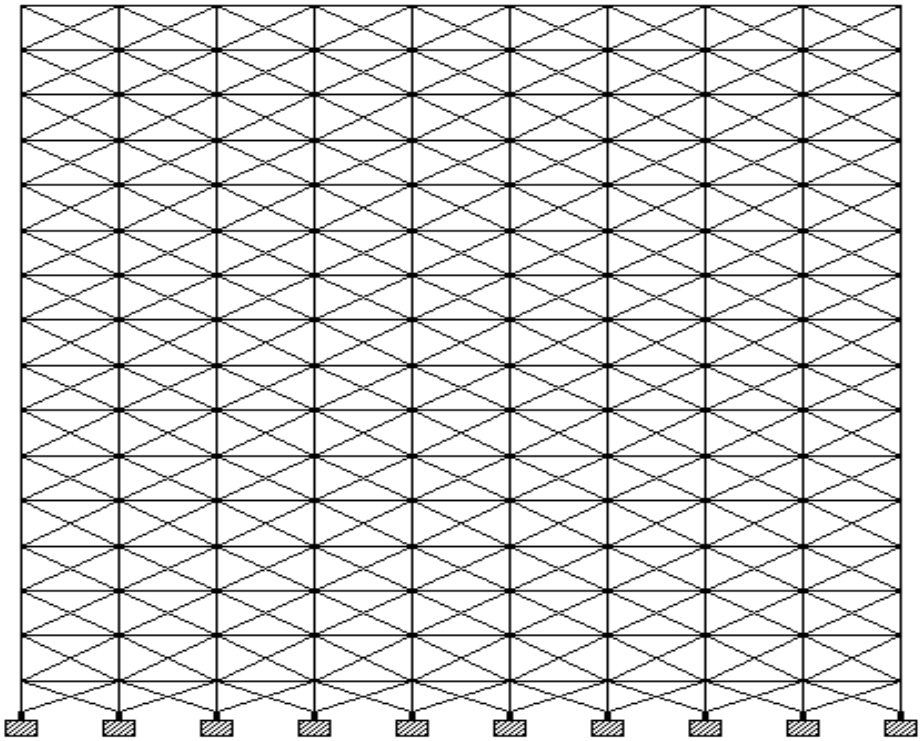

Fig. 3 Elevation of Cross Braced Structure

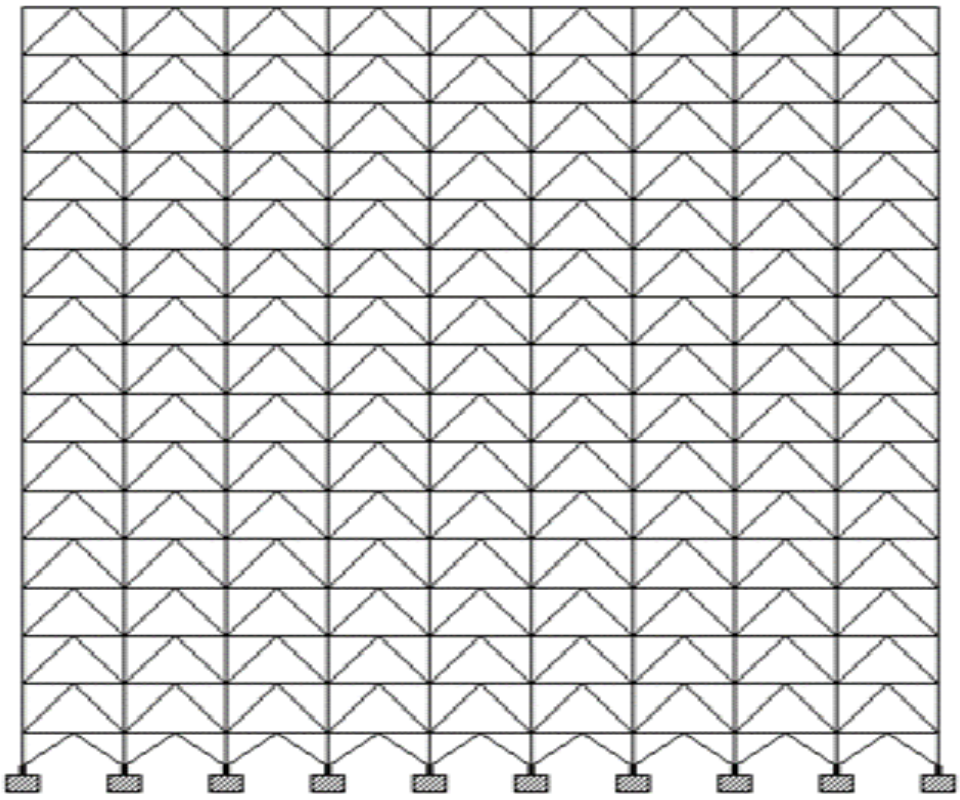

Fig. 4 Elevation of Chevron Braced Structure

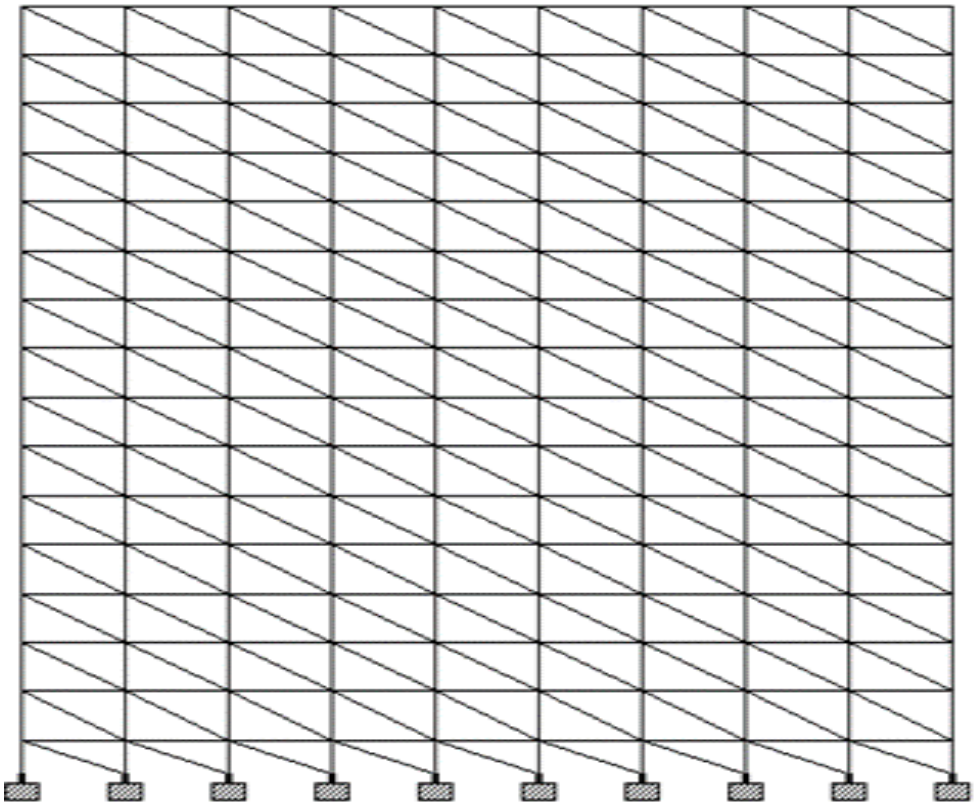

Fig. 5 Elevation of Diagonal Braced Structure

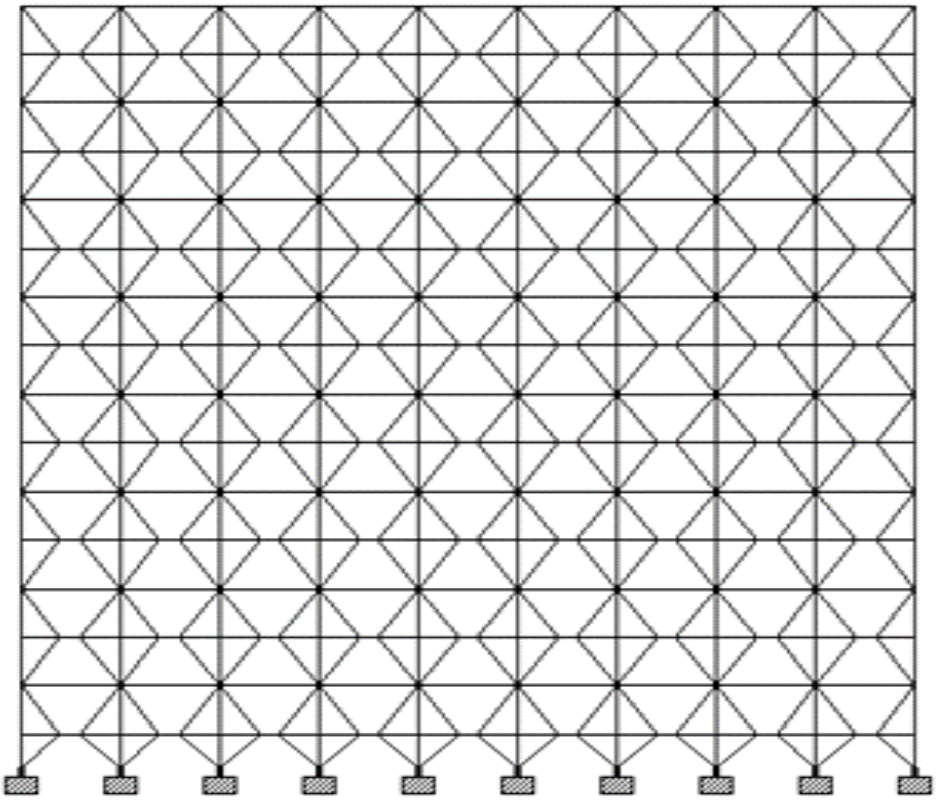

Fig. 6 Elevation of K - Braced Structure

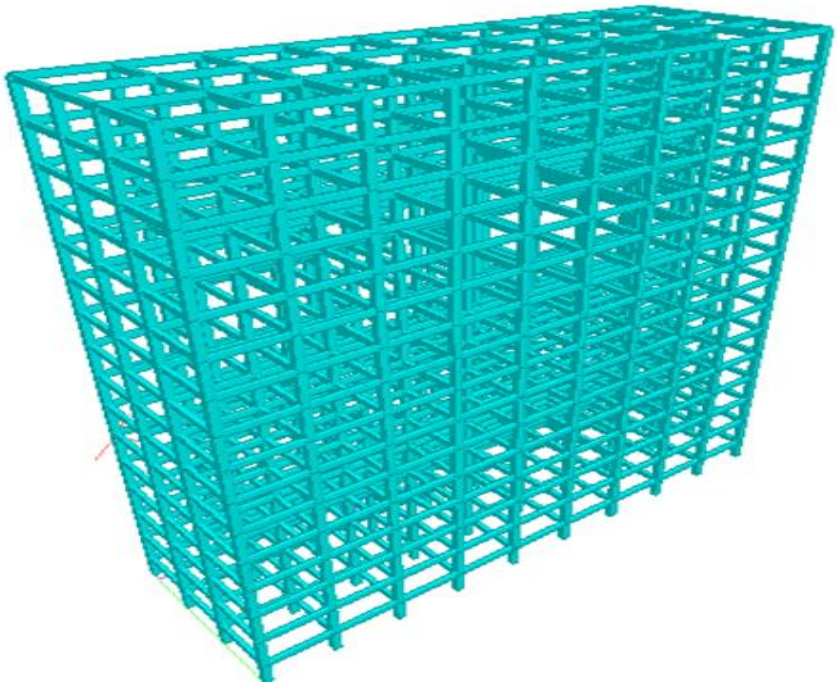

Fig.7 Unbraced Structure

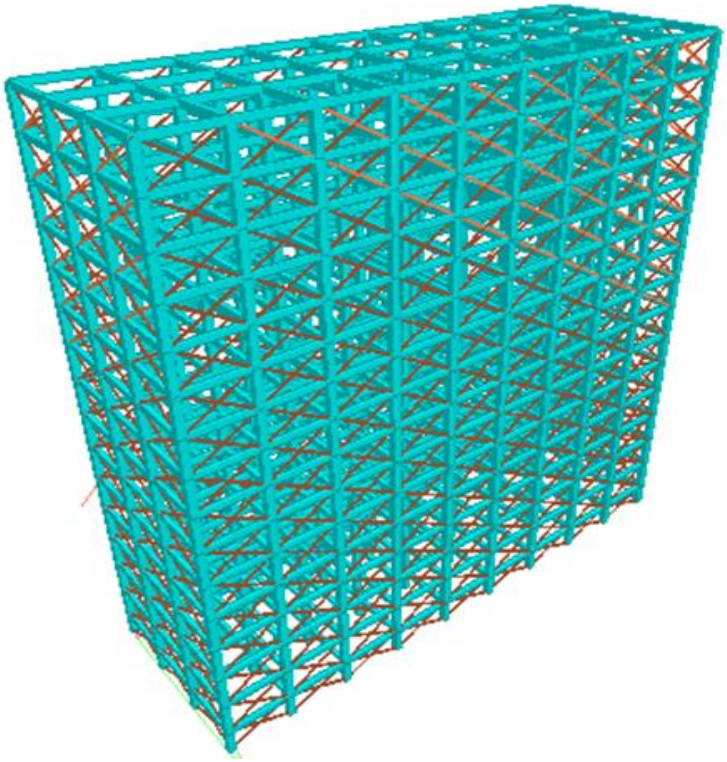

Fig.8 Structure with Cross Bracings

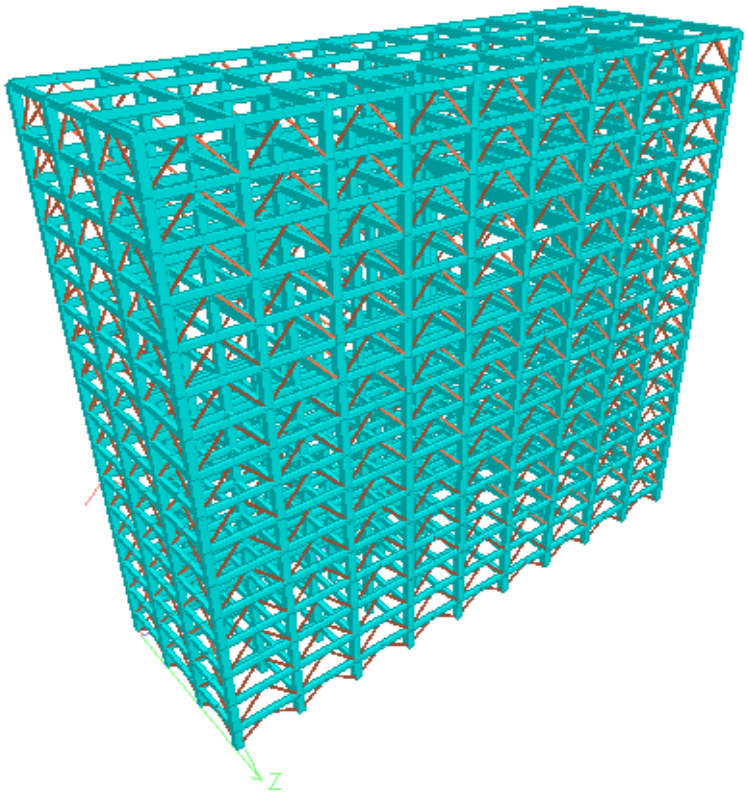

Fig.9 Structure with Chevron Bracings

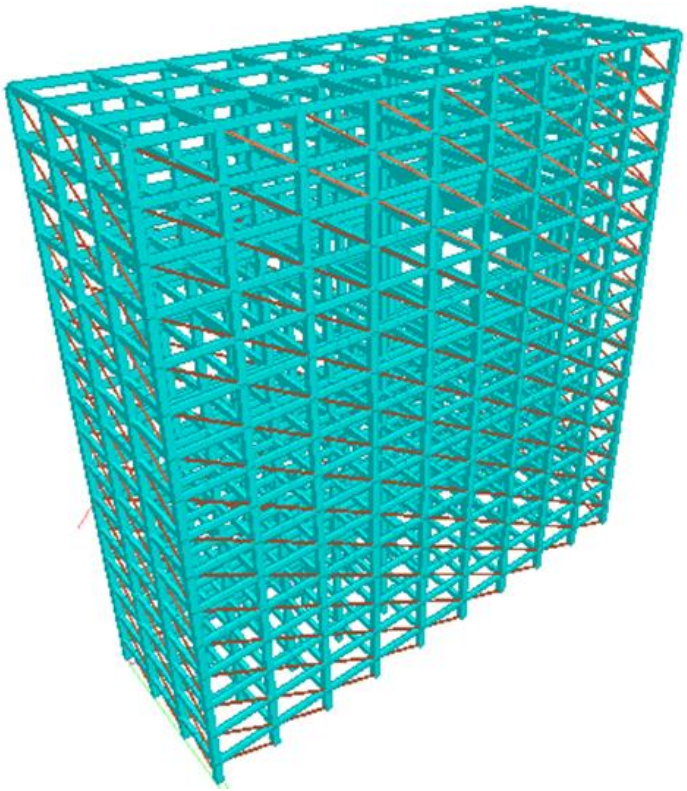

Fig.10 Structure with Diagonal Bracings

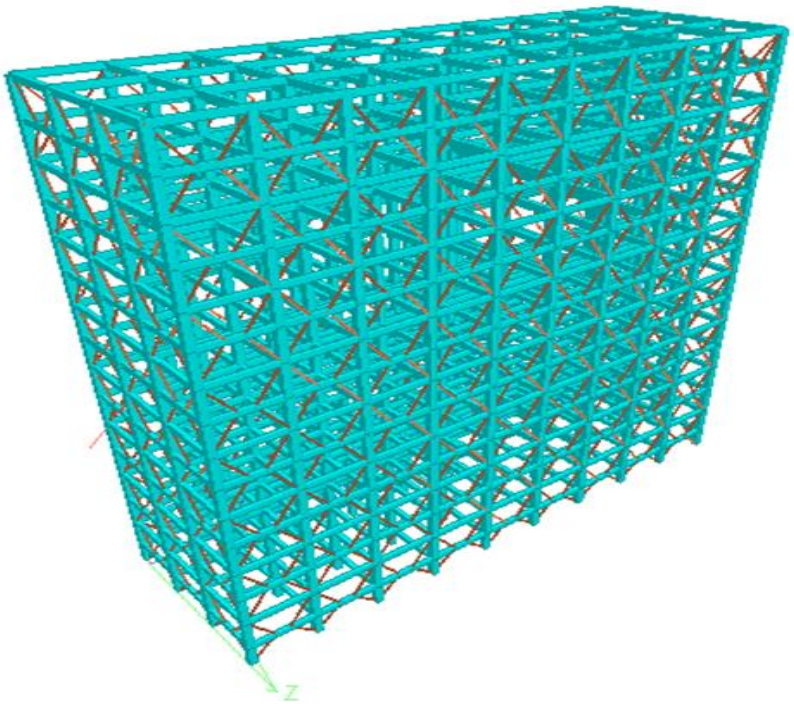

Fig.11 Structure with K- Bracings

IV. RESULTS

TABLE 2. Maximum Lateral Displacement (mm) in X Direction

Level	Structure Type				
	Unbraced	**Cross Braced**	**Chevron Braced**	**K- Braced**	**Diagonal Braced**
15	120.7	30.6	32.2	53.8	41.2
14	118.5	30.9	29.5	49.5	35.4
13	115.0	29.1	28.0	50.4	37.9
12	110.1	26.8	26.1	45.0	31.8
11	104.1	24.4	23.9	44.9	32.7
10	97.0	21.9	21.6	39.0	27.0
9	89.1	19.3	19.3	37.5	26.8
8	80.4	16.8	16.9	32.0	21.7
7	71.3	14.3	14.6	29.5	20.5
6	61.7	11.9	12.3	24.4	16.2
5	51.7	9.7	10.1	21.2	14.4
4	41.6	7.6	7.9	16.5	10.8
3	31.3	5.7	5.9	12.9	8.6
2	21.0	3.8	4.0	8.7	5.6
1	10.9	2.1	2.2	4.8	3.3
Ground	2.4	0.6	0.6	1.5	1.0
Base	0	0	0	0	0

TABLE 3. Maximum Lateral Displacement (mm) in Z Direction

Level	Structure Type				
	Unbraced	**Cross Braced**	**Chevron Braced**	**K- Braced**	**Diagonal Braced**
15	133.0	75.7	77.4	93.7	84.5
14	130.3	75.0	73.6	88.0	78.1
13	126.1	71.7	70.5	87.9	78.7
12	120.5	67.5	66.5	80.3	70.7
11	113.7	62.6	61.9	78.1	69.2
10	105.7	57.3	56.7	69.4	60.4
9	96.9	51.6	51.1	65.5	57.4
8	87.3	45.6	45.3	56.5	48.5
7	77.2	39.6	39.4	51.4	44.5
6	66.6	33.6	33.4	42.5	36.1
5	55.7	27.6	27.5	36.5	31.3
4	44.6	21.8	21.7	28.2	23.6
3	33.3	16.1	16.0	21.8	18.4
2	22.2	10.6	10.6	14.1	11.6
1	11.4	5.5	5.5	7.6	6.3
Ground	2.5	1.2	1.2	1.8	1.5
Base	0	0	0	0	0

Table 4. Maximum Axial Force (kN) in Columns for Dead and Live Load

Level	Structure Type				
	Unbraced	**Cross Braced**	**Chevron Braced**	**K- Braced**	**Diagonal Braced**
Base to Ground	3197.2	3189.8	3189.0	3169.9	3195.9
Ground to 1st	2991.3	2983.9	2983.2	2964.2	2989.7
1st to 2nd	2786.0	2778.8	2777.9	2759.3	2784.5
2nd to 3rd	2581.9	2574.9	2574.1	2556.0	2580.5
3rd to 4th	2379.0	2372.4	2371.5	2354.1	2377.7
4th to 5th	2177.3	2171.1	2170.1	2153.6	2176.1
5th to 6th	1976.5	1970.7	1969.8	1954.3	1975.4
6th to 7th	1776.7	1771.3	1770.4	1756.2	1775.7
7th to 8th	1577.7	1572.8	1571.9	1559.0	1576.8
8th to 9th	1379.3	1375.1	1374.2	1362.7	1378.6
9th to 10th	1181.7	1177.9	1177.1	1167.2	1181.0
10th to 11th	984.5	981.4	980.6	972.3	983.9
11th to 12th	787.8	785.3	784.6	778.0	787.3
12th to 13th	591.4	589.6	589.0	584.1	591.1
13th to 14th	395.3	394.1	393.7	390.5	395.1
14th to 15th	200.0	199.2	199.1	197.7	199.7

Table 5. Maximum Axial Force (kN) in Columns for Seismic Load in X-Direction

Level	Structure Type				
	Unbraced	**Cross Braced**	**Chevron Braced**	**K- Braced**	**Diagonal Braced**
Base to Ground	145.8	435.9	432.7	308.5	429.0
Ground to 1st	137.6	367.5	364.0	330.1	373.4
1st to 2nd	125.4	311.1	307.4	221.1	346.6
2nd to 3rd	112.6	264.9	258.8	246.4	314.4
3rd to 4th	99.8	225.0	216.1	156.5	279.5
4th to 5th	87.1	189.4	177.8	178.6	244.0
5th to 6th	74.9	164.4	149.8	100.7	209.1
6th to 7th	63.0	140.8	127.7	119.7	175.5

7th to 8th	51.7	118.0	106.3	63.7	143.6
8th to 9th	41.0	96.4	85.9	69.6	114.6
9th to 10th	31.1	76.3	66.9	43.0	95.6
10th to 11th	22.3	57.9	49.5	43.7	75.9
11th to 12th	14.7	41.4	33.9	23.7	57.5
12th to 13th	8.4	27.1	20.3	25.0	43.0
13th to 14th	3.9	15.2	9.0	7.3	28.4
14th to 15th	1.2	7.9	2.2	10.2	15.6

Table 6. Maximum Axial Force (kN) in Columns for Seismic Load in Z-Direction

Floor Level	Structure Type				
	Unbraced	**Cross Braced**	**Chevron Braced**	**K- Braced**	**Diagonal Braced**
Base to Ground	163.4	428.5	445.1	369.7	481.1
Ground to 1st	154.8	364.6	378.8	393.9	441.8
1st to 2nd	141.7	307.6	321.2	268.9	393.2
2nd to 3rd	127.7	258.1	269.5	298.2	344.1
3rd to 4th	113.5	214.8	222.9	192.1	297.7
4th to 5th	99.6	176.3	180.9	218.2	254.4
5th to 6th	85.9	141.8	143.1	125.5	214.1
6th to 7th	72.6	115.0	110.5	147.9	176.8
7th to 8th	59.9	95.8	91.2	70.1	142.7
8th to 9th	47.8	77.8	73.1	88.3	112.0
9th to 10th	36.6	61.3	56.4	45.7	85.6
10th to 11th	26.6	48.1	41.3	45.3	68.7
11th to 12th	17.8	36.0	28.1	25.2	52.9
12th to 13th	10.6	25.7	16.8	25.8	38.1
13th to 14th	5.1	18.8	7.9	10.3	24.4
14th to 15th	1.7	17.6	2.9	11.1	11.9

Table 7. Maximum Shear Force (kN) in Columns for Dead and Live Load

Floor Level	**Structure Type**				
	Unbraced	**Cross Braced**	**Chevron Braced**	**K- Braced**	**Diagonal Braced**
Base to Ground	17.8	21.3	17.8	17.9	19.6
Ground to 1st	17.6	17.7	17.6	17.9	19.1
1st to 2nd	18.5	18.7	18.7	19.0	19.8
2nd to 3rd	20.9	19.9	19.8	20.4	20.8
3rd to 4th	20.5	20.9	20.9	21.5	21.7
4th to 5th	21.3	21.8	20.8	22.6	22.5
5th to 6th	22.1	22.7	22.7	23.5	23.3
6th to 7th	22.7	23.5	23.4	24.4	23.9
7th to 8th	23.5	24.1	24.1	25.2	24.6
8th to 9th	23.9	24.8	24.8	25.9	25.0
9th to 10th	24.3	25.3	25.3	26.4	25.4
10th to 11th	24.7	25.7	25.8	27.0	25.7
11th to 12th	25.0	26.0	26.1	27.3	26.0
12th to 13th	25.4	26.5	26.5	27.8	26.3
13th to 14th	24.8	25.9	26.1	27.3	25.7
14th to 15th	34.7	36.0	36.1	37.9	35.6

Table 8. Maximum Shear Force (kN) in Columns for Seismic Load in X-Direction

Floor Level	Structure Type				
	Unbraced	Cross Braced	Chevron Braced	K- Braced	Diagonal Braced
Base to Ground	20.4	10.2	9.8	9.2	32.4
Ground to 1st	20.8	4.6	5.1	9.1	6.4
1st to 2nd	21.2	4.8	5.3	9.1	6.6
2nd to 3rd	21.1	5.2	5.7	9.2	6.8
3rd to 4th	20.9	5.7	6.1	9.3	7.1
4th to 5th	20.6	6.2	6.6	9.6	7.5
5th to 6th	20.2	6.7	7.2	9.7	7.9
6th to 7th	19.6	7.3	7.7	9.8	8.3
7th to 8th	18.8	7.8	8.1	9.8	8.5
8th to 9th	17.7	8.2	8.5	9.8	8.7
9th to 10th	16.3	8.5	8.7	9.4	8.8
10th to 11th	14.7	8.5	8.7	9.1	8.7
11th to 12th	12.7	8.3	8.4	8.3	8.3
12th to 13th	10.3	7.7	7.6	7.4	7.5
13th to 14th	7.5	6.5	6.2	5.7	6.2
14th to 15th	4.4	4.6	4.1	4.0	4.4

Table 9. Maximum Shear Force (kN) in Columns for Seismic Load in Z-Direction

Floor Level	Structure Type				
	Unbraced	Cross Braced	Chevron Braced	K- Braced	Diagonal Braced
Base to Ground	21.0	14.9	15.2	16.9	24.8
Ground to 1st	22.0	15.5	16.0	17.7	16.3
1st to 2nd	23.1	16.5	17.0	18.7	17.4
2nd to 3rd	23.2	16.9	17.3	18.9	17.7
3rd to 4th	23.1	17.2	17.6	19.1	17.9
4th to 5th	22.8	17.5	17.9	19.2	18.1
5th to 6th	23.3	17.7	18.0	19.1	18.2
6th to 7th	21.6	17.7	18.0	19.0	18.2
7th to 8th	20.7	17.5	17.8	18.4	17.9
8th to 9th	19.5	17.0	17.3	17.9	17.4
9th to 10th	18.0	16.3	16.4	16.7	16.5
10th to 11th	16.1	15.1	15.1	15.5	15.2
11th to 12th	13.9	13.4	13.3	13.3	13.5
12th to 13th	11.2	11.1	10.9	11.3	11.2
13th to 14th	8.0	8.2	7.8	7.8	8.2
14th to 15th	5.0	5.2	4.6	5.3	5.2

Table 10. Maximum Bending Moment (kN-m) in Columns for Dead and Live Load

Floor Level	Structure Type				
	Unbraced	Cross Braced	Chevron Braced	K- Braced	Diagonal Braced
Base to Ground	24.7	24.7	24.7	24.9	24.9
Ground to 1st	26.7	26.9	26.9	27.2	26.0
1st to 2nd	28.3	28.7	28.6	29.2	27.4
2nd to 3rd	29.9	30.4	30.3	31.1	28.9
3rd to 4th	31.3	31.9	31.9	32.9	30.4
4th to 5th	32.6	33.3	33.3	34.5	31.8
5th to 6th	33.7	34.6	34.6	36.0	33.1
6th to 7th	34.8	35.7	35.8	37.3	34.2
7th to 8th	35.7	36.7	36.8	38.4	35.3

8th to 9th	36.5	37.6	37.7	39.5	36.2
9th to 10th	37.2	38.4	38.5	40.3	37.0
10th to 11th	37.9	39.0	39.2	41.1	37.7
11th to 12th	38.2	39.5	39.7	41.6	38.3
12th to 13th	39.2	40.4	40.6	42.6	39.2
13th to 14th	38.2	39.4	39.7	41.7	38.6
14th to 15th	66.7	68.9	69.3	72.6	67.3

Table 11. Maximum Bending Moment (kN-m) in Columns for Seismic Load in X-Direction

Floor Level	**Structure Type**				
	Unbraced	**Cross Braced**	**Chevron Braced**	**K- Braced**	**Diagonal Braced**
Base to Ground	38.1	13.7	13.7	24.0	44.8
Ground to 1st	36.9	8.2	9.0	15.8	11.4
1st to 2nd	33.1	7.7	8.5	14.3	10.3
2nd to 3rd	31.8	8.2	8.9	13.9	10.5
3rd to 4th	31.5	8.9	9.6	14.3	11.0
4th to 5th	31.3	9.8	10.4	14.3	11.6
5th to 6th	30.8	10.6	11.2	14.7	12.2
6th to 7th	30.1	11.3	11.9	14.8	12.7
7th to 8th	29.0	12.0	12.5	14.7	13.0
8th to 9th	27.6	12.5	12.9	15.0	13.2
9th to 10th	25.9	12.8	13.1	14.4	13.2
10th to 11th	23.7	12.9	13.1	14.3	13.3
11th to 12th	21.0	12.9	13.0	13.1	13.0
12th to 13th	17.7	12.4	12.4	12.4	12.2
13th to 14th	13.7	11.1	10.8	10.0	10.7
14th to 15th	9.2	8.8	8.1	7.8	8.5

Table 12. Maximum Bending Moment (kN-m) in Columns for Seismic Load in Z-Direction

Floor Level	**Structure Type**				
	Unbraced	**Cross Braced**	**Chevron Braced**	**K- Braced**	**Diagonal Braced**
Base to Ground	39.5	27.9	28.7	31.7	35.1
Ground to 1st	39.2	27.9	28.6	31.6	29.3
1st to 2nd	36.4	26.2	26.9	29.5	27.5
2nd to 3rd	35.1	25.9	26.5	28.9	27.0
3rd to 4th	34.6	26.2	26.8	28.8	27.2
4th to 5th	34.4	26.5	27.1	28.9	27.4
5th to 6th	33.9	26.2	27.2	28.7	27.4
6th to 7th	33.1	26.5	27.1	28.7	27.4
7th to 8th	31.9	26.4	26.9	28.1	27.2
8th to 9th	30.4	26.1	26.5	27.6	26.7
9th to 10th	28.5	25.2	25.5	26.0	25.7
10th to 11th	26.0	23.8	24.0	24.7	24.1
11th to 12th	22.9	21.7	21.7	21.8	22.0
12th to 13th	19.3	18.9	18.7	19.3	19.0
13th to 14th	14.7	14.8	14.4	14.3	14.8
14th to 15th	10.2	10.6	9.6	10.7	10.6

V. DISCUSSION ON RESULTS

Table 2 & Table 3 show the maximum lateral displacement for seismic load in X & Z direction respectively at different storey levels. The lateral displacements of the structure for various bracings system are compared. The maximum lateral displacement at terrace level in X direction is 120.7mm, 30.6mm, 32.2mm, 53.8mm and 41.2 mm for unbraced, cross braced, chevron braced, K-braced & diagonal braced structural systems. Whereas the lateral displacement at the same storey level in Z direction for the above said structural systems are 133mm, 75.7mm, 77.4mm, 93.7mm & 84.5 mm respectively. It is noted that the lateral displacement is drastically reduced after the application of bracings system. Maximum reduction in the lateral displacement has been observed after the application of Chevron bracing system.

Table 4, Table 5 & Table 6 show the maximum axial force in columns for dead & live load, seismic load in X- direction and seismic load in Z direction respectively. The axial forces of the structure for various types of bracings systems are compared. For dead & live load case, it has been observed that the axial force in the structure has been reduced after the application of the bracing system. But the reduction is very less but the same has been increased drastically for the seismic loads. The axial force for seismic load in X direction for unbraced structure at the base level is 145.8 kN which has been increased considerably to 435.9 kN, 432.7 kN, 308.5 kN and 429 kN for cross braced, chevron braced, K-braced & diagonal braced structure respectively. The maximum increment in axial force has been observed in cross braced structure.

Table 7, Table 8 & Table 9 show the shear forces at different stories for all the structural systems i.e. unbraced, cross braced, chevron braced, K-braced & diagonal braced structural systems for dead & live load, seismic load in X direction and seismic load in Z direction respectively. It can be seen that the shear force for column for dead & live load for unbraced and different types of braced structural systems is almost the same, but there is a considerable change in the shear forces for seismic load in both the directions for unbraced and different types of braced structural systems. It is observed that maximum shear force for the unbraced structure for seismic load at base level in X direction is 20.4 kN and it has been change to 10.2 kN, 9.8 kN, 9.2 kN and 32.4 kN for cross braced, chevron braced, K-braced & diagonal braced structure respectively. It has been reduced to 4.4 kN for unbraced and 4.6 kN, 4.1 kN, 4 kN and 4.4 kN cross braced, chevron braced, K-braced & diagonal braced structure respectively at terrace level.

Table 10, Table 11 & Table 12 show the maximum values of bending moments at different stories for all the structural systems for dead & live load, seismic load in X and Z direction respectively. It can be seen that the bending moments for columns for dead & live load for unbraced and different types of bracing system is almost the same. But it can be seen that the maximum bending moments for seismic load in X direction for unbraced, cross braced, chevron braced, K-braced, and diagonal braced structure at base level is 38.1 kN-m, 13.7 kN-m, 13.7 kN-m, 24 kN-m and 44.8 kN-m respectively. It has been reduced to 9.2 kN-m, 8.8 kN-m, 8.1 kN-m, 7.8 kN-m and 8.5 kN-m for unbraced, cross braced, chevron braced, K-braced, and diagonal braced structure at terrace level respectively.

VI. CONCLUSION

After the analysis of the structure with different types of structural systems, it has been concluded that the displacement of the structure decreases after the application of bracing system. The maximum reduction in the lateral displacement occurs after the application of cross bracing system. Bracing system reduces bending moments and shear forces in the columns. The lateral load is transferred to the foundation through axial action. The performance of cross bracing system is better than the other specified bracing systems. For gravity loads, there is no change in the axial force for all the specified structural systems.

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