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Assessment of Different types of Bracing in Tall Building using Response Spectrum Method

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Abstract: Tall Buildings are subjected to lateral movements or Torsional deflections under the action earthquake loads. To prevent the lateral movement of the structure, the structure must be made sufficiently stiff with respect to lateral loads .To improve the lateral stiffness and lateral stability of the tall buildings, bracing the frame members is one of the methods popularly adopted. A Bracing is a system that is provided to minimize the lateral deflection of structure. The members of a braced frame are subjected to tension and compression, so that they are provided to take these forces similar to a truss. The different types of bracing approach are adopted as per mechanism.

The project is based on the assessment of different types of bracing using a G+24 Storey. The plinth area taken as 45m x 25 m (rectangular section pattern) i.e. 1125 m^2. The Structural parameters are used in three different stage levels which storey as per the need of the structure. The earthquake response can evaluate by using response spectrum method into it. The zone III is taken as per codal approach IS 1893(part1):2016. The Staad software mechanism is used for the modeling. To Analysis of structure based on varying the bracing types such X, K, V, Inverted V, Single Diagonal Bracing in to it by alternate arrangement. The final conclusion made such that with adding the bracing element in tall building the resisting capacity of structure against the lateral forces increases. Most effective structure is diagonal bracing structure. The diagonal and X bracing are most effective types of bracing is all cases of modeling. The inverted V bracing then preferably adopted in it.

Keywords: Tall Buildings, X, K, V, Inverted V, Single Diagonal Bracing, zone III, Response Spectrum Method, IS 1893(part1):2016, zone III.

I. INTRODUCTION

During earthquake motions, deformations take position across the elements of the weight-bearing method as a result of the response of constructions to the ground motion. Because of these deformations, interior forces boost across the factors of the load-bearing approach and displacement behaviour seems across the building. The consequent displacement demand varies relying on the stiffness and mass of the constructing. As a rule, buildings with higher stiffness and diminish mass have smaller horizontal displacements demands. On the contrary, displacement needs are to increase. Then again, every building has a specific displacement potential. In different words, the quantity of horizontal displacement that a building can have the funds for without collapsing is restricted. The reason of strengthening ways is to ensure that the displacement demand of a constructing is to be kept beneath its displacement potential. It will most commonly be finished by means of decreasing anticipated displacement demand of the constitution for the period of the strong motion or improving the displacement ability of the constitution. To oppose lateral earthquake loads, shear dividers are normally utilized in RC confined structures, while, steel propping is the regularly utilized in steel structures. In the previous two decades, various reports have likewise demonstrated the compelling utilization of steel propping in RC outlines. Steel supporting of RC structures began as a retrofitting measure to fortify earthquake-harmed structures or to expand the heap opposing limit of existing structures. The bracing methods adopted in the past fall into two main categories, namely external bracing and internal bracing. In the external bracing system, existing buildings are retrofitted by attaching a local or global steel bracing system to the exterior frames. In the internal bracing method, the buildings are braced by incorporating a bracing system inside the individual bays of the RC frames. The bracing may be attached to the RC frame either indirectly or directly.

A Bracing is a system that is provided to minimize the lateral deflection of structure. The members of a braced frame are subjected to tension and compression, so that they are provided to take these forces similar to a truss A braced frame is a structural system commonly used in structures subject to lateral loads such as wind and seismic pressure. The members in a braced frame are generally made of structural steel, which can work effectively both in tension and compression. The beams and columns that form the frame carry vertical loads, and the bracing system carries the lateral loads. The positioning of braces, however, can be problematic as they can interfere with the design of the façade and the position of openings. Buildings adopting high-tech or post-modernist styles have responded to this by expressing bracing as an internal or external design feature.

II. MODELLING AND ANALYSIS

For this study on "Assessment of Different types of Bracings in Tall Buildings Using Response Spectrum Method" seven different models with same structural properties has been modelled in Staad Pro v8i and analysed using response spectrum method. The plan area for the modelling is considered as 25.00 m x 45.00m. The different types of bracing system can be taken in the G+24 Storey building which X bracing, diagonal bracing, V bracing, Inverted V bracing, K bracing in alternate grid arraignment in the tall building. For modelling and analysis purpose Stadd.pro v8i has been used. All the structural models follows the criteria mentioned in above paragraphs. Fig 3.4 to Fig. 3.24 shows the models completed in the Stadd.pro v8i software. The structure system modelled than analyzed in the software to get the results for this study.

The seven models are modelled on staad.pro software. The coding name is as follows:

1) *Model 1:* BE1 – Regular Building (No Bracing Element)
2) *Model 2:* BE2 – Building with X- Bracing Element
3) *Model 3:* BE3 – Building with Diagonal Bracing Element
4) *Model 4:* BE4 – Building with Inverted Diagonal Bracing Element
5) *Model 5:* BE5 – Building with K- Bracing Element
6) *Model 6:* BE6 – Building with V- Bracing Element
7) *Model 7:* BE7 – Building with Inverted V Bracing Element

Table 1, 2 & 3 can be tabulated the basic requirement of the building analysis. Table 1 show the Structure Parameters, table 2 to give the details of Seismic Data and Table 3 tabulated the Material Properties in it.

TABLE 1: Structure Parameters

S. No	Particular	Details	S. No	Particular	Details
1	Column Size		4	Slab thickness	130 mm thick
1.a	Ground - G+8	750x750mm	5	Bracing Size	230 mm x 450 mm
1.b	G+9 - G+17	700x650 mm	6	Partition Wall Density	20.00 KN/m^3
1.c	G+18 - G+24 & tower	600x550 mm	7	Shear Wall thickness	180 mm (Single core type)
2	Column Spacing		8	Stair Waste slab thickness	150 mm
2.a	X-direction	5.00 m c/c	6	Column-Foundation Joint	Fixed at base
2.b	Z-direction	5.00 m c/c	4	Slab thickness	130 mm thick
3	Beam Size (Main)		5	Bracing Size	230 mm x 450 mm
3.a	Ground - G+8	550x500mm	6	Partition Wall Density	20.00 KN/m^3
3.b	G+8 - G+17	500x450 mm			
3.c	G+18 - G+24 & tower	450x350 mm			

TABLE 2: Seismic Data

S. No.	Description	Details
1	Seismic Zone	III
2	Zone Factor	0.16
3	Soil Type	Medium
4	Importance Factor	1.2
5	Response Reduction Factor	4
7	Time Period (Second)	Tx= 1.71, Tz =1.27
8	Method of Analysis	Response Spectrum
9	Damping	0.05(5%)

TABLE 3: Material Properties

S. No.	Property	Concrete (N/mm$^{2)}$	Rebar N/mm$^{2)}$
1	Designation	M-25	HYSD-500
2	Yield Strength	500	-
3	Compressive Strength	-	20
4	Unit Weight	76.9729	25
5	Modulus of Elasticity	200000	31622.78

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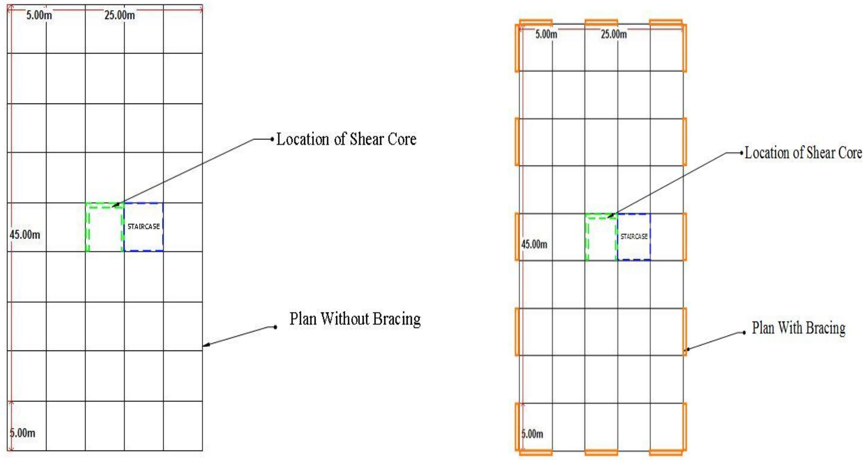
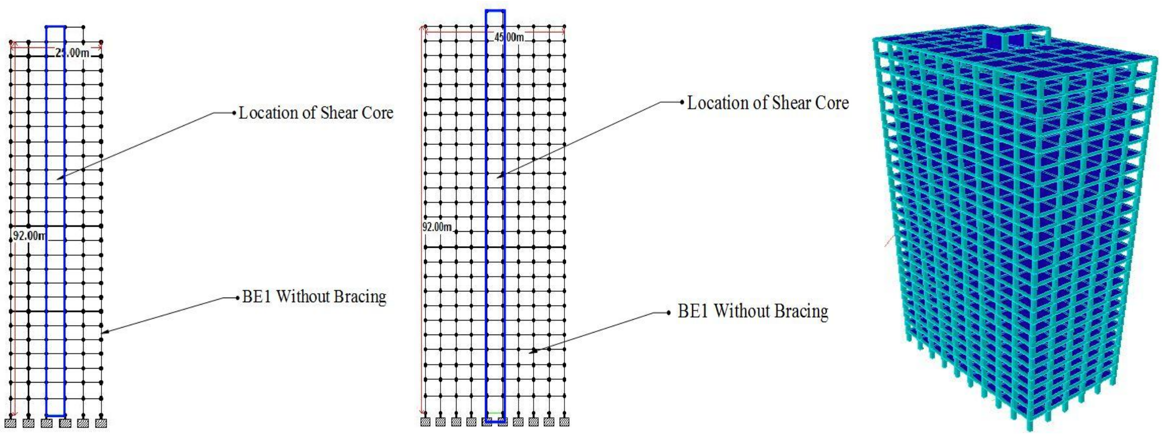
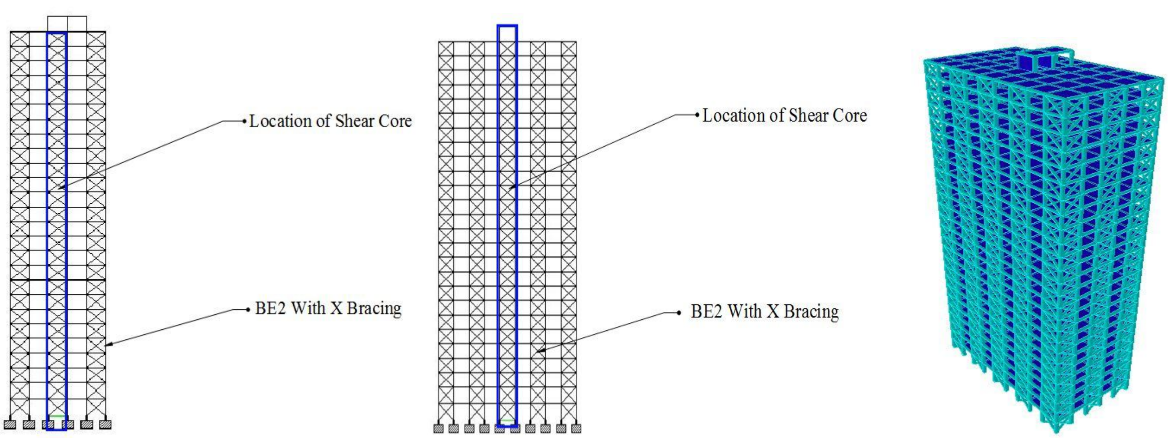


Fig 1: a) Common Grid plan for modelling b) Grid plan with bracing position



a) b) c)

Fig. 2: Case BE1 Regular Model: a) Elevation @ X Direction, b)Elevation @Z Direction c)3D View



a) b) c)

Fig. 3: Case BE2 X Bracing: a) Elevation @ X Direction, b) Elevation @Z Direction c) 3D View

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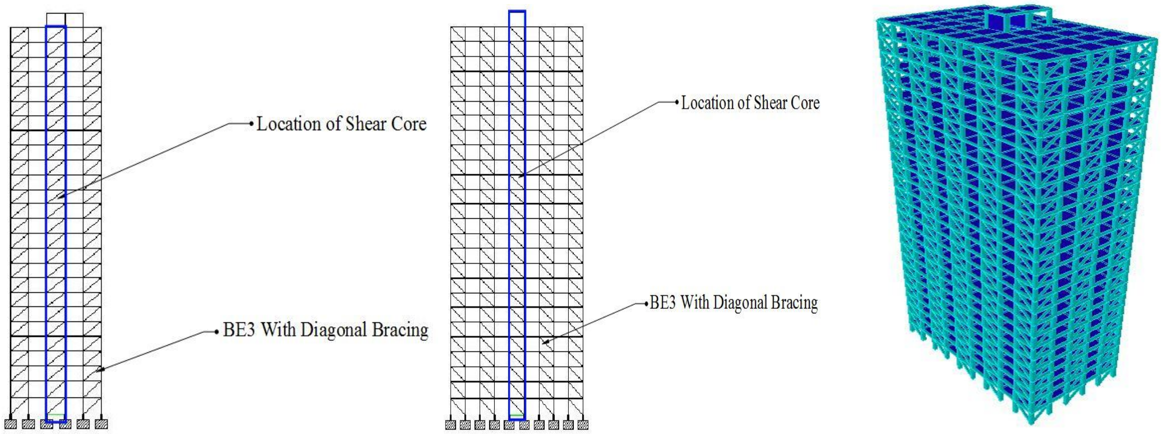
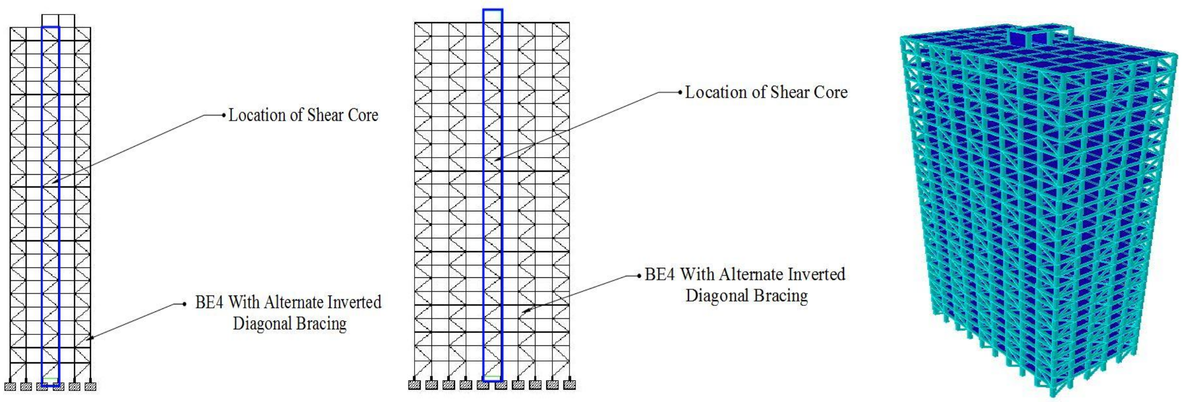


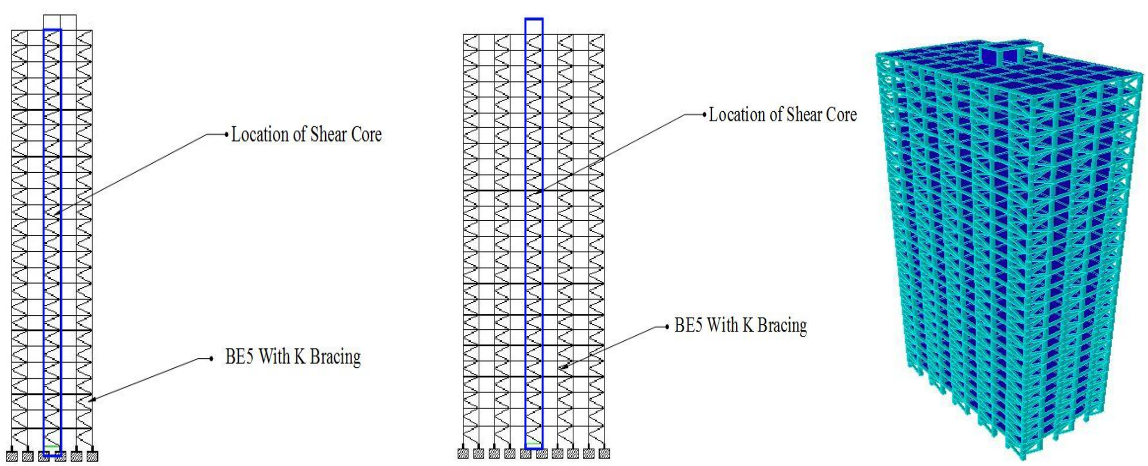
a) b) c)

Fig 4: Case 3: BE3 Diagonal -Bracing : a) Elevation @ X Direction, b) Elevation @Z Direction c) 3D View



a) b) c)

Fig 5: Case 4: BE4 Inverted Diagonal Bracing Model: a) Elevation @ X Direction, b) Elevation @Z Direction c) 3D View



a) b) c)

Fig 6: Case 5: BE5 K- Bracing Model: a) Elevation @ X Direction, b) Elevation @Z Direction c) 3D View

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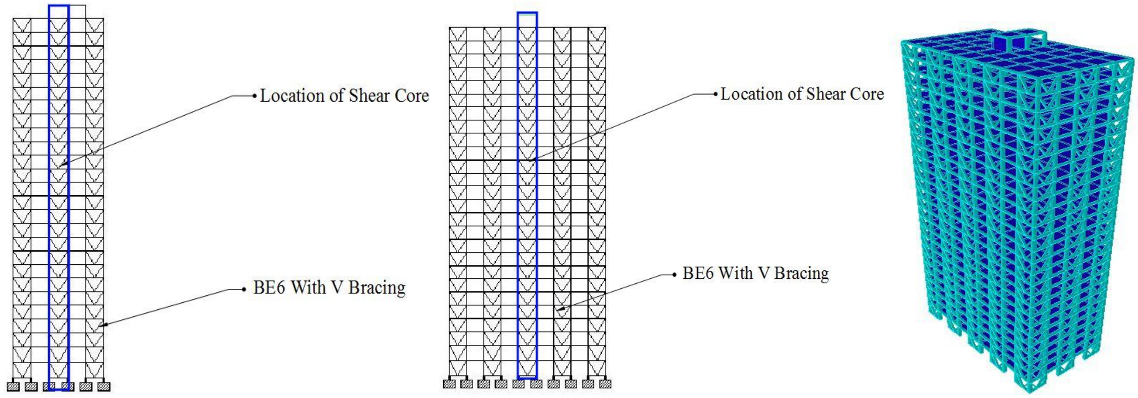
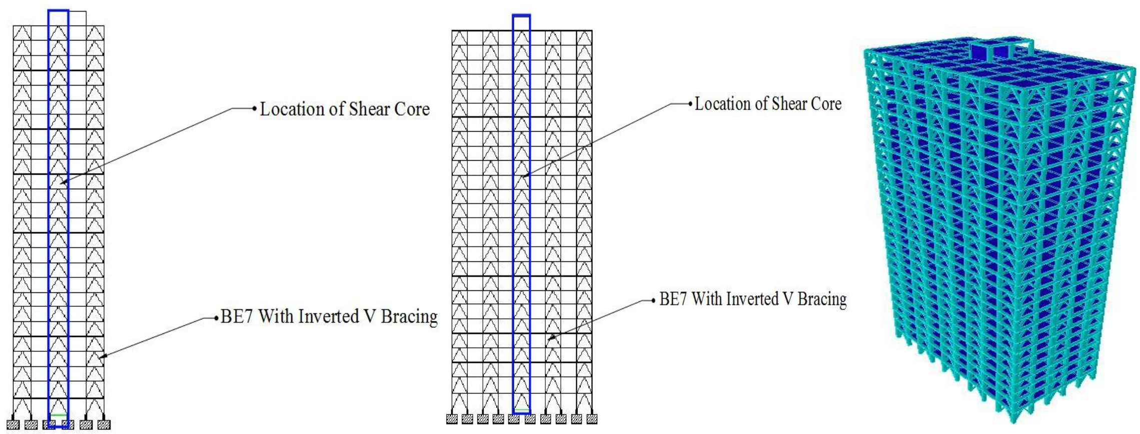


a) b) c)

Fig 7: Case 6: BE6 V- Bracing Model: a) Elevation @ X Direction, b) Elevation @Z Direction c) 3D View



a) b) c)

Fig 8: Case 7: BE7 Inverted V- Bracing Model: a) Elevation @ X Direction, b) Elevation @Z Direction c) 3D View

III.RESULTS AND DISCUSSIONS

Based on the modelling approach the following results are to be evaluated by tabulated and graphical representation forms.
The parameters taken for the results are Maximum Displacement (at top level of the building) , Base shear, Maximum Axial forces, SF and BM in beam and columns, Torsional Moment. Table 4 to 11 shows all the tabulated results and fig no 9 to 16.

Table 4: Maximum Displacement in X direction for all 7 Buildings in Zone III

Building	Maximum Displacement (mm)	Maximum Displacement (mm)
	For X Direction	For Z Direction
BE1	258.262	298.201
BE2	214.620	229.448
BE3	162.154	137.569
BE4	218.806	235.464
BE5	222.994	239.775
BE6	220.068	236.275
BE7	214.684	229.343

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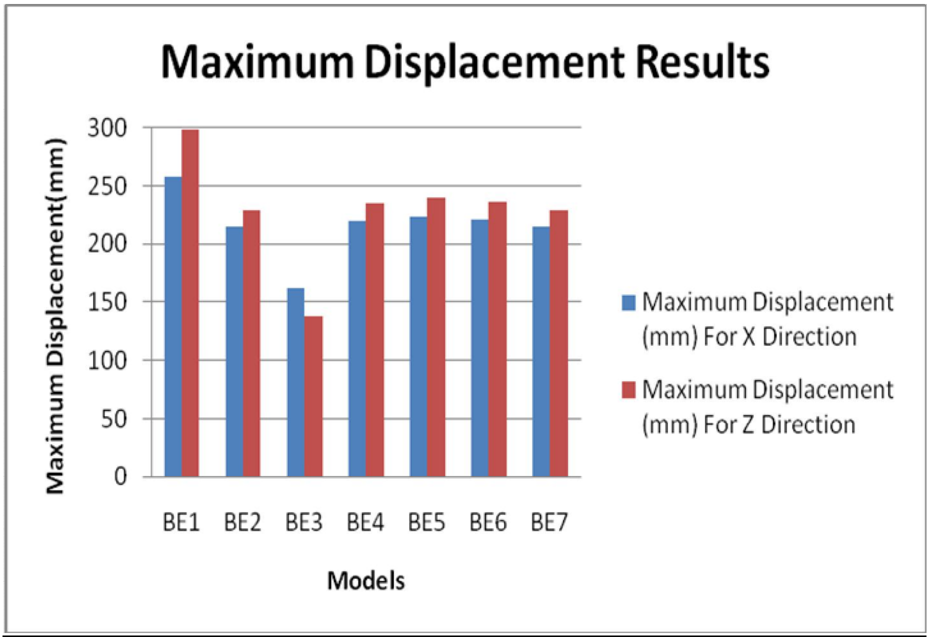

Fig.9: Maximum Displacement in X direction for all 7 Buildings in Zone III

Table 5: Base Shear in X and Z direction for all 7 Buildings in Zone III

Building	Base Shear (KN)	
	X direction	Z direction
BE1	14718.21	21134.72
BE2	19320.20	25652.37
BE3	23213.83	25864.15
BE4	18601.09	24854.05
BE5	18507.54	24691.10
BE6	18837.74	25051.37
BE7	19113.14	25415.41

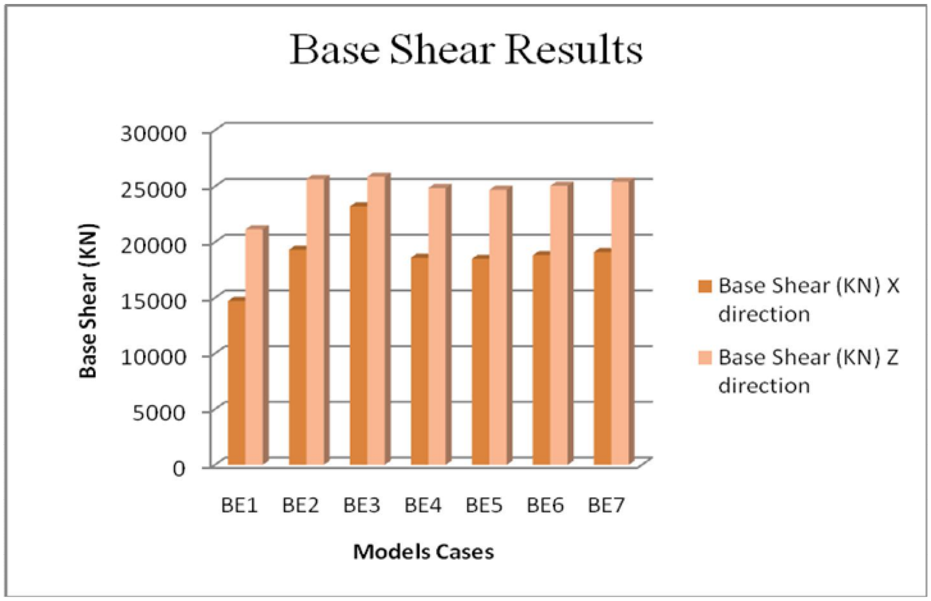

Fig. 10: Base Shear in X direction for all 7 Buildings in Zone III

Table 6: Maximum Axial Forces in Column at ground level for all 7 Buildings in Zone III

Building	Column Axial Force (KN)
BE1	17395.314
BE2	13868.139
BE3	15036.048
BE4	14619.401
BE5	14877.746
BE6	18837.74
BE7	13966.06

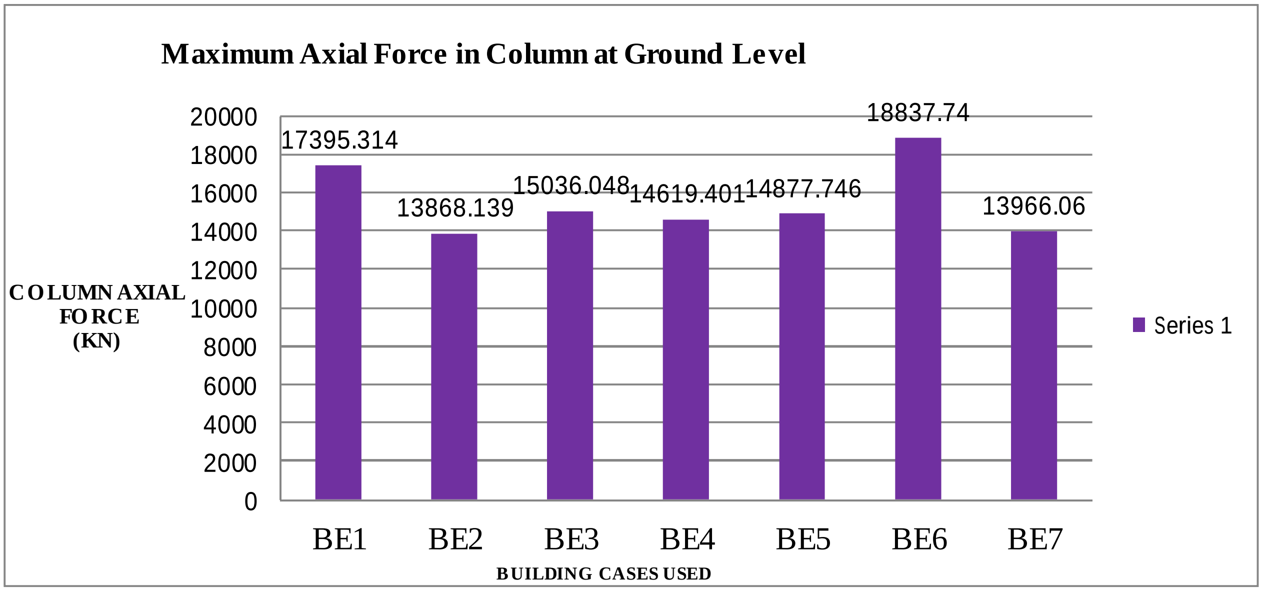

Fig. 11: Maximum Axial Forces in Column at ground level for all 7 Buildings in Zone II

Table 7: Maximum Shear Forces in Columns for all 7 Buildings in Zone III

Building	Column Shear Force (KN)	
	Shear along Y	Shear along Z
BE1	383.360	627.674
BE2	330.011	486.058
BE3	254.668	318.500
BE4	338.195	495.515
BE5	378.625	509.944
BE6	336.308	497.474
BE7	329.105	487.501

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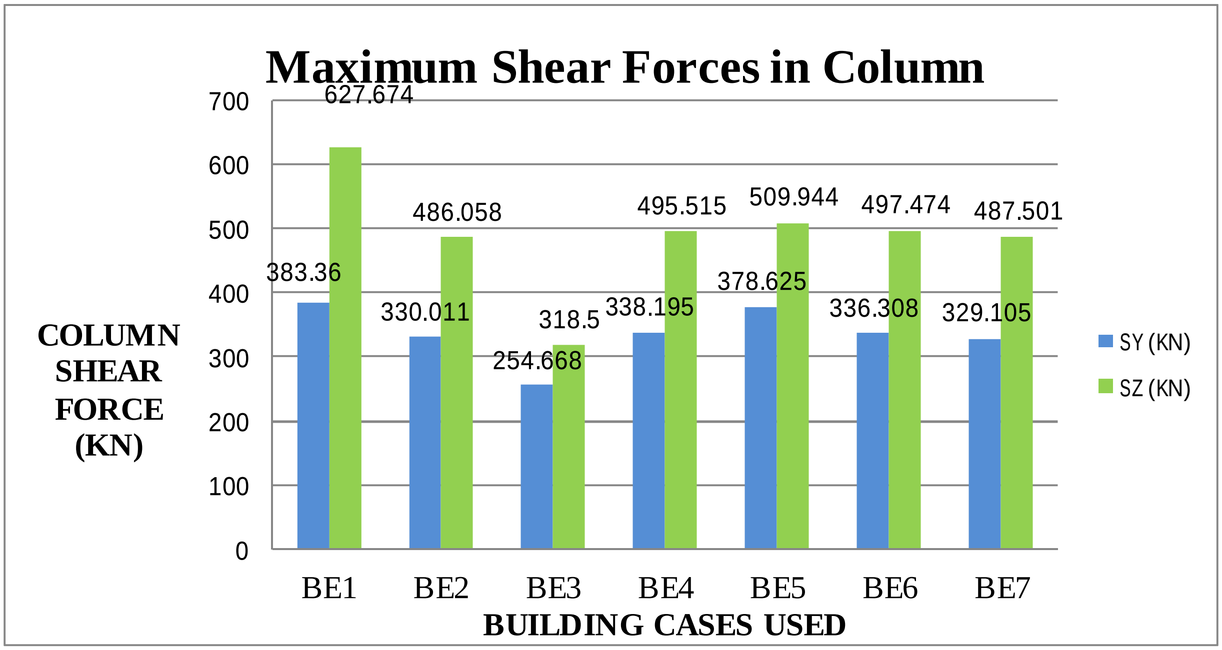

Fig. 12: Maximum Shear Forces in Columns for all 7 Buildings in Zone III

Table 8: Maximum Bending Moment in Columns for all 7 Buildings in Zone III

Building	Column Bending Moment (KN.m)	
	Moment along Y	Moment along Z
BE1	1129.169	678.854
BE2	875.777	584.169
BE3	576.746	485.251
BE4	890.501	598.684
BE5	918.144	697.253
BE6	896.146	595.529
BE7	877.356	582.459

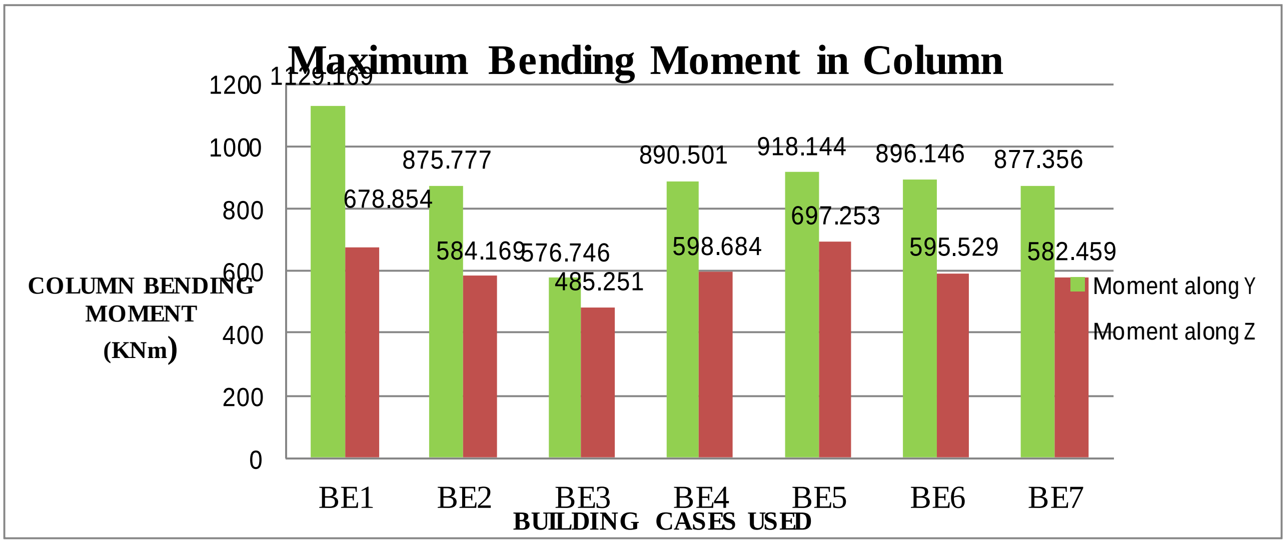

Fig. 13: Maximum Bending Moment in Columns for all 7 Buildings in Zone III

Table 9: Maximum Shear Forces in beams parallel to X direction for all 7 Buildings in Zone III

Building	Beam Shear Force (parallel to X direction) (KN)	Beam Shear Force (parallel to Z direction) (KN)
BE1	151.749	167.806
BE2	139.723	142.54
BE3	116.194	119.56
BE4	140.901	144.686
BE5	140.432	146.428
BE6	155.672	154.345
BE7	232.412	233.718

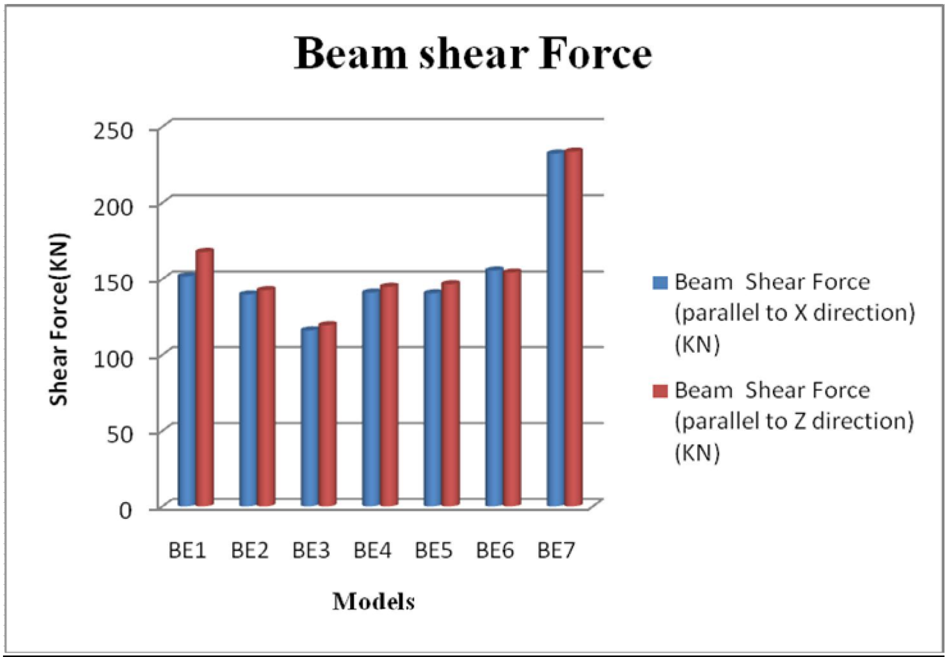

Fig. 14: Maximum Shear Forces in beams parallel to X direction for all 7 Buildings in Zone III

Table 10: Maximum Bending Moment in beams parallel to X direction for all 7 Buildings in Zone III

Building	Beam Bending Moment (along X direction) (KN.m)	Beam Bending Moment (along Z direction) (KN.m)
BE1	317.171	363.106
BE2	282.338	297.862
BE3	208.606	218.301
BE4	285.615	302.787
BE5	290.484	307.696
BE6	286.361	301.681
BE7	305.401	309.033

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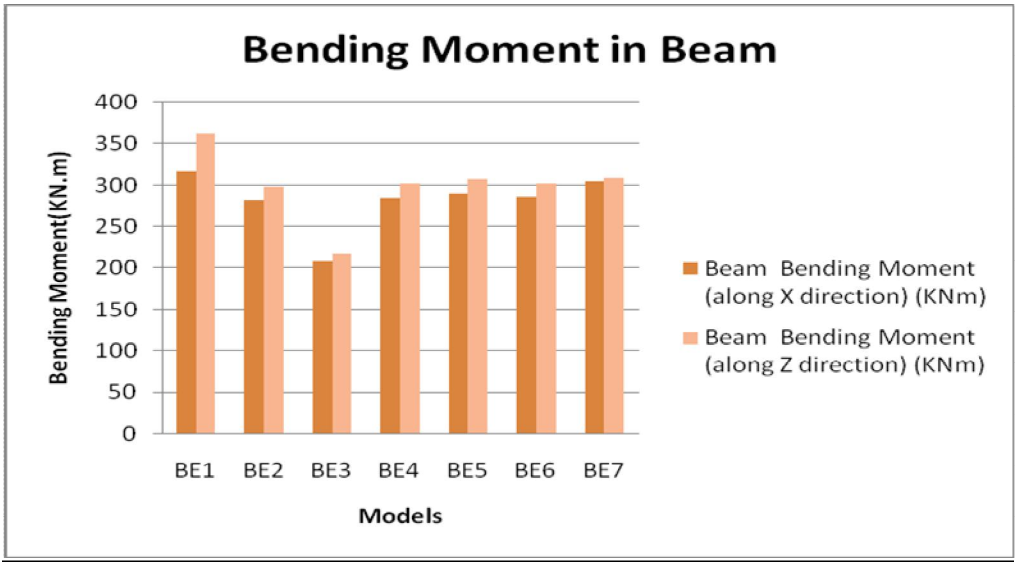

Fig. 15: Maximum Bending Moment in beams parallel to X direction for all 7 Buildings in Zone III

Table 11: Maximum Torsional Moment in beams along X and Z direction for all 7 Buildings in Zone III

Building	Beam Torsional Moment (along X direction) (KN.m)	Beam Torsional Moment (along Z direction) (KN.m)
BE1	12.387	10.11
BE2	10.086	9.401
BE3	6.79	6.276
BE4	10.155	8.518
BE5	12.352	8.677
BE6	15.026	14.349
BE7	13.567	12.686

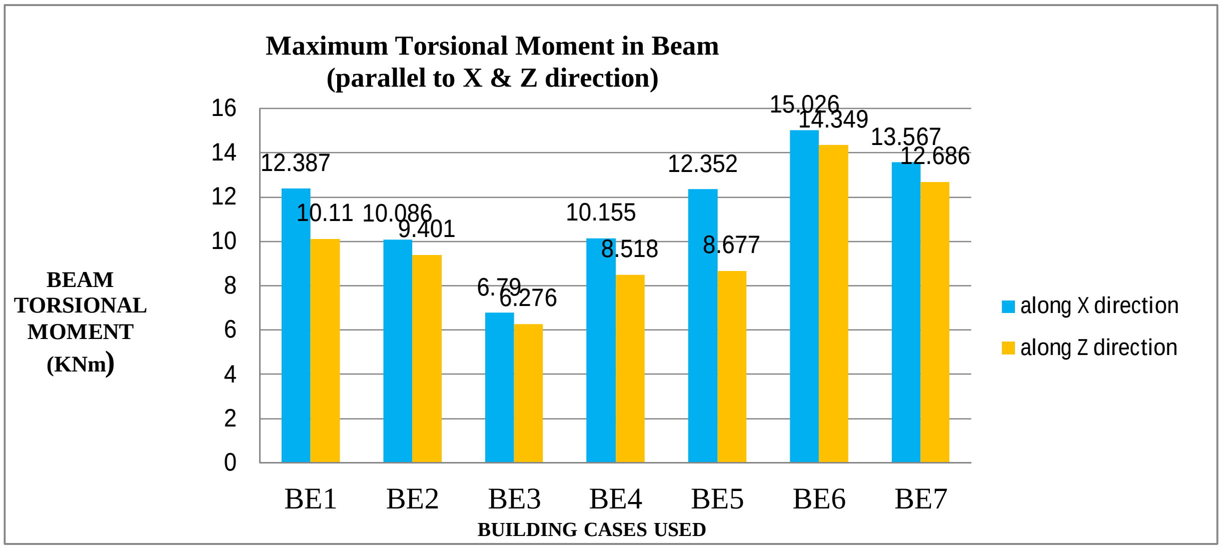

Fig. 16: Maximum Torsional Moment in beams parallel to X & Z direction for all 7 Buildings in Zone III

IV. CONCLUSIONS

Based on the modelling and analysis of the different models BE1 to BE7 (Total 7 Models) in which is use of different types of bracing system in alternate arrangement pattern and compare with the regular building(BE1) having no bracing element. The results are tabulated and graphical represented on the previous chapter. Based on these results the following conclusions are made. These conclusions are as follows:

A. There is decrement in maximum displacement value will be observed when bracing system adopted in the building. The decrement value is 16.90%, 37.21%, 15.28%,13.66%, 14.79% & 16.87% in observed in BE2,BE3,BE4,BE5,BE6 & BE7 respectively with respect to BE1(regular building.) in X-direction. Similarly 23.06%, 53.87%, 21.04%, 19.59%, 20.77% & 23.09% decrement in displacement value in BE2 to BE7 with respect to BE1 in Z-Direction.

B. There is increment in base shear value will be observed when bracing system adopted in the building due to self weight is increases. The increment in value is 31.27%, 57.72%, 26.38%, 25.75%, 27.99% & 29.86 in X direction. Similarly 21.38%, 22.38%,17.60%,16.83%,18.53% & 20.25% in Z Direction in BE2 to BE7 with reference to BE1 (without bracing element model).

C. The Axial forces value is decreases which are 20.28%, 13.56%, 15.96%, 14.47% & 19.71% in BE2, BE3, BE4, BE5 & BE7 respectively with respect to BE1. The increment is observed in case of BE 6 which 8.29%.

D. The shear force value in column is decreases in all bracing models. There is decrement of 13.92%, 33.57%, 11.78%, 1.24%, 12.27%, and 14.15% in BE2 to BE7 as compare to BE1 in X direction. Similarly decrement value of 22.56%, 49.26%, 21.06%, 18.76%, 20.74%, and 22.33% in BE2 to BE7 as compare to BE1 in Z-direction.

E. The Bending moment value in column is decreases in all bracing models. There is decrement of 22.44%, 48.92%, 21.14%, 18.69%, 20.64%, and 22.30% in BE2 to BE7 as compare to BE1 in X direction. Similarly decrement value of 13.95%, 28.52%, 11.81%, 12.27%, 14.20%, in BE2, BE3, BE4, BE6, and BE7 as compare to BE1 in Z-direction. Increment of 2.71% in BE5 in Z direction.

F. The Torsional moment value is decrement in BE2,BE3,BE4,BE5 in both direction which is 18.58%, 45.18%, 18.02% in X direction and 7.01%,37.92%, 15.75% in Z direction respectively. The increment value of 21.30%, 9.53% in BE6, BE7 in X direction and 41.93%, 25.48% in Z direction with reference to BE1(regular Building).

G. The shear force value in beam is decreases in BE2, BE3, BE4, BE5 which is 7.92%, 23.43%, 7.15%, 7.46% in X-direction and 15.06%, 28.75%, 13.78%, 12.74%, 8.02% in BE2 to BE 6 in Z direction, increment value is observed in BE7 which is 39.28%.

H. The Bending moment value in beam is decreases in all bracing Buildings. There decrement of 10.98%, 34.23%, 9.95%, 8.41%, 9.71%, 3.71% in BE2 to BE7 in X direction. Similarly in Z direction the decrement is observed is 17.97%, 39.88%, 16.61%, 15.26%, 16.92%, 14.89% in BE2 to BE7 with reference to BE1 model.

The overall concluded that with introduce of bracing element in tall building the resisting capacity of structure against the lateral forces increases. The diagonal and X bracing are most effective types of bracing is all cases of modelling. The inverted V bracing than preferably adopted in it.

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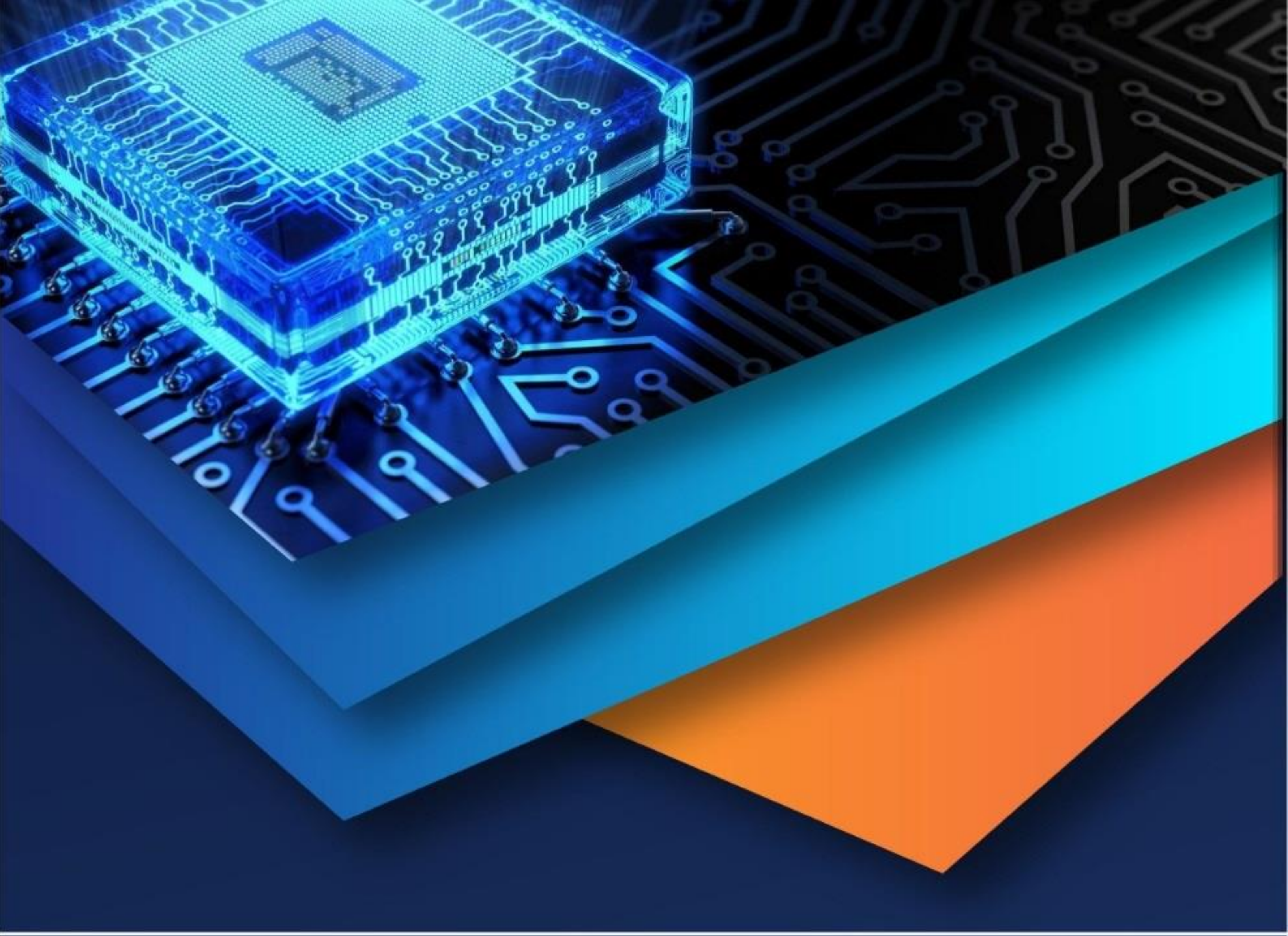

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