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Seismic Analysis of High Rise Building with Shear walls and Bracings

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Abstract: A natural hazard like Earthquake causes damage or collapse of buildings if not designed for lateral loads. Hence for seismic resistance for high rise structures, it is important to provide Lateral Load Resisting System which will supplement the behavior of moment resisting frames in resisting the lateral load. The dual structural system consisting of special moment resisting frame and concrete shear wall has better seismic performance due to improved lateral stiffness and lateral strength. Steel bracings are also one of the successful lateral load resisting system. In the present study, we have analysed a 12 storey building.

The software used for the analysis is Staad pro. and the work has been carried out for the different cases using shear wall and bracings. The modeling is done to analysis the seismic parameters- Bending moment, Shear force, Base shear, Storey drift and Storey displacement. The study has been carried out for the zone iv and hard soil as specified in IS 1893-2002. Such a study may help to provide guidelines to assess more accurately the seismic vulnerability of building frames and may be useful for seismic design.
Keywords: Bare Frame, Bracings, Shear Walls, Storey Displacement, Storey Drift, Base Shear, Staad pro.

I. INTRODUCTION

Reinforced concrete frames are the most commonly adopted building construction practices in world. Due to the scarcity of land because of rapid growing of population, high-rise structures have become highly preferable in buildings scenario. A natural hazard like Earthquake causes damage or collapse of these high rise structures, if not designed for lateral loads. Hence such high-rise structures, constructed especially in highly seismic prone zones, should be analyzed and designed with extra lateral stiffening system to improve their seismic performance and reduce damages. Two of the most commonly used lateral stiffening systems in buildings are shear walls and bracings. Both have better seismic performance due to improved lateral stiffness and lateral strength.

A. Shear Wall

Earthquake resistant buildings should possess, at least a minimum lateral stiffness, so that they do not swing too much during small levels of shaking. Moment frame buildings may not be able to offer this always. Hence shear walls, can be introduced to help reduce overall displacement of buildings, because these vertical plate-like structural elements have large in-plane stiffness and strength. Shear walls resist lateral forces through combined axial-flexure-shear action. Also, shear walls help reduce shear and moment demands on beams and columns in the moment frames of the building, when provided along with moment frames as lateral load resisting system. Shear walls should be provided throughout the height of buildings for best performance. Also, walls offer best performance when rested on hard soil strata.It is not sufficient to provide shear walls in buildings; their location in a building governs the overall response of the building. Shear walls are most effective when placed at the periphery of buildings.

B. Bracing

Bracing is a structural system which is designed primarily to resist wind and earthquake forces. Members in a braced frame are designed to work in tension and compression similar to a truss. Braces help in reducing overall lateral displacement of buildings, and in reducing bending moment and shear force demands on beams and columns in buildings. The earthquake force is transferred as axial force in the brace members. Various types of bracings can be used along the building height namely, X, Chevron and K bracing systems. X- and Chevron braces effectively reduce bending moment, shear force and axial force demands on the beams and columns of the original frame and are commonly used. Braced frames are simple to erect on site, and bracing elements can be orientated to accommodate horizontal movement across the floor plate. Although braced frame systems can be incorporated within concrete framed structures, they are better suited to steel framed buildings.

II. OBJECTIVE OF STUDY

A. To model the building with different lateral stiffness systems using Staad Pro software.
B. To perform dynamic analysis of the building by response spectrum method.
C. To determine the parameters such as Bending Moment, Shear Force, Base shear, Storey drift, Storey displacement for building models.
D. To compare and get a better and efficient lateral stiffness system.

III. METHODOLOGY

Manual analysis of high rise structure is a very tedious process, time consuming and probability committing error. Now a days various software has been developed for the design such as Staad.pro, Etabs, sap2000, Revit structure etc. These software work on stiffness matrix method, finite element method etc.

The analysis in this work has been done with the help of Staad pro. software. Staad pro. is engineering software that performs analysis and design of structures. The following Steps are adopted:

1) *Step 1:* Selection of building geometry, bays and number of stories.
2) *Step 2:* Defining the material properties and section of Beam, Column & Slab.
3) *Step 3:* Assigning the live load and dead load.
4) *Step 4:* Defining the earthquake load and it parameters i.e. Zone factor, importance factor Response reduction factor etc.
5) *Step 5:* Considering the following load combination.
a) 1.5(DL+LL)
b) 1.2(DL+LL+EL)
c) 1.2(DL+LL- EL)
d) 1.5(DL+ EL)
e) 1.5(DL-EL)
f) 0.9DL+1.5EL
g) 0.9DL- 1.5EL
6) *Step 6:* Analysing the structure.
7) *Step 7:* Comparison of results in terms of Bending Moment, Shear Force, Storey drift, Storey displacement, Base shear.

IV. LITERATURE REVIEW

1) *K.G.Viswanath (2010) [1]:* investigated the seismic performance of reinforced concrete buildings using concentric steel bracing of different types (Diagonal type, K type, X type). Analysis of a four, eight, twelve and sixteen storied building in seismic zone IV was done using Staad Pro software, as per IS 1893: 2002 (Part-I). The bracing was provided for peripheral columns. It was found that lateral displacements is minimum in X-type bracings. Steel bracings were found to reduce flexure and shear demand on the beams and columns and transfer lateral load by axial load mechanism. Building frames with X- type bracing were found to have minimum bending as compared to other types of bracing.
2) *P. Chandurkar (2011) [2]:* evaluated the response of a 10 storey building with seismic shear wall using ETAB v 9.5. Main focus was to compare the change in response by changing the location of shear wall in the multi-storey building. Three models were studied-one being a bare frame structural system and rest two were shear walled structural system (shear wall in middle and shear wall at corner). The results were excellent for shear wall at corners. Shear wall is an effective and economical option for high-rise structures. The storey drift and lateral displacement is minimum for shear wall at corners. Hence proper positioning of shear wall is vital.
3) *Chavan Krishnaraj (2012) [3]:* has done seismic analysis of reinforced concrete buildings with different types of bracing (Diagonal, V type, inverted V type, X type). The bracing is provided for peripheral columns. He analysed a seven-storey building situated in seismic zone III. The building models are analyze by equivalent static analysis using Staad Pro. software. The main parameters consider in the study are storey displacement, storey drift and base shear. It is found that the X type of steel bracing significantly reduces the storey drift of R.C.C building than other bracing system. It was observed that lateral displacement reduced by 50% to 56% by use of X-type bracing .Base shear of the building was also found to increase by use of X-type bracing, indicating increase in stiffness.

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4) *Ashok Thakur (2013) [4]:* analysed and compared four different models for different location of shear wall. The four different cases are :building without shear wall, building with Shear walls in middle, building with shear walls at corners and building with shear walls at core. Results have been obtained using STAAD Pro. From the above four cases it is found that shear walls at corners show minimum displacement. Also the base shear is maximum at the ground level for for this case compare to other case. It is found that building with shear wall at corner is more efficient than all other types of shear wall.

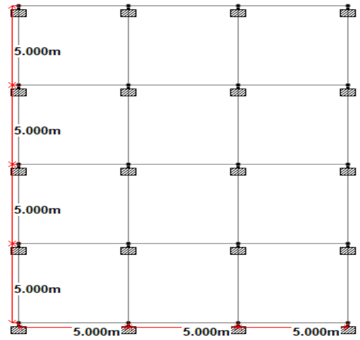
V. STRUCTURAL MODELING

In this study, various models of 12-storeyed building in zone IV were analyzed by changing the location of shear walls and bracings .The building models are modeled using Staad pro Software. Five different models are studied with different positioning of shear wall and bracing in building. The details of plan and elevation of each model is given below.

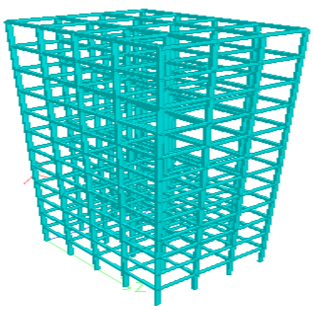
Table 1: Preliminary Data for Frame

Specifications	Data
No. of bays along X direction	3
No. of bays along Z direction	4
No. of bays along Y direction	12
Bay Length along X direction	5m
Bay Length along Z direction	5m
Bay Length along Y direction	3.5m
Columns size	0.5m X 0.5m
Beams size	0.30m X 0.45m
Slab Thickness	0.125m
Wall thickness	0.25m
Bracing size (X type)	ISA 110x110x10
Shear wall thickness	0.25m
Live Load	3.5 KN/m^2
Floor finish	1 KN/m^2
Unit weight of wall	20 KN/m^2
Grade of concrete	M25
Grade of steel	Fe415
Building frame type	SMRF
Zone	IV
Soil Condition	Hard Soil
Damping Ratio	5%

A. *Modeling of Bare Frame*



(a) Plan



(b) Isometric view

Fig. 1 Modeling of Bare frame .

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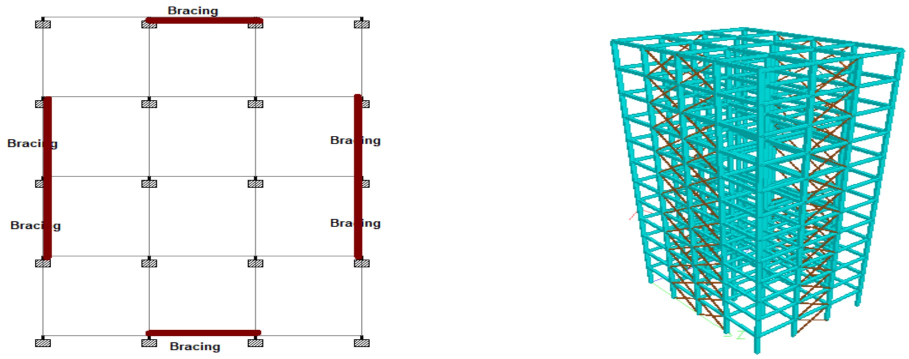
B. Modeling of braced frame

For bracing, angle section ISA 110 X 110 X 10 is used. Bracings are of X-type , modeled throughout the height of the building. There are two trial locations in the building where bracing are placed for their effect on lateral stiffness .

The two locations are as follows:

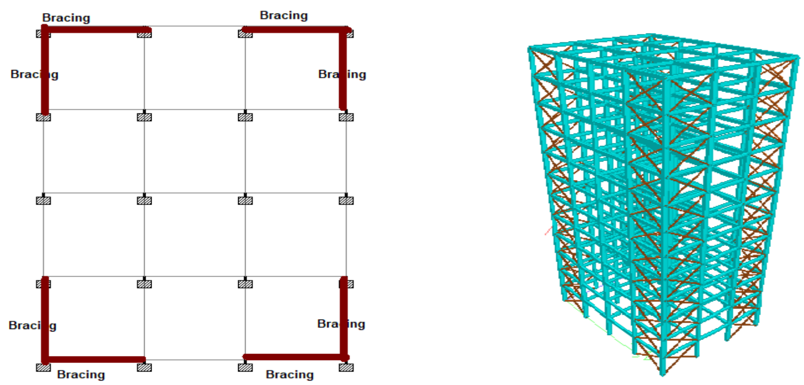
1) *Location 1:* (Frame model Bracing A) In middle bays of the exterior side of the frame along both XY and ZY-plane.



(a) Plan (b) Isometric view

Fig.2 Modeling of Frame model Bracing A.

2) *Location 2:* (Frame model Bracing B) In corner bays of the exterior side of the frame along both XY and ZY-plane.



(a) Plan (b) Isometric view

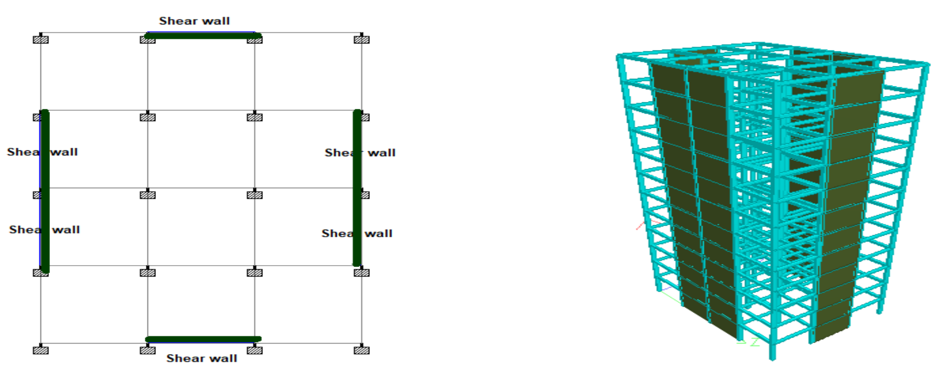
Fig. 3 Modeling of Frame model Bracing B.

C. Modeling of shear walled frame

Shear Wall considered is of 250mm thickness, and placed along the entire height of the structure.

The two locations are as follows:

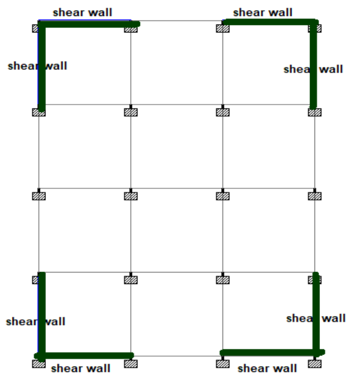
1) *Location 1:* (Frame model Shear wall A) In middle bays of the exterior side of the frame along both XY and ZY-plane.



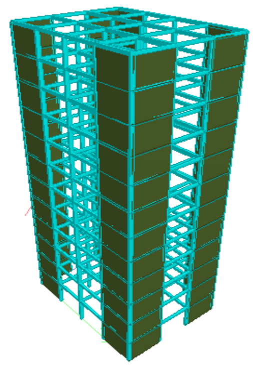
(a) Plan (b) Isometric view

Fig.4 Modeling of Frame model Shear wall A.

2) *Location 2:* (Frame model Shear wall B) In corner bays of the exterior side of the frame along both XY and ZY-plane .



(a) Plan



(b) Isometric view

Fig. 5 Modeling of Frame model Shear wall B.

VI.RESULTS

By the software, the parameters- Storey drift, Storey Displacement, Base shear, Bending Moment and Shear Force are calculated and then these results are compared for different proposed building models.

1) *Storey Drift:* It is defined as the difference of displacement of the floors at the top and bottom of storey under consideration. or, It is also defined as difference of displacement of two consecutive floors.
2) *Storey Displacement:* It is the lateral displacement of the storey relative to the base.
3) *Base Shear:* It is an estimate of the maximum expected lateral force that will occur due to seismic ground motion at the base of a structure.

Table 2: Comparison of Storey Drift (mm) for ground motion in X- direction

Storey	Bare Frame	Bracing A	Bracing B	Shear wall A	Shear wall B
1	2.9043	1.3115	0.9452	0.9639	0.3024
2	5.1519	2.1900	1.5779	1.4992	0.4870
3	5.5024	2.3883	1.7252	1.7096	0.5882
4	5.3303	2.4302	1.7578	1.7898	0.6599
5	5.0184	2.4317	1.7704	1.8511	0.7198
6	4.6951	2.4295	1.7914	1.9277	0.7711
7	4.3833	2.4171	1.8114	2.0029	0.8116
8	4.0400	2.3635	1.8002	2.0335	0.8363
9	3.5948	2.2324	1.7249	1.9767	0.8404
10	2.9940	1.9979	1.5644	1.8094	0.8216
11	2.2360	1.6610	1.3192	1.5444	0.7816
12	1.4311	1.2473	1.0278	1.2724	0.7283

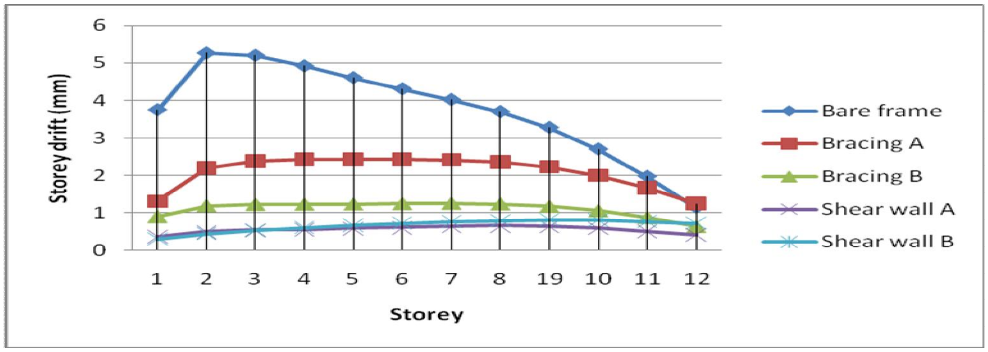


Fig. 6 Comparison of Storey Drift (mm) for ground motion in X- direction .

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Table 3: Comparison of Storey Displacement (mm) for ground motion in X- direction

Storey	Bare Frame	Bracing A	Bracing B	Shear wall A	Shear wall B
1	2.9043	1.3115	0.9452	0.9639	0.3024
2	8.0562	3.5015	2.5231	2.4631	0.7894
3	13.5586	5.8898	4.2483	4.1727	1.3776
4	18.8889	8.3200	6.0061	5.9625	2.0375
5	23.9073	10.7517	7.7765	7.8136	2.7573
6	28.6024	13.1812	9.5679	9.7413	3.5284
7	32.9857	15.5983	11.3793	11.7442	4.3400
8	37.0257	17.9618	13.1795	13.7777	5.1763
9	40.6205	20.1942	14.9044	15.7544	6.0167
10	43.6145	22.1921	16.4688	17.5638	6.8383
11	45.8505	23.8531	17.788	19.1082	7.6199
12	47.2816	25.1004	18.8158	20.3806	8.3482

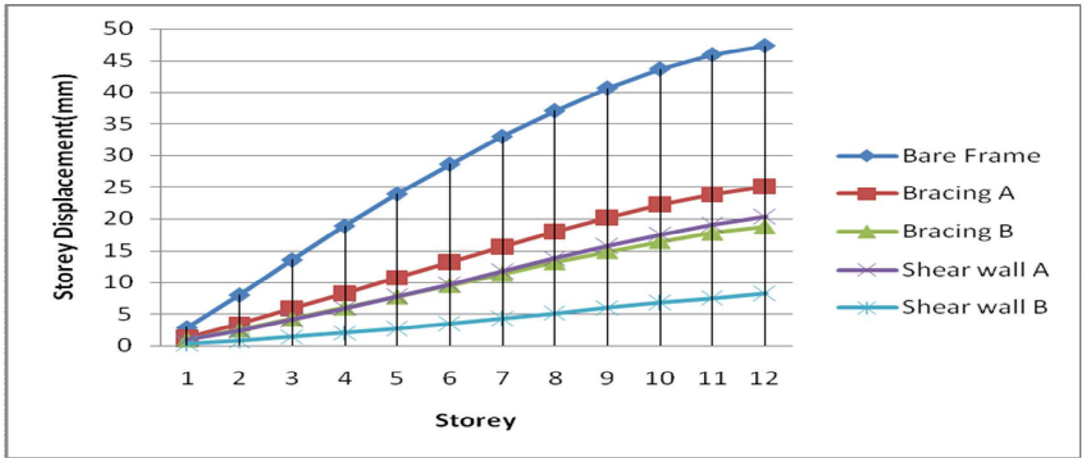

Fig.7 Comparison of Storey Displacement (mm) for ground motion in X- direction .

Table 4: Comparison of Base Shear (kN) for ground motion in X- direction

Storey	Bare Frame	Bracing A	Bracing B	Shear wall A	Shear wall B
12	96.31	92.97	90.55	96.03	101.82
11	186.30	180.48	176.61	209.45	221.85
10	260.19	254.22	250.71	306.97	326.85
9	315.82	312.90	311.73	387.07	415.88
8	355.49	358.53	361.06	451.21	490.01
7	385.70	395.71	402.06	503.53	551.74
6	414.42	429.64	438.47	549.01	603.94
5	446.89	463.45	472.56	591.01	648.55
4	482.44	496.57	503.93	629.57	685.85
3	515.28	525.23	529.92	661.74	714.56
2	538.22	544.74	547.15	683.56	732.95
1	547.22	552.50	553.91	693.02	740.41
BASE	547.22	552.50	553.91	693.66	740.75

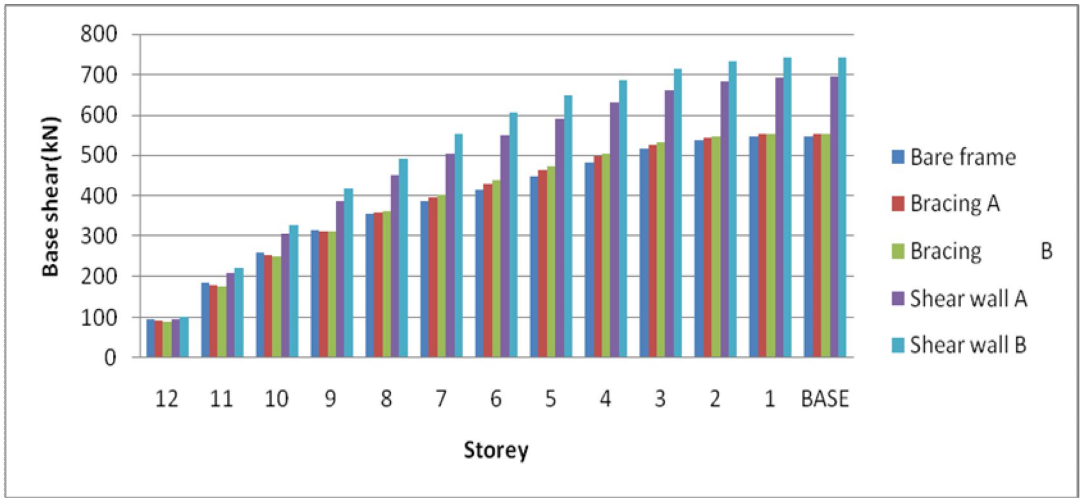

Fig.8 Comparison of Base Shear (kN) for ground motion in X- direction .

By the Staad pro.software, Bending Moments and Shear Forces of all beams and columns have been calculated. But for illustration, the result of only sample beam A_6D_6 (Continuous Beam) is shown in table.The sample beam A_6D_6 is shown in Fig 9.

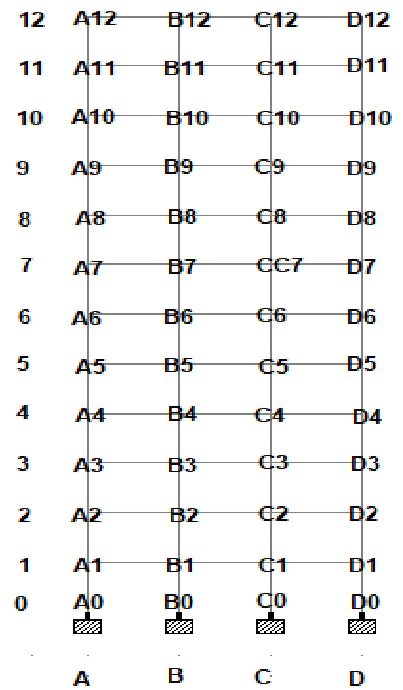

Fig.9 Beam Nomenclature (view from +Z)

Table 5: Comparison of Bending Moment (kNm) of Continuous Beam A_6D_6

Beam	A_6B_6			B_6C_6			C_6D_6		
Section	Left End	Mid Point	Right End	Left End	Mid Point	Right End	Left End	Mid Point	Right End
Bare Frame	127	-32	94	112	-32	112	94	-32	127
Bracing A	109	-33	80	63	-33	63	80	-33	109
Bracing B	62	-33	62	93	-33	93	62	-33	62
Shear Wall A	70	-33	74	64	-33	64	74	-33	70
Shear Wall B	58	-33	61	81	-33	81	61	-33	58

Table 6: Comparison of Shear Force (kN) of Continuous Beam A_6D_6

Beam	A_6B_6			B_6C_6			C_6D_6		
Section	Left End	Mid Point	Right End	Left End	Mid Point	Right End	Left End	Mid Point	Right End
Bare Frame	95	27	-41	89	21	-47	83	15	-53
Bracing A	88	20	-48	69	1	-67	76	8	-60
Bracing B	69	1	-67	81	13	-55	70	2	-66
Shear Wall A	73	5	-63	69	1	-67	86	18	-50
Shear Wall B	67	0	-69	77	8	-60	69	1	-67

VII. CONCLUSIONS

A. Storey drift is significantly lower after inserting shear wall and bracings.Storey drift decreases remarkably in case of shear wall B.

B. There is reduction in Storey deflection in the frame due to bracing and shear wall. The Storey deflection is minimum in case of shear wall B.

C. The base shear is found to be increasing from bare frame to braced frame and is even more for shear walled frame. Base shear is highest in case of Shear wall B.

D. Bending moment and shear force demands on beams are significantly reduced by introduction of Bracing and Shear wall.

E. From the study it is found that frame model Shear wall B (i.e.Shear Wall at corners) is performing better and more efficient than all other frame models.

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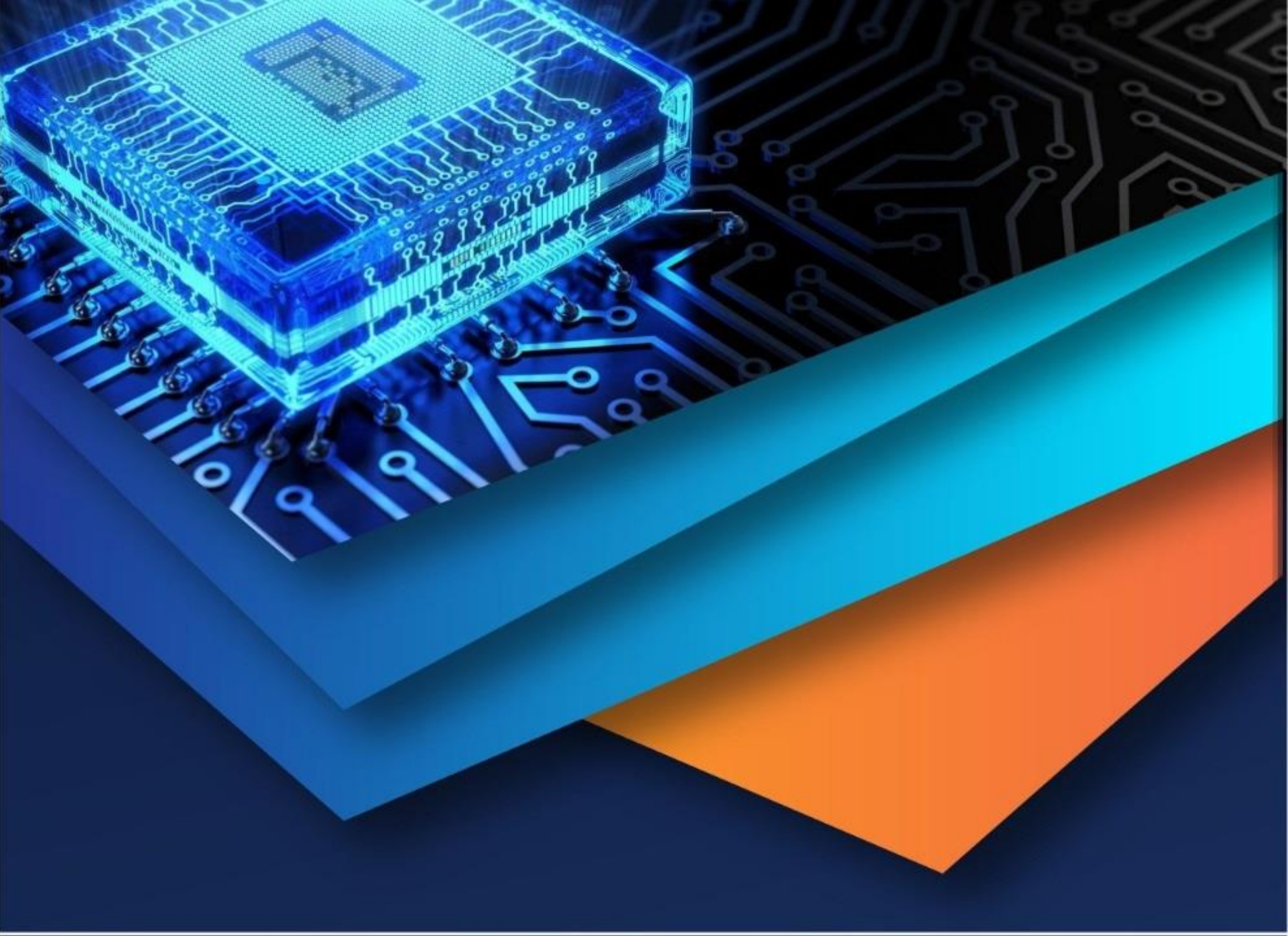

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