ISSN 2277 – 8322

Seismic Behaviour of Podium Connected Tower in Seismic Zone-V With Different Type of Bracings

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***ABSTRACT*- Now a days in India, Higher the land price and scarcity of land in various cities. Vacant land in developed area becomes very less. So, growth in tall building is to be seen.**

This Study is performed on tall building with an earthquake analysis of (2B+G+29) Floor building using Indian Standard code of practice (IS 1893:2016). Seismic forces on a building are calculated using load combination according to (IS 456:2000) limit state method. The structure is designed in line with seismic code. (IS 1893:2016) under seismic zone (V) and (IS 16700:2023). IS 16700:2023 specially for tall building with range in (50m to 250m). Dead load and live load is calculated by (IS 875:1987 PART 1&2) with using (CSI ETABS:2017) software.

The primary objective is how different configuration of bracing impact the structural of the building under earthquake loading utilizing ETABS software. The analysis includes a detailed examination and comparison of lateral displacement, storey drift, storey shear, overturning moment and base shear across various types of bracing such as, X-bracing, XX-bracing & V-bracing.

KEYWORDS: Shear wall, Bracing, Tall building, Storey shear, Storey drift, Response Spectrum Analysis.

I INTRODUCTION

In tall building vertical and horizontal loads impact such as wind & earthquake but when we see in detail part lateral forces impact majorly. As we increase the height of building vertical forces increase linearly. But in lateral forces it varies and increase rapidly as the building height increase. Horizontal/lateral forces impact majorly to building so it gets displace and sway effect can be seen. Which causes failure in building. And these are mainly seen in highly seismic Zone. While designing the structure first noticeable thing is to check lateral stability of structure.

As we know tall building structure component such as slab, beam, column, in rigid frame structure is not capable for stability for above 50-meter structure. These component gets failure in buckling, bending, deflection. We can get out structure stable by increasing the size of other component to overcome the forces. The structure is designed in extreme condition with combining the load combination.

Earthquake forces developed at different floor level in building down to ground. Any deviation or break in this load transfer path leads to building not serviceable. At the time of earthquake, the building such have floating columns or a smaller number of columns which could not transfer the load to the foundation may get major impact at the time of earthquake.

II LITERATURE REVIEW

Mohammad Sameed Ahmed (2024) –He conducted the researchon G+20 floor building with five modelsto analyse the effect of earthquake in different zones. Then, the combination of shear wall and belt truss at different storeys concluded that this combination increased the stiffness of structure. The effective result was seen when belt truss was placed at 12^{th} floor thendisplacement and drift wasreduced.

Aparna Shiny Gottem, Lingeshwaran (2023) - They conducted the researchon50 storey structure and five types of models was taken with different seismic zone to analysis bare frame, forward inclined, inverted V, zig-zag and X-platter. Inverted V gave better result as compared to others. BRB (buckling resisting bracing) reduced the storey drift and displacement.

Mohit Kumrawat, Sambhav Gangwal (2023) - They conducted the researchonG+14 storey structure with four different model was seen to analyse bare frame, belt wall, bracing and damper. 5 storey, 10 storey, 15 storey to analysis of bending moment, shear force, base shear and displacement. Damper in bending moment value suddenly increased in 5,10,15 storey and decreased in 6,11 storey, shear force in 1 to 14th storey gradually increased but in 15th it highly increased. Base reaction in belt wall was high as compare to other.

Yaseen Ahmad (2023) - They conducted this researchonG+14 storey structure to analyse different types of bracing in earthquake zone. They concluded thatin seismic zone (IV) as we move in upward storey the lateral force effect increased. So, (X) bracing was used to reduce the effect and it gave better result as compared to others.

Anamika Singh, Rajeev Singh Parihar, Abhay Kumar Jha, Barun Kumar, Rajesh Misra (2022) - They conducted this researchonG+14 storey structure with four different model such as, Without Bracing, bracing in (X) direction, bracing in (Y) and bracing in corners. This was conducted for seismic zone (3,4,5). They concluded that base shear was same for all the model in all the zone. Shear force and torsion was increased in some cases. Minimum bending moment was seen when the bracing was used in both the directions.

Md. Rajibul Islam, Sudipta Chakraborty and Dookie Kim(2022) - They conducted the researchon using three types of frame and G+10 storey building. Frames such as, bare frame, bracing and shear wall. The use of shear wall reduced the lateral forces and drift ratio. Shear force building showed high moment due to more weight. And it provided more resistance to reduce torsion.

III SEISMIC ANALYSIS

In this study, the modelling of the structure has been classified. Such as, structural frame with bracing and the structural frame without bracing, in comparison with various types of bracing. The multistorey building is G+29 storey and four models are designed in earthquake Zone-V with IS code 1893:2016 with the help of ETABS 2017 software, so that the parameters of structure is evaluated such as storey shear, base shear, storey drift, storey displacement and overturning moment followed by response spectrum method is considered for the analysis of structure.

For modelling ETABS software is used. IS code used for concrete IS 456: 2000, earthquake IS 1893: 2016, shear wall IS 13920: 1993, and for tall building IS 16700: 2023 is use.

Procedure of seismic analysis is categorized into the five methods which is given below:

- Equivalent Static Analysis
- Response Spectrum Analysis
- Linear Dynamic Analysis
- Non-Linear Static Analysis
- Non-Linear Dynamic Analysis

This study conducts on Response Spectrum Analysis. The methodology incorporates the ability to consider a structure's response in various forms. It is found in most building codes except the easiest or the most difficult architectures, that is almost always need. One may describe the behaviour of structural system which is the sum of values of several individual shapes (mode) that correspond the harmonics of a vibrating string. A computer-aided design program can compute those modes for the given design. At each point, a response corresponding to that mode is obtained by design spectrum incorporating the modal frequency and modal mass, and response is summed to get the structure's response. This required calculation of magnitude of forces in all the three direction and then observe the changes in the structure and analyse the changes in structure and their associations of procedure as following:

- Absolute- peak values are added together
- Square root of the sum of the squares
- Complete quadratic combination

Outcomes from this method used for analysing utilizing a response spectrum from earth movement is distinct from what we obtained with linear dynamic analysis using that particular earth particular earth movement through physical model, as phase information is lost in this generation process.

In instances if structure is overly asymmetric in nature or excessively high the response spectrum concept becomes inappropriate, and often more advanced analytical techniques followed by nonlinear static & dynamic analysis are employed instead.

IV METHODOLOGY

Four models having the same number of floors with G+29 having the same floor plan of X-138 m and Y-138 m are considered for the study, in which three models having same thickness of shear wall 300 mm in all models except Model-1. The building floor height was considered 4 m for basement to ground floor and 3.5 m for ground floor to the Top floor of the building. And Bracing dimension are same for all type 300x300 mm. Data-based structure design is performed with the help of ETABS 2017.

In this study the modelling is classified with combination of shear wall and bracing. Such as,

Model 1- Without Bracing Structure

Model 2- X-Bracing Structure

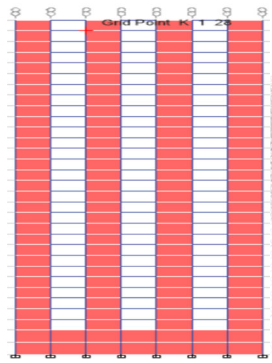
Model-3 XX-Bracing Structure

Model-4 V-Bracing Structure

Table 1 Geometry of Building

Frame Type	R.C.C Frame
Structure Type	Business and office Building
Building Geometry	Irregular Building
Number of storeys	G+29
Total Height of Building	101.5
Dimension in X-Direction	138 m
Dimension in Y-Direction	138 m
Storey Height from basement to Ground Floor	4m
Storey Height From Ground Floor to Top floor	3.5m
Slab thickness	150mm
R.C.C. Beam Size	450x450mm
R.C.C. Column Size	900x900mm 750x750mm
Thickness of Shear Wall	300mm
R.C.C. Bracing Beam	300x300mm
Concrete Grade	M35
Steel Grade	Fe550
Methodology of Analysis	Response Spectrum Analysis
Soil Type	Medium

Model 1 Building Without Bracing



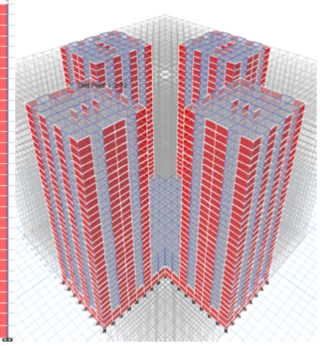


Fig. 1 Elevation view Fig. 2 3D view

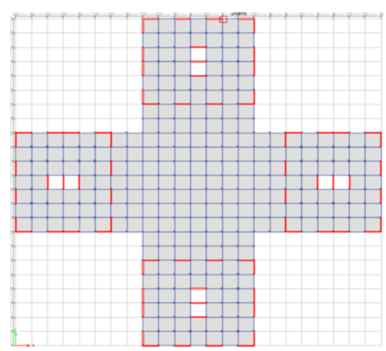


Fig. 3A Plan View Basement To 4th Floor

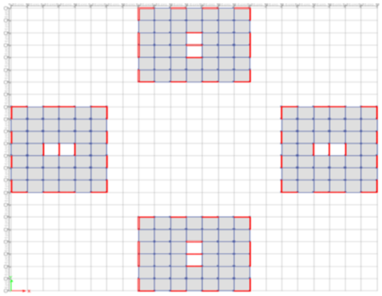
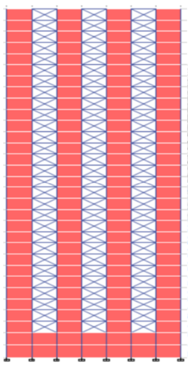


Fig. 4B Plan View 4th Floor to Top Floor

Model-2 Building With X-Bracing



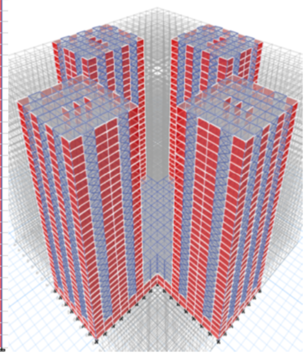


Fig. 5 Elevation view   Fig. 6 3D view

Model-3 Building With XX-Bracing

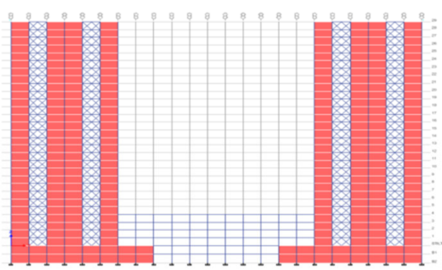


Fig. 7 Elevation view

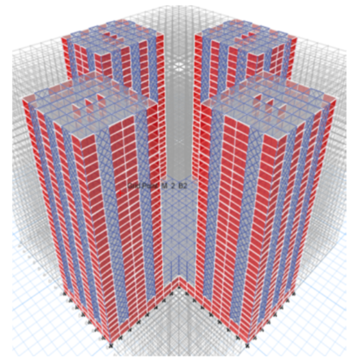


Fig. 8 3D view

Model-4Building With V-Bracing

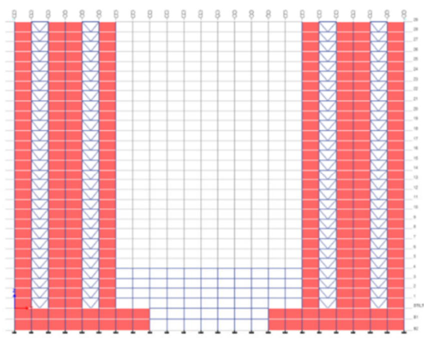


Fig. 9 Elevation view

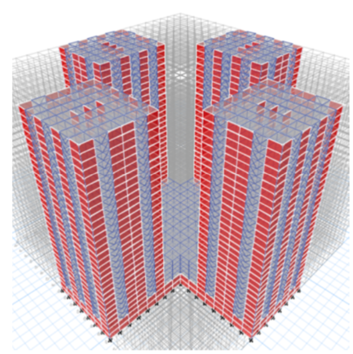


Fig. 10 3D view

Base Shear

Sliding force that a base of structure withstands during ground motion, the forces is called base shear.

Vb=Ah*W

Vb = Base Shear

Ah = Spectral Acceleration Coefficient

h = Total Height of Structure

d = Width of Structure

Time Period and Seismic Coefficient Calculation

According to IS 1893:2016 Time period is calculated by

$T = 0.075h^{0.75}$

T = 2.39 sec

Sa/g = 1.36/T

Sa/g = 0.56

Seismic Coefficient,

Ah = ZI (Sa/g) / 2R

Ah = 0.0241

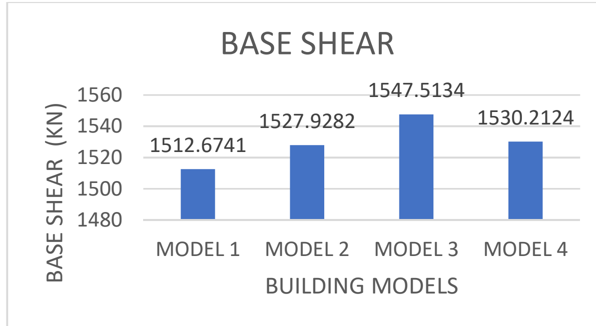
Table 2 Base Shear Calculation

S.NO.	Building Models	Design Horizontal Acceleration (sec)	Seismic Weight as per ETABS (W)	Base Shear (KN)
1	Building Without Bracing (M1)	**2.398**	**62766.5634**	**1512.6741**
2	Building With X-Bracing (M2)	**2.398**	**63399.5112**	**1527.9282**
3	Building With XX-Bracing (M3)	**2.398**	**64212.1759**	**1547.5134**
4	Building With V-Bracing (M4)	**2.398**	**63494.2916**	**1530.2124**

VI COMPARISION & RESULTS

Base shear comparison of four different models with building having without bracing, X-bracing, XX-bracing and V-bracing.The value of building without bracing is 1512 KN considered as the reference for comparing the base shear.

The result of comparison for base shear, noticed that the building with XX-bracing (Model-3) has increased by 2.25%, in building with V-bracing (Model-4) value is increased by 1.14% and in building with X-bracing (Model-2) 1%.



Graph 1 Graphical Comparison of Base Shear Across Building Type

STOREY DISPLACEMENT

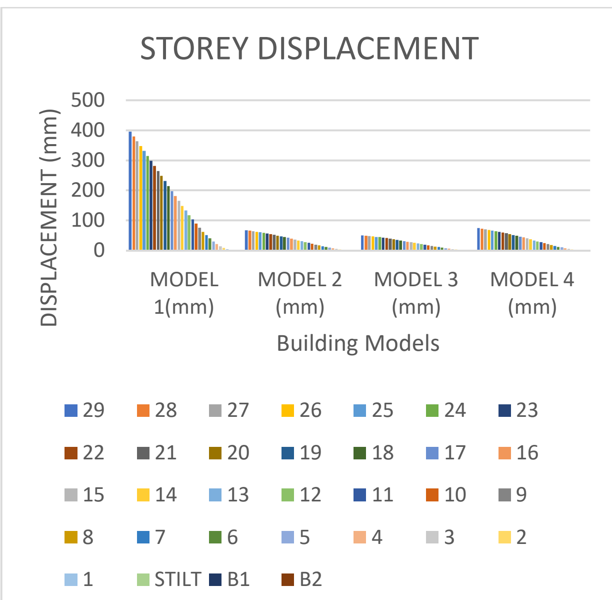
On comparison of four different models designed with different bracing. Such as, X-bracing, XX-bracing and V-bracing to find the storey deflection the without bracing building displaced by 395.98 mm considered as the reference for comparing and the value of displacement and graphical representation of all models.

On comparing the above data with base Model-1 the storey displacement has been decreased by 83% in Model-2, 87.27% in Model-3 and 81.3% in Model-4 observed. The minimum value of storey displacement has been observed in Model-3.

Table 3 Storey Displacement Valur Extracted Form ETABS Across Building Type

STOREY	MODEL 1(mm)	MODEL 2 (mm)	MODEL 3 (mm)	MODEL 4 (mm)
29	395.98	67.337	50.394	73.984
28	380.055	65.705	49.191	72.184
27	363.99	64.008	47.931	70.311
26	347.809	62.225	46.6	68.343
25	331.491	60.342	45.19	66.266
24	315.036	58.352	43.696	64.071
23	298.452	56.253	42.12	61.756
22	281.755	54.046	40.465	59.322
21	264.971	51.735	38.734	56.773
20	248.133	49.325	36.933	54.114

19	231.282	46.825	35.07	51.355
18	214.463	44.243	33.151	48.505
17	197.73	41.59	31.185	45.575
16	181.142	38.875	29.179	42.578
15	164.763	36.112	27.142	39.526
14	148.661	33.312	25.083	36.433
13	132.912	30.489	23.01	33.315
12	117.592	27.657	20.932	30.187
11	102.786	24.83	18.86	27.067
10	88.576	22.024	16.802	23.972
9	75.066	19.259	14.772	20.926
8	62.328	16.551	12.779	17.947
7	50.469	13.924	10.837	15.061
6	39.588	11.402	8.962	12.297
5	29.788	9.014	7.172	9.688
4	21.18	6.796	5.49	7.272
3	13.903	4.795	3.951	5.103
2	8.003	3.046	2.579	3.217
1	3.603	1.608	1.42	1.679
STILT	0.899	0.587	0.561	0.6
B1	0.484	0.307	0.294	0.313
B2	0	0	0	0



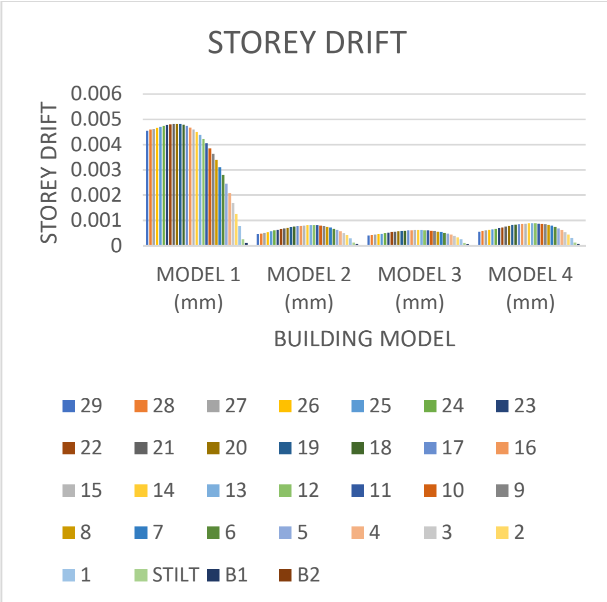
Graph 2 Graphical comparison of storey displacement across Building type

STOREY DRIFT

The data extracted from storey drift. The structure which showing difference in the all models with different types of bracing in structure. On comparing the data with base Model-1 the storey drift has been decreased by 89.75% in Model-2, 91.1% in Model-3 and 87.62% in Model-4 observed. The lesser value in Model-3.

Table 4 Storey Drift Value Extracted from ETABS Across Building Type

STOREY	MODEL 1 (mm)	MODEL 2 (mm)	MODEL 3 (mm)	MODEL 4 (mm)
29	0.00455	0.000466	0.000404	0.000563
28	0.00459	0.000485	0.000419	0.000579
27	0.004623	0.00051	0.000437	0.0006
26	0.004662	0.000538	0.000458	0.000625
25	0.004701	0.000568	0.00048	0.000651
24	0.004738	0.0006	0.000501	0.000678
23	0.004771	0.000631	0.000521	0.000705
22	0.004795	0.00066	0.00054	0.00073
21	0.004811	0.000688	0.000558	0.00076
20	0.004815	0.000714	0.000573	0.000788
19	0.004805	0.000738	0.000586	0.000814
18	0.004781	0.000758	0.000597	0.000837
17	0.004739	0.000775	0.000605	0.000856
16	0.00468	0.000789	0.000611	0.000872
15	0.0046	0.0008	0.000615	0.000884
14	0.0045	0.000807	0.000616	0.000891
13	0.004377	0.000809	0.000614	0.000894
12	0.00423	0.000808	0.00061	0.000891
11	0.00406	0.000802	0.000603	0.000884
10	0.00386	0.00079	0.000592	0.00087
9	0.003639	0.000774	0.000579	0.000851
8	0.003388	0.000751	0.000562	0.000824
7	0.003109	0.000721	0.000541	0.00079
6	0.0028	0.000682	0.000514	0.000746
5	0.002459	0.000634	0.000481	0.00069
4	0.002079	0.000572	0.00044	0.00062
3	0.001686	0.0005	0.000392	0.000539
2	0.001257	0.000411	0.000331	0.000439
1	0.000773	0.000292	0.000245	0.000308
STILT	0.000256	0.000123	0.000112	0.000128
B1	0.000121	7.70E-05	7.30E-05	7.80E-05
B2	0	0	0	0



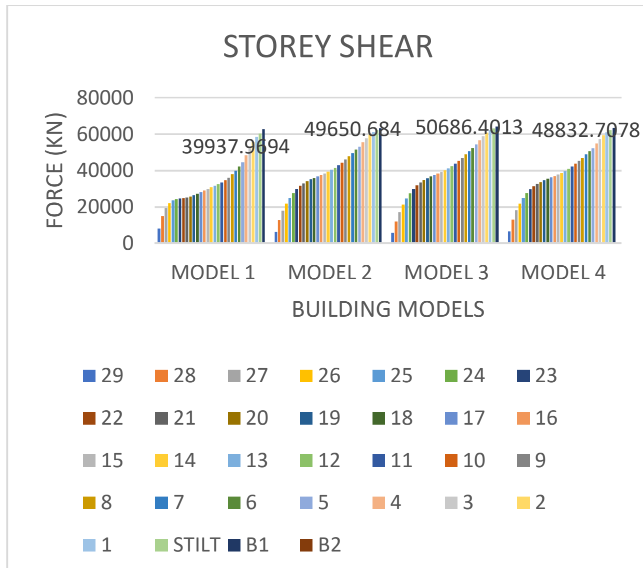
Graph 3 Graphical Comparison of Storey Drift across Building Type.

STOREY SHEAR

On comparison of four different models designed with and without bracing such as, X-bracing, XX-bracing, V-bracing. To find the storey shear the minimum value of building without bracing is 62766.52 KN considered as the base for comparing and the value of displacement and graphical variation of the displacement for different orientation. On comparing the above data, the base Model-1 the storey shear has been increased by 1% in Model-2, 2.30% in Model-3, and 1.15% in Model-4 observed. The increased value Model-3 is obtaining due to the XX-bracing.

Table 5 Storey Shear Value Extracted from ETABS Across Building Type

STOREY	MODEL 1 (KN)	MODEL 2 (KN)	MODEL 3 (KN)	MODEL 4 (KN)
29	8154.7358	6528.9605	6016.3891	6660.8753
28	15090.2016	12907.108	12120.8895	13101.8305
27	19541.0781	17951.904	17149.0351	18135.077
26	22149.2071	21949.4998	21284.1606	22063.1057
25	23589.2836	25181.0118	24722.1377	25190.9706
24	24342.3938	27820.1103	27592.6774	27714.8198
23	24707.4722	29958.0247	29966.9049	29740.6856
22	24925.8682	31674.0469	31903.3344	31354.7943
21	25221.3291	33063.2831	33474.3741	32655.9834
20	25732.1362	34217.1488	34762.1708	33740.7617
19	26454.7162	35200.4839	35841.6692	34678.4305
18	27292.8094	36057.9015	36771.7638	35510.1763
17	28168.1491	36841.0793	37605.4582	36275.9911
16	29064.4456	37618.371	38406.2519	37035.4819
15	29973.0485	38451.9774	39245.1179	37851.9338
14	30857.0309	39378.6996	40179.754	38764.3798
13	31702.5574	40421.6195	41244.2736	39790.0892
12	32567.3493	41604.9092	42457.128	40945.4866
11	33545.8394	42942.9294	43826.7332	42246.4886
10	34729.3669	44446.189	45367.6549	43712.631
9	36177.5413	46097.631	47065.0569	45332.4139
8	37909.2092	47844.8795	48855.4219	47051.618
7	39937.9694	49650.684	50686.4013	48832.7078
6	42217.6679	51462.7586	52501.2519	50630.3193
5	44623.788	53210.983	54235.6762	52379.5483
4	48356.2235	55559.7987	56636.6113	54877.0807
3	52237.3442	57820.4545	58903.2279	57315.5357
2	55753.6172	59775.438	60821.6002	59445.2461
1	58521.8138	61267.1501	62260.727	61090.0979
STILT	60456.6964	62280.0155	63218.9029	62220.9453
B1	62766.52	63399.5112	64212.1659	63494.2765
B2	0	0	0	0



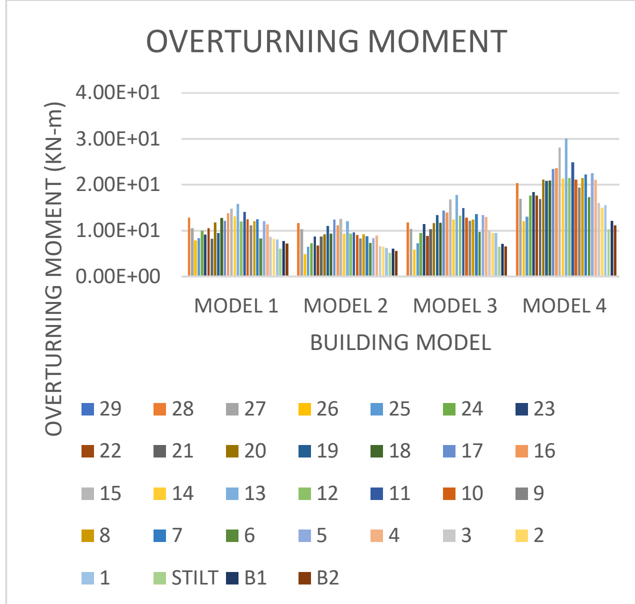
Graph 4 Storey Shear Value Extracted from ETABS Across Building Type

OVERTURNING MOMENT

The analyze shows that maximum overturning moment is in Model-4 with V-bracing. In V-bracing maximum overturning moment is 30.0393 KN-m, X-bracing maximum overturning moment is 12.5671 KN-m, XX-bracing maximum overturning moment is 17.7823 KN-m, and without bracing overturning moment is 15.8373 KN-m

Table 6 Overturning Moment Value Extracted from ETABS Across Building Type

STOREY	MODEL 1 (KN-m)	MODEL 2 (KN-m)	MODEL 3 (KN-m)	MODEL 4 (KN-m)
29	4.57E-05	3.13E-05	7.22E-06	3.01E-05
28	12.8909	11.7218	11.8518	20.343
27	10.6044	10.3167	10.3677	16.9432
26	7.8877	4.8627	5.8622	12.0934
25	8.3895	6.491	7.229	13.0622
24	10.0066	7.2076	9.4804	17.6558
23	9.1251	8.7157	11.4005	18.4599
22	10.5462	6.7791	8.8828	17.6814
21	8.1932	8.7423	10.3401	16.8562
20	11.8515	9.187	11.7113	21.1348
19	9.5024	11.0326	13.395	20.8879
18	12.8267	9.3132	11.7683	20.9326
17	12.1195	12.4348	14.3776	23.3973
16	13.8458	11.1376	13.99	23.6683
15	14.7523	12.5671	16.8142	28.1476
14	13.1249	9.3509	12.4372	21.3054
13	15.8373	12.0758	17.7823	30.0393
12	12.0127	9.3562	13.2331	21.5059
11	14.0882	9.6388	14.8776	24.9513
10	12.4443	9.0612	12.8572	21.1173
9	11.1802	8.3045	12.1255	19.3948
8	12.1135	9.1687	12.4213	21.5268
7	12.4734	8.8068	13.5854	22.2383
6	8.2724	7.3356	9.7515	17.3063
5	12.1009	8.3929	13.4212	22.49
4	11.3345	8.9674	13.0095	21.043
3	8.6949	6.6255	10.0713	16.1036
2	8.1937	6.5042	9.4429	15.0446
1	8.1088	6.2274	9.4762	15.5333
STILT	6.0701	5.2049	6.4797	10.3238
B1	7.7515	6.063	7.0767	12.1189
B2	7.1593	5.5734	6.5808	11.169



Graph 5 Overturning Moment Value Extracted from ETABS Across Building Type

V CONCLUSION

This study completed with seismic performance of building in Zone-V by analysis of various models with and without bracing using Response Spectrum by ETABS software and assigning the parameter according to IS1893:2016. Results follow a comparison with building without bracing and with bracing of various types. The results under significant differences in performance and structural behaviour under seismic loading and enhancing the lateral stability and overall resilience of structure subjected to seismic forces and concluded as:

1. The structure designed with XX-bracing gives more stability and stiffness to the building as compare to other type of bracing.
2. Lateral displacement with XX-bracing type significantly lower than without bracing. The reduction in displacement is 83% in X-bracing, 87.27% in XX-bracing and 81.3% in V-bracing compare with building without bracing. This shows that the structure with XX-bracing provides better seismic activity and less displacement in structure.
3. Comparing all the models the storey drift is decreased by 89.75% in X-bracing, 91.1% by XX-

bracing and 87.62% by V-bracing. XX-bracing shows the better results as compared to other Models.

4. The base shear rise in the XX-bracing of structure due to more stiffness.
5. Performance comparison- The building with XX-bracing show better results in lateral stiffness and structural stability. The bracing minimizes the lateral displacement.
6. In this study shear wall is also provided but due to higher earthquake shear wall is insufficient to resist the lateral forces so that bracing is to be provided for better results.

From the results this study concluded that use of bracing in higher seismic region is better option with shear wall. and also, in the comparison concluded that XX-bracing gives more effective results as compared to other bracing models. XX-bracing overcome the lateral forces that affect to the building.

This study will help structural engineers and designers to choose optimum use of different type of bracing and save time on working on IS 1893:2016 outline the criteria of seismic assessment.

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