STRUCTURAL PERFORMANCE WITH DIFFERENT BUILDING CONFIGURATIONS AND BRACING SYSTEMS: ANALYTICAL APPROACH

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Abstract

Earthquake-resistant structures are designed to protect buildings during seismic events. While no structure can be completely immune to earthquake damage, the goal of earthquake-resistant construction is to enhance the performance of buildings compared to conventional structures. According to building codes, such structures are intended to withstand the largest probable earthquake at a given location, minimizing loss of life by preventing collapse during rare events and limiting functionality loss during more frequent earthquakes. In recent years, steel bracing systems have been widely adopted for designing earthquake-resistant buildings due to their ease of construction, simple installation, and effectiveness in reducing lateral deflection and shear forces. Previous studies have demonstrated significant improvements in the structural behavior of braced buildings under seismic loading. In the present study, a G+15 storey building is modelled using ETABS software and analyzed using the Response Spectrum Method. A comparison is made between unbraced buildings, V-type braced buildings, and X-type braced buildings for three different plan configurations: Regular, T-shaped, and H-shaped. Key seismic performance parameters such as storey drift, storey shear, storey moment, building torsion, time period, and modal stiffness are evaluated to assess and design efficient earthquake-resistant structures.

Key words: Earthquake-resistant structures, ETABS software, seismic performance, G+15 stored building

1. Introduction

Earthquakes are one of the most destructive natural disasters, causing significant damage to buildings and infrastructure. The unpredictable nature of earthquakes makes it essential to design structures that can withstand seismic forces, reducing the risk to human lives and minimizing property damage. Over the years, seismic engineering has advanced with the development of various strategies to improve building performance during earthquakes. This study analyzes the seismic behavior of G+15 stored buildings with V-type and X- type bracing systems in three plan configurations: Regular, T-shaped, and H-shaped. Using ETABS software and the Response Spectrum Method. The analysis covers only the specified configurations and bracing types, using the Response Spectrum Method to model the seismic effects on the buildings. The results aim to provide insights into the advantages and limitations of different bracing systems in improving the seismic performance of multi-stored buildings.

2. Objectives

2.1. Seismic Performance Evaluation of G+15 storey buildings with V-type and X-type steel bracing systems.

2.2. Impact of Plan Configurations on Seismic Response of Regular, T-shaped, and H- shaped

2.3. Comparative Analysis of Bracing Systems of V-type and X-type bracing systems in terms of their ability to resist lateral forces, reduce structural deformation, and improve overall stability

3. Methodology

3.1 Building Description

In the present study, analysis of G+ 8 stories building in Zone V seismic zones is carried out in ETABS.

Basic parameters considered for the analysis are as follows: -

1. Utility of Buildings : Residential Building
2. No of Storey : 16 Stories (G+25 Building)
3. Grade of concrete : M40
4. Grade of Reinforcing steel : HYSD Fe500
5. Type of construction : RCC framed structure
6. Dimensions of beam : 460x460mm

7. Dimensions of column : 5690mmX690mm
8. Thickness of slab : 150mm
9. Height of bottom story : 3m
10. Height of Remaining story : 3m
11. Building height :48m
12. Live load : 3 KN/m^2
13. Dead load : 2 KN/m^2
14. Density of concrete : 25 KN/m^3
15. Loads considered in Buildings : Dead load, Live load, Floor load Earthquake, Wind load
16. Seismic Zones : Zone V
17. Site type II
18. Importance factor : 1.5
19. Response reduction factor :5
20. Damping Ratio : 5%
21. Structure class : B
22. Basic wind speed : 44m/s
23. Method of Analysis : Response spectrum
24. Wind design code : IS 875: 1987 (Part 3)
25. RCC design code : IS 456:2000
26. Steel design code : IS 800: 2007
27. Earthquake design code : IS 1893: 2002 (Part 1).

3.2 Modeling in ETABS

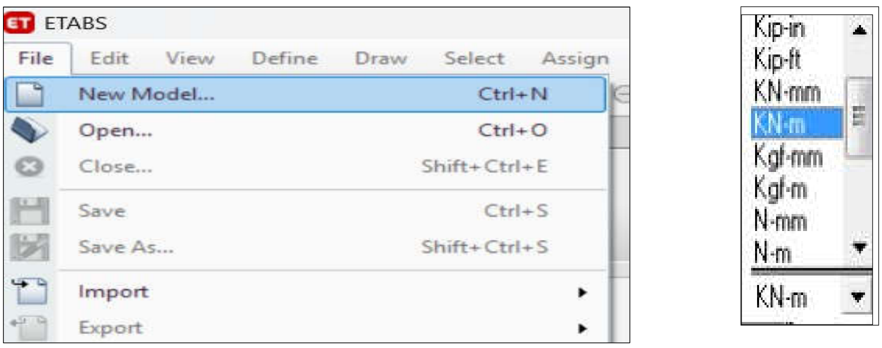


Fig 1 File selection and altering Units

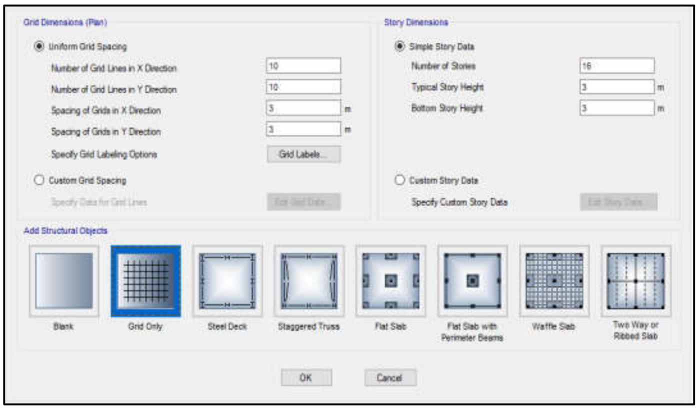
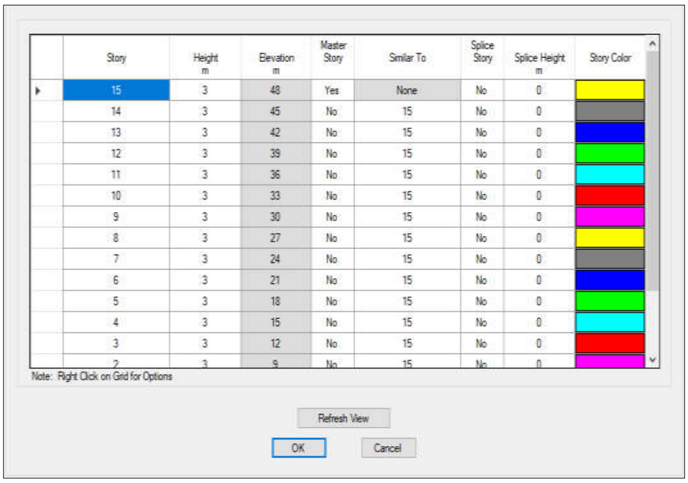


Fig 2 Grid Dimensioning and Story Dimensioning



Story	Height m	Elevation m	Master Story	Similar To	Splice Story	Splice Height m	Story Color
15	3	48	Yes	None	No	0	
14	3	45	No	15	No	0	
13	3	42	No	15	No	0	
12	3	39	No	15	No	0	
11	3	36	No	15	No	0	
10	3	33	No	15	No	0	
9	3	30	No	15	No	0	
8	3	27	No	15	No	0	
7	3	24	No	15	No	0	
6	3	21	No	15	No	0	
5	3	18	No	15	No	0	
4	3	15	No	15	No	0	
3	3	12	No	15	No	0	
2	3	9	No	15	No	0	

Fig 3 Elevation data of Building

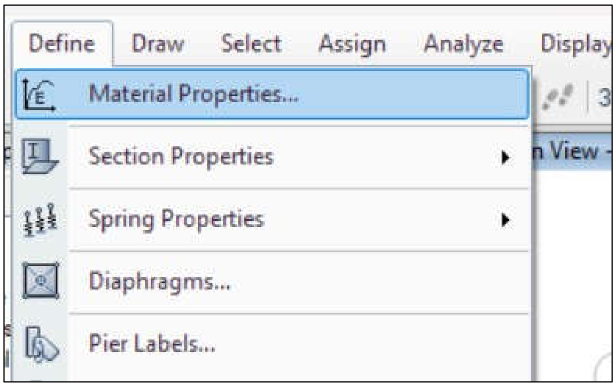


Fig 4 Defining Material Properties

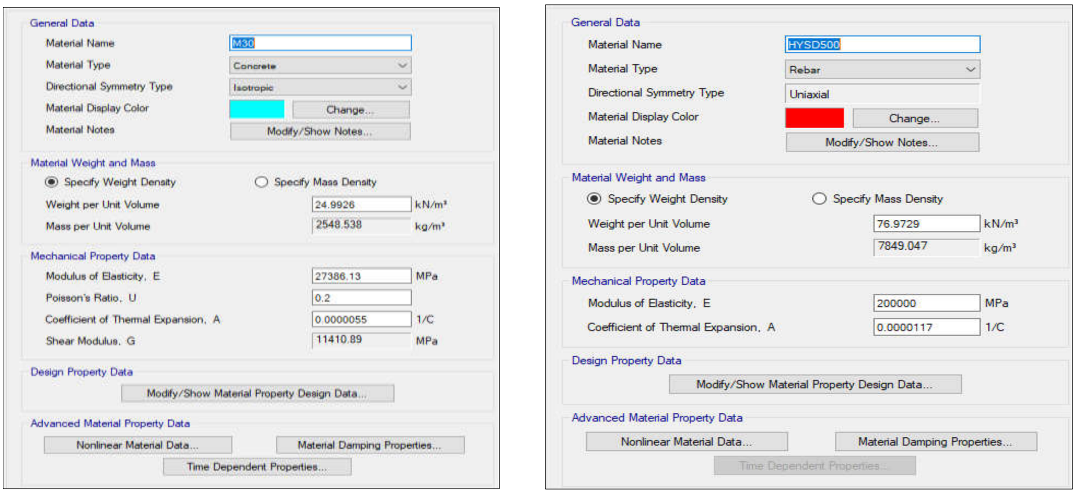


Fig 5 Defining M40 and Fe 500 grade Steel

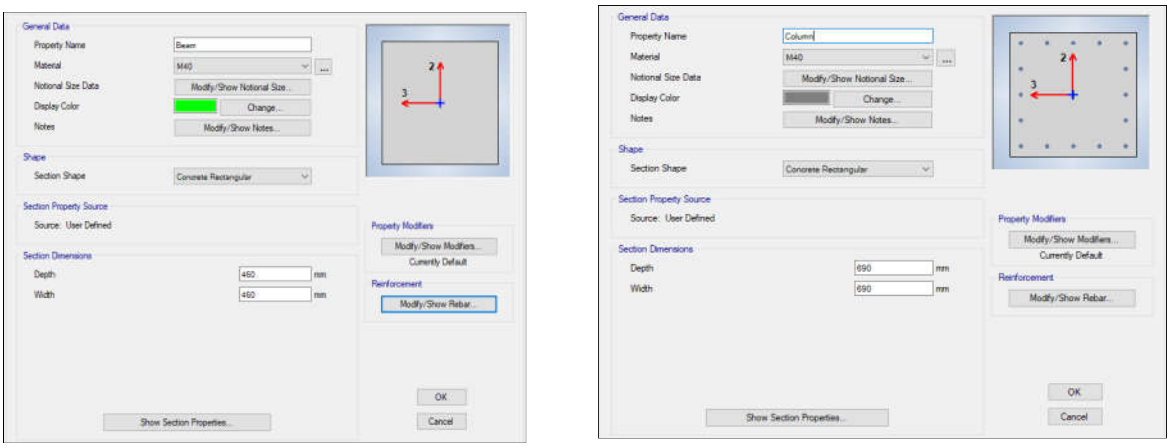


Fig 6 Defining Beam and Column Sections

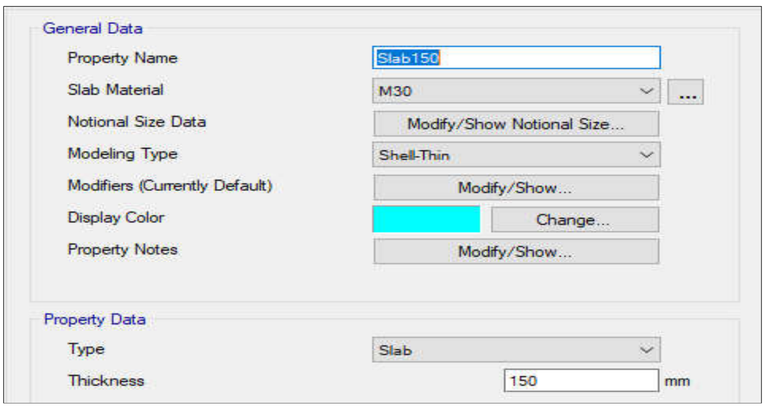


Fig 7 Defining Slab section

Building Geometry Creation

The structural components of the building, such as beams, columns, floors, and walls, are modelled using the Quick Draw tools provided in ETABS. These tools enable fast and accurate creation of structural members necessary for seismic and gravity load analysis.

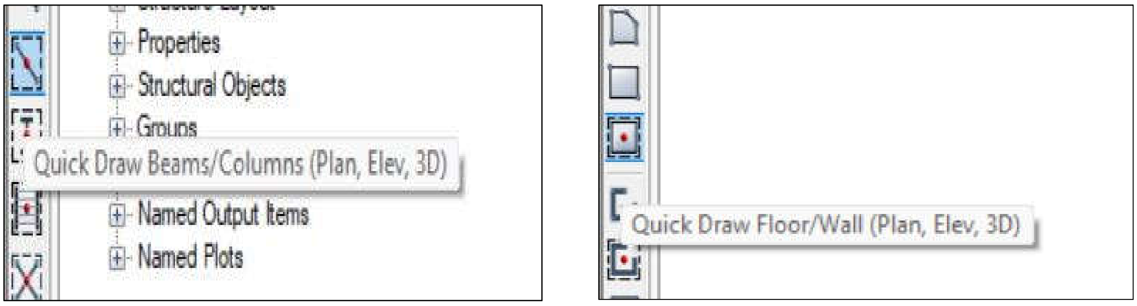


Fig 8 Beams/ Columns Tool & Floor/ wall Tool

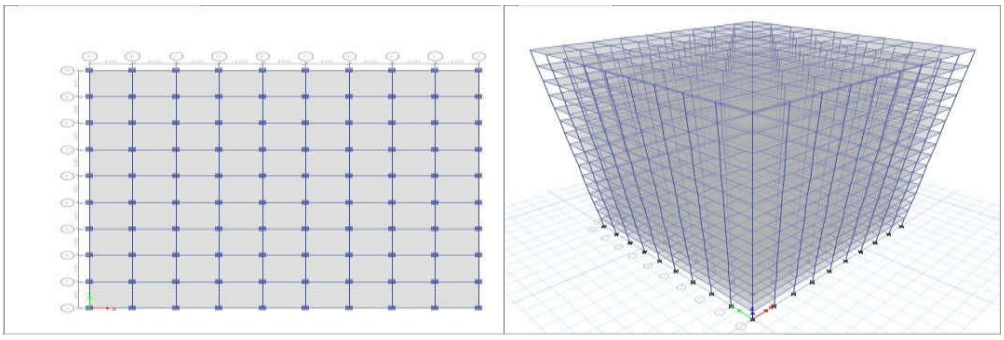


Fig 9 Assigning Beams, Columns, Slab to Regular Shape Building

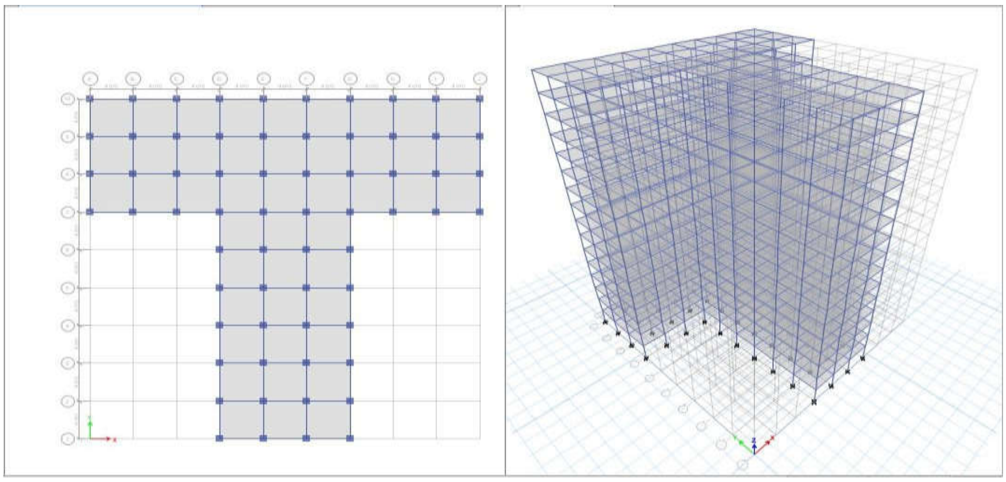


Fig 10 Assigning Beams, Columns, Slab to T Shape Building

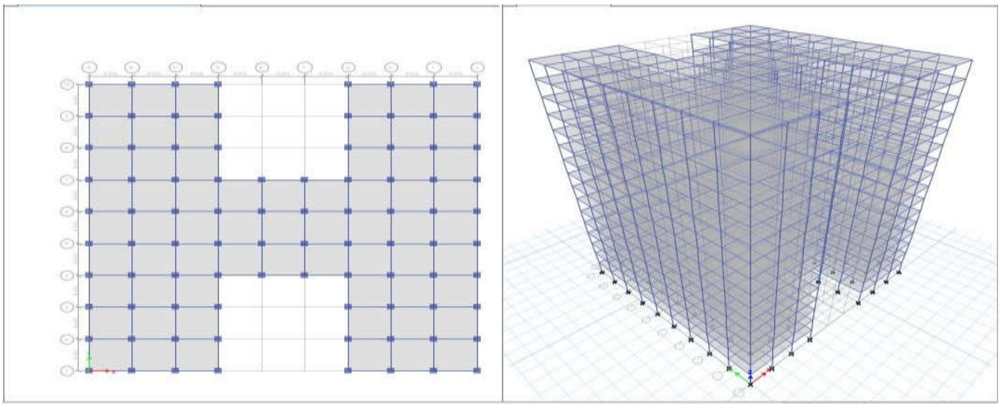


Fig 11 Assigning Beams, Columns, Slab to H Shape Building

Replication of Structure Elements

After modelling the beams, columns, and slabs at the base level, the replication feature of ETABS was used to efficiently generate the full structure. Using the "Replicate" command, the modelled elements were copied vertically to create all the storeys, maintaining the defined storey height of 3 meters. This process ensured that the structure had uniform geometry across all floors, minimizing manual modelling effort and errors. Replication was also used horizontally (in X and Y directions) to extend the framing system across the building plan as per the grid layout. By using replication, a complete G+15 storey model was generated quickly and accurately.

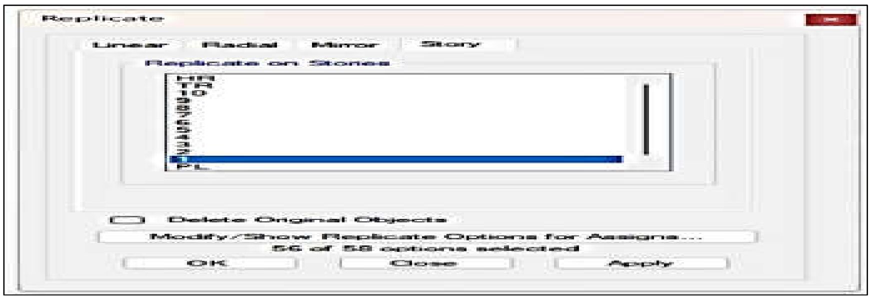


Fig 12 Replicating to top floors

Boundary Conditions

Proper boundary conditions were assigned to the structural model to accurately simulate the real-world behavior of the structure. Supports were applied to the base-level joints by restraining translations along the X, Y, and Z directions, thereby representing fixed support conditions. The assignment of restraints was carried out using the "One Story" selection mode to ensure accurate placement at the required story level.

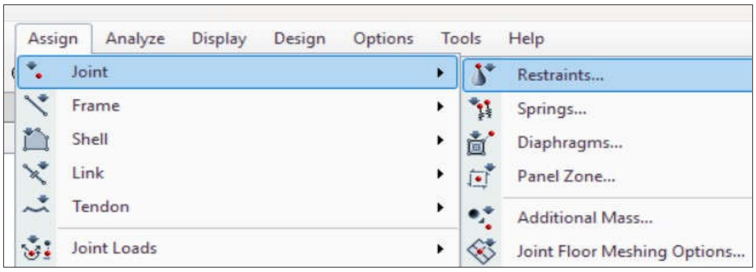


Fig 13 Selection of story Levels and navigating to Assigning Restraints

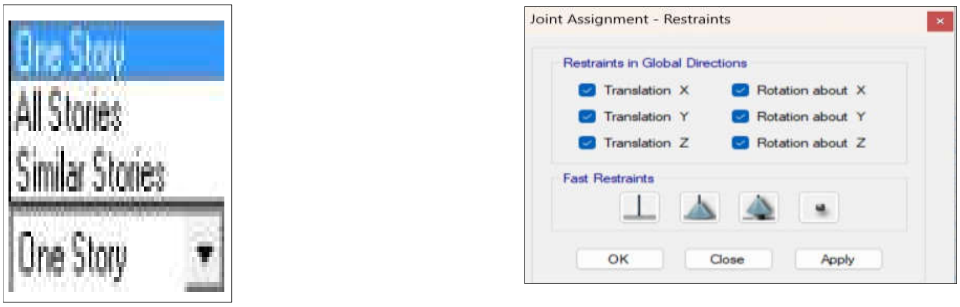


Fig 14 Assignment of Restraints to Joints

Bracing Assignment

After building the basic geometry of the models, steel bracings were assigned to improve the seismic performance of the structures. Two types of bracing systems, V-type bracings and X- type bracings were modelled using steel sections and placed at selected bays to increase lateral stiffness and reduce story drift under seismic loading. Separate models were created for Regular, T-shaped, and H-shaped buildings in three configurations: without bracings, with V- type bracings, and with X-type bracings. This setup is intended to enable a detailed comparison of their behavior under earthquake forces.

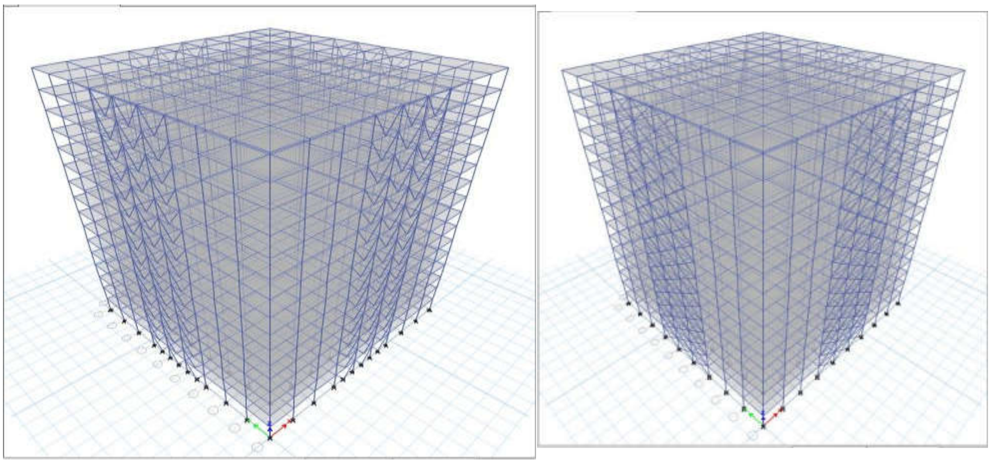


Fig 15 Regular shape building with V type bracings & Regular shape building with X type bracings

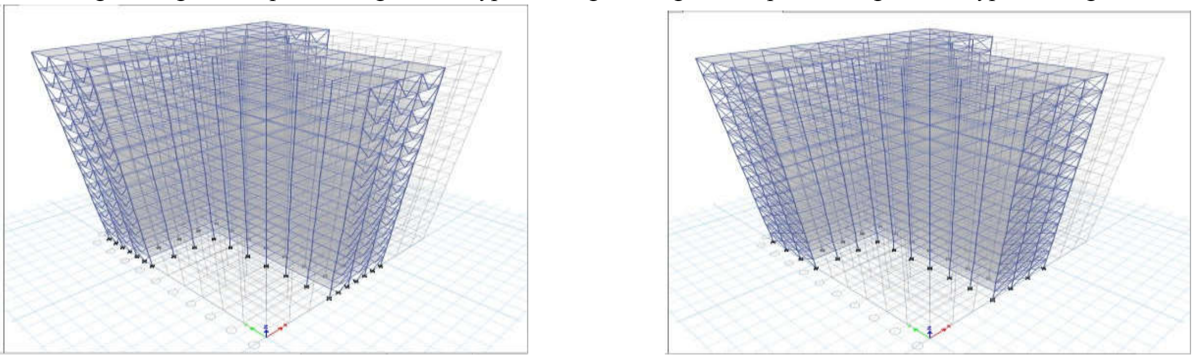


Fig 16 T Shape Building with V type bracings & T Shape Building with X Type Bracings

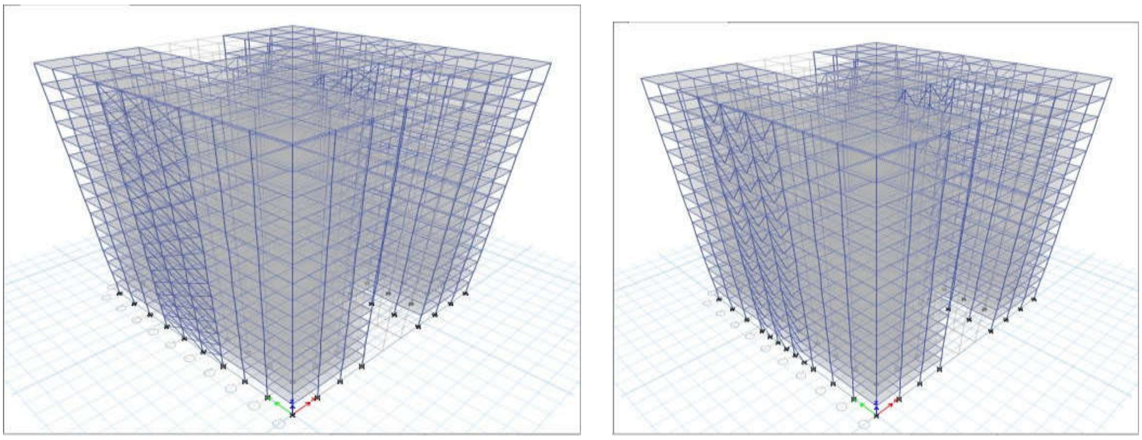


Fig 17 H Shape X Type Bracings & H Shape V Type Bracings

Load Characterization and Allocation

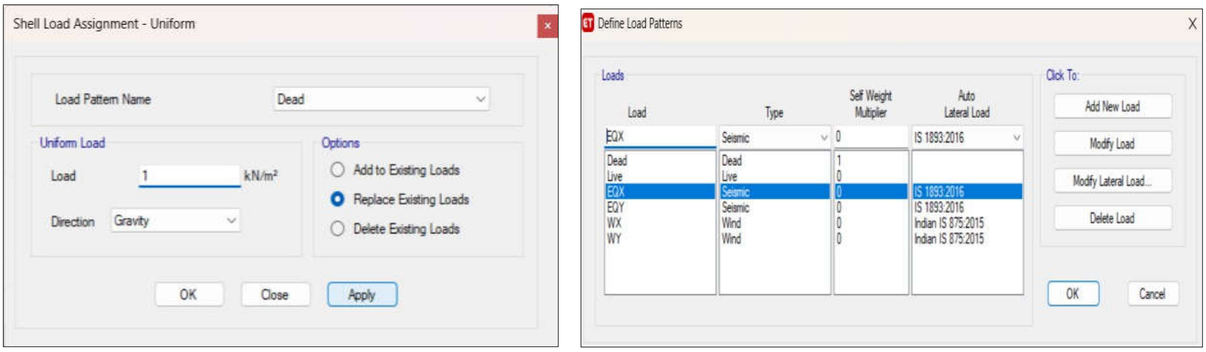


Figure .18 Assigning loads Defining loads

In the present study, diaphragm constraints were assigned at each floor level to ensure that the slabs act as rigid diaphragms. Rigid diaphragms distribute lateral loads to the vertical structural elements, such as columns and bracings, based on their relative stiffness. Assigning diaphragms helps accurately capture the in-plane stiffness of floors and improves the distribution of seismic forces during dynamic analysis in ETABS. In building, slab is considered as a single rigid member during earthquake analysis. For that, all slabs are selected first and applied diaphragm action for rigid or semi rigid condition.

Figure .19 Assigning Diaphragms for the building

Defining Mass Source

The mass source ensures that the dynamic analysis accurately accounts for the inertial forces generated during an earthquake. Proper mass definition is crucial for calculating seismic responses such as base shear, story drift, and time period, which are compared across the general building, V-braced building, and X-braced building models.

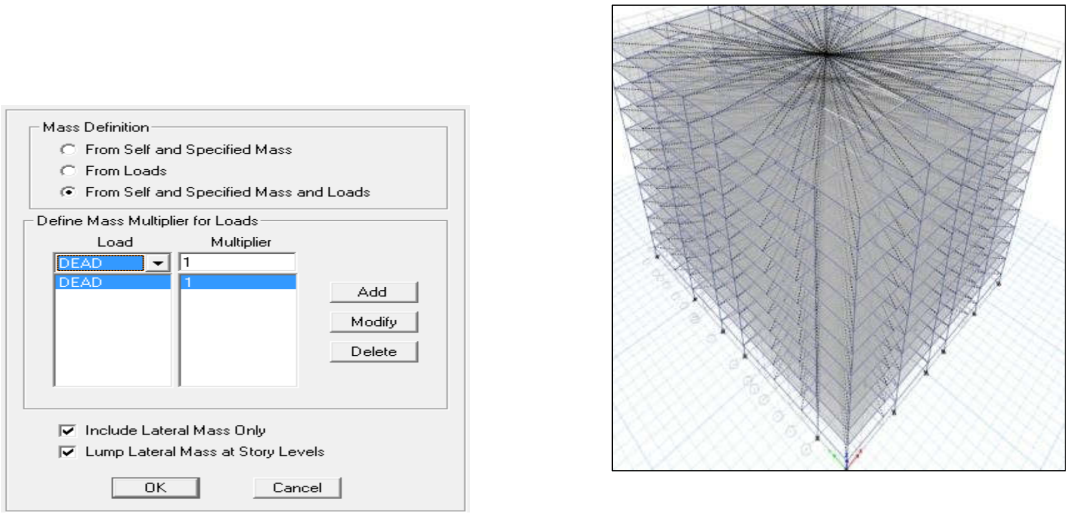


Figure .20 Mass Source command & Defining mass source

Load Combinations

Load combinations were defined according to IS 1893 (Part 1): 2016 guidelines to account for the combined effects of dead load, live load, and seismic loads during analysis. In this study, response spectrum analysis was carried out, and the following load combinations were considered: 1.5 (DL + LL), 1.2 (DL + LL ± EQx), 1.2 (DL + LL ± EQy), 1.5 (DL ± EQx), 1.5 (DL ± EQy), and 0.9 DL ± 1.5 EQx/y. These combinations ensure that the structure is adequately designed for both gravity and lateral loads, maintaining safety and performance under earthquake conditions.

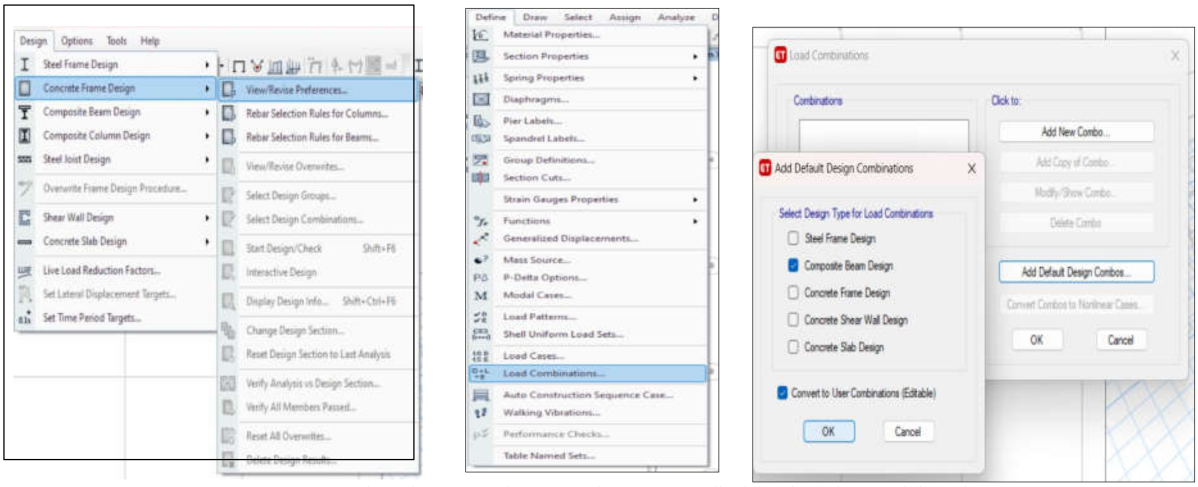


Figure .21 Selecting Design Code & Defining load combinations

Design Code Selection

For the design of reinforced concrete structures, IS 456:2000 was selected as the governing design code. the necessary strength and stability requirements ensure that the structural elements such as beams, columns, slabs, and foundations meet under both gravity and seismic loads to allowing for the safe and efficient design of earthquake-resistant structures.

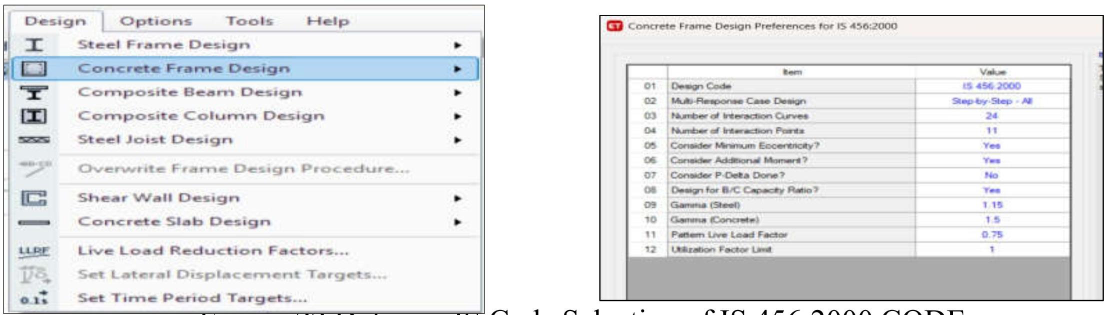


Figure .22 Defining IS Code Selection of IS 456:2000 CODE

Response Spectrum Analysis

In this a Response Spectrum Analysis was performed to evaluate the seismic behavior of the building models under earthquake loading. The analysis was conducted using ETABS, where appropriate seismic parameters based on IS 1893 (Part 1): 2016. This specifies the necessary provisions for seismic design, including the definition of seismic zones, soil types, and the response spectrum function. The damping ratio was set at 5%, and the time period for the buildings was determined using the fundamental frequency of vibration,

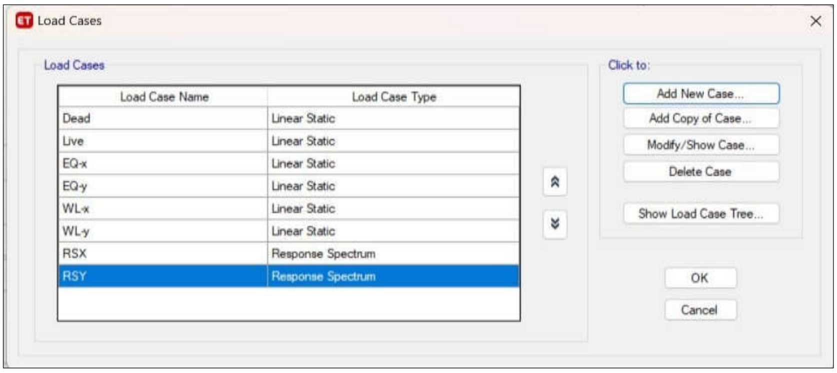


Figure .23 Defining Response Spectrum Analysis

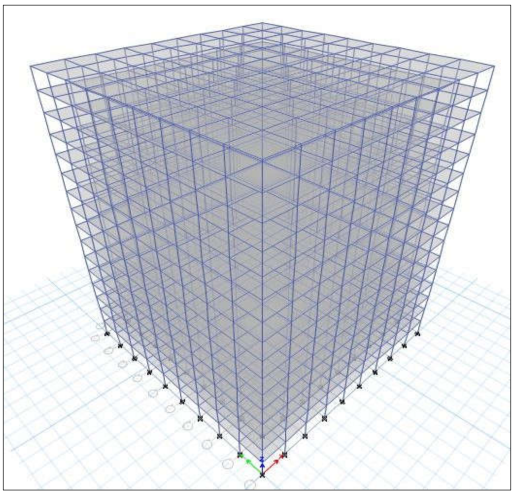
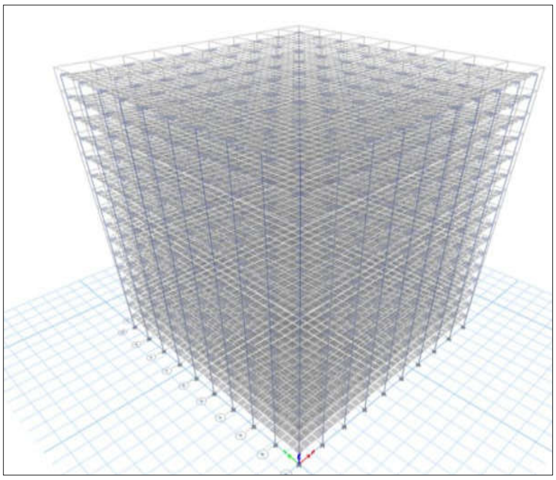



Figure .35 3D Rendered View of building & Final building after analysis

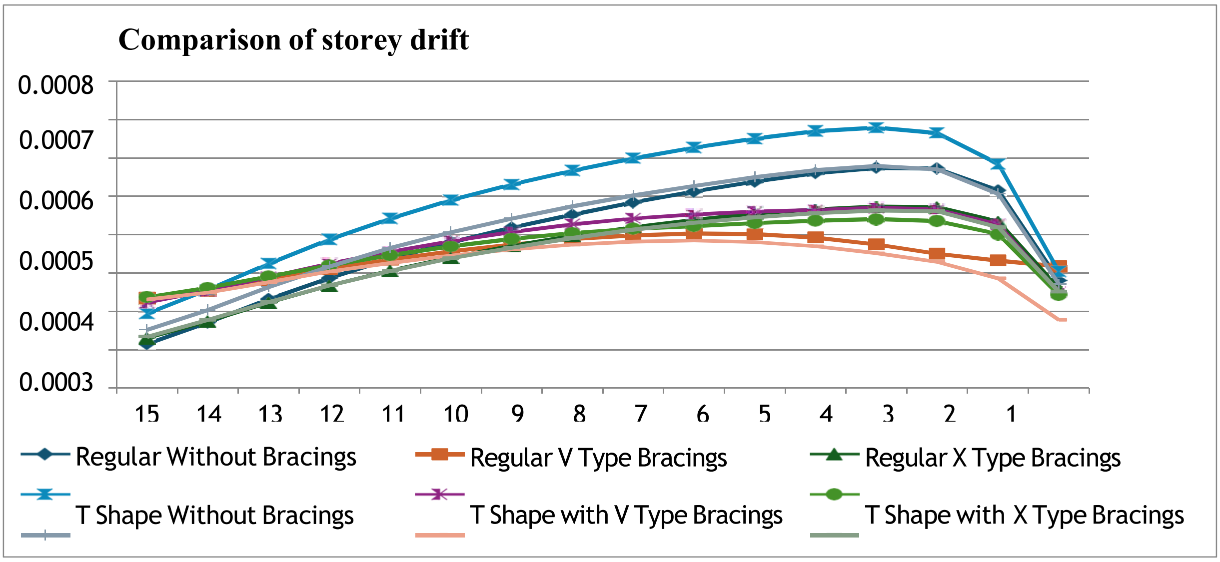
4. RESULTS AND ANALYSIS

4.1 Comparison of storey drift

Table .1 Comparison of storey drift

Storey Number	Regular Without Bracings	Regular with V Type Bracings	Regular with X Type Bracings	T Shape Without Bracings	T Shape with V Type Bracings	T Shape with X Type Bracings	H Shape Without Bracings	H Shape with V Type Bracings	H Shape with X Type Bracings
15	0.00012	0.00024	0.00013	0.0002	0.00022	0.00024	0.00015	0.00023	0.00013
14	0.00017	0.00025	0.00017	0.00026	0.00025	0.00026	0.0002	0.00025	0.00018
13	0.00023	0.00028	0.00022	0.00033	0.00029	0.00029	0.00026	0.00028	0.00023
12	0.00029	0.00031	0.00027	0.00039	0.00032	0.00032	0.00032	0.0003	0.00027
11	0.00034	0.00034	0.00031	0.00044	0.00036	0.00035	0.00037	0.00033	0.00031
10	0.00038	0.00036	0.00034	0.00049	0.00038	0.00037	0.00041	0.00035	0.00034
9	0.00042	0.00038	0.00037	0.00053	0.00041	0.00039	0.00044	0.00036	0.00037

8	0.00045	0.00039	0.0004	0.00057	0.00043	0.00041	0.00048	0.00037	0.00039
7	0.00049	0.0004	0.00042	0.0006	0.00044	0.00042	0.0005	0.00038	0.00041
6	0.00051	0.0004	0.00044	0.00063	0.00045	0.00042	0.00053	0.00039	0.00043
5	0.00054	0.0004	0.00046	0.00065	0.00046	0.00043	0.00055	0.00038	0.00045
4	0.00056	0.00039	0.00047	0.00067	0.00046	0.00044	0.00057	0.00037	0.00046
3	0.00058	0.00038	0.00047	0.00068	0.00047	0.00044	0.00058	0.00035	0.00046
2	0.00057	0.00035	0.00047	0.00067	0.00047	0.00044	0.00057	0.00033	0.00046
1	0.00052	0.00033	0.00044	0.00059	0.00043	0.0004	0.00051	0.00029	0.00042
G	0.00028	0.00032	0.00026	0.0003	0.00025	0.00024	0.00027	0.00018	0.00025

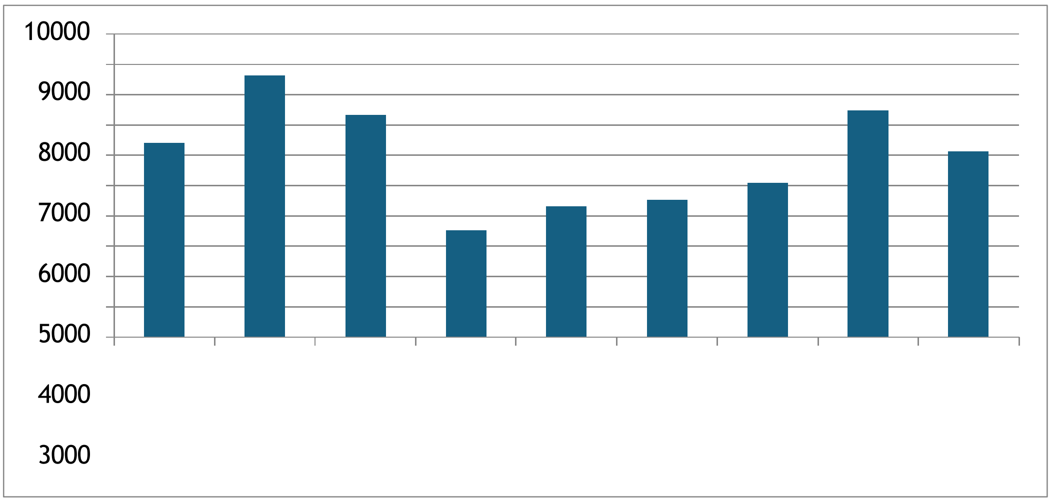


Graph .1 Comparison of stored drift

Comparison of base shear

S. No	Regular Without Bracings	Regular V Type Bracings	Regular X Type Bracings	T Shape Without Bracings	T Shape with V Type Bracings	T Shape with X Type Bracings	H Shape Without Bracings	H Shape with V Type Bracings	H Shape with X Type Bracings
1	6414.5676	8627.2037	7329.6495	3526.7565	4319.0984	4528.4004	5097.7565	7473.8852	6119.6966

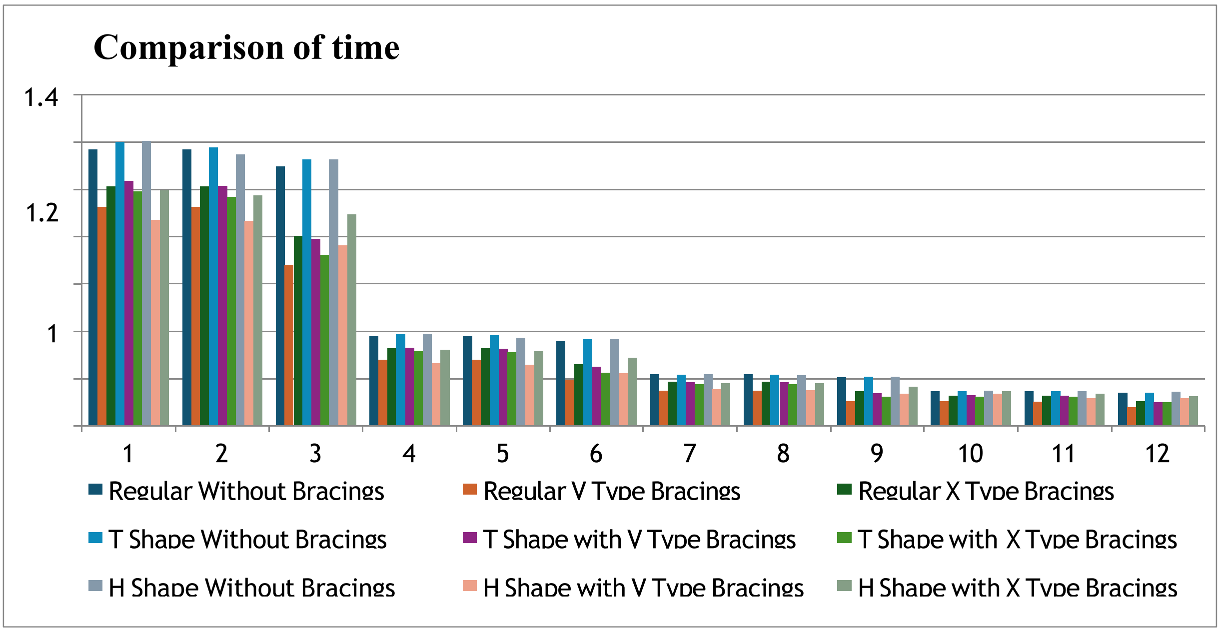
Table .2 Comparison of base shear



Graph .2 Comparison of base shear

4.2 Comparison of Time Period

Mode	Regular Without Bracings	Regular V Type Bracings	Regular X Type Bracings	T Shape Without Bracings	T Shape with V Type Bracings	T Shape with X Type Bracings	H Shape Without Bracings	H Shape with V Type Bracings	H Shape with X Type Bracings
1	1.168	0.926	1.012	1.2	1.035	0.991	1.204	0.873	0.995
2	1.168	0.926	1.012	1.178	1.015	0.968	1.148	0.868	0.974
3	1.099	0.68	0.804	1.126	0.791	0.724	1.127	0.762	0.893
4	0.38	0.279	0.328	0.387	0.33	0.315	0.389	0.264	0.321
5	0.38	0.279	0.328	0.382	0.326	0.31	0.373	0.258	0.316
6	0.359	0.196	0.261	0.366	0.249	0.225	0.366	0.223	0.289
7	0.218	0.149	0.186	0.217	0.185	0.176	0.219	0.155	0.181
8	0.218	0.149	0.186	0.216	0.185	0.175	0.213	0.15	0.181
9	0.207	0.103	0.148	0.208	0.137	0.124	0.208	0.137	0.164
10	0.148	0.103	0.128	0.147	0.129	0.123	0.149	0.135	0.146
11	0.148	0.101	0.128	0.146	0.128	0.122	0.148	0.117	0.135
12	0.141	0.08	0.103	0.141	0.099	0.099	0.145	0.117	0.126

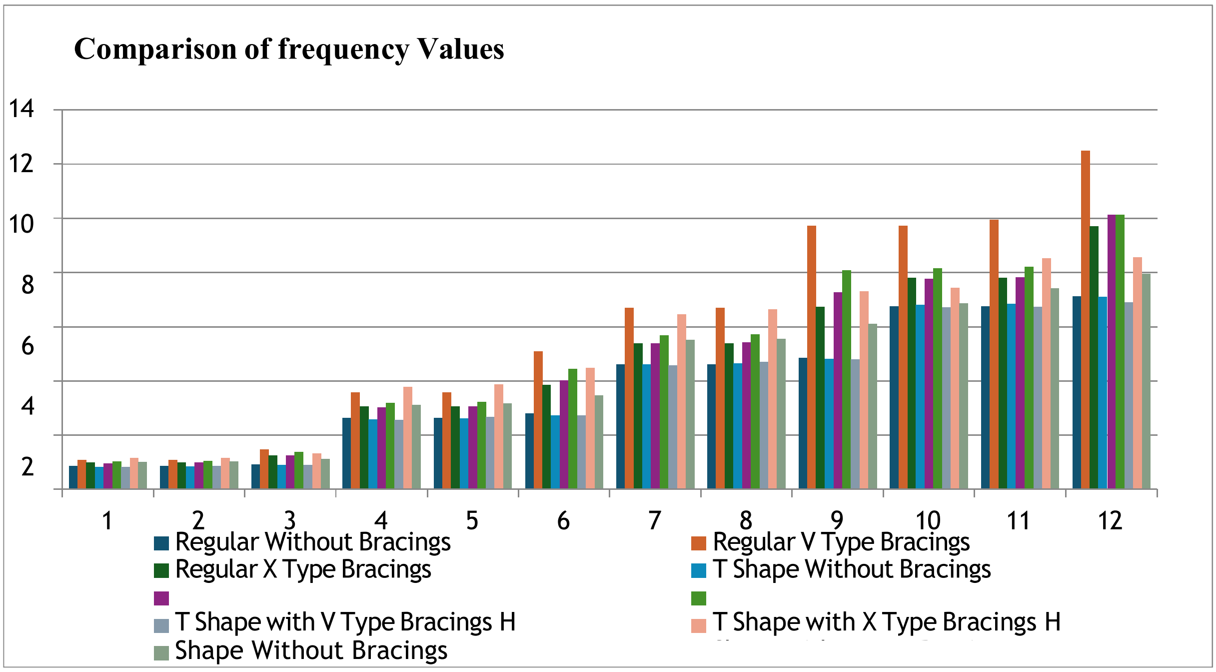


Graph .3 Comparison of Time Period

Comparison of Frequency

Mode	Regular Without Bracings	Regular V Type Bracings	Regular X Type Bracings	T Shape Without Bracings	T Shape with V Type Bracings	T Shape with X Type Bracings	H Shape Without Bracings	H Shape with V Type Bracings	H Shape with X Type Bracings
1	0.856	1.08	0.988	0.833	0.966	1.009	0.831	1.145	1.005
2	0.856	1.08	0.988	0.849	0.985	1.033	0.871	1.152	1.027
3	0.91	1.471	1.244	0.888	1.264	1.381	0.887	1.313	1.119
4	2.629	3.586	3.052	2.584	3.029	3.176	2.571	3.786	3.116
5	2.629	3.586	3.052	2.621	3.068	3.226	2.679	3.881	3.165
6	2.788	5.103	3.838	2.735	4.02	4.441	2.732	4.483	3.46
7	4.596	6.712	5.379	4.599	5.397	5.671	4.562	6.456	5.521
8	4.596	6.712	5.379	4.629	5.418	5.712	4.692	6.649	5.538
9	4.838	9.726	6.743	4.807	7.277	8.082	4.803	7.318	6.099
10	6.754	9.726	7.803	6.801	7.777	8.146	6.716	7.429	6.85
11	6.754	9.947	7.803	6.831	7.83	8.21	6.741	8.524	7.418
12	7.106	12.508	9.705	7.093	10.121	10.128	6.905	8.577	7.938

Table .4 Comparison of Frequency



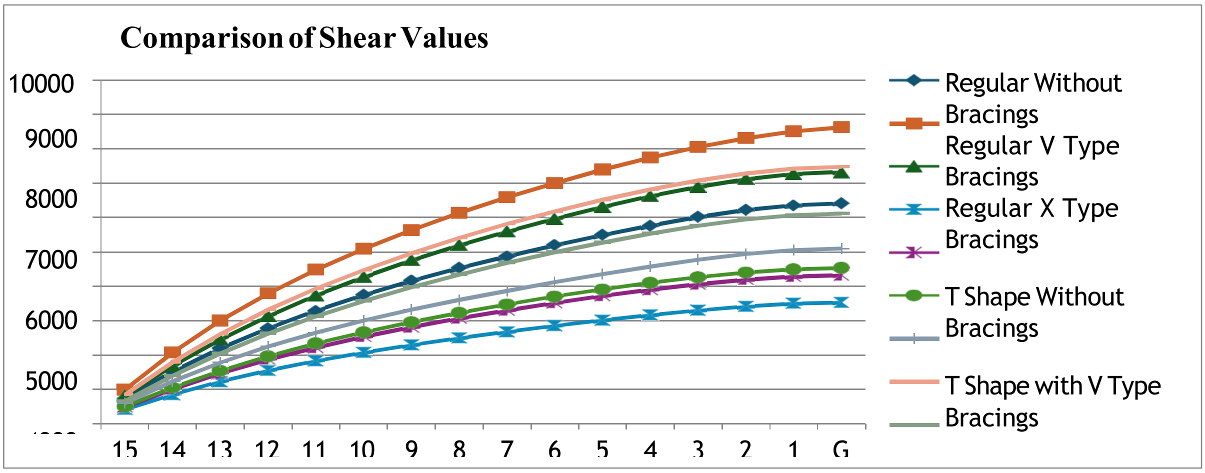
Graph .4 Comparison of Frequency

Comparison of Shear Values

Storey Number	Regular Without Bracings	Regular V Type Bracings	Regular X Type Bracings	T Shape Without Bracings	T Shape with V Type Bracings	T Shape with X Type Bracings	H Shape Without Bracings	H Shape with V Type Bracings	H Shape with X Type Bracings
15	728.7181	991.0702	809.9115	409.3031	478.5267	500.9537	596.0917	844.15	659.0254
14	1509.52	2072.136	1686.873	848.795	1002.308	1050.545	1234.504	1791.067	1392.204
13	2189.465	3001.195	2460.635	1226.23	1463.123	1535.361	1782.798	2615.706	2049.054
12	2775.897	3793.569	3137.092	1547.43	1864.236	1958.351	2248.798	3322.906	2623.761
11	3290.603	4481.034	3736.333	1826.57	2217.268	2330.82	2652.182	3933.817	3125.321
10	3749.053	5090.017	4273.49	2073.48	2531.501	2662.214	3007.148	4474.087	3570.399
9	4158.192	5636.132	4756.012	2292.548	2812.236	2958.329	3320.866	4963.119	3973.938
8	4527.13	6130.759	5192.448	2489.567	3065.552	3225.481	3602.622	5410.002	4343.946
7	4869.023	6585.11	5594.287	2672.856	3299.019	3471.08	3865.038	5816.968	4682.945
6	5191.489	7006.57	5968.127	2847.183	3516.981	3699.303	4115.447	6185.44	4992.71
5	5492.548	7394.906	6312.059	3011.337	3718.492	3909.27	4352.39	6518.532	5276.52
4	5767.906	7745.258	6621.681	3162.876	3900.883	4098.389	4572.08	6817.85	5536.114
3	6014.287	8053.177	6893.407	3300.152	4061.625	4264.112	4771.245	7078	5766.067
2	6220.107	8312.841	7116.815	3416.3	4193.879	4399.771	4939.158	7284.692	5951.424

1	6360.091	8511.022	7268.872	3495.867	4283.549	4491.687	5053.568	7419.902	6072.766
G	6414.568	8627.204	7329.65	3526.757	4319.098	4528.4	5097.757	7473.885	6119.697

Table .5 Comparison of Shear Values



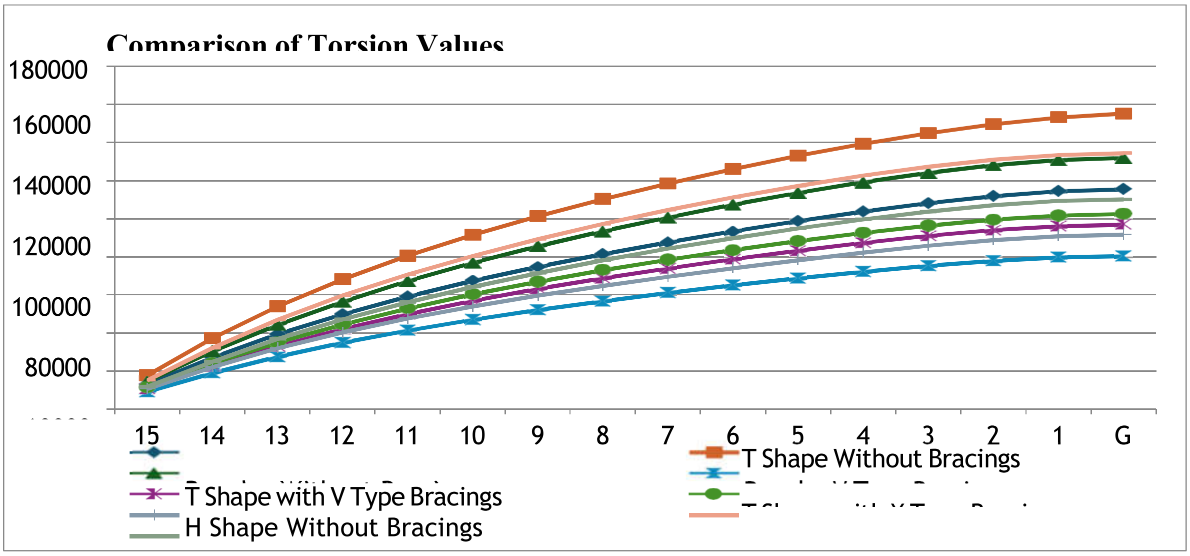
Graph .5 Comparison of Shear Values

Comparison of Torsion Values

Storey Number	Regular Without Bracings	Regular V Type Bracings	Regular X Type Bracings	T Shape Without Bracings	T Shape with V Type Bracings	T Shape with X Type Bracings	H Shape Without Bracings	H Shape with V Type Bracings	H Shape with X Type Bracings
15	13116.96	17849.08	14578.41	9165.644	10898.16	11523.7	10729.65	15194.7	11862.45
14	27171.36	37309.3	30363.72	19054.43	22772.71	24105.38	22221.07	32239.2	25059.65
13	39410.34	54025.09	44291.43	27610.06	33140.43	35110.92	32090.36	47082.7	36882.97
12	49966.13	68282.67	56467.66	34950.86	42095.74	44632.51	40478.36	59812.3	47227.71
11	59230.88	80660.19	67253.99	41378.78	49950.68	52985.6	47739.27	70808.71	56255.79
10	67482.97	91626.19	76922.81	47100.29	56943.96	60420.76	54128.66	80533.57	64267.18
9	74847.45	101452.8	85608.22	52201.9	63190.99	67065.92	59775.58	89336.14	71530.88
8	81488.33	110350	93464.06	56799.68	68818.76	73050.81	64847.19	97380.04	78191.03
7	87642.42	118530	100697.2	61065.21	74004.31	78548.65	69570.69	104705.4	84293
6	93446.82	126121.3	107426.3	65095.52	78860.22	83673.23	74078.04	111337.9	89868.78
5	98865.86	133108.6	113617.1	68861.44	83371.81	88416.44	78343.03	117333.6	94977.36
4	103822.3	139408	119190.3	72310.16	87477.82	92717.29	82297.43	122721.3	99650.06
3	108257.2	144952.2	124081.3	75409.13	91119.87	96509.08	85882.41	127404	103789.2

2	111961.9	149632.5	128102.7	78014.33	94137.97	99628.77	88904.85	131124.5	107125.6
1	114481.6	153195.7	130839.7	79793.81	96196.65	101750.3	90964.22	133558.2	109309.8
G	115462.2	155274.6	131933.7	80485.54	97015.75	102599.6	91759.62	134529.9	110154.5

Table .6 Comparison of Torsion Values



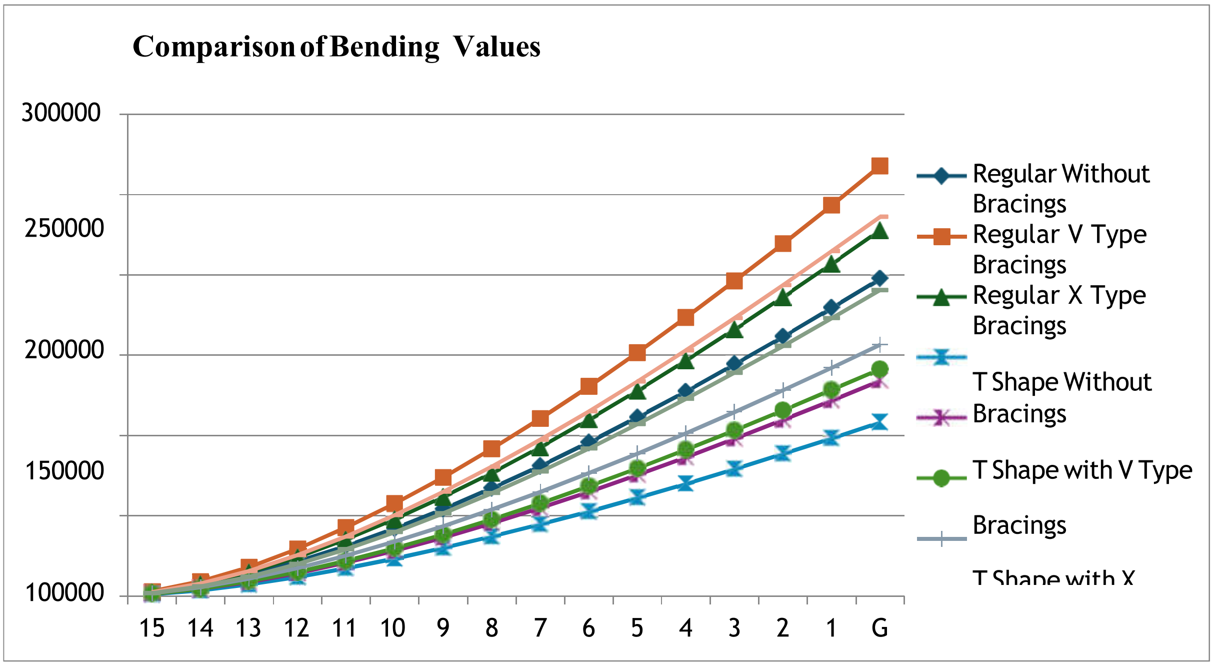
***Graph .6** Comparison of Torsion Values*

Comparison of Bending Values

Storey Number	Regular Without Bracings	Regular V Type Bracings	Regular X Type Bracings	T Shape Without Bracings	T Shape with V Type Bracings	T Shape with X Type Bracings	H Shape Without Bracings	H Shape with V Type Bracings	H Shape with X Type Bracings
15	2186.154	2973.211	2429.735	1227.909	1435.58	1502.861	1788.275	2532.45	1977.076
14	6710.763	9185.173	7486.788	3771.823	4440.414	4652.488	5488.281	7903.109	6152.333
13	13254.8	18162.17	14846.53	7435.484	8816.972	9246.254	10815.48	15735.18	12290.59
12	21504.04	29457.59	24186.05	12029.57	14368.26	15081.41	17494.07	25653.03	20129.26
11	31205.8	42711.73	35238.46	17405.02	20929.29	21985.98	25303.68	37331.09	29421.11
10	42169.97	57653.84	47795.55	23452.34	28369.76	29822.26	34079.71	50516.39	39962.94
9	54243.08	74075.89	61685.31	30084.99	36582.5	38476.46	43691.66	65024.08	51601.92
8	67295.39	91810.73	76759.51	37231.28	45477.1	47852.7	54033.05	80715.9	64224.02
7	81225.56	110723.9	92896.17	44837.43	54981.48	57873.86	65025.78	97476.99	77736.97
6	95961.31	130708.9	109999.1	52867.95	65040.96	68480.13	76620.2	115202.1	92058.75
5	111445.9	151675.8	127985.5	61297.2	75610.32	79621.02	88782.59	133792.6	107114.6
4	127623.2	173537.5	146772.6	70100.35	86645.06	91246.92	101481.3	153156.2	122836
3	144431.9	196201.7	166271.5	79249.89	98097.09	103304.8	114680.4	173202.3	139154.8
2	161798.2	219568.1	186381.5	88711.48	109910.4	115734.1	128332.4	193828.8	155988.1
1	179618.8	243524.4	206975	98433.13	122012	128457.6	142362.9	214909.3	173223.8

G	197752.7	267933.9	227889.5	108339.2	134307.1	141377.5	156662.9	236292.6	190720.9

Table .7 Comparison of Bending Values



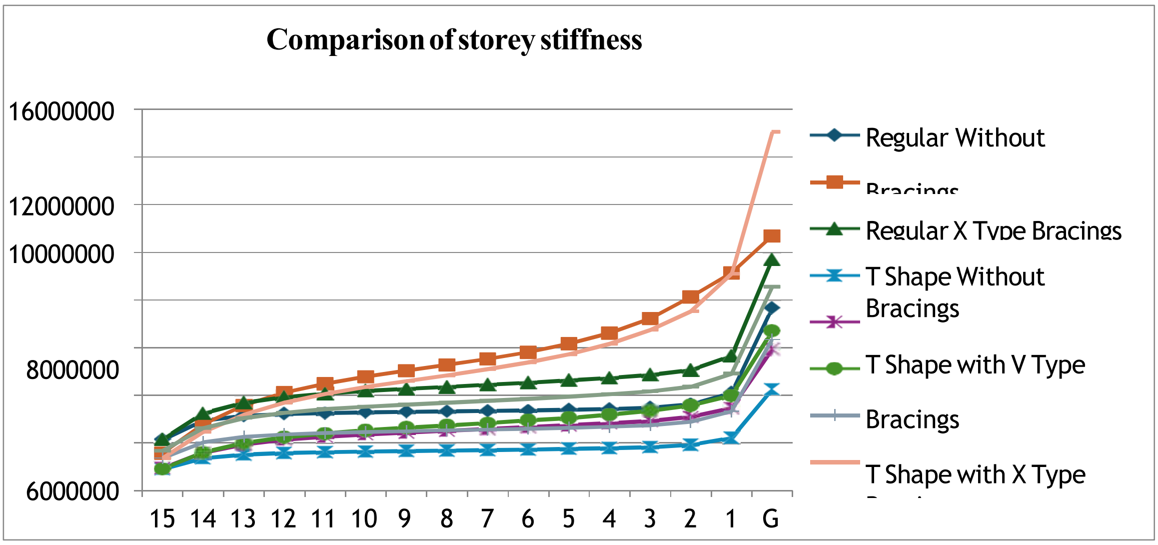
Graph .7 Comparison of Bending Values

Comparison of Storey Stiffness Values

Storey Number	Regular Without Bracings	Regular V Type Bracings	Regular X Type Bracings	T Shape Without Bracings	T Shape with V Type Bracings	T Shape with X Type Bracings	H Shape Without Bracings	H Shape with V Type Bracings	H Shape with X Type Bracings
15	2144489	1573620	2165613	906372.8	940871.2	917901.9	1360440	1362847	1668498
14	2942916	2769613	3247505	1355329	1593237	1596957	2025265	2461554	2622581
13	3147842	3570095	3690641	1511988	1935731	1991237	2257120	3191587	3046401
12	3220674	4104470	3926631	1576972	2133338	2234694	2357731	3692409	3274438
11	3259148	4485888	4078085	1613392	2263482	2401853	2416607	4058413	3417718
10	3287287	4780594	4190787	1640226	2361019	2530072	2460353	4346015	3522969
9	3309738	5031528	4283064	1662180	2441184	2637854	2496209	4597261	3611969
8	3329318	5269665	4365852	1682385	2513332	2736711	2528420	4839941	3694720
7	3349670	5519005	4448206	1704066	2584765	2836023	2561350	5094577	3776155
6	3372484	5806216	4535519	1727456	2659843	2941268	2597032	5379204	3859818
5	3397826	6156680	4629946	1752597	2740756	3051578	2635620	5722371	3949757
4	3429572	6603272	4734920	1782034	2821235	3190825	2680578	6164994	4049717
3	3484630	7222186	4862302	1826522	2930795	3352899	2747014	6749487	4167694

2	3622728	8118271	5071838	1921666	3099203	3574282	2887094	7527960	4356664
1	4112479	9133109	5669056	2220570	3470990	4001529	3329890	9097050	4904148
G	7667699	10689491	9716723	4245648	5935586	6705638	6339635	15060984	8560073

Table .8 Comparison of Storey Stiffness Values



Graph .8 Comparison of Storey Stiffness Values

CONCLUSION

Impact of Bracing Systems on Seismic Loads:

The study shows that providing bracing systems significantly reduces the seismic load action on buildings. Braced structures, whether in V-type, X-type, or other configurations, demonstrate better seismic resistance and are more suitable for earthquake-resistant design.

Effectiveness of Building Shapes:

Among the various building shapes studied, H-shaped buildings with V-type bracings consistently showed the lowest storey drift values, particularly in seismic Zone V conditions. This suggests that the combination of bracing and specific building shapes provides superior stability under seismic loading.

Base Shear Behavior:

In terms of base shear, T-shaped buildings without bracings exhibited the lowest values compared to other building models in Zone V seismic conditions. This indicates that T- shaped configurations are more efficient in resisting seismic forces when no bracing is used.

Shear, Bending, and Torsion:

Regular buildings without bracings experienced the highest values of shear, bending, and torsion, signifying their vulnerability under seismic loads. In contrast, T-shaped buildings with V-type bracings exhibited the lowest values in these parameters, suggesting that bracing systems significantly reduce the structural response to seismic forces.

Natural Time Period and Frequency:

The natural time period of the buildings decreased as the bracing systems were introduced, with the maximum values observed for unbraced buildings. The **frequency** of vibrations showed an increasing trend, with lower frequencies associated with buildings lacking bracings.

Reduction in Displacements, Storey Drifts, and Accelerations: The amplitude of displacements, storey drifts, and accelerations were considerably reduced in buildings with bracing systems. This indicates that bracing helps control excessive movements during seismic events, improving the structural performance and occupant safety.

Braced Buildings' Vulnerability:

Although bracing systems provide better seismic performance, the results suggest that braced buildings, particularly those with V-type and X-type bracings, may be more vulnerable to specific types of loading conditions compared to unbraced buildings. The interaction between bracing type and seismic force demands requires careful consideration during design.

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