M. Tech. Structural Engineering   Rahul Mandal   2021

ANALYSIS AND DESIGN OF G+10 STOREY BUILDING UNDER DIFFERENT SLOPING CONDITION

A PROJECT REPORT

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MASTER OF TECHNOLOGY

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DECLARATION

I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person nor material which to a substantial extent has been accepted for the award of any other degree or diploma of the university or other institute of higher learning, except where due acknowledgment has been made in the text.

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CERTIFICATE

This is to certify that the project report entitled "**Analysis and design of G+10 storey building under different sloping condition",** is the bonafide work of **RAHUL MANDAL , 2K19/STE/16** the award of Masters of Technology in Structural Engineering from Department of Civil and Environmental Engineering, The Delhi Technological University, Delhi. The work has been carried out fully under my supervision. The content and results of this report, in full or in parts has not been submitted to any other institute or university for the award of a degree.

SUPERVISOR
PROF. NIRENDRA DEV

PLACE: DELHI
DATE: 22 JULY 2021

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ABSTRACT

Structures are typically built on level ground; however, due to a lack of level ground, construction operations have begun on sloping terrain. The step back and step back setback are two different types of construction configurations on sloping terrain. For the purposes of this study, a G+ 10 storey RCC structure with a ground slope of 20 and 44 degrees was investigated. The building has been compared to one that is standing on flat ground. The structure analysis programme ETAB 2018 was used for modelling and analysis of the building. To use the time history and response spectrum approach to assess a structure on sloping terrain with or without a shear wall. On the basis of the results from both analyses, a comparison of different response parameters is made. Designing and optimizing various structural elements under the current conditions by comparing the analysis of the identical structure on level ground with the structure on sloping land. The seismic study was carried out using response spectrum analyses and time history in accordance with IS:1893(part 1) 2016. Top storey displacement, storey shear, and storey drift were used to get the results.

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CHAPTER 1:-INTRODUCTION

1.1 General

Seismic analysis is a branch of structural analysis that involves calculating a structure's response to dynamic excitation. It is a subset of the structural design, earthquake engineering, or structural assessment and retrofit process in earthquake-prone areas. During seismic excitation, a structure can "wave" back and forth.. During a strong windstorm, this behavior is also observable. The 'basic mode,' as the name implies, corresponds to the lowest frequency of building response. The structure takes the least amount of energy to vibrate at this frequency. The majority of structures, on the other hand, have greater reaction modes that are only triggered during earthquakes. Nonetheless, in most cases, the first and second modes cause the most damage. For seismic response analysis of structures, various forms of ground motion inputs are necessary. Methods used for seismic response analysis of structures can be classified as (i) time history analysis, (ii) response spectrum method of analysis, and (iii) frequency domain spectral analysis, depending on the available input information.

Time history analysis can be used for both elastic and inelastic response ranges, the other two methods are only useful for elastic responses. However, by employing appropriate approaches, these methods can be expanded to approximation response analysis in the inelastic range. To determine the response of structures across a particular time history of stimulation, several approaches such as Duhamel integration, step-by-step numerical integration, and the Fourier transform approach are employed.

The response spectrum technique of analysis takes earthquake response spectra as input to generate a set of lateral equivalent forces for the structure. which will have the most effect on it due to ground motions A static analysis is used to determine the structure's internal forces. Frequency domain spectrum analysis is performed when the earthquake ground motion is considered as a stationary random process. It returns the power spectral density function (PSDF) of any response quantity of interest using random vibration analysis methods for a given PSDF of ground motion as input. The root mean square response is calculated and predicted using the moments of the PSDF of response.

When opposed to high-rise buildings, the likelihood of sway is substantially lower in low-rise structures [1].

High-rise buildings that are more vulnerable to lateral pressures arise as a result of increased industry, economic reasons, population, and people's lifestyles in urban areas. Structural engineers have been attempting to counteract these lateral stresses and provide enough stiffness by including ‘‘moment resistant frames, cross braces, diaphragms, and shear walls [2]' into the strengthening of a structure. Shear walls are built to counteract the effects of lateral loads and provide the necessary strength and stiffness when a building is subjected to seismic activity. Shear walls are the most effective lateral force-resisting approach when compared to all other lateral force-resisting methods, especially for tall buildings and lift scenarios.

1.2 What is shear wall?

Shear walls, which are made out of vertically oriented wide beams in a reinforced concrete framed structure, are used to protect structures from lateral stresses. These are given in addition to slabs, beams, and columns in a building, and they give the needed rigidity, particularly in residential constructions, and they act as a case in the structure. Shear walls have been employed widely in mid- and high-rise buildings for the past two decades. Shear walls are extremely significant in structures, particularly tall ones, since they are particularly vulnerable to lateral loads and seismic pressures. The beam and column dimensions in high-rise structures are rather enormous, and the reinforcement at the beam-column joints is extremely heavy, resulting in clogging at joints. To avoid these sorts of practical difficulties, we employ shear walls as a key to give enough stiffness. [2]

1.3 Objective of present study

Objective of present study are as follows:-

1. To analyze the structure on sloping ground with or without shear wall using time history method.
2. To analyze the structure on sloping ground with or without shear wall using response spectrum method.
3. Comparison of different response parameters, based on results obtained in both the analysis.
4. Comparing the analysis of same structure on flat ground with the structure on sloping ground
5. Designing and optimizing various structural elements in the prevailing conditions.

CHAPTER 2:-LITERATURE REVIEW

Sylviya.B et al. (2018) did a comparative study on the effective arrangement of shear walls at different sites in different seismic zones for an RCC multi-story structure. Four models were developed for the investigation, and storey drift, displacement, and storey shear were observed in all zones, i.e. (Zone II, III, IV and V). Shear walls are most effective when placed at the building's extremities, and storey drift and displacement are highest at zone. [3]

Tarun Magendra et al.(2016). The optimal positioning of shear walls in multi-story structures has been investigated in this research. It has been discovered that shear walls located in the center or at the corners of a building's design, forming a box, indicate that the structure is more stable for characteristics such as storey displacement and storey drift, and that overturning moments are minimal in traditional buildings. [4]

A research on the configuration of shear walls that have been exposed to seismic forces stress was conducted by **R.S.Mishra (2015)**. When comparing the core and peripheral positions of shear walls in a structure, it is found that the midway site is most suited. [5]

Jaimin Dodiya et al. (2018) investigated the study of multi-story buildings employing shear walls at various points throughout the structure. Three models have been created, and it has been demonstrated that when shear walls are situated in the opposite directions of the structure, displacement is minimised. [2]

M V Naresh et al. (2019) conducted a research on the static and dynamic analysis of multi-story buildings, concluding that static analysis is insufficient for high-rise structures and emphasising the importance of dynamic analysis to counteract the lateral stresses created during earthquakes. [6]

When **Kusuma.S** (2020) utilised Etabs to evaluate response spectrum analysis and time history analysis for a multi-story structure, they observed that the response spectrum technique yields more accurate conclusions and higher base shear values.

Bagheri et al. (2012) examined the damage assessment of an irregular building using static and dynamic analysis, and concluded that static analysis caused more displacement than dynamic analysis. [7]

R. Chittiprolu et al. [2014] conducted research on response spectrum analysis and lateral load for structures with and without shear walls. The shear forces and tale drifts of both examples were compared. In an uneven structure, he determined that structures with shear walls are more resistant to lateral stresses than those without shear walls. There is a reduction in storey drift in case of structure with shear wall. [8]

Nagargoje and Sable 2 (2012) investigated the unstable behaviour of structures on a steep slope. They used 3D house frame analysis to assess the structures' dynamic response in terms of primary floor displacement and base shear. In unstable zone III, a constant quantity analysis was conducted on 36 structures with three configurations: step back, step backset back, and set back structures. [9]

B.G.Biradar and S.S.Nalawade (2004) investigated the unstable performance of hill structures at storey levels up to eleven, while in this work, the analysis is applied at construction levels ranging from four to fifteen (15.2 m to 52.6m). They discovered that step back buildings had a higher construction displacement than step back –set back structures. They discovered that the bottom shear created in step back set back structures is sixty to 260% more than in set back structures. On sloping ground, they advised for step back setback buildings to be favoured.. [10]

Jagadish Kori G+5 and Prashant D (2013) The seismic response of a single technique slope RC frame building with a soft structure was investigated. The behaviour of structures on sloping ground with and without infill walls, as well as the impact of infill walls on structures on sloping ground, are the subject of this research. On ten structural structures, including a clean frame building with no infill wall and an alternative model with infill wall, as well as a soft structure building on sloping ground, nonlinear static pushover analysis is done. All buildings have five bays on a slope of twenty-seven degrees with the horizontal, and are located in seismal zone III. The SMRF building frame system has been considered. They discovered that the period of the clean frame model is one.975 seconds, which is roughly 96-135% faster than other models with infill walls. They conclude that the style base shear in clean frame models on sloping terrain is overestimated as a result of the higher price of natural amount in clean frame compared to infill frame. Because of the abrupt changes in the slope profile, they determined that the displacement in the clean frame model is much higher than in other models with infill wall due to reduced stiffness. Infill models had approximately 250% more bottom shear than expose frames, according to the researchers. In comparison to totally filled fames, the development of plastic hinges is much more common in clean frame models and soft structure development. The focus of this research is on the difference in stiffness caused by the presence of an infill wall and a soft structure on sloping ground. [11]

Jitendra Babu et al. 7 (2012) investigated the pushover behaviour of several symmetric and asymmetric buildings built on flat and sloping ground and exposed to varied loads. They considered a wide range of configurations in plan symmetry and asymmetry, as well as different bay sizes in mutual direction. They suggested a four-story structure with one storey above ground level, set at a 30 degree inclination to the horizontal, on sloping terrain. They observed that the short column is beyond collapse prevention (CP) due to pushover analysis, and they computed displacement and base shear for asymmetric sloping terrain to be $104*10^{-3}$ m and $2.77*10^{3}$ kN, respectively, for asymmetric sloping terrain. They contrasted the numerous cases they studied by creating pushover curves with displacement on the X-axis and base shear on the Y-axis based on the data. They observed that symmetric constructions are 70% more resistant to base shear for maximum displacement up to the failure limit, whereas asymmetric inclined buildings resist base shear by 24% more than asymmetric buildings on plain ground. They come to the conclusion that a structure with vertical irregularity is more essential than one with regular irregularity. [12]

CHAPTER 3:-METHODOLOGY

3.1 Geometric parameters

One building layout is investigated in this study, which includes structures that are positioned on flat land. The number of stories taken into account for each type of setup is ten. All variants of the building frame have the same plan arrangement. To prevent complications like orientation, the columns are assumed to be square.

3.2 Software used

ETABS - Extended Three-Dimensional Analysis of Building System

ETABS is a cutting-edge, multi-purpose research and design programme designed specifically for building systems. With its best-integrated systems and skills, even the largest and most complicated building models may be readily sketched. [13]

Etabs-2018 software was used to do a response spectrum analysis and a time history study on a normal building, as illustrated in fig. The response spectrum of the El Centro earthquake was matched using the time domain approach. For each level, the storey displacement, storey drift, storey shear forces, spectral acceleration, and spectral displacement were computed, and the graph was shown. [14]

3.3 Model description

Number of stories	**G+10**
Grade of concrete	M30 and M25
Grade of Steel	Fe415
Beam size	450mm*300mm
Column size	600mm*300mm
Slab thickness	100mm
Zone factor (Z)	0.36
Damping ratio	5%
Floor to floor height	3.1m
Ground floor height	3.5m
Importance factor	1
Response reduction factor (R)	5
Soil type	I (Rock, Hard soil)
Ecc. Ratio	0.05

Wall thickness	150 mm
Live load	2 kN/m^2

3.4 Models consider for study

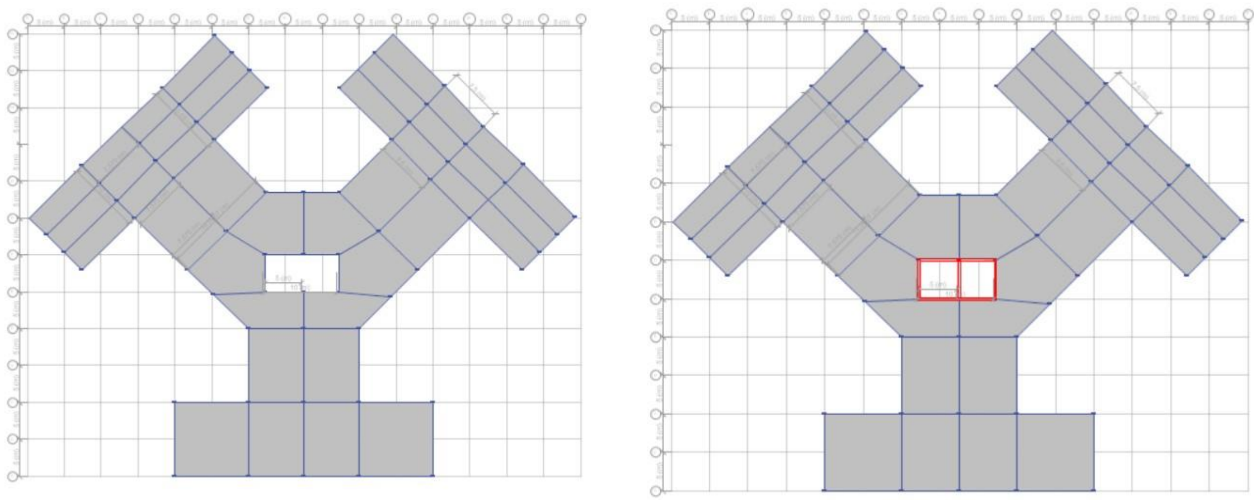
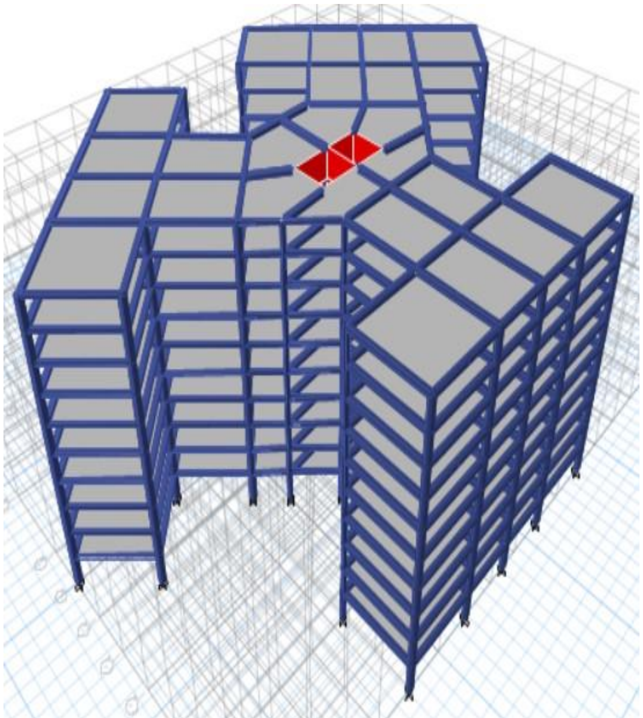
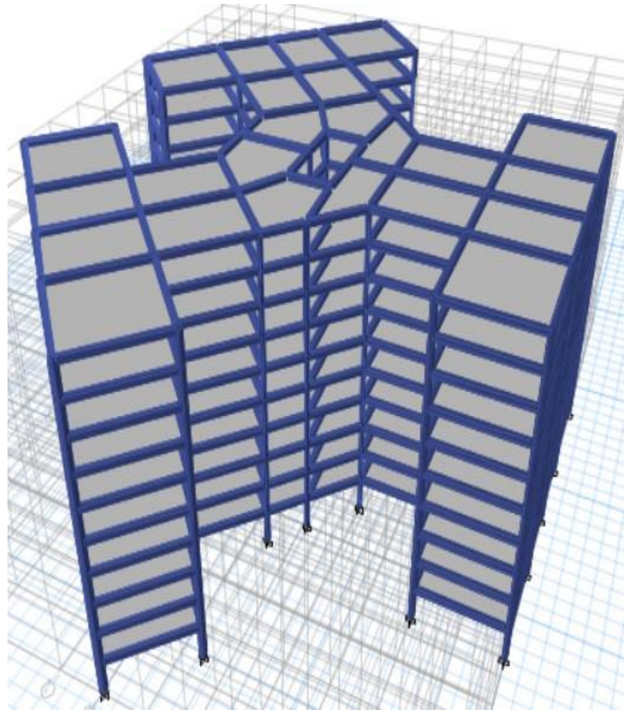
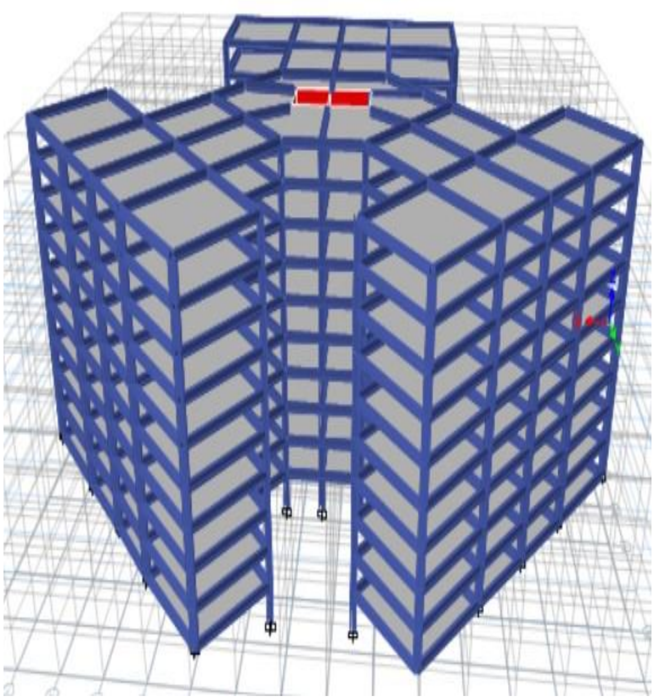
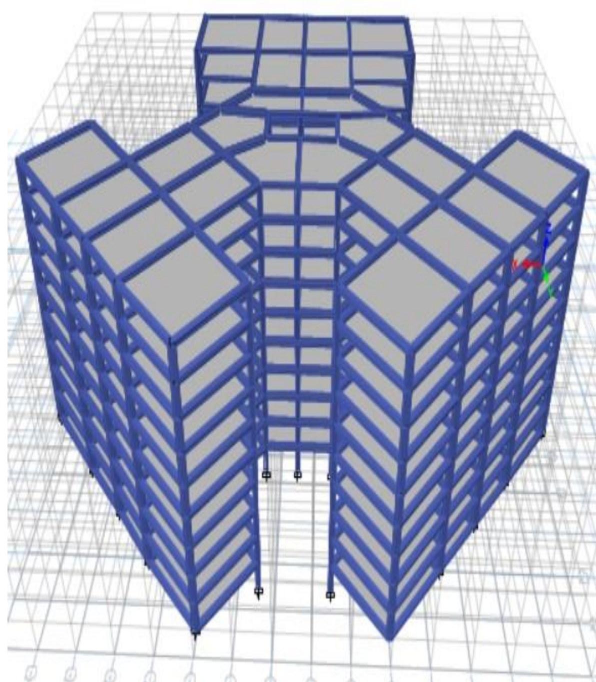


Figure 3. 1 Plan view without and with shear wall

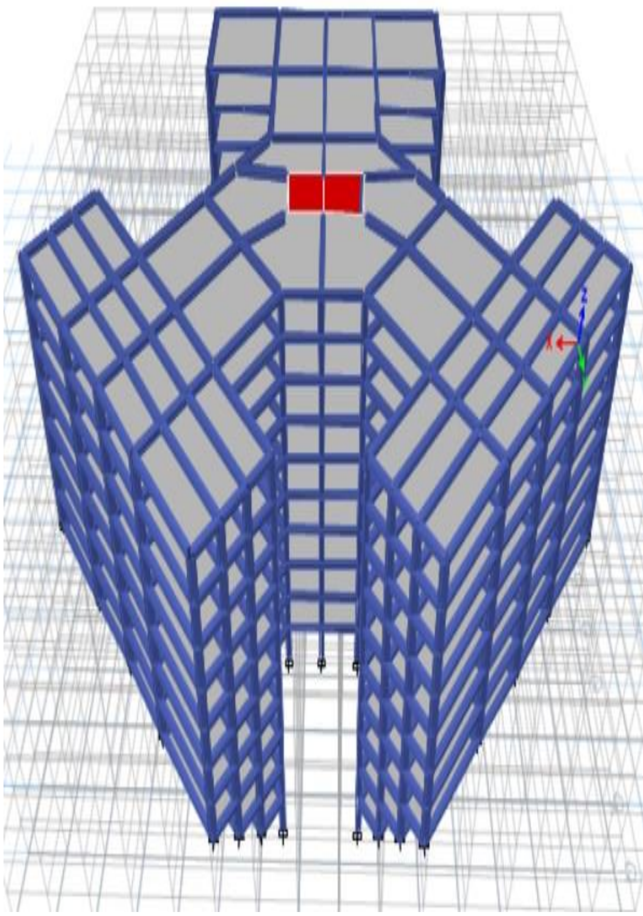
Model 1 **Model 4**

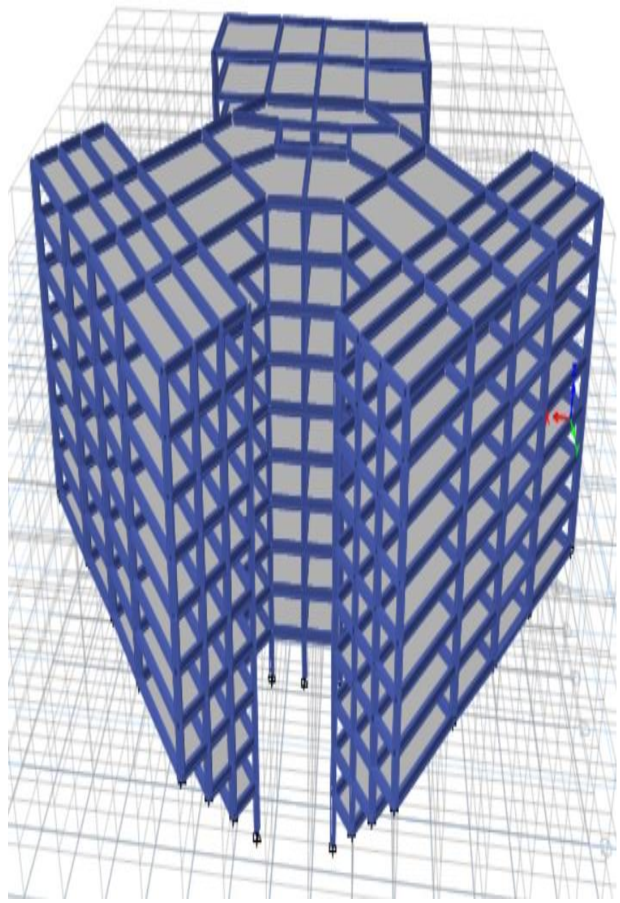
Figure 3. 2 on plain ground with and without shear wall

Model 2 **Model 5**

Figure 3. 3 Inclined on 20-degree slope with and without shear wall





Model 3 **Model 6**

Figure 3. 4 Inclined on 44-degree slope with and without shear wall

CHAPTER 4:-RESULTS

4.1 Storey displacement

Table 4. 1 Displacement (mm) using response spectrum analysis in X and Y direction with shear wall.

STOREY	RESPONSE SPECTRUM					
	MODEL 1		MODEL 2		MODEL 3	
	X	Y	X	Y	X	Y
10	21.083	48.131	19.446	53.154	20.131	52.521
9	19.957	44.094	18.44	48.517	18.828	47.609
8	18.441	39.545	17.127	43.476	17.299	43.224
7	16.59	34.564	15.475	37.997	15.524	37.963
6	14.473	29.275	13.556	32.215	13.519	32.372
5	12.165	23.822	11.431	26.264	11.334	26.564
4	9.728	18.351	9.158	20.288	9.022	20.674
3	7.217	13.02	6.785	14.444	6.636	14.847
2	4.678	8	4.357	8.902	4.237	9.25
1	2.181	3.523	1.923	3.857	1.899	4.082
BASE	0	0	0	0	0	0

Table 4. 2 Displacement (mm) using time history analysis in X and Y direction with shear wall.

STOREY	TIME HISTORY					
	MODEL 1		MODEL 2		MODEL 3	
	X	Y	X	Y	X	Y
10	20.425	27.791	27.9	33.119	31.034	34.336
9	18.243	24.573	25.647	29.321	28.092	30.531
8	15.899	21.255	23.141	25.429	24.941	26.795
7	13.455	17.888	20.4	21.487	21.719	22.893
6	10.993	14.528	17.452	17.57	18.391	18.98
5	8.597	11.255	14.356	13.765	15.01	15.121
4	6.34	8.166	11.188	10.168	11.638	11.399
3	4.424	5.371	8.039	6.88	8.35	7.914
2	2.692	2.991	5.011	4.01	5.237	4.773
1	1.176	1.173	2.214	1.673	2.398	2.091
BASE	0	0	0	0	0	0

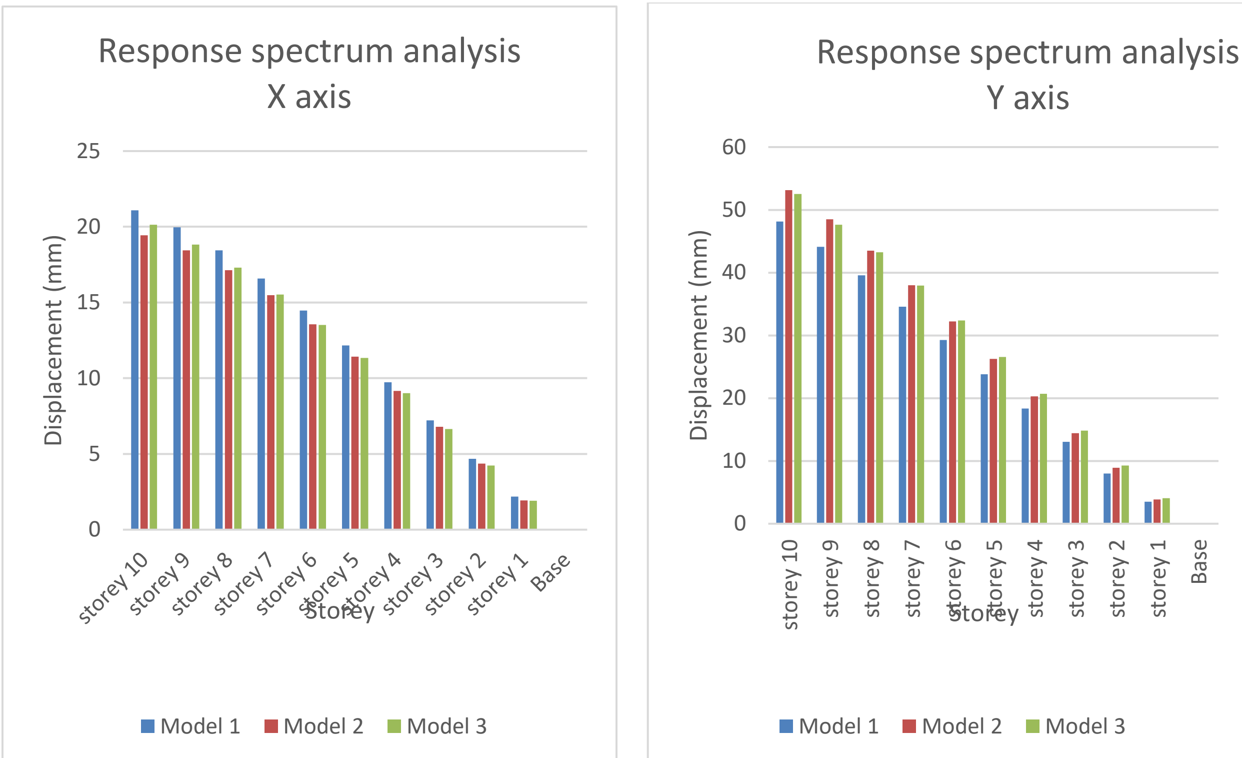


Figure 4. 1 Storey displacement graph using response spectrum analysis in X and Y direction with shear wall.

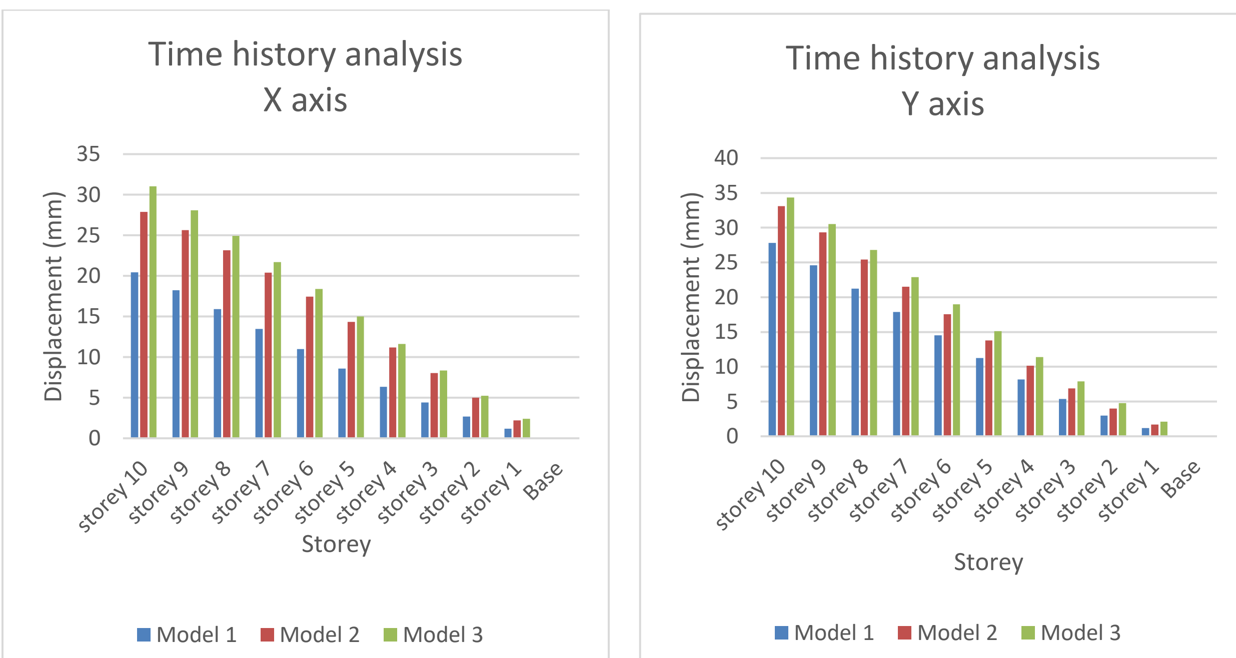


Figure 4. 2 Storey displacement graph using time history analysis in X and Y direction with shear wall.

Table 4. 3 Displacement (mm) using response spectrum analysis in X and Y direction without shear wall.

STOREY	RESPONSE SPECTRUM					
	MODEL 4		MODEL 5		MODEL 6	
	X	Y	X	Y	X	Y
10	39.056	113.895	47.22	157.109	32.462	81.936
9	37.69	110.031	44.673	148.971	31.206	80.027
8	35.525	103.999	41.333	138.63	29.275	76.468
7	32.652	95.876	37.338	126.142	26.76	71.133
6	29.146	85.871	32.766	111.733	23.744	64.24
5	25.061	74.129	27.677	95.564	20.281	55.924
4	20.445	60.774	22.131	77.778	16.411	46.29
3	15.349	45.939	16.18	58.515	12.172	35.439
2	9.869	29.941	9.937	37.988	7.64	23.456
1	4.39	14.439	3.88	16.915	3.283	10.659
BASE	0	0	0	0	0	0

Table 4. 4 Displacement (mm) using time history analysis in X and Y direction without shear wall.

STOREY	TIME HISTORY					
	MODEL 4		MODEL 5		MODEL 6	
	X	Y	X	Y	X	Y
10	89.94216	84.58846	51.68754	234.9788	87.50866	35.82112
9	134.0514	100.8895	70.97357	257.8385	122.2956	62.55149
8	169.286	110.2273	85.30704	260.2177	142.569	68.90184
7	190.0467	89.13151	93.79019	227.1107	36.37881	70.5653
6	197.0205	93.5921	96.4193	226.765	130.3457	70.0321
5	194.4491	90.24999	94.29177	211.1584	31.79205	64.71777
4	178.9965	82.01856	86.74048	191.9718	29.28384	55.11552
3	148.9066	67.86799	71.77709	157.0556	26.31125	42.97003
2	98.86272	48.22422	48.14238	118.0747	47.32398	29.23734
1	34.7634	23.46855	16.56795	51.35305	17.47935	12.68365
BASE	**0**	0	0	0	0	0

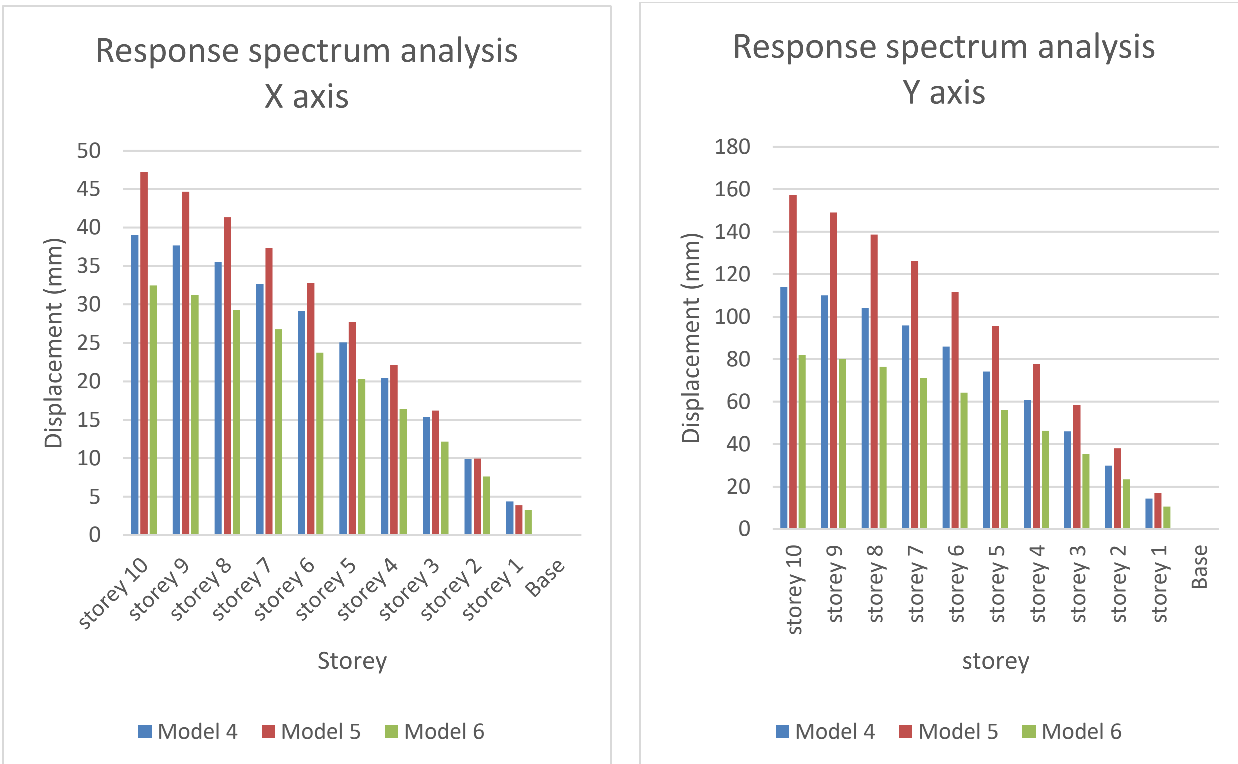


Figure 4. 3 Storey displacement graph using response spectrum analysis in X and Y direction without shear wall.

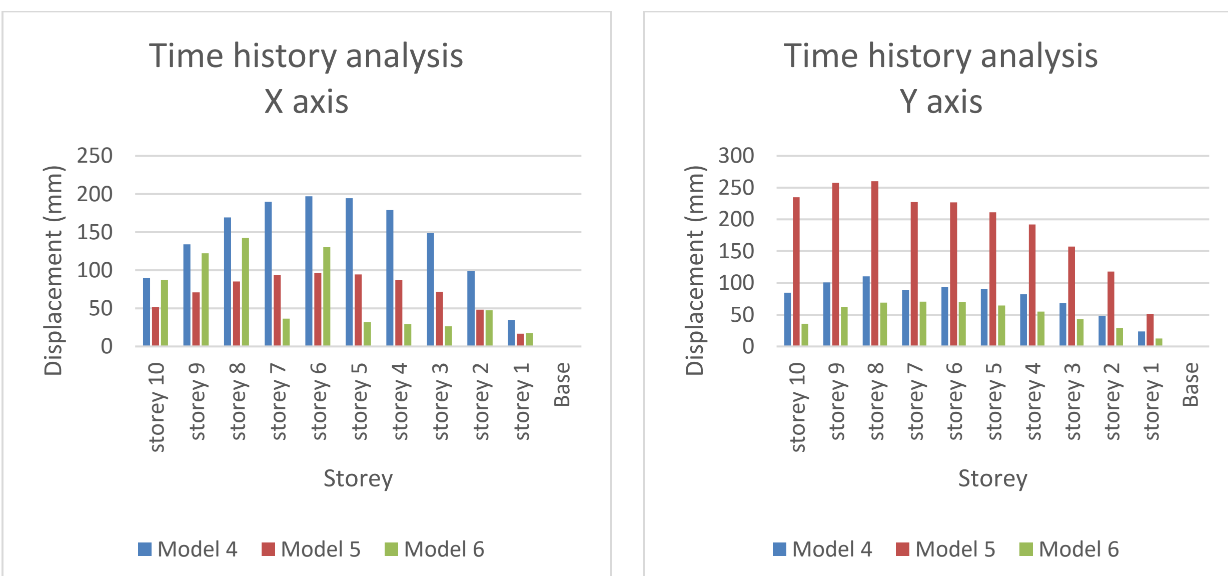


Figure 4. 4 Storey displacement graph using time history analysis in X and Y direction without shear wall.

4.2 Storey drift

Table 4. 5 Drift (mm) using response spectrum analysis in X and Y direction with shear wall.

STOREY	RESPONSE SPECTRUM					
	MODEL 1		MODEL 2		MODEL 3	
	X	Y	X	Y	X	Y
10	1.178	4.0827	1.0788	4.712	1.3485	4.3865
9	1.5748	4.6252	1.3795	5.1088	1.5934	5.3754
8	1.922	5.0809	1.7236	5.5614	1.6554	5.3165
7	2.1886	5.3878	1.984	5.8621	2.0243	5.6451
6	2.3777	5.5304	2.1855	6.0109	2.201	5.8497
5	2.4955	5.518	2.325	6.014	2.325	5.9148
4	2.5544	5.3537	2.4056	5.8621	2.3901	5.8373
3	2.5637	5.0282	2.4428	5.549	2.4025	5.6017
2	2.5048	4.4795	2.4366	5.0468	2.3374	5.1708
1	1.9313	3.1217	1.922	3.8564	1.9003	4.0827
BASE	0	0	0	0	0	0

Table 4. 6 Drift (mm) using time history analysis in X and Y direction with shear wall.

STOREY	TIME HISTORY					
	MODEL 1		MODEL 2		MODEL 3	
	X	Y	X	Y	X	Y
10	2.1824	2.9574	2.6226	4.6097	3.007	4.2904
9	2.3436	3.0504	2.8613	4.619	3.3201	4.8174
8	2.4459	3.0907	3.0163	4.6531	3.5061	4.4764
7	2.4614	3.0659	3.0783	4.6097	3.7076	4.5012
6	2.2568	2.9574	3.038	4.4578	3.8378	4.4392
5	2.0522	2.7559	1.6182	4.1943	3.8874	4.2749
4	1.7856	2.4521	2.7032	3.8688	3.8471	3.999
3	1.5159	2.0522	2.4304	3.4038	3.7014	3.5991
2	1.0416	1.5345	2.1204	2.7869	3.441	3.0752
1	2.1824	0.8463	1.6709	2.0057	2.8644	2.4087
BASE	0	0	0	0	0	0

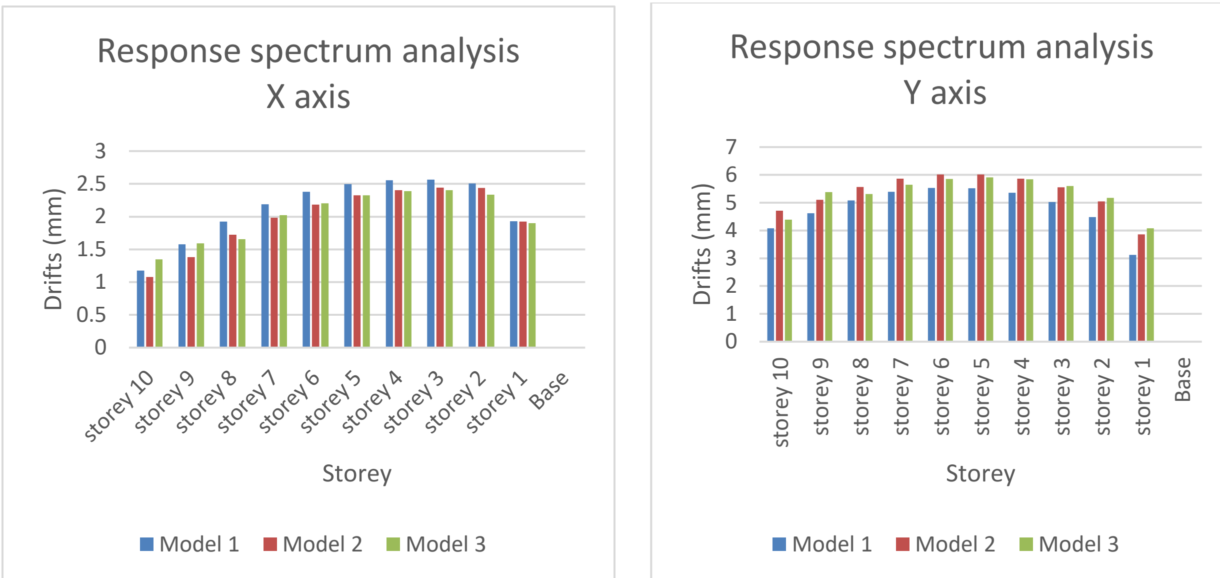


Figure 4. 5 Storey drift graph using response spectrum analysis in X and Y direction with shear wall.

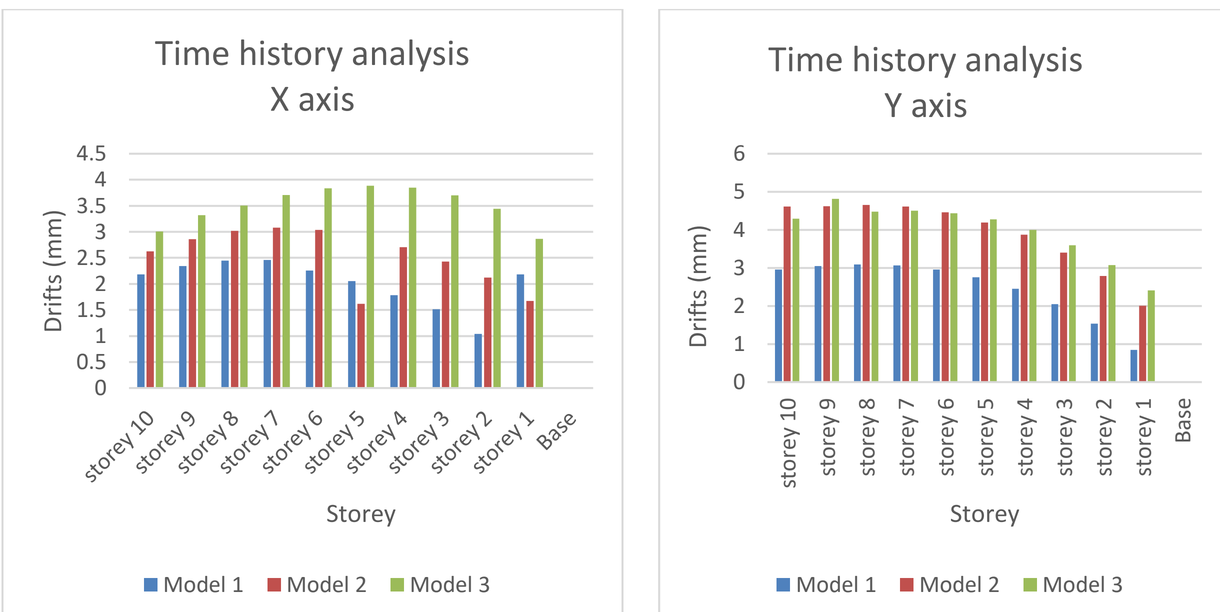


Figure 4. 6 Storey drift graph using time history analysis in X and Y direction with shear wall.

Table 4. 7 Drift (mm) using response spectrum analysis in X and Y direction without shear wall.

STOREY	RESPONSE SPECTRUM					
	MODEL 4		MODEL 5		MODEL 6	
	X	Y	X	Y	X	Y
10	1.6523	5.2421	2.7807	9.3868	1.4632	2.8892
9	2.5513	7.7128	3.6301	11.8792	2.2289	4.9414
8	3.2395	9.6348	4.2656	13.9128	2.8241	6.6433
7	3.8006	11.3119	4.7895	15.6488	3.2767	8.0197
6	4.3276	12.803	5.27	17.174	3.6704	9.2442
5	4.8019	14.1763	5.6916	18.5566	4.0145	10.3509
4	5.2111	15.4256	6.0357	19.8214	4.3152	11.3646
3	5.5273	16.3804	6.2713	20.8475	4.557	12.2295
2	5.487	15.6364	6.0605	21.1451	4.5198	12.8464
1	3.8874	12.7875	3.8812	16.9136	3.2829	10.6578
BASE	0	0	0	0	0	0

Table 4. 8 Drift (mm) using time history analysis in X and Y direction without shear wall.

STOREY	TIME HISTORY					
	MODEL 4		MODEL 5		MODEL 6	
	X	Y	X	Y	X	Y
10	2.8644	2.6939	1.6461	7.4834	2.7869	1.1408
9	4.7368	3.565	2.5079	9.1109	4.3214	2.2103
8	6.7177	4.3741	3.3852	10.3261	5.6575	2.7342
7	8.5994	4.0331	4.2439	10.2765	1.6461	3.193
6	10.3695	4.9259	5.0747	11.935	6.8603	3.6859
5	12.2295	5.6761	5.9303	13.2804	1.9995	4.0703
4	13.9841	6.4077	6.7766	14.9978	2.2878	4.3059
3	15.3512	6.9967	7.3997	16.1913	2.7125	4.4299
2	14.9792	7.3067	7.2943	17.8901	7.1703	4.4299
1	9.9324	6.7053	4.7337	14.6723	4.9941	3.6239
BASE	0	0	0	0	0	0

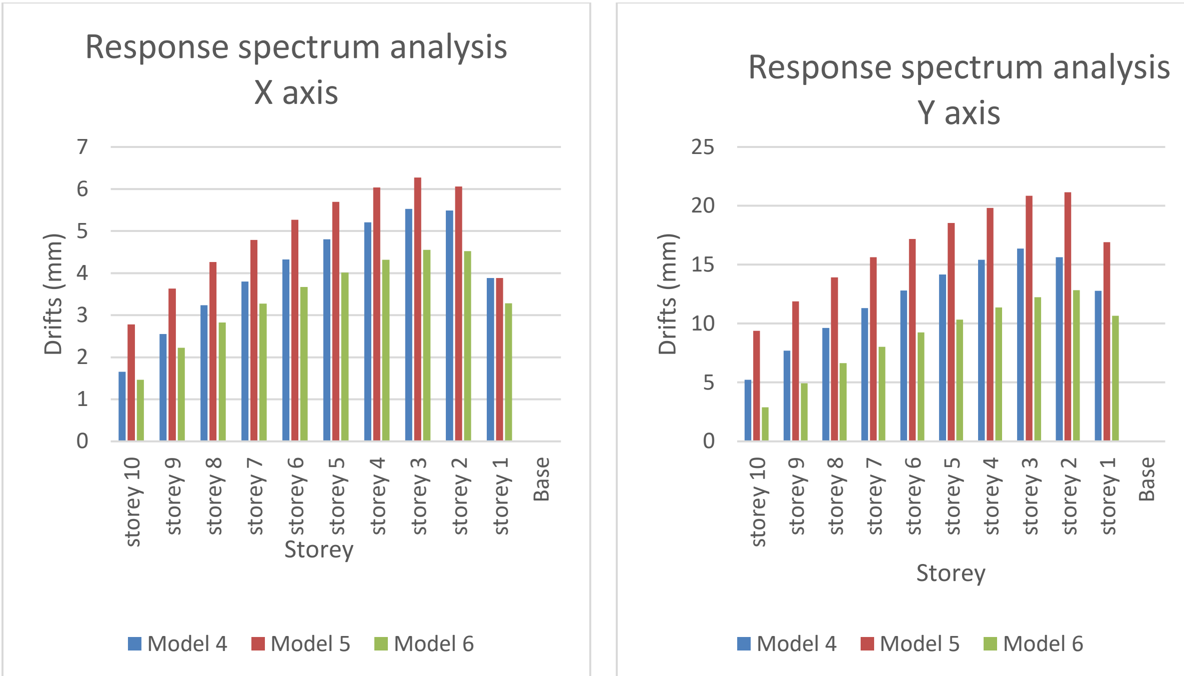


Figure 4. 7 Storey drift graph using response spectrum analysis in X and Y direction without shear wall.

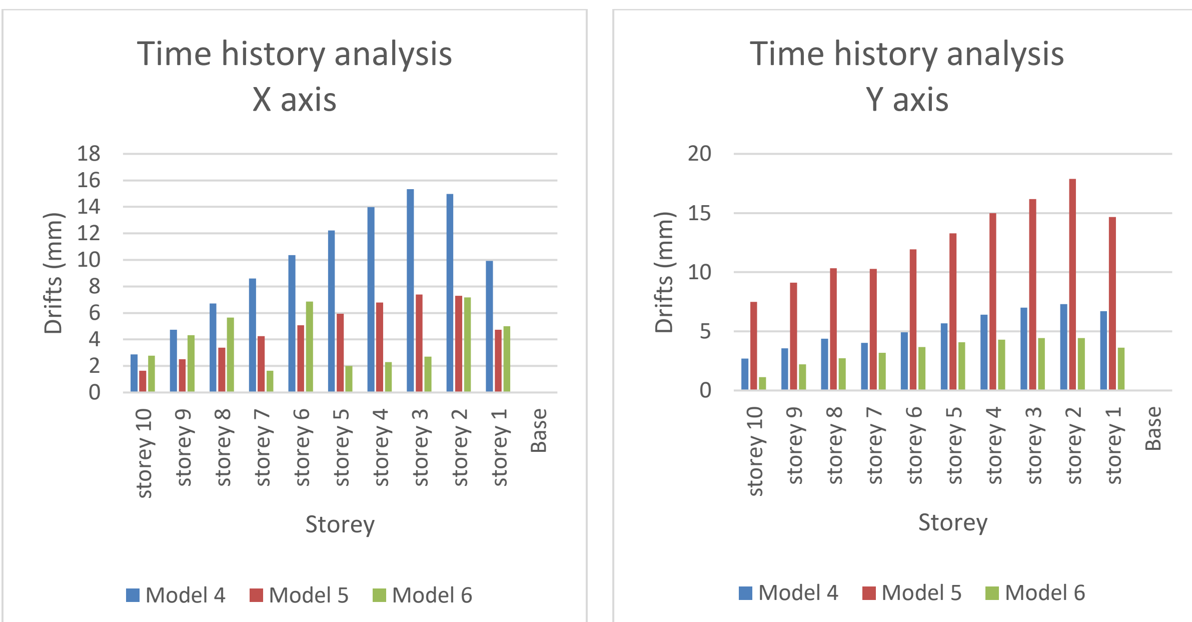


Figure 4. 8 Storey drift graph using time history analysis in X and Y direction without shear wall.

4.3 Storey shear

Table 4. 9 Storey shear (kN) using response spectrum analysis in X and Y direction with shear wall.

STOREY	RESPONSE SPECTRUM					
	MODEL 1		MODEL 2		MODEL 3	
	X	Y	X	Y	X	Y
10	1647.8927	1035.8946	1400.5528	902.9259	1508.0016	1010.8873
9	3155.7043	1981.3226	2690.669	1730.7638	2921.0624	1954.6477
8	4457.052	2795.5745	3815.3455	2449.1046	4160.0565	2778.7245
7	5548.7865	3477.2045	4771.5107	3056.8816	5222.9661	3482.6137
6	6431.9818	4027.3229	5558.8099	3554.6968	6108.3114	4065.9496
5	7113.165	4450.3715	6180.5082	3945.3905	6817.6243	4530.4644
4	7605.0665	4754.6683	6643.9766	4234.4489	7356.0972	4880.488
3	7927.2301	4952.8489	6961.1013	4430.3346	7733.0091	5123.3304
2	8106.4646	5062.1501	7148.6228	4544.7312	7962.1513	5269.604
1	8186.8872	5110.8931	7227.9561	4592.4588	8061.8535	5333.1776

Table 4. 10 Storey shear (kN) using time history analysis in X and Y direction with shear wall.

STOREY	TIME HISTORY					
	MODEL 1		MODEL 2		MODEL 3	
	X	Y	X	Y	X	Y
10	1833.3501	1225.8042	1810.5651	1173.6835	1735.736	1169.0337
9	3373.9049	2256.4391	3364.1657	2181.6092	3285.3122	2213.2448
8	4596.3672	3074.8736	4627.3538	3001.9354	4590.7899	3093.4912
7	5537.5237	3705.5855	5630.1786	3653.9811	5673.0541	3823.7239
6	6234.1562	4173.0447	6402.6778	4157.0497	6552.9648	4417.8616
5	6723.0434	4501.716	6974.8783	4530.4302	7251.3682	4889.8075
4	7040.9612	4716.0595	7376.7907	4793.3935	7789.0937	5253.4495
3	7224.6813	4840.5316	7638.3961	4965.1831	8186.9457	5522.6569
2	7310.9664	4899.582	7789.6122	5064.9885	8465.688	5711.2745
1	7339.9242	4920.0519	7860.1676	5111.8354	8646.0075	5833.0965

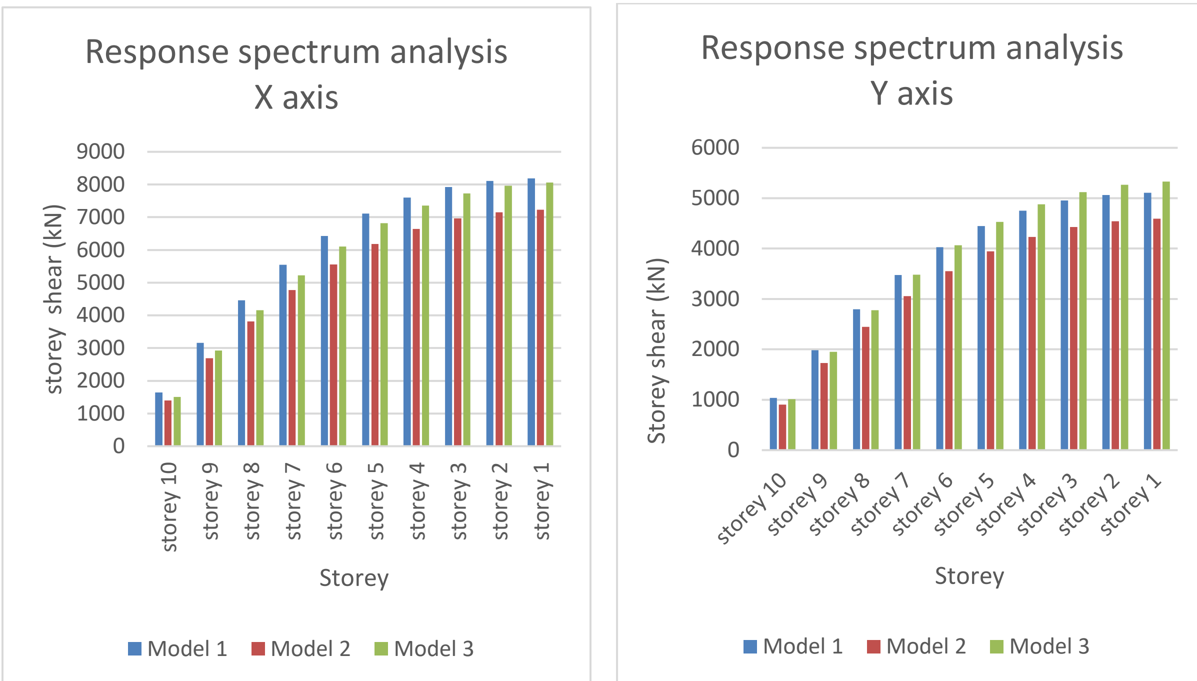


Figure 4. 9 Storey shear graph using response spectrum analysis in X and Y direction with shear wall.

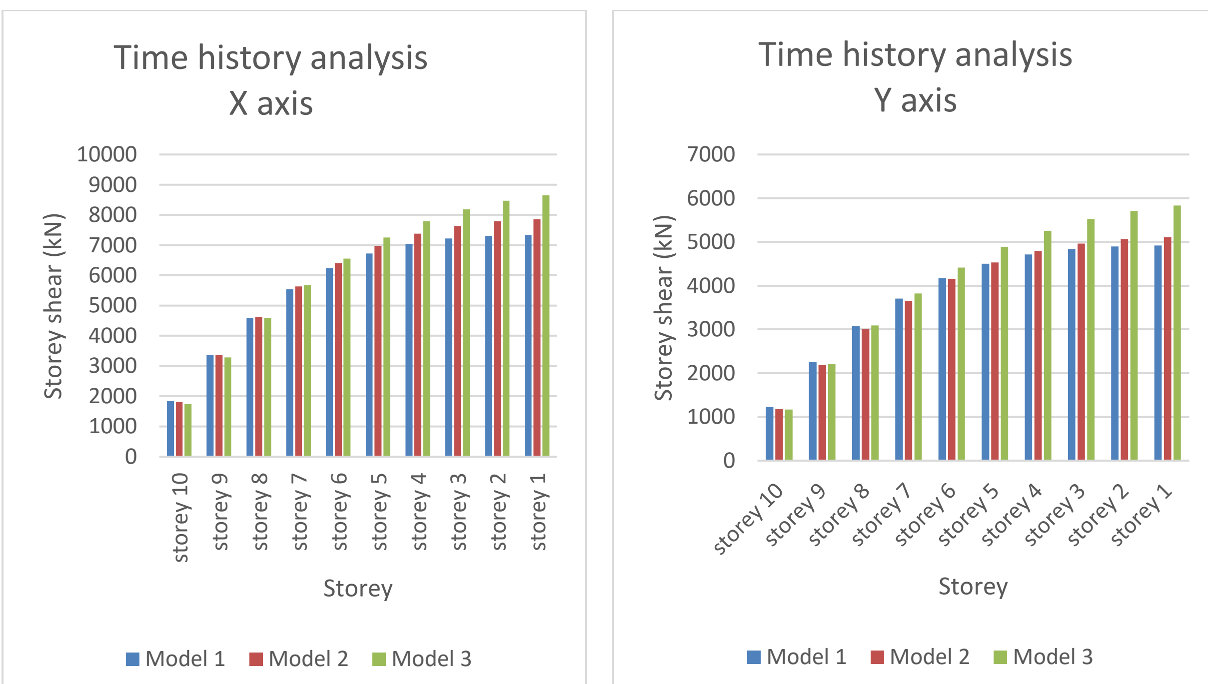


Figure 4. 10 Storey shear graph using time history analysis in X and Y direction with shear wall.

Table 4. 11 Storey shear (kN) using response spectrum analysis in X and Y direction without shear wall.

STOREY	RESPONSE SPECTRUM					
	MODEL 4		MODEL 5		MODEL 6	
	X	Y	X	Y	X	Y
10	760.5121	565.4336	757.0961	574.662	999.3733	783.359
9	1309.4337	891.4361	1308.2756	893.7855	1773.9713	1317.7841
8	1623.0994	1099.6917	1631.2523	1111.1691	2265.447	1634.7556
7	1850.829	1294.6071	1869.79	1309.8669	2611.1158	1910.7663
6	2106.1446	1466.6391	2127.3833	1480.0643	2932.1182	2157.5488
5	2340.6318	1625.6677	2358.0869	1635.4914	3221.7495	2381.8161
4	2514.6765	1779.5696	2533.6605	1789.4493	3476.1257	2590.9102
3	2702.3895	1923.5326	2727.4196	1927.0186	3762.0377	2766.2565
2	2933.3512	2055.6305	2952.7269	2058.2942	4065.3136	2973.7315
1	3119.1897	2242.9708	3090.0562	2195.2761	4241.8198	3149.5261

Table 4. 12 Storey shear (kN) using time history analysis in X and Y direction without shear wall.

STOREY	TIME HISTORY					
	MODEL 4		MODEL 5		MODEL 6	
	X	Y	X	Y	X	Y
10	591.4776	409.5577	606.5049	412.7943	754.16	541.9397
9	1091.5229	759.0612	1128.5575	771.0565	1427.7476	1027.6197
8	1492.6888	1042.9364	1556.4862	1067.7967	1997.1955	1439.8436
7	1806.2748	1268.6027	1899.8262	1309.0909	2471.2058	1784.5967
6	2043.5653	1443.4812	2168.0749	1500.9784	2858.4461	2067.827
5	2215.8202	1574.9762	2370.6716	1649.4258	3167.5351	2295.4217
4	2334.2357	1670.4293	2516.9424	1760.2502	3407.0121	2473.1646
3	2409.852	1737.0074	2615.9851	1838.9518	3585.2841	2606.6599
2	2453.3505	1781.4713	2676.429	1890.3102	3710.5482	2701.189
1	2477.6535	1815.02	2705.9997	1917.3741	3790.7771	2761.4779

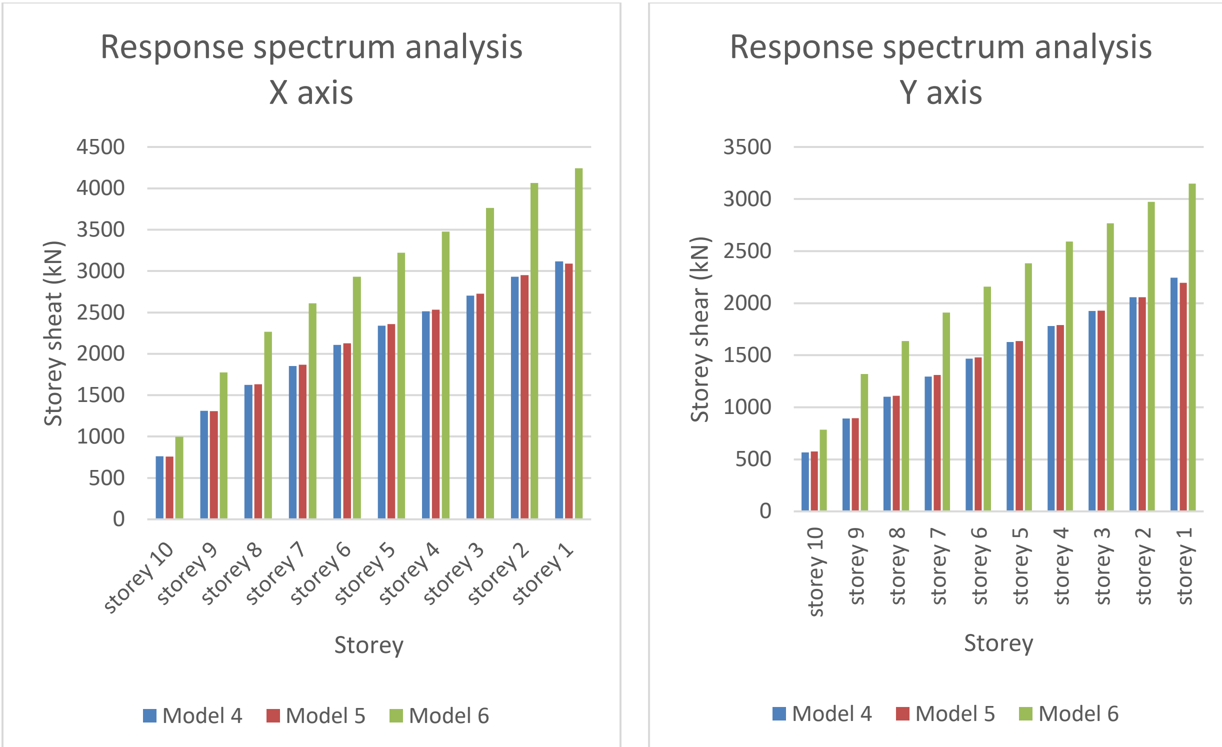


Figure 4. 11 Storey shear graph using response spectrum analysis in X and Y direction without shear wall.

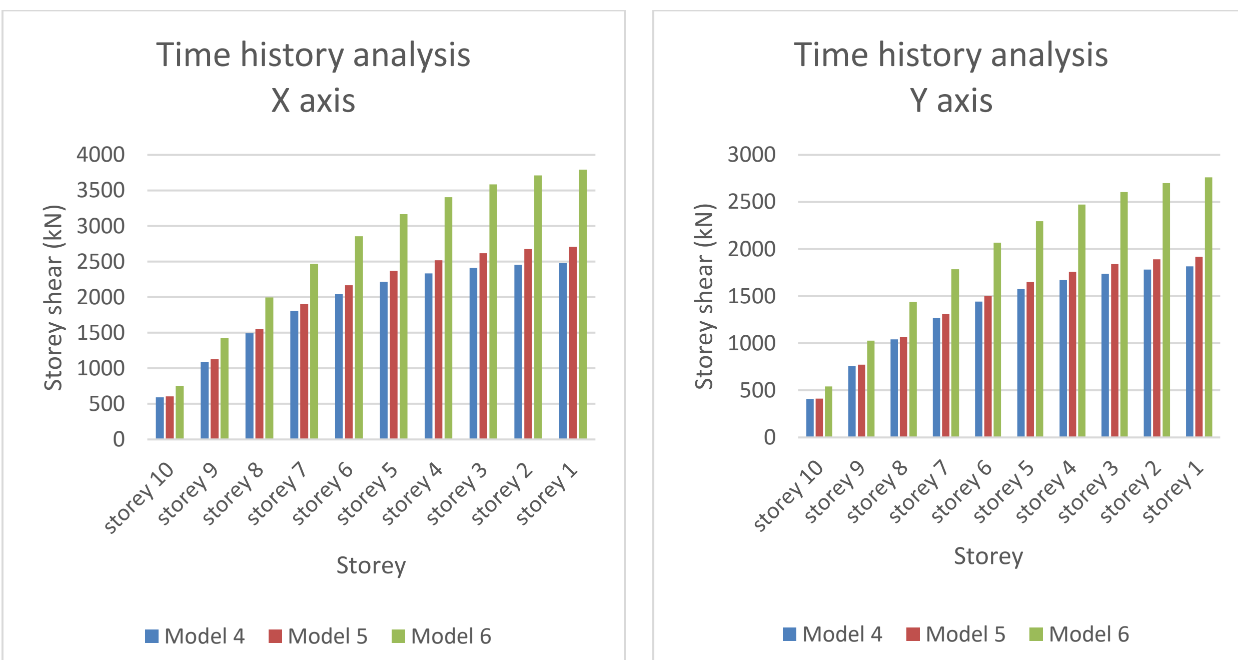


Figure 4. 12 Storey shear graph using time history analysis in X and Y direction without shear wall.

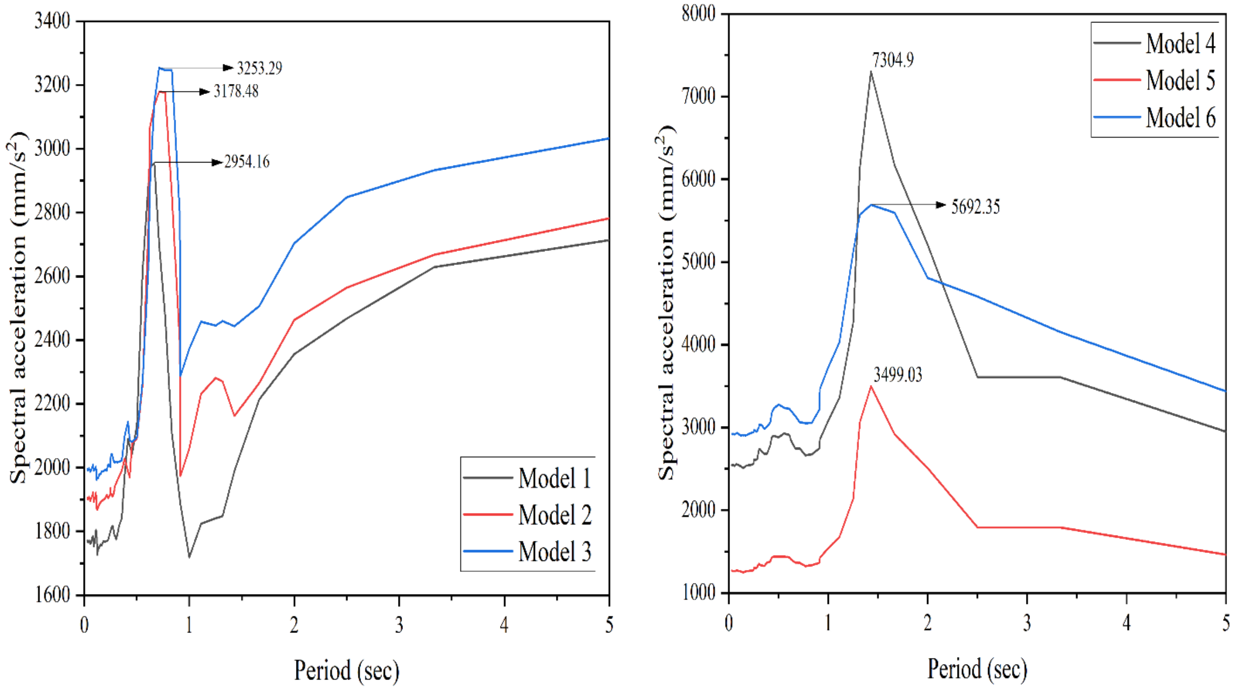


Figure 4. 13 Spectral acceleration with and without shear wall.

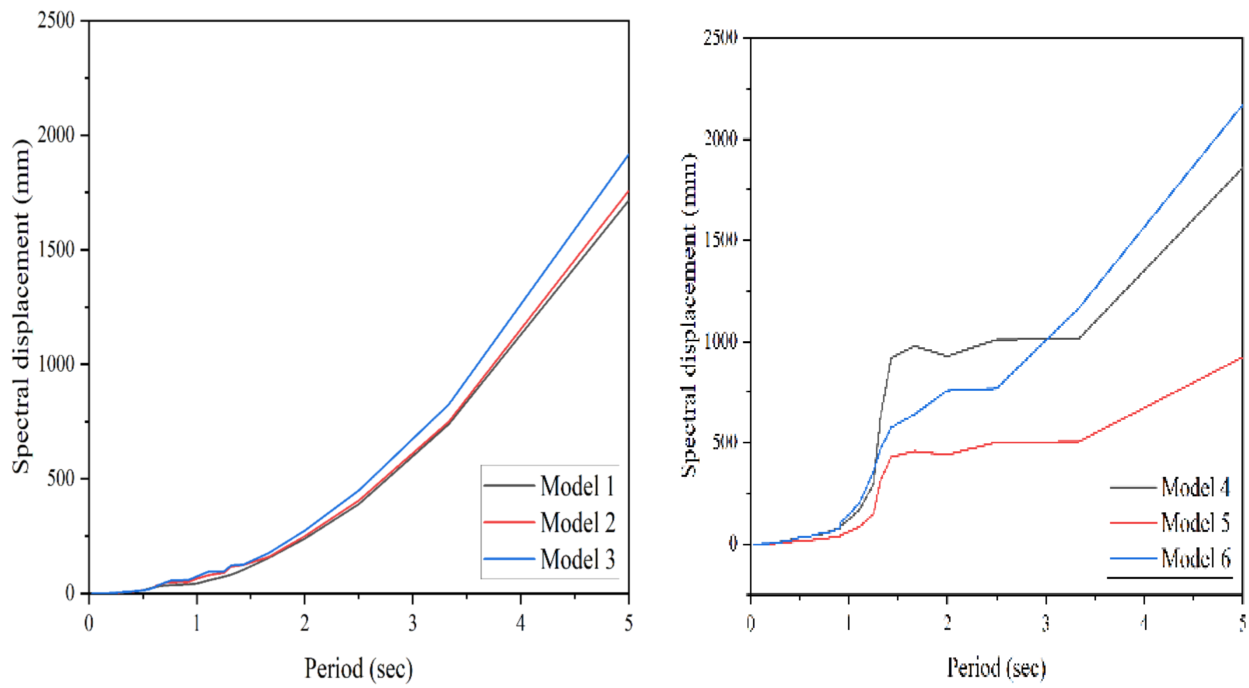


Figure 4. 14 Spectral displacement with and without shear wall.

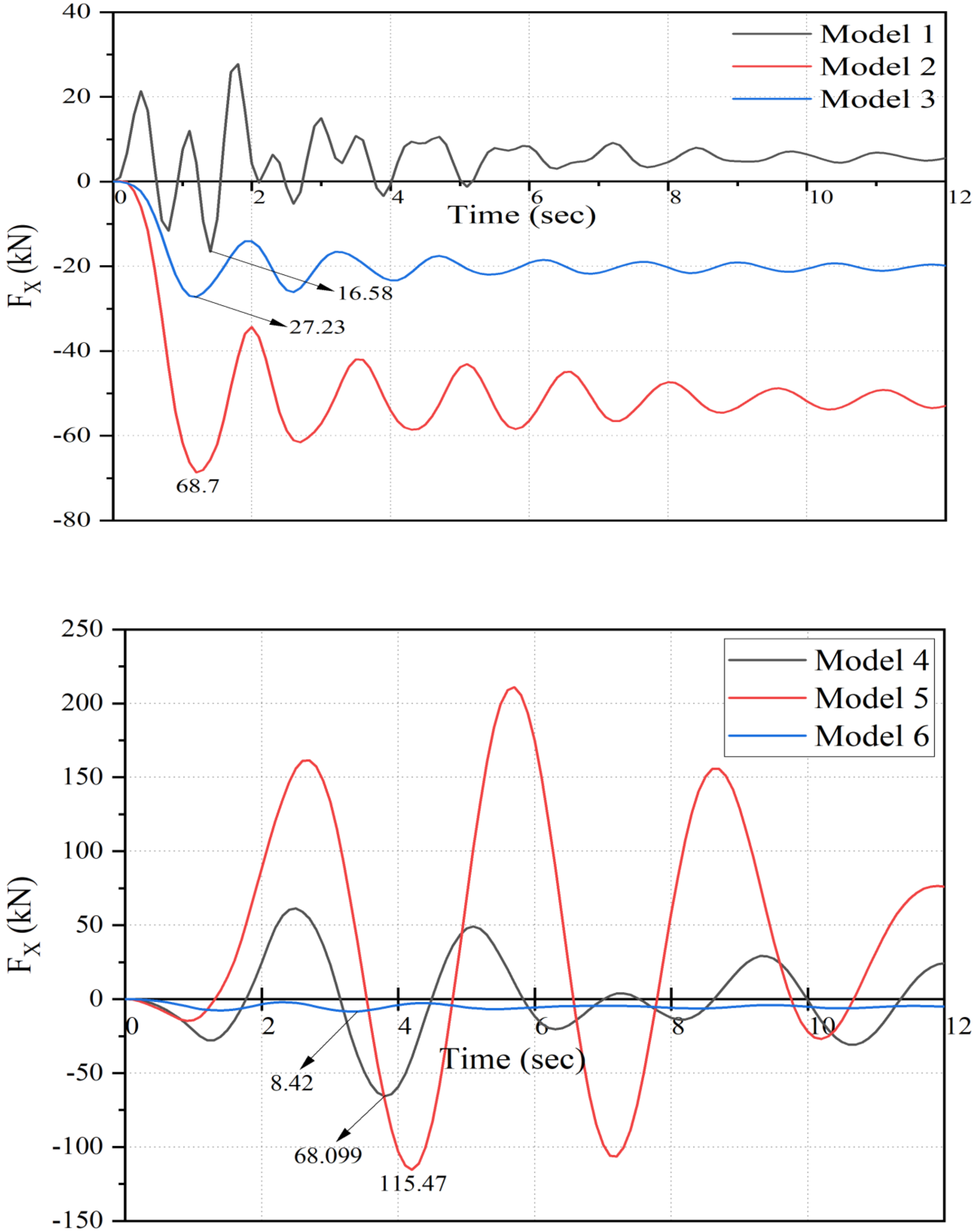


Figure 4. 15 Time history base shear with and without shear wall.

4.4 Check

4.4.1 Check for torsional irregularity

The formulas D_{max}/D_{avg} are used to check for torsional irregularity in buildings. [15]

1. Torsional Irregularity exist if $D_{max}/D_{avg} > 1.2$.

2. Extreme Torsional Irregularity exist if $D_{max}/D_{avg} > 1.4$.

So in our case there is extreme torsional irregularity exist $D_{max}/D_{avg} > 1.4$

When shear wall is at core:-

STOREY	DRIFTS		RATIO	CHECK	Extreme torsional
	Max. drifts	**Avg. drifts**	**DMAX/DAVG**		**irregularity check**
10	0.000645	0.000481	1.343	Irregular	Regular
9	0.000803	0.000514	1.564	Irregular	Irregular
8	0.000929	0.000532	1.748	Irregular	Irregular
7	0.001019	0.000537	1.899	Irregular	Irregular
6	0.001073	0.000526	2.039	Irregular	Irregular
5	0.001092	0.000499	2.187	Irregular	Irregular
4	0.001078	0.000455	2.367	Irregular	Irregular
3	0.001033	0.000395	2.62	Irregular	Irregular
2	0.000949	0.000315	3.009	Irregular	Irregular
1	0.000682	0.000198	3.454	Irregular	Irregular

Table 4. 13 Table for checking irregularity

After applying, shear walls at corner

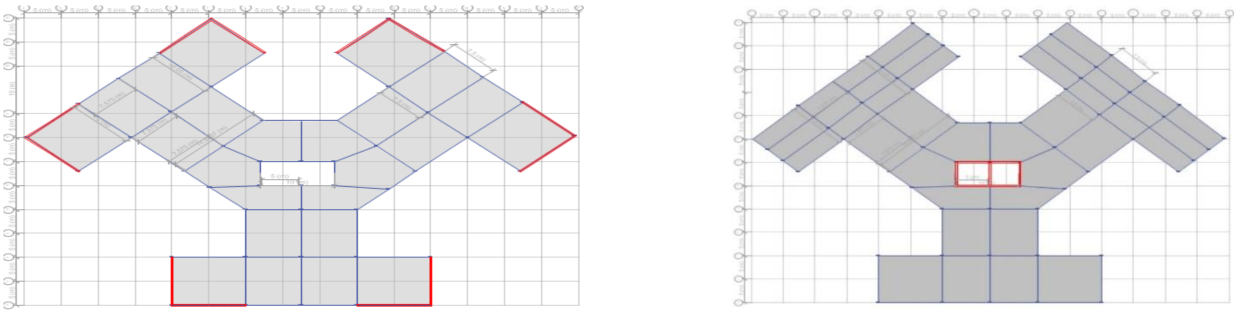


Figure 4. 16 Applying shear wall at corner

STOREY	DRIFTS		RATIO	CHECK	Extreme torsional
	Max. drifts	**Avg. drifts**	**DMAX/DAVG**		**irregularity check**
10	0.000345	0.000342	1.010	Regular	Regular
9	0.000359	0.000355	1.011	Regular	Regular
8	0.000366	0.000362	1.011	Regular	Regular
7	0.000364	0.00036	1.011	Regular	Regular
6	0.000352	0.000349	1.011	Regular	Regular
5	0.00033	0.000326	1.011	Regular	Regular
4	0.000296	0.000292	1.011	Regular	Regular
3	0.000249	0.000246	1.011	Regular	Regular
2	0.000191	0.000188	1.015	Regular	Regular
1	0.000111	0.000109	1.017	Regular	Regular

Table 4. 14 Table after correcting irregularity

Similarly, Building on 20-degree and 44-degree sloping ground there is an extreme torsional irregularity exist.

So on applying shear walls at corner building instead at core of building can be safe against torsional irregularity

4.4.2 Check for soft storey

A soft storey is a storey whose lateral stiffness is less than that of the storey above.

According to ASCE 7

A) Irregularity exist if stiffness of any storey is less than 70% of the stiffness of the storey above or less than 80% of the average stiffness of the three stories above.
B) An extreme irregularity exist if stiffness of any storey is less than 60% of the stiffness of the storey above or less than 70% of the average stiffness of the three stories above.
C) EXCEPTION:- irregularity does not exist if no storey drift ratio is greater than 1.3 times drift ratio of storey above

Storey	Stiffness(kN/m)	K_i/K_{i+1}	Check	K_{avg}=Avg($K_{i-1,i-2,i-3}$)	K_i/K_{avg}	Check
		0.6			0.7	
Story10	3072966.281	-	-	-	-	-
Story9	5706220.93	1.86	Regular	-	-	-
Story8	7744950.542	1.36	Regular	-	-	-
Story7	9439536.46	1.22	Regular	5508045.92	-	-
Story6	11018941.88	1.17	Regular	7630235.98	1.44	Regular
Story5	12723065.9	1.15	Regular	9401142.96	1.35	Regular
Story4	14878782.24	1.17	Regular	11060514.75	1.35	Regular
Story3	18120501.96	1.22	Regular	12873596.67	1.41	Regular
Story2	23997884.68	1.32	Regular	15240783.37	1.57	Regular
Story1	36851069.89	1.54	Regular	18999056.29	1.94	Regular

Table 4. 15 Table for checking Soft storey.

Hence, our all buildings are **safe in soft storey**.

4.4.3 Check for deflection

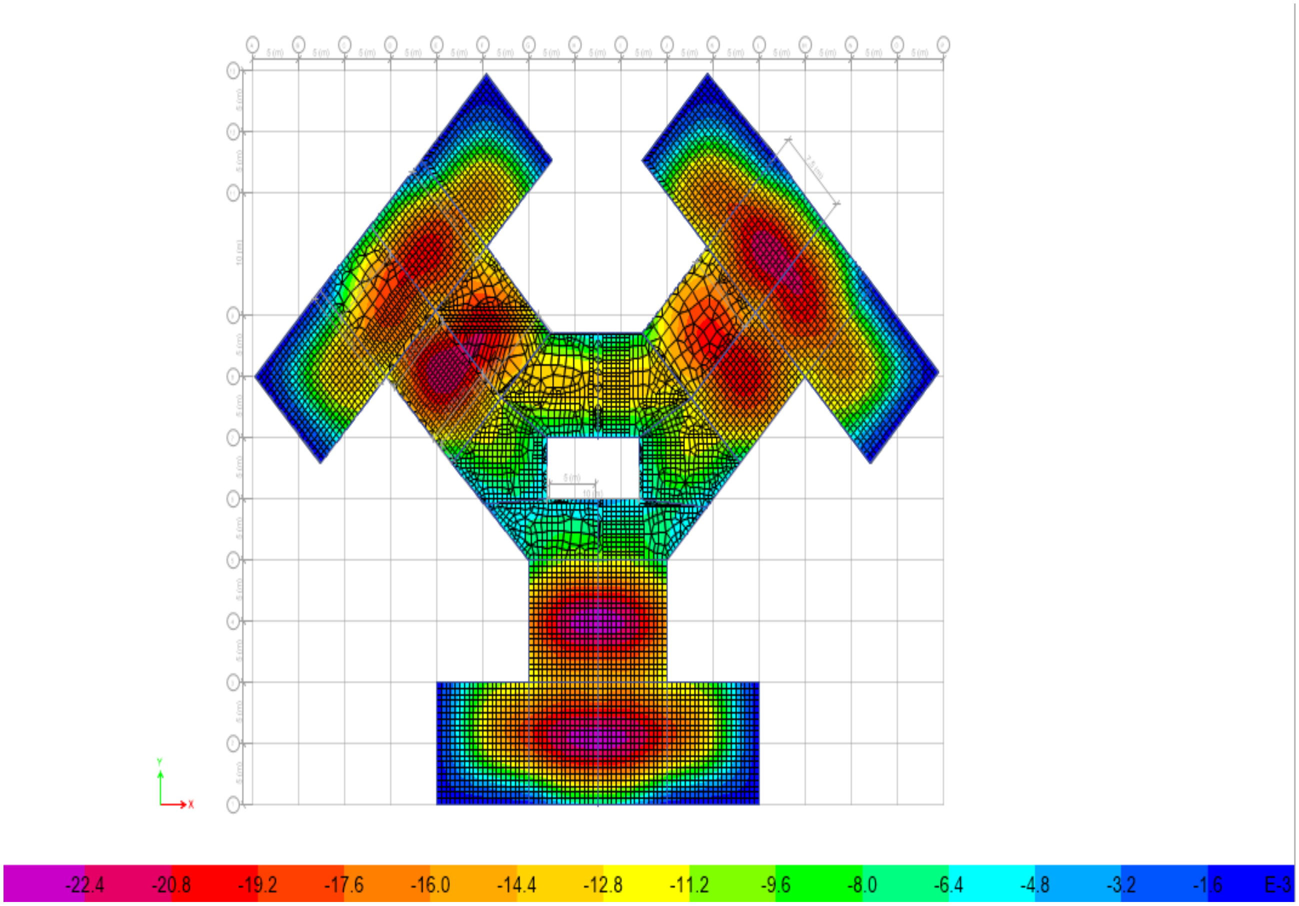


Figure 4. 17 Maximum deflection

For deflection, according to IS456:2000 [16]

Permissible deflection= span/350 or 20mm whichever is less

A) For 100mm slab

   (Maximum deflection – Axial shortening)* Creep coefficient< Permissible deflection

   Span=10m

   Permissible deflection= 28.57mm or 20mm whichever is less

   = 20mm

   (48 – 25.1)*1.1=25.19mm >20mm Hence **UNSAFE.**

B) Now, depth of the slab is increased =150mm

   (22.9 – 14.6)*1.1=9.13mm<20mm Hence **SAFE.**

4.4.4 Check for member passed

Section of **beam 450*300mm** and **column 600*300mm** has been adopted initially to carry the analysis whereas when we designed the section for the required forces and moment, the initially adopted section are failed and eventually a section of **beam 850*550mm** and **column 1000*500mm** has passed all the checks.

4.4.5 Check for percentage of reinforcement for beam and column

According to IS456:2000

A) Minimum percentage of reinforcement for beam
   $(A/bd) = (0.85/F_y)$
B) Maximum percentage of reinforcement for beam shall not exceed 0.04bD.
C) For column the reinforcement should be between (0.8% to 6%) of gross area.

Hence the entire member passed.

CHAPTER 5:-CONCLUSION

1) On analysis by time history method of 3D mathematical model following conclusions have been made:-
   a) With shear wall
      i) The 3D model on 44^o sloping ground was found to have maximum displacement in both the direction. Whereas model on flat ground has less displacement in both the direction.
      ii) It is observed that maximum storey drift is seen on the 9^{th} storey of 44^o sloping ground model. It is also observed that on increasing sloping angle from 0^o to 44^o slope storey drift increases.
      iii) Building model on 44^o sloping ground was found to have maximum value of storey shear in both the direction, while on flat ground is least.
   b) Without shear wall
      i) The 3D model on 20^o sloping ground was found to have maximum displacement in Y direction. While model on flat ground have maximum displacement in X direction.
      ii) It is observed that maximum storey drift is seen on the 2^{th} storey of 20^o sloping ground model.
      iii) Building model on 44^o sloping ground was found to have maximum value of storey shear in both the direction, while on flat ground is least.
2) On analysis by response spectrum method of 3D mathematical model following conclusions have been made:-
   a) With shear wall
      i) The 3D model on 20^o sloping ground was found to have maximum displacement in Y direction. Whereas model on flat ground has maximum displacement in X direction.
      ii) It is observed that maximum storey drift is seen on the 5^{th} storey of 20^o sloping ground model.
      iii) Building model on flat ground was found to have maximum value of storey shear in X direction, while on 44^o sloping ground has maximum values in Y direction.

b) Without shear wall

i) The 3D model on 20^o sloping ground was found to have maximum displacement in both the direction.

ii) It is observed that maximum storey drift is seen on the 2^{nd} storey of 20^o sloping ground model.

iii) Building model on 44^o sloping ground was found to have maximum value of storey shear in both the direction.

3) On performing some checks building model was found to have fail in torsional irregularity check , deflection and in member passed.

a) So on changing the location of shear wall building model made safe against the torsional irregularity.

b) On increasing the depth of slab building model made safe against deflection.

c) On increasing the dimensions of beam and column all member passed.

4) It has been observed that building is safe in soft storey check and in Check for percentage of reinforcement for beam and column.

5) It has been observed that spectral acceleration is maximum for building model on 44^o sloping ground with shear wall. While building without shear wall gets maximum spectral acceleration on flat ground model.

6) It has been observed that spectral displacement is maximum for building model on 44^o sloping ground, for both with and without shear wall.

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