To Analyse the Effects of Change in Podium Height and Diaphragm Conditions On Backstay Effect in High Rise Building

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Abstract

Tower-Podium type buildings are being quite popular now days, because they allow optimum use of land as well as financial leverage to satisfy demand of larger commercial space. Podium can be defined as part of structure whose lateral load resistance is more than that of tower. The backstay effect is a set of lateral forces developing within a podium structure to equilibrate the lateral forces and moment of a tower extending above podium structure. In this study to analyse Tower-Podium Structure CSI ETABS software is used. Different models are prepared by changing the no. of stories of podium and diaphragm conditions. After analysing, it is observed that backstay effect increases with increase in podium floors and it is more in case of rigid than semi-rigid. So, it is inferred that Tower with 5 storey Podium and Rigid Diaphragm can resist more lateral forces than any other models

Keyword: *Backstay, Diaphragm, ETABS, Podium Height, lateral forces.*

1. INTRODUCTION

The demand for tall structures is increasing daily due to rising population and land scarcity in metropolitan regions. Tall structures are becoming more popular in developing nations, including India. After a certain amount of horizontal development, no more land is accessible for growth in any city, especially in metro cities. As a result, multi-storey towers became popular as a way to maximize land utilization. High-rise buildings cannot be designed in the same manner that low and medium-rise structures are designed. Tall buildings are extremely complex engineering projects, so the most sophisticated design methods are required in tall structures. To satisfy the demand of increasing population as well as to satisfy the demand for the minimum parking space for such types of buildings under current bye-laws, Architects and Engineers proposed/put forward the new concept of Podium kind structures. The bottom few storeys have bigger plan dimensions than towers in many tall structures. These lower few stories of the building can be used for different purposes such as parking, retail shops, etc. A podium is a term used to describe the base of a tall building. Podium in architecture is any of various elements that form the foot or base of a structure and have a low wall supporting columns, or the structurally or decoratively emphasized the lowest portion of a wall. A building's basement story is sometimes used as a podium. In many multi-functional tall buildings, this type of configuration is seen.

1.1. Podium Type Towers

Increase in population, urbanization and requirement of various infrastructure resulted into limited availability of suitable land for development. These has resulted into sharp increase in land cost. So, to take optimum use of land, multi-storey tower became popular. But to take financial leverage as well as to satisfy demand of larger commercial space near to road level and making building compliant to minimum parking space requirements for such mixed-use development according to prevailing bye laws Architects and Developers have come up with unique idea of Podium type Buildings. They may be below ground, above ground or both. In general terms a Podium can be defined as that part of a building whose floor area is relatively much larger than the tower above and in terms of Structural Engineering a podium can be defined as that part of the structure whose lateral load resistance is relatively much more than that of the tower above So, Podium type buildings are multi-functional like parking + residential, parking + commercial, commercial + residential etc.

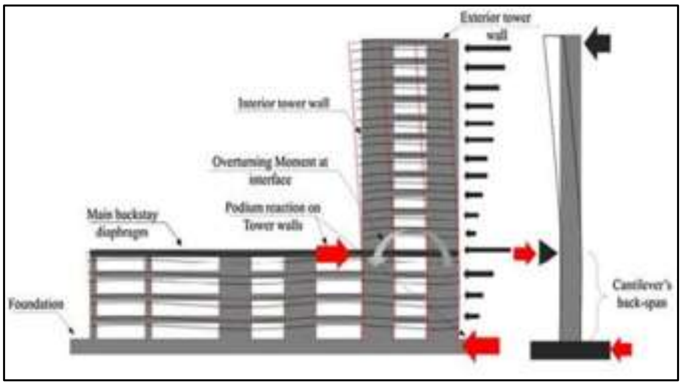


Fig 1 Tower with Podium

1.2 Diaphragms

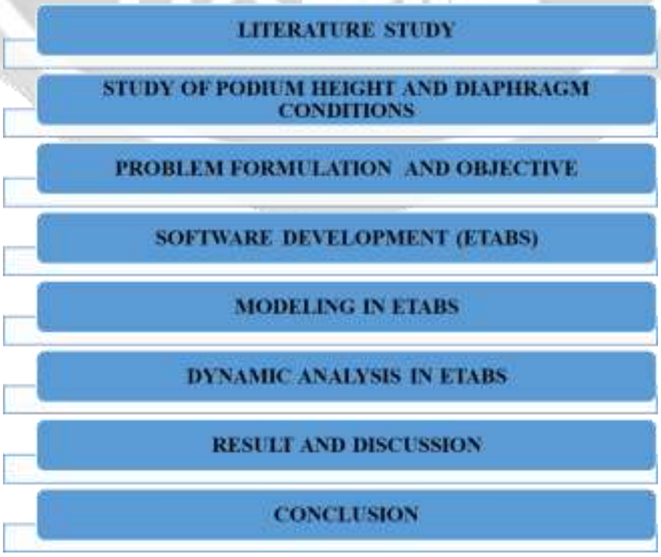
Diaphragms are horizontal structural elements with two primary roles in structures: to resist and transmit various types of load and to tie the vertical elements firmly. Load passes through lateral and vertical load paths until it reaches to the soil from the roof.

In general, there are three kinds of components contributing to these paths: Vertical elements, Horizontal elements and Foundation. Diaphragms, such as slab, are horizontal components with major functions such as:

1. To resists in-plane shear, axial, and bending actions due to lateral loads.
2. To transfer loads from a vertical element to the other,
3. To transfer the lateral loads acting on non-structural elements, like cladding, wall, etc.
4. To the vertical load-bearing/transferring elements through connections,
5. To provide lateral support(bracing) to structural elements which are not designed
6. To resist lateral loads,
7. To resist out-of-plane loads. For example, loads on the slab, uplift pressure due to wind action, etc.

2. METHODOLOGY & PROBLEM STATEMENT

It is gaining popularity in engineering due to its versatility and adaptability as an analysis tool. The rapid advancement of computer hardware technology and the lowering of computer costs have increased this strategy, as the computer is required for its implementation. A number of prominent brand finite element analysis software are now commercially accessible. Popular packages include ETABS, STAAD-PRO, GT-STRUDEL, NASTRAN, NISA, and ANSYS.



2.1 Problem Statement

For the current work, the construction is a building with 20 stories. The dimensions of the tower are 25m x 25m, and the podium is 75m x 75m. The work is to be done on different structural formations of tower-podium construction by varying the number of podium stories and diaphragm conditions, 10 different models will be prepared and analysed in the structural analysis and design tool ETABS. After analysis the conclusion will be made on basis of results. Rough sketch of the building
7 different models prepared in ETABS 2016 to analyze the effect. List of Models are as follow:

1) M1. Tower without podium (T)
2) M2. Tower + 3 story podium with rigid diaphragm (T+3-R)
3) M3. Tower + 3 story podium with semi rigid diaphragm (T+3-S)
4) M4. Tower + 4 story podium with rigid diaphragm (T+4-R)
5) M5. Tower + 4 story podium with semi rigid diaphragm (T+4-S)
6) M6. Tower + 5 story podium with rigid diaphragm (T+5-R)
7) M7. Tower + 5 story podium with semi rigid diaphragm (T+5-S)

2.2 Modeling

1) M1. Tower without podium (T)

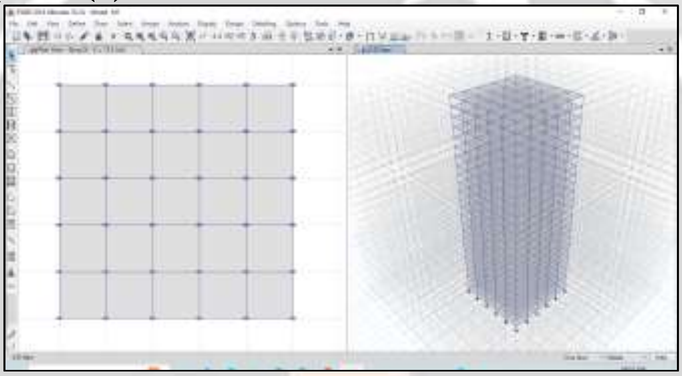


Fig 2- M1. Tower without podium (T)

2) M2. Tower + 3 story podium with rigid diaphragm (T+3-R)

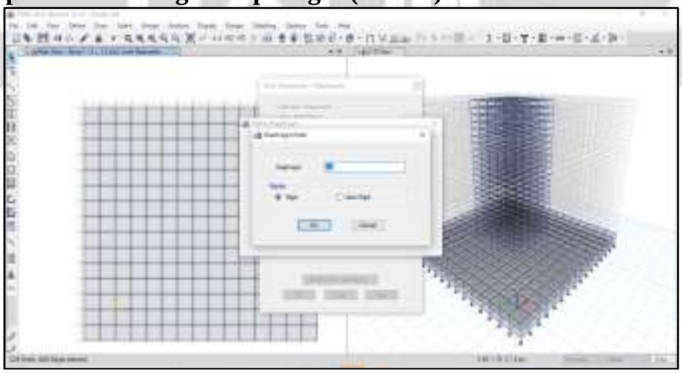


Fig 3 - M2. Tower + 3 story podium with rigid diaphragm (T+3-R)

3) M3. Tower + 3 story podium with semi rigid diaphragm (T+3-S)

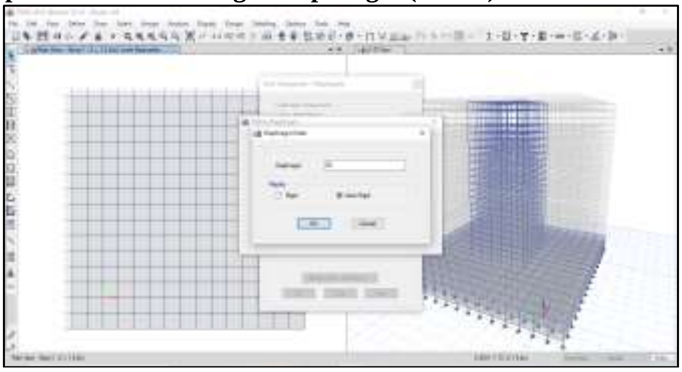


Fig 4- M3. Tower + 3 story podium with semi rigid diaphragm (T+3-S)

4) M4. Tower + 4 story podium with rigid diaphragm (T+4-R)

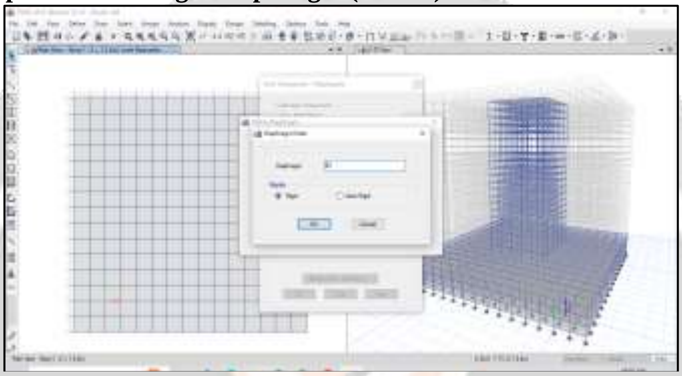


Fig 5 - M4. Tower + 4 story podium with rigid diaphragm (T+4-R)

5) M5. Tower + 4 story podium with semi rigid diaphragm (T+4-S)

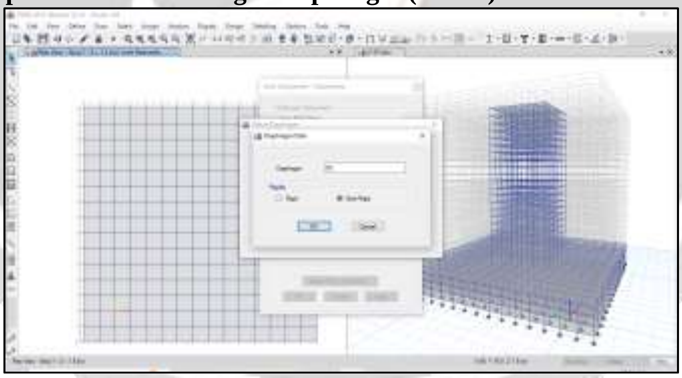


Fig 6- M5. Tower + 4 story podium with semi rigid diaphragm (T+4-S)

6) M6. Tower + 5 story podium with rigid diaphragm (T+5-R)

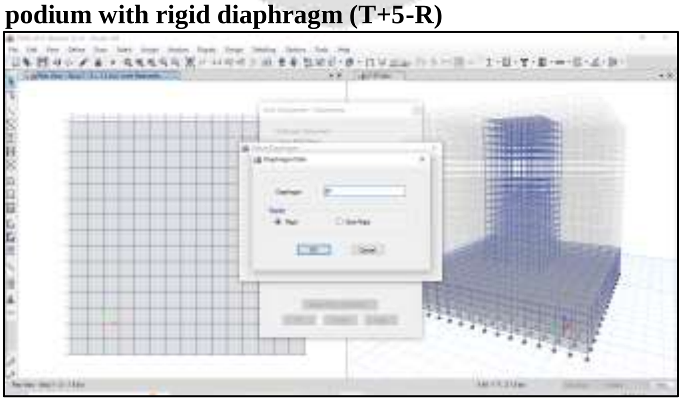


Fig 7- M6. Tower + 5 story podium with rigid diaphragm (T+5-R)

7) M7. Tower + 5 story podium with semi rigid diaphragm (T+5-S)

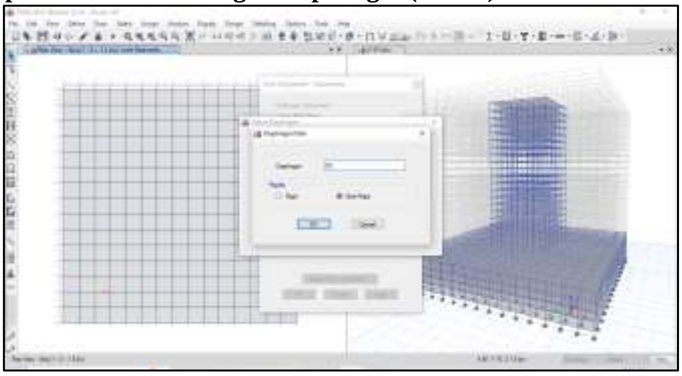


Fig 8- M7. Tower + 5 story podium with semi rigid diaphragm (T+5-S)

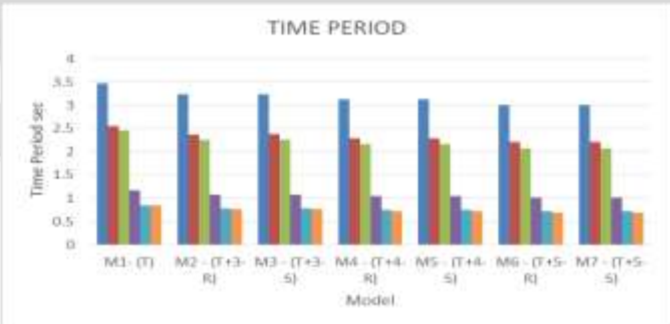
3. SOFTWARE ANALYSIS RESULTS

3.1 Time Period

Every building has a number of natural frequencies, at which it offers minimum resistance to shaking induced by external effects (like earthquakes and wind) and internal effects (like motors fixed on it). Each of these natural frequencies and the associated deformation shape of a building constitute a Natural Mode of Oscillation

Table 1 Time Period

TIME PERIOD							
MODE NO	**M1- (T)**	**M2 - (T+3-R)**	**M3 - (T+3-S)**	**M4 - (T+4-R)**	**M5 - (T+4-S)**	**M6 - (T+5-R)**	**M7 - (T+5-S)**
1	3.479	3.236	3.238	3.123	3.125	3.008	3.011
2	2.548	2.373	2.378	2.291	2.296	2.206	2.211
3	2.459	2.253	2.256	2.161	2.164	2.069	2.072
4	1.173	1.079	1.08	1.04	1.041	1.008	1.009
5	0.848	0.776	0.778	0.746	0.749	0.721	0.723
6	0.837	0.759	0.761	0.726	0.727	0.694	0.695



Graph 1 Time Period Sec.

From the above table and graph, we can observe the percentage variation for time period for response spectrum analysis for models with backstays and diaphragms. The variation is found to be 10-15% less for the model with the highest podium, i.e., the model with a T+5 podium. The results analysed after changing the diaphragm condition show that the semi-rigid diaphragm has a longer time period than the rigid diaphragm.

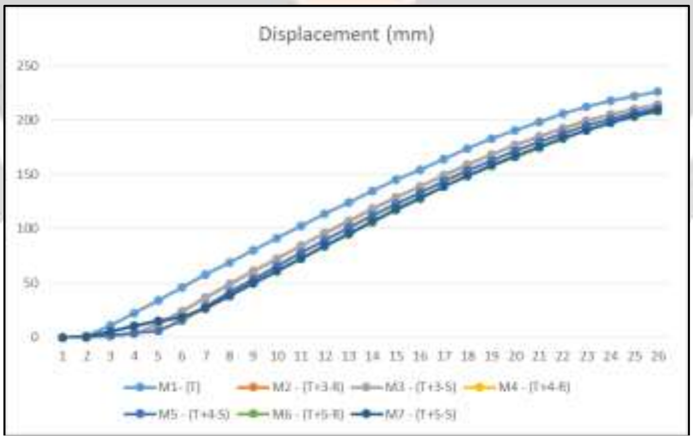
3.2 Displacement (mm)

Displacement can be defined as "It is the displacement of a storey with respect to the base of a structure.

Table 2 Displacement (mm)

Displacement (mm)							
Storey	**M1- (T)**	**M2 - (T+3-R)**	**M3 - (T+3-S)**	**M4 - (T+4-R)**	**M5 - (T+4-S)**	**M6 - (T+5-R)**	**M7 - (T+5-S)**
25	226.29	214.22	214.718	210.512	211.025	208.255	208.779
24	222.373	210.212	210.575	206.264	206.645	203.566	203.956

23	217.746	205.225	205.63	200.94	201.365	197.611	198.048
22	212.199	199.284	199.698	194.631	195.068	190.627	191.079
21	205.846	192.505	192.932	187.526	187.977	182.972	183.441
20	198.768	185	185.44	179.78	180.242	174.918	175.402
19	191.043	176.857	177.309	171.478	171.949	166.572	167.067
18	182.734	168.132	168.598	162.633	163.114	157.87	158.371
17	173.889	158.863	159.341	153.228	153.72	148.648	149.155
16	164.541	149.073	149.562	143.252	143.753	138.754	139.259
15	154.75	138.797	139.316	132.738	133.27	128.136	128.661
14	145.024	128.63	129.146	122.34	122.869	117.49	118.004
13	134.945	118.079	118.614	111.594	112.138	106.436	106.964
12	124.501	107.156	107.706	100.543	101.097	95.162	95.703
11	113.717	95.867	96.435	89.188	89.753	83.807	84.368
10	102.598	84.194	84.776	77.455	78.03	72.372	72.947
9	91.192	72.109	72.743	65.219	65.845	60.693	61.317
8	80.354	60.601	61.236	53.421	54.051	49.57	50.179
7	69.259	48.702	49.374	41.048	41.722	38.05	38.65
6	57.851	36.444	37.143	28.225	28.929	26.784	27.258
5	46.168	24.022	24.74	15.656	16.307	18.427	18.552
4	34.281	12.086	12.737	6.181	6.505	15.234	15.028
3	22.358	3.17	3.511	4.17	4.074	10.84	10.7
2	10.87	1.542	1.48	2.11	2.069	5.629	5.555
1	1.667	0.239	0.231	0.333	0.325	0.898	0.885
Base	0	0	0	0	0	0	0



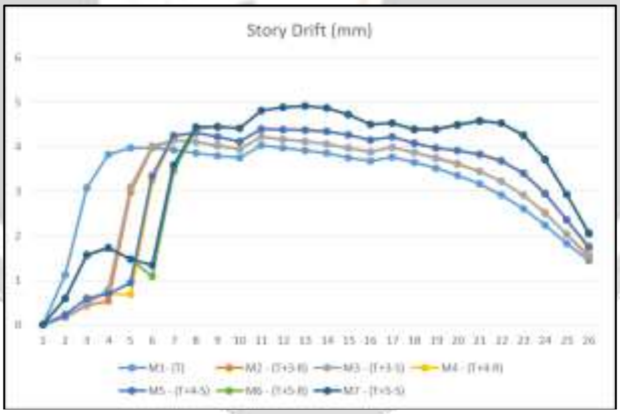
Graph 2 Displacement (mm)

From the above table and graph, we can observe the percentage variation for Displacement for response spectrum analysis for models with backstays and diaphragms. The variation is found to be 5-10% less for the model with the highest podium, i.e., the model with a T+5 podium. The results analyzed after changing the diaphragm condition show that the semi-rigid diaphragm has a slightly highest displacement than the rigid diaphragm due to elasticity.

3.3 Story Drift (mm)

Table 3 Story Drift (mm)

Story Drift (mm)							
Storey	**M1-(T)**	**M2 - (T+3-R)**	**M3 - (T+3-S)**	**M4 - (T+4-R)**	**M5 - (T+4-S)**	**M6 - (T+5-R)**	**M7 - (T+5-S)**
25	1.44	1.52	1.56	1.71	1.75	2.03	2.07
24	1.83	2.03	2.03	2.36	2.36	2.93	2.93
23	2.24	2.52	2.51	2.96	2.95	3.72	3.71
22	2.61	2.92	2.91	3.41	3.40	4.27	4.26
21	2.92	3.23	3.22	3.69	3.68	4.54	4.54
20	3.16	3.45	3.45	3.84	3.83	4.59	4.58
19	3.36	3.62	3.61	3.91	3.91	4.50	4.49
18	3.52	3.75	3.74	3.98	3.97	4.40	4.39
17	3.65	3.87	3.87	4.09	4.08	4.40	4.39
16	3.77	3.99	3.99	4.23	4.23	4.54	4.54
15	3.68	3.89	3.89	4.15	4.15	4.51	4.51
14	3.76	3.98	3.98	4.27	4.27	4.72	4.72
13	3.85	4.06	4.06	4.35	4.34	4.87	4.87
12	3.92	4.12	4.12	4.38	4.37	4.92	4.92
11	3.98	4.17	4.17	4.38	4.38	4.89	4.88
10	4.03	4.23	4.22	4.40	4.40	4.82	4.82
9	3.76	3.95	3.95	4.11	4.12	4.41	4.41
8	3.80	4.03	4.02	4.23	4.22	4.46	4.45
7	3.86	4.11	4.11	4.33	4.32	4.40	4.44
6	3.93	4.15	4.15	4.23	4.26	3.46	3.59
5	3.98	3.98	4.02	3.22	3.34	1.09	1.34
4	3.98	2.98	3.09	0.68	0.94	1.47	1.47
3	3.83	0.54	0.80	0.69	0.70	1.74	1.72
2	3.08	0.43	0.46	0.59	0.59	1.58	1.57
1	1.12	0.16	0.17	0.22	0.23	0.60	0.60
Base	0.00	0.00	0.00	0.00	0.00	0.00	0.00



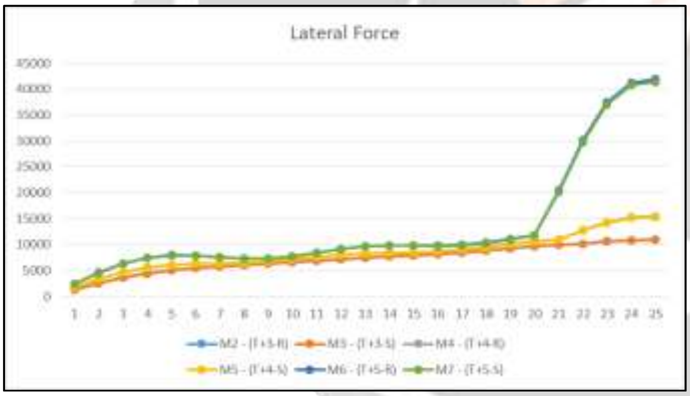
Graph 3 Story Drift (mm)

From the above table and graph, we can observe the percentage variation for Story Drift for response spectrum analysis for models with backstays and diaphragms. The variation is found to be 5-10% less for the model with the highest podium, i.e., the model with a T+5 podium. The results analyzed after changing the diaphragm condition show that the semi-rigid diaphragm has a slightly highest displacement than the rigid diaphragm due to elasticity.

3.4 Lateral Force

Lateral Force						
Storey	**M2 - (T+3-R)**	**M3 - (T+3-S)**	**M4 - (T+4-R)**	**M5 - (T+4-S)**	**M6 - (T+5-R)**	**M7 - (T+5-S)**
25	1296.4	1290.5	1730.3	1717.5	2366.2	2361.4
24	2542.1	2531.4	3350.6	3327.2	4565.9	4556.5
23	3599.5	3585.5	4647.6	4618.1	6288.7	6275.5
22	4430.2	4415.2	5553.8	5523.4	7418.0	7401.8

21	5033.9	5019.5	6073.2	6046.6	7931.2	7913.1
20	5449.3	5436.5	6291.2	6270.9	7921.8	7902.6
19	5745.9	5734.4	6363.5	6348.8	7608.9	7589.6
18	6001.9	5990.9	6470.3	6457.3	7313.4	7295.3
17	6275.9	6264.4	6732.3	6716.4	7341.6	7326.3
16	6585.5	6573.2	7145.1	7124.4	7787.5	7776.0
15	6910.5	6897.9	7603.8	7580.0	8477.6	8469.7
14	7222.1	7210.4	8001.1	7978.0	9163.5	9157.7
13	7492.7	7482.5	8264.6	8245.4	9643.1	9637.6
12	7721.4	7712.2	8399.9	8385.6	9844.2	9836.0
11	7935.3	7925.7	8487.8	8475.8	9830.1	9816.0
10	8177.0	8164.7	8647.5	8632.6	9775.8	9753.0
9	8483.1	8466.3	8973.7	8951.0	9895.8	9863.9
8	8864.4	8843.0	9480.5	9448.4	10334.	10296.
7	9283.5	9259.3	10073.	10035.	11038.	11000.
6	9680.1	9656.5	10618.	10580.	11835.	11802.
5	9988.7	9969.8	10996.	10965.	20417.	20241.
4	10163.	10152.	12780.	12704.	30103.	29774.
3	10614.	10599.	14358.	14236.	37418.	36978.
2	10870.	10851.	15241.	15093.	41295.	40798.
1	10911.	10890.	15381.	15229.	41900.	41394.



Graph 4 Lateral Force

From the above table and graph, we can observe the percentage variation for Lateral Force for response spectrum analysis for models with different diaphragms. The variation is found to be 5-10% high for the model with the highest podium, i.e., the model with a T+5 podium. The results analyzed after changing the diaphragm condition show that the semi-rigid diaphragm has a slightly less Lateral Force than the rigid diaphragm due to elasticity

5. CONCLUSION

The main purpose of this study is to analyze Backstay Effect and changes in Diaphragm Conditions high rise building by ETABS. Dynamic analysis has been carried out to know time period, Story Drift, displacements and lateral force by using Different 7 types of models models of the 25th floors for the analysis. The analysis include participation of 90% of the building mass for every principal horizontal direction of response as per IS 1893(Part-I)-2016 by complete Quadratic Combination (CQC). High performance concrete is used in the analysis, along with modern structural framings such as moment resisting frames. The building is tested for Equivalent Static & response spectrum analysis. According to FEA results, the results found that buildings with podiums give better results than normal buildings; buildings with a higher number of podium levels give better results; in our analysis, podiums at the 5th level give the best results. For analysis models with rigid and semi-rigid diaphragms, the results conclude that for the time period, story drift, displacements are increased in semi-rigid models due to stiffness, and lateral force is reduced

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