International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 11 Issue: 06 | Jun 2024 www.irjet.net p-ISSN: 2395-0072

ANALYZING EFFECTS OF WIND LOAD ON HIGH RISE BUILDINGS & AUTOMATION USING SOFTWARE INTEGRATION

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Abstract: - *Wind is the movement of air in the Earth's atmosphere, primarily caused by differences in air pressure and temperature across the globe. High-rise construction is rapidly increasing in Indian metropolitan areas. The wind is the critical load that must be taken into account in tall buildings for the structure's safety and serviceability. In this paper, parametric study has been done for high rise buildings with height and size variation and software has been used to carry out the static and dynamic analysis of all the cases of high rise building to verify the manual results. The static and dynamic lateral forces obtained by all cases have been compared in order to find the static and dynamic force variation with increase in height of the building.*

Key Words: Wind load, high rise building, software integration, StaadPro software.

1.Introduction

The analysis for High Rise Buildings is based on IS: 875 (Part 3), 1987. Both static and dynamic analysis are carried out manually and with the help of STAAD Connect software and forces on the building as a whole are calculated. Parametric study with respect to height has shown that as the building becomes slender, the dynamic forces dominate.

The second and the most significant objective of this work is to save time in the today's era of time bound competition without compromising on quality of output produced by integrating excel with STAAD connect using VBA. In order to enable smooth transition of data from STAAD Connect to Excel and vice versa, the powerful feature of STAAD named OPEN STAAD is brought into use.

1.1 Wind effects on structure

Wind is a moving air. The air has a particular mass (density or weight) and moves in a particular direction at a particular velocity. It thus has kinetic energy of the form expressed as

$$E = 1/2 * m * v2$$

The buildings and other civil engineering structures are three dimensional bodies with a large variety of shapes and have complex flow patterns and therefore varied pressure distributions.

2 Literature Review

Mohammed Asim Ahmed(2015) Wind has flow with very rough surface of earth which is affected to the high rise building of the earth. Wind flows in low speed in rough terrain and it is high speed in the smooth terrain of the structure. This paper shows that the different story due to wind effect to the different terrain category. It is made models in ETABS2015. This model also gives information of the different height with different terrain category of wind effect. When the story increase than the displacement of the story is also increased.

Ranjitha K. P (2014) This shows that the calculation of static load and dynamic work loading analysis of the tall structure. The dynamic analysis with gust response factor and static wind effect are saying in this project. The different shape of the building with zone I to zone IV to determine wind effect based on IS875 part3.The wind pressure is very effective on the tall structure. Wind loading is load that different in to the both in time and space. The wind effect are calculate by physical and analytical for static wind effect by purpose of safety. The wind effect for Displacement of TG-1 is top as contrast to the other category for all types of different story building. The wind effect for Story drift of TG 1 is top as contrast to the other category for all types of different story building.

3. Parametric Investigation

Here six different cases of tall buildings have been taken. The variation of building is due to size and height of building.

- In first case, a fifteen storied building of height 60m with seven bays in X direction and seven bays in Y-direction has been studied.
- In second case, the building is 72m high and 18 storied with seven bays in X direction and seven bays in Y-direction.
- In third case, it is 104m high and 26 storied with seven bays in X direction and seven bays in Y-direction.
- In fourth case, a fifteen storied building of height 60m with ten bays in X direction and five bays in Y-direction has been studied.

- In fifth case, the building is 72m high and 18 storied with ten bays in X direction and five bays in Y-direction.
- In sixth case, it is 104m high and 26 storied with ten bays in X direction and five bays in Y-direction.

Table -1: Physical parameters of the building

Parameters	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9
Type of structure	RCC Frame structure								
Floor to floor height (m)	4	4	4	4	4	4	4	4	4
Ground storey height (m)	4	4	4	4	4	4	4	4	4
Length (m)	35	35	35	50	50	50	40	40	40
Width (m)	35	35	35	25	25	25	40	40	40
Storey height (m)	60	72	104	60	72	104	60	72	104

Table -2: Material properties of structure

Parameters	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9
Size of column	0.6 x 0.6	0.6 x 0.6	0.6 x 0.6	0.6 x 0.6	0.6 x 0.6	0.6 x 0.6	0.6 x 0.6	0.6 x 0.6	0.6 x 0.6
Size of beam	0.6 x 0.3	0.6 x 0.3	0.6 x 0.3	0.6 x 0.3	0.6 x 0.3	0.6 x 0.3	0.6 x 0.3	0.6 x 0.3	0.6 x 0.3
Panel size	5 x 5	5 x 5	5 x 5	5 x 5	5 x 5	5 x 5	5 x 5	5 x 5	5 x 5

Table -3: Wind data on structure

City	Solapur
V_b	39 m/s
Terrain category	3
Class of structure	C
Life of structure	25 years
Risk factor, K_1	1
Topography, K_3	1
C_f	2

Table -4: Gravity loads on structure

Deal load	Selfweight command in STAAD
Live load	5 kN/m^2

3.1 Case 1: 35M X 35M X 60M

- **Static analysis**

Table -5: Computation of Wind Load At Different Elevations of The Building for case 1

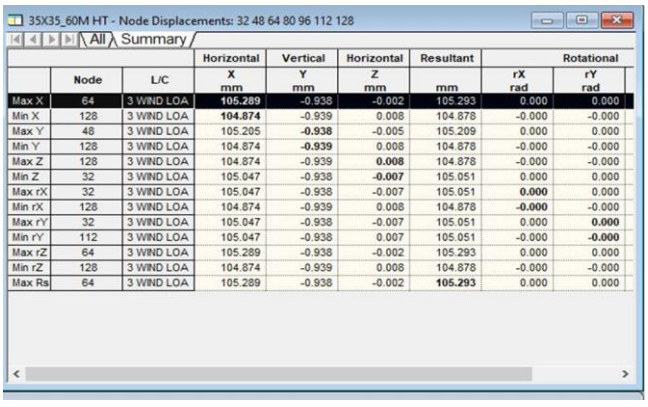
Storey No.	Elevation (m)	k_2	v_z (m/s)	p_z (N/m^2)	Force (kN)	Base shear (kN)
15	60	1.14	44.30	1177.71	164.88	164.88
14	56	1.13	44.03	1163.24	325.71	490.59
13	52	1.12	43.80	1150.91	322.25	812.84
12	48	1.11	43.45	1132.53	317.11	1129.95
11	44	1.10	42.98	1108.27	310.31	1440.26
10	40	1.09	42.51	1084.26	303.59	1743.86
9	36	1.08	42.04	1060.52	296.95	2040.80
8	32	1.07	41.57	1037.04	290.37	2331.17
7	28	1.05	40.95	1006.14	281.72	2612.89
6	24	1.03	40.17	968.18	271.09	2883.98
5	20	1.01	39.39	930.94	260.66	3144.64
4	16	0.98	38.14	872.89	244.41	3389.05
3	12	0.93	36.43	796.11	222.91	3611.96
2	8	0.91	35.49	755.72	211.60	3823.57
1	4	0.91	35.49	755.72	211.60	4035.17
0	0	0.91	35.49	755.72	105.80	4140.97

- **Dynamic analysis**

$$T = \frac{0.09\,x\,H}{\sqrt{d}} = \frac{0.09\,x\,60}{\sqrt{35}} = 0.9127 \text{ Sec}$$

$$F = \frac{1}{T} = \frac{1}{0.9127} = 1.0956 \text{ Hz}$$

Dynamic analysis is required if frequency is less than 1 Hz.
Here, frequency = 1.0956 > 1
Therefore, dynamic analysis is not required for this case.
Base shear obtained:
Static analysis = 4140.97 Kn



	Node	L/C	Horizontal X mm	Vertical Y mm	Horizontal Z mm	Resultant mm	Rotational rX rad	Rotational rY rad
Max X	64	3 WIND LOA	**105.289**	-0.938	-0.002	105.293	0.000	0.000
Min X	128	3 WIND LOA	**104.874**	-0.939	0.008	104.878	-0.000	-0.000
Max Y	48	3 WIND LOA	105.205	**-0.938**	-0.005	105.209	0.000	0.000
Min Y	128	3 WIND LOA	104.874	**-0.939**	0.008	104.878	-0.000	-0.000
Max Z	128	3 WIND LOA	104.874	-0.939	**0.008**	104.878	-0.000	-0.000
Min Z	32	3 WIND LOA	105.047	-0.938	**-0.007**	105.051	0.000	0.000
Max rX	32	3 WIND LOA	105.047	-0.938	-0.007	105.051	**0.000**	0.000
Min rX	128	3 WIND LOA	104.874	-0.939	0.008	104.878	**-0.000**	-0.000
Max rY	32	3 WIND LOA	105.047	-0.938	-0.007	105.051	0.000	**0.000**
Min rY	112	3 WIND LOA	105.047	-0.938	0.007	105.051	-0.000	**-0.000**
Max rZ	64	3 WIND LOA	105.289	-0.938	-0.002	105.293	0.000	0.000
Min rZ	128	3 WIND LOA	104.874	-0.939	0.008	104.878	-0.000	-0.000
Max Rs	64	3 WIND LOA	105.289	-0.938	-0.002	**105.293**	0.000	0.000

Fig -1: Maximum storey displacement for case 1

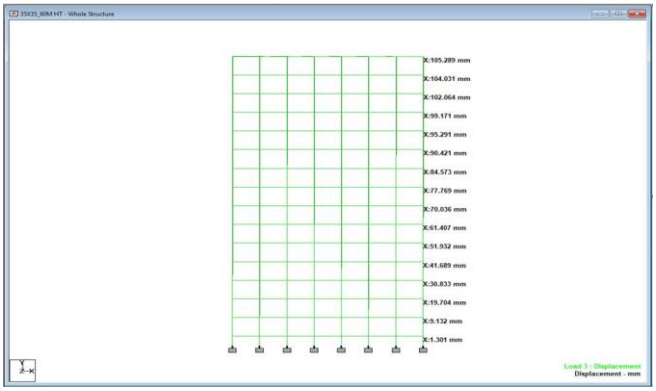


Fig -2: Maximum storey drift for case 1

Table -6: Storey drift for case 1

Sr. no.	Storey number	Storey drift (mm)
1	15	1.258
2	14	1.967
3	13	2.893
4	12	3.88
5	11	4.87
6	10	5.848
7	9	6.804
8	8	7.733
9	7	8.629
10	6	9.475
11	5	10.243
12	4	10.856
13	3	11.129
14	2	10.572
15	1	7.831

3.2 Case 2: 35M X 35M X 72M

- **Static analysis**

Table -7: Computation of Wind Load At Different Elevations of The Building for case 2

Storey No.	Elevation	k_2	v_z	p_z	Force	Base shear
	(m)		(m/s)	(N/m^2)	(kN)	(kN)
18	72	1.16	45.05	1217.43	170.44	170.44
17	68	1.15	44.77	1202.72	336.76	507.20
16	64	1.14	44.54	1190.18	333.25	840.45
15	60	1.14	44.30	1177.71	329.76	1170.21
14	56	1.13	44.03	1163.24	325.71	1495.92
13	52	1.12	43.80	1150.91	322.25	1818.17
12	48	1.11	43.45	1132.53	317.11	2135.28
11	44	1.10	42.98	1108.27	310.31	2445.59
10	40	1.09	42.51	1084.26	303.59	2749.19
9	36	1.08	42.04	1060.52	296.95	3046.13
8	32	1.07	41.57	1037.04	290.37	3336.50
7	28	1.05	40.95	1006.14	281.72	3618.22
6	24	1.03	40.17	968.18	271.09	3889.31
5	20	1.01	39.39	930.94	260.66	4149.98
4	16	0.98	38.14	872.89	244.41	4394.38
3	12	0.93	36.43	796.11	222.91	4617.30
2	8	0.91	35.49	755.72	211.60	4828.90
1	4	0.91	35.49	755.72	211.60	5040.50
0	0	0.91	35.49	755.72	105.80	5146.30

- **Dynamic analysis**

$$T = \frac{0.09\,x\,H}{\sqrt{d}} = \frac{0.09\,x\,72}{\sqrt{35}} = 1.0953 \text{ Sec}$$

$$F = \frac{1}{T} = \frac{1}{1.0953} = 0.9129 \text{ Hz}$$

Dynamic analysis is required if frequency is less than 1 Hz.
Here, frequency = 0.9129 < 1
Therefore, dynamic analysis is required for this case.

Table -8: Computation of Wind Load At Different Elevations of The Building for case 2

Storey No.	Elevation	k_2'	v_z'	p_z'	Force	Base shear
	(m)		(m/s)	(N/m^2)	(kN)	(kN)
18	72	0.68	26.58	423.79	287.75	287.75
17	68	0.68	26.42	418.67	568.55	856.30
16	64	0.67	26.28	414.30	562.62	1418.92
15	60	0.67	26.14	409.96	556.73	1975.65
14	56	0.67	25.98	404.92	549.89	2525.53
13	52	0.66	25.84	400.63	544.06	3069.59
12	48	0.66	25.63	394.23	535.37	3604.96
11	44	0.65	25.36	385.79	523.90	4128.86
10	40	0.64	25.08	377.43	512.55	4641.41
9	36	0.64	24.80	369.17	501.33	5142.74
8	32	0.63	24.53	360.99	490.23	5632.97
7	28	0.62	24.16	350.24	475.62	6108.59
6	24	0.61	23.70	337.02	457.68	6566.27
5	20	0.60	23.24	324.06	440.08	7006.34
4	16	0.58	22.50	303.85	412.63	7418.97
3	12	0.55	21.49	277.13	376.34	7795.31
2	8	0.54	20.94	263.07	357.25	8152.56
1	4	0.54	20.94	263.07	357.25	8509.80
0	0	0.54	20.94	263.07	178.62	8688.43

Base shear obtained:
Static analysis = 5146.30 kN
Dynamic analysis = 8688.43 kN

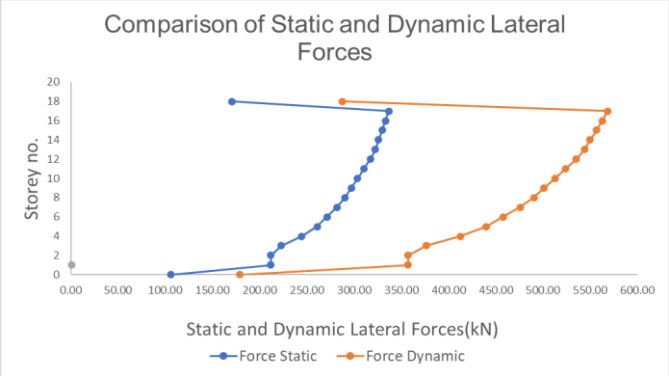
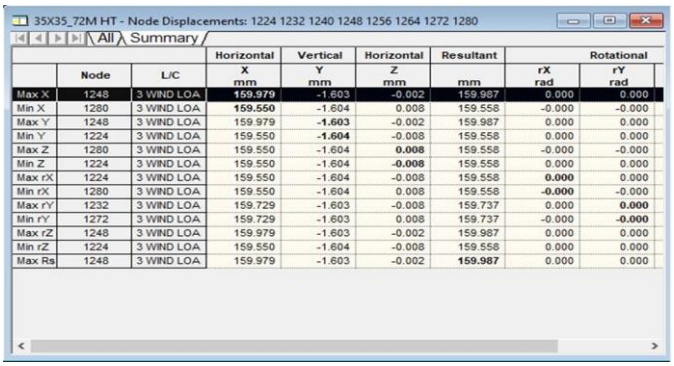


Fig. 3: Comparison of Static and Dynamic Forces for Case 2



	Node	L/C	Horizontal X mm	Vertical Y mm	Horizontal Z mm	Resultant mm	Rotational rX rad	Rotational rY rad
Max X	1248	3 WIND LOA	159.979	-1.603	-0.002	159.987	0.000	0.000
Min X	1280	3 WIND LOA	159.550	-1.604	0.008	159.558	-0.000	-0.000
Max Y	1248	3 WIND LOA	159.979	-1.603	-0.002	159.987	0.000	0.000
Min Y	1224	3 WIND LOA	159.550	-1.604	-0.008	159.558	0.000	0.000
Max Z	1280	3 WIND LOA	159.550	-1.604	0.008	159.558	-0.000	-0.000
Min Z	1224	3 WIND LOA	159.550	-1.604	-0.008	159.558	0.000	0.000
Max rX	1224	3 WIND LOA	159.550	-1.604	-0.008	159.558	0.000	0.000
Min rX	1280	3 WIND LOA	159.550	-1.604	0.008	159.558	-0.000	-0.000
Max rY	1232	3 WIND LOA	159.729	-1.603	-0.008	159.737	0.000	0.000
Min rY	1272	3 WIND LOA	159.729	-1.603	0.008	159.737	-0.000	-0.000
Max rZ	1248	3 WIND LOA	159.979	-1.603	-0.002	159.987	0.000	0.000
Min rZ	1224	3 WIND LOA	159.550	-1.604	-0.008	159.558	0.000	0.000
Max Rs	1248	3 WIND LOA	159.979	-1.603	-0.002	159.987	0.000	0.000

Fig. 4: Maximum storey displacement for Case 2

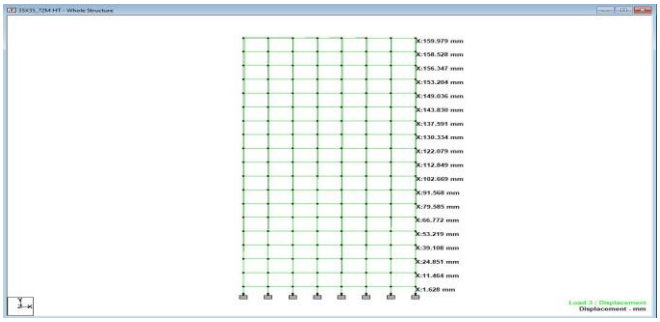


Fig. 5: Maximum storey drift for Case 2

Table -9: Storey drift for case 2

Sr. no.	Storey number	Storey drift (mm)
1	18	1.451
2	17	2.181
3	16	3.143
4	15	4.168
5	14	5.206
6	13	6.239
7	12	7.257
8	11	8.255
9	10	9.23
10	9	10.18
11	8	11.101
12	7	11.983
13	6	12.813
14	5	13.553
15	4	14.111
16	3	14.257
17	2	13.387
18	1	9.836

3.3 Case 3: 35M X 35M X 104M

- **Static analysis**

Table -10: Computation of Wind Load At Different Elevations of The Building for case 3

Storey No.	Elevation (m)	k_2	v_z (m/s)	p_z (N/m^2)	Force (kN)	Base shear (kN)
26	104	1.20	46.92	1320.72	184.90	184.90
25	100	1.20	46.80	1314.14	367.96	552.86
24	96	1.19	46.53	1298.86	363.68	916.54
23	92	1.19	46.29	1285.83	360.03	1276.57
22	88	1.18	46.02	1270.70	355.80	1632.37
21	84	1.17	45.79	1257.81	352.19	1984.56
20	80	1.17	45.55	1244.99	348.60	2333.16
19	76	1.16	45.28	1230.11	344.43	2677.59
18	72	1.16	45.05	1217.43	340.88	3018.47
17	68	1.15	44.77	1202.72	336.76	3355.23
16	64	1.14	44.54	1190.18	333.25	3688.48
15	60	1.14	44.30	1177.71	329.76	4018.24
14	56	1.13	44.03	1163.24	325.71	4343.94
13	52	1.12	43.80	1150.91	322.25	4666.20
12	48	1.11	43.45	1132.53	317.11	4983.31
11	44	1.10	42.98	1108.27	310.31	5293.62
10	40	1.09	42.51	1084.26	303.59	5597.21
9	36	1.08	42.04	1060.52	296.95	5894.16
8	32	1.07	41.57	1037.04	290.37	6184.53
7	28	1.05	40.95	1006.14	281.72	6466.25
6	24	1.03	40.17	968.18	271.09	6737.34
5	20	1.01	39.39	930.94	260.66	6998.00
4	16	0.98	38.14	872.89	244.41	7242.41
3	12	0.93	36.43	796.11	222.91	7465.32
2	8	0.91	35.49	755.72	211.60	7676.93
1	4	0.91	35.49	755.72	211.60	7888.53
0	0	0.91	35.49	755.72	105.80	7994.33

- **Dynamic analysis**

$$T = \frac{0.09\,x\,H}{\sqrt{d}} = \frac{0.09\,x\,104}{\sqrt{35}} = 1.5821 \text{ Sec}$$

$$F = \frac{1}{T} = \frac{1}{1.5821} = 0.6320 \text{ Hz}$$

Dynamic analysis is required if frequency is less than 1 Hz.

Here, frequency = 0.6320 < 1

Therefore, dynamic analysis is required for this case.

Table 11: Computation of Wind Load At Different Elevations of The Building for case 3

Storey No.	Elevation (m)	k_2'	v_z' (m/s)	p_z' (N/m^2)	Force (kN)	Base shear (kN)
26	104	0.71	27.68	459.74	334.69	334.69
25	100	0.71	27.61	457.45	666.05	1000.75
24	96	0.70	27.45	452.13	658.30	1659.05
23	92	0.70	27.31	447.60	651.70	2310.75
22	88	0.70	27.15	442.33	644.04	2954.79
21	84	0.69	27.01	437.85	637.50	3592.29
20	80	0.69	26.88	433.38	631.00	4223.29
19	76	0.68	26.71	428.20	623.46	4846.75
18	72	0.68	26.58	423.79	617.04	5463.79
17	68	0.68	26.42	418.67	609.58	6073.37
16	64	0.67	26.28	414.30	603.22	6676.59
15	60	0.67	26.14	409.96	596.90	7273.49
14	56	0.67	25.98	404.92	589.57	7863.06
13	52	0.66	25.84	400.63	583.32	8446.38
12	48	0.66	25.63	394.23	574.01	9020.38
11	44	0.65	25.36	385.79	561.71	9582.09
10	40	0.64	25.08	377.43	549.54	10131.63
9	36	0.64	24.80	369.17	537.51	10669.13
8	32	0.63	24.53	360.99	525.61	11194.74
7	28	0.62	24.16	350.24	509.95	11704.69
6	24	0.61	23.70	337.02	490.70	12195.39
5	20	0.60	23.24	324.06	471.83	12667.22
4	16	0.58	22.50	303.85	442.41	13109.63
3	12	0.55	21.49	277.13	403.50	13513.13
2	8	0.54	20.94	263.07	383.03	13896.16
1	4	0.54	20.94	263.07	383.03	14279.18
0	0	0.54	20.94	263.07	191.51	14470.70

Base shear obtained:
Static analysis = 7994.33 kN
Dynamic analysis = 14470.70 kN

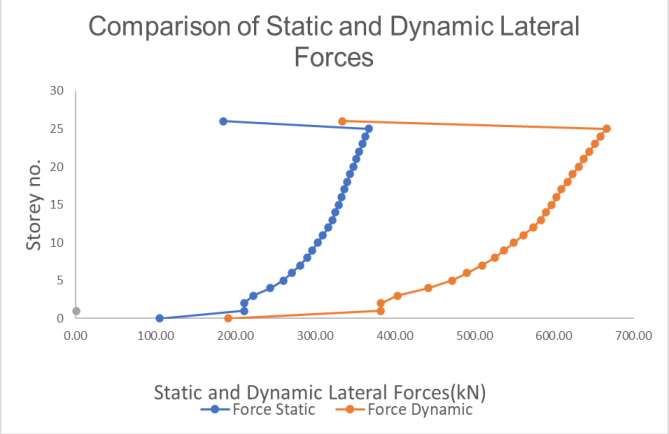


Fig. 6: Comparison of Static and Dynamic Forces for Case 3

35X35_104M HT - Node Displacements: 1736 1744 1752 1760 1768 1776 1784 1792

All Summary

	Node	L/C	Horizontal X mm	Vertical Y mm	Horizontal Z mm	Resultant mm	Rotational rX rad	Rotational rY rad
Max X	1760	3 WIND LOA	**375.300**	-4.691	-0.002	375.329	0.000	0.000
Min X	1736	3 WIND LOA	**374.833**	-4.692	-0.009	374.862	0.000	0.000
Max Y	1760	3 WIND LOA	375.300	**-4.691**	-0.002	375.329	0.000	0.000
Min Y	1736	3 WIND LOA	374.833	**-4.692**	-0.009	374.862	0.000	0.000
Max Z	1792	3 WIND LOA	374.833	-4.692	**0.009**	374.862	-0.000	-0.000
Min Z	1736	3 WIND LOA	374.833	-4.692	**-0.009**	374.862	0.000	0.000
Max rX	1736	3 WIND LOA	374.833	-4.692	-0.009	374.862	**0.000**	0.000
Min rX	1792	3 WIND LOA	374.833	-4.692	0.009	374.862	**-0.000**	-0.000
Max rY	1744	3 WIND LOA	375.027	-4.691	-0.008	375.057	0.000	**0.000**
Min rY	1784	3 WIND LOA	375.027	-4.691	0.008	375.057	-0.000	**-0.000**
Max rZ	1760	3 WIND LOA	375.300	-4.691	-0.002	375.329	0.000	0.000
Min rZ	1736	3 WIND LOA	374.833	-4.692	-0.009	374.862	0.000	0.000
Max Rs	1760	3 WIND LOA	375.300	-4.691	-0.002	**375.329**	0.000	0.000

Fig. 7: Maximum storey displacement for Case 3

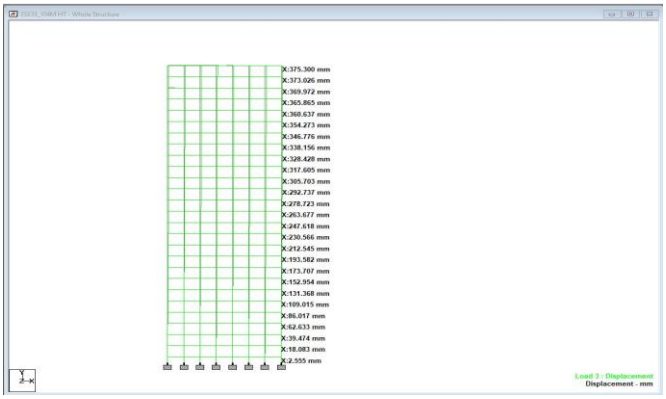


Fig. 8: Maximum storey drift for Case 3

Table -12: Storey drift for case 3

Sr. no.	Storey number	Storey drift (mm)
1	26	2.274
2	25	3.054
3	24	4.107
4	23	5.228
5	22	6.364
6	21	7.497
7	20	8.62
8	19	9.728
9	18	10.823
10	17	11.902
11	16	12.966
12	15	14.014
13	14	15.046
14	13	16.059
15	12	17.052
16	11	18.021
17	10	18.963
18	9	19.875
19	8	20.753
20	7	21.586
21	6	22.353
22	5	22.998
23	4	23.384
24	3	23.159
25	2	21.391
26	1	15.533

3.4 Case 4: 50M X 25M X 60M

- **Static analysis**

Table -13: Computation of Wind Load At Different Elevations of The Building for case 4

Storey No.	Elevation (m)	k_2	v_z (m/s)	p_z (N/m^2)	Force (kN)	Base shear (kN)
15	60	1.14	44.30	1177.71	117.77	117.77
14	56	1.13	44.03	1163.24	232.65	350.42
13	52	1.12	43.80	1150.91	230.18	580.60
12	48	1.11	43.45	1132.53	226.51	807.11
11	44	1.10	42.98	1108.27	221.65	1028.76
10	40	1.09	42.51	1084.26	216.85	1245.61
9	36	1.08	42.04	1060.52	212.10	1457.71
8	32	1.07	41.57	1037.04	207.41	1665.12
7	28	1.05	40.95	1006.14	201.23	1866.35
6	24	1.03	40.17	968.18	193.64	2059.99
5	20	1.01	39.39	930.94	186.19	2246.17
4	16	0.98	38.14	872.89	174.58	2420.75
3	12	0.93	36.43	796.11	159.22	2579.97
2	8	0.91	35.49	755.72	151.14	2731.12
1	4	0.91	35.49	755.72	151.14	2882.26
0	0	0.91	35.49	755.72	75.57	2957.84

- **Dynamic analysis**

$$T = \frac{0.09\,x\,H}{\sqrt{d}} = \frac{0.09\,x\,60}{\sqrt{25}} = 1.08 \text{ Sec}$$

$$F = \frac{1}{T} = \frac{1}{1.08} = 0.9259 \text{ Hz}$$

Dynamic analysis is required if frequency is less than 1 Hz.
Here, frequency = 0.9259 < 1
Therefore, dynamic analysis is required for this case.

Table -14: Computation of Wind Load At Different Elevations of The Building for case 4

Storey No.	Elevation (m)	k_2'	v_z' (m/s)	p_z' (N/m^2)	Force (kN)	Base shear (kN)
15	60	0.67	26.14	409.96	127.91	127.91
14	56	0.67	25.98	404.92	252.67	380.58
13	52	0.66	25.84	400.63	249.99	630.57
12	48	0.66	25.63	394.23	246.00	876.58
11	44	0.65	25.36	385.79	240.73	1117.31
10	40	0.64	25.08	377.43	235.52	1352.82
9	36	0.64	24.80	369.17	230.36	1583.18
8	32	0.63	24.53	360.99	225.26	1808.44
7	28	0.62	24.16	350.24	218.55	2026.99
6	24	0.61	23.70	337.02	210.30	2237.29
5	20	0.60	23.24	324.06	202.21	2439.51
4	16	0.58	22.50	303.85	189.60	2629.11
3	12	0.55	21.49	277.13	172.93	2802.04
2	8	0.54	20.94	263.07	164.15	2966.19
1	4	0.54	20.94	263.07	164.15	3130.35
0	0	0.54	20.94	263.07	82.08	3212.42

Base shear obtained:
Static analysis = 2957.84 kN
Dynamic analysis = 3212.42 kN

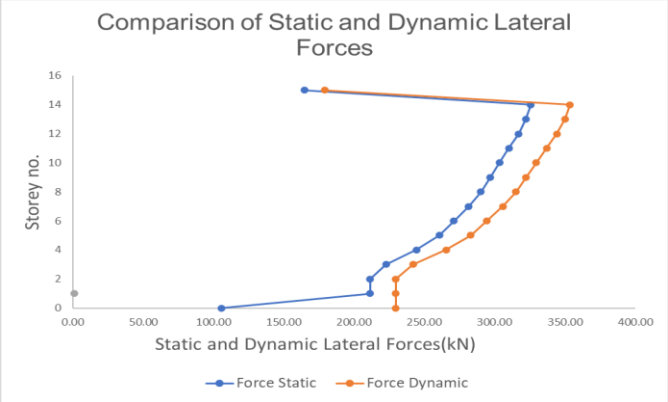
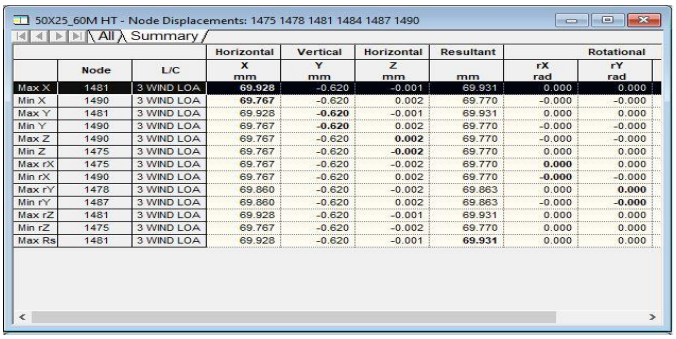


Fig. 9: Comparison of Static and Dynamic Forces for Case 4



	Node	L/C	Horizontal X mm	Vertical Y mm	Horizontal Z mm	Resultant mm	Rotational rX rad	Rotational rY rad
Max X	1481	3 WIND LOA	**69.928**	-0.620	-0.001	69.931	0.000	0.000
Min X	1490	3 WIND LOA	**69.767**	-0.620	0.002	69.770	-0.000	-0.000
Max Y	1481	3 WIND LOA	69.928	**-0.620**	-0.001	69.931	0.000	0.000
Min Y	1490	3 WIND LOA	69.767	**-0.620**	0.002	69.770	-0.000	-0.000
Max Z	1490	3 WIND LOA	69.767	-0.620	**0.002**	69.770	-0.000	-0.000
Min Z	1475	3 WIND LOA	69.767	-0.620	**-0.002**	69.770	0.000	0.000
Max rX	1475	3 WIND LOA	69.767	-0.620	-0.002	69.770	**0.000**	0.000
Min rX	1490	3 WIND LOA	69.767	-0.620	0.002	69.770	**-0.000**	-0.000
Max rY	1478	3 WIND LOA	69.860	-0.620	-0.002	69.863	0.000	**0.000**
Min rY	1487	3 WIND LOA	69.860	-0.620	0.002	69.863	-0.000	**-0.000**
Max rZ	1481	3 WIND LOA	69.928	-0.620	-0.001	69.931	0.000	0.000
Min rZ	1475	3 WIND LOA	69.767	-0.620	-0.002	69.770	0.000	0.000
Max Rs	1481	3 WIND LOA	69.928	-0.620	-0.001	**69.931**	0.000	0.000

Fig. 10: Maximum storey displacement for Case 4

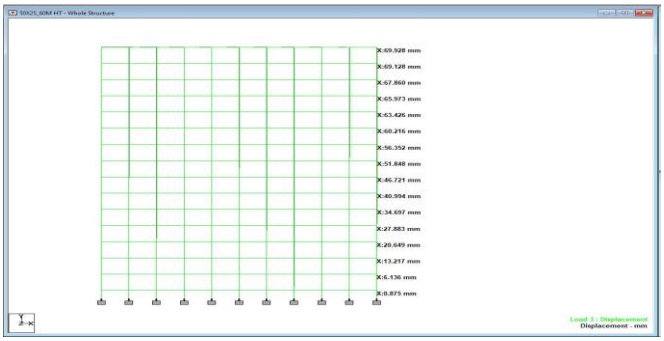


Fig. 11: Maximum storey drift for Case 4

Table -15: Storey drift for case 4

Sr. no.	Storey number	Storey drift (mm)
1	15	0.8
2	14	1.268
3	13	1.887
4	12	2.547
5	11	3.21
6	10	3.864
7	9	4.504
8	8	5.127
9	7	5.727
10	6	6.297
11	5	6.814
12	4	7.234
13	3	7.432
14	2	7.081
15	1	5.261

3.5 Case 5: 50M X 25M X 72M

- **Static analysis**

Table -16: Computation of Wind Load At Different Elevations of The Building for case 5

Storey No.	Elevation (m)	k_2	v_z (m/s)	p_z (N/m^2)	Force (kN)	Base shear (kN)
18	72	1.16	45.05	1217.43	121.74	121.74
17	68	1.15	44.77	1202.72	240.54	362.29
16	64	1.14	44.54	1190.18	238.04	600.32
15	60	1.14	44.30	1177.71	235.54	835.86
14	56	1.13	44.03	1163.24	232.65	1068.51
13	52	1.12	43.80	1150.91	230.18	1298.69
12	48	1.11	43.45	1132.53	226.51	1525.20
11	44	1.10	42.98	1108.27	221.65	1746.85
10	40	1.09	42.51	1084.26	216.85	1963.70
9	36	1.08	42.04	1060.52	212.10	2175.81
8	32	1.07	41.57	1037.04	207.41	2383.22
7	28	1.05	40.95	1006.14	201.23	2584.44
6	24	1.03	40.17	968.18	193.64	2778.08
5	20	1.01	39.39	930.94	186.19	2964.27
4	16	0.98	38.14	872.89	174.58	3138.85
3	12	0.93	36.43	796.11	159.22	3298.07
2	8	0.91	35.49	755.72	151.14	3449.21
1	4	0.91	35.49	755.72	151.14	3600.36
0	0	0.91	35.49	755.72	75.57	3675.93

- **Dynamic analysis**

$$T = \frac{0.09\,x\,H}{\sqrt{d}} = \frac{0.09\,x\,72}{\sqrt{25}} = 1.296 \text{ Sec}$$

$$F = \frac{1}{T} = \frac{1}{1.296} = 0.7716 \text{ Hz}$$

Dynamic analysis is required if frequency is less than 1 Hz.
Here, frequency = 0.7716 < 1
Therefore, dynamic analysis is required for this case.

Table 17: Computation of Wind Load At Different Elevations of The Building for case 5

Storey No.	Elevation (m)	k_2'	v_z' (m/s)	p_z' (N/m^2)	Force (kN)	Base shear (kN)
18	72	0.68	26.58	423.79	205.54	205.54
17	68	0.68	26.42	418.67	406.11	611.64
16	64	0.67	26.28	414.30	401.87	1013.52
15	60	0.67	26.14	409.96	397.66	1411.18
14	56	0.67	25.98	404.92	392.78	1803.95
13	52	0.66	25.84	400.63	388.61	2192.56
12	48	0.66	25.63	394.23	382.41	2574.97
11	44	0.65	25.36	385.79	374.21	2949.19
10	40	0.64	25.08	377.43	366.11	3315.29
9	36	0.64	24.80	369.17	358.09	3673.38
8	32	0.63	24.53	360.99	350.16	4023.55
7	28	0.62	24.16	350.24	339.73	4363.28
6	24	0.61	23.70	337.02	326.91	4690.19
5	20	0.60	23.24	324.06	314.34	5004.53
4	16	0.58	22.50	303.85	294.74	5299.27
3	12	0.55	21.49	277.13	268.81	5568.08
2	8	0.54	20.94	263.07	255.18	5823.25
1	4	0.54	20.94	263.07	255.18	6078.43
0	0	0.54	20.94	263.07	127.59	6206.02

Base shear obtained:
Static analysis = 3675.93 kN
Dynamic analysis = 6206.02 kN

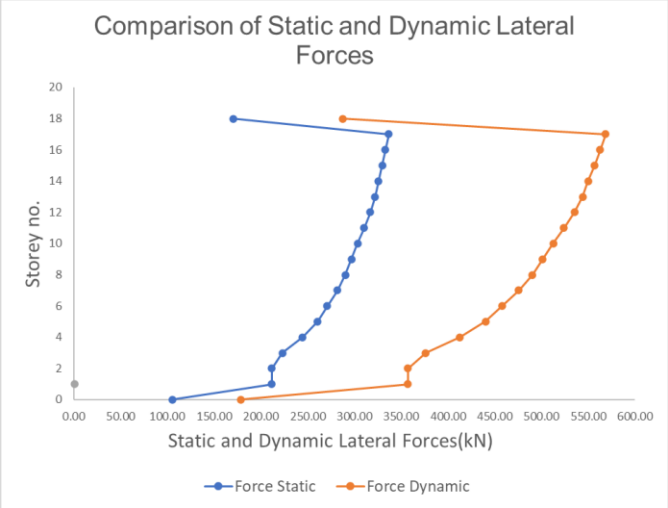
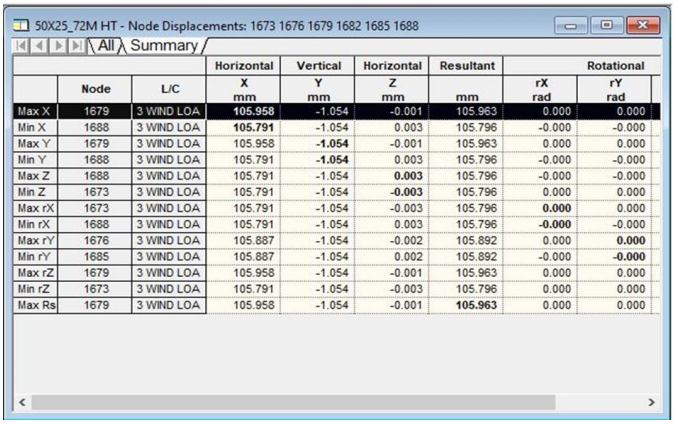


Fig. 12: Comparison of Static and Dynamic Forces for Case 5



	Node	L/C	Horizontal X mm	Vertical Y mm	Horizontal Z mm	Resultant mm	Rotational rX rad	Rotational rY rad
Max X	1679	3 WIND LOA	**105.958**	-1.054	-0.001	105.963	0.000	0.000
Min X	1688	3 WIND LOA	**105.791**	-1.054	0.003	105.796	-0.000	-0.000
Max Y	1679	3 WIND LOA	105.958	**-1.054**	-0.001	105.963	0.000	0.000
Min Y	1688	3 WIND LOA	105.791	**-1.054**	0.003	105.796	-0.000	-0.000
Max Z	1688	3 WIND LOA	105.791	-1.054	**0.003**	105.796	-0.000	-0.000
Min Z	1673	3 WIND LOA	105.791	-1.054	**-0.003**	105.796	0.000	0.000
Max rX	1673	3 WIND LOA	105.791	-1.054	-0.003	105.796	**0.000**	0.000
Min rX	1688	3 WIND LOA	105.791	-1.054	0.003	105.796	**-0.000**	-0.000
Max rY	1676	3 WIND LOA	105.887	-1.054	-0.002	105.892	0.000	**0.000**
Min rY	1685	3 WIND LOA	105.887	-1.054	0.002	105.892	-0.000	**-0.000**
Max rZ	1679	3 WIND LOA	105.958	-1.054	-0.001	105.963	0.000	0.000
Min rZ	1673	3 WIND LOA	105.791	-1.054	-0.003	105.796	0.000	0.000
Max Rs	1679	3 WIND LOA	105.958	-1.054	-0.001	**105.963**	0.000	0.000

Fig. 13: Maximum storey displacement for Case 5

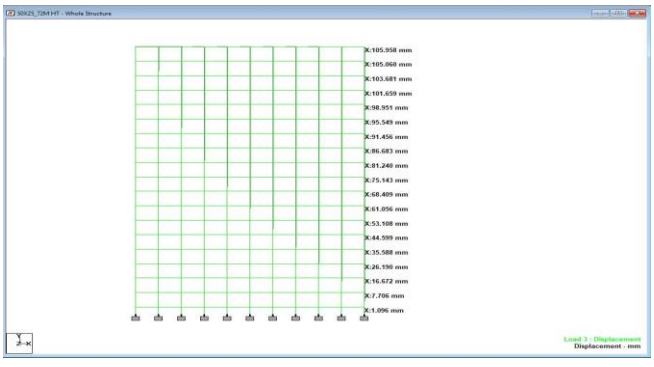


Fig. 14: Maximum storey drift for Case 5

Table -18: Storey drift for case 5

Sr. no.	Storey number	Storey drift (mm)
1	18	0.898
2	17	1.379
3	16	2.022
4	15	2.708
5	14	3.402
6	13	4.093
7	12	4.773
8	11	5.443
9	10	6.097
10	9	6.734
11	8	7.353
12	7	7.948
13	6	8.509
14	5	9.011
15	4	9.398
16	3	9.518
17	2	8.966
18	1	6.61

3.6 Case 6: 50M X 25M X 104M

- **Static analysis**

Table -19: Computation of Wind Load At Different Elevations of The Building for case 6

Storey No.	Elevation (m)	k_2	v_z (m/s)	p_z (N/m²)	Force (kN)	Base shear (kN)
26	104	1.20	46.92	1320.72	132.07	132.07
25	100	1.20	46.80	1314.14	262.83	394.90
24	96	1.19	46.53	1298.86	259.77	654.67
23	92	1.19	46.29	1285.83	257.17	911.84
22	88	1.18	46.02	1270.70	254.14	1165.98
21	84	1.17	45.79	1257.81	251.56	1417.54
20	80	1.17	45.55	1244.99	249.00	1666.54
19	76	1.16	45.28	1230.11	246.02	1912.56
18	72	1.16	45.05	1217.43	243.49	2156.05
17	68	1.15	44.77	1202.72	240.54	2396.59
16	64	1.14	44.54	1190.18	238.04	2634.63
15	60	1.14	44.30	1177.71	235.54	2870.17
14	56	1.13	44.03	1163.24	232.65	3102.82
13	52	1.12	43.80	1150.91	230.18	3333.00
12	48	1.11	43.45	1132.53	226.51	3559.50
11	44	1.10	42.98	1108.27	221.65	3781.16
10	40	1.09	42.51	1084.26	216.85	3998.01
9	36	1.08	42.04	1060.52	212.10	4210.11
8	32	1.07	41.57	1037.04	207.41	4417.52
7	28	1.05	40.95	1006.14	201.23	4618.75
6	24	1.03	40.17	968.18	193.64	4812.38
5	20	1.01	39.39	930.94	186.19	4998.57
4	16	0.98	38.14	872.89	174.58	5173.15
3	12	0.93	36.43	796.11	159.22	5332.37
2	8	0.91	35.49	755.72	151.14	5483.52
1	4	0.91	35.49	755.72	151.14	5634.66
0	0	0.91	35.49	755.72	75.57	5710.24

- **Dynamic analysis**

$$T = \frac{0.09\,x\,H}{\sqrt{d}} = \frac{0.09\,x\,104}{\sqrt{25}} = 1.872 \text{ Sec}$$

$$F = \frac{1}{T} = \frac{1}{1.872} = 0.5341 \text{ Hz}$$

Dynamic analysis is required if frequency is less than 1 Hz.
Here, frequency = 0.5341 < 1
Therefore, dynamic analysis is required for this case.

Table -20: Computation of Wind Load At Different Elevations of The Building for case 6

Storey No.	Elevation (m)	k_2'	v_z' (m/s)	p_z' (N/m^2)	Force (kN)	Base shear (kN)
26	104	0.71	27.68	459.74	239.07	239.07
25	100	0.71	27.61	457.45	475.75	714.82
24	96	0.70	27.45	452.13	470.22	1185.04
23	92	0.70	27.31	447.60	465.50	1650.54
22	88	0.70	27.15	442.33	460.03	2110.56
21	84	0.69	27.01	437.85	455.36	2565.92
20	80	0.69	26.88	433.38	450.72	3016.64
19	76	0.68	26.71	428.20	445.33	3461.97
18	72	0.68	26.58	423.79	440.74	3902.71
17	68	0.68	26.42	418.67	435.41	4338.12
16	64	0.67	26.28	414.30	430.87	4768.99
15	60	0.67	26.14	409.96	426.36	5195.35
14	56	0.67	25.98	404.92	421.12	5616.47
13	52	0.66	25.84	400.63	416.66	6033.13
12	48	0.66	25.63	394.23	410.00	6443.13
11	44	0.65	25.36	385.79	401.22	6844.35
10	40	0.64	25.08	377.43	392.53	7236.88
9	36	0.64	24.80	369.17	383.93	7620.81
8	32	0.63	24.53	360.99	375.43	7996.24
7	28	0.62	24.16	350.24	364.25	8360.49
6	24	0.61	23.70	337.02	350.50	8710.99
5	20	0.60	23.24	324.06	337.02	9048.02
4	16	0.58	22.50	303.85	316.01	9364.02
3	12	0.55	21.49	277.13	288.21	9652.24
2	8	0.54	20.94	263.07	273.59	9925.83
1	4	0.54	20.94	263.07	273.59	10199.42
0	0	0.54	20.94	263.07	136.80	10336.21

Base shear obtained:
Static analysis = 5710.24 kN
Dynamic analysis = 10336.21 kN

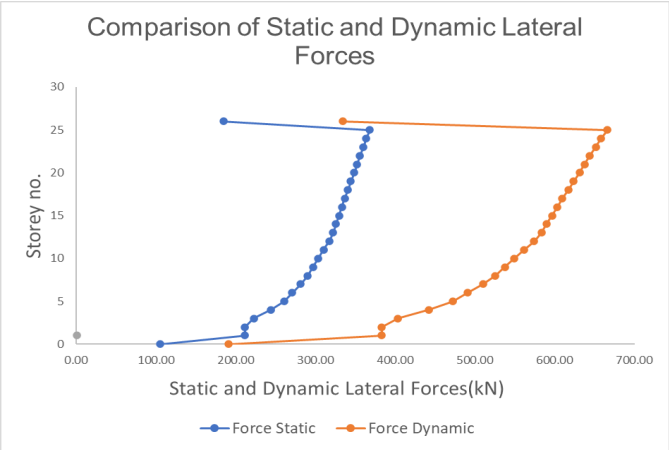
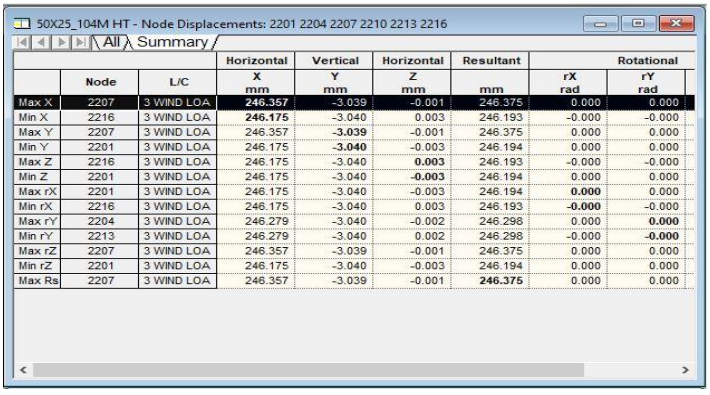


Fig. 15: Comparison of Static and Dynamic Forces for Case 6


50X25_104M HT - Node Displacements: 2201 2204 2207 2210 2213 2216

All Summary

	Node	L/C	Horizontal X mm	Vertical Y mm	Horizontal Z mm	Resultant mm	Rotational rX rad	Rotational rY rad
Max X	2207	3 WIND LOA	**246.357**	-3.039	-0.001	246.375	0.000	0.000
Min X	2216	3 WIND LOA	**246.175**	-3.040	0.003	246.193	-0.000	-0.000
Max Y	2207	3 WIND LOA	246.357	**-3.039**	-0.001	246.375	0.000	0.000
Min Y	2201	3 WIND LOA	246.175	**-3.040**	-0.003	246.194	0.000	0.000
Max Z	2216	3 WIND LOA	246.175	-3.040	**0.003**	246.193	-0.000	-0.000
Min Z	2201	3 WIND LOA	246.175	-3.040	**-0.003**	246.194	0.000	0.000
Max rX	2201	3 WIND LOA	246.175	-3.040	-0.003	246.194	**0.000**	0.000
Min rX	2216	3 WIND LOA	246.175	-3.040	0.003	246.193	**-0.000**	-0.000
Max rY	2204	3 WIND LOA	246.279	-3.040	-0.002	246.298	0.000	**0.000**
Min rY	2213	3 WIND LOA	246.279	-3.040	0.002	246.298	-0.000	**-0.000**
Max rZ	2207	3 WIND LOA	246.357	-3.039	-0.001	246.375	0.000	0.000
Min rZ	2201	3 WIND LOA	246.175	-3.040	-0.003	246.194	0.000	0.000
Max Rs	2207	3 WIND LOA	246.357	-3.039	-0.001	**246.375**	0.000	0.000

Fig. 16: Maximum storey displacement for Case 6

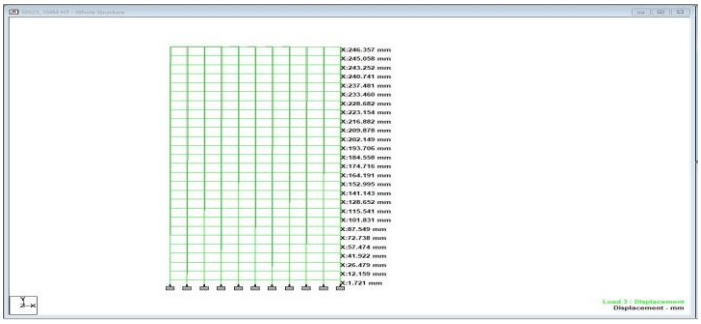


Fig. 17: Maximum storey drift for Case 6

Table -21: Storey drift for case 6

Sr. no.	Storey number	Storey drift (mm)
1	26	0.777
2	25	2.328
3	24	2.511
4	23	3.26
5	22	4.021
6	21	4.778
7	20	5.528
8	19	6.272
9	18	7.004
10	17	7.729
11	16	8.443
12	15	9.148
13	14	9.842
14	13	10.525
15	12	11.196
16	11	11.852
17	10	12.491
18	9	13.111
19	8	13.71
20	7	14.282
21	6	14.811
22	5	15.264
23	4	15.552
24	3	15.443
25	2	14.32
26	1	10.438

4 Summary

The nature of wind and its behavior has been studied in depth.

The types of wind effect and the behavior of high rise building due to such effect have been studied. The clauses of IS: 875 (Part 3)-2015 and ASCE 7-16 for the wind analysis buildings have been studied. Generalized Excel sheets for the static and dynamic analysis of high rise buildings have been made and the lateral forces and base shears obtained by them have been compared by preparing bar charts and graphs.

Parametric study has been done for high rise buildings with height and size variation. Software, STAAD pro CONNECT edition has been used to carry out the static analysis of all the cases of high rise building to verify the manual results.

Conclusions

The conclusions derived from the study are as follows:

- Dynamic analysis gives more force than the static analysis. The variation of static and dynamic lateral forces goes on increasing as the height of the building increases.

- The static and dynamic base shears vary as follows:

For case 1 (35m x 35m x 60m) dynamic analysis is not required as frequency is more than 1.
For case 2 (35m x 35m x 72m) dynamic analysis is performed and base shear varies by 68.8 %.
For case 3 (35m x 35m x 104m) dynamic analysis is performed and base shear varies by 81 %.
For case 4 (50m x 25m x 60m) dynamic analysis is performed and base shear varies by 5.7 %.
For Case 5 (50m x 25m x 72m) dynamic analysis is performed and base shear varies by 68.8 %.
For Case 6 (50m x 25m x 104m) dynamic analysis is performed and base shear varies by 81 %.

- It is observed that as the building height increases the dynamic forces govern. The variation of static base shear is lesser in comparison with dynamic base shear for all the cases. The dynamic forces gradually increase by that of static forces with increase in height.

- Therefore, high rise buildings are majorly affected by dynamic forces and hence that should be considered in design.

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