

Parametric Evaluation of Wind Load on Low, Medium and High Rise Buildings Considering Different Terrain Categories using ETABS

Abhishek Anand
M. Tech Student, Structural Engineering,
K. K. University, Nalanda, Bihar, India

Mr. Deepak Kumar
Assistant Professor, Dept. of Civil Engineering
K. K. University, Nalanda, Bihar, India

Abstract: Wind load is one of the most critical lateral forces affecting the stability and serviceability of buildings, particularly in regions subjected to varying terrain conditions and increasing urbanization. The present study focuses on the parametric evaluation of wind loads on low rise, medium rise, and high rise reinforced concrete buildings considering different terrain categories using ETABS v23.2.0. The objective of this study is to investigate the variation in wind response characteristics such as storey displacement, storey drift, base shear, and overturning moment under different building heights and terrain conditions as specified in relevant design standards. Three-dimensional building models of varying heights were developed and analysed using the wind load provisions recommended by the Indian Standard code. The study includes comparative analysis of buildings located in multiple terrain categories to evaluate the influence of surrounding obstructions and ground roughness on wind pressure distribution. Parametric variations were performed by altering building height and terrain category while maintaining other structural parameters constant. The results indicate that wind effects become significantly more pronounced with increase in building height and are strongly influenced by terrain conditions. Terrain Category TC1 shows maximum structural response, whereas TC2, TC3, and TC4 exhibit gradual reduction in wind-induced effects due to increased terrain roughness. The research highlights the importance of accurate wind load assessment during structural design and demonstrates the effectiveness of ETABS software in analysing wind induced structural behaviour. The findings of this study can assist structural engineers in achieving safer and more economical building designs under varying environmental conditions.

Keywords: Wind load analysis, terrain categories, ETABS v23.2.0, storey drift, storey displacement, base shear, overturning moment, structural analysis.

I. INTRODUCTION

Wind is one of the most important environmental actions affecting civil engineering structures, particularly buildings that rise significantly above ground level. With the rapid growth of urbanization and vertical expansion of cities, the construction of medium and high-rise buildings has increased tremendously. As the height of a structure increases, lateral loads such as wind loads become more dominant compared to gravity loads. Unlike dead loads, which remain constant throughout the life of a structure, wind loads are highly variable in nature and depend on several parameters such as wind speed, terrain conditions, height of the structure, and exposure.

In the design of buildings subjected to wind loads, two fundamental performance criteria must be satisfied: structural safety and serviceability. While structural safety ensures that a building does not collapse or suffer major damage under extreme wind conditions, serviceability ensures that the building remains functional, comfortable, and acceptable for occupants during normal wind events. Both aspects are equally important, particularly in the design of medium-rise and high-rise buildings.

India experiences a wide range of wind conditions due to its vast geographical extent, varied topography, and diverse climatic patterns. Wind characteristics in India are influenced by factors such as monsoon systems, cyclonic storms, coastal exposure, plains, deserts, and mountainous regions. As a result, wind load becomes a significant design consideration for buildings across many parts of the country, especially for medium-rise and high-rise structures. Due to these varying wind conditions, the Indian Standard code IS 875 (Part-3) provides a detailed framework for estimating wind loads on structures. The code divides India into different wind zones based on basic wind speed, which represents the peak gust wind speed with a 50-year return period measured at a height of 10 m above ground level in open terrain. Basic wind speeds in India typically range from 33 m/s to 55 m/s, depending on the geographical location.

Table 1 : Classification of buildings based on height

Building Category	Typical Height / Storeys	Structural Behaviour under Wind Load
Low-rise buildings	Up to 6 storeys (G+5)	Relatively stiff, low lateral displacement
Medium-rise buildings	7 to 15 storeys (G+6 to G+15)	Moderate flexibility, noticeable wind effects
High-rise buildings	Above 15 storeys	Highly flexible, significant wind response

Table 2 : Summary of terrain categories as per IS 875 (Part 3)

Terrain Category	Surface Roughness	Typical Area	Wind Effect on Buildings
TC-1	Very low	Coastal areas, open plains	Maximum wind pressure
TC-2	Low	Rural / semi-open areas	High wind pressure
TC-3	Moderate	Suburban / industrial areas	Moderate wind pressure
TC-4	High	Dense urban areas	Minimum wind pressure

II. OBJECTIVES

- (1) To analyse the effect of wind load on low, medium and high rise RCC buildings.
- (2) To study the influence of different terrain categories on wind induced structural responses.
- (3) To compare wind response parameters for buildings of different heights under varying terrain conditions.
- (4) To perform wind load analysis using ETABS v23.2.0 as per IS 875(Part-3).
- (5) To assess the safety and serviceability performance of RCC buildings subjected to wind loading.

III. LITERATURE REVIEW

Harsh Raj (2026), investigated the effect of wind load combinations on tall RCC structures using IS 875 (Part-3):2015 guidelines. The study emphasized that wind load combinations considerably affect member forces, bending moments, and column design. The researcher concluded that proper load combination consideration is essential for safe and economical structural design of high-rise buildings.

Prasanna et al. (2026), studied wind behavior of irregular high-rise buildings with different plan configurations under varying terrain categories. The analysis indicated that irregular structures experience higher torsional moments and uneven stress distribution compared to regular buildings. The study also revealed that wind-induced effects increase significantly with building height and decrease with increase in terrain roughness. Proper structural symmetry and stiffness distribution were recommended to improve wind resistance.

Kulkarni et al. (2025), evaluated the wind performance of high-rise buildings located in urban and open terrain conditions. The study revealed that buildings situated in open terrain experience higher wind pressures and larger overturning moments due to reduced obstruction effects. Urban terrain conditions significantly reduced wind velocity and structural response. The study highlighted the necessity of accurate terrain classification for economical and safe design of tall structures.

Kanhaya Prasad Maletha and Astha Verma (2025) investigated the influence of aspect ratio and building height on wind-induced behavior of reinforced concrete structures. Different building heights ranging from G+5 to G+40 were analyzed using ETABS. The results indicated that slender high-rise buildings are more vulnerable to wind-induced vibrations and excessive lateral displacement. The study recommended increasing stiffness and damping characteristics to improve structural performance.

Pratik Patle and Rahul Hinge (2025) carried out comparative evaluation of static and dynamic wind analysis methods for tall buildings. The authors observed that static analysis is suitable for low-rise rigid structures, whereas dynamic analysis becomes essential for flexible high-rise buildings subjected to fluctuating wind forces. The study concluded that dynamic effects considerably influence storey drift and acceleration response in tall buildings.

P. R. Ramdas and D.B. Mohite (2024) investigated the influence of wind load on irregular multi-storey RCC buildings located in different wind zones of India. Using ETABS software, the authors evaluated the effect of plan irregularity and terrain roughness on storey drift and torsional response. The study concluded that irregular buildings experience higher torsional effects and displacement compared to regular buildings. Terrain Category 1 generated maximum wind pressure, whereas terrain category 4 considerably reduced the structural response.

Ashwini and Tushar (2024), performed comparative analysis of low-rise, medium-rise, and high-rise buildings under varying wind speeds using IS 875 (Part-3):2015 provisions. The study observed that wind effects become increasingly dominant with increase in building height. Maximum storey displacement and drift were observed in high-rise structures due to greater flexibility. The authors recommended the use of shear walls and bracing systems to improve lateral stability and reduce excessive deformation.

Md. Sahid and Preetal Singh (2024) studied the effect of terrain categories on wind-induced response of RCC framed structures using dynamic analysis techniques in ETABS. The study concluded that dynamic wind effects become significant in high-rise buildings with larger aspect ratios. The results showed progressive reduction in displacement and overturning moment from terrain category 1 to terrain category 4. The study emphasized the importance of terrain consideration during wind load calculation.

IV. METHODOLOGY

The methodology adopted in the present study consists of a systematic procedure for evaluating the effect of wind load on low, medium, and high rise buildings under different terrain categories using ETABS software. Initially, the building configurations were selected based on varying heights and structural parameters. Material properties such as grade of concrete, steel reinforcement, and sectional dimensions were then defined according to relevant IS code provisions.

Further, different terrain categories were selected to study the variation of wind characteristics under diverse surrounding conditions. Wind load parameters were calculated in accordance with IS 875 (Part-3), considering factors such as basic wind speed, terrain factor, height factor, and topography factor. Based on these parameters, the building models were developed in ETABS software.

After modelling, wind loads were applied to the structures, and structural analysis was carried out to determine important response parameters such as storey displacement, storey drift, base shear, overturning moment, and bending moment. The obtained results were extracted and compared for different building heights and terrain categories.

Finally, the structural performance of the buildings was evaluated in terms of safety and serviceability requirements. Based on the analytical results, conclusions and recommendations were presented regarding the influence of terrain categories on the wind behavior of low, medium, and high rise buildings.

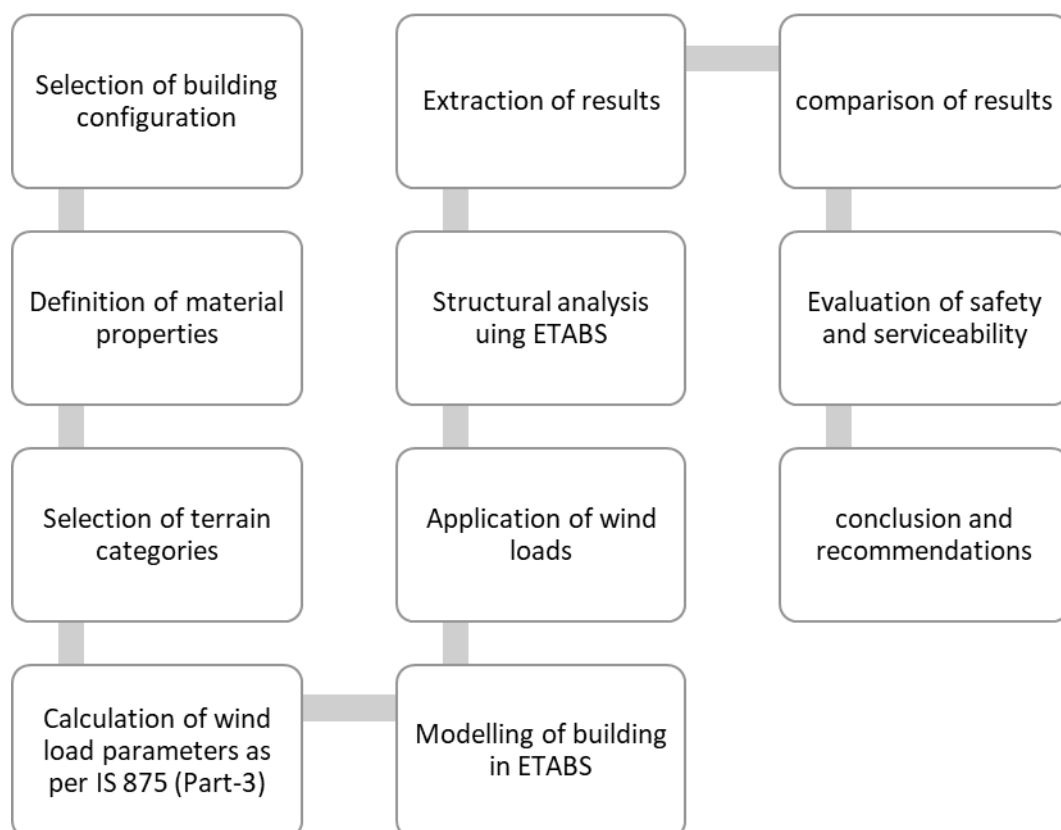


Fig 1: Methodology flow chart

V. MODELING AND ANALYSIS

(1) SELECTION OF BUILDING HEIGHT

The primary objective of selecting multiple building heights is to study the variation of wind load effects with increase in height while keeping other parameters constant. This approach helps in isolating the influence of height and terrain category on structural response under wind loading.

The buildings considered in the present study are categorized based on the number of storeys as follows:

- Low rise building: G+5
- Medium rise building: G+10
- High rise building: G+15

(2) SIGNIFICANCE OF IS 875 WIND LOAD CALCULATION

The wind load calculation procedure prescribed by IS 875 (Part-3) provides a rational and standardized approach for estimating wind effects on buildings. It ensures uniformity in design practice across India and helps engineers achieve safe and economical designs by considering location-specific and terrain-specific wind characteristics.

(3) MODELLING ASSUMPTION

The following assumptions are made while modelling the buildings:

- Buildings are assumed to be symmetric in plan and elevation.
- Floor slabs are assumed to act as rigid diaphragms.
- Effects of construction sequence are neglected.
- Cracking of concrete sections is not explicitly considered.
- Only wind load is considered as the lateral load, seismic load is excluded.
- The basic wind speed adopted in the present analysis corresponds to Sheikhpura district of Bihar as specified in IS 875 (Part 3): 2015.

These assumptions help in simplifying the analysis while maintaining sufficient accuracy for comparative evaluation.

(4) MODELLING PHILOSOPHY IN ETABS

The building models are developed using ETABS software by defining grid systems, storey levels, material properties, and section properties. Structural elements such as beams, columns, and slabs are modelled using frame and shell elements. Wind loads are defined using the code-based wind load option as per IS 875 (Part-3).

The same modelling philosophy is adopted for all building configurations to ensure consistency and reliability of results.

(5) DESIGN DETAILS AND BUILDING MODELS

Table 3 : Design detail of building

Parameter	Details
Type of structure	RCC frame structure
No. of stories in low rise building	6 stories
No. of stories in medium rise building	11 stories
No. of stories in high rise building	16 stories
Story to story height	3 m
Ground story height	3.5 m
Grade of concrete	M30 for columns and slab M25 for beams
Thickness of slab	0.12 m
Thickness of wall	0.23 m
Beam size	0.3 m × 0.4 m
Column size	0.4 m × 0.6 m
Density	Concrete: 24 kN/m ³ Brick wall: 19 kN/m ³

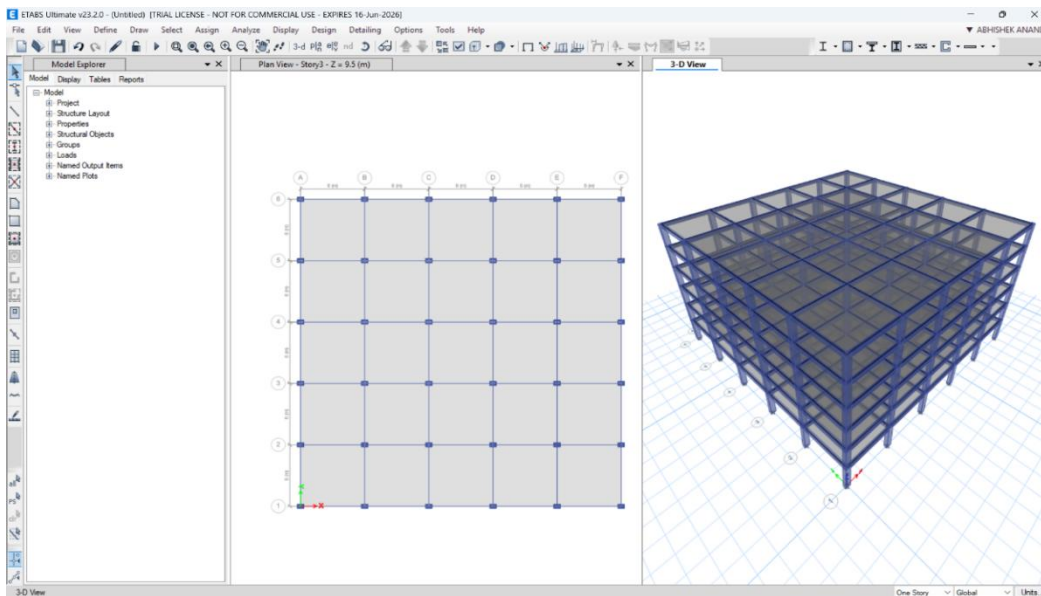


Fig 2: Model of low rise building

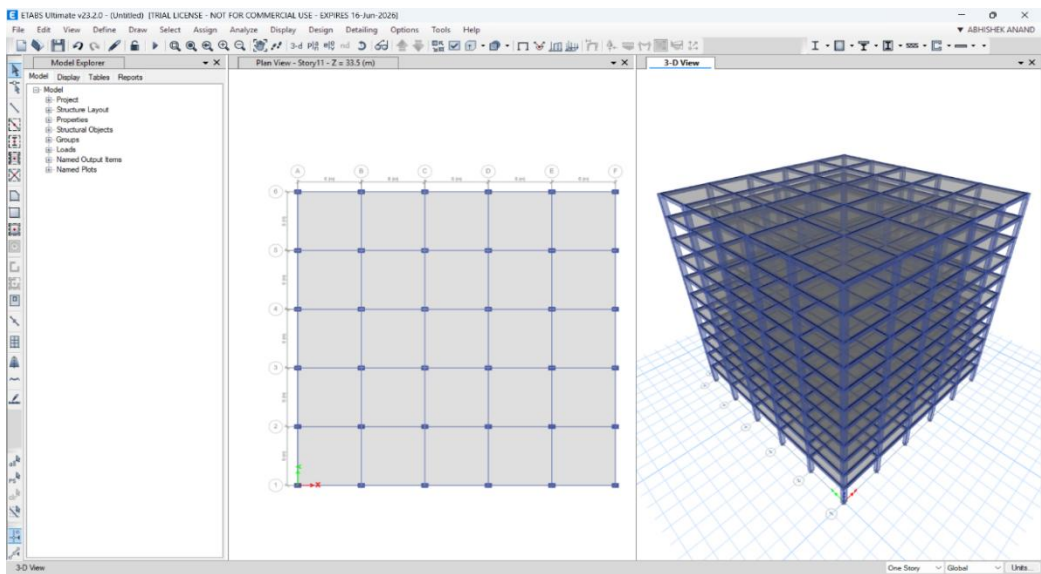


Fig 3: Model of medium rise building

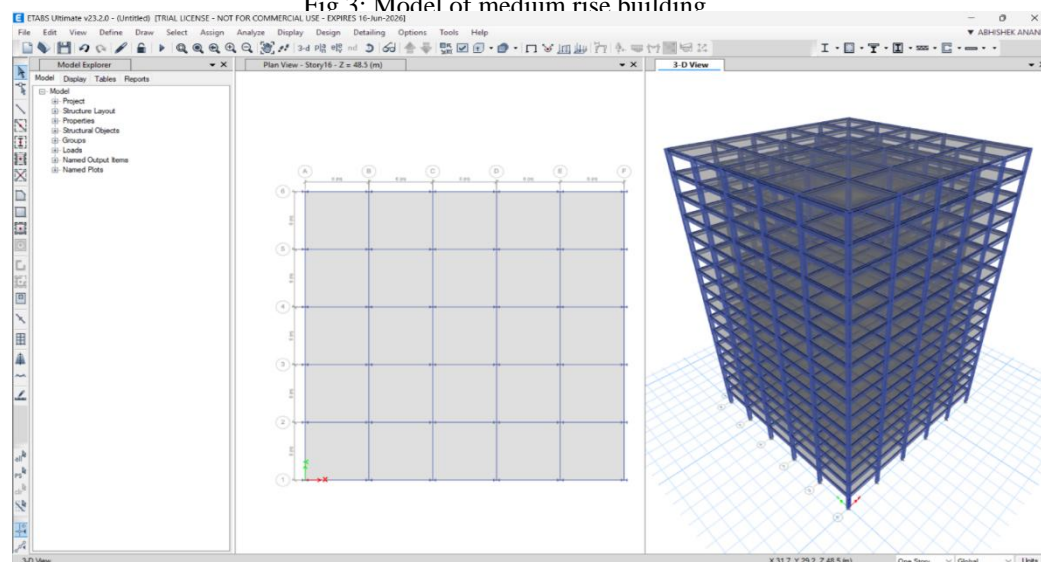


Fig 4: Model of high rise building

VI. RESULTS AND DISCUSSION

(1) STOREY DRIFT IN DIFFERENT TERRAIN CATEGORIES

It is the relative horizontal displacement between two consecutive floors of a building due to lateral loads such as wind or earthquake forces. It indicates the lateral stiffness and stability of the structure. Excessive storey drift may cause structural and non-structural damage; therefore, it should remain within the permissible limits specified in design codes.

Low rise building (G+5)

Table 4: Storey drift variation in G+5

STOREY	DRIFT IN			
	TC1	TC2	TC3	TC4
Storey 6	0.000002	0.000002	0.000002	0.000001
Storey 5	0.000002	0.000002	0.000002	0.000001
Storey 4	0.000002	0.000002	0.000002	0.000001
Storey 3	0.000002	0.000002	0.000002	0.000001
Storey 2	0.000002	0.000002	0.000002	0.000001
Storey 1	0.000001	0.000001	0.000001	0.000001

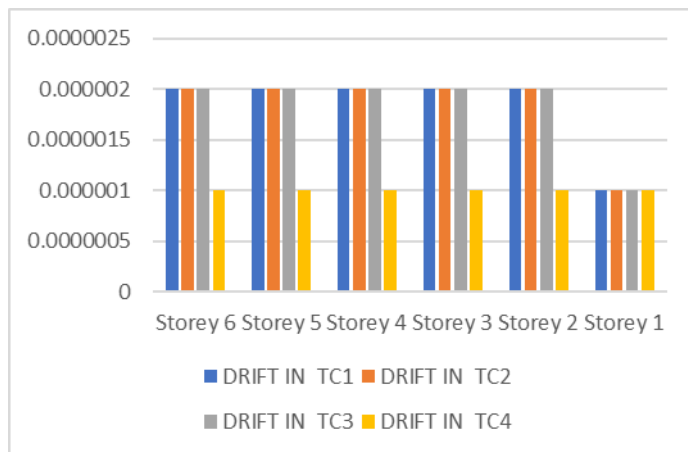


Fig 5: Storey drift variation in G+5

The storey drift graph of the G+5 building shows that the drift values are nearly uniform from Storey 2 to Storey 6, while the minimum drift is observed at Storey 1. Terrain Categories TC1, TC2, and TC3 exhibit almost identical behaviour with drift values around 0.000002, whereas TC4 shows comparatively lower drift values of about 0.000001, indicating nearly 50% reduction in drift due to increased terrain roughness. Overall, all drift values remain within permissible limits, demonstrating satisfactory lateral stability and stiffness of the structure under wind loading conditions.

Medium rise building (G+10)

Table 5 : Storey drift variation in G+10

STOREY	DRIFT IN			
	TC1	TC2	TC3	TC4
Storey 11	0.000013	0.000012	0.000011	0.000008
Storey 10	0.000013	0.000013	0.000011	0.000008
Storey 9	0.000014	0.000013	0.000011	0.000008
Storey 8	0.000014	0.000013	0.000011	0.000008
Storey 7	0.000013	0.000012	0.000011	0.000008
Storey 6	0.000013	0.000012	0.000011	0.000008
Storey 5	0.000012	0.000011	0.000011	0.000007
Storey 4	0.000011	0.000011	0.000009	0.000006
Storey 3	0.000009	0.000009	0.000007	0.000005
Storey 2	0.000007	0.000006	0.000006	0.000004
Storey 1	0.000004	0.000003	0.000003	0.000002

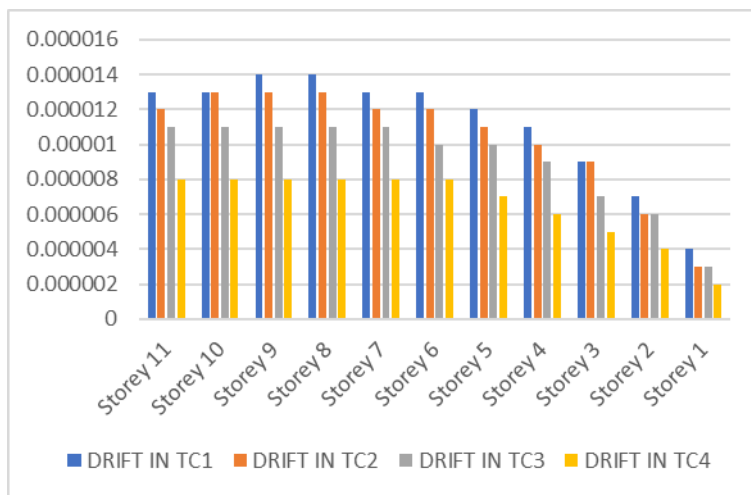


Fig 6: Storey drift variation in G+10

The storey drift graph of the G+10 building shows that the maximum drift occurs at the upper storeys (Storey 8 to Storey 11) and gradually decreases towards the lower storeys, with the minimum drift observed at Storey 1. Terrain Categories TC1 and TC2 show almost similar behaviour, while TC3 exhibits slightly lower drift values. TC4 shows the least drift among all terrain

categories, with an approximate 35 % reduction compared to TC1 at the top storeys due to higher terrain roughness reducing wind intensity. Overall, the drift values decrease progressively along the building height and remain within permissible limits, indicating satisfactory lateral stability of the structure under wind loading conditions.

High rise building (G+15)

Table 6 : Storey drift variation in G+15

STOREY	DRIFT IN			
	TC1	TC2	TC3	TC4
Storey 16	0.000037	0.000035	0.000031	0.000026
Storey 15	0.000038	0.000035	0.000031	0.000026
Storey 14	0.000038	0.000036	0.000032	0.000027
Storey 13	0.000038	0.000036	0.000032	0.000027
Storey 12	0.000038	0.000036	0.000032	0.000027
Storey 11	0.000038	0.000036	0.000032	0.000027
Storey 10	0.000037	0.000035	0.000031	0.000026
Storey 9	0.000036	0.000034	0.00003	0.000025
Storey 8	0.000035	0.000033	0.000029	0.000024
Storey 7	0.000033	0.000031	0.000028	0.000023
Storey 6	0.000031	0.000029	0.000026	0.000021
Storey 5	0.000024	0.000026	0.000023	0.000019
Storey 4	0.00002	0.000023	0.00002	0.000016
Storey 3	0.000014	0.000018	0.000016	0.000013
Storey 2	0.000004	0.000013	0.000012	0.000009
Storey 1	0.000007	0.000006	0.000005	0.000004

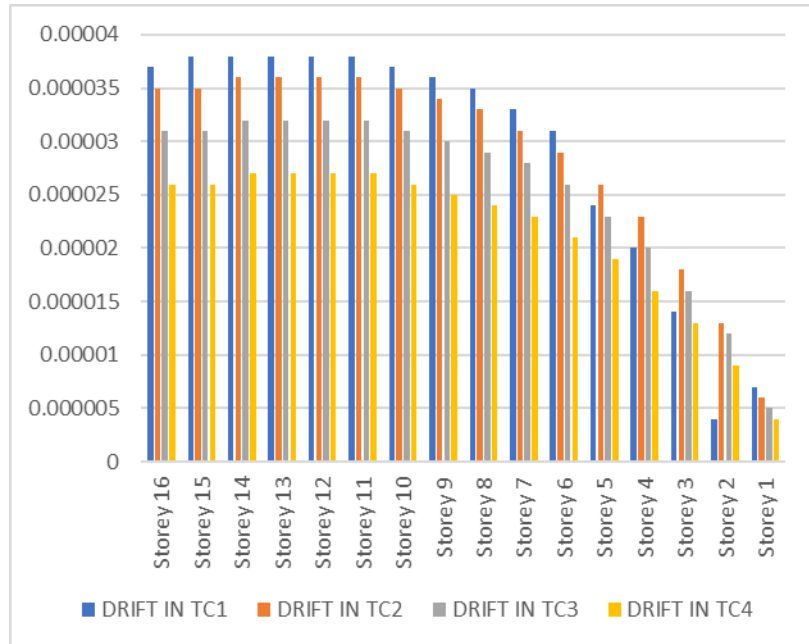


Fig 7: Storey drift variation in G+10

The storey drift graph of the G+15 building shows that the maximum drift occurs at the upper storeys (Storey 11 to Storey 16) and gradually decreases towards the lower storeys, while the minimum drift is observed at Storey 1. Terrain Category TC1 shows the highest drift values, whereas TC2, TC3, and TC4 show progressively lower drift values. Compared to TC1, the drift values in TC2 decrease by approximately 6%, TC3 by about 20%, and TC4 by nearly 28% at the top storeys due to increased terrain roughness reducing wind intensity. Overall, the gradual reduction in drift along the building height indicates stable structural behaviour, and all values remain within permissible limits under wind loading conditions.

(2) OVER TURNING MOMENTS IN DIFFERENT TERRAIN CATEGORIES

Overtuning moment is the rotational effect developed in a structure due to lateral forces such as wind or earthquake loads, which creates a tendency for the building to overturn about its base. It is an important parameter used to evaluate the stability and safety of structures during structural analysis.

Low rise building (G+5)

Table 7:Overtuning moment in G+5

STOREY	OVERTURNING MOMENT IN			
	TC1	TC2	TC3	TC4
Storey 6	247.924	225.601	194.092	121.643
Storey 5	732.369	665.928	568.574	364.928
Storey 4	1196.794	1087.18	917.474	608.213
Storey 3	1645.665	1493.622	1246.249	851.498
Storey 2	2092.516	1898.143	1572.426	1094.783
Storey 1	2576.605	2336.373	1925.785	1358.342

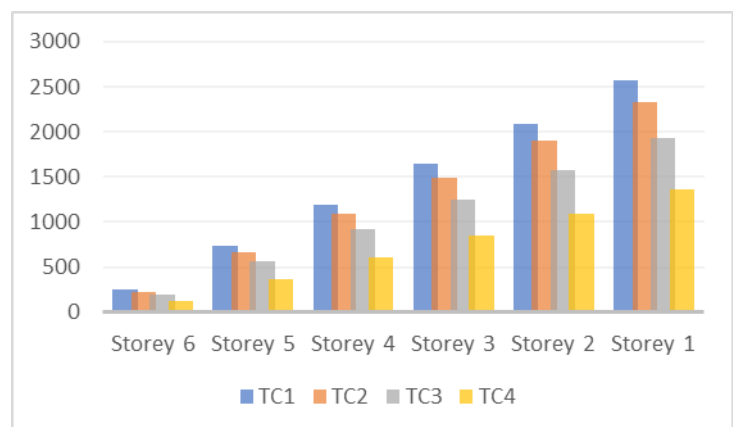


Fig 8: Overtuning moment in G+5

The values gradually decrease with increase in building height due to reduction in wind-induced torsional effects. Terrain Category TC1 shows the highest torque values, whereas TC2, TC3, and TC4 exhibit reduced torque values by approximately 9.30%, 25.28%, and 47.28%, respectively, compared to TC1. This indicates that increasing terrain roughness significantly reduces the torsional response of the structure under wind loading conditions.

Medium rise building (G+10)

Table 8: Overturning moment in G+10

STOREY	OVERTURNING MOMENT IN			
	TC1	TC2	TC3	TC4
Storey 11	271.897	257.729	226.69	188.072
Storey 10	810.785	767.876	674.35	552.288
Storey 9	1341.504	1266.021	1110.432	884.211
Storey 8	1863.748	1750.525	1533.757	1179.122
Storey 7	2377.41	2221.516	1944.354	1439.867
Storey 6	2878.604	2677.93	2338.912	1683.841
Storey 5	3363.049	3118.257	2713.394	1927.127
Storey 4	3827.474	3539.509	3062.295	2170.412
Storey 3	4276.345	3945.952	3391.07	2413.697
Storey 2	4723.196	4350.472	3717.247	2656.982
Storey 1	5207.285	4788.703	4070.606	2920.541

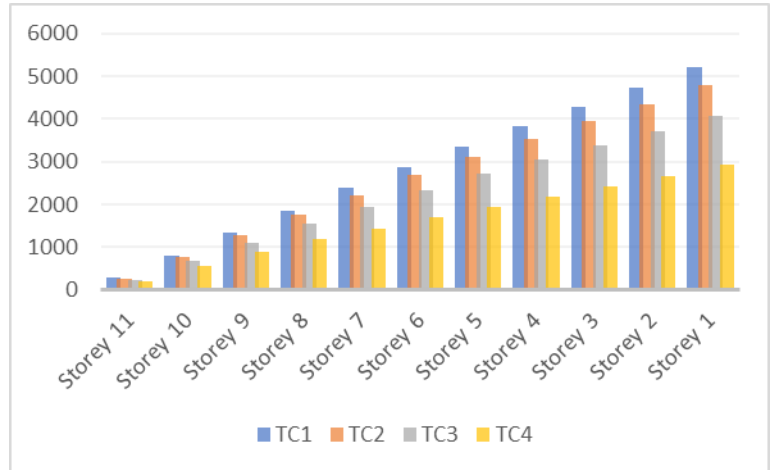


Fig 9: Overturning moment in G+10

The graph of the G+10 building shows that the maximum torque is observed at the lower storeys, particularly at Storey 1, while the minimum torque occurs at the top storey (Storey 11). The torque values gradually decrease with increase in building height due to reduction in wind-induced torsional effects along the structure. Terrain Category TC1 exhibits the highest torque values, whereas TC2, TC3, and TC4 show reduced torque values by approximately 8.25%, 21.98%, and 43.93%, respectively, compared to TC1. This indicates that increasing terrain roughness significantly reduces the torsional response of the building under wind loading conditions.

High rise building (G+15)

Table 9: Overturning moment in G+15

STOREY	OVERTURNING MOMENT IN			
	TC1	TC2	TC3	TC4
Storey 16	290.14	275.499	246.782	225.601
Storey 15	865.494	821.694	734.896	666.421
Storey 14	1414.48	1380.71	1214.833	1001.87
Storey 13	1994.166	1892.625	1686.81	1502.209
Storey 12	2547.58	2417.445	2150.747	1897.722
Storey 11	3093.776	2935.245	2606.761	2278.679
Storey 10	3632.663	3445.389	3034.42	2642.895
Storey 9	4163.383	3943.534	3490.503	2974.819
Storey 8	4685.627	4428.038	3913.827	3269.729
Storey 7	5199.289	4899.029	4324.424	3530.474
Storey 6	5704.483	5359.447	4718.582	3774.449
Storey 5	6184.928	5795.77	5093.465	4017.734
Storey 4	6649.333	6217.021	5442.965	4261.019
Storey 3	7098.224	6623.464	5771.14	4504.304
Storey 2	7545.075	7027.984	6097.317	4747.589
Storey 1	8029.163	7466.215	6450.676	5011.148

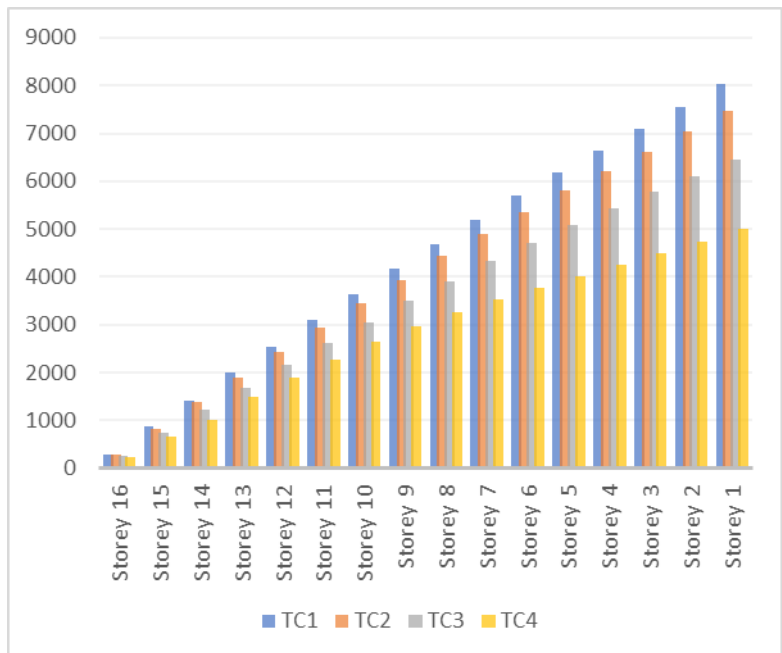


Fig 10: Overturning moment in G+15

The graph of the G+15 building shows that the maximum moment is observed at the lower storeys, particularly at Storey 1, while the minimum torque occurs at the top storey (Storey 16). The torque values gradually decrease with increase in building height

due to reduction in wind-induced torsional effects along the structure. Terrain Category TC1 exhibits the highest torque values, whereas TC2, TC3, and TC4 show reduced torque values by approximately 7.57%, 19.88%, and 39.04%, respectively, compared to TC1. This indicates that increasing terrain roughness significantly reduces the torsional response of the building under wind loading conditions.

(3) SHEAR FORCE (V) IN DIFFERENT TERRAIN CATEGORIES

Shear force in a building is the lateral internal force developed at different storey levels due to external actions such as wind or earthquake loads. It represents the total horizontal force transferred through the structure and is important for evaluating the stability and strength of the building against lateral loads.

Low rise building (G+5)

Table 10: Shear force variation in G+5

STOREY	SHEAR FORCE IN			
	TC1	TC2	TC3	TC4
Storey 6	-33.06	-30.08	-25.88	-16.22
Storey 5	-97.65	-88.79	-75.81	-48.66
Storey 4	-159.57	-144.96	-122.33	-81.1
Storey 3	-219.42	-199.15	-166.17	0
Storey 2	-279	-253.09	-209.66	-145.97
Storey 1	-343.55	-311.52	-256.77	-181.11

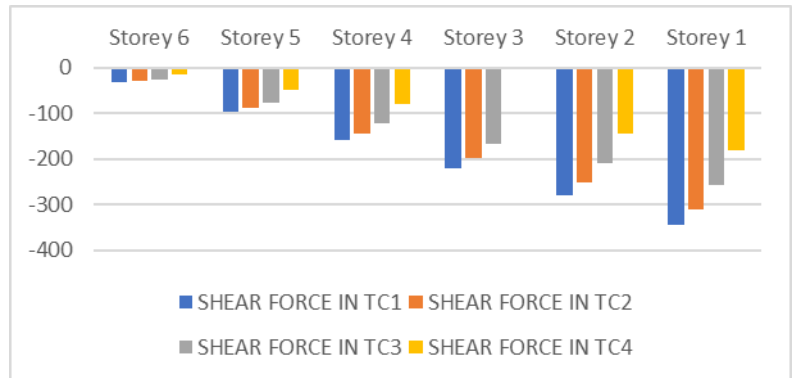


Fig 11: Shear force variation in G+5

The shear force graph of the G+5 building indicates that the maximum shear force is developed at the lower storeys, particularly at Storey 1, and gradually decreases towards the upper storeys, with the minimum value observed at Storey 6. Terrain Category TC1 shows the highest shear force values due to greater wind exposure, while TC2, TC3, and TC4 exhibit comparatively lower shear forces. In comparison with TC1, the shear force reduces by approximately 9.01% in TC2, 25.26% in TC3, and 47.85% in TC4, demonstrating that increased terrain roughness significantly minimizes lateral wind effects on the structure.

Medium rise building (G+10)

Table 11: Shear force variation in G+10

STOREY	SHEAR FORCE IN			
	TC1	TC2	TC3	TC4
Storey 11	-36.25	-34.36	-30.23	-25.08
Storey 10	-108.1	-102.38	-89.91	-73.64
Storey 9	-178.87	-168.8	-148.06	-117.89
Storey 8	-248.5	-233.4	-204.5	-157.22
Storey 7	-316.99	-296.2	-259.25	-191.98
Storey 6	-383.81	-357.06	-311.85	-224.51
Storey 5	-448.41	-415.77	-361.79	-266.95
Storey 4	-510.33	-471.93	-408.31	-289.39
Storey 3	-570.18	-526.13	-452.14	-321.83
Storey 2	-629.76	-580.06	-495.63	-354.26
Storey 1	-694.3	-638.49	-542.75	-389.41

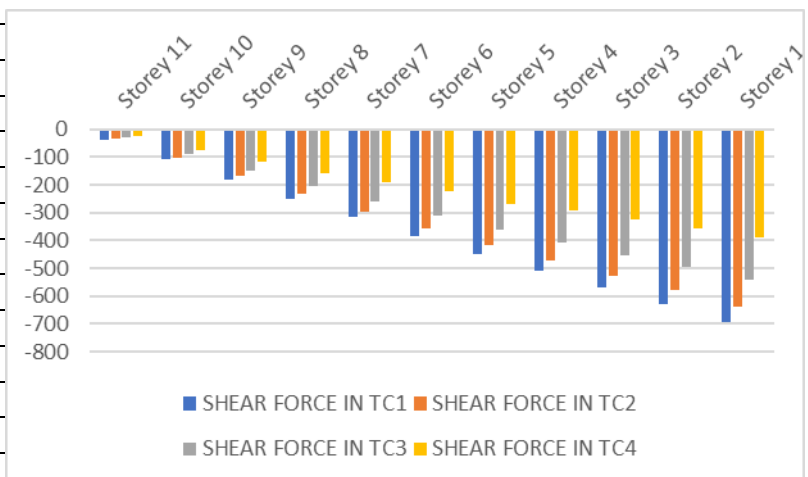


Fig 12: Shear force variation in G+10

The shear force graph of the G+10 building shows that the shear force magnitude progressively increases towards the lower storeys, with the maximum value occurring at Storey 1 and the minimum at Storey 11. Terrain Category TC1 experiences the highest shear force due to greater wind intensity, whereas TC2, TC3, and TC4 show comparatively lower values throughout the building height. Compared to TC1, the shear force decreases by approximately 8.04% in TC2, 21.83% in TC3, and 43.91% in TC4, indicating that higher terrain roughness effectively reduces lateral wind-induced forces on the structure.

High rise building (G+15)

Table 12: Shear force variation in G+15

STOREY	SHEAR FORCE IN			
	TC1	TC2	TC3	TC4
Storey 16	-38.68	-36.73	-32	-30.08
Storey 15	-115.4	-109.56	-97.09	-88.86
Storey 14	-191.13	-181.43	-161.98	-145.58
Storey 13	-265.88	-252.33	-224.71	-200.98
Storey 12	-339.68	-322.33	-286.77	-253.03
Storey 11	-412.5	-391.37	-347.57	-303.82
Storey 10	-484.6	-459.19	-406.1	-352.39
Storey 9	-555.12	-525.8	-463.4	-396.64
Storey 8	-624.75	-590.41	-521.84	-439.96
Storey 7	-693.24	-653.2	-576.59	-470.72
Storey 6	-760.06	-714.06	-629.2	-503.26
Storey 5	-824.66	-772.7	-679.13	-535.7
Storey 4	-886.3	-828.84	-726.18	-568.11
Storey 3	-946.43	-883.13	-769.49	-600.57
Storey 2	-1006.01	-937.06	-812.98	-633.01
Storey 1	-1070.56	-995.5	-860.09	-668.15

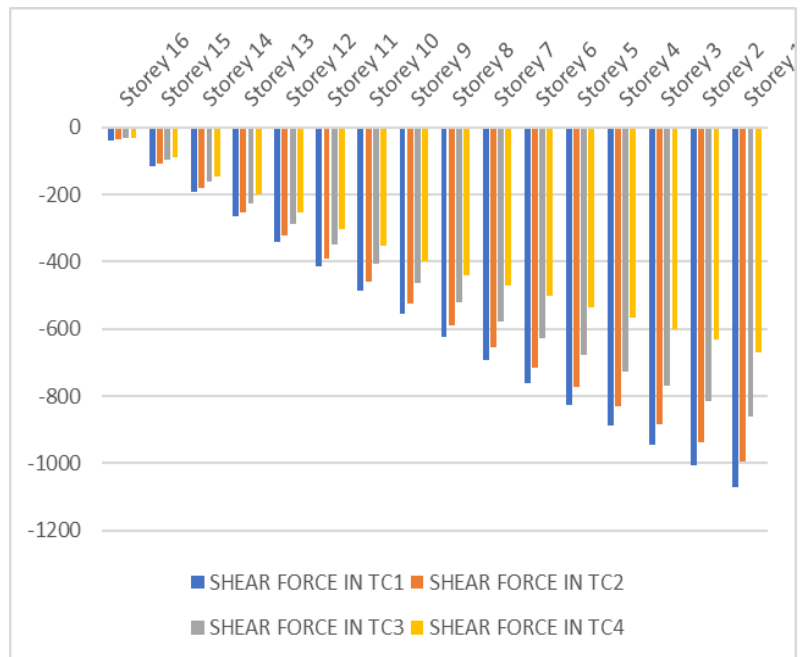


Fig 13: Shear force variation in G+15

The shear force variation for the G+15 building under different terrain categories is presented in the table and graph. The results show that the shear force continuously increases towards the base storey due to the cumulative effect of wind-induced lateral loads along the building height. TC1 exhibits the maximum shear force values, while TC4 shows the minimum response because of greater terrain roughness and reduced wind intensity. At the base storey, the shear force decreases by approximately 7.0% in TC2, 20.0% in TC3, and 37.6% in TC4 compared to TC1, indicating that terrain category significantly influences the lateral load response of tall buildings under wind loading conditions.

(4) BENDING MOMENT IN DIFFERET TERRAIN CATEGORIES

Bending moment in a building is the internal moment developed in structural elements such as beams, columns, and frames due to the action of external loads like dead load, live load, wind load, or seismic load. It represents the tendency of a force to bend or rotate a structural member about a particular point or axis.

In multistorey buildings, bending moments are generated when lateral loads such as wind act on the structure, causing the building to sway and develop internal resisting moments in beams and columns. The magnitude of bending moment generally increases with increase in building height and lateral load intensity. Excessive bending moments may lead to cracking, excessive deformation, or structural failure if not properly resisted by the structural system.

Low rise building (G+5)

Table 13: Bending moment variation in G+5

STOREY	BENDING MOMENT IN			
	TC1	TC2	TC3	TC4
Storey 6	-99.17	-90.24	-77.637	-48.657
Storey 5	-392.117	-356.611	-305.066	-194.628
Storey 4	-870.835	-791.483	-672.056	-437.913
Storey 3	-1529.1	-1388.93	-1170.56	-778.512
Storey 2	-2366.11	-2148.19	-1799.53	-1216.43
Storey 1	-3568.52	-3238.5	-2698.23	-1850.32

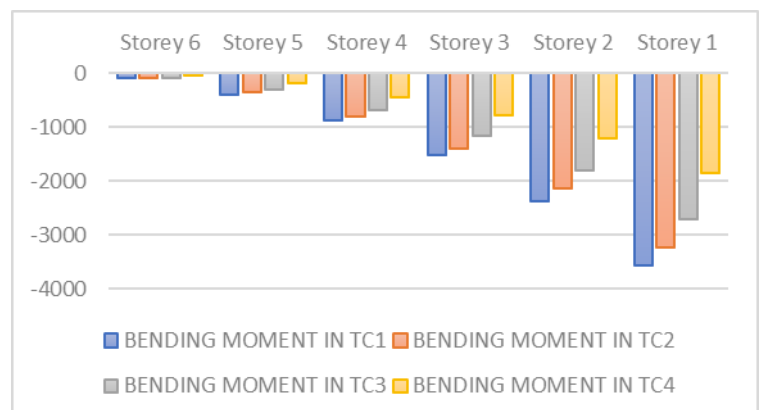


Fig 14: Bending moment variation in G+5

The bending moment graph of the G+5 building shows that the bending moment increases from top to bottom, with the maximum value at Storey 1 and minimum at Storey 6 due to accumulation of wind effects towards the base. TC1 shows the highest bending moment, while TC2, TC3, and TC4 show reductions of approximately 9.25%, 24.39%, and 48.15%, respectively, indicating that higher terrain roughness significantly reduces wind-induced flexural effects in the structure.

Medium rise building (G+10)

Table 14: Bending moment variation in G+10

STOREY	BENDING MOMENT IN			
	TC1	TC2	TC3	TC4
Storey 11	-108.759	-103.092	-90.676	-75.229
Storey 10	-433.073	-410.242	-360.416	-296.144
Storey 9	-969.674	-916.651	-804.589	-649.829
Storey 8	-1715.17	-1616.86	-1418.09	-1121.48
Storey 7	-2666.14	-2505.47	-2195.83	-1697.42
Storey 6	-3817.58	-3576.64	-3131.4	-2370.96
Storey 5	-5162.8	-4823.94	-4216.76	-3141.81
Storey 4	-6693.79	-6239.75	-5441.67	-4009.98
Storey 3	-8404.33	-7818.13	-6798.1	-4975.46
Storey 2	-10293.6	-9558.32	-8285	-6038.25
Storey 1	-12723.7	-11793	-10184.6	-7401.17

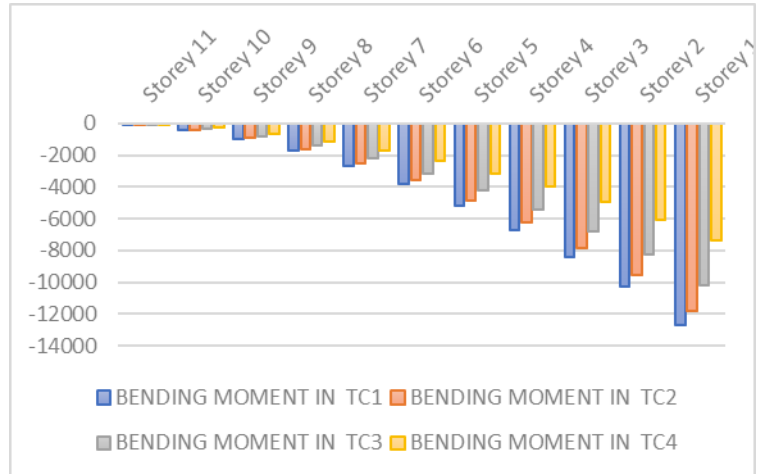


Fig 15: Bending moment variation in G+10

The bending moment graph of the G+10 building indicates that the bending moment progressively increases towards the lower storeys, with the maximum value observed at Storey 1 and the minimum at Storey 11 due to accumulation of lateral wind effects along the height. TC1 shows the highest bending moment values, while TC2, TC3, and TC4 exhibit reductions of approximately 7.34%, 19.98%, and 41.82%, respectively, indicating that increased terrain roughness effectively decreases wind-induced flexural response and improves structural behaviour.

High rise building (G+15)

Table 15: Bending moment variation in G+15

STOREY	BENDING MOMENT IN			
	TC1	TC2	TC3	TC4
Storey 16	-116.056	-110.199	-98.713	-90.24
Storey 15	-462.254	-438.877	-392.671	-356.809
Storey 14	-1033.65	-983.165	-878.624	-793.353
Storey 13	-1833.32	-1740.21	-1553.35	-1394.44
Storey 12	-2852.35	-2707.19	-2413.65	-2153.53
Storey 11	-4089.86	-3881.29	-2413.65	-3065
Storey 10	-5542.92	-5259.44	-4678.12	-4122.16
Storey 9	-7208.28	-6836.86	-6074.32	-5312.09
Storey 8	-9082.53	-8608.07	-6074.32	-6619.98
Storey 7	-11162.2	-10567.7	-9369.62	-8032.17
Storey 6	-13442.4	-12709.9	-11257.2	-9541.95
Storey 5	-15916.4	-15028.2	-13294.6	-11149
Storey 4	-18576.1	-17515	-15471.5	-12853.4
Storey 3	-21415.4	-20164.4	-17780	-14535.2
Storey 2	-24433.5	-22975.6	-20218.9	-16554.2
Storey 1	-28130.4	-26459.8	-23229.2	-18892.7

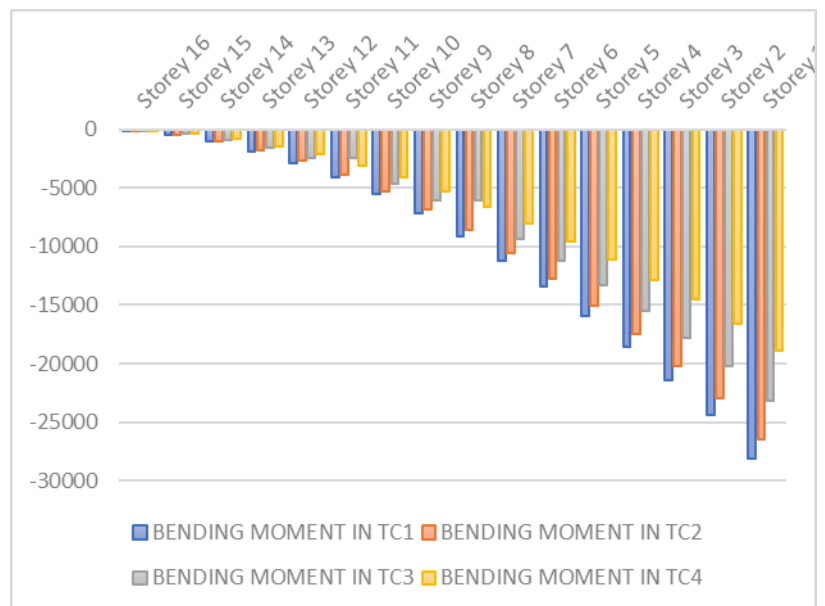


Fig 16: Bending moment variation in G+15

The bending moment graph of the G+15 building shows that the bending moment continuously increases towards the lower storeys, with the maximum value observed at Storey 1 and the minimum at Storey 16 due to accumulation of wind-induced lateral effects along the building height. TC1 exhibits the highest bending moment values throughout the structure, while TC2, TC3, and TC4 show reductions of approximately 6.00%, 17.29%, and 32.78%, respectively, indicating that higher terrain roughness considerably reduces the flexural response and enhances structural stability under wind loading conditions.

VII. CONCLUSION

The study leads to the following important conclusions :

1. Storey drift increases with increase in building height, with maximum drift observed at the upper storeys, while TC1 shows the highest drift and TC2, TC3, and TC4 exhibit reduced drift values due to increased terrain roughness.
2. The overturning moment increases with increase in building height, with maximum observed at the lower storeys in all building models, while TC1 shows the highest torsional response and TC2, TC3, and TC4 exhibit average reductions of approximately 8.37%, 22.38%, and 43.42%, respectively, due to increased terrain roughness reducing wind-induced torsional effects.
3. The shear force increases with increase in building height, with G+15 showing the maximum shear force followed by G+10 and G+5, while the highest shear force is consistently observed at the lower storeys in all building models. Terrain Category TC1 produces the maximum shear force, while others show reduced values due to increased terrain roughness, indicating reduction in wind-induced lateral forces on the structure.
4. The bending moment analysis indicates that the flexural response increases with increase in building height, with G+15 showing the maximum and G+5 has minimum. TC1 produces the highest bending moment values, whereas TC4 shows an average reduction of approximately 40.92%.
5. From the overall analysis of storey drift, shear force, torque, and bending moment, the G+5 building exhibits the best structural performance among all building models due to its lower lateral displacement, torsional response, shear force, and bending moment under wind loading conditions. Among the terrain categories, Terrain Category TC4 performs best because its higher terrain roughness significantly reduces wind intensity, resulting in minimum drift, shear force, torque, and bending moment compared to TC1, TC2, and TC3. Therefore, the combination of G+5 building in Terrain Category TC4 provides the most stable and efficient structural response against wind effects.

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