

Wind Load Impact Upon Tall Structures In Diverse Terrain Categories

Sailesh Jadhav¹, Vishwanath K²

¹PG Student, Department of Civil Engineering Sharnbasava University Kalaburagi India,
sachinj45@gmail.com,

²Assistant Professor, Department of Civil Engineering Sharnbasava University Kalaburagi India

ABSTRACT

The passage of wind may cause any tall structure to shake in both the "along wind" and "across wind" directions. Buildings intended to meet lateral drift criteria may nonetheless swing excessively during a storm, even if they have been designed to meet these requirements. As structures rise in height, they become more susceptible to wind oscillations and pose a hazard to the tall building. Oscillations may cause pain to the inhabitants even if the structure is not in danger of collapsing. As a result, a precise evaluation of structure movement is a precondition to serviceability. There are a few methods for determining the Wind Load Response of tall structures.

Air currents moving in a certain direction are a sort of wind that is apparent to the human eye. Civil engineering constructions have a severe drawback in that they may load anything that enters their way. In rocky terrain, the wind travels at a slower pace, whereas in flat ground, it travels at a faster pace. Using wind data from three distinct terrain types and three different building heights (Lower Moderate & High Rise), this research examines the effects of story drift, shear, & support responses on three various building heights. ETABSv9.7.4 is used to assess all 12 models of G+5, G+10, and G+15. The current study is an excellent source of information regarding the variability into drifting, shear with model height and the % variation into drifting, shear of the same model in various terrain categories.

Keywords: Wind load, Tall buildings, Terrain, Etabs, Storey drift, Bending moment, Shear force.

I. INTRODUCTION

1.1. GENERAL

Wind is made up of two parts. You may create electricity, sailing ships & decrease temperature in hot day using its energy. The other is that it acts as a parasite, loading everything gets in its path. Engineers are concerned with either since weight of load must be supported by a structure that meets required safety standards. All above-ground civic and industrial constructions must be able to withstand wind loads. This essay serves as an introduction to field of wind engineering as it pertains to buildings built by civil engineers.

1.2. ESTIMATING WIND LOAD UPON BUILDINGS:

Wind loading upon heightened building maybe deliberated by:

1. Analytical Method described by A.G.Davenport in code IS 875: part 3-1987 (1967). Analytical methods work well for buildings with regular shapes and sizes since they almost entirely rely on the geometric qualities of the structure itself and do not take surrounding structures into account.
2. Wind tunnel testing using a so-called building model was utilized to estimate the wind load. Structural study in the Wind Tunnel is carried out using Balendra's (1997) technique, whereas cladding design utilizes Surface Pressure Measurement assessment using a pressure measurement device. In the same manner as an isolated building model, the impacts of surrounding structures have been taken into account as Interference impacts upon that buildings.

1.3. TERRAIN

The influence of impediments upon roughness of ground must be taken into account while determining terrain classifications. Based upon that wind direction, terrain type utilized in construction of building might change. The direction of wind may be used to design the alignment of every structural element if there is enough meteorological data available. The kind of terrain wherein certain construction is situated will be determined by the following criteria:

A. TERRAIN CATEGORY 1

An area that is exposed to elements but also has minimal object height of 1.5m or less around building.

If there are no trees or buildings to obscure your view, you're looking at open landscape. An airport is one example of land area that's been specifically cleared for the purpose of agriculture.

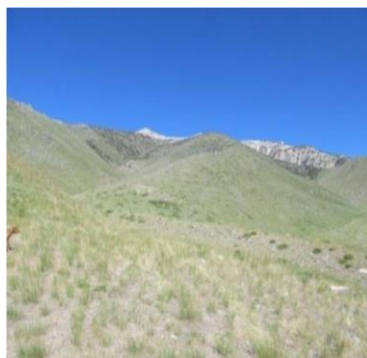


Fig 1 OPEN GROUND



Fig 2 OPEN REGION

B. TERRAIN CATEGORY 2

As a rule of thumb, a forest may be split in 3 classes: sparse, moderate & dense. An enormous forest might have all three, with sparse terrain at outer forest & thicker forest regions. To give you an idea of how probable its that a specific square contains a terrain feature, we've put up the following table.

Table1: kinds of trees & under growing variances into scant, moderate, denser

	Sparse	Medium	Dense
Typical trees	50%	70%	80%
Massive trees	-	10%	20%
Light undergrowth	50%	70%	50%
Heavy undergrowth	-	20%	50%



Fig 3.Terrain class 2

C. TERRAIN CATEGORY 3

Presence or non- presence of some insulated large structures, this terrain has more closely spaced impediments size of buildings upto 10 meters in height



Fig 4. Terrain category3

D. TERRAIN CATEGORY 4

Terrain having various larger & highly closed spacing concerns.



Fig 5. Terrain category 4

II. LITERATURE REVIEW

1. Trupti Nikose, Godbole.P.N, Arvind Y. Vyavahare, 2012,- As per study, Tall buildings are thin, elastic constructions should be examined for determining importance of wind speed-induced excitation in a particular zone. When it comes to tall structures and wind loads, the Indian code only specifies how to estimate the along-wind response, leaving out the across-wind response and intervention impact. The GSDMA project for tall buildings and structures to gain across wind reaction as per the Australian/New Zealand standard 'Framework Actions – Part 2 Wind Action. The Australian codal regulation specifies that coefficient must be calculated for certain ratios in order to achieve the cross wind response. With the little data that was provided, this article used ANN to extend aforementioned method in order to get a building's ratio-based wind reaction across buildings.

2. Shaikh Muffassir ¹,L.G. Kalurkar ², 2016, This research demonstrates. Metropolises cannot function without their skyscrapers. As compared to compound constructions, multi - storied tall rising RC buildings are both larger & less elastic. Compound construction also comprises unlike plan configurations, so this research explores the similarity or comparability among RCC & composite under influence of wind. A total of 15 building models were assembled and analyzed using ETABS 2015 software for wind load. Earthquake and wind assessment may be done using a variety of programs, however we use the one called ETABS 2015. For varying altitudes, such as 20 meters, 50 meters, and 80 meters, wind evaluation is done out. Compound structures are more risky and more elastic than RCC structures, as well as compound choice is preferable to RCC for multistory structures, according to the comparison research. Software analysis keeps track of the whole

investigation. As furthermore, comparison of different plan configurations demonstrates that parameters like storey dislocation, storey rigidity, base response, & time frame under influence of wind are all affected by wind's influence. The goal of this investigation is to identify best cost-effective building design in horizontal zone.

3. S.Gomathinayagam*, N.Lakshmanan, A.Abraham, P.Harikrishna and S.Chitra Ganapathi, 2009, The Indian Meteorological Department has gathered long-term statistics about hour wind velocity at 70 weather data. Each site's yearly maximum wind velocity (in kmph) has been calculated using daily gust wind data. Quantiles based on the Gumbel probabilistic papers technique have been calculated. There was also an evaluation of a 50-year return period design based wind velocity to every location in the study. The modern wind zone map for building/structure design highlights site-specific changes in design wind speeds and suggests revising the map..

4. Shiromal Fernando, Tharaka Gunawardena¹, Bhatiya Waduge, Priyan Mendis ¹, Dilina Hettiarachchi ², 2017, There is an ever-increasing demand for skyscrapers in urban areas across the globe because of the growing population. As Colombo's skyline continues to grow swiftly, Sri Lanka is facing this reality in the current day. Tall buildings' reaction to wind loads is an important design requirement, requiring both traditional force-based designs and performance-based approaches. A tall structure that isn't always sturdy, secure, & robust when subjected to wind stresses, but also aesthetically pleasing and highly useful is subject of this study, which explores technical solutions needed to meet these problems.

5. Aslam Hussain², Umakant Arya¹, Waseem Khan³. (2014), A wind speed investigation and structural reaction of a sloping ground building frame was examined and analyzed in this research article. Taking into account different ground slopes and frame geometries. Consideration is given to the combination of static and wind stresses, as well. There are several variations on sloping terrain. There are three distinct building frame heights and three separate wind zones to consider when looking at combinations. For the purposes of analysis, STAAD-Pro software was used. Storey proportionate drifting, Shear force, momentum, axial force, supporting response and Displacement are all taken into account.

III. OBJECTIVES OF THE STUDY

The following are project's primary goals::

1. To begin with, the primary goal of this research is to examine the influence and fluctuation of wind pressure on three types of structures in diverse terrains.
2. The dynamic analysis approach described in drafting code IS-875 section 3 will be used to determine how wind pressure changes upon typical multi-story buildings in this research.
3. Terrain types 1, 2, 3, and 4 will all be taken into consideration while simulating the current work's multistory structures, which range from six stories to eleven stories to sixteen stories.
4. ETABSV9.7 will be used to analyze the structure.
5. The dynamic analysis approach is used in this step.

A comparison is made between the model findings (story drift and shear) for several building types (lower, moderate, and higher rise) on various terrain types.

IV. METHODOLOGY

EFFECT OF WIND LOAD ON BUILDINGS AND STRUCTURES

4.1. NATURE OF WIND IN ATMOSPHERE

With 0 at ground surface to a maximal at a height referred to as the gradient height, wind velocity as in atmosphere outermost layer generally rises with height. The Code does not take into account Ekman effect, which is a little shift in direction. The change in height is mostly dependent on the topography. As a result, it was considered advantageous to divide the wind speed in mean or average value and a variable element near this estimated value. As per average period used in analysis of meteorological data, this

average value might range as few seconds to few minutes. The greater average duration, the greater the fluctuation element of wind velocity, that indicates gustiness of wind. The higher wind speed, smaller average interval.

4.2. BASIC WIND SPEED:

For each region of India, a basic wind speed chart at 10 meters over average ground level is shown in Figure 6. A 10m height above average ground level in open terrain is used to calculate the basic wind speed, which is derived from highest gust speed average across a short span of around 3s (Category 2). Towards a 50-year return time, the basic wind speeds shown in Fig6 were calculated.

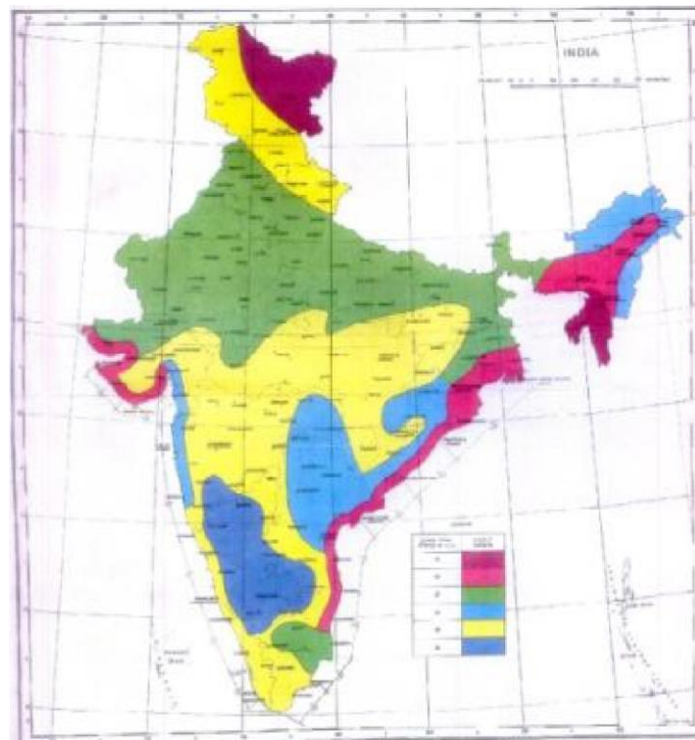


Fig 6. Basic wind speed in m/s (based on 50 year return period)

4.3. Design Wind Speed (V_z)

To acquire the design wind speed, V_z , at any height, Z , for the specified structure, start with wind speed shown in Fig. 1 and modify it to incorporate following effects: Risk, terrain roughness, structure height, local topography, and importance to cyclonic area are all factors to consider. This is how it may be stated mathematically:

$$V_z = V_b K_1 K_2 K_3 K_4$$

Here

V_z	Design wind speed at any height z in m/s
V_b	Basic wind speed
K_1	Probability factor (risk coefficient)
K_2	Terrain roughness and height factor
K_3	Topography factor
K_4	Importance factor for the cyclone region

4.4. DESIGNING DELIBERATIONS & MODEL OF BUILDING IN ETABS

Table 2, 3, and 4 show the specifics of lower, moderate, and high-rise structures. Additionally, prototypes may be seen in figures 7, 8, & 9

Table 2. Designing particulars of Low Rise Buildings

G+5 Design	Details
Type of structure	RCC frame structure
Number of stories(G+5)	6 stories
Story to story height	3m
Ground story height	3.5m
Grade of concrete	M30 for columns and slab M25 for Beams
Thickness of slab	0.12m
Thickness of wall	0.23m
Beams size	0.3mx0.4m
Column size	0.4mx0.6m
Density	For concrete 24KN/m ³ For brick wall 19KN/m ³

Table 3. Designing particulars of Moderate rise buildings

G+10 Design	Details
Type of structure	RCC frame structure
Number of stories(G+5)	11 stories
Story to story height	3m
Ground story height	3.5m
Grade of concrete	M30 for columns and slab M25 for Beams
Thickness of slab	0.12m
Thickness of wall	0.23m
Beams size	0.3mx0.4m
Column size	0.4mx0.6m
Density	For concrete 24KN/m ³ For brick wall 19KN/m ³

Table 4.Designing particulars of High rise buildings

G+15 Design	Details
Type of structure	RCC frame structure
Number of stories(G+5)	16 stories
Story to story height	3m
Ground story height	3.5m
Grade of concrete	M30 for column and slab M25 for beams
Thickness of slab	0.12m
Thickness of wall	0.23m
Beams size	0.3mx0.4m
Column size	0.4mx0.6m
Density	For concrete 24KN/m ³ For brick wall 19KN/m ³

4.5 MODELS IN ETABS

a. Low Rise Building (G+5)

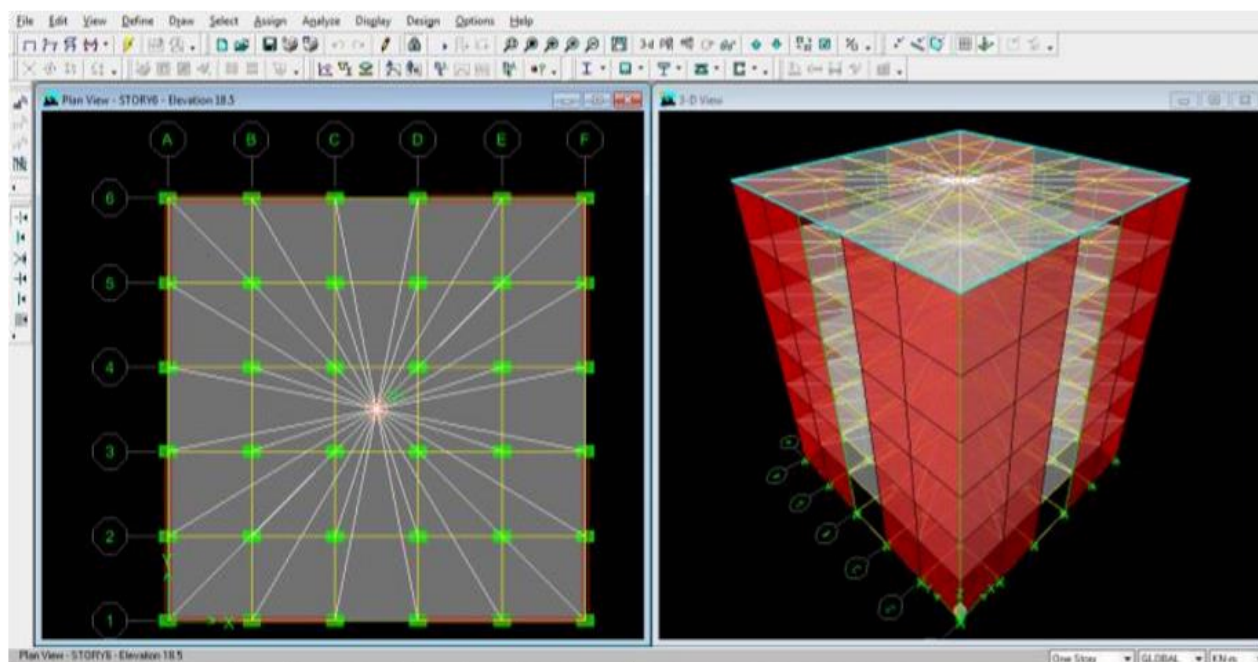


Fig 7 Model 1

b. Medium Rise Building (G+10)

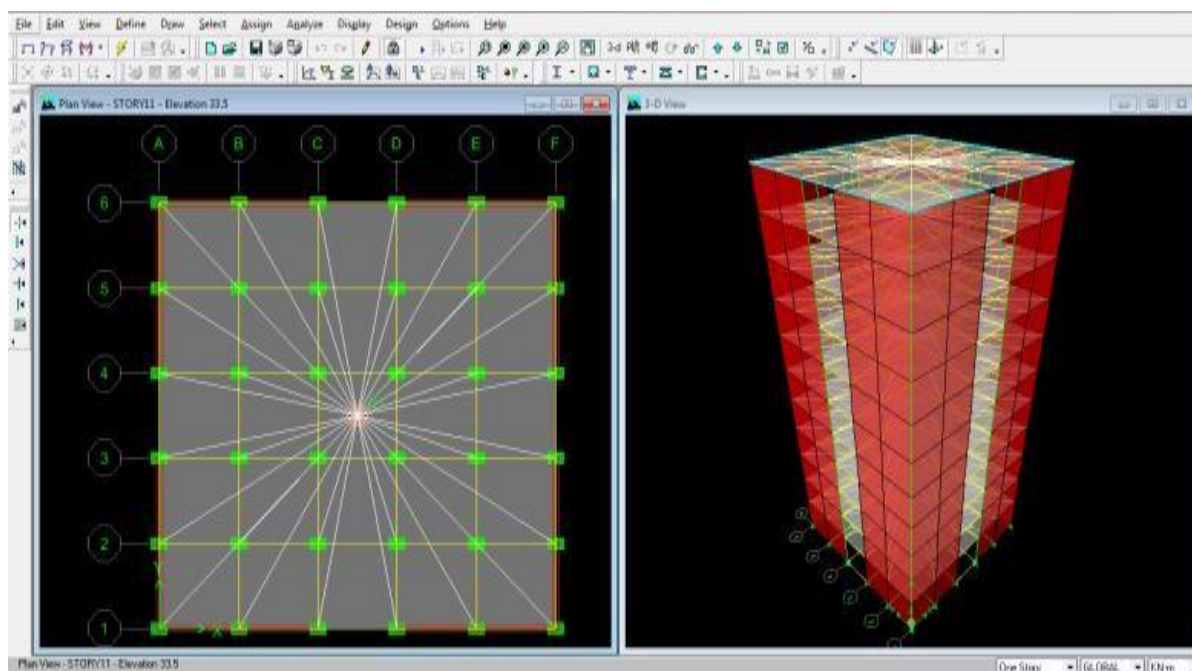


Fig 8 Model 2

c. High Rise Building (G+15)

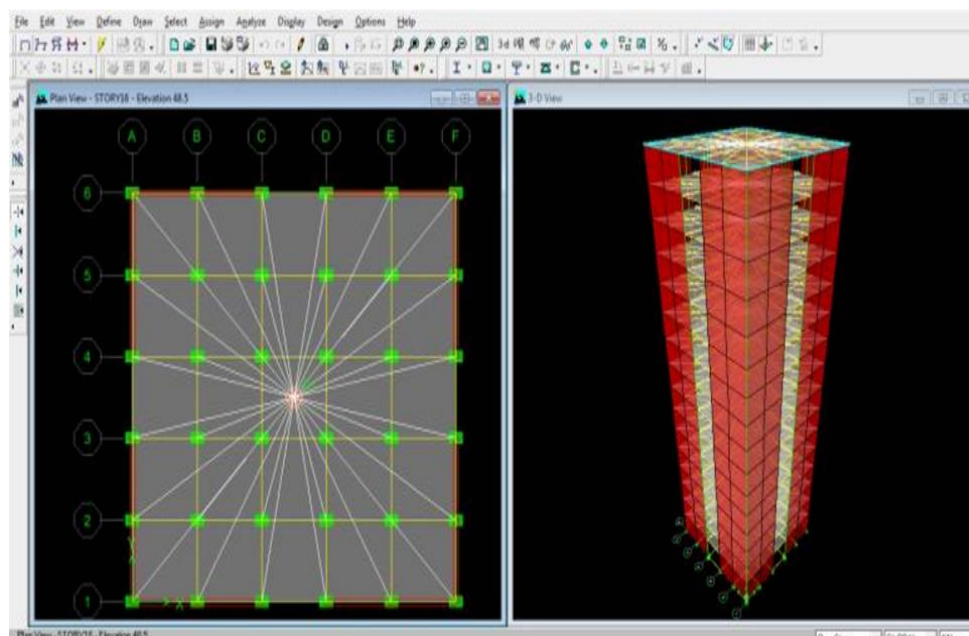


Fig 9 Model 3

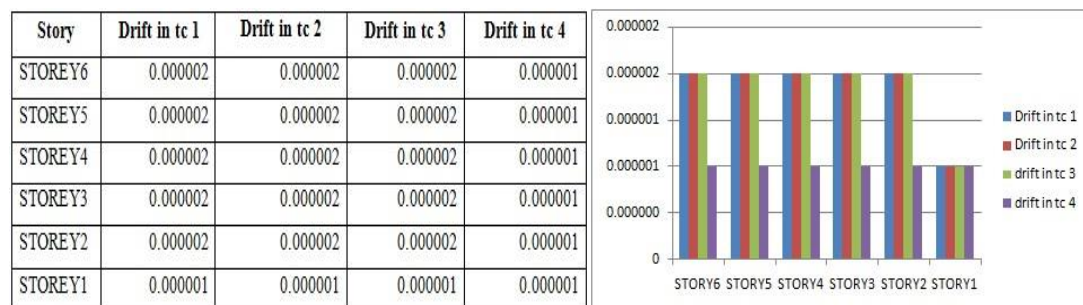
V. RESULTS AND DISCUSSIONS

5.1 STOREY DRIFT

The lateral displacement is known as drift. An example of storey drift is movement of a multi-story structure with respect to the one below it in the hierarchy of levels. Between an earthquake, the difference in roof and floor displacements, normalized by storey height, is known as "inter storey drift." An inter-story drift of 0.1 implies that roof of a 10-foot-tall level is shifted by 1 foot in reference to flooring below.

a.G+5

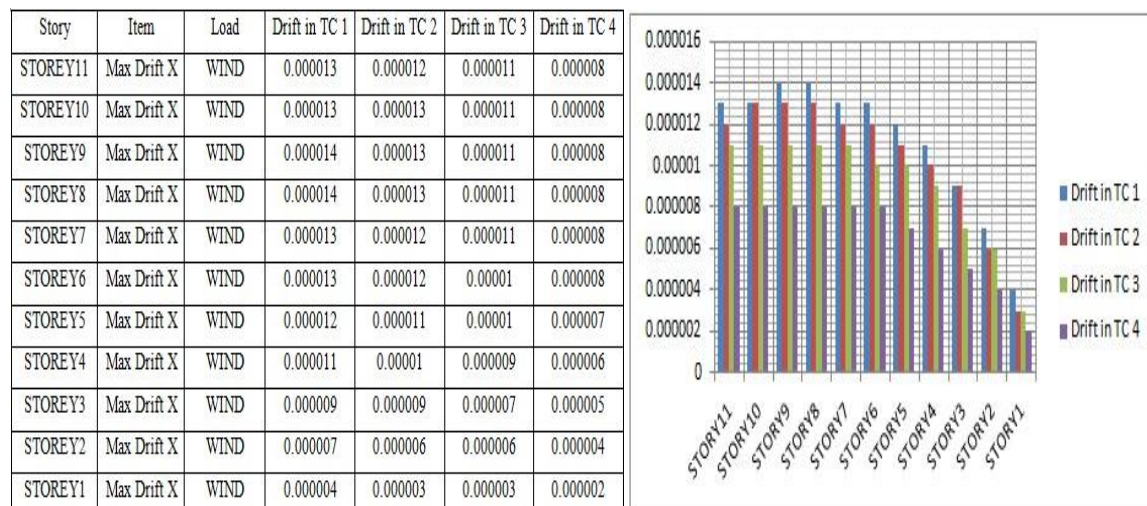
Table5. Drifting Values into terrain groupings (all following tables in meters)



As seen by this graph, terrain type 4 has lower values for storey drift (lateral displacement). Low-rise structures in terrain category 4 are less affected by wind load. When comparing low-rise structures in terrain categories 1 and 4, the percentage decrease in drift is 50%; in terrain categories 2 & 4, it is 50%; and in terrain categories 3 & 4, it is 50%.

b. G+10

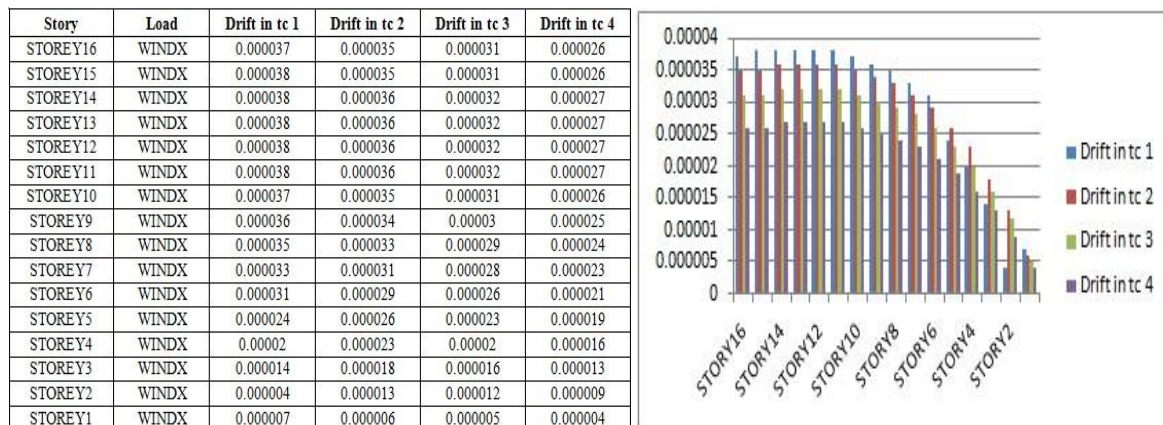
Table 6 Drifting Values into terrain categories



Terrain type 4's value of storey drift (lateral displacement) is lower than other terrain types (Terrain category 1,2,3). In each Terrain type, storey drifting values were observed to reduce from top storey to bottom storey. According to a comparison between terrain categories 1 and 4, percentage of drift reduction in medium rise structures is 38.46 percent, 33.33 percent for terrain category 2, and 27.27 percent for terrain category 3.

c. G+15

Table7 Drifting Values into terrain categories



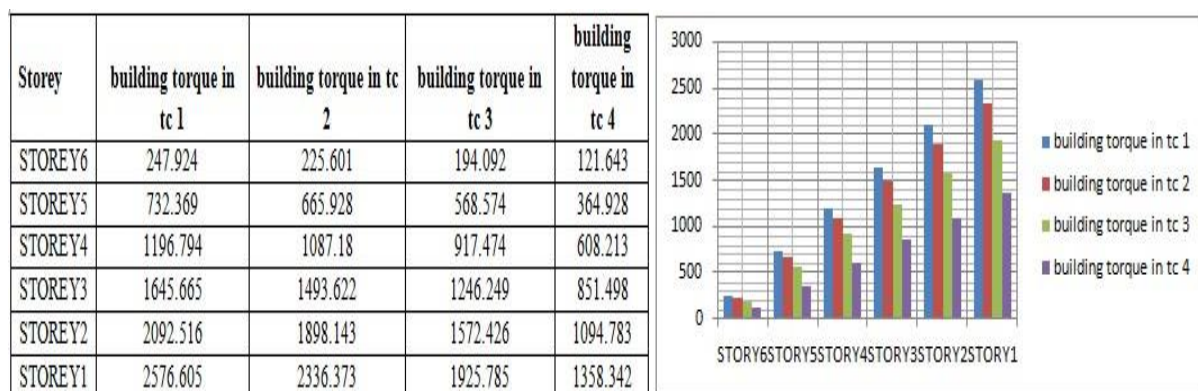
High-rise buildings possess larger values for storey drift (lateral displacement) as lower- & moderate-rise structures. While storey drift (lateral displacement) in Terrain category 4 has a lower value compared to other terrain types (Terrain category 1,2,3). Drift in high-rise structures is reduced by 29.73 percent when comparing terrain categories 1 & 4, by 25.71 percent when comparing terrain categories 2 & 3, & by 16.12 percent when comparing terrain categories 3 & 4.

5.2. STOREY SHEARS & OVER TURNING MOMENTS BUILDING TORQUE (T)

Twisting or turning force which helps to produce rotation around some fixed point, such as the center of mass, is known as torque.

a. G+5

Table8: Building Torque (t) into terrain categories

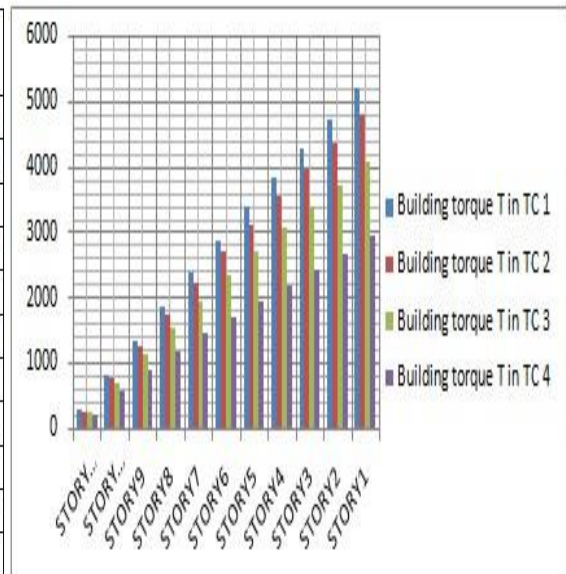


Torque value T for low-rise structures is lower for terrain category 4 than for other kinds of terrain (Terrain category 1, 2, 3). Building torque, on the other hand, was found to have lower values for stories 6 as well as highest values for stories 1 and 2. Between terrain categories 1 and 4, the percentage of drift reduction is 50.93 percent, with 46.08 percent in categories 2 & 4; proportion of drift decrease is 37.32 percent between terrain categories 3 & 4.

b. G+10

Table9 Building Torque (t) into terrain category

Storey	Load	Building torque T in TC 1	Building torque T in TC 2	Building torque T in TC 3	Building torque T in TC 4
STOREY11	WIND	271.897	257.729	226.69	188.072
STOREY10	WIND	810.785	767.876	674.35	552.288
STOREY9	WIND	1341.504	1266.021	1110.432	884.211
STOREY8	WIND	1863.748	1750.525	1533.757	1179.122
STOREY7	WIND	2377.41	2221.516	1944.354	1439.867
STOREY6	WIND	2878.604	2677.93	2338.912	1683.841
STOREY5	WIND	3363.049	3118.257	2713.394	1927.127
STOREY4	WIND	3827.474	3539.509	3062.295	2170.412
STOREY3	WIND	4276.345	3945.952	3391.07	2413.697
STOREY2	WIND	4723.196	4350.472	3717.247	2656.982
STOREY1	WIND	5207.285	4788.703	4070.606	2920.541

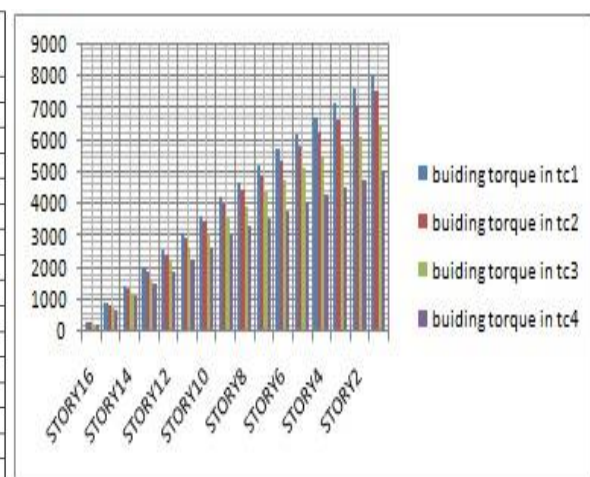


Terrain type 1 is most favorable for medium-rise structures (G+10), whereas terrain category 4 is the least favorable for medium-rise buildings (G+10). Building twist value grows from uppermost to lowestmost stories. For medium-rise structures, the difference among terrain categories 1 - 4 is 30.82 percent; among terrain categories 2 & 4 it's 27.02 percent; and among terrain categories 3 & 4 it's 17.03 percent.

c. G+15

Table10 Building Torque (t) into terrain category

STOREY	Load	Building torque in tc1	Building torque in tc2	Building torque in tc3	building torque in tc4
STOREY16	WINDX	290.14	275.499	246.782	225.601
STOREY15	WINDX	865.494	821.694	734.896	666.421
STOREY14	WINDX	1433.487	1360.719	1214.883	1091.867
STOREY13	WINDX	1994.166	1892.62	1686.81	1502.209
STOREY12	WINDX	2547.58	2417.445	2150.747	1897.722
STOREY11	WINDX	3093.776	2935.242	2606.761	2278.679
STOREY10	WINDX	3632.663	3445.389	3054.42	2642.895
STOREY9	WINDX	4163.383	3943.534	3490.503	2974.819
STOREY8	WINDX	4685.627	4428.038	3913.827	3269.729
STOREY7	WINDX	5199.289	4899.029	4324.424	3530.474
STOREY6	WINDX	5700.483	5355.442	4718.982	3774.449
STOREY5	WINDX	6184.928	5795.77	5093.465	4017.734
STOREY4	WINDX	6649.353	6217.022	5442.365	4261.019
STOREY3	WINDX	7098.224	6623.464	5771.14	4504.304
STOREY2	WINDX	7545.075	7027.984	6097.317	4747.589
STOREY1	WINDX	8029.163	7466.215	6450.676	5011.148



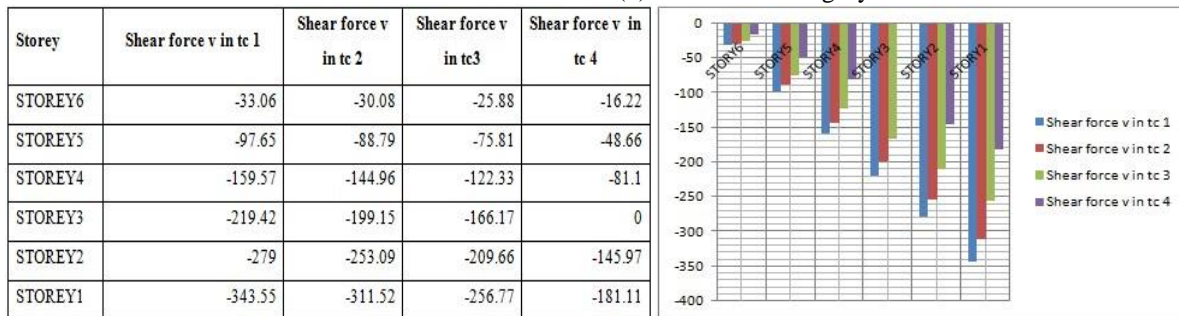
All terrain types (i.e., terrain categories 1, 2, and 3) have a lower value for producing torque (T) than the fourth terrain category (i.e., terrain category 4). When comparing high-rise structures with different terrain categories, the percentage of drift reduction is 22.24 percent in terrain classification 1; 18.11 percent in terrain category 2; and 8.58 percent in terrain class 3-4

5.3. SHEAR FORCE (V)

The unbalanced vertical force to left or right of section can be used to describe shear force at beam's C/S.

a.G+5

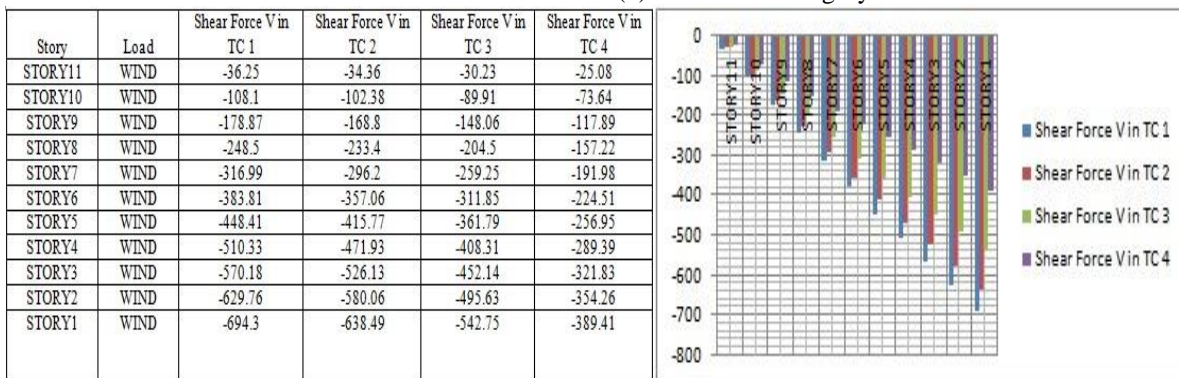
Table11. Shear force (v) into terrain category



The highest shear force was found in terrain type 1 & the least value was found in terrain type 4, as shown in the table and graph above. This value climbs from the sixth floor to the first floor in low-rise structures. Among terrain type 1 & 4 varied, the percentage of drift reduction is 50.93 percent, with 46.07 percent in terrain category 2 as well as terrain category 4, and 37.32 percent in other two categories, respectively.

b.G+10

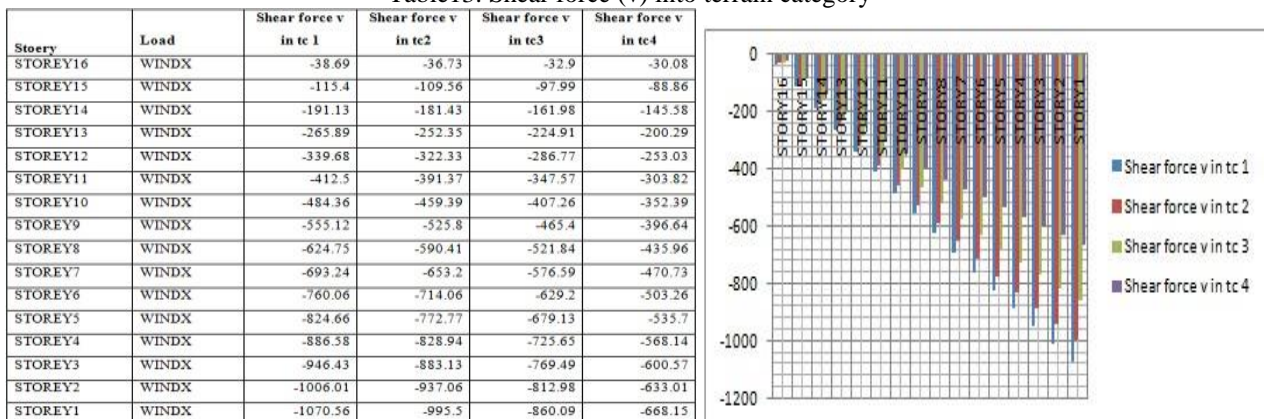
Table12. Shear force (v) into terrain category



It's also true for medium-rise structures, where shear force is at its lowest in terrain type 4 & highest in category 1. Between terrain type 1 & 4 varied, the percentage of drift reduction is 30.81 percent, 27 percent in Terrain Category 2 & 4 as well as 17.53% for Terrain Category 3 & 4.

c.G+15

Table13. Shear force (v) into terrain category



In all instances, highest shear force value was found in terrain class 1 & lowest shear force value was found in terrain category 4. The shear force values of low- and medium-rise structures are lower than those of medium- and high-rise constructions. Shear force deflection is inversely proportional to its magnitude. There is a 22.5 percent decrease in drift in high-rise structures compared to terrain category 1, 18 percent in terrain category 2 & 4, and 8.57 percent in terrain category 3 & 4.

5.4. BENDING MOMENT (M)

Beam bending moment can be calculated by summing up moments of all forces acting on it, either to left or right.

a. G+5

Table14. Bending moment M into terrain category

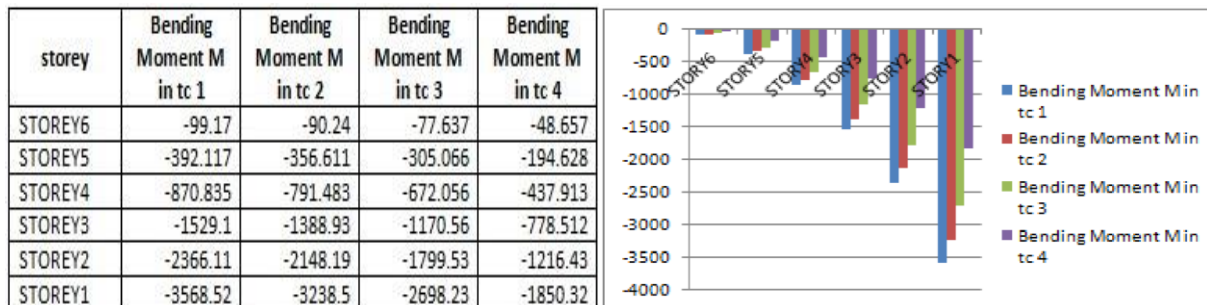
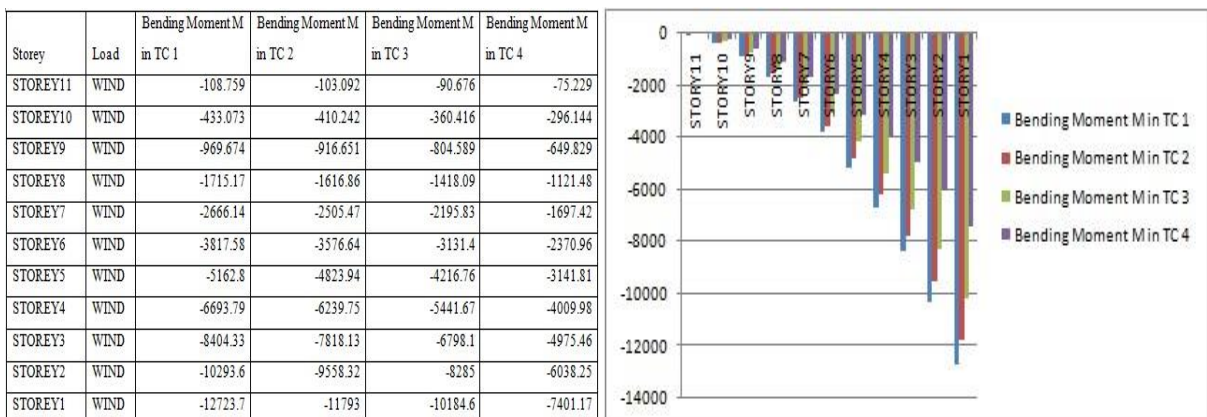


Figure 1 shows that terrain category 1 has the highest bending moment, whereas terrain category 4 has the lowest bending moment. In low-rise structures, Bending moment value rises from 6th floor to the first floor. When comparing low-rise structures in terrain categories 1 and 4, the percentage decrease in drift is 50.93 percent; in terrain categories 2 and 3, the percentage decrease is 46.085 percent; & terrain categories 3 & 4, percentage reduction is 37.32 percent.

b.G+10

Table15. Bending moment M into terrain category.

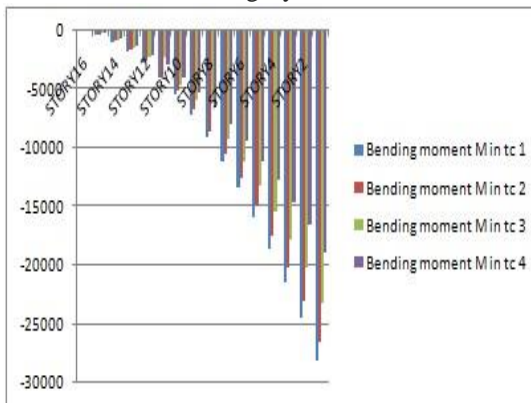


Medium-rise structures have a Bending moment that ranges from a minimum of four to a maximum of one in all storeys for terrain categories of four and 1. When comparing terrain categories 1 & 4, percentage decrease in drift in medium-rise structures is 30.82 percent, 27.02 percent in terrain groups 2 as well as 4, & 17.035 percent in terrain types 3 & 4.

c.G+15

Table 16. Bending moment M in terrain category

Storey	Load	Bending moment M in tc 1	Bending moment M in tc2	Bending moment M in tc3	Bending moment M in tc4
STOREY16	WINDX	-116.056	-110.199	-98.713	-90.24
STOREY15	WINDX	-462.254	-438.877	-392.671	-356.809
STOREY14	WINDX	-1035.65	-983.165	-878.624	-793.555
STOREY13	WINDX	-1833.32	-1740.21	-1553.35	-1394.44
STOREY12	WINDX	-2852.35	-2707.19	-2413.65	-2153.53
STOREY11	WINDX	-4089.86	-3881.29	-3413.65	-3065
STOREY10	WINDX	-5542.92	-5259.44	-4678.12	-4122.16
STOREY9	WINDX	-7208.28	-6836.86	-6074.32	-5312.09
STOREY8	WINDX	-9082.53	-8608.07	-7674.32	-6619.98
STOREY7	WINDX	-11162.2	-10567.7	-9369.62	-8032.17
STOREY6	WINDX	-13442.4	-12709.9	-11257.2	-9541.95
STOREY5	WINDX	-15916.4	-15028.2	-13294.6	-11149
STOREY4	WINDX	-18576.1	-17515	-15471.5	-12853.4
STOREY3	WINDX	-21415.4	-20164.4	-17780	-14655.2
STOREY2	WINDX	-24433.5	-22975.6	-20218.9	-16554.2
STOREY1	WINDX	-28180.4	-26459.8	-23229.2	-18892.7



Based on the graphs and tables shown above, the same conclusion might be drawn for high-rise structures as for lower- & moderate-rise ones. At terrain category1, maximal bending moment and minimal shear force were observed in all cases. Low-rise structures have lower values for bending moments than medium- and high-rise structures. Shear force deflection is inversely proportional to its magnitude. There is a 22.22 percent decrease in high-rise building drift when comparing terrain categories 1 and 4, an 18.11 percent reduction when comparing terrain categories 2 and 3, and an 8.58 percent decrease when comparing terrain types 3 & 4.

VI. CONCLUSIONS

The following findings may be drawn from research described above:

- In G+5 building model, values of storey drifts in all terrain categories up to 2ndstorey remain constant; however, it drops to 1ststorey, indicating that wind has less of an impact on low-rise structures.
- The value of storey drift falls from the top floor to the bottom story in medium and high rise structures. Terrain type 1 has highest drift values, while terrain category 4 does have lowest drift values.
- Terrain type 1 yielded the highest levels of building torque (T) compared to the other terrains. A fixed support at the bottom of a building reduces twist value from sixth floor to first floor.
- At terrain category 1, the optimum levels of Shear forces & Bending moments may be found. As you go down the storeys, the pressures and times get less and smaller
- In all circumstances, the highest values are found in terrain category 1, while the lowest values are found in terrain class 4.
- The conclusion drawn from this is that structures in terrain type 4 are not affected by wind as much as those in other terrain categories.

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