MULTISTORY BUILDING ALONG AND ACROSS WIND ANALYSIS

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Abstract : Wind is a perceptible natural motion of air relative to earth surface especially in the form of air current blowing in a particular direction .The major harmful aspect which concern to civil engineering structures is that, it will load any and every object that comes in its way. Wind blows with less speed in rough terrain and higher speed in smooth terrain present study is based an to determine .Wind load is really the result of wind pressures acting on the building surfaces during a wind event.

This wind pressure is primarily a function of the wind speed because the pressure or load increases with the square of the wind velocity. Structural walls, or shear walls, are elements used to resist lateral loads, such as those generated by wind and earthquakes .The effect of gust factor method multistory building along wind and across wind analysis of IS 875 part 3 (2015) on difference H/B ratio and different terrain category for along and across wind analysis. There are several model analysis using ETAB-2016.

IndexTerms - **wind, terrain category, along wind , across wind , ETAB 2016**

I. INTRODUCTION

In general, for design of tall buildings both wind as well as earthquake loads need to be considered. Governing criteria for carrying out dynamic analyses for earthquake loads are different from wind loads. The contribution of the higher mode effects are included in arriving at the distribution of lateral forces along the height of the building. As per IS 875(Part 3):2015, when wind interacts with a building, both positive and negative pressures occur simultaneously, the building must have sufficient strength to resist the applied loads from these pressures to prevent wind induced building failure. Load exerted on the building envelope are transferred to the structural system and they in turn must be transferred through the foundation into the ground, the magnitude of the wind pressure is a function of exposed basic wind speed topography, building height, internal pressure, and building shape .The main objective of this study is to carry out the analysis of G+28 multistory residential building against wind loads as per Indian standard codes of practice IS 875(Part 3):2015. First, the sensitivity of base shear of the building with respect to the location of the building at different wind zones in India is investigated. The wind loads on the building are calculated assuming the building to be located at Mumbai. The member forces are calculated with load combinations for Limit State Method given in IS 456:2000 and the members are designed for the most critical member forces among them. The building is subjected to self weight, dead load, live load as per IS 875(Part 1, Part 2):1987. Safety of the structure is checked against allowable limits prescribed for base shear, roof displacements, inter-storey drifts and accelerations in codes of practice and other references in literature on effects of wind loads on buildings. The emergence of modern materials and construction techniques resulted in structures that are often, to a degree unknown in the past, remarkably low in damping, and light in weight. Generally such structures are more affected by the action of wind. The structural engineer should ensure that the structure should be safe and serviceable during its anticipated life even if it is subjected to wind load. Wind forms the predominant source of loads, in tall free standing structures. The effect of wind on tall structures can be divided into two components they are

1. Along-wind Effect
2. Across-wind Effect

Along wind loads are caused by the drag components of the wind force whereas the across –wind loads are caused by the corresponding lift components

II. LITERATURE REVIEW

***** TOPIC: Numerical analyses of aerodynamic characteristics of integrated L -shaped high-rise building

Weibin Yuan , Zhao Wang , Hao Chen , Kexing Fan

Analysis of wind environment around integrated L-shaped buildings of different length-to-width ratios is carried out by using 2D and 3D numerical simulation methods. The Reynolds Stress Model is employed to examine the velocity distributions, surface pressures and vortex structures around the buildings for various different wind directions, in which the initial altitude of resonance region and shape coefficient are discussed in detail. The results show that the velocity along the central shaft is heavily affected by wind direction and the initial altitude of resonance region increases with increased length-to-width ratio. The vortex structure such as generating, evolution and shedding around the L-shape high-rise building under a 45 °wind direction is also investigated. The shape coefficients predicted from the simulations are found to be consistent with those recommended in some national codes, although they are not fully considered in the current design codes.

The RSM of flow pass the L-shaped high-rise buildings have been carried out at various wind direction angles. The results are showed for the flow field around an integrated L-shaped building including the near wake. A detailed comparison is made between experiments, design codes, and simulations. The wind-induced re- sponse under across-and-along wind load and the development of vertex around the building are analysed and discussed. From the present study, the following conclusions can be drawn

1. Around the L-shaped high-rise building (from $X / L = -0.3$ to 0.3 and $Y / L = -0.5$–0.9), the velocity of flow has the biggest extent

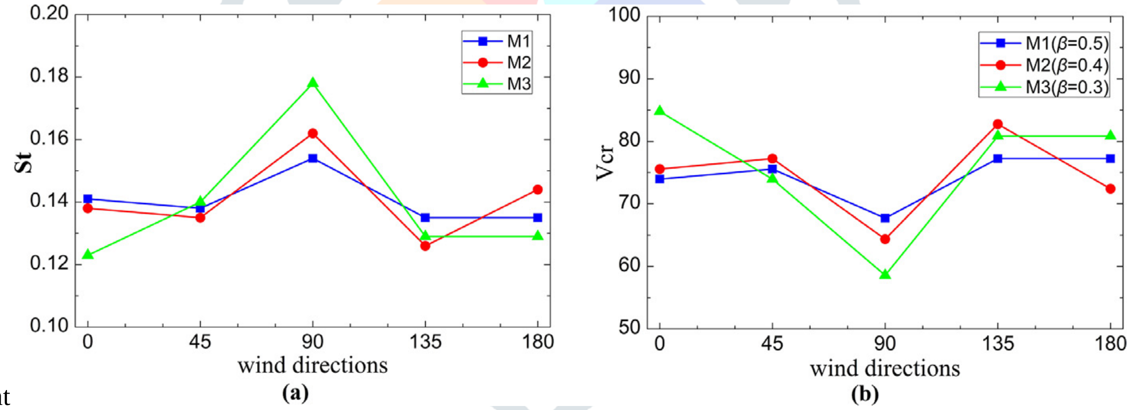


Figure 1 RESONANCE CHARACTERISTICS OF MODELS: (A) STROUHAL NUMBER; (B) CRITICAL WIND SPEED OF VARIATION FOR ALL WIND DIRECTIONS.

The velocity along the central shaft is most heavily affected by wind direction. 2. The surface pressure rises continuously but slowly, and the values get smaller with decreased β. Furthermore, at the height near to Z / H = 0.05, the minimum values are negative for β= 0.4 and 0.3 and they have a sharp decrease at the top floor. This kind of feature is not considered in the current version of GB50 0 09-2012 and ASCE/SEI 7-05 codes. 3. The vortex structures such as generating, evolution and shed- ding around the L-shaped high-rise building under 45 °wind direction are examined in detail, which provides the support for crosswind windward load function. In addition, the shapes and figures of streamlines indicate a good fit to vortex shedding period of 15.6 s continuously. 4. With the reduction of β, the initial altitude of resonance region of L-shaped high-rise building reduces and the region restricts the development of the height of the high-rise buildings. For the discussed two L-shaped structures which have similar natural vibration properties, the resonance regions enlarge with the decrease of β, indicating that the L-shaped structure of low β value is not suitable.

***** TOPIC: EFFECT OF WIND LOAD ON TALL BUILDINGS IN DIFFERENT TERRAIN CATEGORY

Mohammed Asim Ahmed1, Moid Amir, Savita Komur, Vaijainath Halhalli

Wind is a perceptible natural motion of air relative to earth surface ,especially in the form of air current blowing in a particular direction The major harmful aspect which concern to civil engineering structures is that, it will load any and every object that comes in its way. Wind blows with less speed in rough terrain and higher speed in smooth terrain .This paper presents displacement accour in different storey due to wind in different terrain category. Three models are analyses using ETABS 2015 package. Present works provides a good source of information about variation in deflection as height of model changes and percentage change in deflection of same model in different terrain category .

- As the height of the model increases, deflection on top storey also increases
- Due to wind load, Deflection on model-3 is more than model-2 and model-1 as shown in Fig-7,8, and 9
- In Model-1: Deflection in TG-1 is 6%, 19% and 38.3% more than TG-2, TG-3, and TG-4 on top storey.
- In Model-2: Deflection in TG-1 is 5%, 15% and 24.5% more than TG-2, TG-3, and TG-4 on top storey.
- In Model-3: Deflection in TG-1 is 4%, 13% and 18.9% more than TG-2, TG-3, and TG-4 on top storey.
- But in all 3 models %age deflection between TG-1 and TG-4 is maximum at 3rd storey .

***** TOPIC: Generalized gust-front factor: A computational framework for wind load effects

Z.R. Shu , Q.S.Li ,Y.C.He , P.W.Chan

This paper presents a unified framework of a generalized gust-front factor for modeling winds in gust fronts and their attendant load effects on structures. This is analogous to the gust loading factor, a widely recognized format used world-wide in codes and standards, for the treatment of gusts in conventional boundary layer winds. The generalized gust-front factor encapsulates dynamic features inherent in wind load effects in gust-fronts originating from winds in downbursts/thunderstorms. In view of the computational complexity of the formulation and the need to promote the usage of such a framework, a web based portal is provided. The portal at http://gff.ce.nd.edu can be conveniently utilized to evaluate the generalized gust-front factor in conjunction with international standards. The proposed generalized gust-front factor reduces to conventional gust loading factor in the case of boundary layer winds, thus, it represents a most generalized dynamic wind load effects modeling framework on structures that is compatible with the format used in ASCE 7 or any other international standard.

This paper introduces a generalized gust-front factor framework that captures dynamic features inherent in wind load effects in gust-fronts originating from a down burst/thunderstorm. This is akin to the gust loading factor format used in codes and standards world-wide for the treatment of conventional boundary layer winds. In the examples presented here, it is observed that as a result of gust-front winds in both ASCE 7 and Euro code standards, a higher local ESWL distribution exists, despite the fact that the dynamic effects (GG,G-F) for the example buildings were lower than those in conventional boundary layer winds (GGLF). This underscores the role of enhancement in the kinematic effects introduced through

the wind profile [VG-F(z)] in gust-fronts, which results in locally enhanced loads around zmax, to the overall design load. Moreover, one should not overlook the possible load enhancement due to transient aerodynamics (CD,G-F), which may result in enhancing local pressures or overall force coefficient in the neighborhood of 5_20% based on preliminary observations thus far in comparison to conventional CD. Additional research in the measurement of drag force in suddenly applied gust-fronts may further reinforce their initial finding.

It is anticipated that the generalized gust-front factor presented here would experience further refinements over time similar to the many subsequent modifications/enhancements in conventional gust loading factor presented by Davenport [6], including its application to rigid structures even though the current format may still be acceptable for the case. For immediate design application, a computational framework of the gust-front factor is available in a user-friendly web-based portal (http://gff.ce.nd.edu). This promises to offer application of gust-front factor to international codes and standards and the flexibility of examining several loading configurations on-the-fly without actually becoming involved in detailed intensive computations for the evaluation of the generalized gust-front factor in terms of Eq. (9). This feature promises to make this as a valuable design tool that offers attractive features regardless of the user's background in the various underlying computational aspects.

It is worth noting that this framework relies on a series of simplifications and assumptions not only in an attempt to realistically capture the characteristics of gust-front winds but also to enable a closed-form solution, e.g., half-sine pulse wave, Vicroy Model, quasi- steady and strip hypothesis of the loading used in conventional gust loading/effect factor approach. These assumptions and hypothesis may not be fully representative of the actual complex gust-front winds with rapidly evolving wind field and attendant pressures/loads may differ spatially and temporally, e.g., effects of aerodynamics due to the opposing velocity gradients [31]. Experimental verification will be necessary in the future to either corroborate initial assumptions and validate the current framework or introduce modifications as deemed necessary. The web-enabled portal introduced here can be utilized for convenient modeling and as a tool for analysis/design. A preliminary framework has been introduced that is immediately applicable, but it also accommodates continual improvements as additional information becomes available. In particular, advances in understanding of gust fronts and the rational characterization of the flow field and its interaction with structures is necessary.

***** TOPIC: Gust factors for tropical cyclone, monsoon and thunderstorm winds

Z.R. Shu , Q.S.Li ,Y.C.He , P.W.Chan

Gust factor, defined as the ratio of peak gust wind (of a given duration) to mean wind speed (for a given averaging time), is an important parameter for describing the turbulence characteristics of wind flows. Such information is useful for structural design, prevention of air pollution, air ventilation assessment and prospection of wind farms, etc. This study presents a comprehensive investigation on the characteristics of gust factor in tropical cyclones, monsoons and thunderstorms. Based on a 6-year wind database recorded at 6 meteorological stations in Hong Kong, the relations of gust factor with various wind parameters are explored. It is found that, in general, the variation of gust factor depends greatly on mean wind speed. This paper focuses on the comparison of gust factor in connection with tropical and extra-tropical winds, which shows that the deviation of gust factors is related to topographic condition and wind speed. The characteristics of gust factor associated with thunderstorm events are also investigated, and it is found that thunderstorms may generate larger statistic maximum values of gust factor when compared with those during strong synoptic winds. The dependence of gust factor against different gust durations are comparatively established, which implies that the time scales for thunderstorms are markedly different from those of tropical cyclones and monsoons. Finally, the correlation of gust factor with turbulence intensity is presented and discussed.

This study investigated the wind characteristics associating with different wind storms based on six-year wind measurements from a network of meteorological stations in Hong Kong, with emphasis on the evaluation of gust factors under tropical cyclones, monsoons and thunderstorms. The variation of gust factor was found to be sensitive to mean wind speed. It is also strongly related to the terrain characteristic and topographic features. The comparisons of gust factor in relation to different storm types were estimated. The deviation between tropical cyclone and monsoon cases is generally small under strong wind condition. Comparing with tropical cyclone and monsoon winds, thunderstorms may yield larger statistic maximum values while the median values of the different wind climates are approximately equivalent. The correlations of gust factor with different gust durations were comparatively investigated. The regression slope for tropical cyclones is generally more steepthan that for monsoon winds, which is possibly due to the different sizes of gust. The time-dependence curve for thunderstorms cannot be consistently well represented in accordance with those for monsoon and tropical cyclone winds, which implies the time scales of thunderstorms are different from those of the other two types of wind storms. The case study at SHW showed that different upwind terrain conditions may account for different features of time correlations. Last but not least, the relation between gust factor and turbulence intensity was presented and compared with several existing formulas, which shows a good agreement.

The authors would like to express their gratitude to Hong Kong Observatory for the provision of the wind data records and the permission of using the data for this study.

***** TOPIC: Natural convection flows along a 16-storey high-rise building

Yifan Fan , Yuguo Li , Jian Hang , Kai Wang , Xinyan Yang

The flow caused by natural convection adjacent to a heated vertical wall (wall flow) is an important mechanism in the creation of wind flows in a city when the background wind is weak. The wall flows along a 16-storey building were measured in Guangzhou, China. Fourteen three-dimensional ultrasonic anemometers were installed on three floors to study the boundary layer structure. Continuous measurements were taken during three test periods. The Rayleigh numbers were approximately 10^{13}, 10^{13} and 10^{14} at the height of the 5th, 10th and 14th floors, respectively. The diurnal changes in the velocity of the wall flows, the wall surface temperature and the ambient air temperature were analysed. Our new experimental data support the theory that the natural convection boundary layer has a three layer structure, i.e. an inner viscous layer, a transition layer and an outer turbulent layer, as first proposed theoretically by Wells and Worster. The outer turbulent layer is governed by the law of plumes with a Gaussian profile. The vertical velocity changes with g04=9x1=3 along the vertical wall, where g0 is the
buoyancy force and x is the coordinate along the vertical wall. It was noted that only the building's roof was significantly cooler than the ambient air at night, due to the sky radiation effect, so no downward flow adjacent to the wall caused by the cooling plate effect was found in our field measurements.

The wall flows (natural convection flows) along a 16-storey high-rise building were measured. The knowledge of real building scale turbulent flow was broadened. The results can be used to model urban canopy layer ventilation. Based on the existing theory, the laboratory experimental data and the results of these in situ measurements, the following conclusions can be drawn.

The turbulent boundary layer of natural convection along a high rise building wall can be divided into an layer and an outer turbulent layer. The flow in the outer turbulent layer is governed by the rule of plumes with a Gaussian profile across the outer turbulent layer. Theverticalvelocityalongthewallincreaseswithg04=9x1=3 .The widths of the boundary can be approximated as the plume widths at a certain height. The widths of the boundary layers have an order of 6 m, 7 m and 8 m at 5F, 10F and 14F, respectively, when the Rayleigh numbers are on the order of 10^{13},10^{13} and 10^{14} at the corresponding heights. The flow in this experiment is in Region II, where the buoyancy instability criterion holds true when the Rayleigh number is on the order of 10^{14}. Only the roof of the building might be significant cooler than the ambient air due to the sky radiation effect. There is no downward flow adjacent to the vertical wall caused by the ‘cooling plate effect’ analogous to down slope flow.

TOPIC: Wind loading on high-rise buildings and the comfort effects on the occupants

Authors: Ramtin Avini, Prashant Kumar, Susan J. Hughes

Research highlights

- Wind loads for tall buildings studied by codes and Computational Wind Tunnel (CWT)
- Design Standards gave rise to larger surface pressures than CWT estimates
- Complex terrain led to more fragmented vortices in New York City
- Shielding effect was crucial for depleting the mean component of the load

The design of low to medium-rise buildings is based on quasi-static analysis of wind loading. Such procedures do not fully address issues such as interference from other structures, wind directionality, across-wind response and dynamic effects including acceleration, structural stiffness and damping which influence comfort criteria of the occupants. This paper studies
wind loads on a prototype, rectangular cross-section building, 80m high. Computational Wind Tunnel (CWT) tests were performed using Autodesk Flow Design with the buildings located in London and New York City. The analysis included tests with and without the surrounding structures and manual computation of wind loads provided data for comparison. Comfort criteria (human response to building motion) were assessed from wind-induced horizontal peak accelerations on the top floor. As expected, analytical methods proved conservative, with wind pressures significantly larger than those from the CWT tests.

Surrounding structures reduced the mean component of the wind action. As for comfort criteria, across-wind direction governed the horizontal accelerations with wind targeted on the building's narrow face. CWT tests provide a cheaper alternative to experimental wind tunnel tests and can be used as preliminary design tools to aid civil engineers, architects and designers with high-rise developments in urban environments.

***** TOPIC: Variations in wind load on tall buildings due to urban
development

Authors: Ahmed Elshaer, Anant Gairola, Kimberley Adamek,
Girma Bitsuamlak

Highlights

- Numerical methodology to assess changes in wind load on buildings as a city develops is
- developed
- Generic and realistic city topology test cases are presented
- Variation of wind-induced risk with the change in urban topology is examined for both
- the structural and cladding system.

Due to the continuous urban development, it becomes necessary to investigate the complex aerodynamic interactions within the built environment. These interactions lead to a significant
variation in wind loads on structural systems and non-structural components. With the change
in urban topology, an individual building immersed in a complex surrounding can experience different flow mechanisms, such as wake effects and channeling. These flow mechanisms depend on the shape, height and location of the surrounding structures, which alter with the city
development. The current study investigates the risks associated with changing wind loads as
urban surroundings develop. The study adopts two cases. *Case I* examines the change in wind
loads on a typical tall building with generic surrounding configuration of different heights. For *Case II*, the built environment of the Financial District, Toronto is examined for three development stages. The changes in urban topology are found to have different impacts on structural and nonstructural elements from wind hazard perspective. Based on the study cases, mean wind pressures are reduced while fluctuations are increased as the urban environment becomes denser. The effect of increased pressure fluctuations on cladding elements is viewed as a higher wind risk due to damage accumulation.

*TOPIC: Effect of Static and Dynamic Wind Forces on RC Tall Structures at different Height, in different Zones and in different Terrain Category using Gust Factor Method As Per Is: 875 (Part 3) 1987

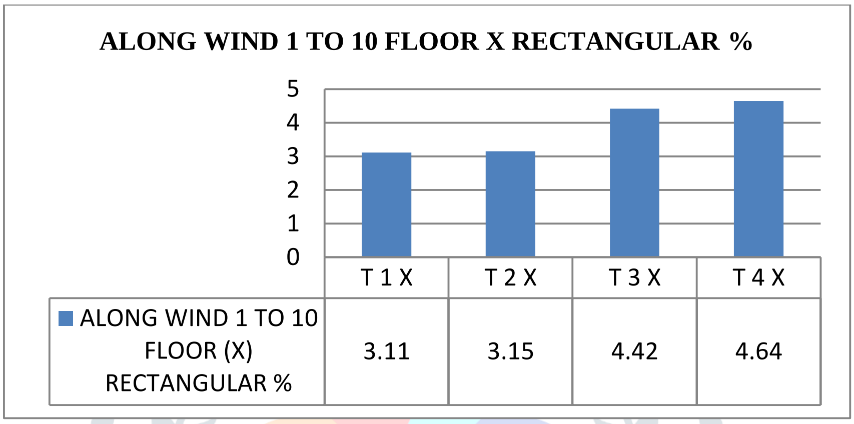
1Suraj Nayak U, 2Dr. Ananthayya M.B

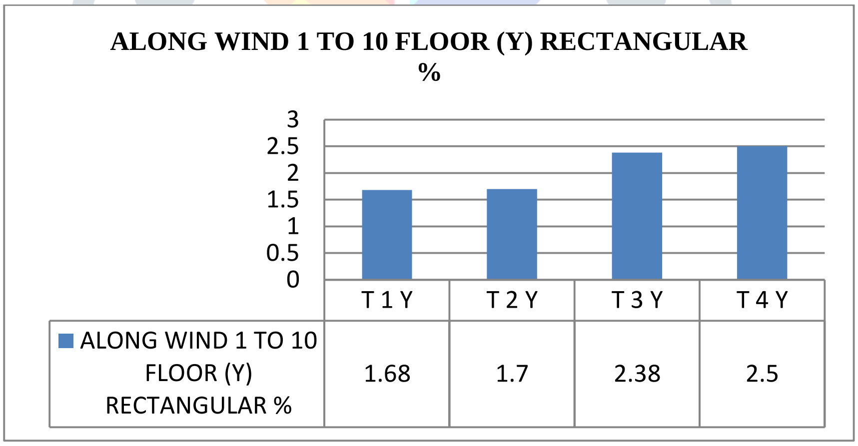
The high-rise Structure construction has become a feasible solution to the issues related with the urban society. Very tall buildings are being built due to the recent advancements in construction technology and material science. However, the comfort of occupants and safety of built structures under the action of lateral forces such as earthquake and wind is of major concern in engineering. Due to the introduction of new development methods and improvement of modern and new materials, new type of structures which are regular and irregular in shape with high flexibility and light weight properties has emerged. These kinds of structures are highly susceptible to wind. Therefore it is necessary to develop tools to enable the designer to estimate the effects of wind with a high degree of confidence. In this project, irregular shape of RC structures are analyzed for static and dynamic wind load cases and the severity of wind load on the structure in various wind zones (like 33m/s, 55m/s) at different heights and in different terrain category are studied. ETABS 15 is being used for the modeling of RC bare frames and to analyze the structure. This project focuses on the study of effect of wind response on different irregular shapes with gust response factor and without gust response factor method and also the variation of wind response factor for the irregular shaped RC structures in various wind zones and for different terrain category. In this present analysis, the variation of wind forces on particular RC bare frames at different wind zones, at different heights and also at different terrain category are shown. The effect of variation in terrain category is the major factor in this work because as the height increases the wind speed increases so the displacement increase as the storey height increases but as the terrain category varies from 1-4 the obstruction for the wind flow increases so the effect of wind force decreases on the particular High Rise Structure, when the wind load is applied in both X & Y-direction. The analysis has been done by considering Static and Dynamic wind load cases.

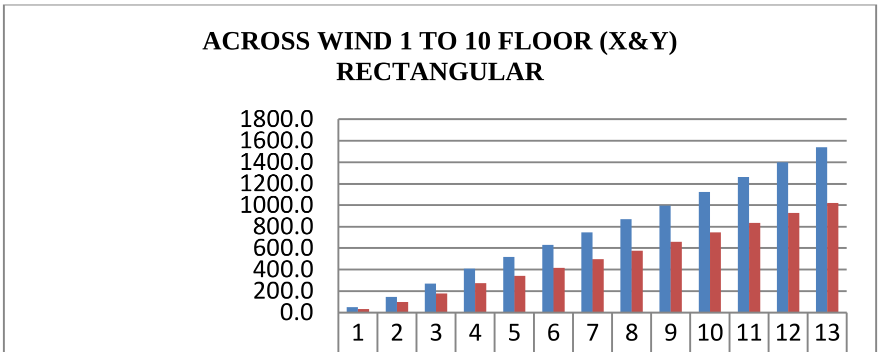
III. CONCLUSION

- As the height of the model increases, deflection on top storey also increases
- The determine wind analysis study high rise building are done MS EXCEL as per is 875 2015 for this purpose wind loading in term of along and across analysis done different condition the results of the analysis are show below in this graph.

  Rectangular plan:

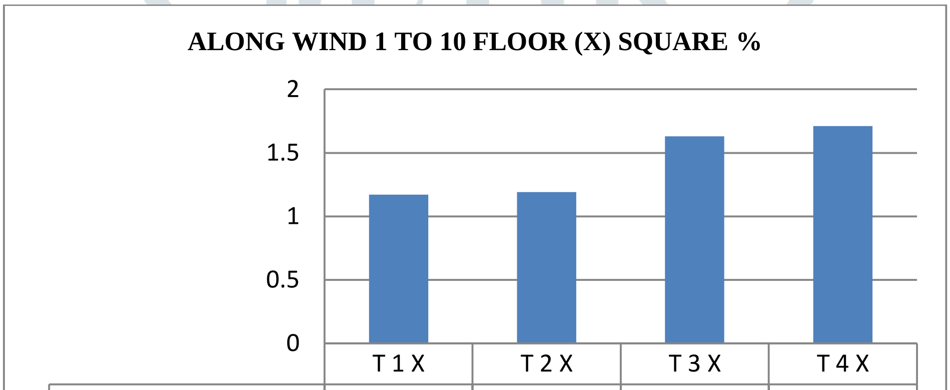




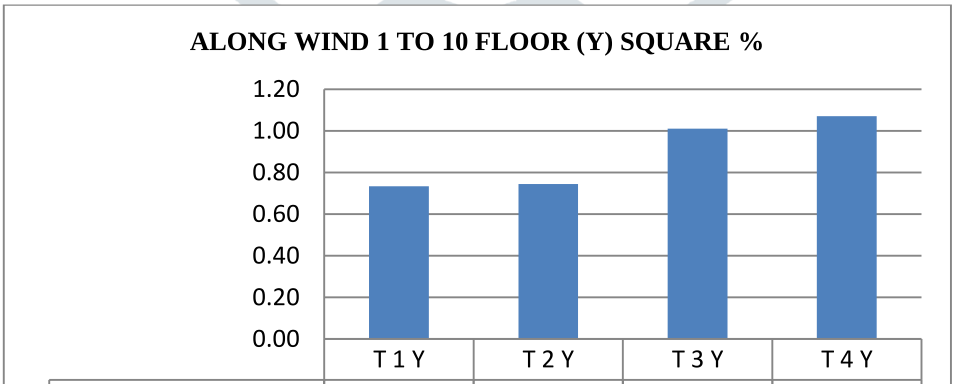


	1	2	3	4	5	6	7	8	9	10	11	12	13
ACROSS WIND 1 TO 10 FLOOR (X) RECTANGULAR	48.5	146	269	410	516	628	746	868	995	1125	1260	1398	1539
ACROSS WIND 1 TO 10 FLOOR (X) RECTANGULAR	32.1	96.9	178	272	342	417	495	576	660	746	835	927	1021

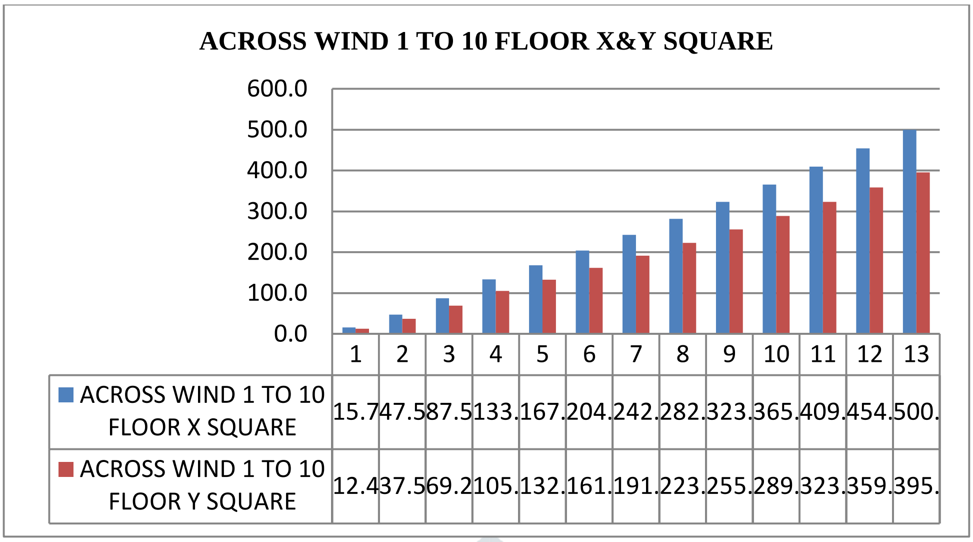
Square plan:



	T 1 X	T 2 X	T 3 X	T 4 X
ALONG WIND 1 TO 10 FLOOR (X) SQUARE %	1.17	1.19	1.63	1.71



	T 1 Y	T 2 Y	T 3 Y	T 4 Y
ALONG WIND 1 TO 10 FLOOR (Y) SQUARE %	0.73	0.74	1.01	1.07



FUTURE SCOPE

- Building analysis is done here by taking different condition height of building but it is suggested to exclusive experimental test building will be carried out in wind tunnel test to check and compare the analytical and experimental results.
- Infill walls may be considered and the effect of which can be observed.
- Analysis can be carried out for different heights and remaining wind zones.

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[14] Gust factors for tropical cyclone, monsoon and thunderstorm winds Z.R. Shu , Q.S.Li ,Y.C.He , P.W.Chan
[15] Natural convection flows along a 16-storey high-rise building Yifan Fan , Yuguo Li , Jian Hang , Kai Wang , Xinyan Yang
[16] Wind loading on high-rise buildings and the comfort effects on the occupants Ramtin Avini, Prashant Kumar, Susan J. Hughes
[17] Title: Variations in wind load on tall buildings due to urban development Ahmed Elshaer, Anant Gairola, Kimberley Adamek, Girma Bitsuamlak