

# To Study the Torsional Effect on L and T Shape Building Structure due to Wind Pressure

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**ABSTRACT:** Wind induced Loads on a building are invariably especially non-uniform and some twisting about its vertical axis results. The magnitude of this wind-induced moment or torque depends on the shape of Building, the influence of surrounding buildings and the direction of the wind. Even for symmetrical plan forms such as a square or rectangular in homogeneous surroundings, torsional forces occur when the direction of the wind is not along the line of symmetry. Torsional load effects are not the domain of tall buildings alone and significant eccentricities of wind-induced forces. Main objective of project is to Study the Torsional effect on an L and T shape structure due to wind pressure using experimental method and software analysis and comparing the results obtained from these methods. This study enables the designer to give the brief idea about Torsional moment induced in structure due to wind.

**KEYWORDS:** Wind load, Computational Fluid Dynamics (CFD), Torsional load.

## I. INTRODUCTION

Tall buildings have been designed and constructed since the beginning of the 20<sup>th</sup> century. In today's world, there are several buildings which have more than a hundred of floors. Design of such buildings has been preferred especially in overcrowded cities where the prices of building lands cost much. Detailed investigation of wind effects on tall buildings requires consideration of the building geometry, direction of the wind and topographic factors. Researchers conducted in the last 20 years show that the response of the building in the across wind and torsional directions are at least substantial as the response in along wind direction (Mendis, et al., 2007). There are some analytical procedures in literature that are utilised to solve the along wind response of buildings; however, there are no such relations defined in full for the across wind or torsional components or for the local pressure effects. Consequently, a widely accepted and effective tool for the determination of all these components is performing wind tunnel tests (Holmes, 2005). Moreover, wind tunnel tests provide the opportunity to analyse structures with extraordinary geometries which is not possible by using the traditional methods which employ equivalent static loads estimated from wind pressures multiplied by some constants that are derived for ordinary shapes. Every Available building codes and guideline gives more attention to wind load but remains silent about the torsional effect on structure due to wind pressure. But the AS /NZS 1170.2 2011 edition mentioned that A torsional loading requirement for tall buildings greater than 70 meters in height. In IS 875-Part 3 (Wind load) Scope of code noted that the in the case of tall building the design may have to check for torsional effect due to wind pressure is suggested. The characteristics of wind pressures are a function of the characteristics of the approaching wind, the geometry of the structure, and the geometry and proximity of the upwind structures. These effects are all incorporated into design codes such as AS1170.2:2011 (Standards Australia, 2011) in one form or the other, but mostly in a very approximate or generalised way. These complexities of wind and the loads it applies on structures should be kept in mind when designing a tall building. As shown in Figure 1, taller the building the more sensitive it is to wind loads as compared to earthquake loads. Taller buildings will demonstrate dominant mode shapes with shorter natural frequencies (longer periods) and cause complexities in their designs. With urban spaces around the world becoming more congested by the day, taller buildings are at high demand.

## II. LITERATURE SURVEY

**General:** - This chapter is devoted to the studies related to the history and the theoretical developments of wind effects on tall buildings. For understanding the effect of wind loading on structure is various authors and scientist contributed via publishing research papers, books and conferences.

**Review on literature: -P. MENDIS Et. Al. (2007):** - This paper provides an outline of advanced level of wind design, in the context of the Australian wind code, and illustrate the exceptional benefits it offers over simplified approaches. Wind tunnel testing, which has the potential benefits of further refinement in deriving design wind loading and its effects on tall building, is also emphasized. This paper has considered number of key factors associated with the design of tall buildings to the effects of wind loading, the general design requirement for structural strength and serviceability assume particularly importance in the case of tall building design as significant dynamic response can results from both buffeting and cross-wind wind loading excitation mechanism and it also explain the wind tunnel testing, comfort criteria to human response to building motion, use of dampers for effective energy dissipation and Computational Fluid Dynamic Techniques (CFD).

**Ravindra Ahlawat, Ashok Kumar Ahuja. (2015)** In this paper Experimental study is carried out on the 'Y' shaped tall building in an open circuit wind tunnel to investigate the wind loads generated on the building in isolated as well as interference condition. The Base Shear (Fx), Overturning Moment (My), Torsional Moment (Mz). acting on instrumented model were measured. For the isolated condition, the measurements were made for many wind incident angles. For studying the interference effect, two similar building model placing side by side and spacing between two models varied and they observed that wind incidence angle greatly affects the wind induced loads on the 'Y' plan shaped building For this they are perform three experimental setup one is individual setup A is side by side placing of 'Y' shaped building and setup B is tandem configuration where the 'Y' shape building model is placing front to front each other. After performing the wind tunnel testing on 'Y' shaped building they concluded the wind load on 'Y' plan shape building is highly influenced by the wind incidence angle. Interference effects are beneficial for setup B (Tandem Configuration) but have an adverse effect on setup A (Side by Side Configuration). Torsional moment on the building under interference condition may be greater than that of isolated condition due to the asymmetric distribution of wind around the building.

**Bhumika Pashine, V. D. Vaidya, Dr. D. P. Singh (2016):** - In this paper they are study the behaviour of high rise building against the wind force having two irregular geometry (T and L shape) and analysed for different heights. Both the geometries were investigated for 15, 25 and 30 storey and observed that all the parametric coefficient increase per unit length with increase in height. Also, direction of wind plays very vital role in behaviour of structure. The author performs only software analysis (STAAD Pro) of two irregular geometry with different height. They are observed during study the T shape building is more sensitive to wind than the L shape building hence less cost effective and serviceable. Torsional moment is one of the dominating factors and should be analysed properly in case of irregular geometry which increases per unit length with increase in height. Shear force either decrease or remains approximately constant per unit length with increase in height.

**N. Isyumov and P. C. Case. (2000):** - This is a conference paper is explaining about wind load induced torsional momentson structure they give the brief information about torsional load effect on tall building, building of intermediate height, and low building. Their concluding remark is very effective which talks about codes give insufficient attention to the effect of wind- induced torsion on structural frames. Wind-induced torque alters the distribution of wind forces within the main wind force resisting system. The partial loading requirement, while insufficient to fully estimate the effects of eccentricities in the overall wind-induced forces, is step in the right direction. Until the further data is available, it would be advisable to insist that the partial loading requirement, also be applied to low buildings which are now design for load patterns which don't fully recognize possible unbalances in the overall wind load.

**Daryl W. Boggs, Noriaki Hosoya, Leighton Cochran. (2000):** - This paper identifies some common sources of torsional loading in terms of building shape, interfering effects of nearby buildings and dynamic characteristic of the structural frames. It is shown that torsional loading is routinely larger than that provided for in most standards. They perform the wind tunnel testing on various shapes and measure the shear and torque on verity of elementary model shapes. In summary they mentioned the building codes and standards are lagged behind the recognition of torsion load type and ASCE 7 specifies an unbalanced load equivalent to an eccentricity of  $e/D=3.5$  percent and in Eurocode 1 specifies the eccentricity of 10 percent.

**Zhitian Zhang, Mohamed Elsharawy, and Ted Stathopoulos. (2014):** -In this paper the experimental details and the results of extensive wind tunnel parametric investigations on wind induced torsion on L shaped building models. Experiments collected data in terms of wind directions, building heights and aspect ratios. Comparisons with the results obtained from rectangular building specified in current design standards and codes of practice were also carried out it has been shown clearly that these building models do experience significant torsional loads. the paper demonstrate that the torsional wind loads developed on the L-shaped low-rise buildings must be considered for design purpose and should receive further attention for incorporation in design standard. They are performing the wind tunnel test on L shaped building model with aspect ratio B/L from 2/3 to 1.0 and height to width ratio H/B from 0.3 to 0.7, the maximum aerodynamic torque and the other two forces be employed simultaneously without discount.

**Mohamed Elsharawy, Ted Stathopoulos and K Galal. (2013):** -this paper presents wind tunnel test carried out to examine wind-induced overall structural loads on rectangular medium rise buildings and give the special importance to torsion and its peak shear forces in transverse and longitudinal direction. Two building model with same horizontal direction but different gabled-roof angles ( $0^\circ$  and  $45^\circ$ ) were tested at different full scale equivalent eave height (20, 30, 40, 50 and 60 M) in open terrain exposure for all wind direction (every  $15^\circ$ ) and results were obtain for along wind force, across wind force and torsional moment. The study found that flat roofed buildings maximum torsion for winds in transverse direction is associated with 80 percent of the overall shear force perpendicular to the longer horizontal building dimension and 45 percent of the maximum shear occurs perpendicular to smaller horizontal building dimension comparison of the wind tunnel results with current torsion provisions in the American wind standard, the Canadian and European wind codes demonstrate significant discrepancies. Suggested load combination factors were introduced aiming at an adequate evolution of wind load effects on rectangular medium rise buildings.

**Cuong K. Nguyen, et. al. (2006):** - In this paper the researcher's study the rectangular building model using CFD software ANSYS CFX 10. They made selected rectangular building models in this study have the same height of 75cm, and the same width of 10cm, but the depths are varied (10cm, 30cm, and 100cm). The height of the virtual wind tunnel is selected as 160cm and the width is chosen with the criteria that minimize CFD domain but ensure the blockage ratio is less than 5%. The scale of the building models is 1/400 with the highest wind velocity 10m/s at the gradient height, which becomes 125cm in this scaled model. The building models are placed 50cm from the inlet in order to allow the flow fully developed before approaching surfaces of the building models, which have boundary condition as non-slip wall. The dynamic torsional moment of a tall building under wind load has been found to be significant from model study in physical wind tunnels. Results from CFD based virtual wind tunnel for 1:3 and 1:10 rectangular models are comparable to the experimental data except the square planform where CFD simulation gives significant smaller result. The reason for that is the difference in flow condition (wind velocity turbulence profiles). Advantage of CFD simulation is that it can model a given flow profile exactly but the mesh size and quality of the mesh are the most effective parameter of the simulation to the result.

**H. Sarath Kumar and P. Vijaya Bhaskar Reddy (2017):** - This paper presents the experimental results of evaluate wind pressure distribution on all four faces of a rectangular tall building with 1:1.5:7 ratio. The model is made up of acrylic sheets with a geometric scale 1:300 with plan dimension of 10 cm x15 cm and height 70 cm the model is using boundary layer wind tunnel (BLWT) twelve angle ( $0^\circ$ ,  $5^\circ$ ,  $10^\circ$ ,  $15^\circ$ ,  $25^\circ$ ,  $33.5^\circ$ ,  $45^\circ$ ,  $56.5^\circ$ ,  $60^\circ$ ,  $75^\circ$ ,  $87.5^\circ$  and  $90^\circ$ ) of wind incidence under uniform flow condition. Mean and standard deviation of pressure coefficients, drag and lift coefficients along wind direction and perpendicular to wind direction mean moment coefficient are calculated from pressure measurement on the model.

**Tharaka Gunawardena, et. Al. (2017):** - This is a conference paper which is explain the present scenario of wind tunnel testing and the CFD tools and also done the case study of Capitol Twin Peaks, Colombo. For this building they carried out the wind tunnel test on the building model which is mounted turntable. The results were observed every  $10^\circ$  the test was carried out by high frequency base balance method. Side by side the model is analysed by ANSYS CFD method and they found out the coefficient of correlation 0.97 which is very closely match.

**A.W. Rofail And N.K. Truong (2012):** - In this paper they carried out over 50 wind tunnel studies of tall building using high frequency force balance and heights of the buildings varies between 70m to 290m. they found out that maximum peak torsion value using a value of eccentricity factor (e) of 0.2 multiplied by maximum along wind loading and maximum horizontal direction, but it is generally suitable for rectangular shape building with minimum local interference and aspect ratio which is define as minimum width divided by maximum width of structure is between 0.2 to 1.0. the paper also provides the four numbers of methods to calculate maximum torsion moments and eccentricity due to wind and effect of shape parameter.

**Gijo Kuriyan, Nandkumar C. G. (2016):** - This paper based on finite element analysis for industrial structure Chimney they modelled a chimney with eleven segments in varying heights and also varying thickness. They calculated wind load for each segment. Wind loads are calculated around the circumference by treating as eight equal segments to account for the circumferential variation of wind load thus total 88 sets of loads comprise the wind load. After the analysis they conclude that maximum shear arises in the middle and bottom portion deflections are not in the permissible limit hence redesigning is important. Differential changes in the diagonals of the opening proves that twisting of the structure along with bending.

**Problem Statement:** - In general the use of rectangular or square shaped is not popular so we need to give the ideas about irregular shaped models. CFD simulation is now day’s popular but still need to test experiment on wind tunnel but there are possibilities to errors in reading it is very lengthy proceduroso need to give the correlation coefficient of wind tunnel testing to CFD software analysis so we can do fast analysis and results.Wind-induced loads on building vary instantaneously in temporal and spatial dimension building may experience a significant torsional moment due to the shift between the resultant of aeroelastic wind forces and the building centre of rigidity. This this torsional moment should be accounted for during the building design process.Due to limited available sources most of the building codes provide inadequate information about wind induced torsion on buildings. Two main approaches are being used in the wind loading standards for the evolution of the actual effects of wind-induced torsional loads on buildings. (M Elsharawy, K Galal)

### III. METHODOLOGY

**General:** - We are going to perform a project by two methods.

1. Experimental: - In this type of method we are going to perform the wind test on the L Shape, T shape, Square and Rectangular shape building model and find out the pressure exerted on structure. Find out the coefficients of pressure for different angle of attack of wind (0°,45°,90°,135°,180°), Models are made with acrylic sheets and for making model we adopt the scale 1:400 and we are considering same plan area for all models which is 1575sq.meter.



Fig.1: -(a)Picture of Building models casted for various shapes (b)Experimental Setup

2. Software analysis: - For software analysis we perform the computational fluid dynamics (CFD) analysis on ANSYS software where we are trying to analyse the model with same scale, material and other properties like height, orientation of model etc. for modelling the structure we are use the ANSYS FLUENT 19.0 version software. After analysis done successfully calculate the coefficients for pressure, torsion and eccentricity.

### IV. RESULTS

1. Experimental results: the following observation to be noted

Shape of the building	0°	45°	90°	135°	180°
	Force (N)	Force (N)	Force (N)	Force (N)	Force (N)
L-Shape	4	5	4	7	3
T-Shape	4	5	4	5	1
Rectangular Shape	3	3	1	3	3
Square Shape	1	2	1	2	1

Table 1: - Results Obtain from Experiment conducting on model



2. Software results: the following outputs get from software

Shape of the building	0°		45°		90°		135°		180°	
	F	Pressure	F	Pressure	F	Pressure	F	Pressure	F	Pressure
	(N)	(N/mm <sup>2</sup> )	(N)	(N/mm <sup>2</sup> )	(N)	(N/mm <sup>2</sup> )	(N)	(N/mm <sup>2</sup> )	(N)	(N/mm <sup>2</sup> )
L-Shape	3.8	85	5.67	168	3.8	85	6.55	194	2.53	75
T-Shape	3.92	87	4.5	100	3.83	85	4.5	100	0.84	75
Rectangular Shape	2.59	66	2.59	66	0.81	36	2.59	66	2.59	66
Square Shape	1.38	46	2.13	71	1.38	46	2.13	71	1.38	46

Table 2: - Results Obtain from CFD analysis

**Calculation of coefficients:** - For calculation of coefficients Zhang Mohamad Elsharawy et.al. (2014) and H. SarathKumar (2017) suggested these formulas

- Pressure coefficients:  $C_p = \frac{2P}{\rho V^2}$
- Torsional Coefficient:  $C_t = \frac{T}{0.5\rho V^2 B^2 H}$
- Eccentricity:  $E = \frac{e}{B} E = \frac{T}{F_d B}$

Where,  $C_p$  = Coefficient of Pressure,  $C_t$  = Coefficient of torsion, T = Torsional load in vertical direction, V = Velocity Wind velocity, B =Minimum Horizontal dimension of Building, H =Height of the building,  $F_d$  = Drag Force

- L-shape model coefficients: -

	0°	45°	90°	135°	180°
Cp	3.85	7.619	3.85	8.80	3.40
Ct	0.040				
E	0.0113				

Table 3: Pressure, torsion and eccentricity coefficients for L- Shape model

- T-Shape Model coefficients: -

	0°	45°	90°	135°	180°
Cp	3.94	4.535	3.85	4.535	3.40
Ct	0.020				
E	0.0096				

Table 4: Pressure, torsion and eccentricity coefficients for T- Shape model

- Rectangular Shape model Coefficients: -

	0°	45°	90°	135°	180°
Cp	2.993	2.993	1.633	2.993	2.993
Ct	0.050				
E	0.06825				

Table 5: Pressure, torsion and eccentricity coefficients for Rectangular Shape model

- Square Shape Model Coefficients: -

	0°	45°	90°	135°	180°
Cp	2.086	3.22	2.086	3.22	2.086
Ct	0.0269				
E	0.02523				

Table 6: Pressure, torsion and eccentricity coefficients for Square Shape model

## V. CONCLUSION

Wind loading of structure is complex phenomena. The wind is very random in nature like varying sizes and rotational characteristics along in general stream of air moving relative to earth surface. Now a days most of the codes paying attentions towards along the wind direction and across the wind direction but in our IS 875 part 3 -2015 and previous versions remains silent about Torsional load on structure due to wind pressure. In this study I find out the coefficients for Torsion for various shapes. Experimental studies give higher results than CFD but experimental studies may consist human or instrumental errors so we can suggest that CFD is best alternative for wind tunnel testing. In previous IS875-part 3 coefficient of pressure is much lesser than the results obtain from our study. IS 875- part 3 remains silent but in some of the cases it affects severely so we need to consider it. We observed that inclined angle means  $45^{\circ}$  or  $135^{\circ}$  wind incident angle shows greater values of Coefficient of pressure.

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