Wind Analysis and Design of Tall Building

Dissertation Submitted
In
Partial fulfillment of requirement for the award of
Degree of

Bachelor of Technology
In
Civil Engineering

By
Atal Jain (18SOCE1010040)

Guide
Jagan J

Department of Civil Engineering

GALGOTIAS UNIVERSITY UTTAR PRADESH

May 2022

Declaration

I, hereby declare that the dissertation titled “**Wind Analysis and Design of Tall Building”** submitted herein has been carried out by me in the Department of Civil Engineering of Galgotias University, Uttar Pradesh. The work is original and has not been submitted earlier as a whole or in part for the award of any degree at this or any other Institution / University.

I also hereby assign to Galgotias University, Uttar Pradesh all rights under copyright that may exist in and to the above work and any revised or expanded derivatives works based on the work as mentioned. Other work copied from references, manuals etc. are disclaimed.

Name of student

Atal Jain

Date: **5th May 2022**

DEPARTMENT OF CIVIL ENGINEERING

BONAFIDE CERTIFICATE

The project titled "**Wind Analysis and Design of Tall Building"** submitted by **Atal Jain (18SOCE1010040)** for the award of degree of Bachelor of Technology in (Civil Engineering), has been carried out under our supervision at the Department of Civil Engineering of Galgotias University Uttar Pradesh. The work is comprehensive, complete and fit for evaluation.

Guide

Mr. Jagan J
Assistant Professor
Department of Civil Engineering

Dr. Deepak Kumar Soni
Head of Department
Department of Civil Engineering

External Examiner

Approval Sheet

This thesis/dissertation/report "WIND ANALYSIS AND DESIGN OF TALL BUILDING" by **Atal Jain** is approved for the degree of **Bachelor of Technology (Civil Engineering).**

Examiners

____

____

Supervisor (s)

____

____

____

Date:_________

Place:_________

ABSTRACT

The growing urban population has made it necessary to construct tall buildings, as the height of the building is increased wind becomes a major factor. An increase in high lateral wind force also increases. Wind flow around, and on, structures is a complicated phenomenon that consists varieties of flow simulations and the structure gets affected by it, and buffeting, vortex shedding,galloping, etc. is observed. These factors should be considered at the very early stage of designing to avoid any mishap and can contribute to the instability of buildings. Nearby building structures influence the wind pressure on our very own structure that is to be designed, these pressures are very difficult to calculate as they fluctuate. Computational Fluid Dynamics is useful for wind loading on bluff bodies, Wind loading on moving bodies, Heating and Ventilation (HVAC), Fire safety engineering, etc. In this project, we used Simscale to analyze wind loads on different building shapes Using particle trace we can simulate the wind movements on any given point of the building. Using different iterations, we were able to find the best shape for handling wind loads.By analyzing different geometric shapes, we can compare them with each other.Wind moves in a three-dimension direction so it affects different surfaces, it's important to learn about the impact of wind on differential geometry. To learn about the impact of wind on building and its effect on the structure is important to do structural analysis with wind load, dead load, live load, seismic load, and other loads to find the displacement of the building and its stories. An Individual’s state of mind in which he/she feels hot or cold is defined as thermaldiscomfort. Managing thermal discomfort is very important as it increases productivity and improves health and safety.. Suggested thermal comfort must fall in the range -0.5 to +0.5 of PMV.

ACKNOWLEDGEMENT

While bringing out this dissertation work to its final form, I came across a number of people whose contributions in various ways helped my field of research and they deserve special thanks. It is a pleasure to convey my gratitude to all of them.

First and foremost, I would like to express my deep sense of gratitude and thankfulness to my supervisor **Mr. Jagan J** in the Department of Civil Engineering, Galgotias University, Uttar Pradesh for his invaluable encouragement, suggestions, and support from an early stage of this research and providing me extraordinary experiences throughout the work.

I would like to extend similar gratitude to **Dr. Deepak Kumar Soni**, Head of Department, Civil Engineering Galgotias University, Uttar Pradesh for his unconditional help and support to carry out the research work. I would like to thank all the government officials, professionals, and academicians’ librarians whom I consulted for the benefit of my dissertation work.

I express our gratitude to all the scholars and researchers who conducted research and developed theories to explain the basic principles that went behind the making of this report.

I am deeply grateful to my beloved family for their moral support, love, and encouragement without which it would not have been possible to reach this stage of my life. I also want to thank all my friends who have supported me and stood by every time I was in need. This work would not have been possible without them.

Last but not the least; I thank almighty GOD for everything, who continues to look after us despite our flaws and limitations.

Atal Jain
(18SOCE1010040)

TABLE OF CONTENTS

LIST OF FIGURES

.

LIST OF TABLES

Chapter 1

Introduction

1.1. Introduction

The wind is an important factor while designing any tall building. Wind Load' is u refer to anypressures or forces that the wind exerts on a building or structure

If the flow of wind doesn't follow a streamlined surface and thus causing multiple detached separatedflows, is called the bluff.

Simscale can facilitate fast, accurate simulations for turbulent flows around the buildings and help usin our project. Our project involves analyzing the wind flow in society and other building structures around it.

Wind loading is wind pressure acted on buildings and structures. This force is most effective when the surface in question provides a flat face and the torsional directions are greater than zero when thewind force in the along-wind direction is a maximum. Wind loading, in turn, impacts the model or natural frequency of a structure, as well as creates vortex shedding that must be evaluated, or otherwise cause vibrations in the building, vortex shedding, instability due to galloping or flutter, or does not have a site location that requires special consideration.

Literature review:

Tall buildings are slender flexible structures in nature and require to be examined to settle on the significance of wind speed-induced excitation along and across the path of wind in a specific zone.Using Is code and ANN is also suggested by the author.

Due to overpopulation and scarcity of land multi-story building are the best choice for construction inMetro cities, it provides large floor area in a small area and is beneficial.

As high-rise buildings move onward the envelope to larger heights, the structural designers are not only faced with difficulty in choosing a structural element to take the lateral load such as wind loadand earthquake load but also ensuring the design criteria that meets reliability and serviceability requirement under difficult wind environment.

Classification of Tall Buildings by Fazlur Khan:

Fazlur Khan in the form of "Heights for Structural Systems" diagrams. He argued that the rigid framethat had dominated tall building design and construction so long was not the only system fitting for tall buildings. Any interior structure is most likely to have some part of the lateral load-resisting system at the building perimeter, and any exterior structure might have some minor components within the interior of the building.

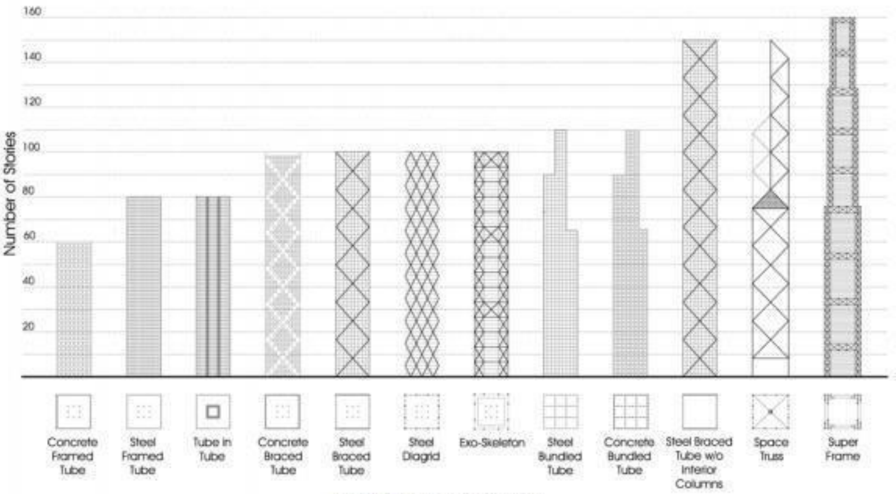


Figure 4-2: Exterior structures.

Fig 1.1 Exterior Structure

Important IS Codes:

IS Code 875 (Part3)-1987, the basic wind speed is specified in a map and categorized by zones.IS-875Part-3 1987 gives a procedure to determine along with wind response of tall structures. IS 456:200.

The wind speed map included in the IS:875 (Part-3)1, serves the primary purpose of choosing the appropriate basic wind velocity for the design of buildings and structures. The recommended basicwind speed in the map refers to peak gust velocity averaged over 3 s duration, at a height of 10 m above ground level in a Category-2 terrain (open terrain with average obstructions on the surface being small and scattered), with a mean return period of 50 years.

But 70 out of 500observations of IMD spread out in india have hourly wind data including winds

Hourly Wind Data:

The hourly wind record have few gaps due to stoppage in continuous operations of sensor and recorded instrumentation, power cuts, and so on. According to the contemporary versionof IS:875 code provisions, strong winds with speeds over 80 kmph are generally associated with cyclonic storms.

Wind history

Wind-force per Day (January 2000 - January 2021)Wind flow history in Chennai for 20 years.

Jan	Feb	Mar	Apr	May	Jun	
6.3	**7.1**	**8.0**	**8.7**	**10.6**	**12.2**	[km/h]
100	99	98	100	99	99	Data availability [%]

Fig 1.2 Hourly Wind data

Jul	Aug	Sep	Oct	Nov	Dec	
13.3	**12.5**	**8.5**	**6.2**	**6.2**	**6.1**	[km/h]
100	100	100	99	100	99	Data availability [%]
Averaged Value (January 2000 - January 2021): **8.8 km/h**						

Wind Speed Data:

Extreme wind speed distributions differ depending upon the meteorological nature of the storms being considered. For this reason, hurricane, synoptic storm, and thunderstorm datashould be analyzed separately. In addition, wind speed data within a data sample must be micro meteorologically homogeneous, meaning that all the data in a set must correspond tothe same: -

(i) Height above the surface,
(ii) Surface exposure (e.g., open terrain),
(iii) Averaging time (e.g., 3 s for peak wind gust speeds, 1min, 10min, or 1 h).

Wind speeds at 10m above terrain with an open exposure, and with the specified averagingtime (typically 3 seconds in the United States) are referred to as standardized wind speeds.

The fundamental difference between the two is duration.

The sustained wind is defined as the average wind speed over two minutes. A sudden burst inwind speed is called the wind gusts and typically lasts under 20 seconds.

Directional and Non-Directional Wind Speeds:

Importance of wind load increase with the increase in hight of building, so wind analysis is veryimportant before any design of a tall structure.

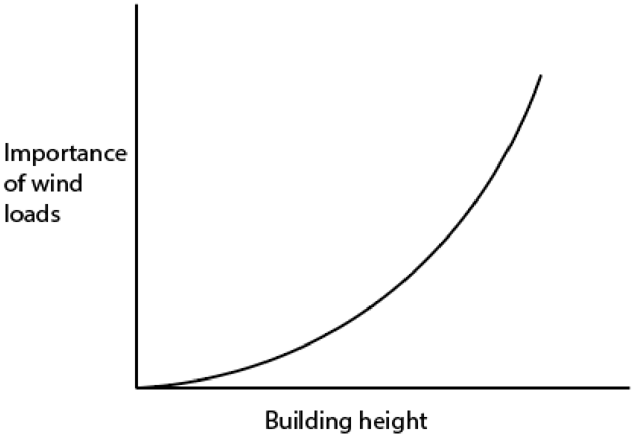


Fig 1.3 Importance of wind load

Loading, Analysis, and Design

Once modeling is complete, ETABS automatically generates and assigns code-based loadingconditions for gravity, the seismic, wind, and thermal forces. Users may specify an unlimitednumber of load cases and combinations

.

Analysis capabilities then offer advanced nonlinear methods for the characterization of static- pushover and dynamic response. Dynamic considerations may include modal, response- spectrum, or time-history analysis. The P-delta effect accounts for geometric nonlinearity.

Given enveloping specification, design features will automatically size elements and systems,design reinforcing schemes, and otherwise optimize the structure according to desired performance measures.

Vortex

It is a region in a fluid in which the flow revolves around an axis line, which may be straightor curved.

Fig 1.3 Vortex Flow

Flow in a Curved Path: Vortex Flow:

Consider a 2-D flow between two locally concentric streamlines with radii of curvature and r +dr. Forthe flow to maintain its curved path with tangential velocity U at radius r, it must experience an acceleration U2/r toward the center of curvature. Let the pressure acting on the fluid element under consideration be denoted by p. The pressure differential between the streamlines at radii r and r+dr, which is responsible for this acceleration, is dp. The equation of motion for a fluid element shown in is then

$dpdA = \rho$ dr dAU2/r

where dA is the area of the element in a plan normal to the plan.

Thereforedp = ρ U2 dr/r

Bernoulli’s equation allows the calculation of the pressure along a curved path of the

flow. In particular, one may consider the case wherein the flow is circular and the value

ofp in is the same on all streamlines. This is the case of vortex flow.

Differentiation of yields

$\rho U\, dU/dr + dp/dr = 0$

From $dU/U = -dr/r$ Integration

yieldsUr = const.

This law states, for an incompressible and inviscid fluid, the theoretical hyperbolic relation between radius r and tangential velocity U in a free vortex. In an actual free vortex,

however, the effects of viscosity are present as well. Viscosity “locks” together with a portionof the fluid near the center and causes it to rotate as a rigid body, instead of as an inviscid fluid described by. Thus, at the center of a free vortex the velocity increases with radius, it decreases with increasing *r*. This decreases actually, occurs outward from a transition region in which *U* attains its maximum value. The value of *U* in this region depends upon the fluid viscosity and the total angular momentum of the vortex. illustrates qualitatively the pressure and velocity dependence on radius in a free vortex occurring in a real fluid. The free vortex is of interest in many flows that occur in engineering applications.

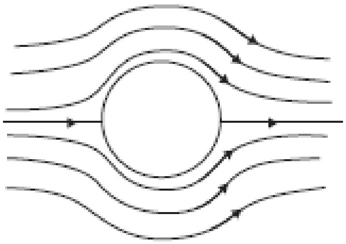


Fig 1.3 2d flow about a circular cylinder

the renowned case of 2-D flow about a circular cylinder is briefly examined. At extremely low Reynolds number based on the diameter of the cylinder ($Re \cong 1$) the flow, assumed laminar as it approaches, remainsattached to the cylinder throughout its complete periphery

A complementary strategy for controlling the response to vortex excitation is to draw the energy out of the building’scrosswind oscillations with special damping systems. Every

building dissipates some of the oscillation energy through the natural damping of its materials and through friction at jointsand partitions

Large Eddy Simulation (LES)

Filtering of NS equations: removing small turbulent eddies (smaller than the size of a filter – can begrid size).

- Large-scale motions resolved; small-scale motions modelled.

- Filtering generates additional unknowns → sub-filter turbulence model.
- LES has superior performance compared to RANS and URANS, becauselarge part of unsteady turbulent flow is actually resolved.
- More expensive and more complex.

Chapter 2

Wind flow pattern inside building.

➔Simulating Thermal Comfort in Auditorium:

Thermal Comfort:

Individual’s state of mind in which he/she feels hot or cold is defined as thermal discomfort.

Importance of Thermal Discomfort:

1) Managing thermal discomfort is very important as it increases the productivity and improvehealth and safety.
2) People in unstable thermal discomfort zones are unsafe and their decision-making ability getscompromised
3) People will take shortcuts to get to comfortable environment
4) Employee will not wear protective gear properly
5) People may remove masks if they feel discomfort which can be the rising cause of the covidcases.
6) Concentration power decreases.

Factors Influencing Thermal Comfort:

Following factors influence thermal discomfort:

1) Metabolic heat production: Humans are endotherms who produce their own heat by metabolism. Physical and mental factors of individuals differ metabolic rate of individuals.Heat is important for thermal discomfort.
2) Clothing: Clothing is a mediator between the energy transfer from skin to the environment.
3) Humidity: Evaporative heat dissipation is caused by relative humidity. Higher the humidity,higher will be the rate to lose heat through bodies. So, low air temperatures will feel hot andwill cause discomfort if humidity is more.

The analysis:

3d Model:

Design 1: The Outlets are situated right below the seats of occupants and the outlet is situated at theceiling of the auditorium.

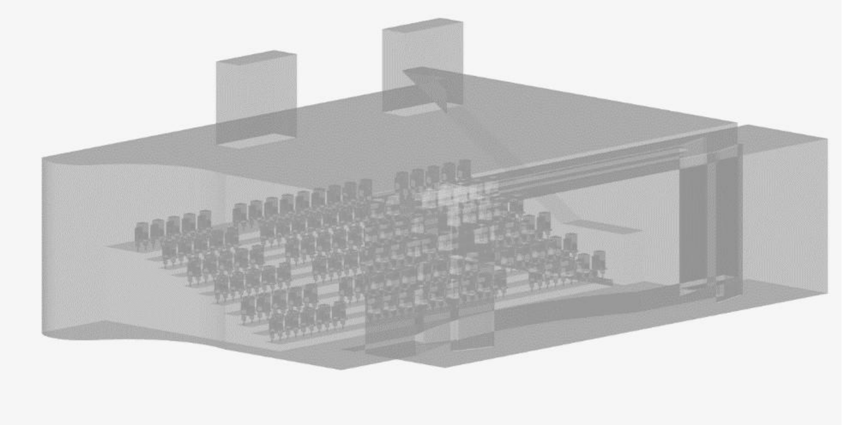


Fig 2.1 Outlet Position in the Auditorium

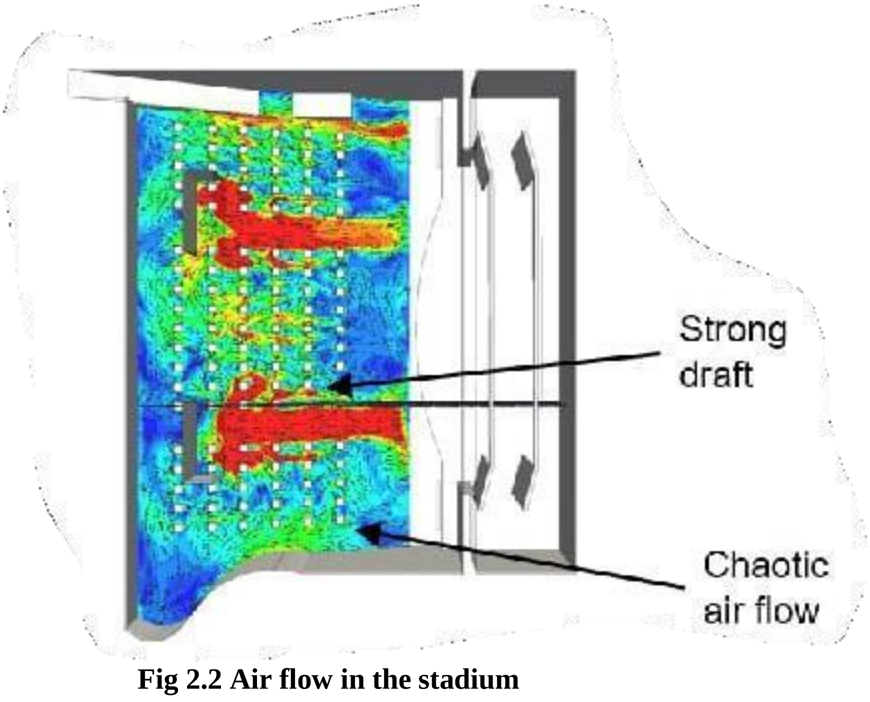


Fig 2.2 Air flow in the stadium

Design 2: The inlets are situated right below the seats of occupants and the outlet is situated at the topof the auditorium at back side.

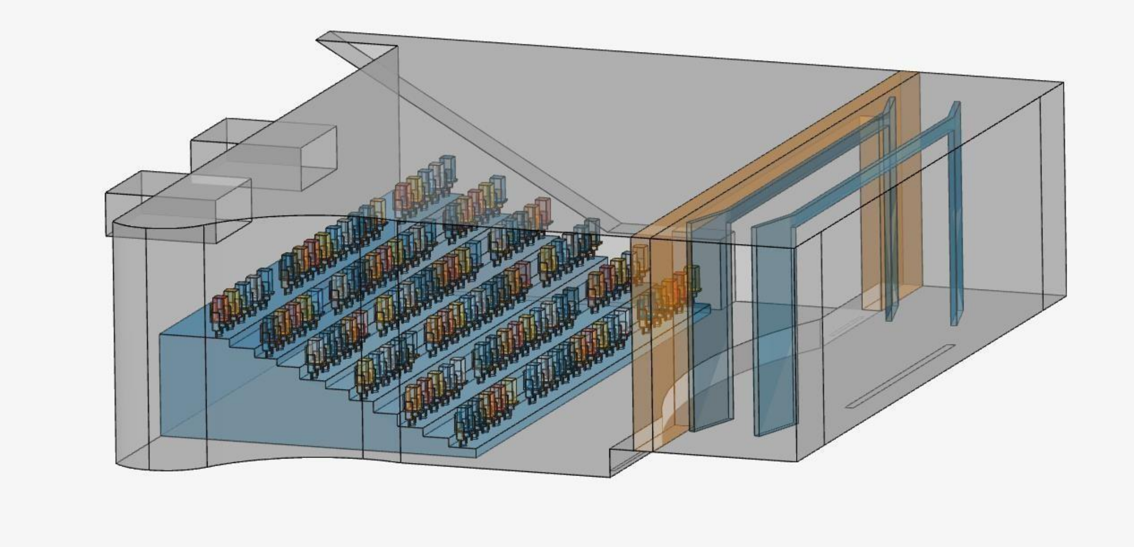


Fig 2.3 Inlet position In the Auditorium

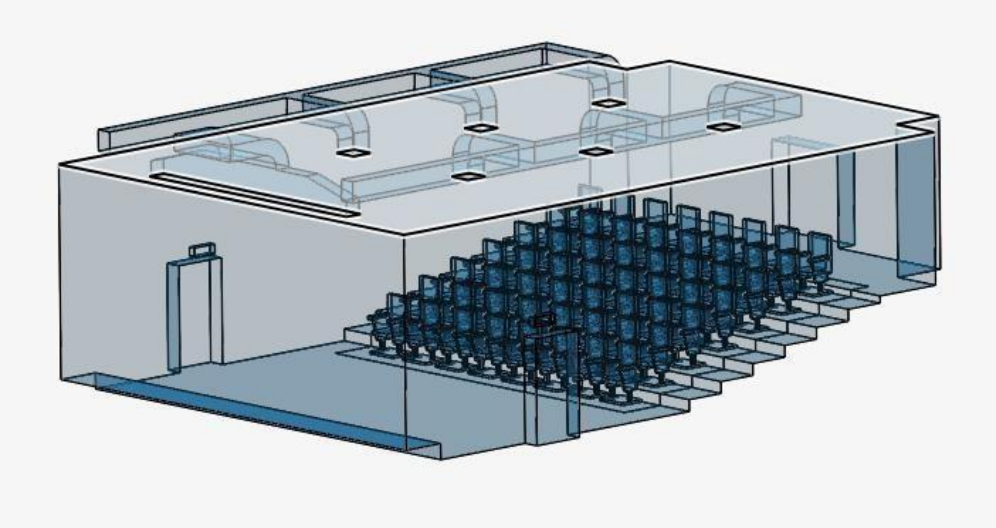
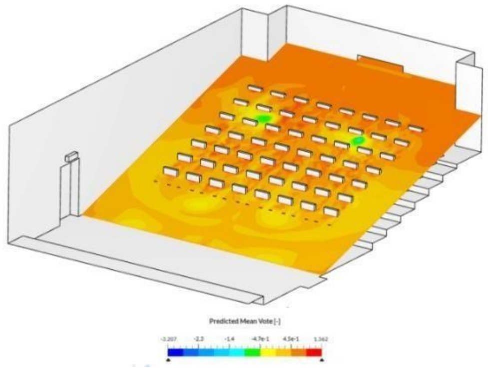


Fig 2.4 3d Models of Auditorium

Parameters for both the designs to be used are as follows:

1) Will be using ‘Convective Heat Transfer Simulation’ as we are simulating a single fluidregion which is air in auditorium space.
2) The radiation is enabled for the simulation so that the heat radiated from other surface orbodies can also be taken in account.
   The direction of the gravity is in -ve Z-axis.
3) The default air material is applied to the full domain/body faces
4) To stabilize the simulation, we applied initial temp. condition = temperature applied to theinlets = **15.85 degree Celsius**
5) Velocity at which air is travelled through ac is **V=0.3 m/s**
6) For outlets, Pressure = zero-gauge pressure **P= 0 pa**
7) On windows we need to apply convective heat transfer condition. We provide the externalroom temperature 283.15 K and heat transfer coefficient as **10 W/km-m^2**
8) For the seats use a no-slip wall condition fixed temperature value: T = 29.85 °C
9) Similarly for outside wall we apply the same settings as we did for windows.
10) For inside walls we use temperature that we provided for the inlets which is **15.85 degree Celsius.** All the walls which are connected to the neighbouring rooms are given the same condition including the flooring. Here we assume that there is only one outside wall and restare internal
11) For Humans we use turbulent heat flux parameter and give them **100 W/m^2**. This value =metabolic rate of the human.
12) Same parameter is applied to the PC or other electrical components at a higher heat flux. Thisdepends upon device to device and the value is variable.

Conclusion:



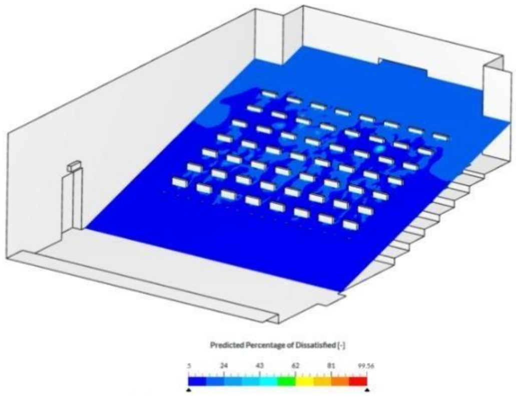
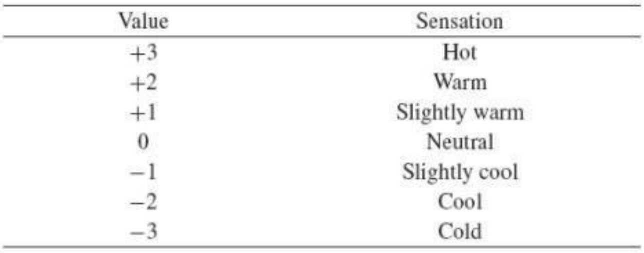


Figure 2.5: Predicted Mean Vote **Figure 2.6 Predicted Mean**
vote

PMV Scale:

Predicted mean vote (PMV) is used to measure thermal comfort. This scale ranges from -3 (cool) to +3 (hot). Range of criteria, metabolic rate, clothing, insulation, air, mean radiant temp. (MRT) and vapour pressure is used to derive this range. Suggested thermal comfort must fall in range -0.5 to +0.5of PMV.



Value	Sensation
+3	Hot
+2	Warm
+1	Slightly warm
0	Neutral
−1	Slightly cool
−2	Cool
−3	Cold

Table: The predicted mean vote (PMV) scale for measuring thermal comfort. From ASHRAEstandard 55.

PMV is used to find the predicted percentage dissatisfied (PPD). PPD is function of PMV, it tells the percentage of individuals that are dissatisfied with thermal space. When PMV moves away from zero,PPD is increased. 100 % PPD indicates that 100 % individuals would be expected to be dissatisfied with the thermal environment. Guidelines suggest that interior spaces should aim for a PPD below 10
%.

Both PMV and PPD were found to be normal in our case.

In design 1 and design 2, two iterations of theatre room were carried out using CFD simulations fromsimscale.

Design 1: Design one had large temperature differences throughout the whole environment. Someindividuals were exposed to very cold temperature air.

Design 2: The temperature was distributed evenly and all the individuals felt cosy due to the rightplacements of inlet and outlet.

Air Circulation inside a room:

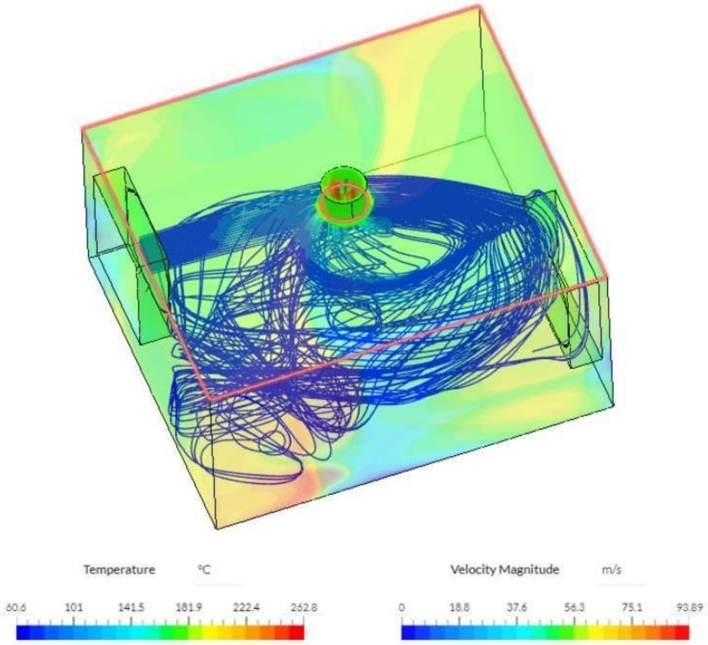


Fig 2.7 Airflow in the room

The following design is of a room with 2 windows and one air outlet. The air comes from the windows and the room is ventilated properly. This ventilated air is sent back to the outer atmosphere through the outlet. If the outlet was not present then the air could not have been circulated properly due to the pressure difference. Using the particle trace feature, we can determine how the wind moves at a particular point. In this case, we traced the particle at the outlet point. At the corners, it is difficult for wind to pass and hence creates turbulence (red areas). For the air to pass, every inlet must have anoutlet for a smooth flow of air around the space.

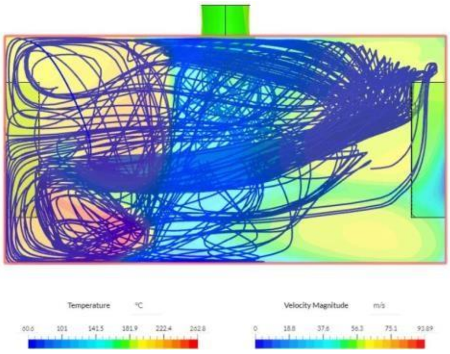


Fig 2.8 Temperature and velocity of wind in the room

Chapter 3

Effect of wind on buildings:

Design in E-tabs using IS Code:

In most general cases, the minimum value clear cover is 50mm for foundation1, 40 mm for a column, 25mm for Beam,25mm for shear wall, 15mm for slab and Stair. For nominal cover requirements based on exposure condition and fire resistance, we can go through table 16A as per IS code 456:2000.

Stiffness Modifiers:

For Design member

- Column-j_1, j_2, j_3=0.7 (For serviceability check 1.0).
- Shear Wall -f_{22}, f_{12}, m_{11}, m_{12}=0 (for serviceability check 1).
- Beam -j, l_2, l_3(for serviceability check 0.5)
- Slab-m_1, m_2, m_{12}=0.25 (for serviceability check

0.35).Loading:

Imposed loads are produced from the weight of movable partitions of buildings, uniformly distributed and concentrated loads. For structures carrying live loads which induced impact andvibration. Imposed loads shall be assumed under IS 875(part -2).

Floor finish (DL)=1.5kN/sqm

Wall Load=0.23m (Wall Width) x18.5kN/m^3 (brick work unit wt) vx3.0 m (Wall Height) = 12.765kN/m

Calculation according to IS code 875(part2)-1987.

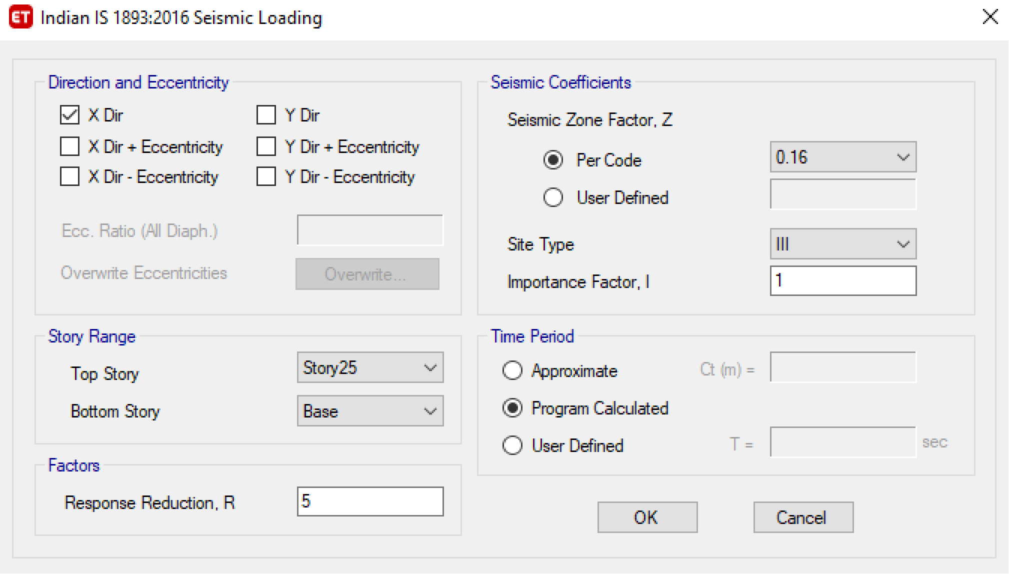
Imposed loads on of roofs: uniformly distributed Imposed load

measuredOn plan area

- Flat, sloping or curved roof with slopes up to and including 10 degrees= 1.5kN/m^2 (according to IS code 1875:1987 part2)

Commonly used occupancies:
Residential building: Floor=2KN/sqm, Corridor & Stair=3kn/sqm.
Commercial building: Office Floors= 3kN/sqm, Corridor & Stair=4KN/sqm(restaurant =4kn/sqm)

Seismic load:
Load Applied according to IS code
1893:2016Direction :X and Y direction
Seismic Zone Factor. (Z)=
0.16Site Type III
Importance Factor I
=1Top Story =25



Indian IS 1893:2016 Seismic Loading

Direction and Eccentricity

☑ X Dir ☐ Y Dir

☐ X Dir + Eccentricity ☐ Y Dir + Eccentricity

☐ X Dir - Eccentricity ☐ Y Dir - Eccentricity

Ecc. Ratio (All Diaph.)

Overwrite Eccentricities [Overwrite...]

Seismic Coefficients

Seismic Zone Factor, Z

● Per Code 0.16

○ User Defined

Site Type: III

Importance Factor, I: 1

Story Range

Top Story: Story25

Bottom Story: Base

Time Period

○ Approximate Ct (m) =

● Program Calculated

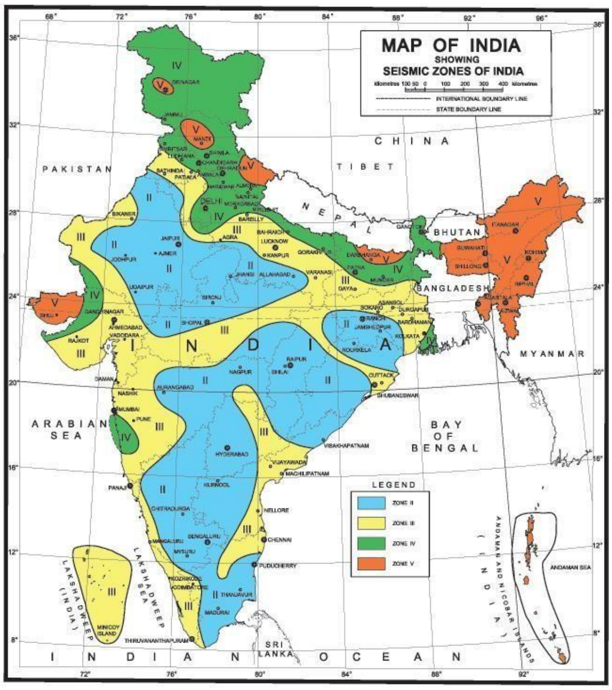
○ User Defined T = sec

Factors

Response Reduction, R: 5

Fig 3.1 Indian IS 1893: Seismic Loading

- Map of India Showing SEISMIC zone of India:



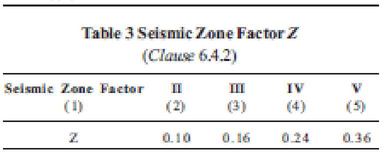


Table 3 Seismic Zone Factor *Z*
(*Clause* 6.4.2)

Seismic Zone Factor (1)	II (2)	III (3)	IV (4)	V (5)
Z	0.10	0.16	0.24	0.36

Fig 3.2 Map of India Showing Seismic zone of India

I stand for importance fector, which is depends on type of building.

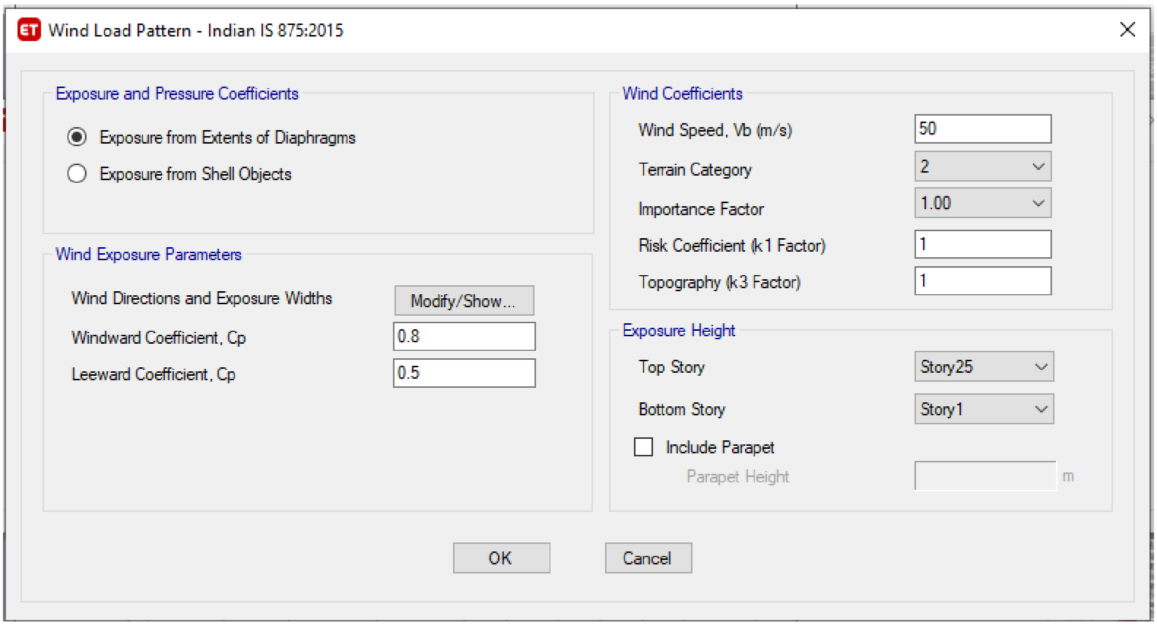
- 1.5 for highly important structure like School, hospital etc.
- 1.2 for commercial/ busness continuity Structures and
- 1 for rest of structure.

Site Type.

- I=hard soil
- II=medium Soil
- III= Soft Soil

WIND LOAD:
The IS 875(part -3) deals with wind loads to be considered when designing building, structures and components thereof. Wind load depends upon wind speed and pressure – a Basic wind speed (Vb): IS875(part-3)
Design Wind Speed (Vz): The basic wind speed (Vb) for any site shall be obtained and shall be modified to include the following effects of design wind velocity at any height (Vz) for the chosenstructure:
Risk level
Terrain roughness, height and size of
structureLocal topography.
It can be mathematically expressed as follows: Vz = Vb * k1 * k2*
k3Vb = design wind speed at any height z in m/s;
K1= probability factor (risk coefficient)
K2 = terrain, height and structure size
factorK3= topography factor As per this
study, Vb = 50 m/s, K1=1, k2= 0.85,
k3=1
Vz=42.3m/s

c)Design Wind Pressure – The design wind pressure at any height above mean ground level shall beobtained by the fallowing relationship between wind pressure and wind velocity :
Pz =0.6 Vz^2
Where, Pz = Disign wind pressure in N/m^2 at height z ,
andVz = Design wind velocity in m/s at height z



Wind Load Pattern - Indian IS 875:2015

Exposure and Pressure Coefficients
● Exposure from Extents of Diaphragms
○ Exposure from Shell Objects

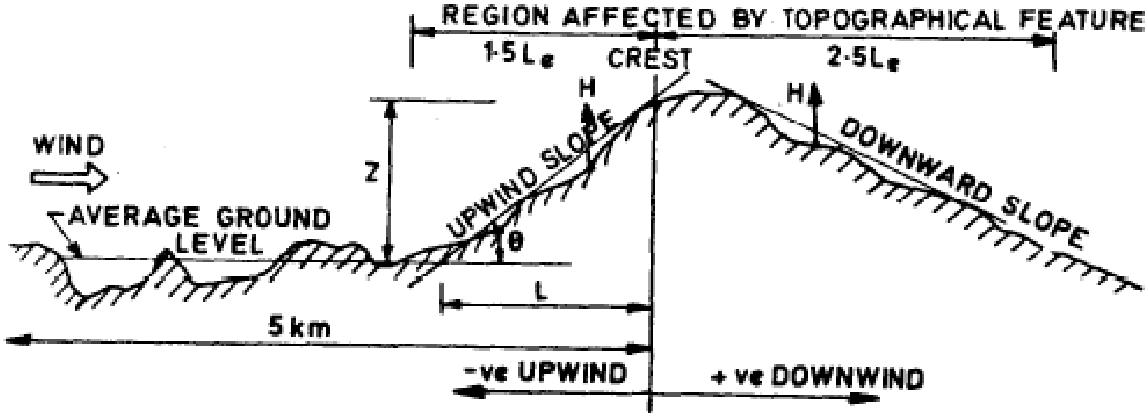
Wind Exposure Parameters
Wind Directions and Exposure Widths: Modify/Show...
Windward Coefficient, Cp: 0.8
Leeward Coefficient, Cp: 0.5

Wind Coefficients
Wind Speed, Vb (m/s): 50
Terrain Category: 2
Importance Factor: 1.00
Risk Coefficient (k1 Factor): 1
Topography (k3 Factor): 1

Exposure Height
Top Story: Story25
Bottom Story: Story1
☐ Include Parapet
Parapet Height: m

Fig 3.3 Wind Load pattern

Topography Factor,K3:



13A General Notations

Fig 3.4 General Notation

K3=1(for wind slope (θs): θ<<3˚

K3= 1+CS_0, C=1.2 for upwind slope (θs): 3˚<θs≤17˚,C=0.36 for upside slop(θs):θs>17˚,So will calcuation from figure 14&15

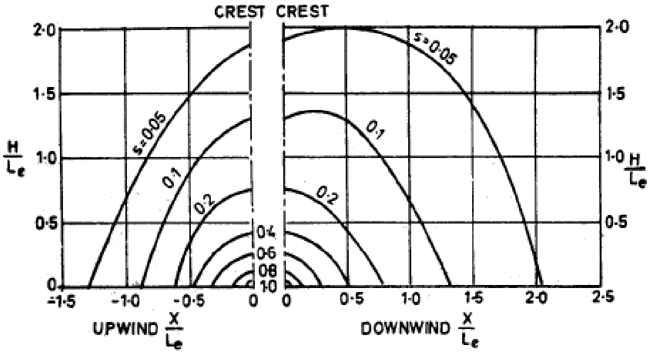


FIG. 14 FACTOR s FOR CLIFF AND ESCARPMENT

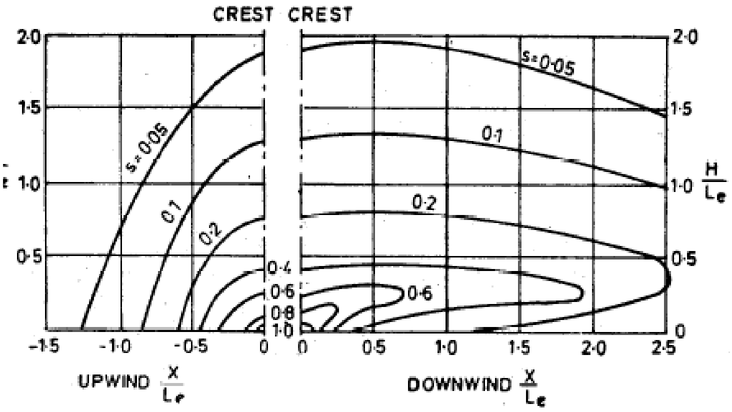


FIG. 15 FACTOR s FOR RIDGE AND HILL

Fig 3.5 Factor for cliff and Escarpment **Fig 3.6 factor for ridge and hull**

Example: Building having medium openings between 5% to 20%, Cpi= +0.5If building length.L= 30m, Width W=25m, Height, H=75m, then H/W=3,

L/W=1.2(so go to 3rd row of building height ratio to 1st row lin between 2 row)

1. Wind direction 0° (i.e. Wx) Windward Side-A, Cpe=+0.8, Windward Cp=0.8-(-0.5)=1.3Side-B, Cpe=-0.25, Cp=-0.25-(+0.5)=-0.75, Using the term Leeward Cp in Etabs, value will be given as positive, so Leward Cp=0.75

2. Wind direction 90° (i.e. Wy) Windward Side-C, Cpe=+0.8, Windward Cp=0.8-(-0.5)=1.3Side-D, Cpe=-0.25, Cp=-0.25-(+0.5)=-0.75, Using the term Leeward Cp in Etabs, value will be given as positive, so Leward Cp=0.75

Building design:

Structure Data:

This provides model geometry information, including items such as story levels, point coordinates, andelement connectivity.

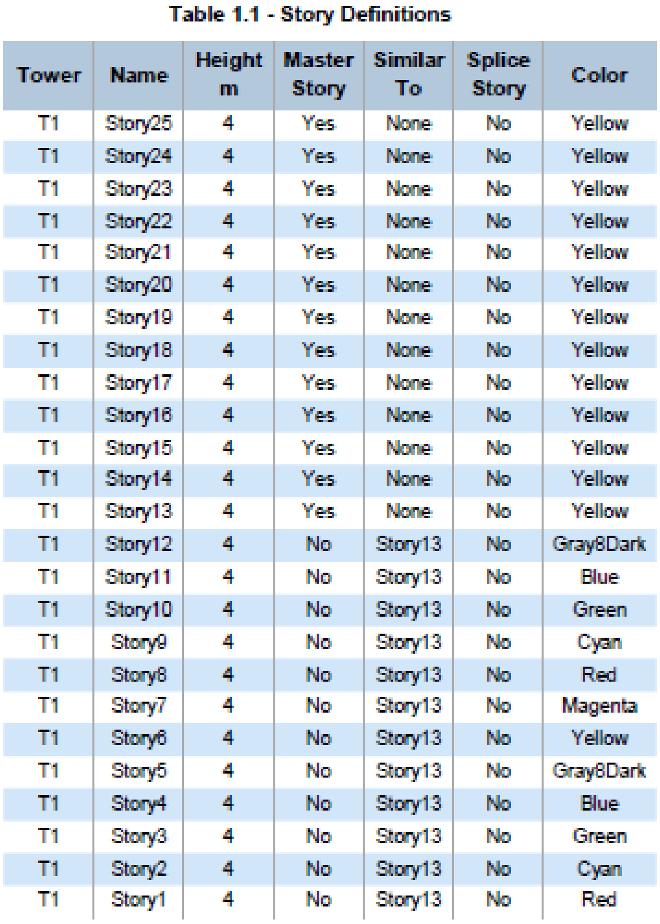


Table 1.1 - Story Definitions

Tower	Name	Height m	Master Story	Similar To	Splice Story	Color
T1	Story25	4	Yes	None	No	Yellow
T1	Story24	4	Yes	None	No	Yellow
T1	Story23	4	Yes	None	No	Yellow
T1	Story22	4	Yes	None	No	Yellow
T1	Story21	4	Yes	None	No	Yellow
T1	Story20	4	Yes	None	No	Yellow
T1	Story19	4	Yes	None	No	Yellow
T1	Story18	4	Yes	None	No	Yellow
T1	Story17	4	Yes	None	No	Yellow
T1	Story16	4	Yes	None	No	Yellow
T1	Story15	4	Yes	None	No	Yellow
T1	Story14	4	Yes	None	No	Yellow
T1	Story13	4	Yes	None	No	Yellow
T1	Story12	4	No	Story13	No	Gray8Dark
T1	Story11	4	No	Story13	No	Blue
T1	Story10	4	No	Story13	No	Green
T1	Story9	4	No	Story13	No	Cyan
T1	Story8	4	No	Story13	No	Red
T1	Story7	4	No	Story13	No	Magenta
T1	Story6	4	No	Story13	No	Yellow
T1	Story5	4	No	Story13	No	Gray8Dark
T1	Story4	4	No	Story13	No	Blue
T1	Story3	4	No	Story13	No	Green
T1	Story2	4	No	Story13	No	Cyan
T1	Story1	4	No	Story13	No	Red

Fig 3.7 Story Definition

Total hight of building =100m

Difference in hight between two floors are 4m

Loads

This provides loading information as applied to the model

For analysis different loads were taken like dead load, live load, wind load in X and Y direction,seismic load (EQ).

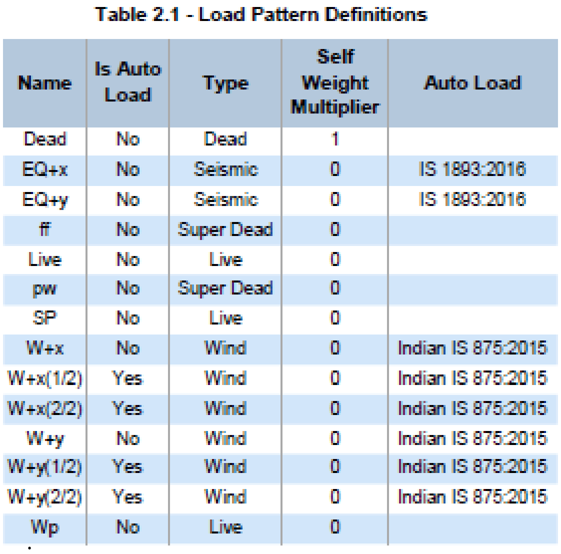


Table 2.1 - Load Pattern Definitions

Name	Is Auto Load	Type	Self Weight Multiplier	Auto Load
Dead	No	Dead	1	
EQ+x	No	Seismic	0	IS 1893:2016
EQ+y	No	Seismic	0	IS 1893:2016
ff	No	Super Dead	0	
Live	No	Live	0	
pw	No	Super Dead	0	
SP	No	Live	0	
W+x	No	Wind	0	Indian IS 875:2015
W+x(1/2)	Yes	Wind	0	Indian IS 875:2015
W+x(2/2)	Yes	Wind	0	Indian IS 875:2015
W+y	No	Wind	0	Indian IS 875:2015
W+y(1/2)	Yes	Wind	0	Indian IS 875:2015
W+y(2/2)	Yes	Wind	0	Indian IS 875:2015
Wp	No	Live	0	

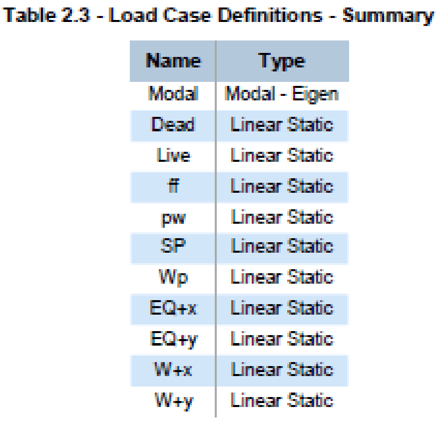


Table 2.3 - Load Case Definitions - Summary

Name	Type
Modal	Modal - Eigen
Dead	Linear Static
Live	Linear Static
ff	Linear Static
pw	Linear Static
SP	Linear Static
Wp	Linear Static
EQ+x	Linear Static
EQ+y	Linear Static
W+x	Linear Static
W+y	Linear Static

Fig 3.8 Load Pattern Definition **Fig 3.9 Load case Definition**

First building Analysis Results:3Dbuilding

These are the plan view of building

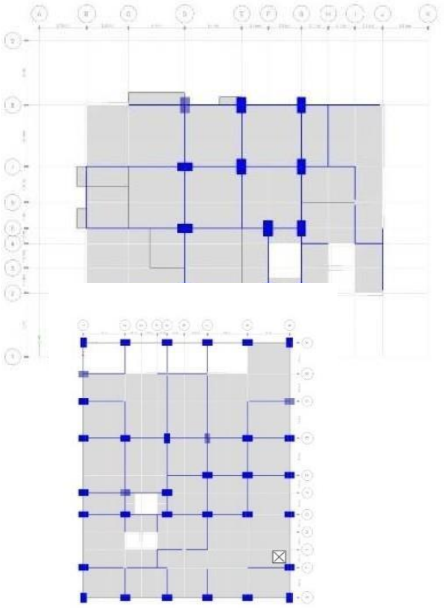


Fig 3.10 Plane view of Building

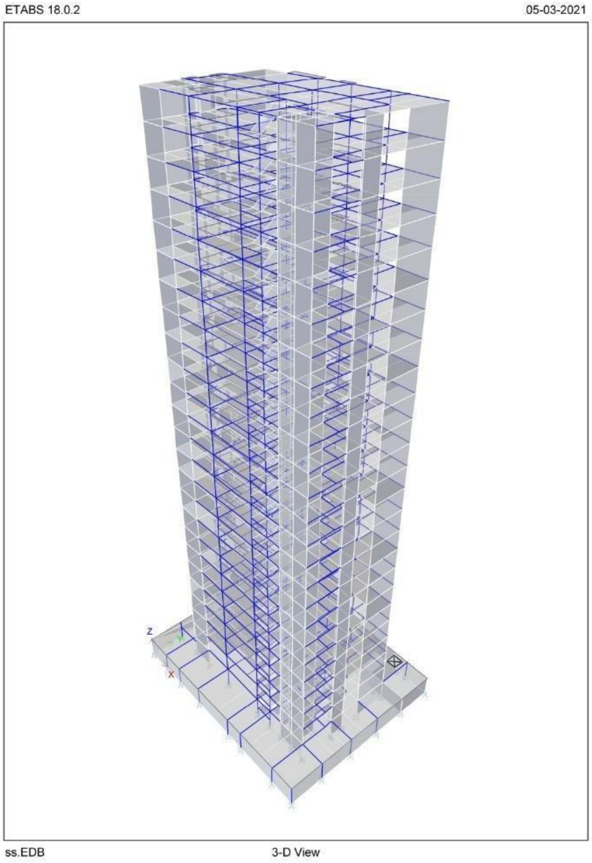


Fig 3.11 3d View of Building

Wind Analysis:

Lateral load to stories:

Lateral loads are live loads that are applied parallel to the ground. They are horizontal forces acting ona structure. They are different from gravity loads for example which are vertical, downward forces.

From our analysis, we can observe that as we move upwards from ground lateral load to stories increase. By taking the x-axis we get different forces in KN on the walls of the building, it increaseson a different story and is maximum on the top story. From the data on this table below, we can get the idea of lateral wind force on the building.

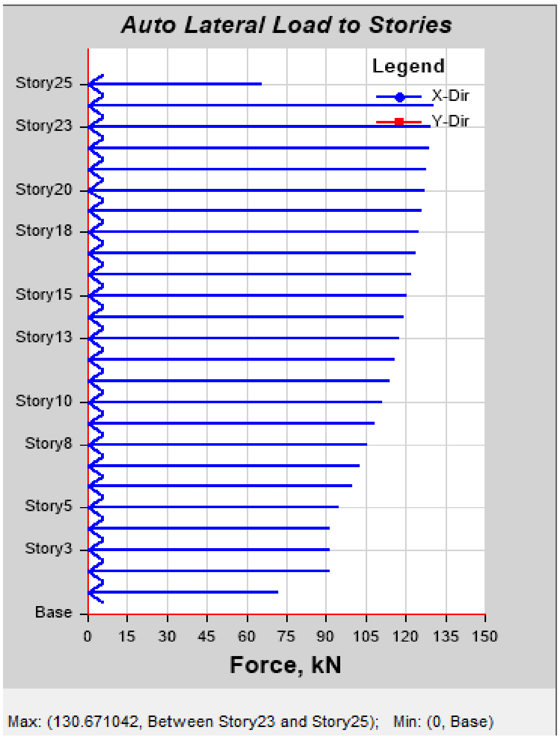


Fig 3.12 Lateral load to Stories

TABLE: Story Response				
Story	**Elevation**	**Location**	**X-Dir**	**Y-Dir**
	m		kN	kN
Story25	75	Top	65.6414	0
Story24	72	Top	130.671	0
Story23	69	Top	129.7554	0
Story22	66	Top	128.8429	0
Story21	63	Top	127.9336	0
Story20	60	Top	127.0276	0
Story19	57	Top	126.1248	0
Story18	54	Top	125.1905	0
Story17	51	Top	123.8568	0
Story16	48	Top	122.2716	0
Story15	45	Top	120.6922	0
Story14	42	Top	119.1231	0
Story13	39	Top	117.5643	0
Story12	36	Top	116.0157	0
Story11	33	Top	114.2228	0
Story10	30	Top	111.4342	0
Story9	27	Top	108.4294	0
Story8	24	Top	105.4946	0
Story7	21	Top	102.9329	0
Story6	18	Top	100.0464	0
Story5	15	Top	94.9945	0
Story4	12	Top	91.532	0

tory2	6	Top	91.26	0
Story1	3	Top	71.955	0
Base	0	Top	0	0

Displacement for Diaphragm

The Center of rigidity is the stiffness centroid within a floor-diaphragm plan. When the center of rigidity is subjected to lateral loading, the floor diaphragm will experience only translational displacement. From the data given below, we can easily see how displacement is happening on a different story of the building. In X-direction maximum of 0.012 was the displacement on the top floor of the building and the ground floor and floors near the ground have negligible displacement. After looking at the graph we can conclude that the maximum displacement was as we move towardsupwards. Wind force can't cause much damage with such small displacement but there might be a concern if there is more displacement than this.

ttttt

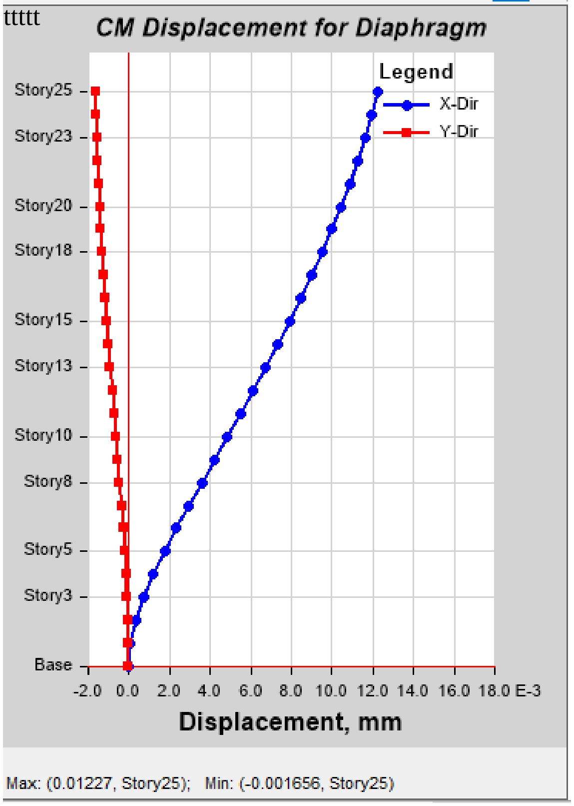


TABLE: Story Response				
Story	**Elevation**	**Location**	**X-Dir**	**Y-Dir**
	m		mm	mm
Story25	75	Top	0.012	-0.002
Story24	72	Top	0.012	-0.002
Story23	69	Top	0.012	-0.002
Story22	66	Top	0.011	-0.002
Story21	63	Top	0.011	-0.001
Story20	60	Top	0.01	-0.001
Story19	57	Top	0.01	-0.001
Story18	54	Top	0.01	-0.001
Story17	51	Top	0.009	-0.001
Story16	48	Top	0.008	-0.001
Story15	45	Top	0.008	-0.001
Story14	42	Top	0.007	-0.001
Story13	39	Top	0.007	-0.001
Story12	36	Top	0.006	-0.001
Story11	33	Top	0.005	-0.001
Story10	30	Top	0.005	-0.001
Story9	27	Top	0.004	-0.001
Story8	24	Top	0.004	-0.0004363
Story7	21	Top	0.003	-0.00037
Story6	18	Top	0.002	-0.00028
Story5	15	Top	0.002	-0.00021

Story4	12	Top	0.001	-0.00014
Story3	9	Top	0.001	-8E-05
Story2	6	Top	0.000339	-3.6E-05
Story1	3	Top	5.91E-05	-1.3E-05
Base	0	Top	0	0

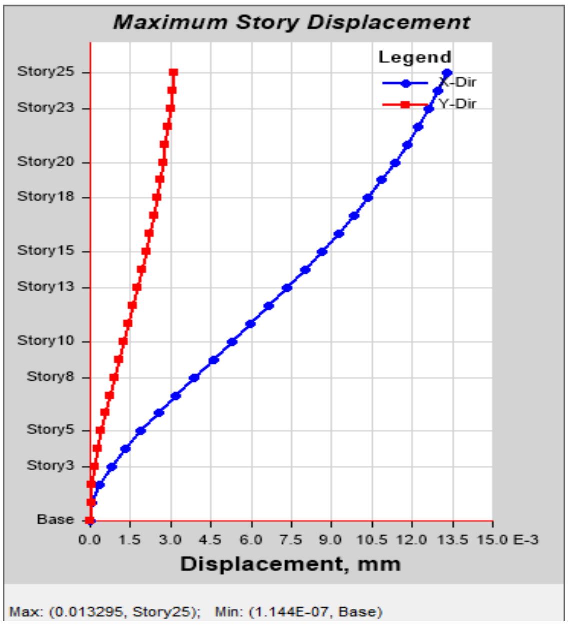
Maximum Story displacement

The total displacement of any stories with respect to ground. the wind is a vertical force that causes displacement on the stories of a building. If this displacement with respect to the ground is very highthe building can be considered dangerous. So, to be safe for anyone to live in such buildings the displacement against the ground should be very less. After looking at the story response table we cantell that the displacement is very less and the highest is on the top floor which is 0.0132mm

Fig 3.14 Maximum story Displacement.

TABLE: Story Response

Story	Elevation (m)	Location	X-Dir	Y-Dir
Story25	75	Top	1.12E-07	2.46E-08
Story24	72	Top	1.19E-07	2.57E-08
Story23	69	Top	1.28E-07	2.77E-08
Story22	66	Top	1.38E-07	3.02E-08
Story21	63	Top	1.48E-07	3.30E-08
Story20	60	Top	1.59E-07	3.61E-08
Story19	57	Top	1.70E-07	3.93E-08
Story18	54	Top	1.81E-07	4.25E-08
Story17	51	Top	1.91E-07	4.57E-08
Story16	48	Top	2.01E-07	4.87E-08
Story15	45	Top	2.09E-07	5.15E-08
Story14	42	Top	2.17E-07	5.40E-08
Story13	39	Top	2.23E-07	5.60E-08
Story12	36	Top	2.28E-07	5.76E-08
Story11	33	Top	2.30E-07	5.85E-08
Story10	30	Top	2.31E-07	5.88E-08



Story8	24	Top	2.26E-07	5.67E-08
Story7	21	Top	2.19E-07	5.41E-08
Story6	18	Top	2.09E-07	5.03E-08
Story5	15	Top	1.93E-07	4.51E-08
Story4	12	Top	1.72E-07	3.86E-08
Story3	9	Top	1.45E-07	3.05E-08
Story2	6	Top	1.13E-07	1.97E-08
Story1	3	Top	2.41E-08	6.37E-09
Base	0	Top	0	0

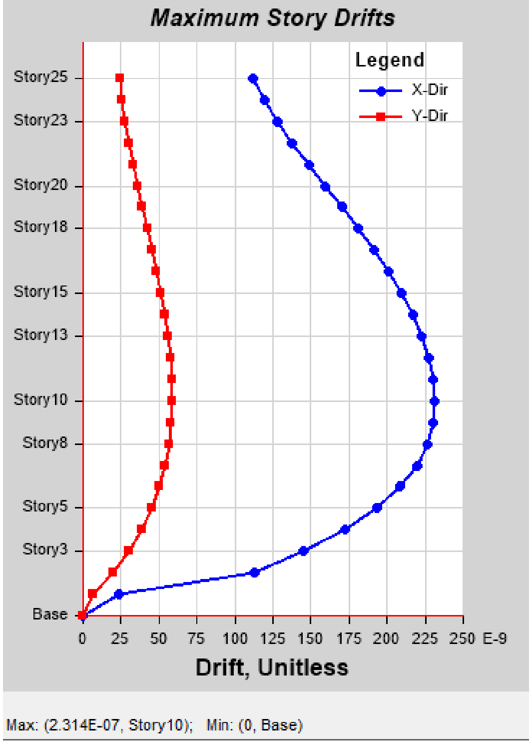
Maximum story drifts

Story drift is the lateral displacement of one level relative to the level above or below.

According to IS 1893:2000 story drift in any story due to the minimum specified design lateral force,with a partial load factor of 1, shall not exceed 0.004 times the story height. Hight of one floor is 3m and the maximum story drift is 0.0000002314 which according to our condition doesn’t have any problem.

TABLE: Story Response				
Story	**Elevation**	**Location**	**X-Dir**	**Y-Dir**
	m			
Story25	75	Top	1.117E-07	2.46E-08
Story24	72	Top	1.189E-07	2.567E-08
Story23	69	Top	1.278E-07	2.774E-08
Story22	66	Top	1.377E-07	3.022E-08
Story21	63	Top	1.482E-07	3.303E-08
Story20	60	Top	1.591E-07	3.608E-08
Story19	57	Top	1.701E-07	3.926E-08
Story18	54	Top	1.808E-07	4.249E-08
Story17	51	Top	1.911E-07	4.566E-08
Story16	48	Top	2.006E-07	4.869E-08
Story15	45	Top	2.092E-07	5.149E-08
Story14	42	Top	2.166E-07	5.396E-08
Story13	39	Top	2.228E-07	5.603E-08

Story12	36	Top	2.275E-07	5.758E-08
Story11	33	Top	2.304E-07	5.854E-08
Story10	30	Top	2.314E-07	5.878E-08
Story9	27	Top	2.301E-07	5.82E-08
Story8	24	Top	2.262E-07	5.667E-08
Story7	21	Top	2.193E-07	5.407E-08
Story6	18	Top	2.085E-07	5.025E-08
Story5	15	Top	1.932E-07	4.512E-08
Story4	12	Top	0.000000172	3.863E-08
Story3	9	Top	1.448E-07	3.052E-08
Story2	6	Top	1.128E-07	1.97E-08
Story1	3	Top	2.411E-08	6.366E-09
Base	0	Top	0	0

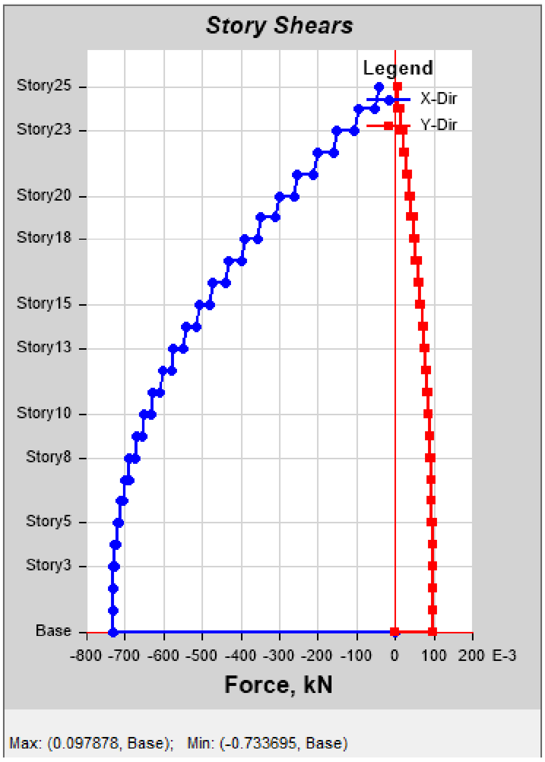


It is the graph that shows how much lateral (horizontal) load, be it wind or seismic, is acting per story.The lower you go, the greater the shear becomes. The maximum story shear is 0.73368KN inthe x- direction and 0.0979Kn in the Y direction. In story shear, you can visualize the possible governing lateral load (wind load) on a certain floor in a given direction. And this will aid in understanding or investigating why wind governs over seismic in a certain direction or vice versa. Aside from which, you can check whether something is problematic or not or something just doesn'tseem right according to the guts of us structural engineers.

Normally, the larger the area that the building catches, the larger or the more wind force it can attract,or simply, it's a function of the tributary area, the area on the x-direction is more the that of x- direction.

Fig 3.15 Story Shear

Story	Elevation	Location	X-Dir	Y-Dir
	m		kN	kN
Story25	75	Top	-0.0415	0.0056
		Bottom	-0.0519	0.007
Story24	72	Top	-0.0968	0.0131
		Bottom	-0.107	0.0144
Story23	69	Top	-0.1506	0.0203
		Bottom	-0.1604	0.0216
Story22	66	Top	-0.2028	0.0274
		Bottom	-0.2122	0.0286
Story21	63	Top	-0.2531	0.0342
		Bottom	-0.2622	0.0354
Story20	60	Top	-0.3015	0.0407
		Bottom	-0.3103	0.0419
Story19	57	Top	-0.3479	0.047
		Bottom	-0.3563	0.0481
Story18	54	Top	-0.3921	0.053
		Bottom	-0.4	0.0541
Story17	51	Top	-0.4339	0.0587
		Bottom	-0.4414	0.0597
Story16	48	Top	-0.4733	0.064
		Bottom	-0.4804	0.0649
Story15	45	Top	-0.5101	0.069
		Bottom	-0.5167	0.0698



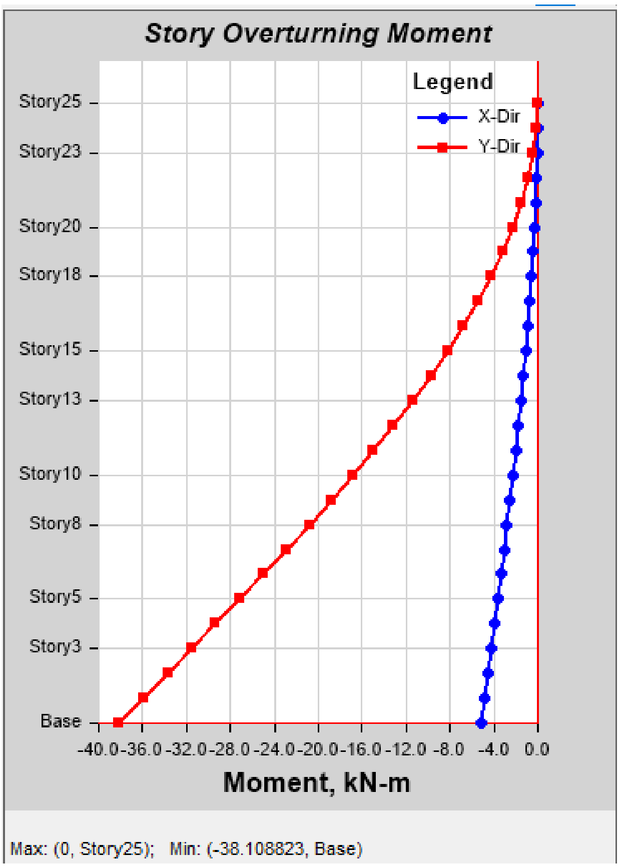
Story14	42	Top	-0.5443	0.0736
		Bottom	-0.5503	0.0744
Story13	39	Top	-0.5757	0.0778
		Bottom	-0.5812	0.0785
Story12	36	Top	-0.6042	0.0816
		Bottom	-0.6091	0.0822
Story11	33	Top	-0.6298	0.085
		Bottom	-0.6342	0.0855
Story10	30	Top	-0.6524	0.0879
		Bottom	-0.6563	0.0884
Story9	27	Top	-0.6721	0.0905
		Bottom	-0.6755	0.0909
Story8	24	Top	-0.6889	0.0926
		Bottom	-0.6917	0.0929
Story7	21	Top	-0.7027	0.0943
		Bottom	-0.705	0.0946
Story6	18	Top	-0.7137	0.0956
		Bottom	-0.7155	0.0958
Story5	15	Top	-0.7221	0.0966
		Bottom	-0.7233	0.0967
Story4	12	Top	-0.7279	0.0973
		Bottom	-0.7287	0.0973
Story3	9	Top	-0.7315	0.0976
		Bottom	-0.732	0.0977
Story2	6	Top	-0.7332	0.0978
		Bottom	-0.7334	0.0978
Story1	3	Top	-0.7337	0.0979
		Bottom	-0.7337	0.0979
Base	0	Top	0	0
		Bottom	0	0

Story overturning moment:

The overturning moment of a building is the moment of energy capable of upsetting the building.

For a building to be stable the overturning moment should be high as it is really important for to building not to overturn doing high wind. As we go upwards the overturning moment also decreases and the highest is on the base of the building. It also depends on the area on the side as we can see thatthe y-direction has more overturning moment than the x-direction. The area on the y side is more the xside. It's a very important aspect for design to have a high overturning moment so that the building is more stable even on the high wind..

Fig 3.16 Story Overturning Moment



Max: (0, Story25); Min: (-38.108823, Base)

TABLE: Story Response				
Story	**Elevation**	**Location**	**X-Dir**	**Y-Dir**
	m		kN-m	kN-m
Story25	75	Top	0	0
Story24	72	Top	-0.0189	-0.1402
Story23	69	Top	-0.0601	-0.4459
Story22	66	Top	-0.123	-0.9126
Story21	63	Top	-0.2071	-1.5352
Story20	60	Top	-0.3115	-2.3082
Story19	57	Top	-0.4355	-3.226
Story18	54	Top	-0.5782	-4.2823
Story17	51	Top	-0.7388	-5.4706
Story16	48	Top	-0.9164	-6.7837
Story15	45	Top	-1.1098	-8.2143
Story14	42	Top	-1.318	-9.7546
Story13	39	Top	-1.5399	-11.3966
Story12	36	Top	-1.7744	-13.132
Story11	33	Top	-2.0201	-14.952
Story10	30	Top	-2.2758	-16.8481
Story9	27	Top	-2.5403	-18.8113
Story8	24	Top	-2.8122	-20.8328
Story7	21	Top	-3.0905	-22.9037
Story6	18	Top	-3.3738	-25.0153
Story5	15	Top	-3.661	-27.1592
Story4	12	Top	-3.951	-29.3274

Story3	9	Top	-4.2429	-31.5125
Story2	6	Top	-4.5359	-33.7078
Story1	3	Top	-4.8294	-35.9078
Base	0	Top	-5.123	-38.1088

Wind Displacement in X direction(mm)

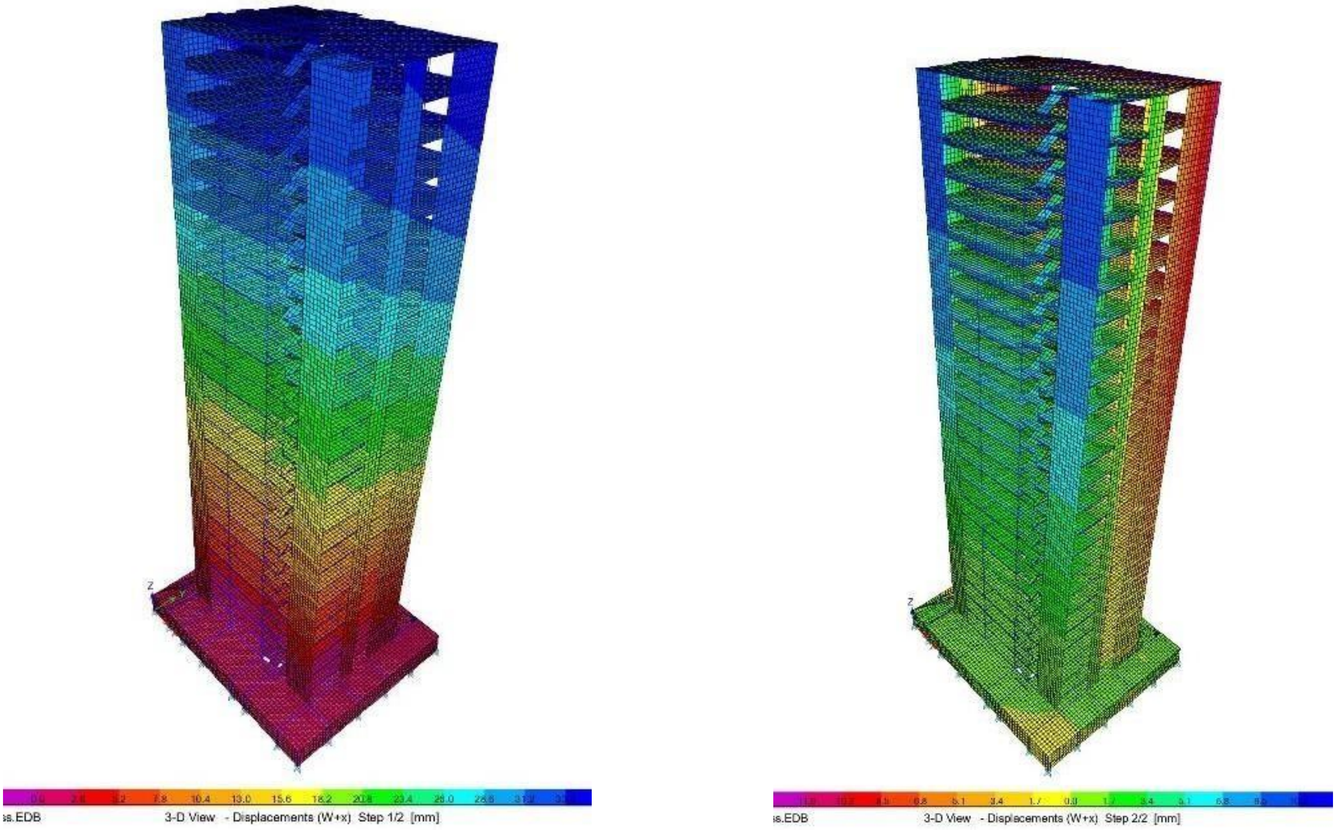


Fig 3.17 & 3.18 3d representation of lateral force and wind load on a Building

This is 3d representation of lateral force or wind load on a building which shows the displacement in the x-direction. With the help of graphical representation, we can see that the displacement on the top of the building is much more than that of near ground. Stories near the ground have less displacementbecause wind force increase as we increase the height of an object or structure. More the surface area more will be contacted for wind hence the wider side will get more wind load and have more displacement on that side. The 3D view helps us understand the gradual increase in displacement of the building stories. the highest displacement is about 33mm on the top floor of the building. The maximum wind force is on the top story of the building and to prevent any damagewe need to make sure that the building is made properly. Displacement in the x-direction is in twoparts because of two sides and to showcase the effect of wind on both the faces of a building.

Second building

Analysis Results:

Fig 3.19 A rendered image of building with a proper atmosphere around it.

After analyzing two rectangular-shaped buildings we got similar results. One of the main important aspects was their faces, which made difference as the surface area more is the wind load on the side ofa building. Rectangular shape building is one of the most common shapes so it was important to include in the analysis. As we get the results, we can conclude that there can be different shapes of a building which can be useful in decreasing the effect of wind load. So, we tried to do our analysis on different shapes to get different results and compare them with the following

Cylinder:

One of the most used shapes is a cylinder, to work on tall building analysis we also need to include a cylinder. As the surface area of a cylinder that comes in contact with wind is less than that of a rectangle,. This is a 25-story building with 4m hight of each story. All the materials and components in this building are similar to that of a rectangular building. analysis of cylinder is important because of its unique shape and how wind flows around it, building doesn’t have any corners which makes it less vulnerable to damage due to high wind speed. This analysis was done on Etabs to learn about thedifferent structural aspects of building. Comparison between two buildings by comparing maximum Story displacement, Drift for the diaphragm, maximum story drifts, Story Shears, Story Overturning Moment, wind Displacement. With the help of CFD wind flow around the building is also shown. It will help in understanding the flow and nature of wind around buildings in a graphical way.

3d cylinder building in Etabs

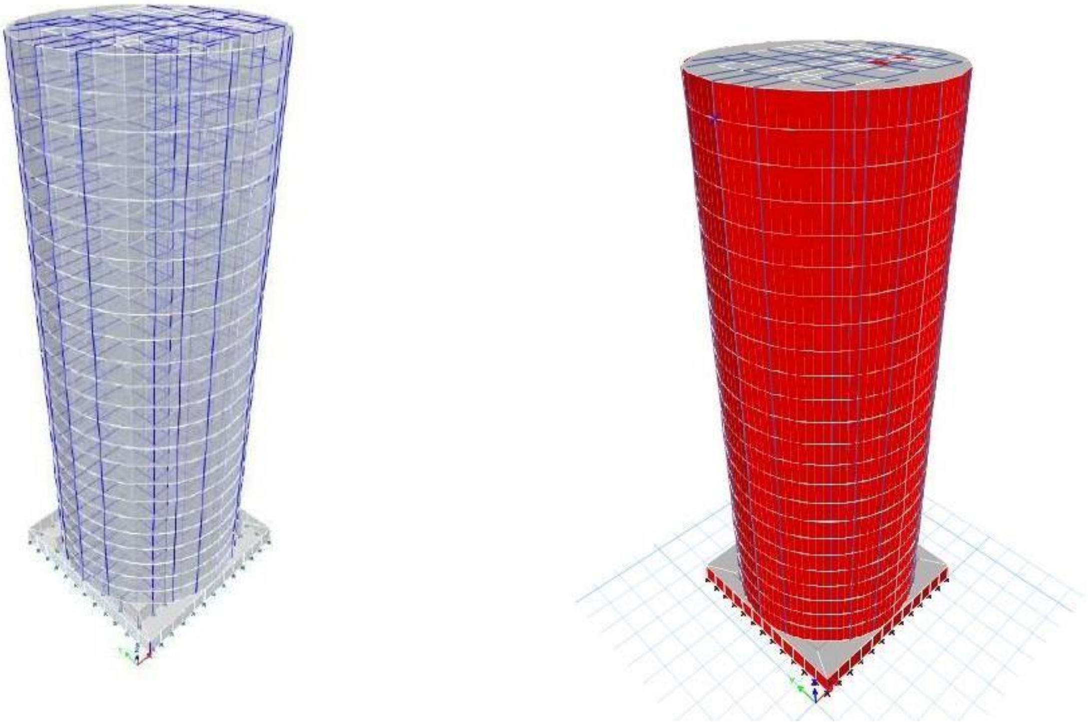
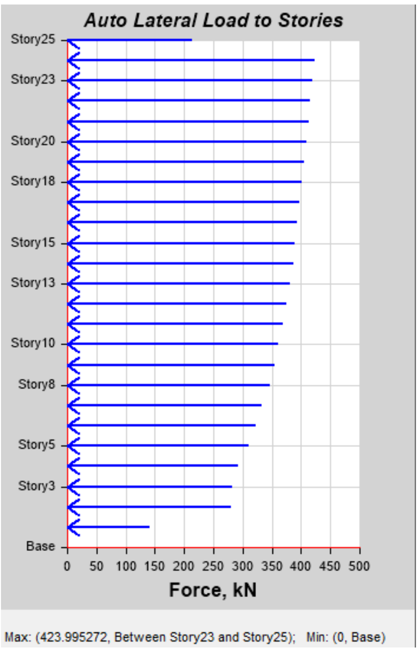


Fig 3.20 3d design of Cylindrical Building

Lateral load to stories:

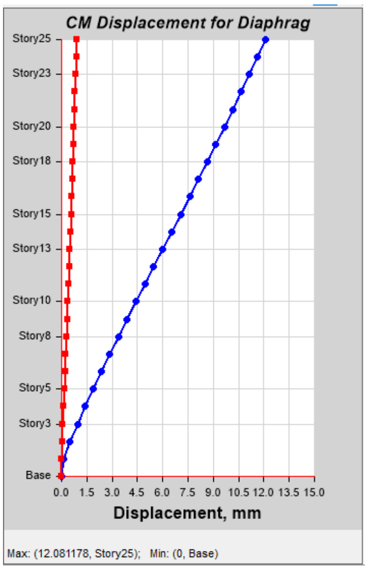
Lateral loads are live loads that are applied parallel to the ground. They are horizontal forces acting ona structure. From our analysis, we can observe that as we move upwards from ground lateral load to stories increase. By taking the x-axis we get different forces in KN on the walls of a building, it increases on a different story and is maximum on the top story. From the data on this table below we can get the idea of lateral wind force on the building. The highest lateral load was 504KN on a rectangular building and this building is 423KN, which is less the that of a rectangular building. lesser the lateral load to stories better it is for a building and less will be the displacement. So cylindershape building is better than rectangular-shaped building.



Displacement for Diaphragm

In X-direction maximum of 0.01208mm was the displacement on the top floorof the building and the ground floor and floors near the ground have negligibledisplacement. After looking at the graph we can conclude that the maximum displacement was as we move towards upwards. Wind force can't cause much damage with such small displacement but there might be a concern if there is more displacement than this.

The displacement in this similar to that of rectangular as the interior of the building is kept the same. So the diaphragm is also the same which means thatthere is the similarity in the values of both the shapes

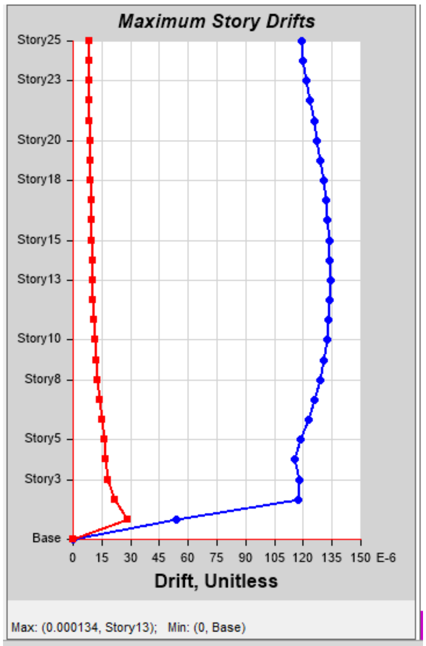


Maximum story drift

Story drift is the lateral displacement of one level relative to the level above or below.

According to IS 1893:2000 story drift in any story due to the minimum specified design lateral force,with a partial load factor of 1, shall not exceed 0.004 times the story height. Hight of one floor is 4m and the maximum story drift is 0.000134 which passes the condition given in is code. There shall be no drift limit for single-story buildings. which has been designed to accommodate story drift. Story drift depends a lot on the materials and components of a building. As the material and components of a building are the same as the rectangular one the maximum story drift is also. Drift is a unitless number resulting from dividing the relative lateral displacement to the story height, and it shows how much a story is displaced by a given load. The usual limit for wind drift is H/500 while for seismic drift it is 0.01H. A graph of a story drift is given below.

Maximum Story Displacement



Total displacement of any stories with respect to ground. the wind is a vertical force that causes displacement on the stories of a building. If this displacement with respect to the ground is very high the building can be considered dangerous. So, to be safe for anyone to live in such buildings the displacement against the ground should be very less.

After looking at the story response table we can tell that the displacement is very less and the highest is on the top floor which is0.0122mm.

When we compare it to rectangular buildings both have similar storydisplacement.

But this can be reduced by using different materials and increasing theconnectivity of different component

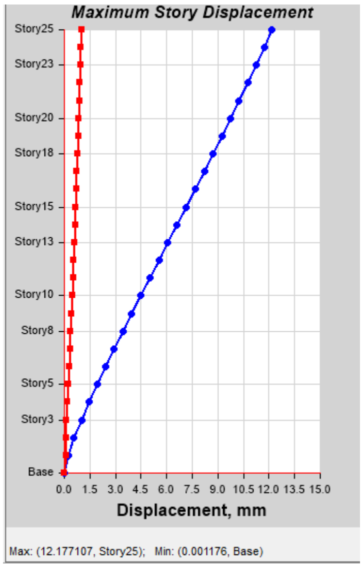
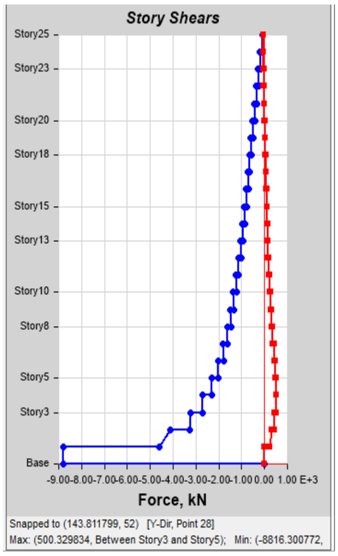
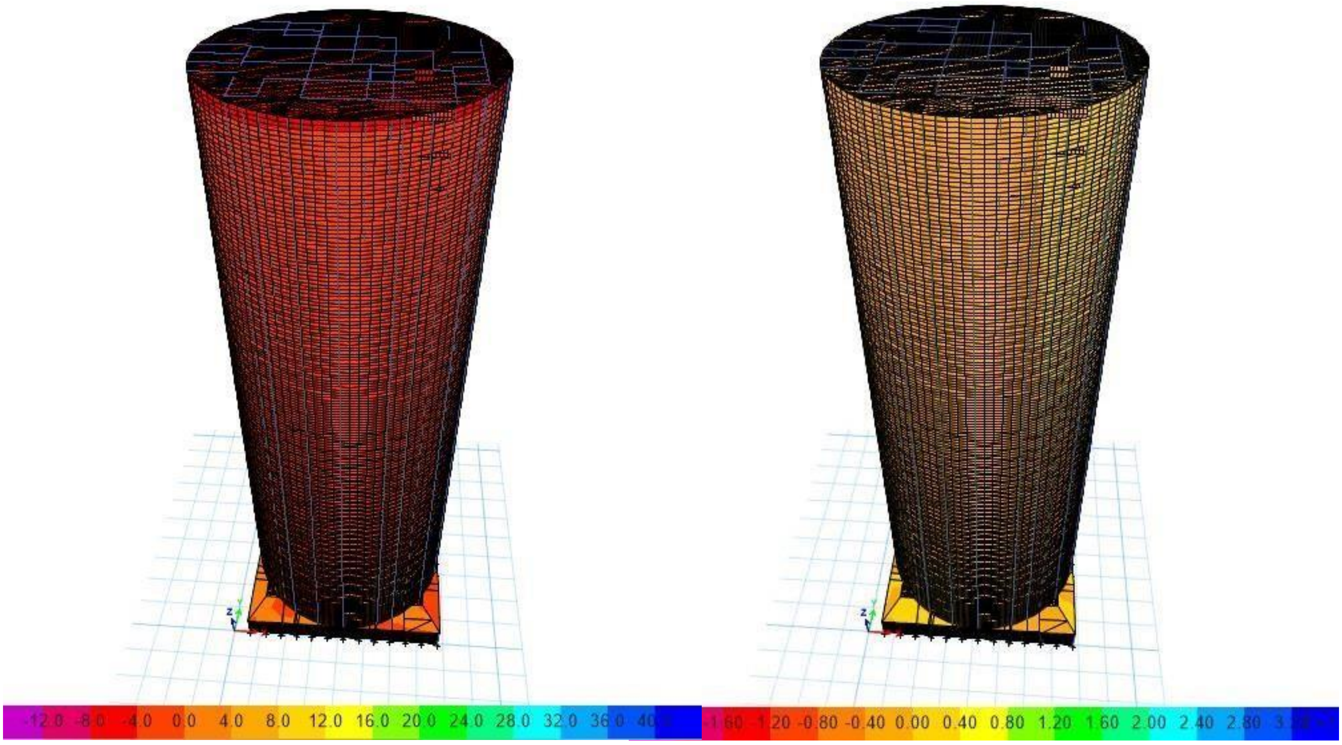


Fig 3.22 story shear



Snapped to (143.811799, 52) [Y-Dir, Point 28]
Max: (500.329834, Between Story3 and Story5); Min: (-8816.300772,

Fig 3.23 3d Representation of cylindrical Building



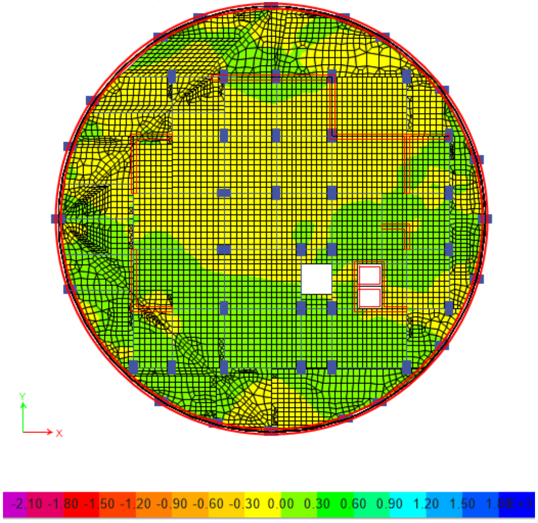
It is a 3D graphical representation that how wind effect building. Different colours are in this showthe displacement of the point or surface due to wind force. The result shown is in the x-direction with both faces. The wind is a literal force that affects the surface of a building so when we look atthe colour of the building we can see that it is almost in the same colour. the highest movement isaround 3mm in part 1 and in part 2 it is around 0.8mm, which is very less as compared to a rectangular building.

2D floor plan of a building. This also shows displacement due to wind load. As it shows that the outer side of the building is more affected by the wind force. There is a slight displacement of 0.3 onthe outer side but the inner side is not much affected by wind force and has negligible displacement which is very good for building.

The specific parameters which include base shear, modal intervals of buildings, story drifts are evaluated. The overall results recommended that as we go upwards in terms of height, wind forces increases and the displacement of a building is more in X and Y direction which may cause a buildingto fail but to we increase the height of building size of column and beam is also increased, change in building material is needed. As time records is a realistic technique, used for seismic evaluation, it gives a maximum higher check to the protection of systems analyzed and designed by way of technique specified by way of IS code.

Maximum axial force in the column increases with increases in the height of the building frame. Maximum shear force in beams increases with an increase in the height of the building and with an increase in the wind velocity also. Maximum bending moment different building heights increase withthe increase in the wind velocity and height of the building. Maximum displacement for different heights of building frame increases with an increase in the wind velocity.

Fig 3.24 2d representation of building



Chapter 4

Effect of wind on different shapes of buildings

Wind-flow pattern around an isolated building.

From the above Illustrations, there are five terms that need to be discussed:
1. Stagnation Point.
2. Point of Maximum velocity.
3. Boundary-Layer.
4. Flow Separation.
5. Wake.

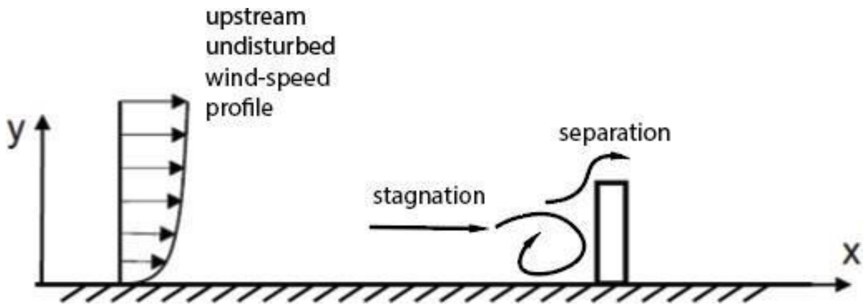
Boundary-Layer:

a boundary layer is the layer of fluid in the immediate vicinity of a bounding surface where the effectsof viscosity are significant. The viscous nature of airflow reduces the local velocities on a surface andis responsible for skin friction. The layer of air over the wings surface that is slowed down or stopped by viscosity, is the boundary layer. There are two different types of boundary layer flow: laminar and turbulent.

Flow separation:

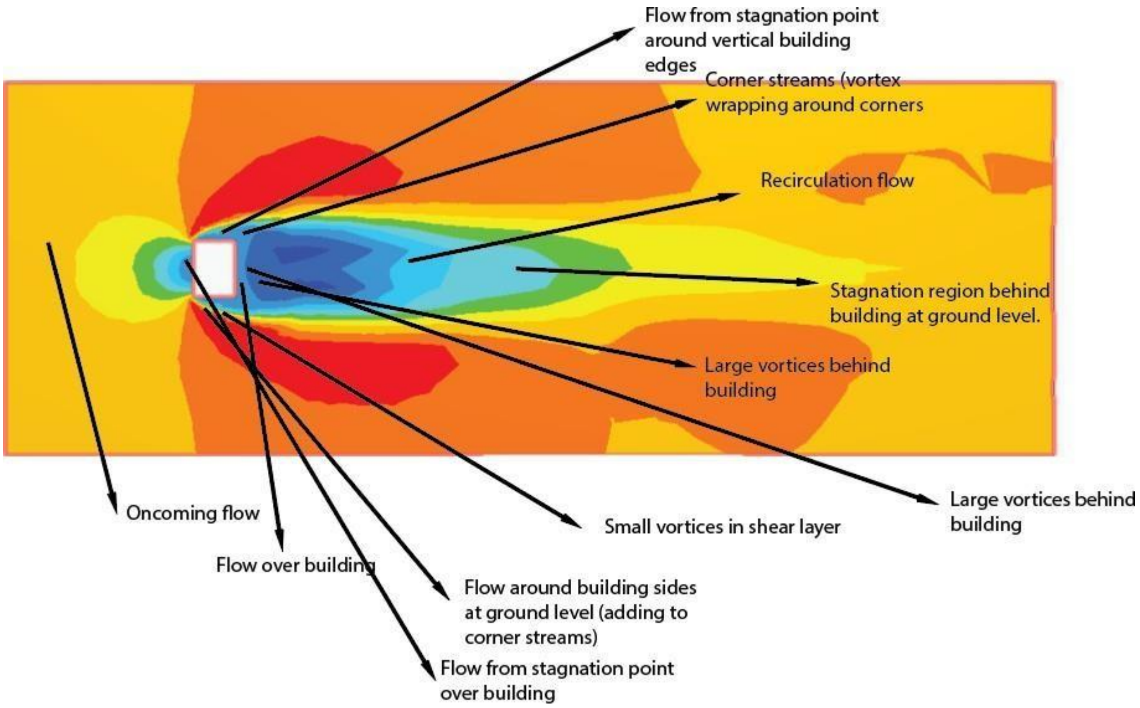
It is important to understand when and why the flow separates when fluid flows through the obstacle or cylinder in this case. In boundary-layer, due to viscosity, there is a change in pressure along the surface of the body.. If the pressure decreases in the direction of the flow, the pressure gradient is saidto be more favourable. In this case, the pressure force can assist the fluid movement and there is no flow retardation., if the pressure is increasing on the direction of the flow, an pressure gradient condition as so it is called exist. In addition to the presence of a strong viscous force, the fluid particles now have to move against the increasing pressure force. Therefore, the fluid particles could be stopped or reversed, causing the neighbouring particles to move away from the surface. This phenomenon is called the boundary Layer separation or flow separation.

Fig 4.1 Process of Flow Seperation



This is a stimulation made on Simscale where flow of wind can be seen with respect to pressure andwind speed. Different colours represent the pressure and wind speed. By the help of this one can determine how wind behaves around different building.

Fig 4.2 Stimulation of wind analysis on different shape



Important factors of wind around the building:

1. Oncoming flow: A direction from where wind is flowing towards building. Wind flowingtowards building.
2. Flow over building: wind flowing over the building.
3. As wind gets saturated it flows from stagnation point to over the building
4. Wind flowing from side of building creating different pressure and saturation point.
5. Large and small vortices behind the building are formed
6. Stagnation and recirculation of air behind the building
7. Corner stream which causes vortex wrapping around corners.
8. Flow around and building sides at ground adding to corner streams.
9. Turbulence generated by the building.
10. Colours showing variation wind speed after coming in contact with corners .

Fig 4.3 Recirculation flow of air after divergence.

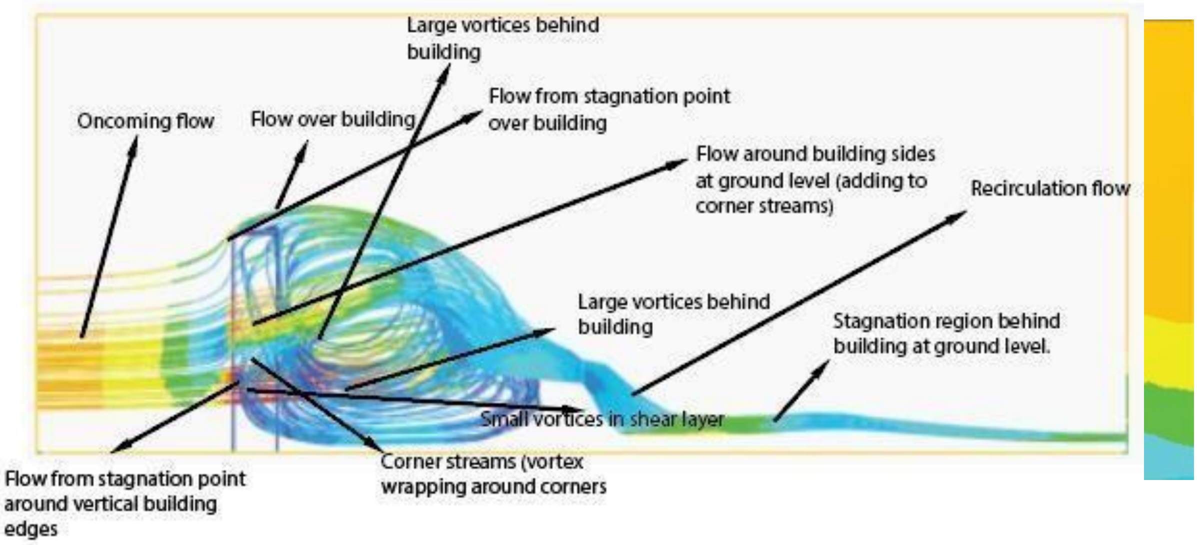
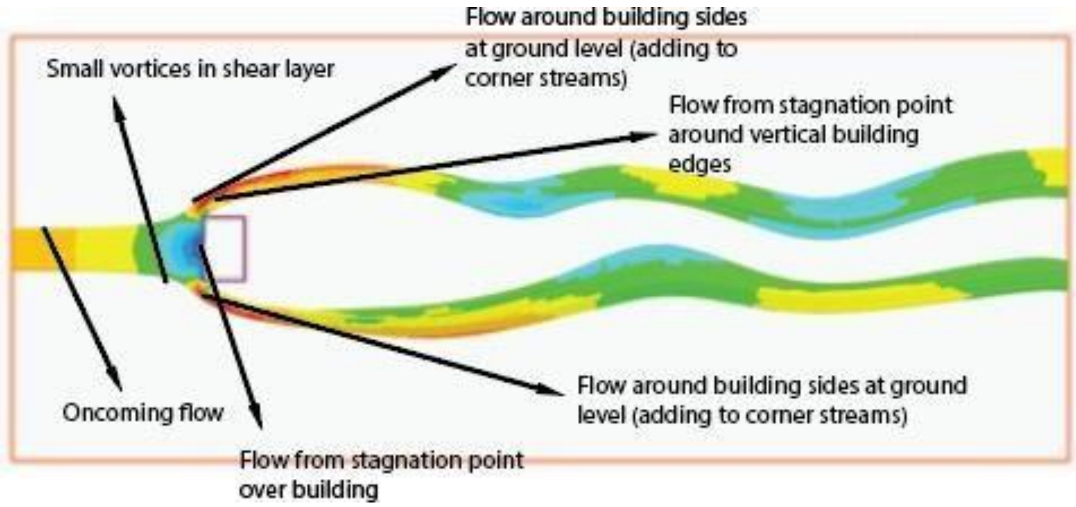


Fig 4.4 Flow around Building sides



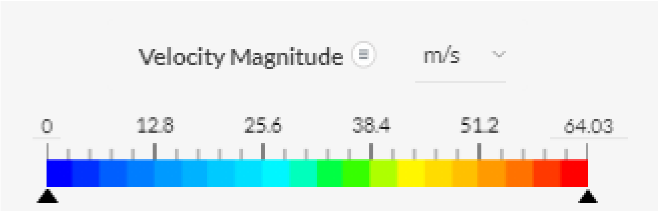


Fig 4.5 Velocity indicator which helps in contour and particle tracing of air at different velocity. .

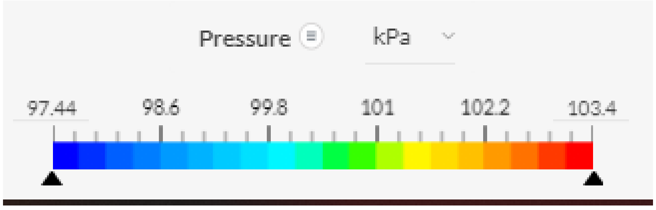


Fig 4.6 Pressure Indicator

101.325Kpa is the atmospharic pressure

Wind load analysis of vortex shedding around a building, we can observe that their variation in speed and pressure at different points, due to which there is discomfort on pedestrians and a nearby building.Simulation can help us understand the movement of wind after it comes in contact with the building. To study the dynamic effects of the wind load, a transient analysis with an incompressible turbulent flow is performed.

The results show the pressure loading and velocity contours for the initial design and the comparisonof the dynamic wind load effects of vortex shedding for the modified design. Large vortexes are formed due to sharp corners.

Different Shapes used in analysis

To study wind flow on buildings, we need to study different shapes and the effect wind has on them, how the effect on one is different from another. For the different shapes can be considered like shownin the figure below

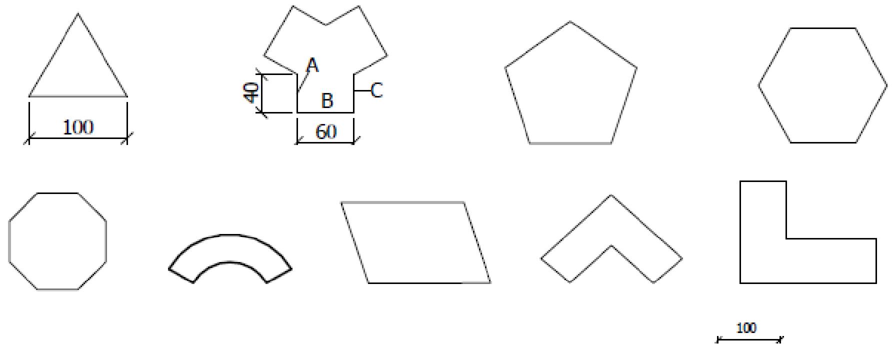
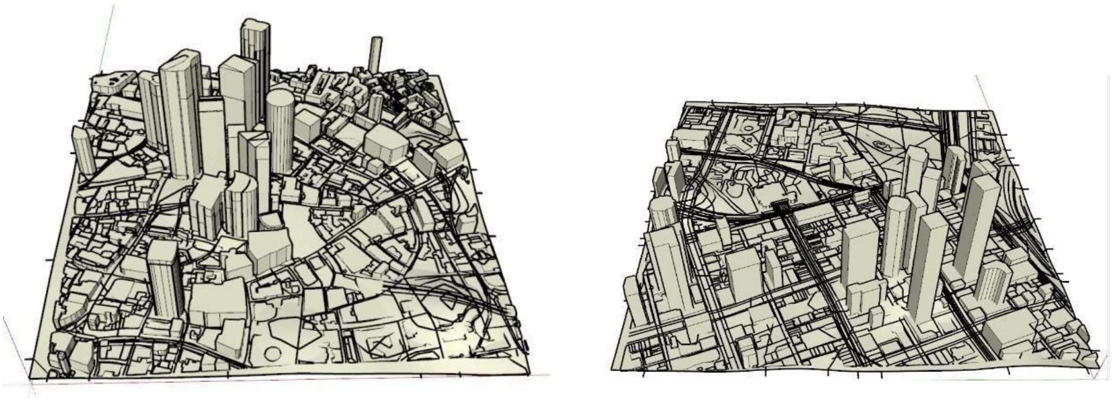


Fig 4.7 3D city view of tall buildings, similar shapes are used to do CFD analysis on it to get results on windflow around it.



Cuboid:

A cuboid is one of the most common shapes of a building, the front side of the buildingis rectangular so this can also be called a rectangular building. It is one of the most conventional types of building shape, above there has been structural analysis proving how wind behaves with a rectangular building. Now after performing CFD, it can be seen that wind react around building and forms complex pressure and velocity difference.

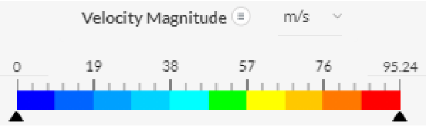
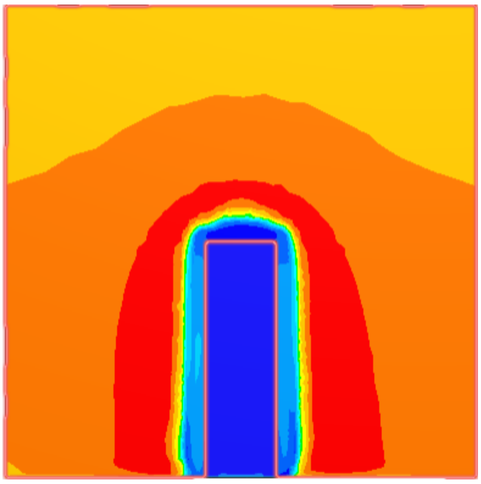


Fig - Velocity Magnitude



Manhattan's 432 Park Avenue features double-story cut-outs every 12 floors to combat the effects of the wind. So that wind could pass through it And wind load can be reduced.

Fig 4.8 This is the front view of a rectangular-Shape building

showing a difference in the speed of wind after it comes in contact with the building. Change in pressure and velocity can be seen as high pressure is created after wind expands from the sharp corners.

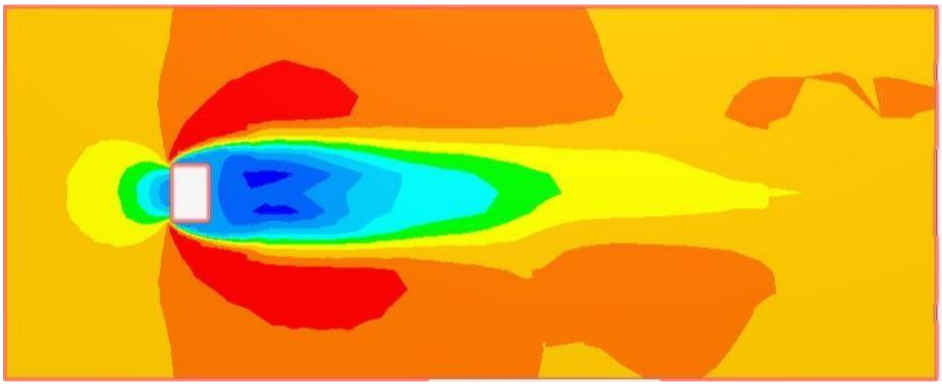


Fig 4.9 Wind flow contour

it depictsthe change in wind flow around the building, formation of a large vortex, separation of speedand pressure. A large red area is formed at the corners showing the highest wind and pressure concentration, that area has the highest wind speed and is dangerous forbuilding. Different vortex is formed at the opposite side of a building.

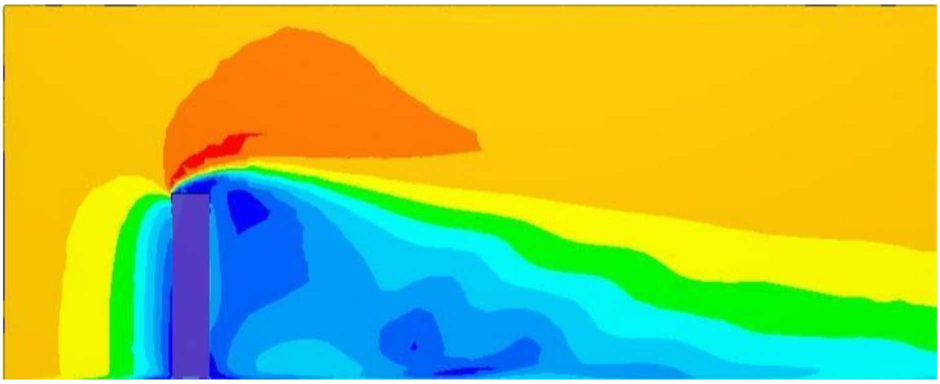


Fig 4.10 Variation of Wind Pressure

wind rotation and changing the speed of wind in different layers can be seen with vortex formation, variation in pressure, and increase in speed of the wind. High-speed wind formation above building after winds move away creating a variation of very high and low wind pressure around thebuilding.

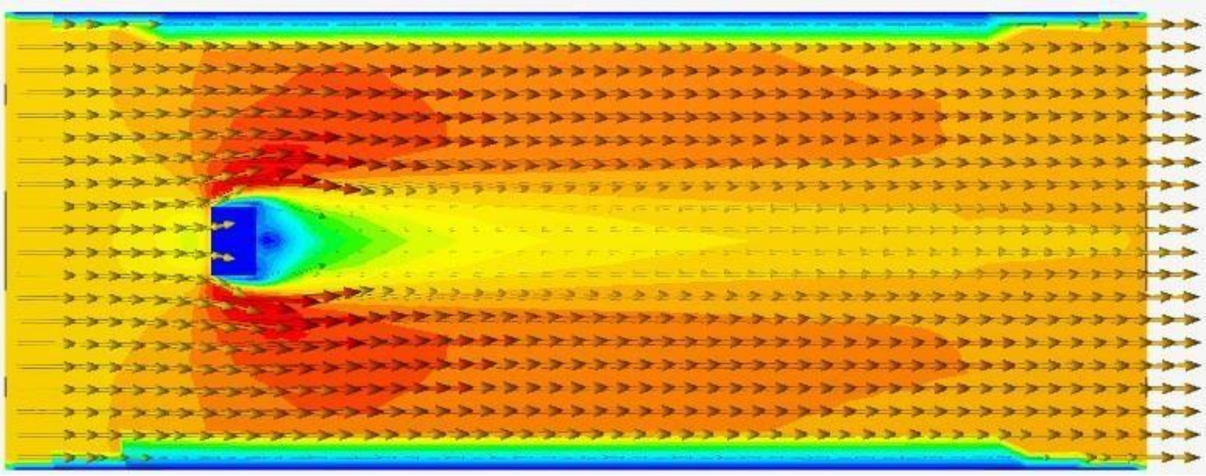


Fig 4.11 A vector representation of wind movement.

Rotation of wind can be seen after touching the corners ofthe building. Fewer vector behind building shows that the speed of wind is decreased after it collides with an opaque object, wind regains its speed after moving some distance away from the building.

Cylinder:

Cylinder-shaped buildings have very little vortex and clear wind movement around them, it is much better than when it's compared to other shapes as it doesn’t have corners, which reduces the point where pressure could be created. a cylinder has less surface area which comes in contact with the wind. As we can see there is no red colour in contours showing that no high-pressure zones are created by the building, which shows that a cylindrical building doesn’t hinder the flow of wind so, itcan be one of the ideal shapes to reduce the effect of wind on the building.

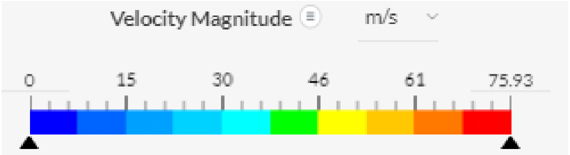


Fig 4.12 Velocity Magnitude

Wind speed of 50m/s was taken as an average wind speed, velocity magnitude represents the colour according to the speed of wind that affects the building.

The front view of the cylinder shows how wind around thebuilding behaves,

Due to the circular shape, there are no corners where the wind could create pressure points. windpasses without creating a dangerous vortex or high velocity and pressure points

In this couture we can see that movement of wind on the opposite side of the building is very differentfrom that of other shapes. There is a gradual increase in wind speed, no vortex is formed, no high- pressure zone is made after high-speed wind.

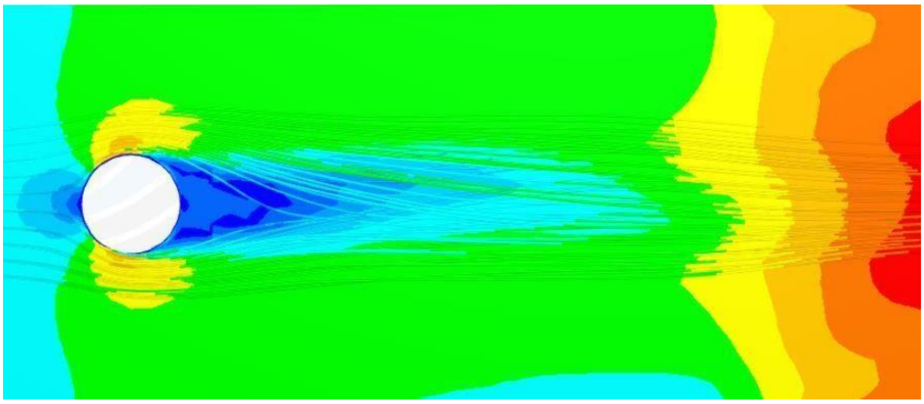


Fig 4.13 Partial Trace of Wind

It shows the partial trace of the wind and how it converges and diverges after colliding with the building. It also has couture of wind velocity, which shows the change in wind speed around the building. The wind doesn't have any major effect on the atmosphere around the building, but there isa gradual increase in the speed of the wind. Which can be considered normal.

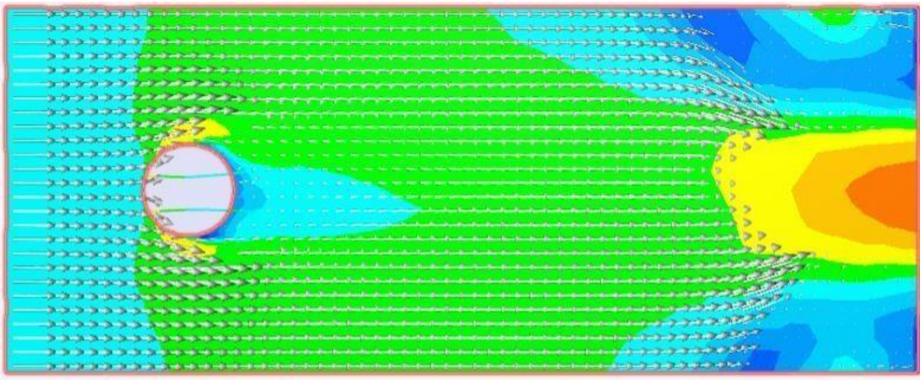
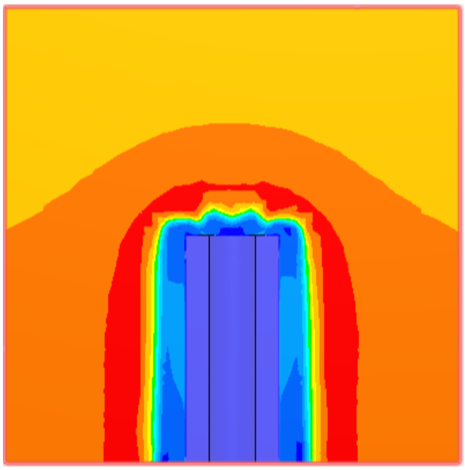


Fig 4.14 This is a Vector representation of the wind moving around the building

.

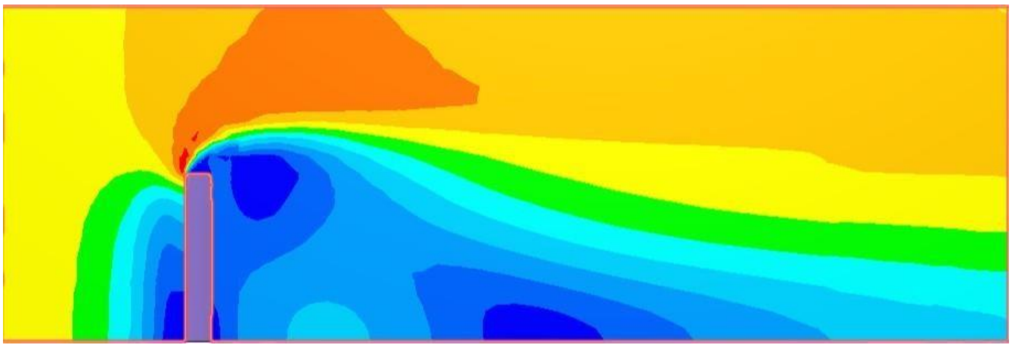
A strong movement of the wind from the left to the right side is represented by vectors, and it shows that the windon the other side of the structure is decreasing, as shown by the decrease in the size of arrows. Arrows show the movement of the wind above the building in a strong way as the topof the building has corners that can influence the wind flow.

Semi-circle



Semi-circle or a building with half of the side which resembles a cylinder.This is an irregular shape that has an irregular impact of wind on its surface. As it has two different faces with different shapes the behavior of wind around both faces will be different. The cylindrical side will behave in a similar manner as of cylinder but if the wind is coming from another side, then it will create different pressure and velocity zones which will create turbulence. The area shown in red has the highest wind speed, instead of two this building has four front corners which come in contact with wind.

Fig 4.14 Front view of building with half a side **Fig 4.15 wind speed**



The couture showing wind flow explains there in this building both on front and back vortex and thelow-pressure zone is created which is unnatural as compare to normal rectangular or cylindrical building. Both sides of the building experience high stress as wind diverges after colliding with corners. Vortex is formed on both sides of the building making discomfort for pedestrians and their building.

This shape of the building must be avoided in high wind zone as the surface area in this building ismore and so there will be more drag and drag force which is harmful to building n

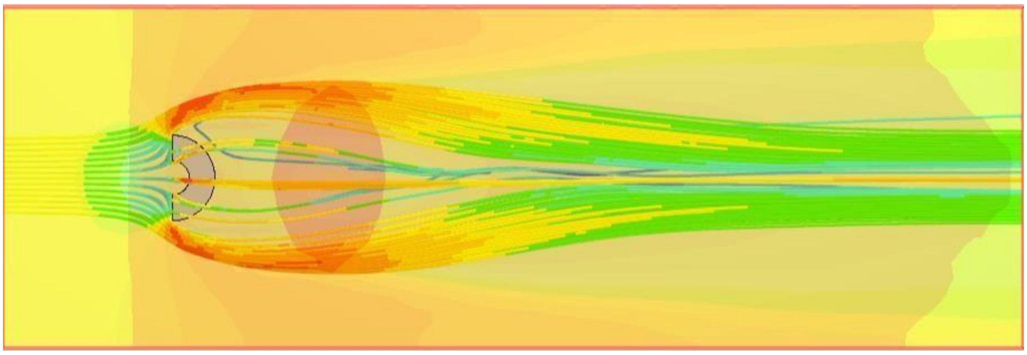


Fig 4.16 Partial tracing view of wind

This is a partial tracing view of the wind. we can see the movement of wind around the building andhow it converges and diverges after coming in contact with a building.

L shaped building

. There is a lot of similarity between L and V shape building as both are irregular buildings which produce high- and low-pressure zones,have multiple corners and fluctuation in speed of wind is common. In L-shaped buildings very thin surface area first comes in contact with the wind. Due to the narrow region and no obstetrical wind moves to their side and creates different pressure zones as shown in

Fig 4.17 the image below. this shape of buildings common in cities but it must be avoided in high wind zones.

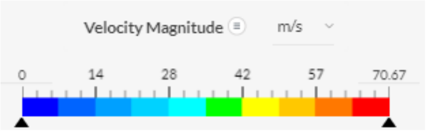
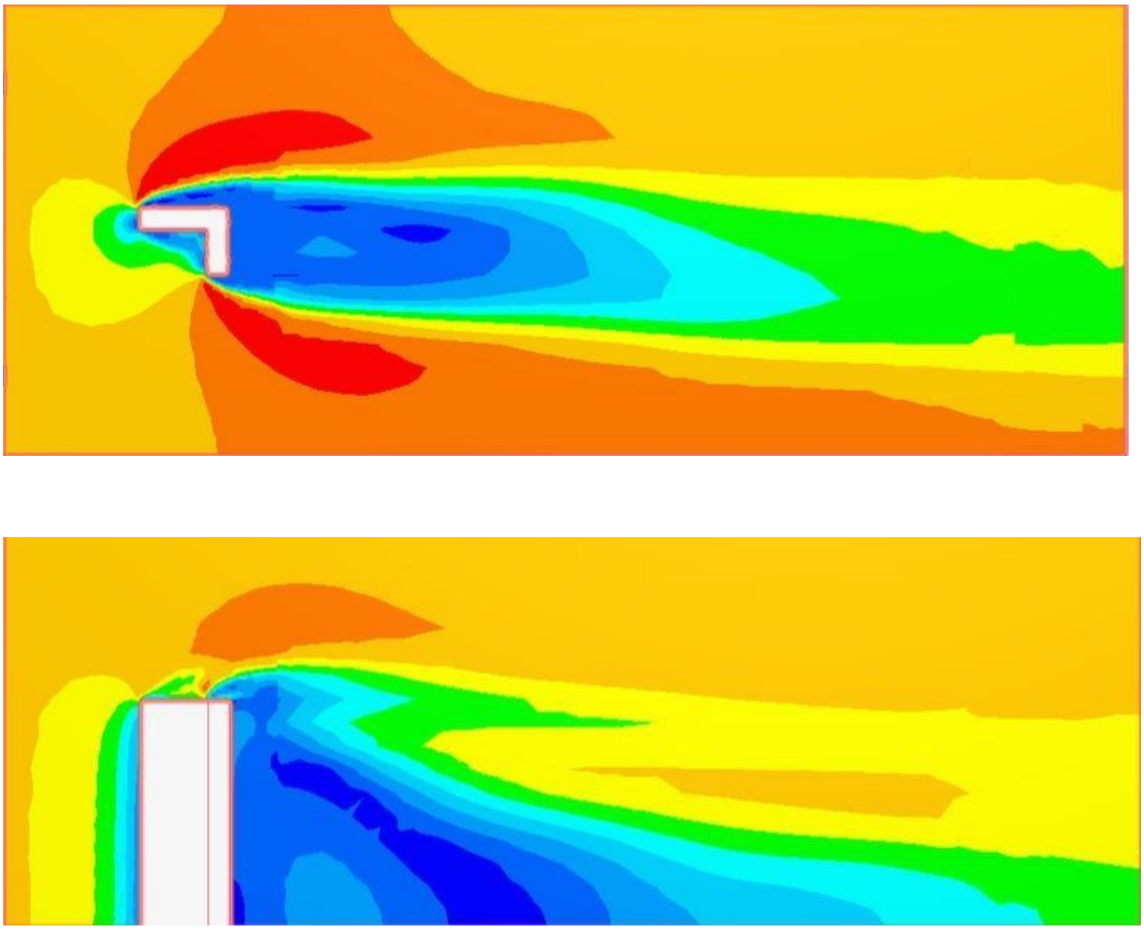


Fig 4.18 Contour showing wind flow around building

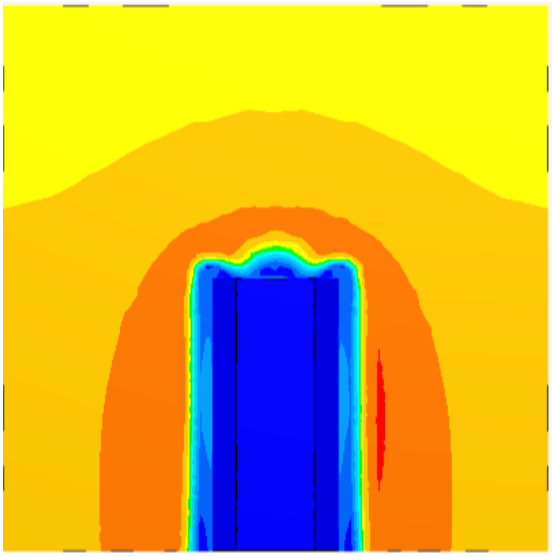


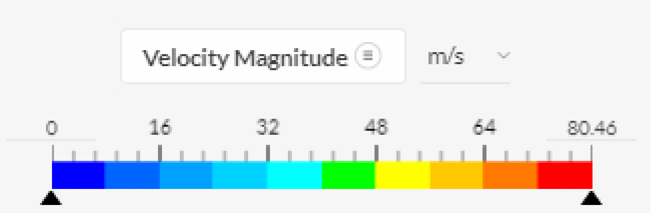
Consideration of the direction of wind pressure is very vital during design of high rise building with irregular geometry

particle tracking of wind shows how wind moves after it comes in contact with a building. Wind moves from one side to another as the other side creating a low-pressure zone and high wind forcebecause it has more surface area which comes in contact with the direct wind. Wind diverges aftercoming into contact with the corners of both sides of the building.

Hexagon:

hexagon-shaped buildings are very famous and are used in many places. As we do our analysis, we find that the behavior of wind on the corners of this building to have high pressure, and a vortex is formed but in less than rectangular buildings. As well look at a contour of wind we can understand how wind reacts around this shape. Hexagon has six corners and has more surface area which comesin contact with lateral wind flow, because of which opposite side of wind flow which comes behind the building experience low pressure and rotational movement of air. This is much better than that ofthe rectangle but due to edges, there are still chances of damage on the sides and corners.





As we look at the front view of the building, it showshow the wind is expanding after it hit the structure and due to concentrated airflow and increasing the speed of air at a different point

Fig 4.19 Front view of Hexagon-shaped Building

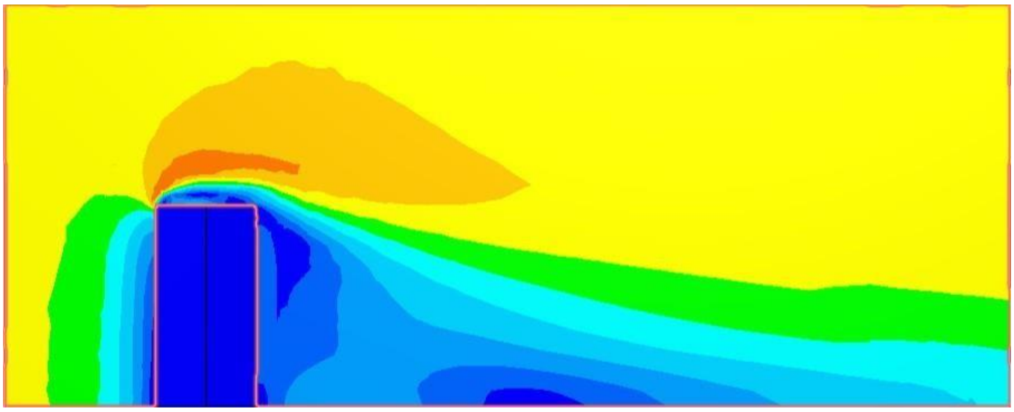


Fig4.20 Wind flow of building with wind flow contour.

In this couture, we can see that the movement of the wind on the opposite side of the building is very different from that of other shapes. There is a rapid increase in wind speed, the side corners of the hexagon create high pressure and high wind speed. Vortex formation is also seen behind the building which can generate turbulence in the surrounding. due to the high-pressure corner can damage. AS thesurface area of the contact is more the effect of wind on the surround is also more.

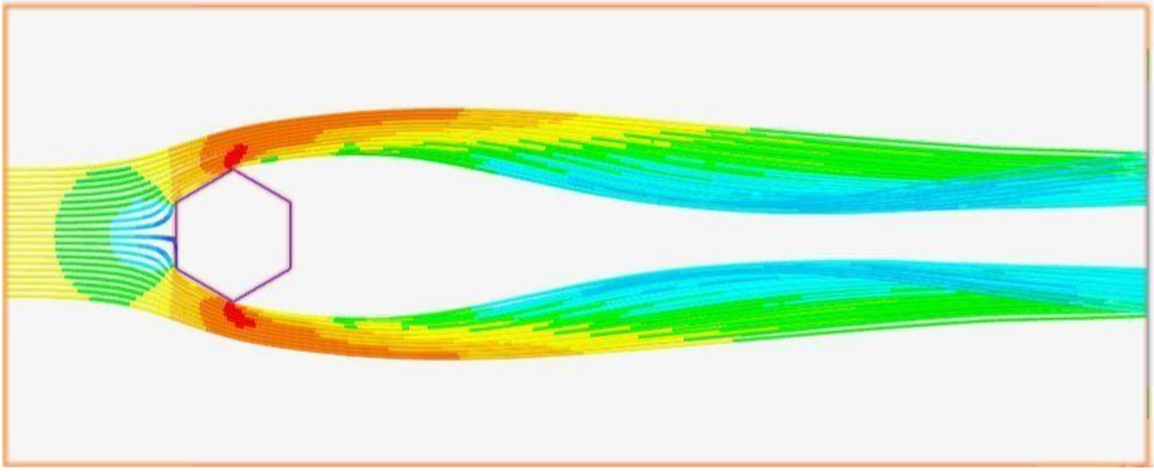
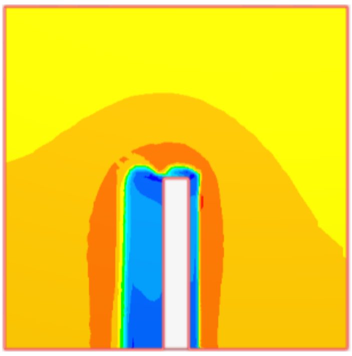


Fig 4.21 Movement of wind in opposite side of building

This is the particle trace view of the wind flow as it shows how flowing wind disperse after it hits thebuilding and where it has more speed. the dispersion and contraction of wind can easily help in identifying the flow of wind to be in a very irregular manner. The contraction of wind in certain areascan create discomfort.

Parallelogram

Parallelograms are similar to rectangular buildings but here they have sharp corners which becomes a position where wind effects are more and could cause damage. In this building, the initial contact area to the wind is different the that of cuboidal as one of the parts comes in contact first so, the wind also changes direction after colliding with the building, because of which one part of thebuilding has to experience more wind force than the other.



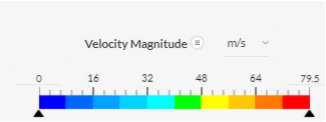


Fig 4.22 Front view of Parallelogram Building

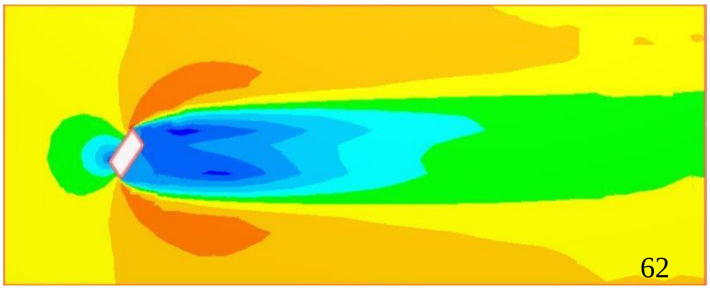


Fig 4.23 This couture showing wind formation around building
Wind flow contour depicts the change in wind flow around building, formation of a large vortex, separation of speed and pressure the wind has a similar

Fig 4.23 Side View of building

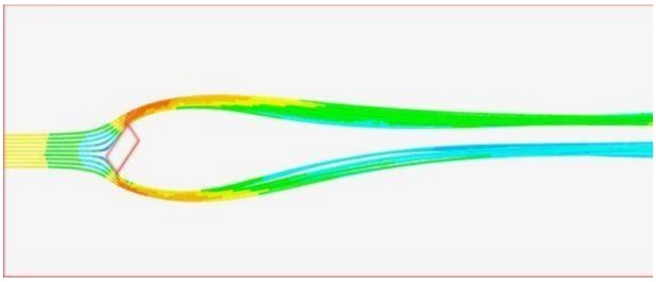


Fig 4.24 Partial tracing of wind flow

in this building show that corners have high pressure and high wind is formed in thatarea.

Pentagon

Pentagon-shaped buildings are very famous and are used in many places. As we do our analysis, we find that the behavior of wind on the corners of this building to have high pressure, and the vortex isformed but in less than rectangular buildings. As well look at the contour of wind we can understandhow wind reacts around this shape.

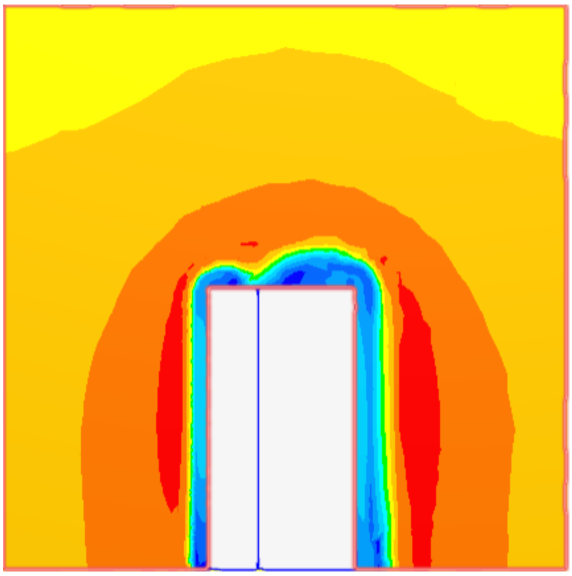


Fig 4.25 front view of the Pentagon Building

it shows how the wind is expanding after it hits the structure and due to concentrated airflow and increasing the speed of air at different points. The redpart has maximum wind speed and dueto change in wind speed from low to high there can be turbulence in the surrounding.

The vortex is formed behind buildings and change in pressure and wind speed can cause turbulence tothe surrounding areas. Corners form high-pressure areas because of which damage can be caused to the building.

Fig 4.26 This couture showing wind formation around building

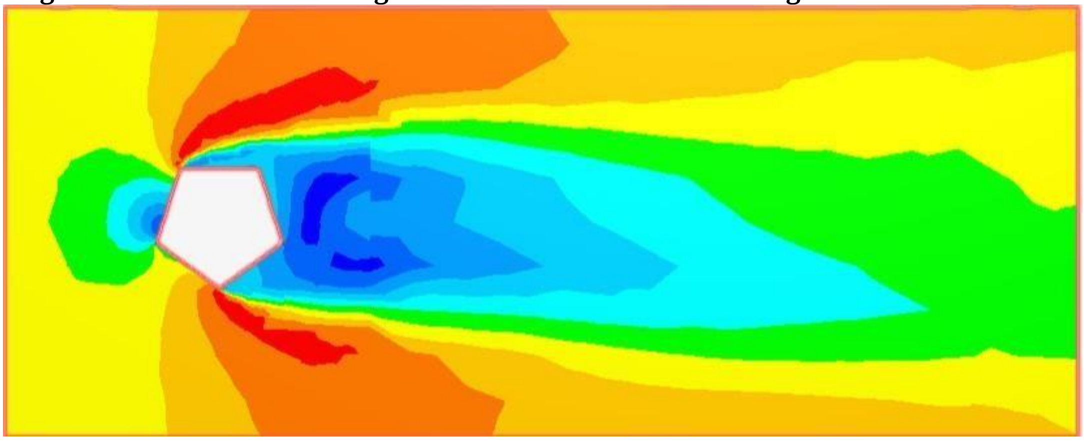
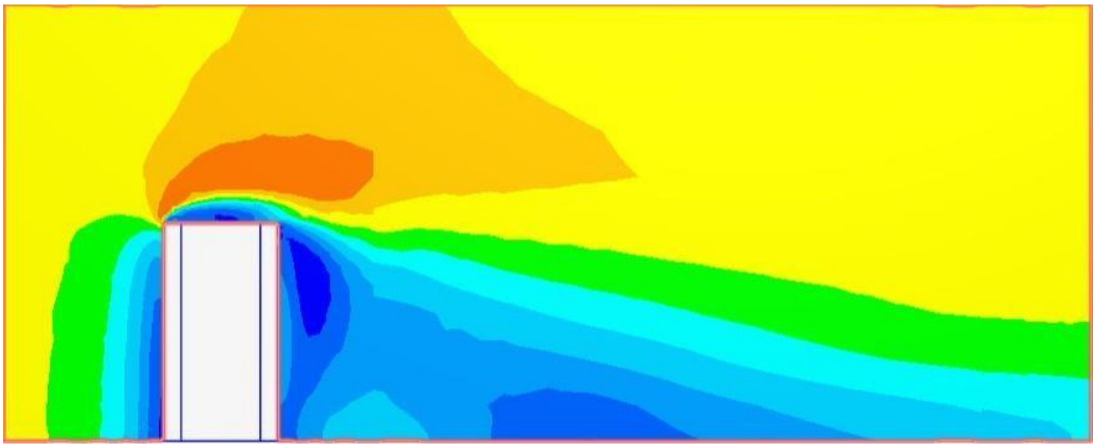


Fig 4.27 Side view of Building



High pressure is formed at the corners of the building as shown in red colour. On the backside of the building, a vortex is formed and the difference in pressure and speed or wind can be seen. on side ofthe building, high wind speed and pressure are formed which is dangerous for others buildings and pedestrians. This building has a very large surface area which comes in contact with direct wind because of which this shape building gets more wind. Wind converges after moving away from shownin the figure above, green colour shows that the speed and pressure of wind decrease as it moves awayfrom the building.

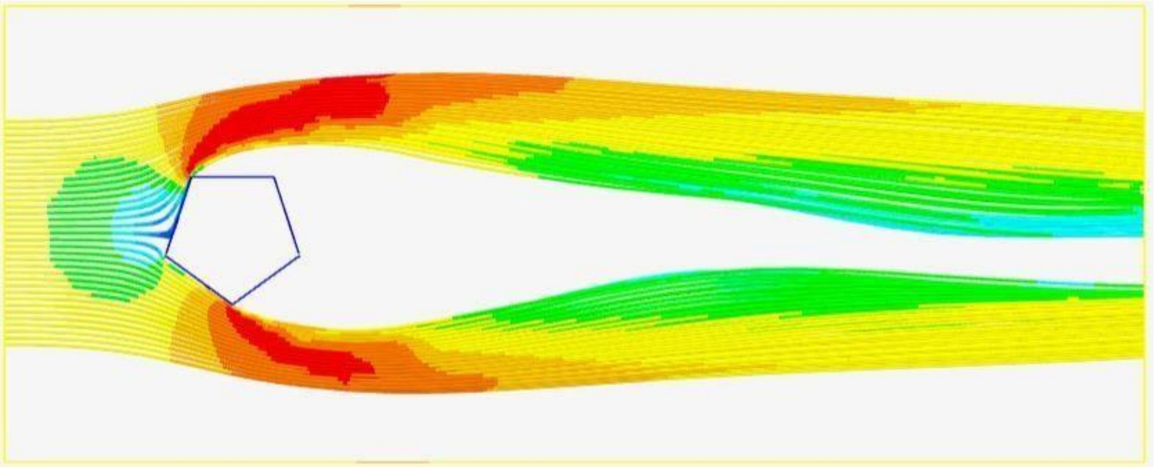
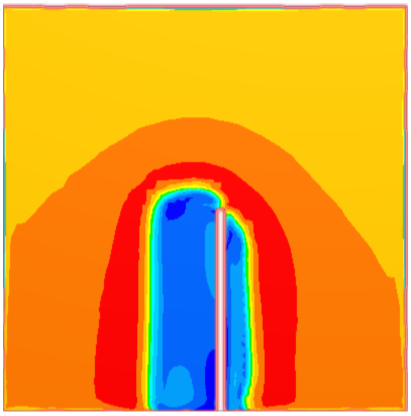


Fig 4.28 Partial tracing of wind flow

Triangle

Triangle-shaped buildings have less surface area which comes in contact with wind moving at high speed. This shape has sharp corners which make them vulnerable to high wind and could have damaged their corners, surface, and others parts. with a wind speed of 71.04m/s, we can determine themost affected area. Large pressure is formed near the Sharpe corners of the triangle building. A large vortex, a saturation of air and pressure is created near the building which is dangerous for build and people living.



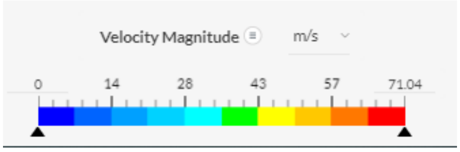


Fig 4.29 Front view of Triangle Shaped building
Contour shows how high-pressure zones are formed after wind comesin contact with building. Triangle have sharp edges, which can be damaged by wind high speed wind converges through it.

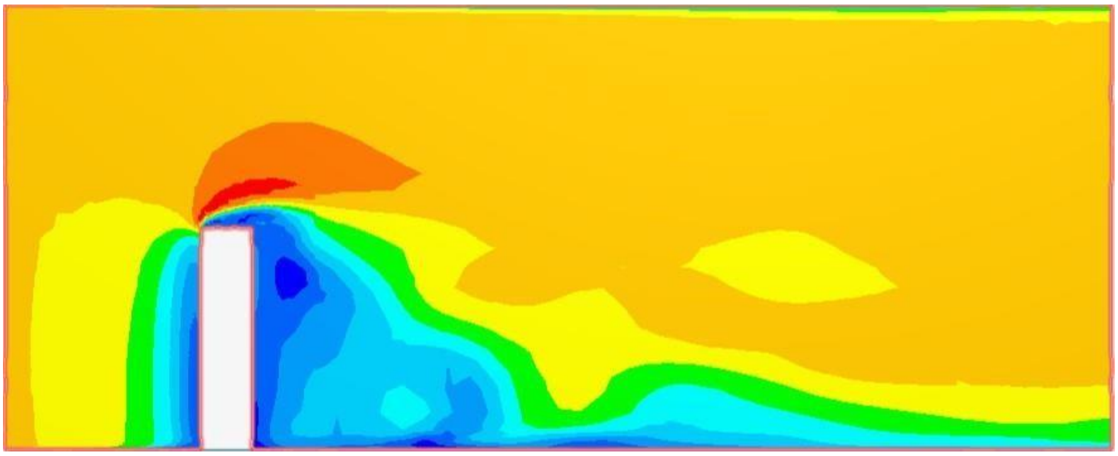


Fig 4.30 Side view Of Building
Different zone of wind speed is formed after impact, as a body of the building is irregular the windpattern is also irregular. Vortex are formed at different points and different low and high-pressure zones are formed which make it not suitable geometry for construction.

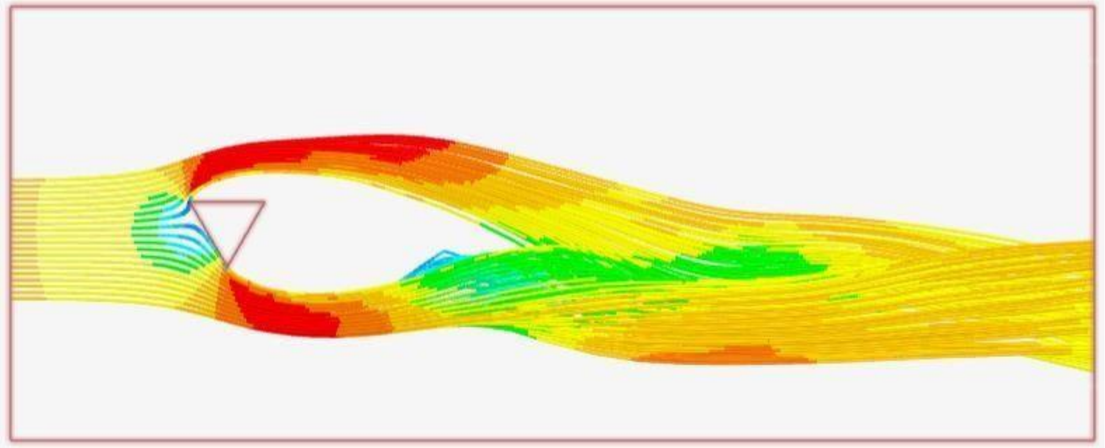


Fig 4.31 Partial tracing of wind flow in Triangle shaped Building

By particle tracing, we can learn the movement of wind partials and their flow. Here we can see thatafter colliding with the structure wind diverges and a high-pressure zone is created. After moving away from the building wind converges again and in this, we can also see rotational motion in the wind flow. Which could create a loop and could be harmful to building nearby structures. Contour shows different zones created by high and low pressure.

Building shape suggestion:

Any shape with less contact area to wind, which has low drag and has a streamlined body canbe suggested. A cylinder is one of the most effective shapes, but it has corners at the top, so ifa building can be cylindrical and as its size decreases and the area reduces in proportion, thenit can be effective in tackling the problem faced by wind force. When wind movement is 2dimentional then the cylinder is one of the best shapes but when wind movement is 3dimentional then the wind can create high velocity and pressure zones near a top corner so ashape that has round corners will reduce wind pressure on that point. So by that, we can conclude that a structure with no corners or round corners can reduce the effect of wind fore and should be used in the design.

Fig 4.32 the lighthouse is cylindrical but has a dome-like shape at the top.

How to reduce wind force on the building:

1) The first and by far simplest way to reduce the impact of high winds on a tall building is with anapproach called corner softening. Corner softening sees sharp edges smoothed off of a structure to make it more aerodynamic, or small cut-outs created on the edges of a structure to “scramble” prevailing winds and reduce the strength of the vortices they create

2) Reducing the vertical surface areas increase in Hight. Reducing the contact area of wind can help in reducing wind force. AS wind is a lateral force and is directly proportional to thearea in contact so if we reduce the contact area impact can also be reduced

3) Another way to reduce the impact of high winds on tall buildings is to increase their porosity, “cutting out” parts out of the structure and allowing air to flow through, as well asaround the building mass.

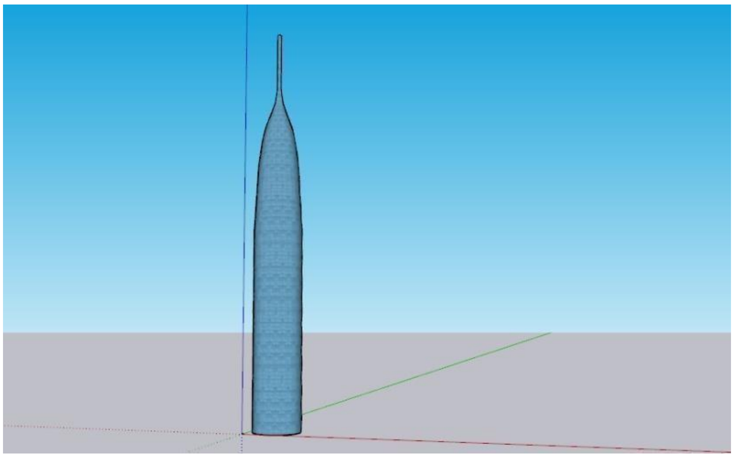


Fig 4.33 Cylindrical Building with no corner

This is a type of design we are suggesting as it full fills most of our criteria. This a cylindrical building with no corners. It’s a streamlined body so the wind can easily move around it. It doesn’t have corners; the impact surface area is less so it has less impact of direct wind flowing towards it. We have done wind flow analysis on the cylinder so we can conclude that this design can be suggested to make a tall building so that the effect of wind is less on the building and its surroundingThis building looks aesthetics and with proper construction, it can tackle problems caused by wind. These types of buildings can be used as office buildings and for other use.

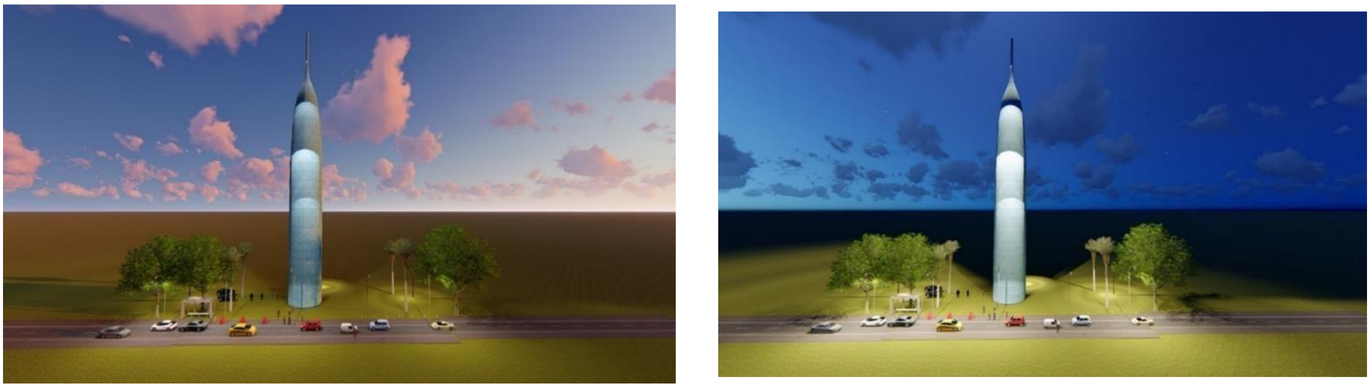


Fig 4.34 Rendered image of suggest building suggested after analysis.

Conclusion:

As the population of the world increases, the flow of people also increases in cities, the pressure to build taller buildings also increases, thus the construction of super-tall buildings is needed. Wind flowis an important subject when we design a tall building, so we used different shapes of the building to determine the change in course of wind around it. We used Simscale software to make CFD which helps in pinning the flow of wind around buildings. As we take reference of a rectangular building, wecan determine the force created by the wind on the boundaries of the building, maximum pressure by the wind on the surface and around its surrounding. Wind-flow patterns around an isolated building can tell us about the design. wind flow around any structure helps us make changes in the shape of thebuilding, the results show the loading pressure and velocitycontours for the initial design and the comparison of the dynamic wind load effects of vortex shedding for the modified design. When we use Etabs to gather information about maximum Storydisplacement, Drift for the diaphragm, maximum story drifts, Story Shears, Story Overturning Moment, wind Displacement in the X and Y direction. After our design, we concluded that the shapeand material of the building are very important to withstand wind force. A shape and design whichdoesn't hinder wind flow is important and was suggested by us. As wind flows in 3 dimensions so any shape design should be streamlined, must have a round or no corners so that wind can flow without disruption. Using particle trace we can simulate the wind movements at any given point ofthe building. Using different iterations, we were able to find the best shape for handling wind loads.An Individual's state of mind in which he/she feels hot or cold is defined as thermal discomfort. Managing thermal discomfort is very important as itincreases productivity and improves health and safety. We suggested the design of the building which we found is most compatible with the wind.

References

[1] Kheir-Al-Kodmany, Guidelines for tall building development, 2021.

[2] CSI Analysis Reference Manual, Computers and Structures Inc., Berkeley, California, USA, : Computers and Structures Inc., , 2013.

[3] A. U. W. a. M. Jayasinghe, *Wind Loads on High-Rise Buildings by Using Five Major International Wind Codes and Standards.*

[4] *Analytical Study of Tall Building with Outrigger System with Respect to Seismic and Wind Analysis Using ETABS.*

[5] M. M. A. a. K. y. S. Moon, *Structural Developments in Tall Buildings: Current Trends andFuture Prospects.*

[6] *ETABS* - *Computers and Structures, Inc.* - *Technical Knowledge Base (csiamerica.com)..*

[7] P. P. G. M. T. (. E. N. I. o. T. Sanhik Kar Majumder, *Comparison Between Wind And Seismic Load On Different Types Of Structures,* Agarpara,Kol-109, W.B.: Narula Institute of Technology.

[8] S. G. P. H. A. A. a. n. S. C. G. N. Lakshmanan, *Basic wind speed map of India with long-trihourly wind data,Structural Engineering Research Centre, CSIR.,* Chennai: Structural Engineering Research Centre, CSIR.

[9] *Wind analysis of multistorey structure with T shape and L Shape geometry.*

[10] *Wind loads on ‘Y’ plan shape tall building.*

[11] *Experimental study of wind pressures on irregular plan shape buildings.*

[12] *Wind Loads on ‘T’ Plan Shape Tall Buildings.*

[13] M. G. Professor, *Study on Wind Loads And Responses Of Tall Buildings And Structures,* Shanghai 200092, China.: State Key Laboratory of Disaster Reduction in Civil Engineering, Tongji University.

[14] "cadmapper.com," [Online].

[15] P. A. Irwin, *Vortices and tall buildings: A recipe for resonance,* Physics Today. American Institute of Physics, 2010.

[16] D. Y. Emil Simiu, *Wind Effects on Structures: Modern Structural Design for Wind.*

[17] "www.simscale.com," [Online]. Available: www.simscale.com.

[18] P. A. Irwin, *Vortices and Tall Buildings: A Recipe for Resonance,* American Institute of Physics, 2010.

[19] P. A. Irwin, *Wind Issues in the Design of Tall Buildings,* RWDI Los Angeles Tall Building Structural Design Council, 2010.

List of Publications

Journal Papers

- Shivanshu, Atal Jain, Shiva Tripathi (2022) “Wind Analysis and Design of a Tall Building”. ICE (Under Review).