### ANALYSIS OF HORIZONTAL FORCES OVER THE STRUCTURE BY AERODYNAMIC SHAPE MODIFICATIONS

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***A DISSERTATION***

#### *Submitted by*

#### **Gauravkumar Ashok Neware**

#### *for the award of the degree*

#### *of*

#### **MASTERS OF STRUCTURAL ENGINEERING**

#### *under the guidance of*

#### **Dr Swati Ambadkar**

****

DEPARTMENT OF CIVIL ENGINEERING

**G H Raisoni University, Amravati**

**Established under Govt. of Maharashtra Act Mah XXIX of 2018**

**Anjangaon Bari Road, Amravati-444701**

**2023-2024**

**DECLARATION**

I certify that

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  6. The Dissertation has been subjected to plagiarism check using professional software and found to be within the limits specified by the University.
  7. The work has not been submitted to any other Institute for any degree or diploma.

GAURAVKUMAR ASHOK NEWARE

M.Tech – 2nd Year

Department of Civil Engineering

**CERTIFICATE**

**This is to certify that the report entitled**

**ANALYSIS OF HORIZONTAL FORCES OVER THE STRUCTURE BYAERODYNAMIC SHAPE MODIFICATIONS**

**is a bonafide work and it is submitted to**

**G H Raisoni University, Amravati**

**by**

**Gauravlumar Ashok Neware**

**For the fulfillment of the requirement in the degree of**

**Master of Technology in Structural Engineering, during the academic year 2023-24.**

**Dr.Swati Ambadkar Prof Hemant Dahake**

**Project Guide Head of the Department**

**Dr./Mr. Dean**

**External Examiner School of Engg. & Tech.**

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I express my gratitude to lab assistant for providing access to their project site/organization and helped with the necessary data and information which are essential to be used in my research work.

Last but not least, I would like to acknowledge the support of my parents and my siblings for their continuing support and encouragement.

GAURAVKUMAR ASHOK NEWARE

**ABSTRACT**

The Wind is air in motion relative to the surface of the earth, whose primary cause is traced to earth’s rotation. The wind generally blow horizontal to the surface at high speed and can be assessed with the aid of Anemometers. Tall and slender structures are flexible and exhibit a dynamic response to the wind. Therefore it is necessary to determine behaviour of structure. The square shape high building with aerodynamic modification is taken. In this study different models such as Corner cut, Setback and Opening are taken to determine the efficient shape modification among the models such as square, setback, corner cut with opening, setback with corner cut and setback with void/opening.

The square model is created by using SolidWorks as well as in Design Modeller in ANSYS software. After modelling, computational domain is provided. The tetrahedron meshing and acceptable fine mesh is provided for convergence. The setup is required following boundary conditions, the inlet velocity is 10m/s at reference point and udf.h(user define function) file is provided to follow power law. The air properties are also applied as per literature. The outlet pressure is zero pascal. The wall are having zero shear and treated as enhanced wall treatment. Then by using the fluent solver force coefficient is calculated. The square models is tested in computational fluid dynamics (CFD) simulations using ANSYS Fluent as well as CFX and validated with the literature results.

**Keywords**: Anaemometer, Aerodynamics, Solid works, Ansys software, User define function.

**INTRODUCTION**

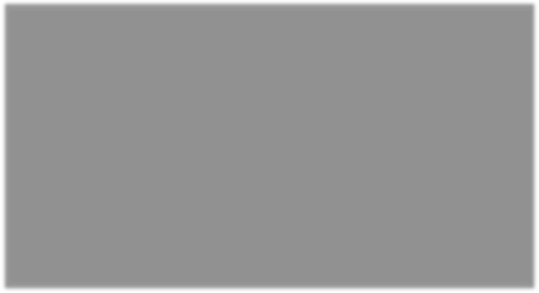
The Wind is air in motion relative to the surface of the earth, whose primary cause is traced to earth’s rotation. The wind generally blows horizontal to the surface of earth at high speeds. The wind speeds are assessed with the aid of Anemometers or Anemographs. Several atmospheric phenomenon are responsible for wind storms. Very strong winds are generally associated with Cyclonic storms, Thunderstorms, Dust storms or Vigorous monsoons. Tornados are a narrow band phenomenon of limited time duration have extremely high wind speeds often higher than in the severest cyclones. These causes severe damage to the structure. Therefore structure is need to be wind resistant. The high building should be designed for wind loads.

Flexible slender structures and structural elements shall be investigated to a certain, the importance of wind induced oscillations or excitations along and across the direction of wind. In general, the following guidelines may be used for wind induced oscillations as per **IS 875 Part3 2015**.

* Buildings and closed structures with a height to minimum lateral dimension ratio of more than about 5.0.
* Buildings and closed structures whose natural frequency in the first mode is less than 1.0 Hz.

Any building or structure which satisfy either of the above two criteria shall be examined for dynamic effects of wind.

The high structures has no specific definition, as a structure height is greater than its adjacent structure. In many countries, it is define on the basis of number of floors or the height of the structure. It has advantages such as it give aesthetic view. To attract people, the structure need to be unique. To fulfil such a demand, A typical high-rise structure which are unique in geometry are came to existence. Based on geometry, there are different types of structure such as symmetric and asymmetric. High structures tend to have well-established occupier profiles.



**Figure :** A typical High-Rise structures

###### Classification :

Based on Geometry, there are many atypical high rise structures are as follow:

1. Basic
   1. Square
   2. Rectangle
   3. Circle
   4. triangle
2. Corner modification
3. Tilted
4. Tapered
5. Helical
6. Void
7. Setback
8. Combinations

###### Advantages :

1. High Density developments, which concentrate multiple dwellings, and offices, etc. into a single development. This reduces the strain on urban infrastructure like roads, water supply, sewage, etc. as the connectivity needs to be provided to only one location as compared to low-rises structures where every dwelling unit needs a public infrastructure connectivity.
2. High-rise structures offer much better security to tenants than a ground level development which provides multiple points of access for intruders.
3. The high-rise structures can accommodate many more people on a smaller land than would be the case with low-rise structures on the same land. They are suitable for highly populated or overpopulated countries where there is a shortage of land.
4. It provides day lighting and greater flow of air.
5. It also gives pleasant as well as aesthetic view.

###### Disadvantages :

1. Difficulties in preventing congestion and bad internet connection.
2. Privacy and social problems and neighbour interference.
3. Due to people imbalance load on municipal services like water supply and electricity.
4. Even if the association has no rule in banning pets in the apartment complex, taking your pet down for a walk becomes difficult if you lives in higher floor.
5. Difficulties in maintenance.

##### COMPUTATIONAL FLUID DYNAMICS

Computational fluid dynamics (CFD) is a branch of mechanics that uses numerical analysis and data structures to analyse and solve problems thatinvolve fluid flows. Computers are used to perform the calculations required to simulate the free-stream flow of the fluid, and the interaction of the fluid (liquids and gases) with surfaces defined by boundary conditions. With high- speed supercomputers, better solutions can be achieved, and are often required to solve the largest and most complex problems. Ongoing research yields software that improves the accuracy and speed of complex simulation scenarios such as transonic or turbulent flows. Initial validation of such software is typically performed using experimental apparatus such as wind tunnels.

CFD is applied to a wide range of research and engineering problems in many fields of study and industries, including aerodynamics and aerospace analysis, hypersonic, weather simulation, natural science and environmental engineering, industrial system design and analysis, biological engineering, fluid flows and heat transfer, engine and combustion analysis, and visual effects for film and games.

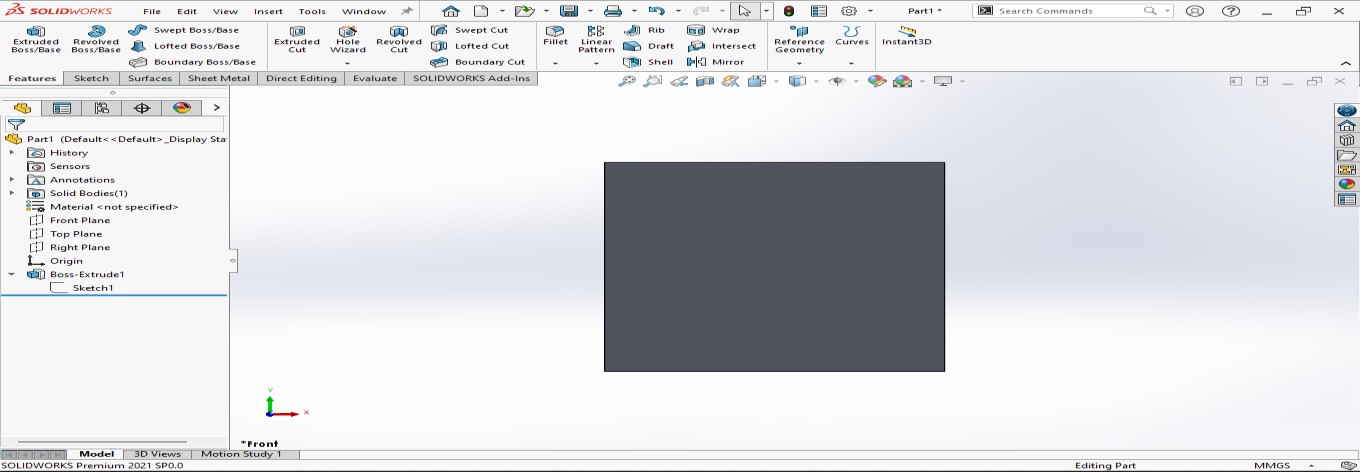
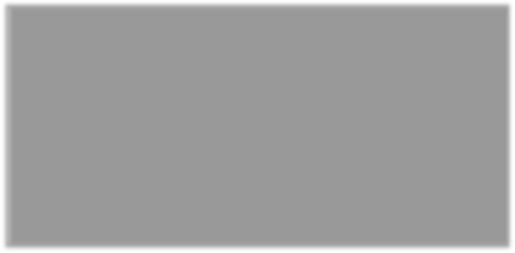
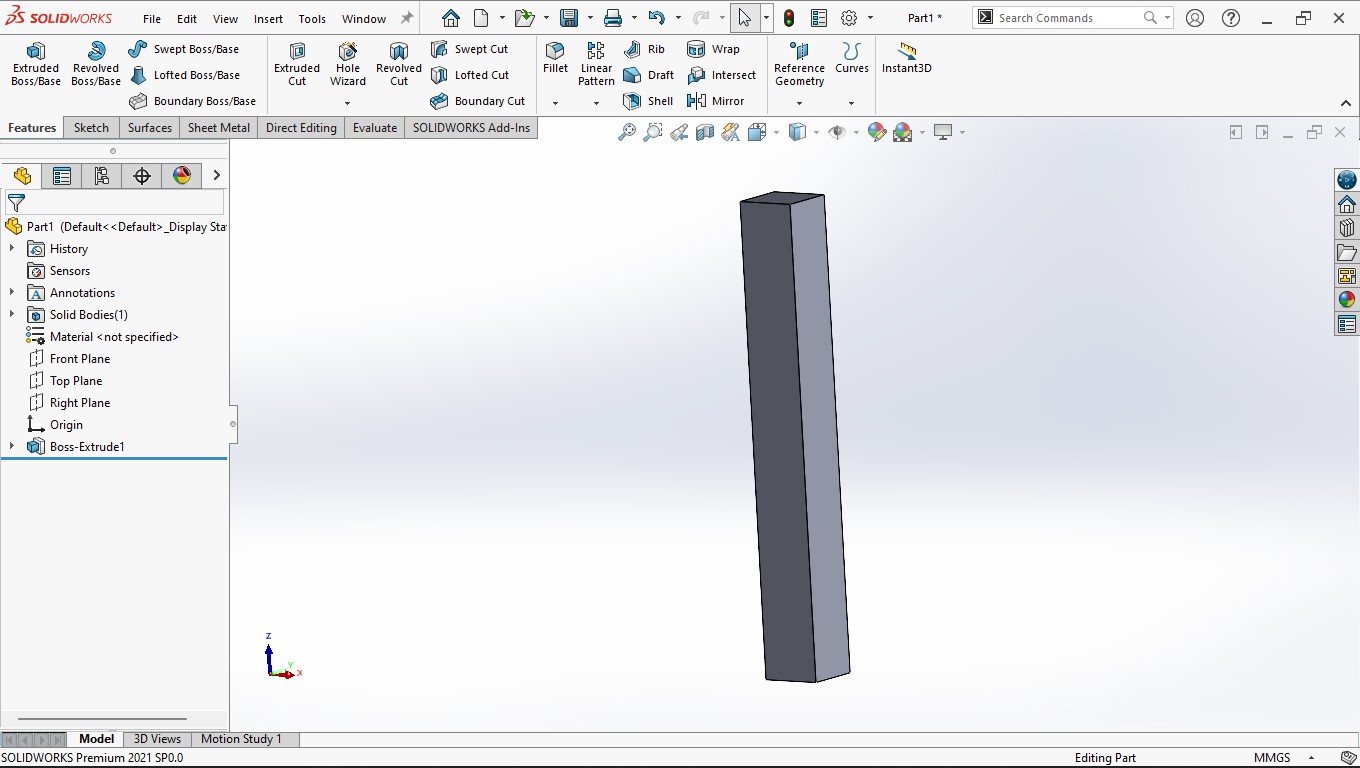
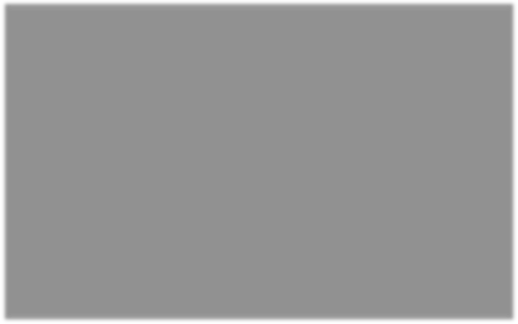
##### OBJECTIVES

1. To study the aerodynamic shape modification of high-rise structures using Ansys software for reducing the impact of wind.
2. To study the prediction of the optimal aerodynamically modified shape of high-rise structures.
3. To study of behavior of aerodynamically shape modified high-rise structures parameter such as pressure and velocity contours.
4. To study and investigation of the drag force coefficient and lift force coefficient.

**METHODOLOGY**

###### Model drafting

The model used in the study is square-shaped in plan. The structure at full scale has an outer diameter of 50m and the height is 400m, giving a B/H ratio is 1/8. The model has been scaled down to a 1:1000 scale to facilitate wind tunnel tests.

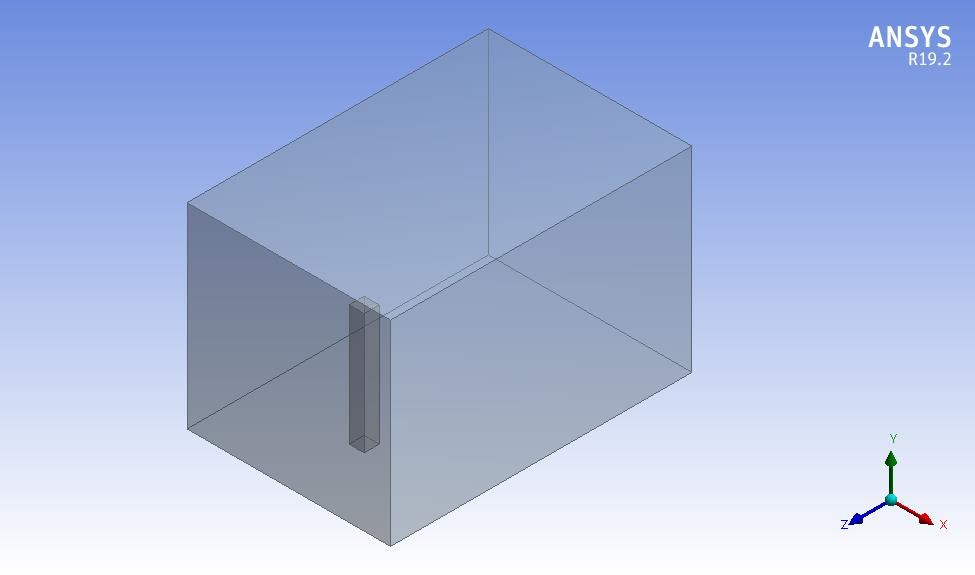
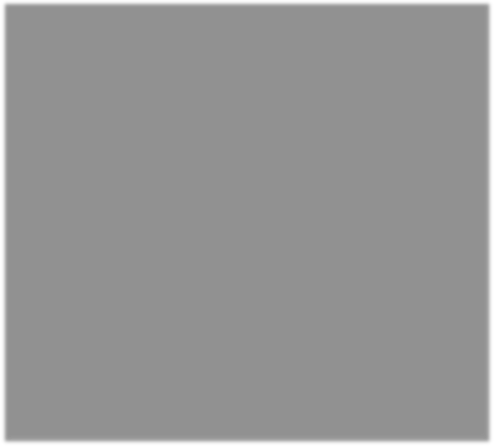


**Figure :** Plan View/Top View

**Figure.:** Side View

###### Computational domain

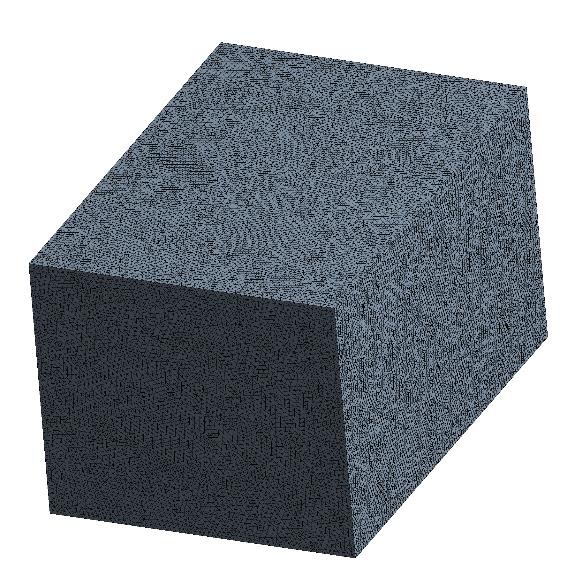
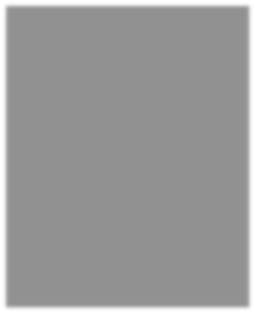
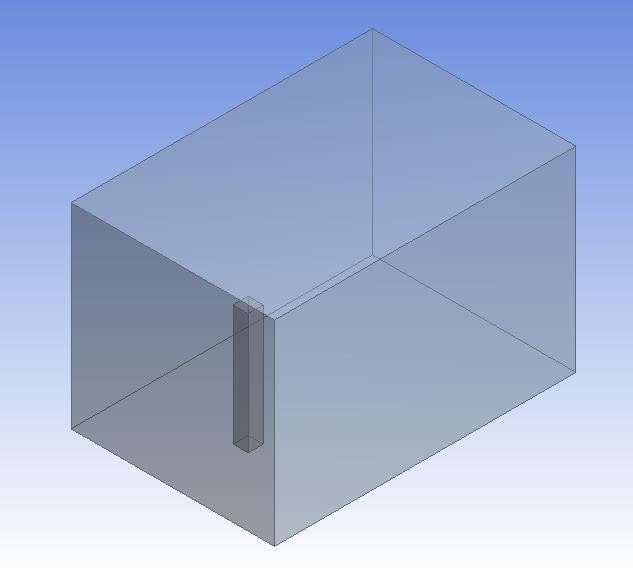
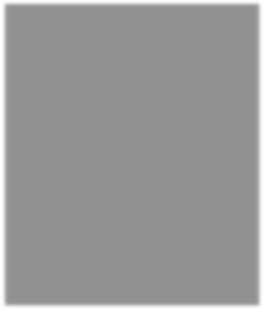
The wind tunnel is a rectangular box. It is designed to have the upstream fetch 5B, side clearance and height to be 5B and the downstream fetch to be 15B, where B is the width of the building. These domain dimensions were determined by Y. Meng and K. Hibi[13]. In order to prevent the recommended inflow profiles along the empty computational domain of the building's windward side from deteriorating, the windward distance was set only a little bit below the suggestions by the AIJ guideline [14].



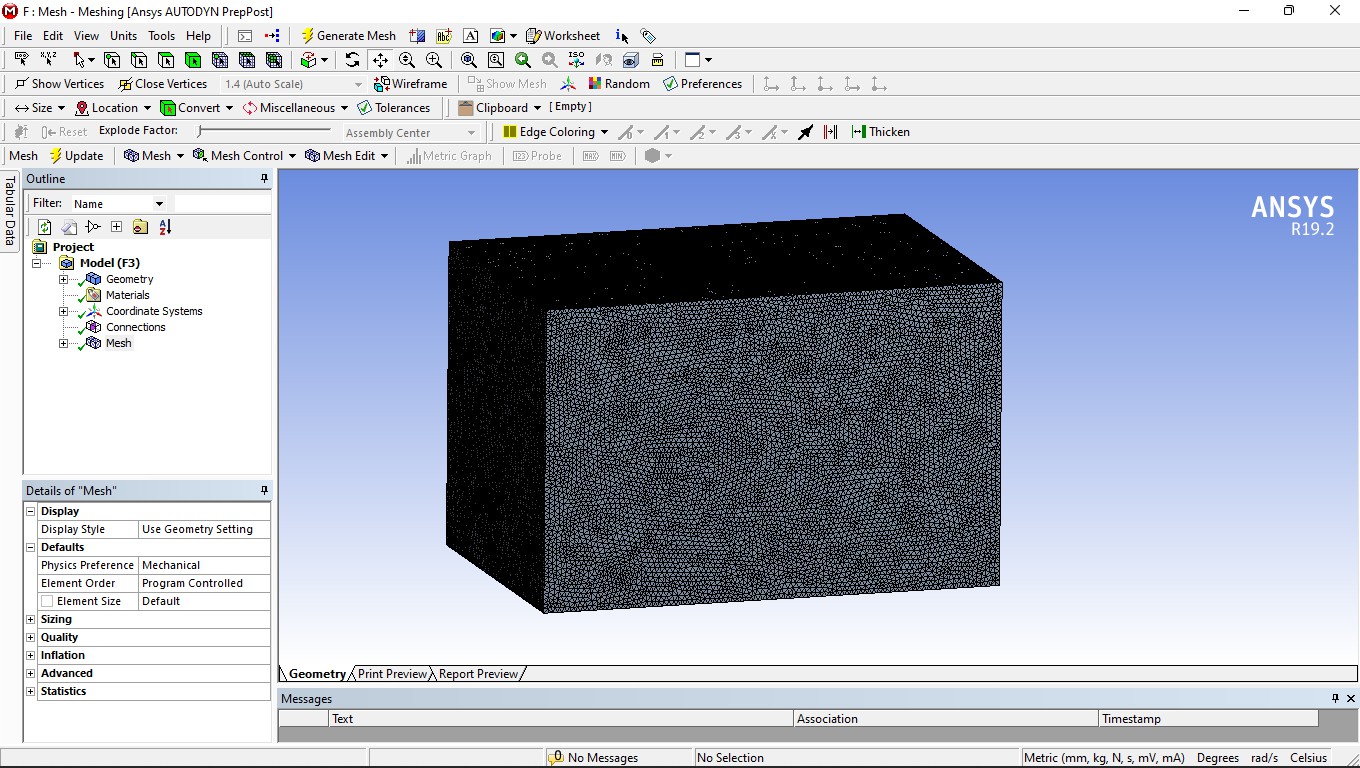
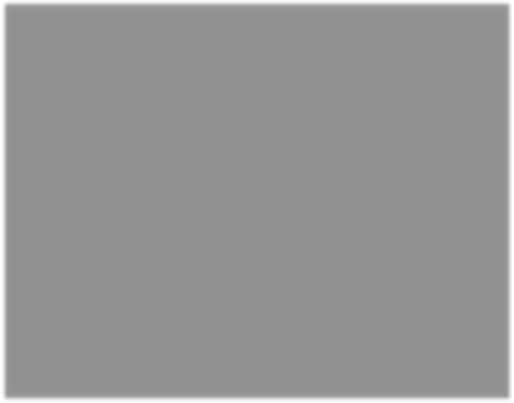
**Figure :** Computational domain from design Modeller

###### Meshing

Meshing is done using ANSYS. Mesh refinements are made so that the solution variables converge down to acceptable levels. Tetrahedron meshing is used and is inflated near all boundaries. All domain faces and edges are sized down appropriately. The meshing is done and around 15-20lakh nodes and 10lakh elements are shown in statistics.



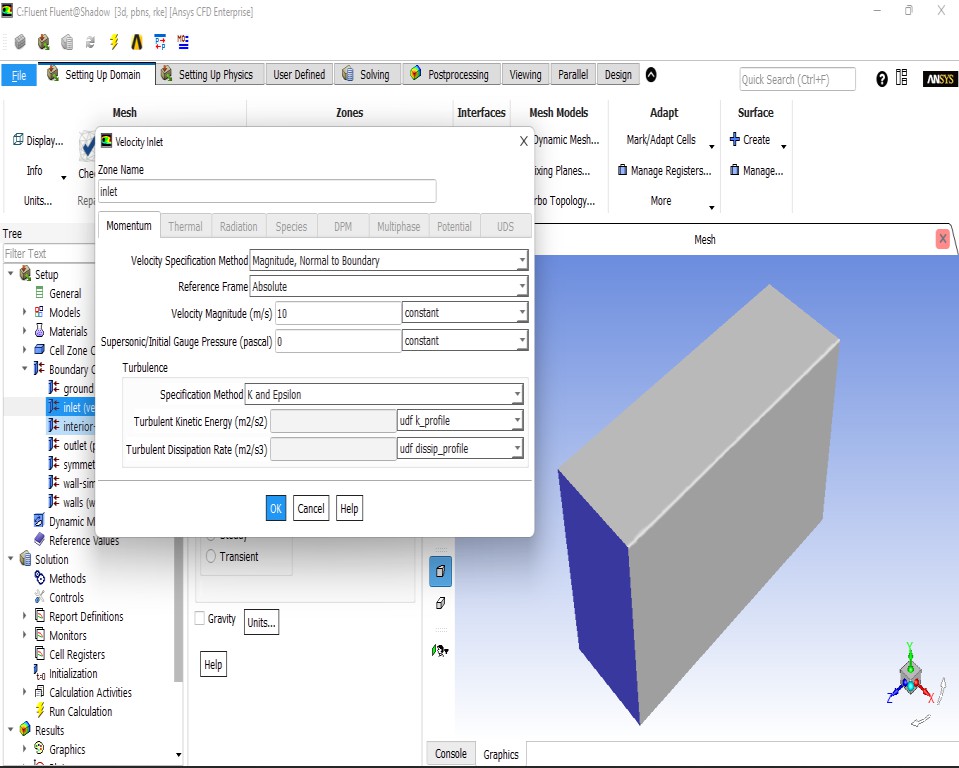
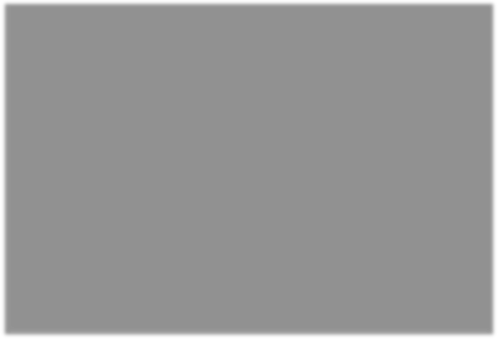
**Figure :** Tetrahedron Meshing



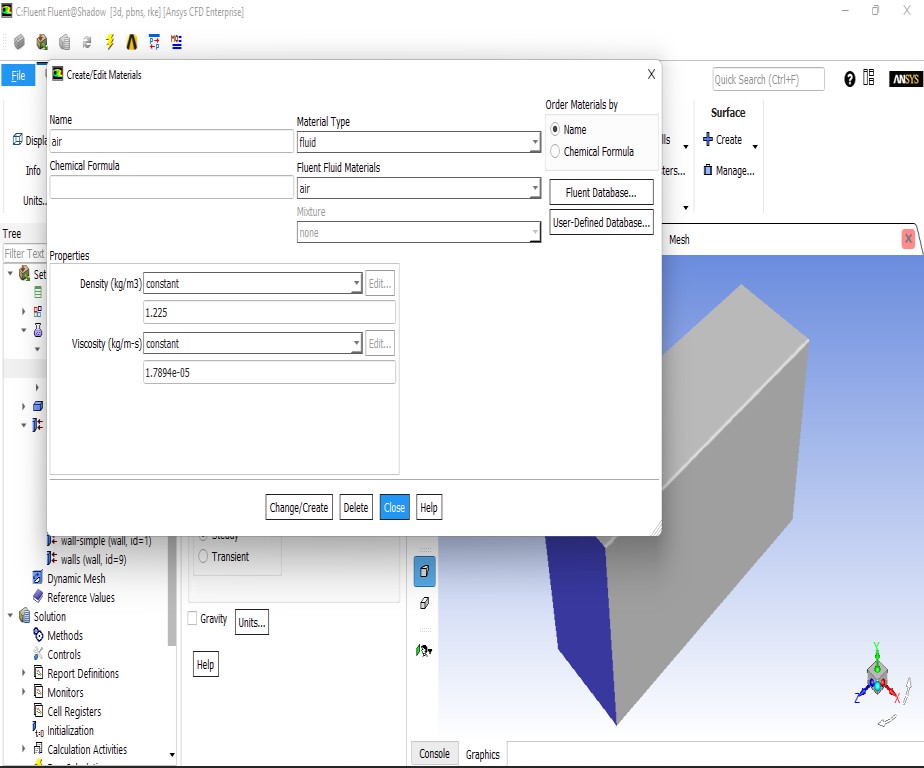
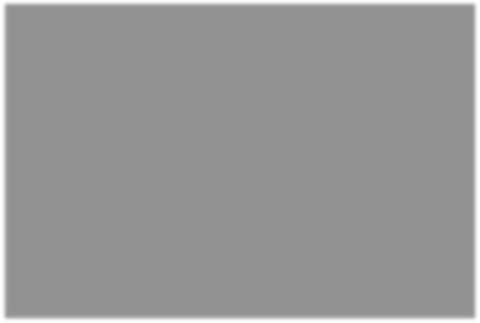
**Figure :** Meshing of the system

###### ANSYS fluent solver

Grid convergence studies were conducted for all the models. The mesh conditions are changed, increasing the number of elements, to achieve convergentvalues of coefficients of pressure and force. The free stream wind velocity applied is 10 m/s and the outlet gauge pressure is zero with no slip wall condition.



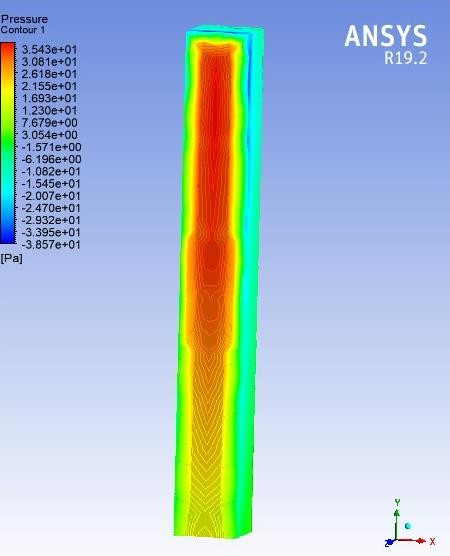
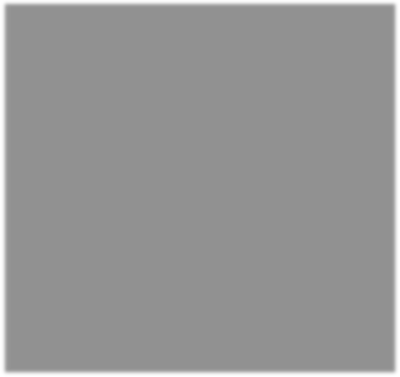
**Figure :** Inlet Condition



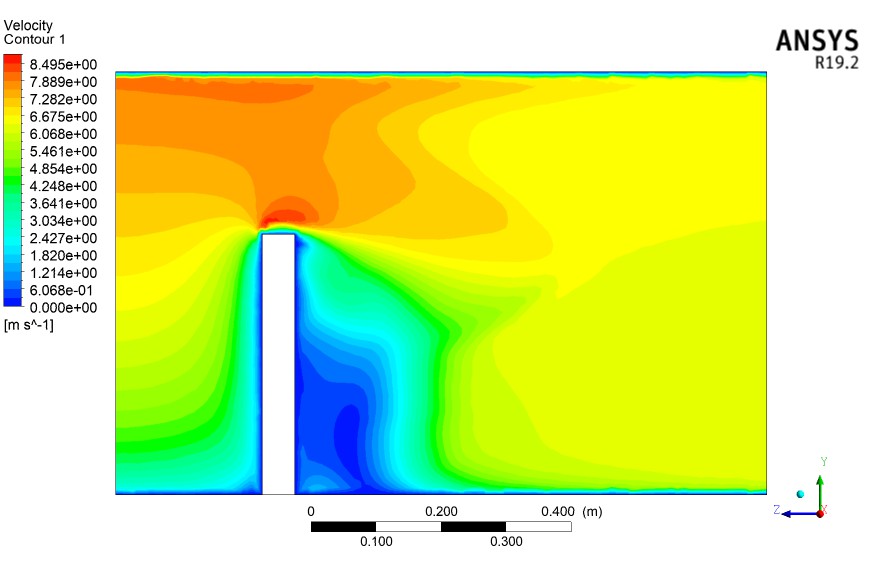
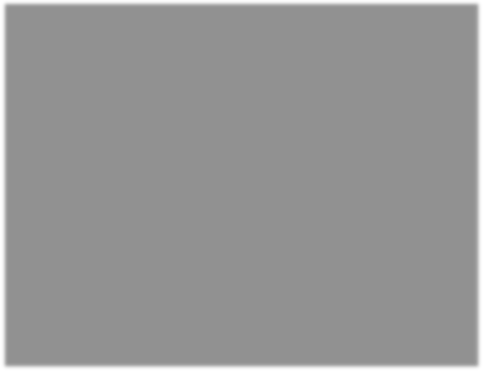
**Figure :** Air Properties

##### RESULTS

The pressure and velocity contour of the square tall building is shown as below:



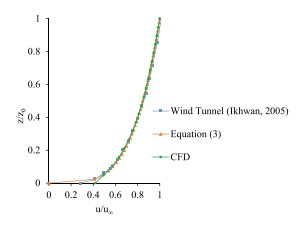
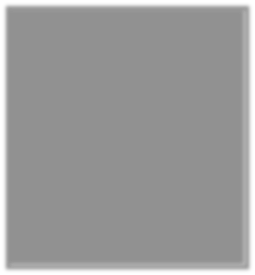
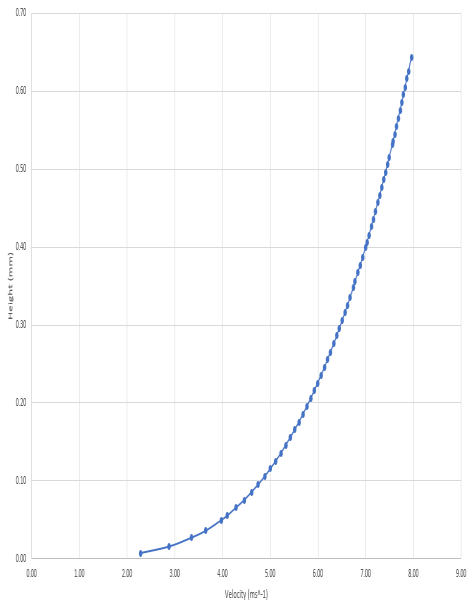
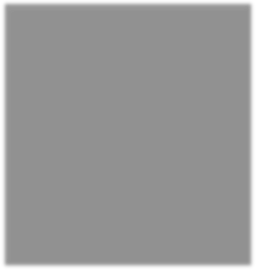
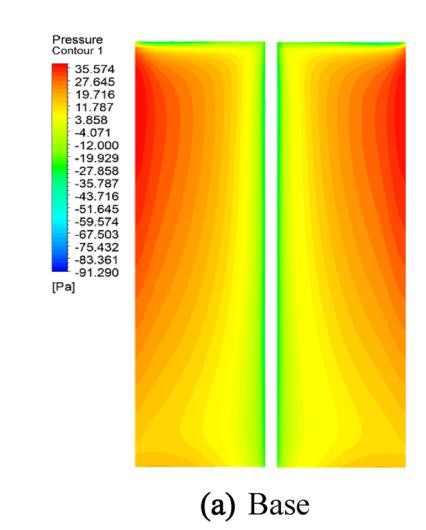
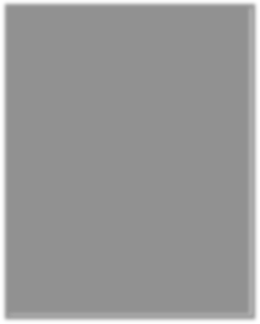
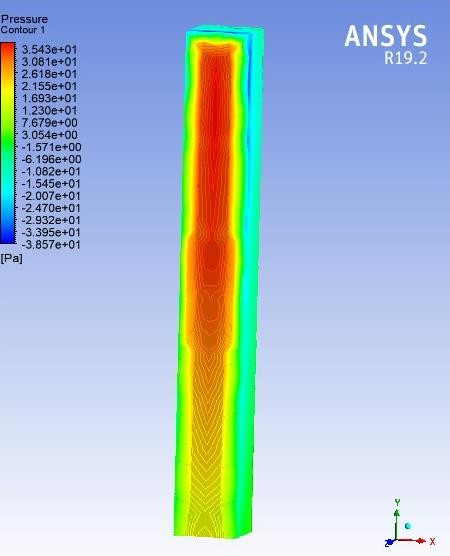
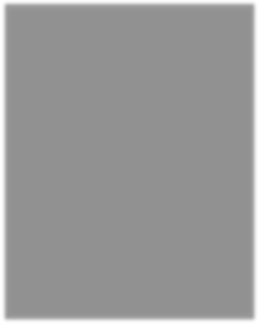
**Figure :** The pressure contours of the XY plane



**Figure :** Velocity contour

To confirm the accuracy of the work, the velocity profile that was developed must be evaluated. The wind tunnel data utilized as illustrated in fig. 5 and the computed profile are compared. Since the wind environments employed in both situations are similar, figure 3.12 demonstrates that the simulated profile reflects the profiles from wind tunnel studies and the power law equation with sufficient accuracy. As a result, it may be said that the study's flow characteristics are acceptable.

**Fig :** Wind profile Diagram



**Fig.:** Pressure contour

##### RESULTS AND COMPARISON

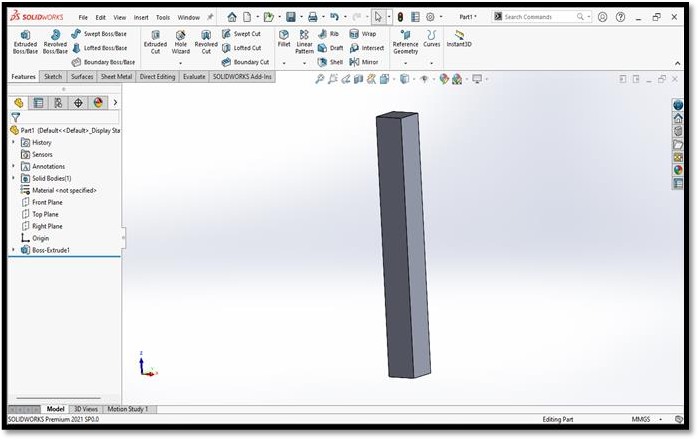
The drag force coefficient and the lift force coefficient for the square model is compared with the reference research paper values as shown below:

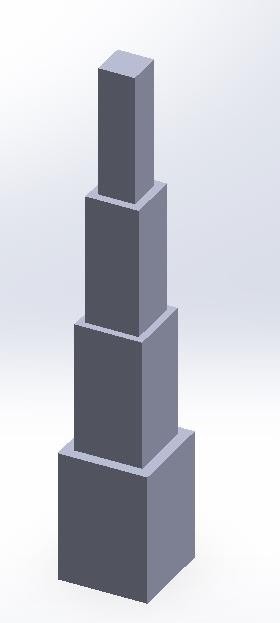
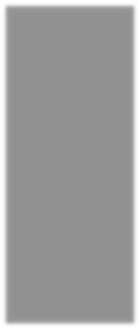
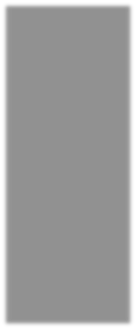
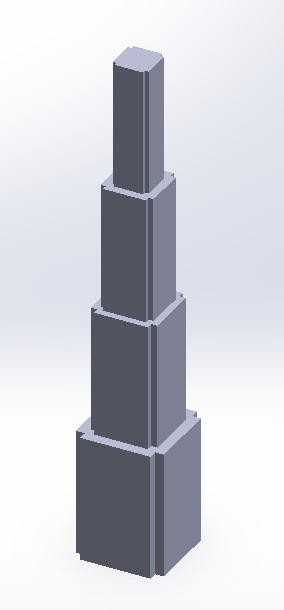
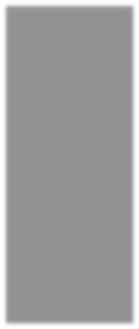
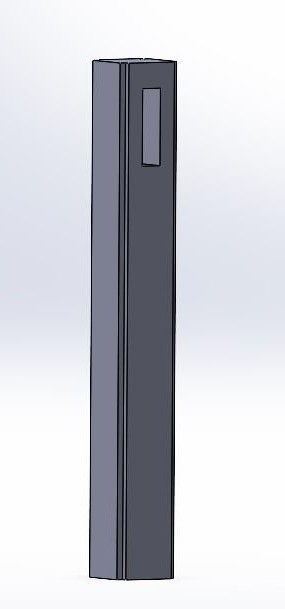
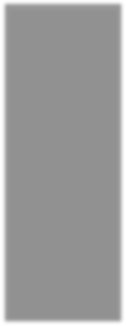
|  |  |  |
| --- | --- | --- |
| Parameters | Literature Values | Validation Results |
| Drag Force  Coefficient | 0.5817 | 0.5 |

**Table 1.** Result comparison

* + MODEL DRAFTING**:**

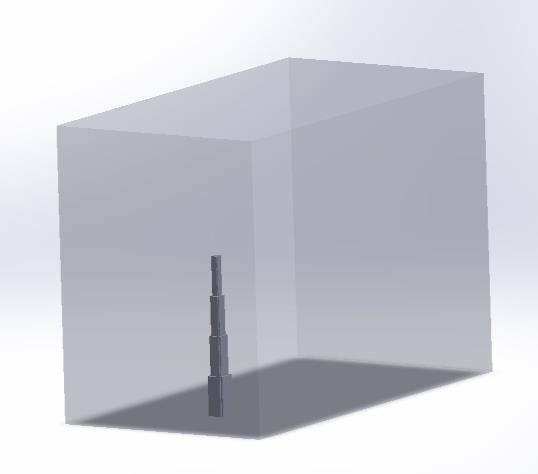
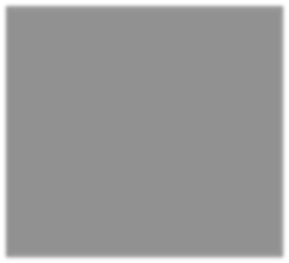
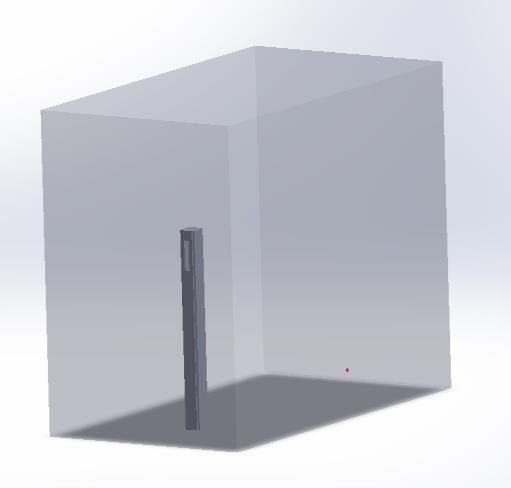
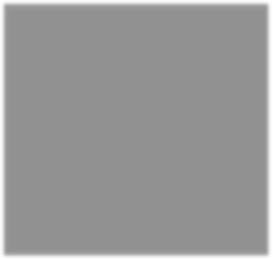
The models which are take in this study are with the help of reference paper. There are aerodynamically shape modifications high-rise structure models such as corner, setback, helical, tilted, tapered and opening modifications. The models corner, setback and void modification is used in this study. The model used in the study ae modified square-shaped in plan. The building at full scale has a breadth of 50m and the height is 400m, giving a B/H ratio is 1/8 and taking Reynolds number as 2\*105. The model has been scaled down to a 1:1000 scale to facilitate wind tunnel tests. The models of the building were made with three aerodynamic modifications including setback, corner cut, void\opening and their combinations such as corner cut with opening, setback with corner cut, setback with void\opening. Model 1 is square, Model 2 is setback which are used for comparative study, Model 3 is corner cut with opening, Model 4 is setback with corner cut and Model 5 is setback with opening.

 MODEL 1

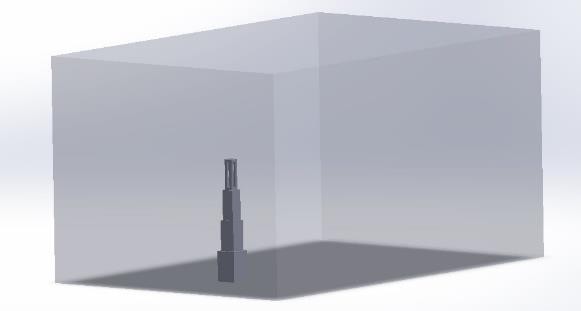
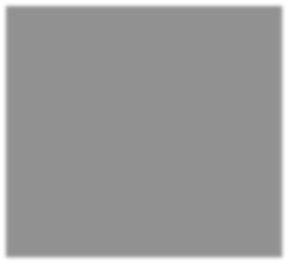
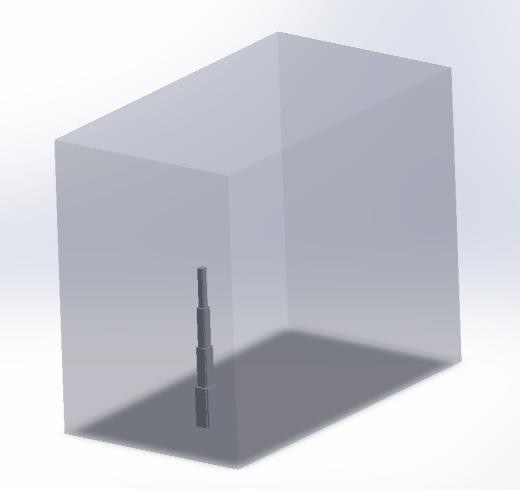
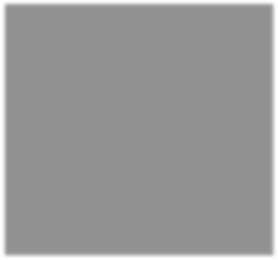


Model 2 Model 3 Model 4 Model 5

### COMPUTATIONAL DOMAIN:



Model 2 Model 3

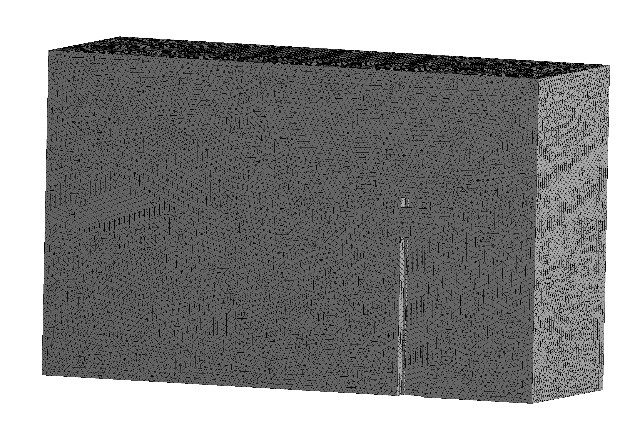
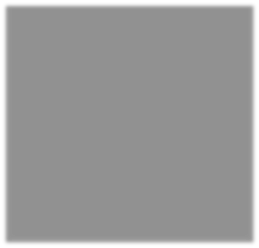
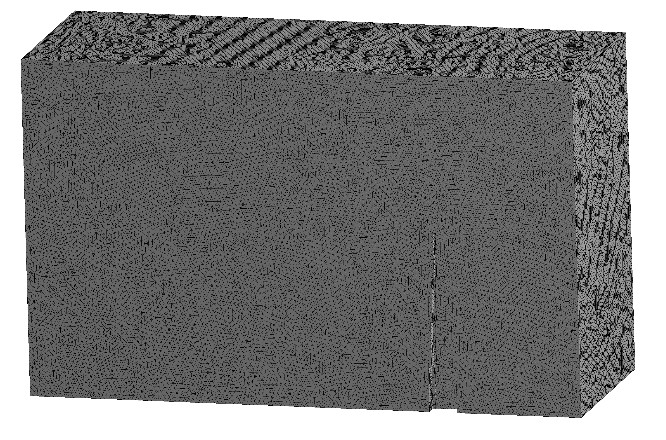
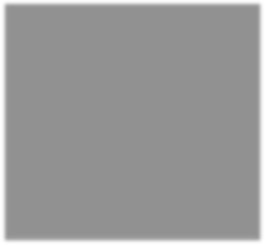


Model 4

Model 5

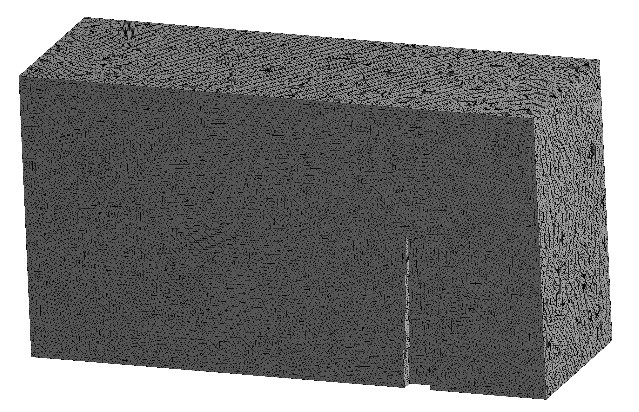
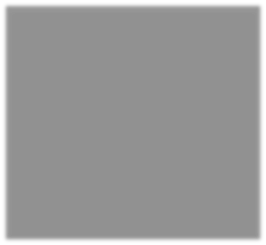
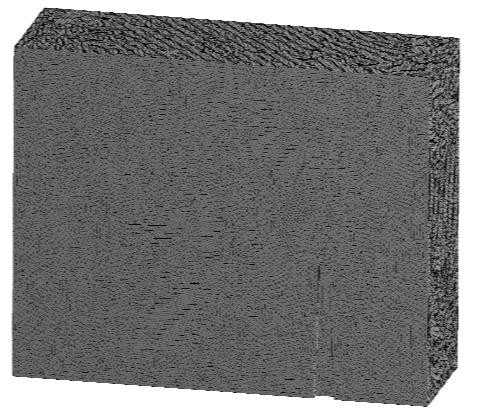
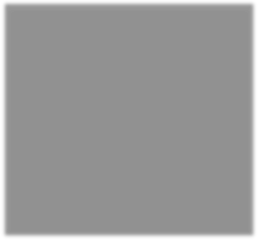
**Figure :** Computational Domain

##### MESHING:



Model 3

Model 2



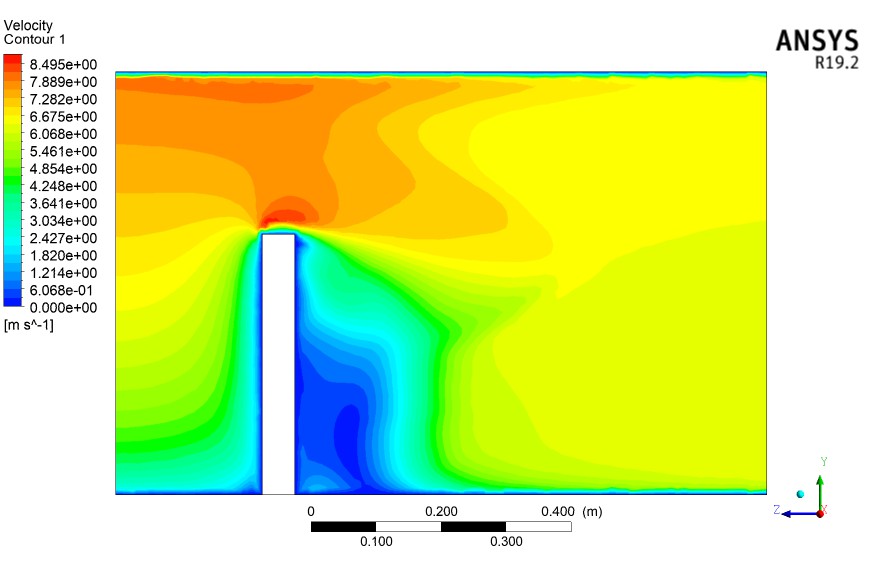
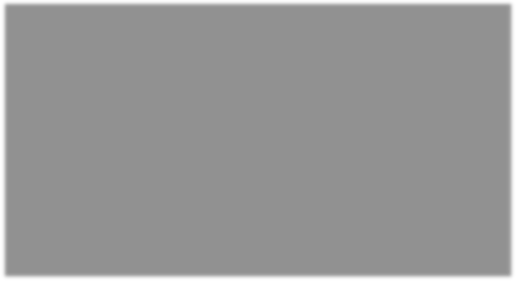
Model 4 Model 5

**Figure :** Meshing

##### RESULTS:

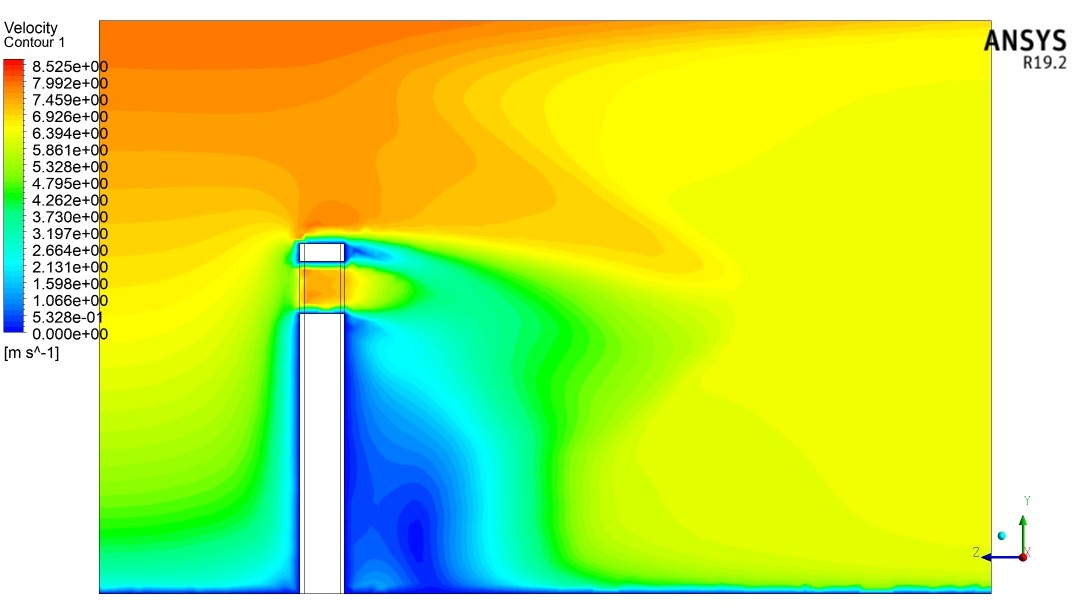
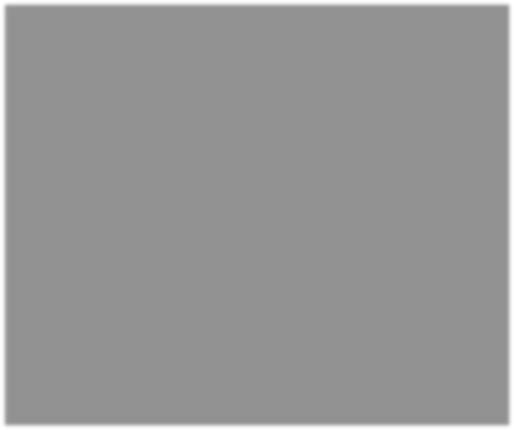
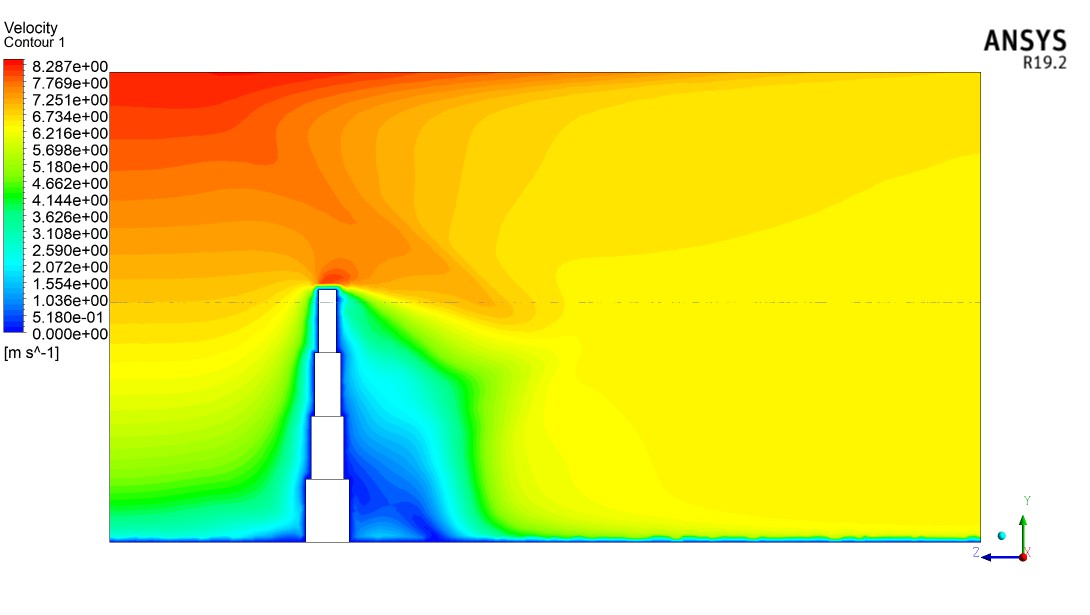
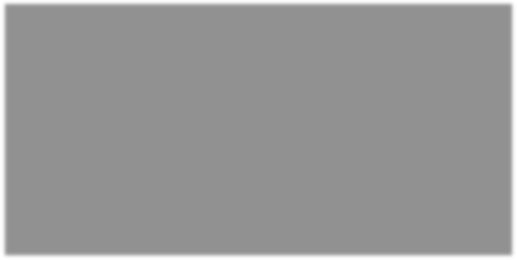
###### Velocity contour :

The velocity contour from the elevation view are as follows:

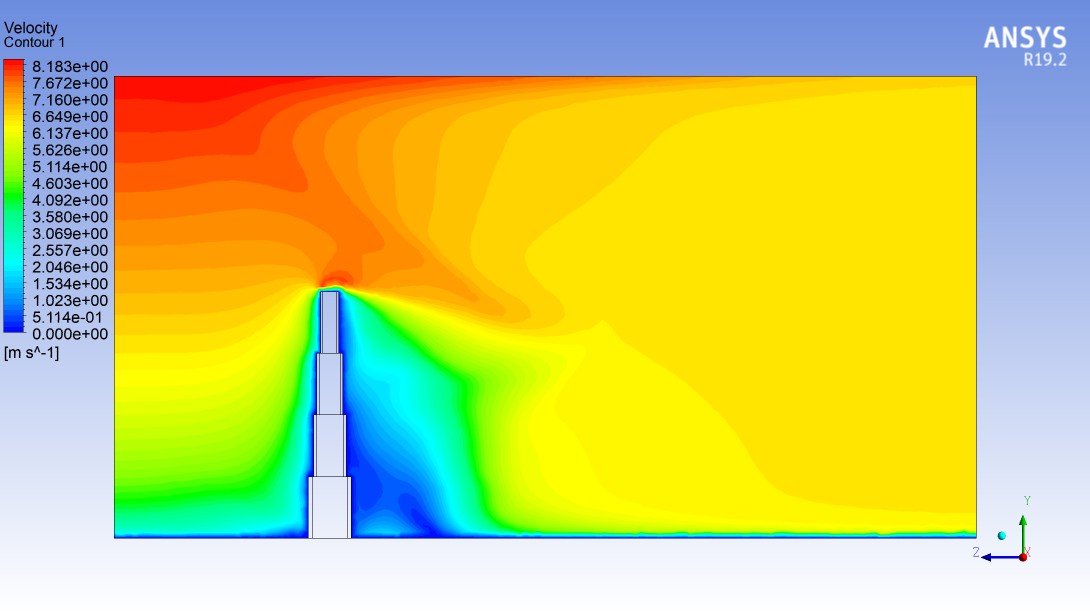
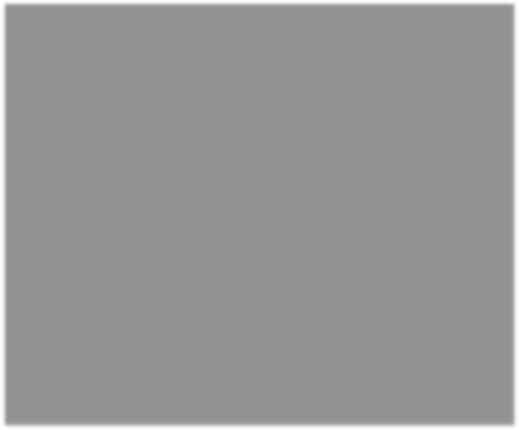


**Figure :** Square model

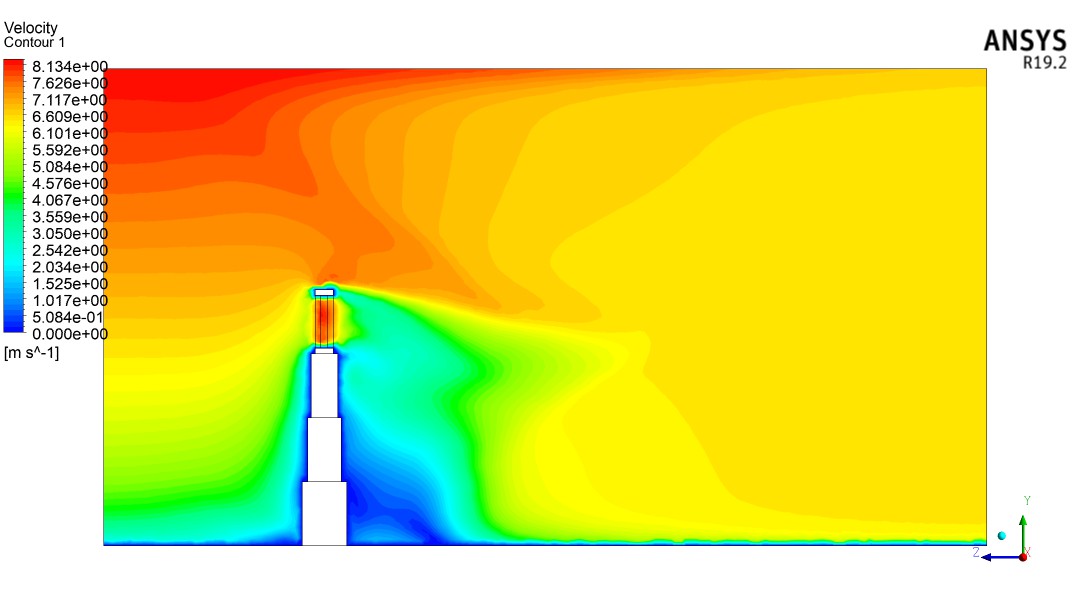
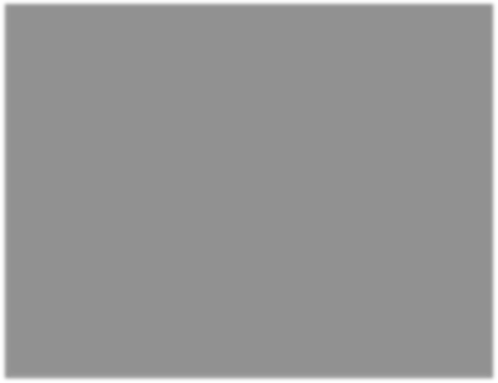
**Figure :** Setback model



**Figure :** Corner cut + Void model

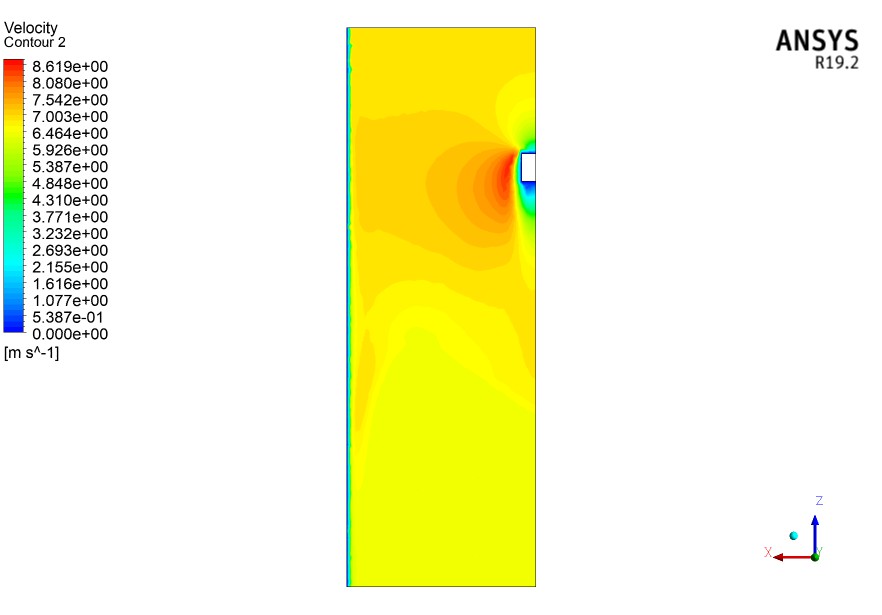
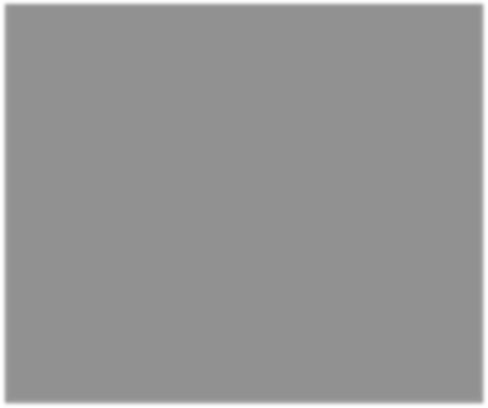


**Figure :** Setback+Corner cut model



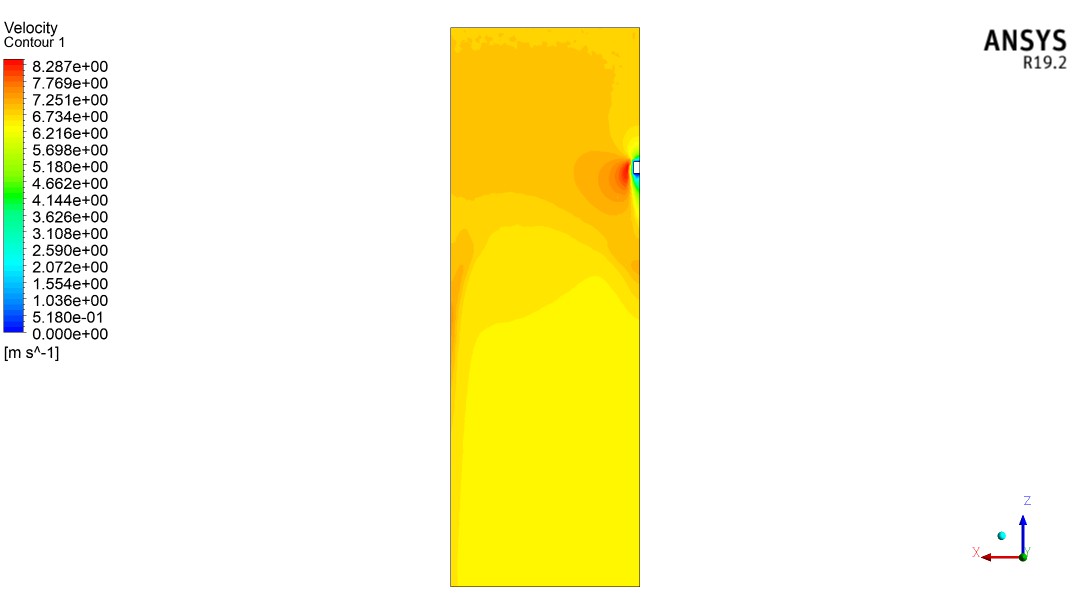
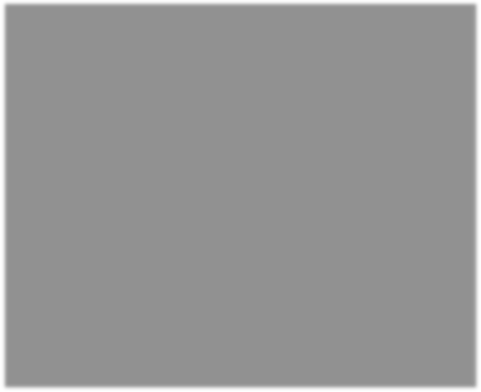
**Figure 4.5** Setback+Void model

The velocity contour from the top view as shown below:

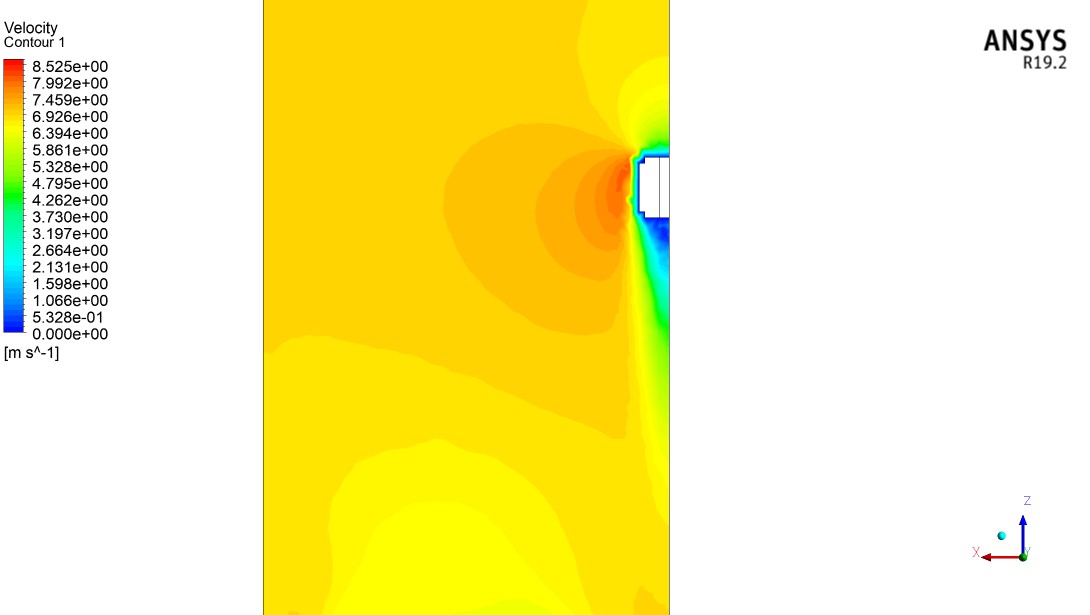
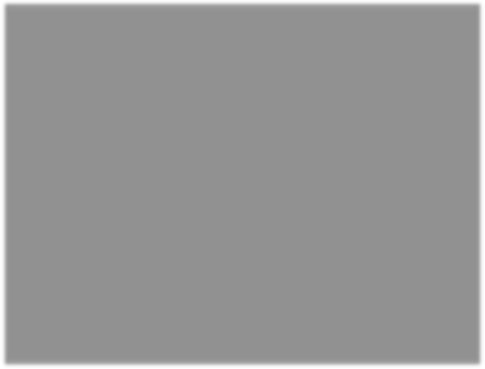


**Figure 4.6** Square model

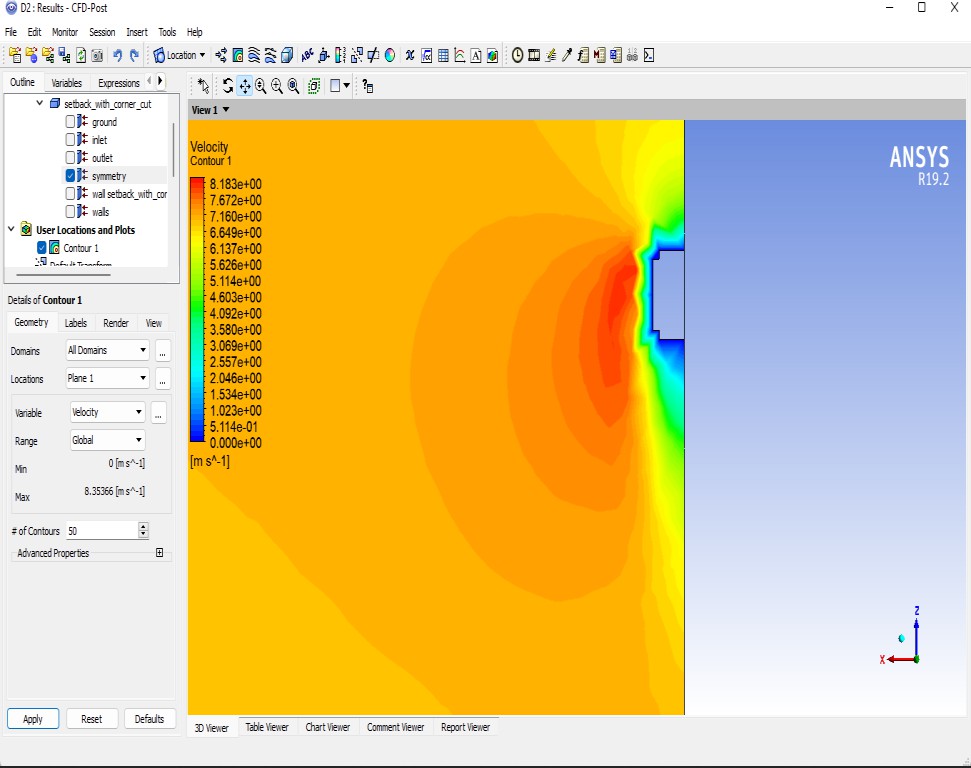
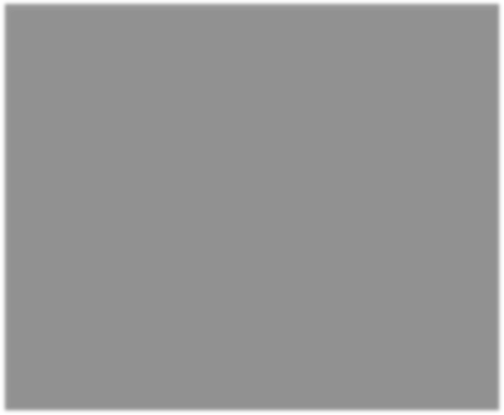
**Figure :** Setback model



**Figure.:** Corner cut+ void model



Setback+ Corner cut model



### PRESSURE CONTOUR

#### The pressure contour for all the model are as follows:

**Figure :** Square model

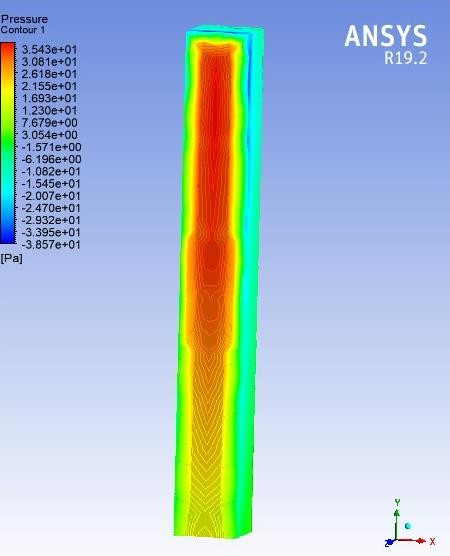
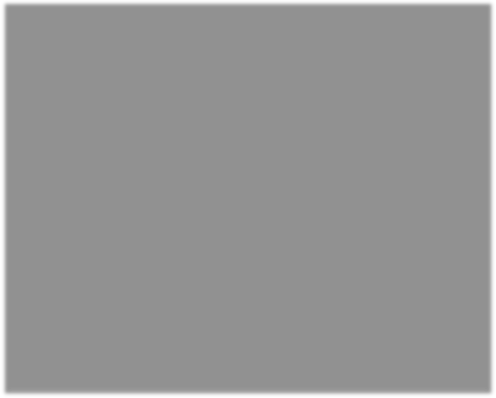
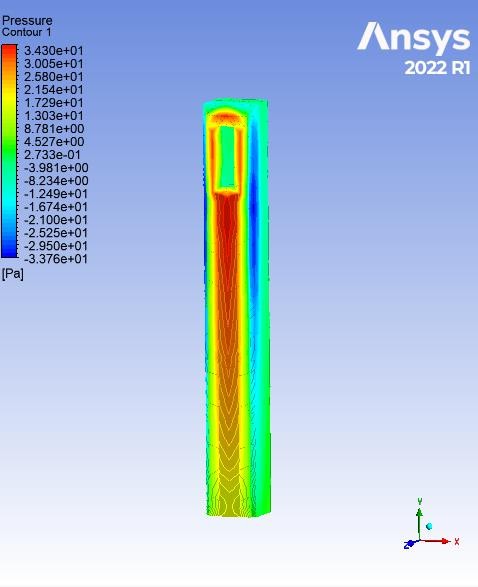
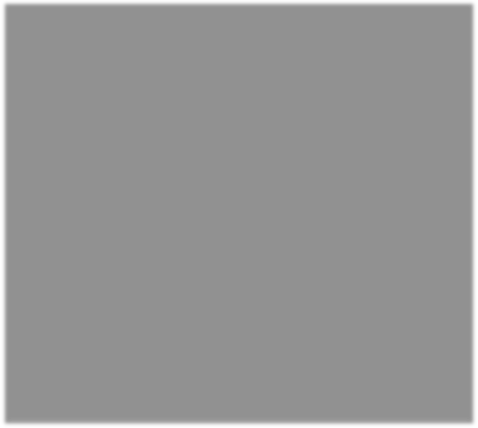
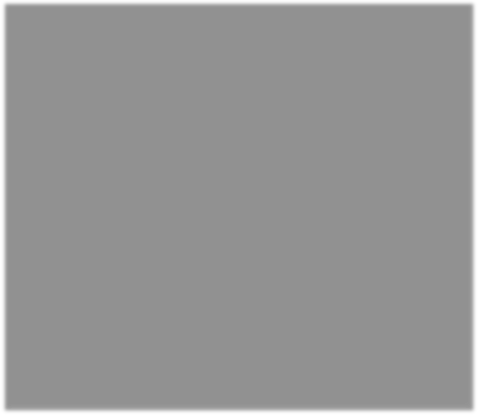
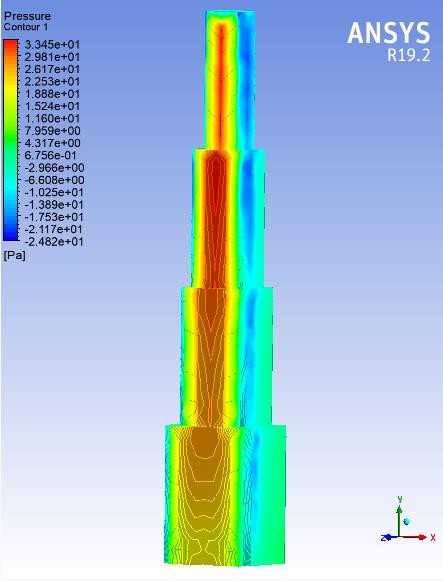
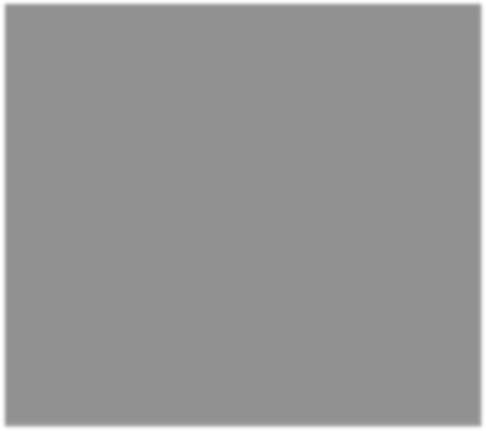


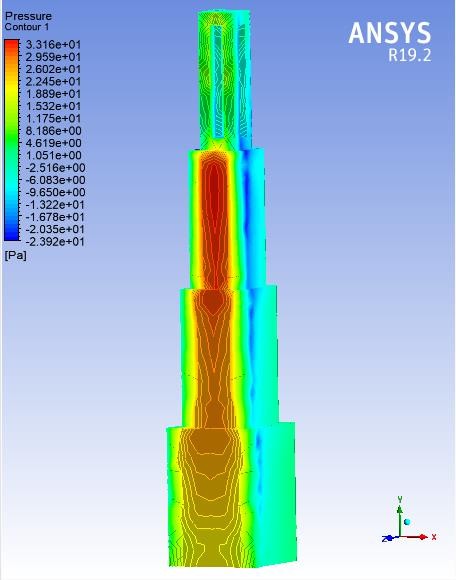
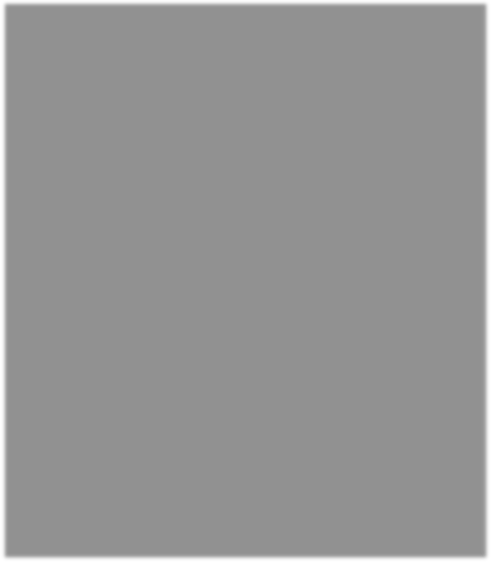
Figure: Setback model



**Figure:** Corner cut + void model



**Figure :** Setback+Corner cut model



* Drag Coefficient

**Figure** : Comparison of drag coefficient



**Drag Coefficient**

0.6

0.5

0.4

0.3

0.2

0.1

0

SQ

CC+VOID

SB

SB+CC

SB+VOID

### LIFT COEFFICIENT



**Lift Coefficient**

0.9

0.8

0.7

0.6

0.5

0.4

0.3

0.2

0.1

0

SQ

CC+VOID

SB

SB+CC

SB+VOID

Figure : Comparision of Lift Coefficient

### CONCLUSION

### EFFECT OF DRAG COEFFICIENT

Shape has a very large effect on the amount of drag produced. In this study corner cut, setback and opening/void shape modification combined with each other and the effect of the drag coefficient on the shape modified square tall building model are described in this section as follows

* + - **Square model** : The drag of simple square model has highest value as compared with shaped modified models which is near to 1.
    - **Setback+Opening** : The setback with opening model has lowest value as compared with other values of drag coefficient.
    - **Cornercut+Opening / Square** : The corner cut with opening model has value of drag coefficient which is lesser than square model by 3.33%
    - **Setback / Square** : The simple setback model has a value of drag coefficient which is lesser as compared to square model by 12.95%.
    - The setback model is also show variation which is also less as compared to square model by 15.75%.
    - The setback with corner cut model has greater value of drag coefficient when it is compared with setback with opening model by 5.71%.
    - This variation helps to understand the shape/geometry effects of the drag on the structured models.
    - The setback model has major effect as compared to corner cut shape optimization method used for reducing the wind effect on the structure.
    - In setback modification, most efficient way to reduce drag is to combine it with opening/void as vented floors. It can reduce drag considerably by 8.78% when compared to simple setback model.
    - . The corner cut model is combine with setback and void in which it shows that corner cut modification gives better efficient result with setback by 12.85% when compared to corner cut with opening model
    - In opening modification with corner cut and setback, it shows reduction in drag coefficient in setback with opening by 19.14%.
    - The Setback with Opening model of structure shows lowest value for drag coefficient compare with other models, which indicate the experience of low air pressure and shows efficient modified shape of structure.
    - This variation of models, i.e. square, cornercut with void, setback, setback with cornercut, setback with void, help us to determining the more efficient and more stable shape of the structure i.e. aerodynamic shape of the structure suitable for the maximum height with high wind pressure.

### EFFECT OF LIFT COEFFICIENT

The lift coefficient is also studied with the variation in shaped/geometries of the square tall building that is also called as aerodynamically shaped modified building. The shape modification includes corner cut, setback and opening and their combined modification as discussed below:

* + - **Square model** : The lift coefficient for the square model has maximum as compared with other models which comes near to 1.
    - **Setback+Opening** : The setback with opening model has minimum value of lift coefficient which comes close to zero.
    - **Cornercut / Setback** : In opening modification with corner cut and setback, it shows reduction in lift coefficient in setback with opening by 4.80%.
    - **Setback+Void / Setback** : In setback modification, most efficient way to reduce lift is to combine it with opening/void as vented floors. It can reduce lift considerably by 70.97% when compared to simple setback model.
    - **Cornercut+Setback / Cornercut+Void** : The corner cut model is combine with setback and void in which it shows that corner cut modification gives better efficient result with setback when compared to corner cut with opening model.
    - The Setback with Opening model of structure shows lowest value for lift coefficient compare with other models, which indicate the experience of low air pressure and shows efficient modified shape of structure.
    - This variation of models, i.e. square, cornercut with void, setback, setback with cornercut, setback with void, help us to determining the more efficient and more stable shape of the structure i.e. aerodynamic shape of the structure suitable for the maximum height with high wind pressure.

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