BLUFF BODY AERODYNAMICS - COMPUTATIONAL FLOW ANALYSIS ON TEMPLE STRUCTURE

A PROJECT REPORT

(Phase I)

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Submitted to the

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for the award of the degree of

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in

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DEPARTMENT OF AERONAUTICAL ENGINEERING

BHARATH INSTITUTE OF SCIENCE AND TECHNOLOGY

BHARATH INSTITUTE OF HIGHER EDUCATION AND RESEARCH

(Declared as Deemed – to – be University under section 3 of UGC Act, 1956)

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BONAFIDE CERTIFICATE

This is to certify that the project report titled, **"BLUFF BODY AERODYNAMICS – COMPUTATIONAL FLOW ANALYSIS ON TEMPLE STRUCTURE"**, is being submitted by

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Submitted for Viva Voce held on ________________

INTERNAL EXAMINER **EXTERNAL EXAMINER**

ABSTRACT

Tall buildings face many challenges with respect to changing environment. To reduce challenges, risks and to ensure safety, sustainability of tall buildings, optimizing building shapes aerodynamically is most used technique and also efficient way to face challenges such as structure resistance against strong winds, vortex shedding, disaster management, long durability of the building. Ancient temples-built years ago still sustain and remain to stand still in various conditions irrespective of environmental surrounding changes. An Indian temple with 21 layered stories is considered to analyse the aerodynamic structure, airflow flow pattern and other various challenges faced by the temple with the help of simulation and experimental results. This research follows the following conditions which execute the flow analysis of a temple structure with and without Kalasam followed by aerodynamic modification and optimization.

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LIST OF ABBREVATION AND SYMBOLS

SYMBOL		ABBREVATION
V	-	Velocity
P	-	Pressure
A	-	Distance from center location to high wind region
B	-	Distance from center to low wind region
Ө	-	Angle between a and b (triangle)
$\partial p / \partial n$	-	Pressure Gradient
Fp	-	Pressure Force
f_c	-	Coriolis Force
Ug	-	Geostrophic wind
p_w	-	Wind power
Z	-	total height
Z_o	-	Roughness length
Zref	-	Reference height
v_{ref}	-	Reference velocity
α	-	Wind shear exponent

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION TO TEMPLE

Dravidian temple architecture emerged in the southern part of Indian sub-continent that reached its final form by the 16th century. This Dravidian style architecture incorporates a design methodology that dominates the feature of the standing still gopuram. The Dravidian style of architecture was defined with fixed components that has a combination of Alpa vimana, Kutashala and Panjara. The Dravidian style incorporates all these elements in the temple arranging them from top to bottom on an increasing scale. The fascinating aspect and idea of the Dravidian's is its their super structure is always in the shape of a stepped pyramid where it's all tiers are strongly visible. The walls of Dravidian style temple always have pillared couplets at intervals. A Niche or aedicule was carved in between those couple pillars in order to place a sculpture with in.

Temples were known as centres for religious meetings. The Dravidian style of architecture has its own name and features such as they had enlarged gopuram, raised walls and many sculptures. The shikara is the word that is used for the crowning element at the top of the temple i.e., shape like a Stupika or octagonal cupola. At the entrance to the garba graha there will be sculptures of fierce dawarapalakas Guarding temple. Subsidiary shrines would be found within the tower or beside the main tower. Figure 1.1 depicts the different architectural styles of temple construction that in followed in olden days.

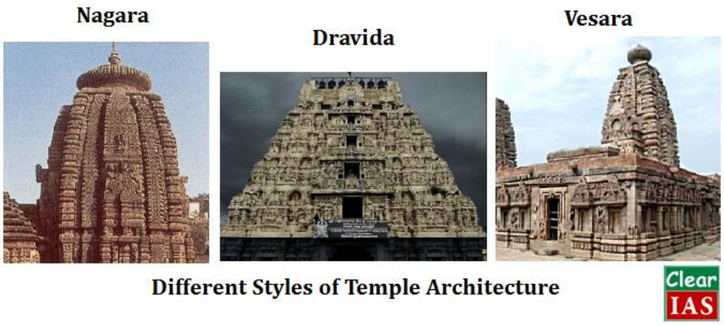


Figure 1.1 Different Temple Architectural Styles

1.2 DRAFTING GOPURAM

Ancient Tamilians Architectural skill and their knowledge based on Architectural development were at peak in the ancient era. The temple is a feast of variety of visual aspects and rendering beauty. These ancient temples take cue from a human body structure. Since the agamic texts describes the Temple as a cosmic man. From figure 1.2 is it observed that Temple is seen as the link between man and God. Ancient temple consists of garbhagriha (womb house), mandapa and gopuram. Ancient architect equated the main sanctum (garbhagriha) with a human head, the ardhamandapa to neck, Maha mandapa to human heart and temple gate way tower to human feet.

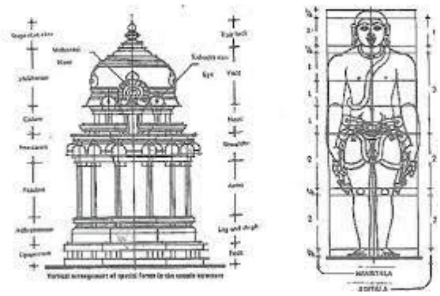


Figure 1.2 Drafting of Temple

CHAPTER 2
LITERATURE SURVEY

Bilal Assaad (2010) expressed his thoughts on Wind and its characteristics. Wind is a phenomenal character of multiple eddies in size variations which are moving air that is relative to surface of earth. Gust and turbulent characteristics are driven in wind is because of eddies in those winds. As moving air gets into surface interaction, there is a rise in gustiness which indirectly indicates strength of the wind at atmosphere in lower heights. Wind speed average with respect to time period, records increasing with altitude on the other hand records decreasing of gustiness with respect to height. From these records the point is clear that there is an inverse relation followed by wind speed average and gustiness with reference to height.

Structural engineer's priority concern during the study of wind and its phenomenal characters for a building is its mean velocity profile. The next prioritized criteria yet very important and special attention given by these engineers is for turbulence. In aspect of turbulence there exist two criteria for check-up namely approaching turbulence state of wind with respect to building and self-provoking turbulence in wind by the structure.

M.J. Andrews et.al. (2003) published When wind interact with structures there arise great complexity in understanding those phenomenal characteristics of wind. To get better understanding of these arising complexity quasi static of wind loading is used while designing low rise structures and determined as conservative approach for high raise structures. Tall building wind designs are ruled by dynamic responses, other structure interference, and direction of wind and responses of wind. Atmosphere is ruled by two most interesting forces, pressure gradient and Coriolis force.

Though air conditioning techniques have upgraded and utilized in all the places still there exists importance for natural ventilation. Many buildings still follow natural ventilation methods for various purposes such as to remove the roof heat because of solar radiation over top of the building, to get proper air circulation inside the building, to circulate hot air outside and get cool air inside the building. Insulation plays a major role in ventilation aspect Advancement in CFD's have improved the status of simulating fluid flows, and other related phenomena.

RESEARCH GAP:

1. Analyzing wind effects on Murdeshwar Temple with varying wind velocity around the temple.
2. Flow analysis of a temple structure with respect to aerodynamic modifications.
3. Flow separation.

PROBLEM STATEMENT:

1. Vorticity formation around temple structure.
2. Wind effects in surrounding environmental conditions.
3. Analysis of the problem when the flow changes from laminar to turbulent and reducing effect during increasing altitude.

OBJECTIVE:

To Find the Flow Analysis around a Temple structure.

METHODOLOGY

Analysis of temple structure

↓

Analyzing air flow pattern around the temple structure

↓

Designing of Murdeshwar temple using CATIA V5 software

↓

Simulation using ANSYS fluent

↓

Scale –down model according to blockage ratio

↓

Again designing and simulating for scale down model

↓

Fabricating the model and conducting experiment in low speed closed subsonic wind tunnel

↓

Comparison of results and validating them.

CHAPTER 3

TEMPLE SELECTION

3.1 REASON WHY WE ARE CHOOSING THIS TEMPLE

This temple has the tallest Gopura in the world and still it is in list of pilgrimage place. It experiences strong gust due to its coastal influence since it is surrounded by water body three sides. It experiences various wind variations as it is situated on top of an elevated terrain.

3.2 OUR MAIN AIM THROUGH THIS PROJECT

Our main intention is to find the flow analysis around the temple relating with varying altitude. Analyzing wind effects on Murdeshwar Temple with varying wind velocity and direction Finding drag force, drag coefficient, and pressure coefficient by numerical method, stimulation and by experimentation with conditions such as temple with Kalasam and holed storied followed by temple without Kalasam and without holed stories.

CHAPTER 4
ARCHITECTURE

The temple is built in Dravidian style of architecture with Shiva statue as a main attraction. The temple is constructed with Chalukya and kadasmba sculpture MURUDESHWAR TEMPLE is located on a hillock that seems to be a magnificent view. Tall pyramid like structure that gives rise to a tapered shape, known as gopuram. The principle features that resemble the ancient tower in the quadrangular enclosure that surrounds the area with notable sculpture. The design varies according to the direction of facing side. The Murdeshwar temple gopura is with 249 ft tall 21 tier raja gopuram, built by RAMA NAGAPPA SHETTY in the year 2008. Befitting the dimensions of the structure has 15 Kalasam on its top most storey. Figure 4.1 and 4.2 are the original existing temple located in Karnataka.

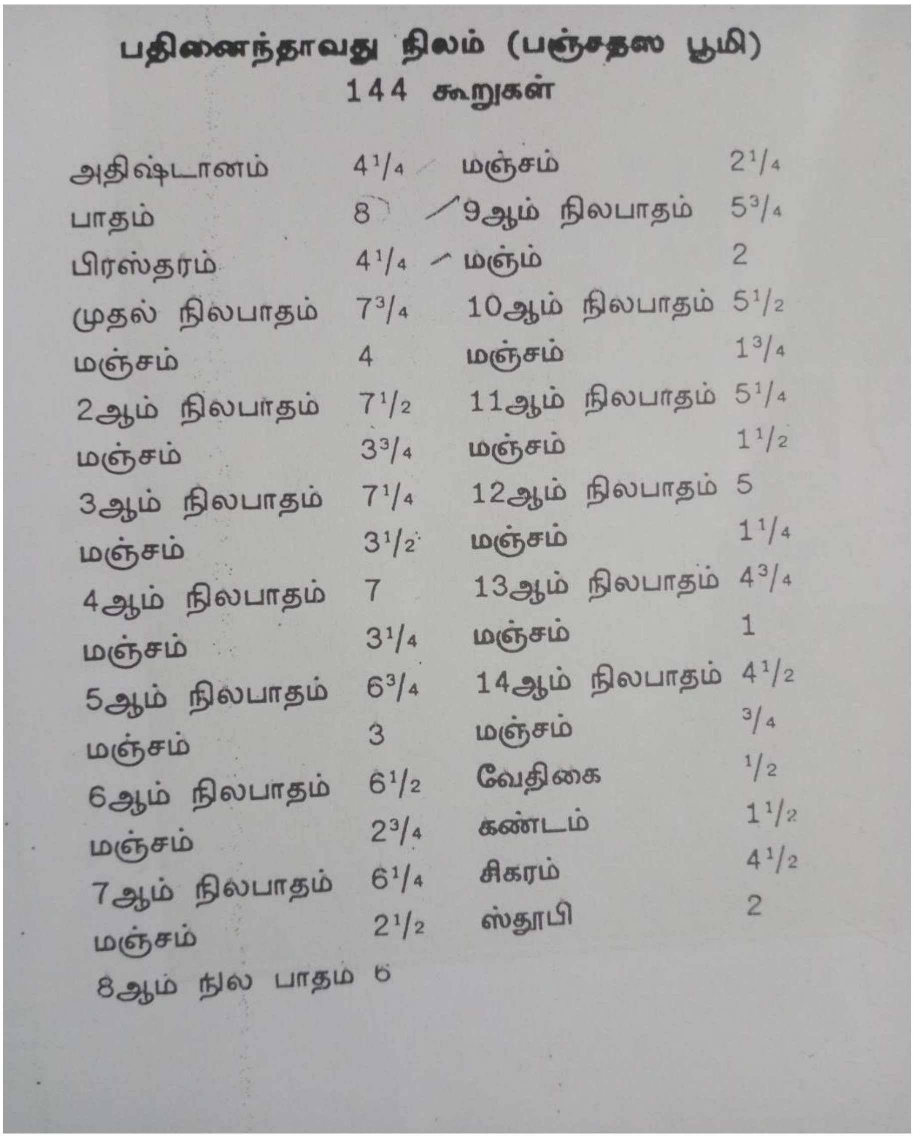
Figure 4.1 Murdeshwar Temple Gopuram

Figure 4.2 Murdeshwar Temple, Uttar Karnataka

CHAPTER 5
CALCULATION

5.1 METHOD OF CALCULATION

Figure 5.1 explains how to obtain dimension values from dimension less numbers which is used for calculating the dimensions of the temple for construction.



பதினைந்தாவது நிலம் (பஞ்சதல பூமி)
144 கூறுகள்

அதிஷ்டானம்	$4\frac{1}{4}$	மஞ்சம்	$2\frac{1}{4}$
பாதம்	8	9ஆம் நிலபாதம்	$5\frac{3}{4}$
பிரஸ்தரம்	$4\frac{1}{4}$	மஞ்சம்	2
முதல் நிலபாதம்	$7\frac{3}{4}$	10ஆம் நிலபாதம்	$5\frac{1}{2}$
மஞ்சம்	4	மஞ்சம்	$1\frac{3}{4}$
2ஆம் நிலபாதம்	$7\frac{1}{2}$	11ஆம் நிலபாதம்	$5\frac{1}{4}$
மஞ்சம்	$3\frac{3}{4}$	மஞ்சம்	$1\frac{1}{2}$
3ஆம் நிலபாதம்	$7\frac{1}{4}$	12ஆம் நிலபாதம்	5
மஞ்சம்	$3\frac{1}{2}$	மஞ்சம்	$1\frac{1}{4}$
4ஆம் நிலபாதம்	7	13ஆம் நிலபாதம்	$4\frac{3}{4}$
மஞ்சம்	$3\frac{1}{4}$	மஞ்சம்	1
5ஆம் நிலபாதம்	$6\frac{3}{4}$	14ஆம் நிலபாதம்	$4\frac{1}{2}$
மஞ்சம்	3	மஞ்சம்	$\frac{3}{4}$
6ஆம் நிலபாதம்	$6\frac{1}{2}$	வேதிகை	$\frac{1}{2}$
மஞ்சம்	$2\frac{3}{4}$	கண்டம்	$1\frac{1}{2}$
7ஆம் நிலபாதம்	$6\frac{1}{4}$	சிகரம்	$4\frac{1}{2}$
மஞ்சம்	$2\frac{1}{2}$	ஸ்தூபி	2
8ஆம் நில பாதம்	6		

Figure5.1 Temple Dimensions for 15 storey structure.

5.2 DIMENSIONS

Height of Gopuram = 75.8 m

Top length = 19.81 m

Number of Kalasam = 15

Distance between each Kalasam = 1.32 m

Length of 15 Kalasam = 29m

Height of Kalasam = 3 m

Diameter of Kalasam = 1.2 m

Base height = 5 m

Base length = 32 m

Base width = 15.54 m

Entrance height = 4m

Entrance width = 15.54m

Entrance length = 3m

Storeyed hole length = 2m

Storeyed hole height = 2 m

5.3 GOPURAM CALCULATIONS:

Table 5.3. (21) Storey Gopuram calculations

MURDESHWAR TEMPLE 249 COMPONENTS:	L/h				Length (cm)	Breadth (cm)
Adhistanam	5.25	0.3047238	1.59979995			
Paadham	11.00	0.3047238	3.3519618	4.95176175		
Prastaram	5.25	0.3047238	1.59979995	6.5515617		
1- Nilapadham	10.50	0.3047238	3.1995999	9.7511616	32	15.54
Manjam	5.00	0.3047238	1.523619	11.2747806		
2 -Nilapadham	10.25	0.3047238	3.12341895	14.39819955	31.4	14.93
Manjam	4.75	0.3047238	1.44743805	15.8456376		
3- Nilapadham	10.00	0.3047238	3.047238	18.8928756	30.8	14.32
Manjam	4.50	0.3047238	1.3712571	20.2641327		
4- Nilapadham	9.75	0.3047238	2.97105705	23.23518975	30.2	13.71
Manjam	4.25	0.3047238	1.29507615	24.5302659		
5- Nilapadham	9.50	0.3047238	2.8948761	27.425142	29.6	13.1
Manjam	4.00	0.3047238	1.2188952	28.6440372		
6- Nilapadham	9.25	0.3047238	2.81869515	31.46273235	29	12.49
Manjam	3.75	0.3047238	1.14271425	32.6054466		
7- Nilapadham	9.00	0.3047238	2.7425142	35.3479608	28.3	11.88
Manjam	3.50	0.3047238	1.0665333	36.4144941		
8- Nilapadham	8.75	0.3047238	2.66633325	39.08082735	27.7	11.27
Manjam	3.25	0.3047238	0.99035235	40.0711797		
9- Nilapadham	8.50	0.3047238	2.5901523	42.661332	27.1	10.66
Manjam	3.00	0.3047238	0.9141714	43.5755034		

10- Nilapadham	8.25	0.3047238	2.51397135	46.08947475	26.5	10.05
Manjam	2.75	0.3047238	0.83799045	46.9274652		
11- Nilapadham	8.00	0.3047238	2.4377904	49.3652556	25.9	9.44
Manjam	2.50	0.3047238	0.7618095	50.1270651		
12- Nilapadham	7.75	0.3047238	2.36160945	52.48867455	25.3	8.83
Manjam	2.25	0.3047238	0.68562855	53.1743031		
13- Nilapadham	7.50	0.3047238	2.2854285	55.4597316	24.7	8.22
Manjam	2.00	0.3047238	0.6094476	56.0691792		
14- Nilapadham	7.25	0.3047238	2.20924755	58.27842675	24.1	7.62
Manjam	1.75	0.3047238	0.53326665	58.8116934		
15- Nilapadham	7.00	0.3047238	2.1330666	60.94476	23.5	7.01
Manjam	1.50	0.3047238	0.4570857	61.4018457		
16- Nilapadham	6.75	0.3047238	2.05688565	63.45873135	22.9	6.4
Manjam	1.25	0.3047238	0.38090475	63.8396361		
17-Nilapadham	6.50	0.3047238	1.9807047	65.8203408	22.3	5.79
Manjam	1.00	0.3047238	0.3047238	66.1250646		
18-Nilapadham	6.25	0.3047238	1.90452375	68.02958835	21.6	5.18
Manjam	0.75	0.3047238	0.22854285	68.2581312		
19-Nilapadham	6.00	0.3047238	1.8283428	70.086474	21	4.57
Manjam	0.50	0.3047238	0.1523619	70.2388359		
20-Nilapadham	5.75	0.3047238	1.75216185	71.99099775	20.4	3.96
Manjam	0.25	0.3047238	0.07618095	72.0671787		
21-Nilapadham	5.50	0.3047238	1.6759809	73.7431596	19.8	3.35
Manjam	1.00	0.3047238	0.3047238	74.0478834		
Vedika	0.25	0.3047238	0.07618095	74.12406435		
Kandham	1.25	0.3047238	0.38090475	74.5049691		
Shikara	3.00	0.3047238	0.9141714	75.4191405		
Stupi	1.25	0.3047238	0.38090475	75.80004525		
	248.75					

The ancient temple gopuram is designed using ancient architectural calculations. Ancient architectural components such as Adhistanam which serves as the base of the gopuram, Man-jam – the ceiling, Nilapadham, Prastaram – pillars and columns. These terms act as a bridge between the ancient architecture and modern-day architectural terms. By using architectural – gopuram calculations. The summation of each man-jam, Nilapadham, Prastaram, Kandham, stupi, shikara and Adhistanam ends up with a numerical value. The overall summation value stands as the Table 5.4.a, 5.4.b, 5.4.c is the resulting calculated dimensions calculated using the above chapter table 5.3

5.4 KALASAM CALCULATION

Table 5.4.a dimensions of Kalasam -lengthwise

Length of 15 Kalasam (29 Meters)		
Stubi	1.32	0.0599173
Padmam	1.5	0.089875
Kambu	0.5	0.02995865
Kalam	0.5	0.02995865
Padmam	0.5	0.02995865
Kudam	5	0.2995865

Table 5.4.b dimensions of Kalasam - widthwise

Diameter of Kalasam		
Stubi	1.2	0.054545
Padmam	1.5	0.0818175
Kambu	0.5	0.0272725
Kalam	0.5	0.0272725
Padmam	0.5	0.0272725
Kudam	5	0.27272725

Table 5.4.c dimensions of Kalasam- height wise

Height of Kalasam		
Stubi	3	0.1363636
Padmam	1.5	0.2045454
Kambu	0.5	0.0681818
Kalam	0.5	0.0681818
Padmam	0.5	0.0681818
Kudam	5	0.681818

Kalasam is also called as Stubi as per ancient Hindu terminology. The Kalasam serves as an important part of the temple that is placed on topmost Storey of the gopuram. The Kalasam is filled with multi-grains, as it was believed that these grains would be used in times of disaster or floods. Once in every 12 years these Kalasam's are changed. Kalasam's are made up of metal they incorporate an inverted pot and cone like structure. The above calculations are carried out to obtain the height, width and length of Kalasam. The Kalasam contains parts such as Padhmam, Kudam, kalam and Kambam. These parts are essentially divided by 22 in order to obtain the dimensions of each Kalasam.

CHAPTER 6
DESIGN

6.1 CATIA DESIGN

Figure 6.1.a,6.1.b,6.1.c shows the 3d diagram drawn using catia software . the design is designed with vent and Kalasam in the temple structure.

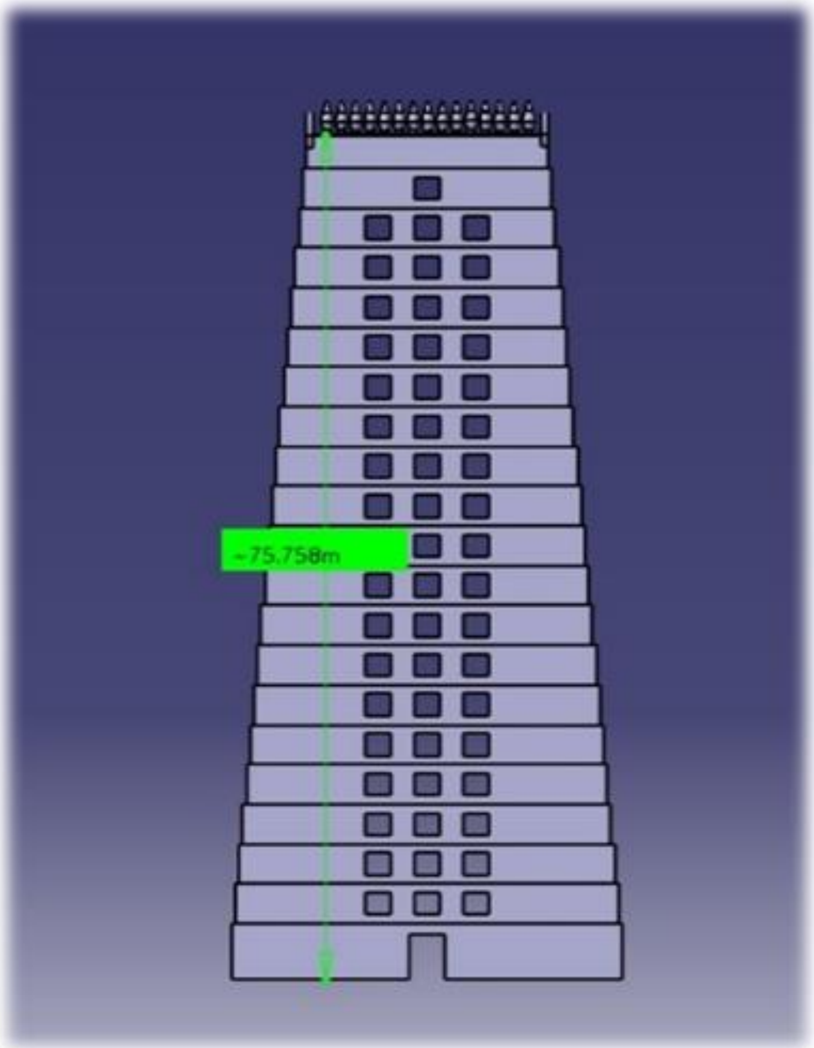


Figure 6.1.a Front view of Murdeshwar temple

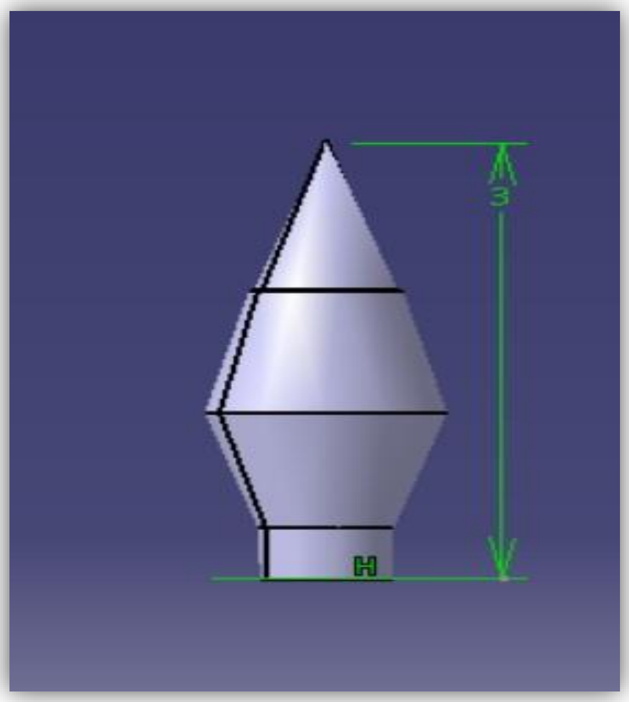


Figure6.1.b CATIA 3D diagram of Kalasam

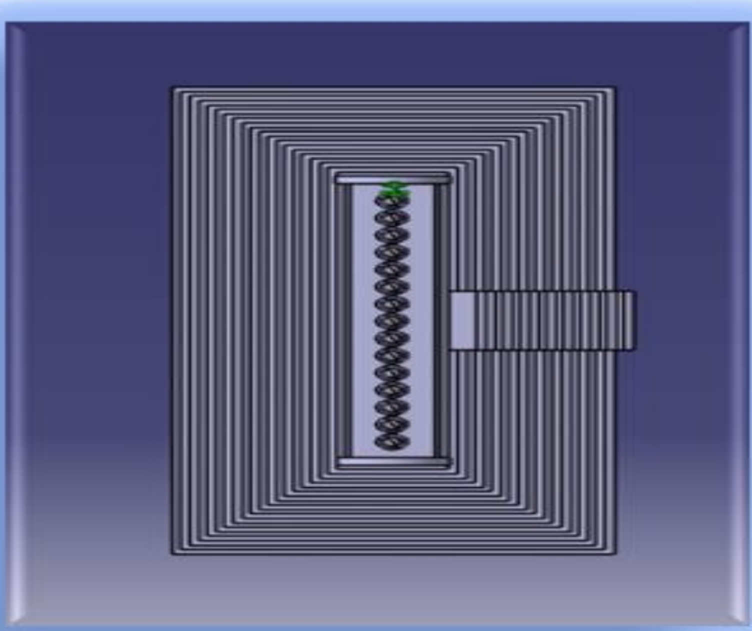


Figure6.1.c 3D CATIA diagram top view- Murdeshwar temple

Figure 6.1.d, 6.1.e , 6.1.f and 6.1.g is also designed with catia software but designed without vent and without kalasam in the temple structure.

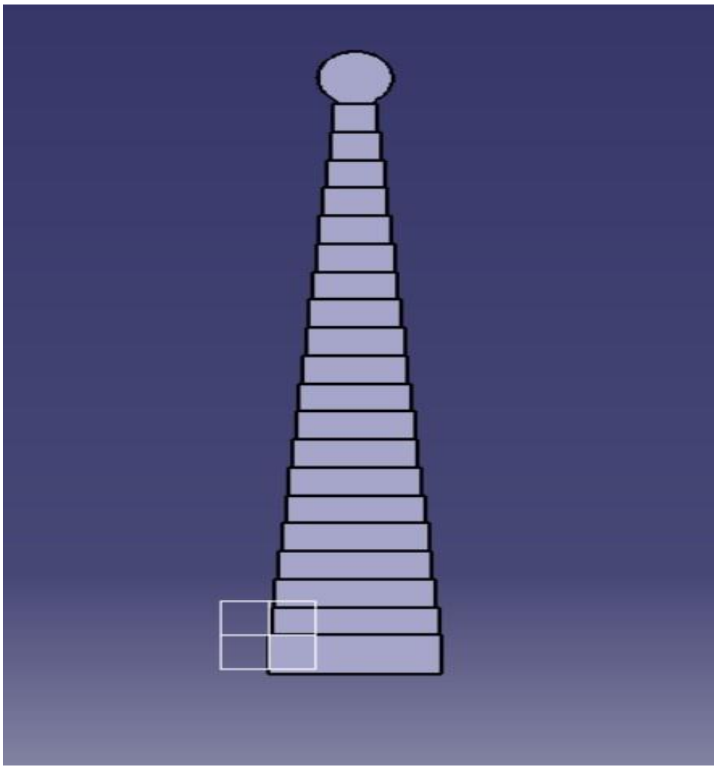


Figure 6.1.d CATIA diagram –Side view

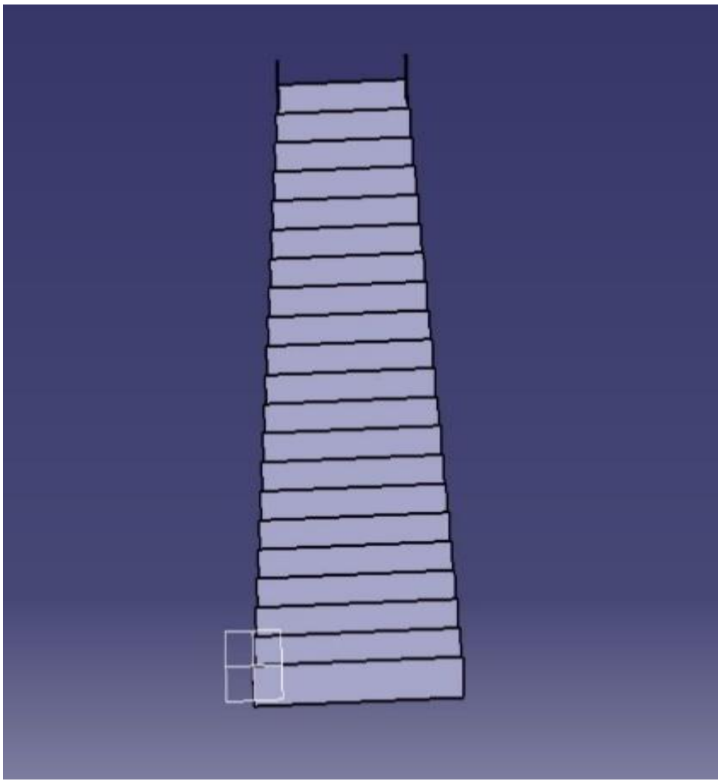


Figure 6.1.e CATIA diagram-front view

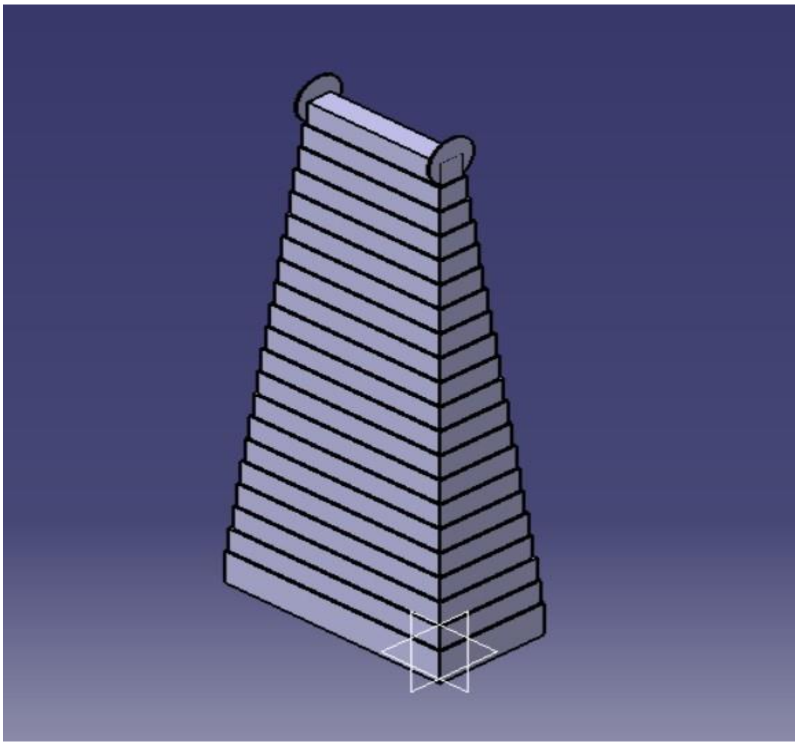


Figure 6.1.f 3D CATIA Sketch- without Kalasam , without vent

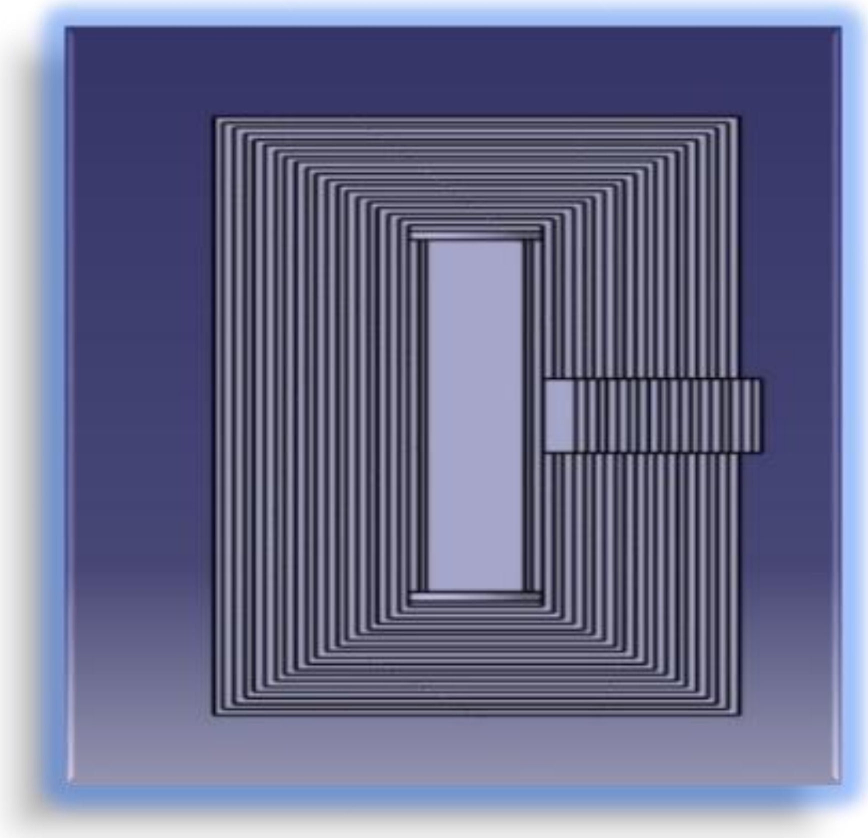


Figure 6.1.g 3D CATIA sketch-top view [without kalasam,without vent]

6.2 DIMENSIONS:

The below figures give dimensions for the previously designed CATIA models.

6. 2.a LENGTH (m) of each storey:

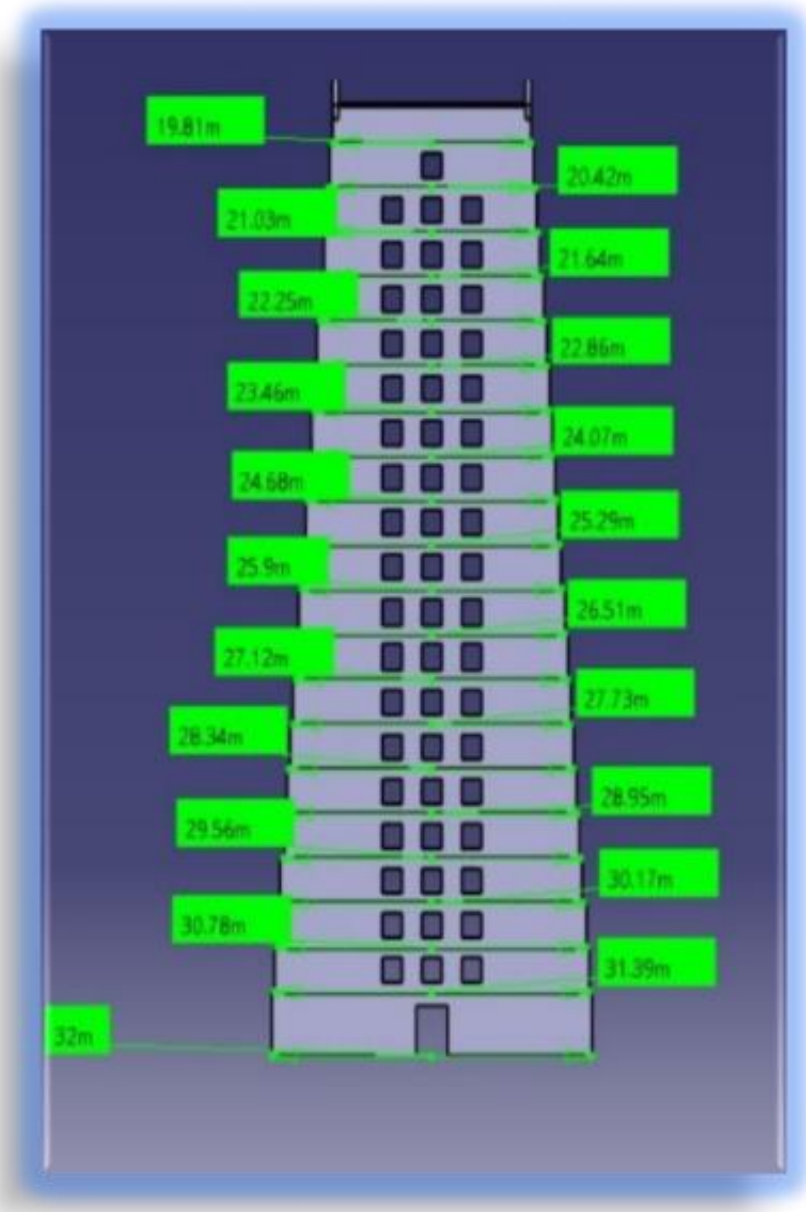


Figure 6.2.a with Kalasam, with Vent – Dimensions Lengthwise

6.2.b WIDTH of each storey (m).

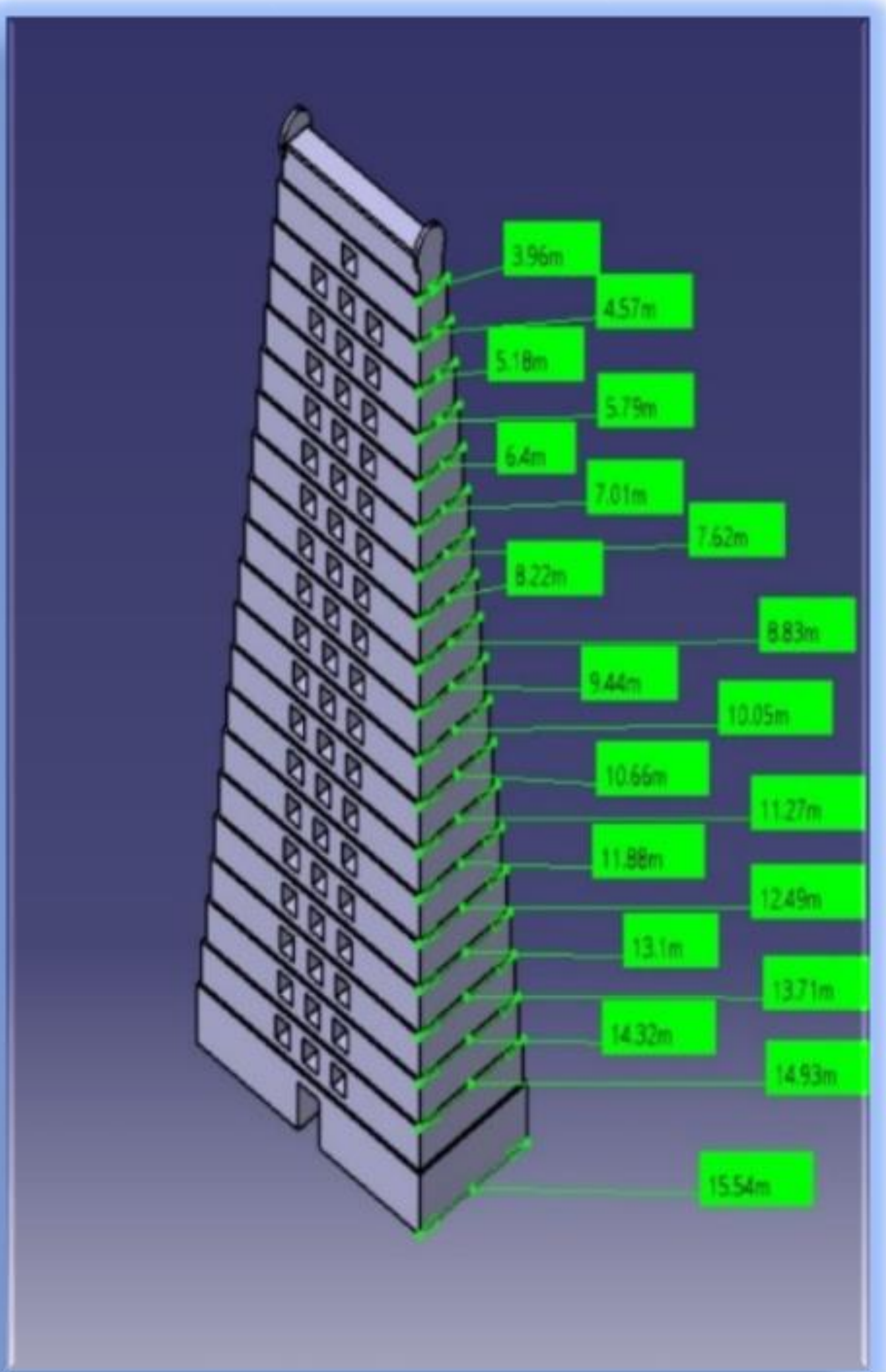


Figure 6.2.b with Kalasam, with vent-Dimensions width wise

CHAPTER 7
DATA ANALYSIS

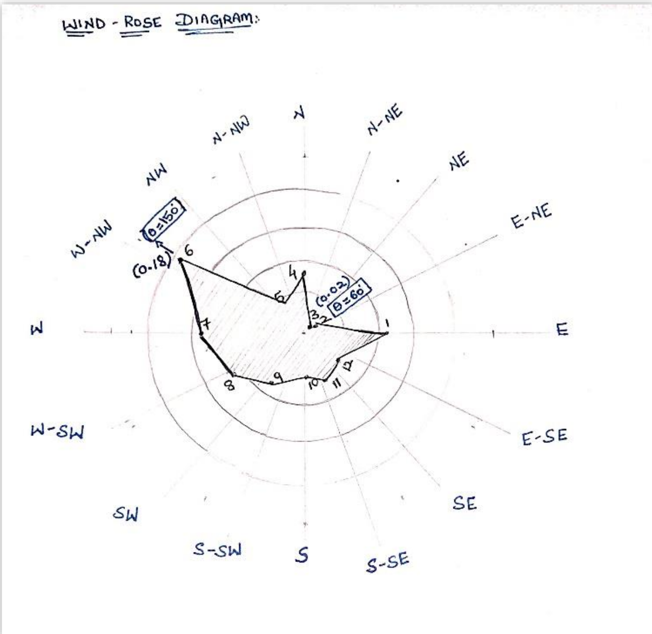


Figure 7.1 Representation of Wind data and peak wind direction in Wind Rose chart

WIND ROSE DIAGRAM:

It is 8/16 radial lines representing wind direction
5 to 10 concentric lines indicating wind frequency
Coloured bars on each radial line indicating the wind speed
Wind rose diagram helps in proper positioning of a building on a site so as to maximise the passive ventilation It helps in deciding the proper position and size of openings of a building.

From the above wind rose diagram, we can find the low wind velocity and high wind velocity form corresponding sector 6 and 3 in the direction W-NW and E

High wind speed = 0.18 m/s

Low wind speed = 0.02 m/s

To obtain pressure from wind speed

Case 1:

$V1 = 0.18$ m/s

$P1 = 0.000082944$ Pa (*since,* $P = 0.00256 * v^2$)

Case 2:

$V2 = 0.02$ m/s

$P2 = 0.000001024$ Pa

To find the distance from high pressure wind to low wind pressure Using cosine formula,

a = distance from centre location to high wind region

b = distance from centre to low wind region

$\theta = 150 - 60 = 90^{\cdot}$

a = 0.038 m

b = 0.002 m

$\theta = 90^{\cdot}$

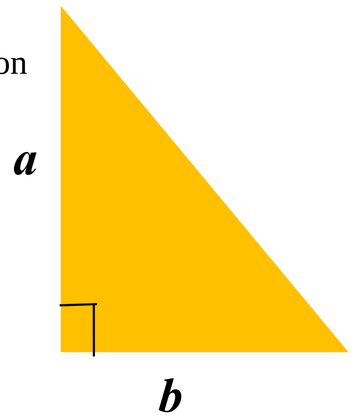


Figure 7.2 Pythagoras theorem triangle

$x = \sqrt{a^2+b^2 - 2ab\cos\theta}$

x = 0.038053 m

Pressure gradient:

P1-P2 / X

$\partial p/\partial n$ = 0.000082944 – 0.000001024 / 0.038053

$\partial p/\partial n$ = 0.00215 Pa/m

Pressure force:

Fp = -1/ρ * $\partial p/\partial n$

= -1/ 1.225 * 0.00215

= -0.00175 Pa

Coriolis force:

Fc = f * u

$[f = 2\omega sin\varphi]$ $(f = 0.127)$ (f represents the latitude and ω) the angular rotation of the earth)

$= 2 \text{ X } 2\frac{\pi}{24} sin(14.0940) X4.2$

= 1.022

Geostrophic wind:

-1/ f *ϱ $*$ ($\partial p/\partial n$)

= -1/0.127*1.225*0.00215

Ug= -0.000216 m/s

Where

Ug- geostrophic wind

f- Latitude

(∂p/∂n) –pressure gradient

Wind power / unit area:

$=\frac{1}{2} * \rho u^3$

$=1/2 * 1.225 *(4.2)^3$

$P_w = 45.3789\ W/m^2$

Wind speed measurement with increasing altitude:

Power Law

$$v_2 = v_1 \cdot \left(\frac{z_2}{z_1}\right)^{\alpha}$$

Log law

$$v \approx v_{\text{ref}} \cdot \frac{\ln\left(\frac{z}{z_0}\right)}{\ln\left(\frac{z_{\text{ref}}}{z_0}\right)}$$

Table 7.1Parameters used on power law and log law

PARAMETERS	SYMBOL	VALUE	UNIT
Total height	Z	75.8	ft
roughness length	Z_0	0.0002	m
Reference height	Zref	10	ft
Reference velocity	V(zref)	5.63	m/s
Wind shear exponent	A	0.1135	

WIND SPEED AT 75.8m BY POWER LAW = 7.086m/s

WIND SPEED AT 75.8m BY LOGARITHMIC LAW = 6.684m/s

CHAPTER 8

ANSYS SIMULATION AND ITS RESULTS

8.1. With Kalasam with vent:

Figure 8.1.a, 8.1.b display pictures of Meshing operation performed by using ICEM CFD with Kalasam and vent in the temple structure. Fine hexa- dominant mesh generated

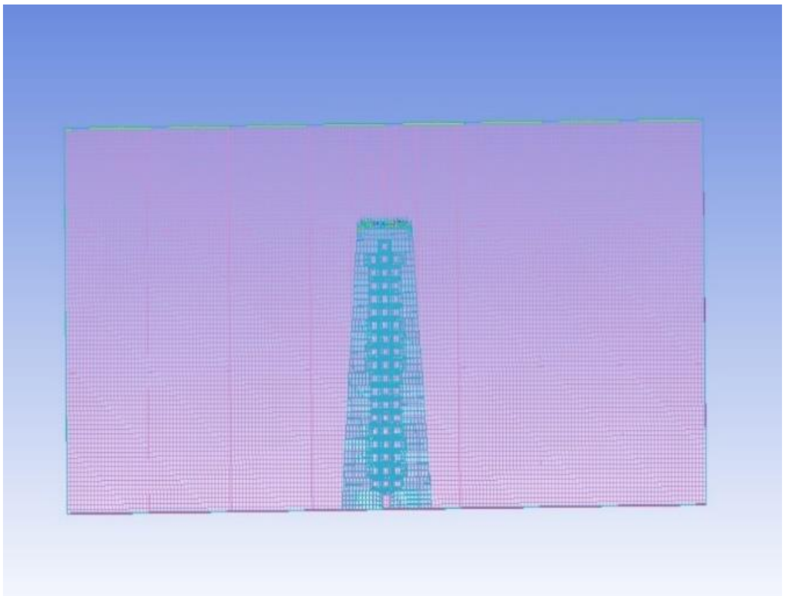


Figure 8.1.a Hexa-dominant mesh of temple structure- With kalasam with vent

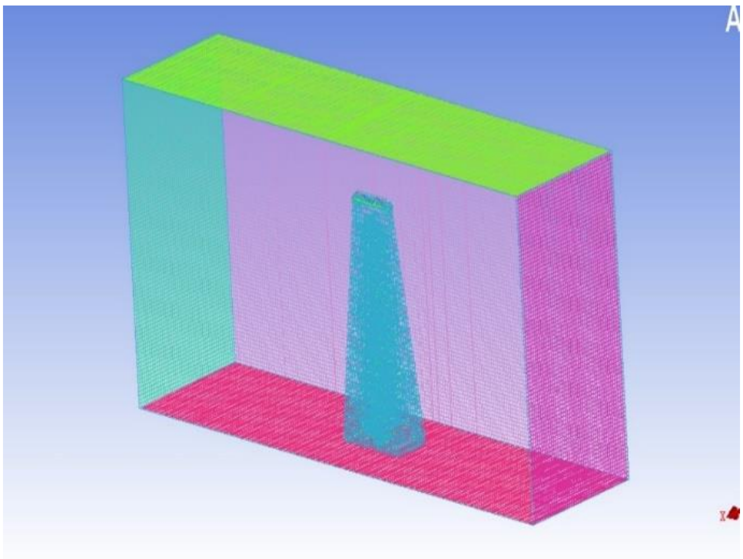


Figure 8.1.b isometric view of meshing

8.2 without vent without kalasam

Figure 8.2.a , 8.2.b display pictures of Meshing operation performed by using icem cfd without Kalasam and without vent in the temple structure . Fine hexa- dominant mesh generated

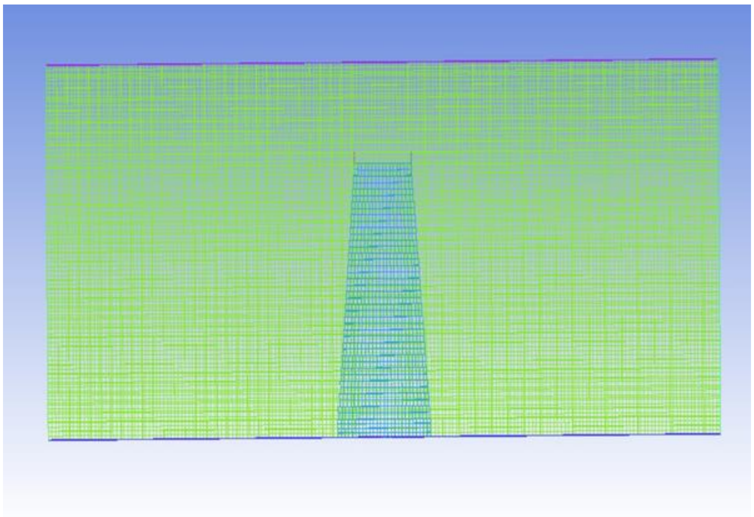


Figure 8.2.a hexa dominant meshing of temple structure

Without vent without kalasam

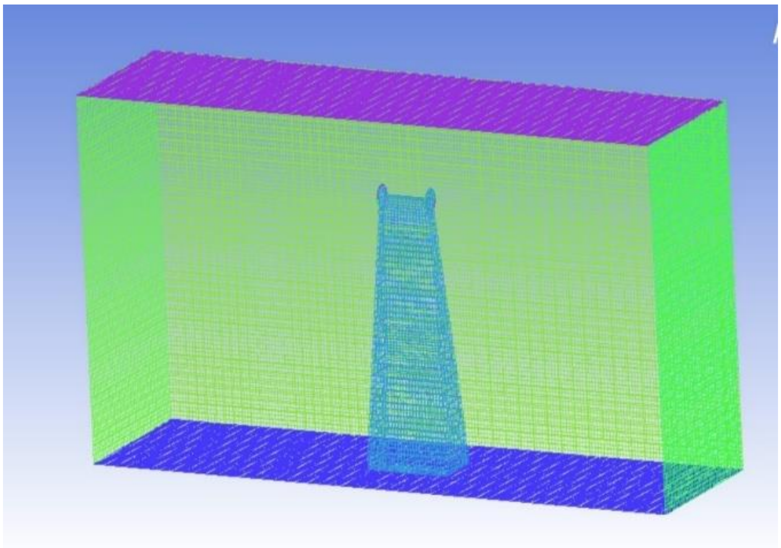


Figure 8.2.b Isometric view of meshing

8.3 CONTOURS:

Figure 8.3.a the velocity contour shows the variation in velocity with respect to the altitude. We could clearly see the wind entering the windward side and exiting at the leeward side. The variation near the Kalasam region is nearing the peak and the flow separation could also be observed near walls.

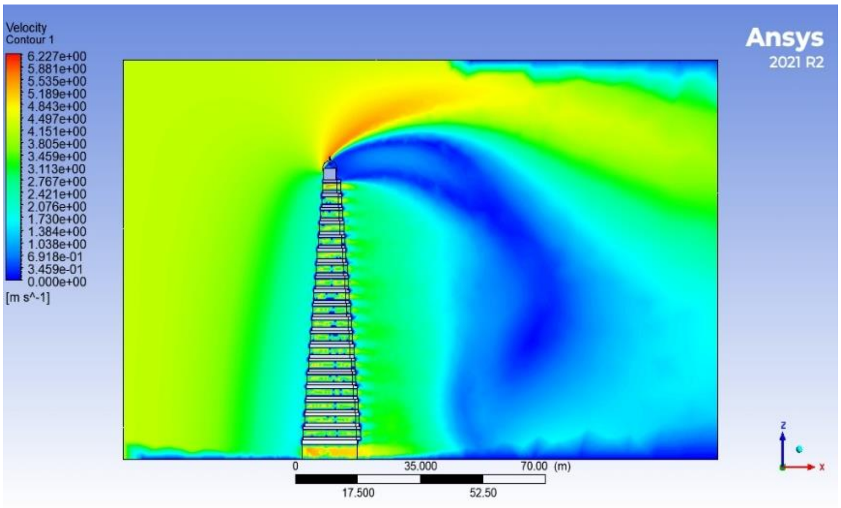


Figure 8.3.a Velocity contour-with Kalasam with vent

Figure 8.3.b contour shows fluctuations in the flow that is major at the Kalasam region.

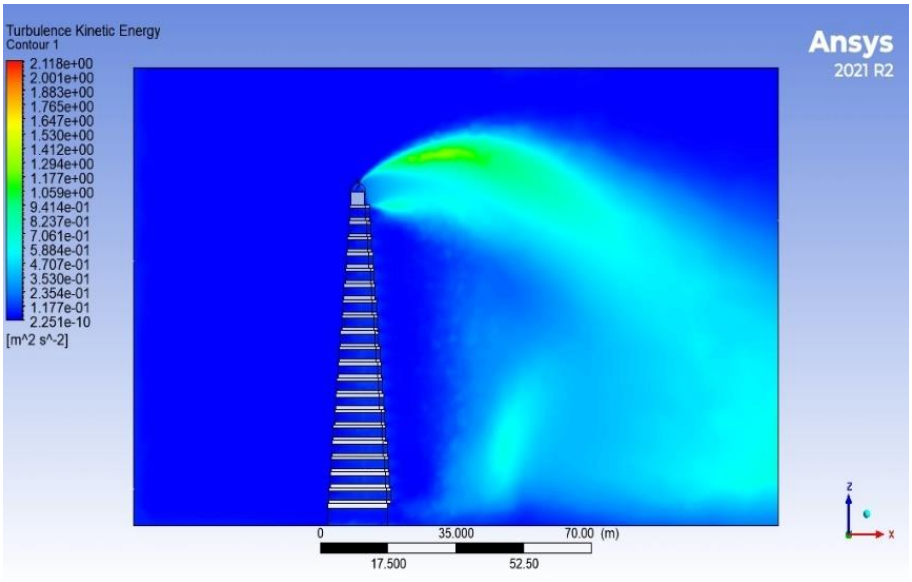


Figure 8.3.b Turbulence Kinetic Energy with Kalasam with vent

Figure 8.3.c the pressure difference over the temple structure is observed in these pressure contour. The pressure is lesser in the leeward side of the structure and more pressure in the windward side of the temple.

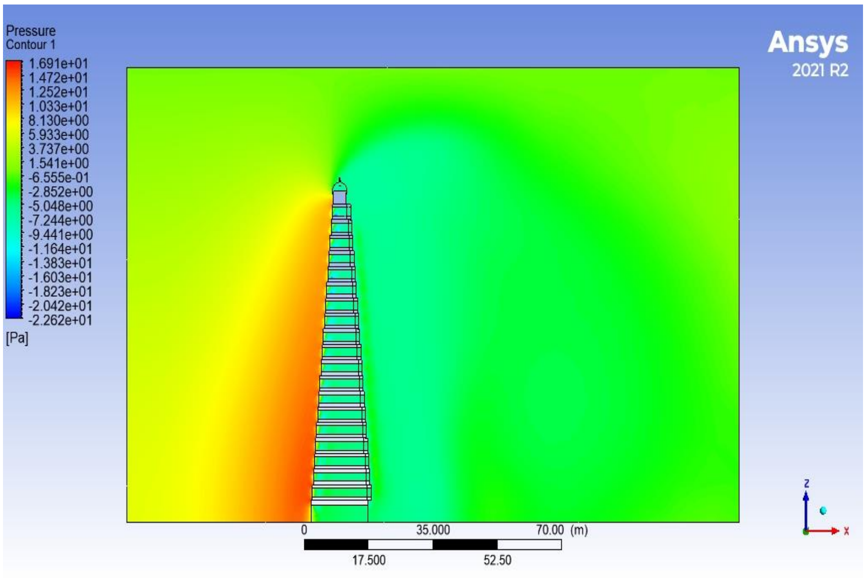


Figure 8.3.c Pressure contour –with Kalasam with vent

Figure 8.3.d von Karman vortex is generated due to eddy viscosity. We could observe the viscous dissipation and the band like formation near Kalasam.

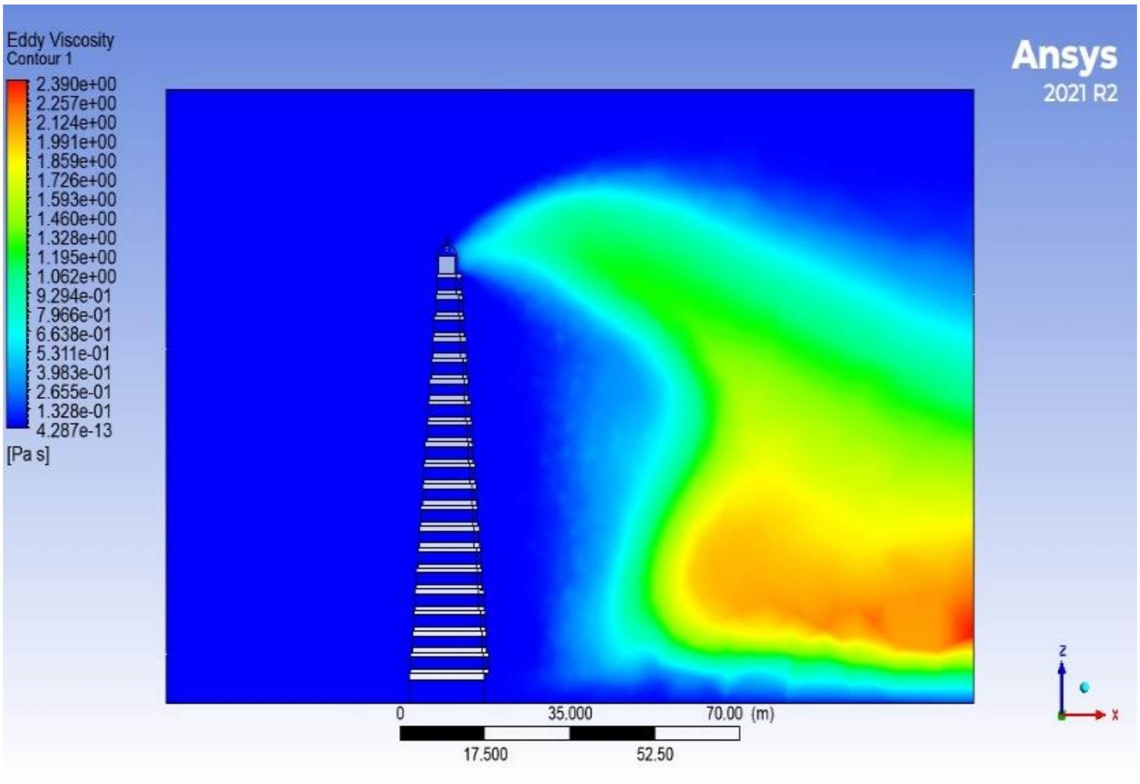


Figure 8.3.d Eddy viscosity contour –with Kalasam with vent

CONCLUSON:

This paper concludes about the basics of choosing terrain, environmental conditions and other important parameters such as wind forces acting on a certain building and the characterization of winds according to the Beaufort scale and direction of peak wind speed. The obtained wind rose chart is essential in calculating Coriolis force, geostrophic wind and gradient wind region on a chosen particular terrain. The wind flow is simulated in ANSYS – CFX and flow pattern around the Kalasam is observed the observations are matched with the obtained wind data for further analysis. This ensures in learning and analyzing wind flow pattern of Murdeshwar temple. Further analysis and detailed study on recirculation, flow separation, vortex shedding and counter balance effect.

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PLAGIARISM REPORT:

BLUFF BODY AERODYNAMICS - COMPUTATIONAL FLOW ANALYSIS ON TEMPLE STRUCTURE

A PROJECT REPORT

(Phase II)

Submitted by

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DEPARTMENT OF AERONAUTICAL ENGINEERING

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BHARATH INSTITUTE OF HIGHER EDUCATION AND RESEARCH

(Declared as Deemed – to – be University under section 3 of UGC Act, 1956)

CHENNAI – 600 073

MAY 2021

ABSTRACT

Tall buildings face many challenges with respect to changing environment. To reduce challenges, Risks and to enhance the safety and sustainability of high-rise buildings, one of the finest approaches is aerodynamic optimization which provides structural resistance against strong winds. Ancient temple-built years ago still sustain and remain standstill in various conditions irrespective of environmental Surrounding changes. An Indian temple with 21 layered stories is considered to analyse its Aerodynamic structure, airflow flow pattern, and other various challenges faced by the temple with the help of simulation and experimental results. The design includes a taper section with vents and Kalasam. The aerodynamic modification includes two types of testing. A 3D model is designed in CATIA V5 software, simulated using Ansys CFD – CFX, and tested in a subsonic wind tunnel with various velocity conditions.

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LIST OF ABBREVIATIONS AND SYMBOLS

SYMBOL	ABBREVIATION
cp	Coefficient of pressure
x/h	Pressure ports with respect to vertical height
cd	Coefficient of drag

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION TO TEMPLE

Dravidian temple architecture emerged in the southern part of the Indian sub-continent that reached its final form by the 16th century. This Dravidian-style architecture incorporates a design methodology that dominates the feature of the standing still gopuram. The Dravidian style of architecture was defined by fixed components that have a combination of Alpa vimana, kutashala, and panjara. The Dravidian style incorporates all these elements in the temple arranging them from top to bottom on an increasing scale.

The major characteristic of the Dravidian architecture is its superstructure, always in the shape of a stepped pyramid where it's all its tiers are strongly visible. The walls of the Dravidian-style temple always have pillared-couplets at intervals. A Niche or aedicule was carved in between those couple pillars in order to place a sculpture within. Temples were known as canters for religious meetings. The Dravidian style of architecture introduces a huge temple tower named Raja gopuram, with high-rise walls covered on all sides.

The gopuram also has tall towers and splendid sculptures. The shikhara is the word that is used for the crowning element at the top of the temple i.e., shapes like a Stupika or octagonal cupola. At the entrance to the Garba Graham, there will be sculptures of fierce dawarapalakas guarding the temple. Subsidiary shrines would be found within the tower or beside the main tower. Figure 1.1 depicts the different architectural styles of temple construction that followed in the olden days.

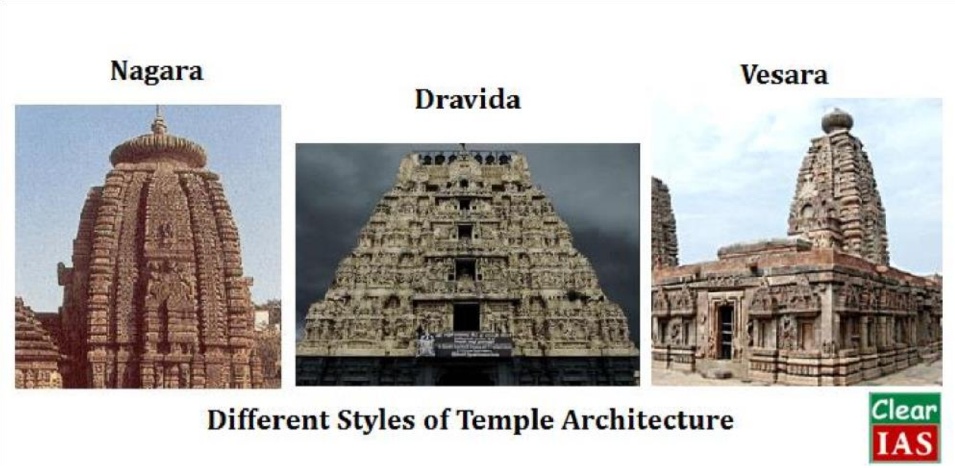

Figure 1.1 Different Temple Architectural Styles

1.2 DRAFTING GOPURAM

Ancient Tamilians Architectural skill and their knowledge based on Architectural development were at their peak in the ancient era. One mandala is an ancient term used to incorporate heavenly bodies with supernatural forces that enclose a metaphysical plan of the temple blueprint. One mandala equals 8X8 with a total of 64 units of meta-state grids. Figure 1. 2 describes the drafting of the temple that helps in the construction of the temple structure.

The temple is a feast of a variety of visual aspects and rendering beauty. These ancient temples take a cue from a human body structure. Since the agamic texts describe the Temple as a cosmic man. Temple is seen as the link between man and God. The ancient temple consists of garbhagriha (womb house), mandapa, and gopuram. Ancient architects equated the main sanctum (Garbhagriha) with a human head, the ardhamandapa to the neck, the Maha mandapa to the human heart, and the temple gateway tower to human feet.

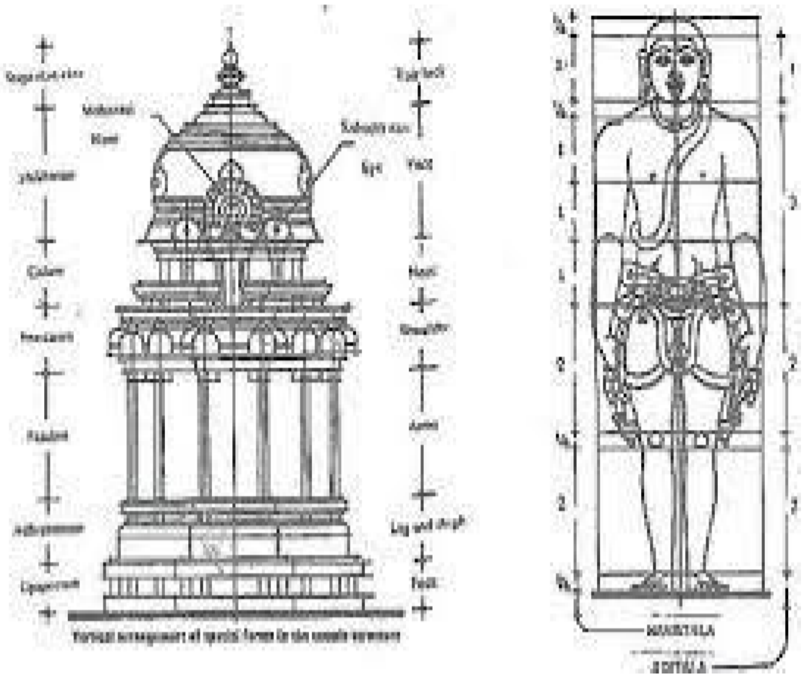

Figure 1.2 Drafting of Temple

CHAPTER 2

LITERATURE SURVEY

INTRODUCTION

High–rise buildings are often subjected to various disturbances and torsional vibrations, for such a reason most high-rise buildings are designed in a rectangular or triangular plan. An aerodynamically efficient building plays an essential role by providing wind resistance and proper crosswind excitations. Aerodynamic modifications are another important feature in providing an efficient structure. These modifications include major and minor changes such as corner modifications, corner cuts, and chamfering that help in reducing the strong wind effects. The wind excitation depends on the shape and size of a building, range of distributed mass and stiffness on a structure, characteristic wind approach over a structure, and the ability of a structure to dissipate vibration. The terrain structure and location of the temple as well as the topographic effects are those factors that influence the aerodynamic loads acting on the structure.

Neethi B and Elsa Joby (2018) reported a general estimation of wind loading that is outraged by obtaining pressure coefficients. The pressure coefficients are influenced by various parameters like shape, incident wind profile, structure, terrain roughness, and location of the building. Bluff bodies are mostly man-made structures, the excess motion produces high base loads that may not lead to a cost-effective design. An optimized structure increases the modal mass and reduces the wind-induced motion

Ashutosh Sharma et al. (2018) established Aerodynamic modifications on top of a building by altering into different angles and various shapes is one of the major factors that comes into play while modifying the structure.it is useful in mitigating the impact of wind on the upper parts of a structure. Top modification is a progressive approach when the wind flow pattern is studied over the building, where the air flows over the top section that traces the shape smoothly. Aerodynamic forms are used to reduce the effect of wind loads on high-rise buildings. These aerodynamic forms are of shapes like taper, helical, elliptical, and cylindrical. Generally, the shape of the building helps in deciding the flow pattern and reducing the generation of vortices and aeroelastic effects on a building. Softening the corners of rectangular or square plan buildings with sharp-edged corners is often accomplished by chamfering and set-backing the structure's corners to a certain pre-defined angle that reduced the wind-induced vibrations. High-rise buildings are mostly subjected to severe wind-induced vibrations that can be effectively reduced by tapering the module while reducing the across wind responses. The taper ratio is determined by negotiating the base width of the building with the top width of the building with reference to the overall building height. As taper structure maintains a larger base that reduces with an increase in height. A tapered high-rise building efficiently distributes the vortex shedding over a broad range frequency that reduces the across wind responses.

Yong Chul Kim et al. (2019) studied the aerodynamic characteristics of wind such as design wind speed, turbulence as well as Mechanical characteristics like damping, mass, and stiffness that influence the response of buildings. While considering safety factors on an aspect of vibrations and serviceability criterion, engineers' perception is to improve safety by minimizing these factors to an acceptable range. In considering the dynamic wind response acting on a building, an optimal design must maintain a high functional performance level. Stiffness increases the structural stability of a building. An increase in stiffness tends to increase the natural frequency of the building. At high wind speed if the stiffness is considerably low then the structure tends to undergo vortex-induced vibrations. To increase serviceability stiffness should be increased.

RESEARCH GAP:

1. Analyzing wind effects on Murdeshwar Temple with varying wind velocity around the temple.
2. Flow analysis of a temple structure with respect to aerodynamic modifications.
3. Flow separation.

PROBLEM STATEMENT:

1. Vorticity formation around temple structure.
2. Wind effects on surrounding environmental conditions.
3. Analysis of the problem when the flow changes from laminar to turbulent and reducing effect during increasing altitude.

OBJECTIVE:

To Find the Flow Analysis around a Temple structure.

METHODOLOGY:

Analysis of temple structure

↓

Analyzing air flow pattern around the temple structure

↓

Designing of Murdeshwar temple using CATIA V5 software

↓

Simulation using ANSYS fluent

↓

Scale –down model according to blockage ratio

↓

Again designing and simulating for scale down model

↓

Fabricating the model and conducting experiment in low speed closed subsonic wind tunnel

↓

Comparison of results and validating them.

CHAPTER 3

TEMPLE SELECTION

3.1 REASON WHY WE ARE CHOOSING THIS TEMPLE

This temple has the tallest Gopura in the world and still, it is on the list of pilgrimage places. It experiences strong gusts due to its coastal influence since it is surrounded by a water body on three sides. It experiences various wind variations as it is situated on top of elevated terrain.

3.2 OUR MAIN AIM THROUGH THIS PROJECT

Our main intention is to find the flow analysis around the temple relating to varying altitudes. Analyzing wind effects on Murdeshwar Temple with varying wind velocity and direction. Finding drag force, drag coefficient, and pressure coefficient by numerical method, stimulation, and experimentation with conditions such as temple with Kalasam and holed storied followed by temple without Kalasam and without holed stories.

CHAPTER 4

ARCHITECTURE

The temple is built in the Dravidian style of architecture with a shiva statue as the main attraction the temple is constructed with Chalukya and kadasmba sculptures MURUDESHWAR TEMPLE is located on a hillock that seems to be a magnificent view. The tall pyramid-like structure gives rise to a tapered shape, known as gopuram. The principal features resemble the ancient tower in the quadrangular enclosure that surrounds the area with notable sculptures. The design varies according to the direction of the facing side. The Murdeshwar temple gopura is with 249 ft. tall 21 tier raja gopuram, built by RAMA NAGAPPA SHETTY in the year 2008. Befitting the dimensions of the structure has 15 Kalasam on its topmost story.

Figure 4.1 Murdeshwar Temple Gopuram

Figure 4.2 Murdeshwar Temple, Uttar Karnataka

CHAPTER 5

WIND DESIGN CALCULATION

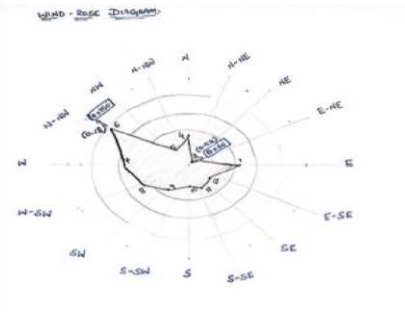

Figure 5.1 Representation of Wind data and peak wind direction in Wind Rose chart

Figure 5.1 describes the wind rose diagram with the respective terrain region . The wind speed of a particular location can be obtained using a wind rose chart. The wind rose chart helps in obtaining the direction of peak wind flow over that particular region. The obtained wind speed can be compared with the Beaufort scale by knowing the corresponding description of wind speed.

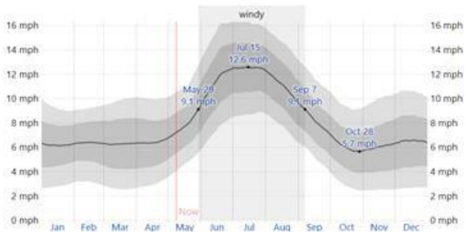

Figure 5.2 Annual data of peak wind speed

Figure 5.2 represents the peak wind data in an annual scale basis.

CHAPTER 6

DESIGN

6.1 3D CATIA Design

A scaled-down model of Murdeshwar temple is designed using CATIA V5 software.

i) With Kalasam with vent	**ii) without Kalasam without vent**
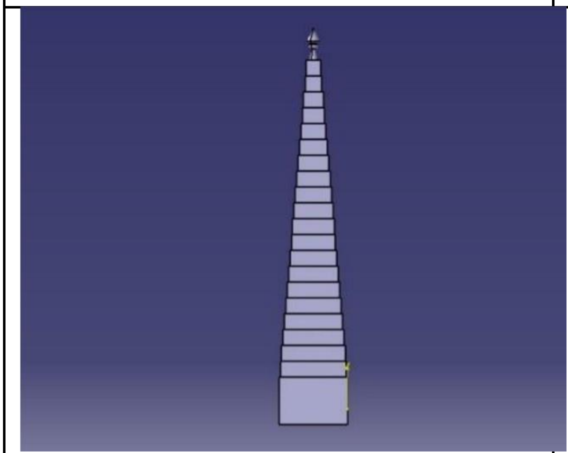	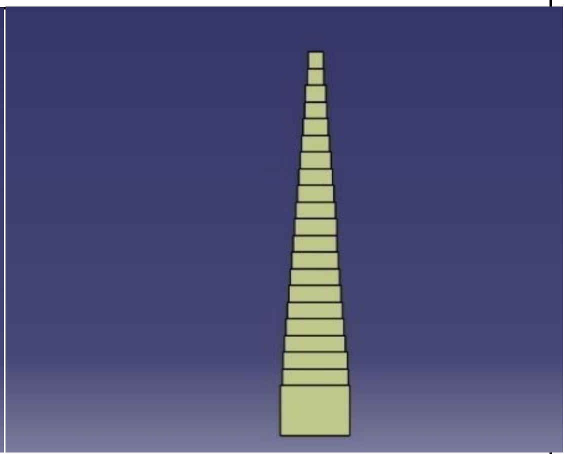
Figure 6.1.a Side view with Kalasam with vent	**Figure 6.1.b Side view without Kalasam without vent**

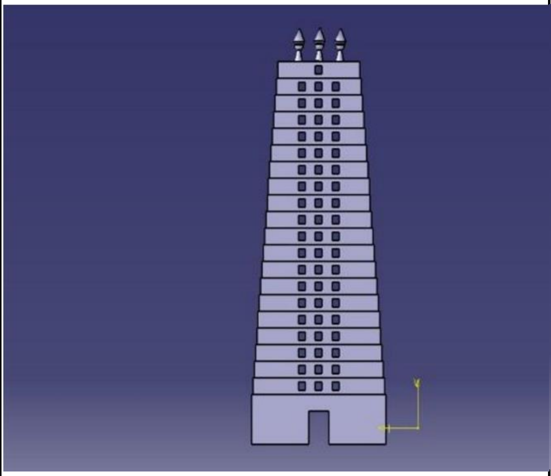	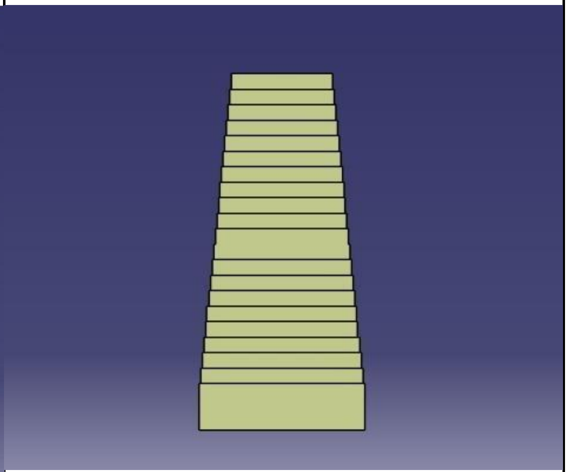
Figure 6.1.c Front view with Kalasam with vent	**Figure 6.1.d Front view without Kalasam without vent**
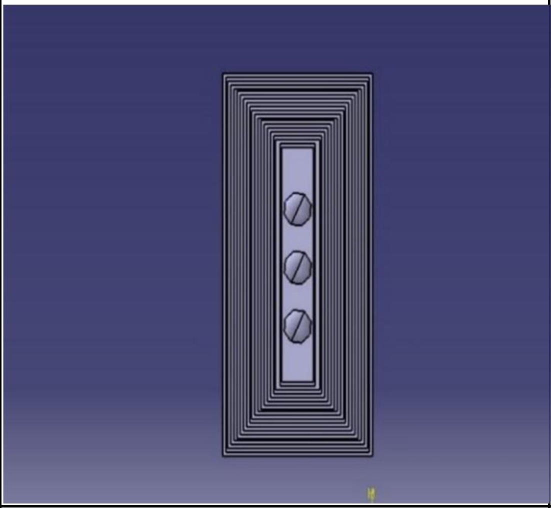	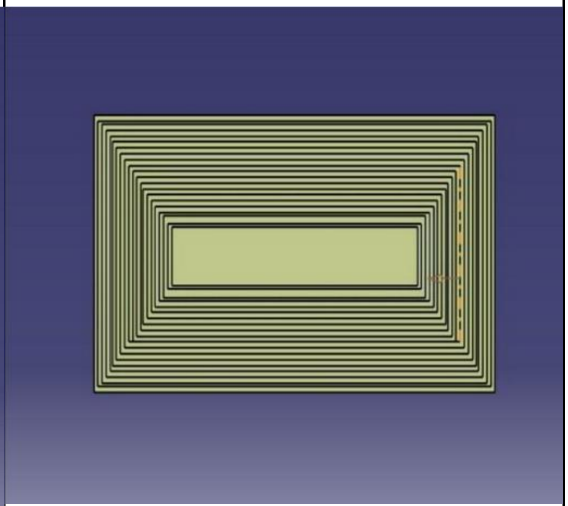
Figure 6.1.e Top view with Kalasam with vent	**Figure 6.1.f Top view without Kalasam without vent**

6.2 SCALED DOWN MODEL DIMENSIONS:

Temple dimensions:

Top length = 6 cm

Bottom length = 9.8 cm

Top width = 1cm

Base width = 4.7 cm

Total height = 23 cm

Kalasam dimensions:

Height =1.5 cm

Diameter = 0.155 cm

Blockage ratio = 5%

Blockage ratio = area of prototype / Area of wind tunnel test section.

CHAPTER 7

SIMULATION AND RESULTS

7.1 WITH VENT WITH KALASAM MESHING:

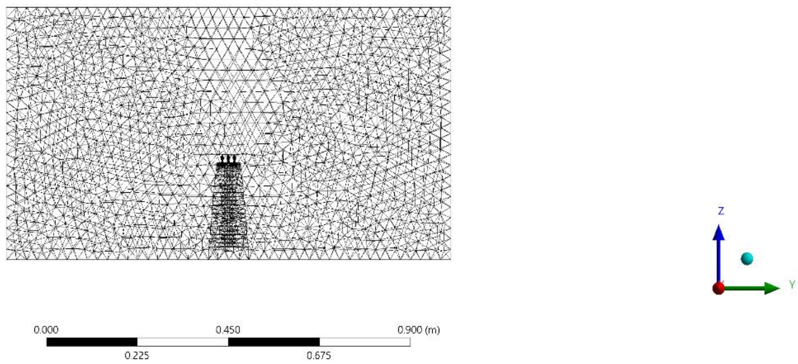

Figure 7.1 with Kalasam with vent Hexa dominant meshing

MESH SIZE:

Table 7.1 Sizing of mesh –with Kalasam with vent

NODES	ELEMENTS
71194	378966

MESH QUALITY:

Table 7.2 Mesh quality –with Kalasam with vent

MINIMUM ORTHOGONAL QUALITY	MAXIMUM SKEWNESS
0.95432	0.50124

7.2 WITHOUT KALASAM WITHOUT VENT MESHING:

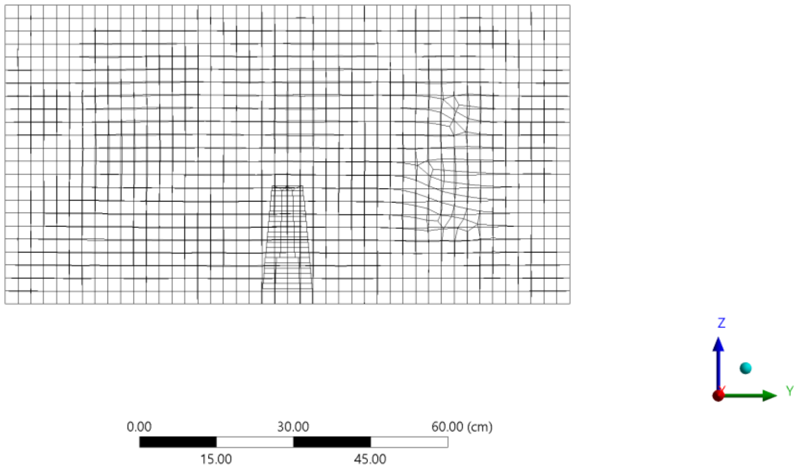

Figure 7.2 Hexa dominant mesh of without Kalasam without vent model

MESH SIZE:

Table 7.3 Mesh sizing – without Kalasam without vent

NODES	ELEMENTS
41588	214232

MESH QUALITY:

Table 7.4 Mesh quality – without Kalasam without vent

MINIMUM ORTHOGONAL QUALITY	MAXIMUM SKEWNESS
0.99451	0.2571

SIMULATION:

7.3 WITH KALASAM WITH VENT-CFX:

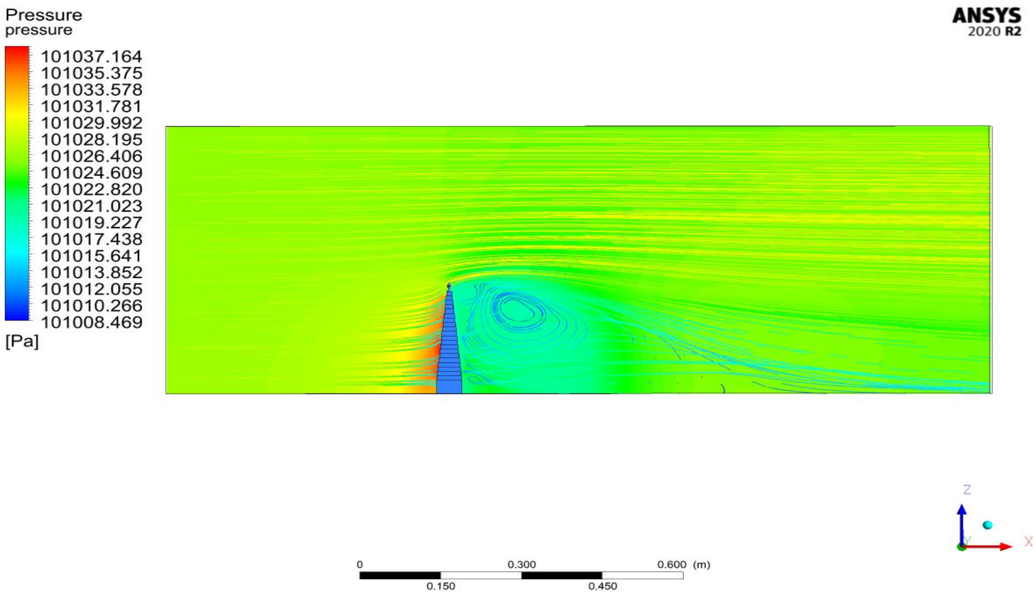

Figure 7.3a Pressure contour- With Kalasam with vent

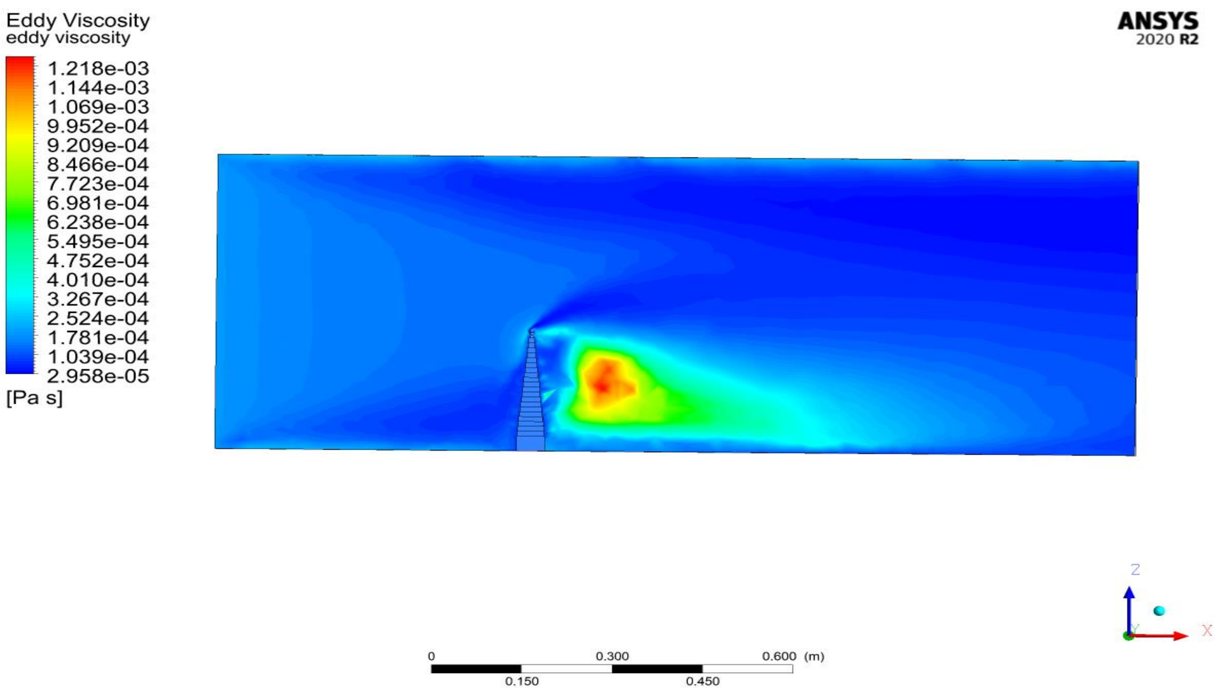

Figure 7.3 b eddy viscosity contour- With Kalasam with vent

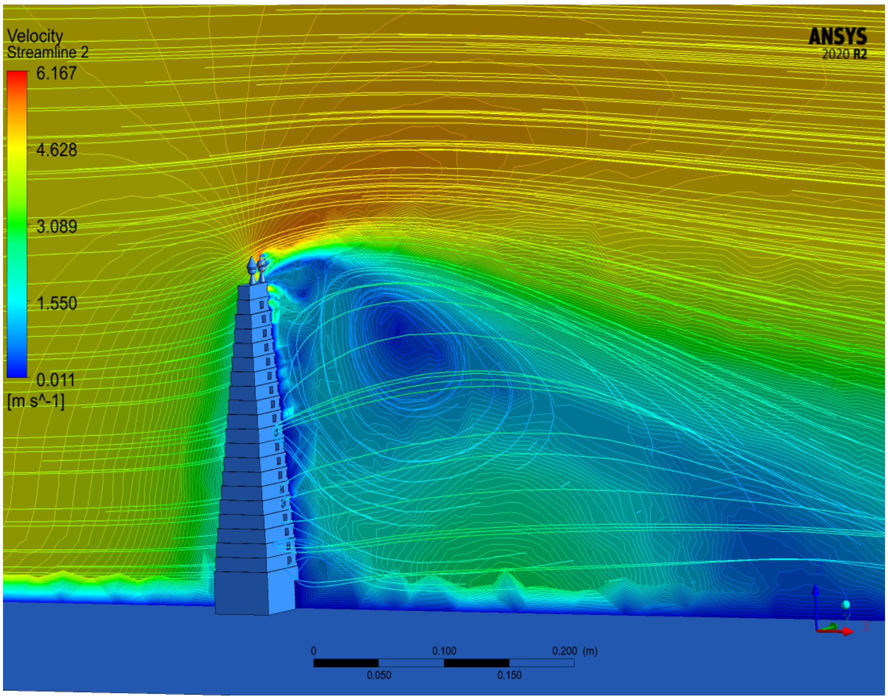

Figure 7.3 c velocity streamline- With Kalasam with vent

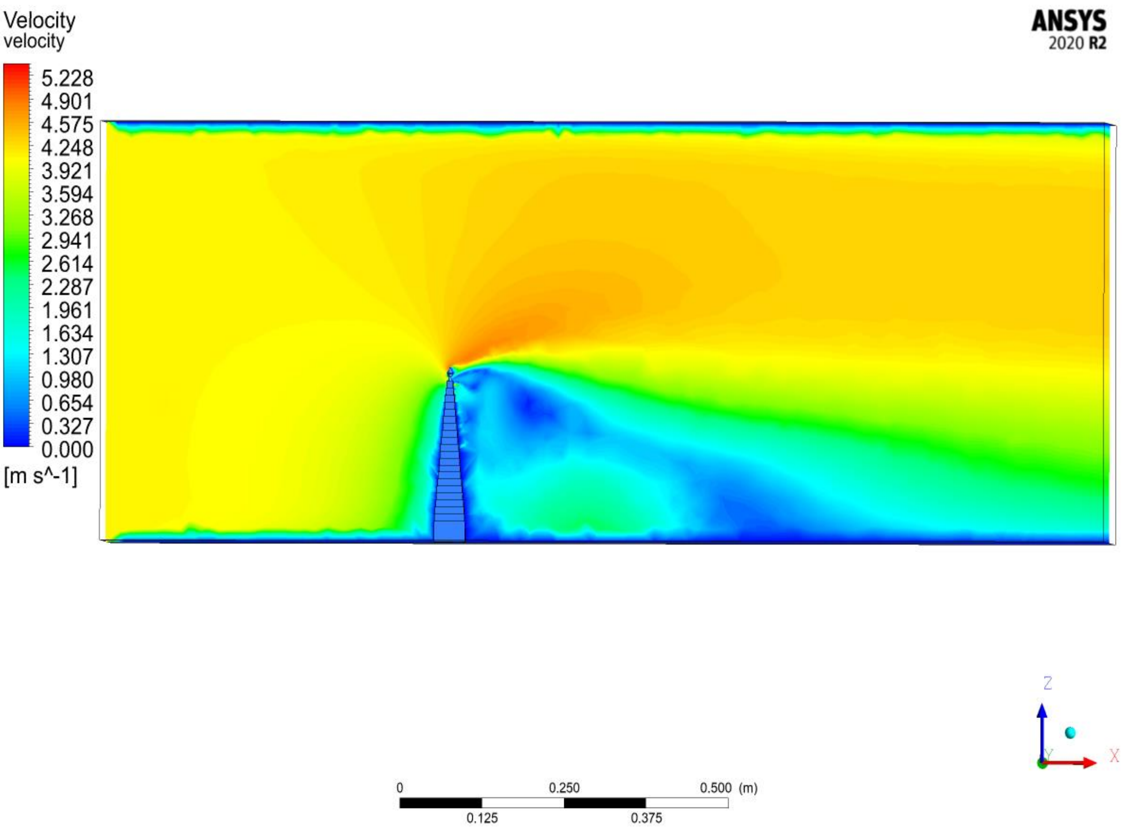

Figure 7.3 d Velocity contour - With Kalasam with vent

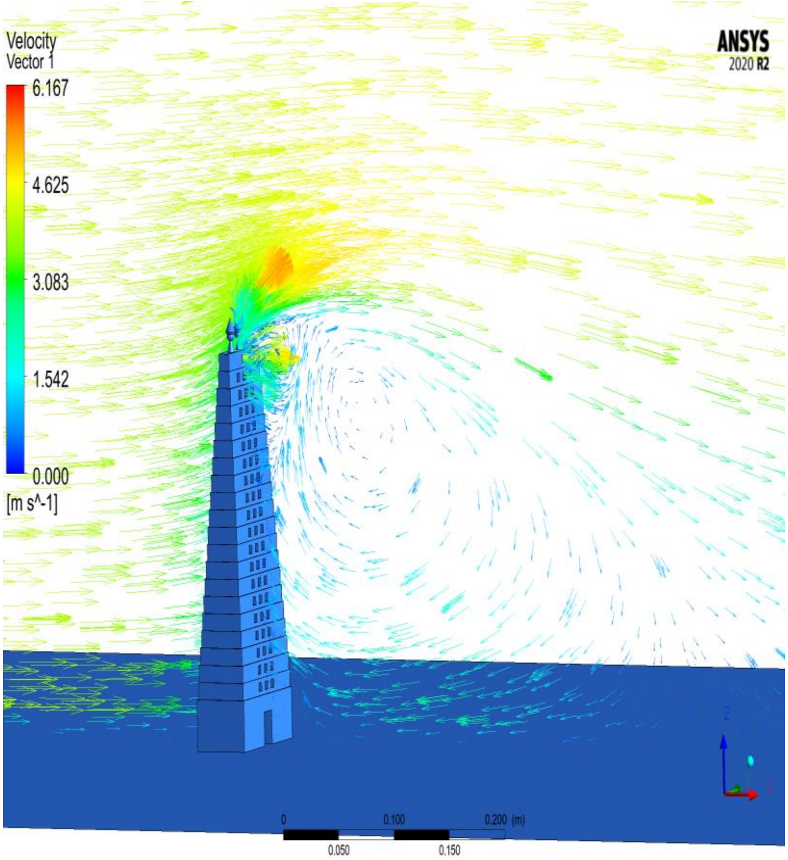

Figure 7.3 e Velocity vector-- With Kalasam with vent

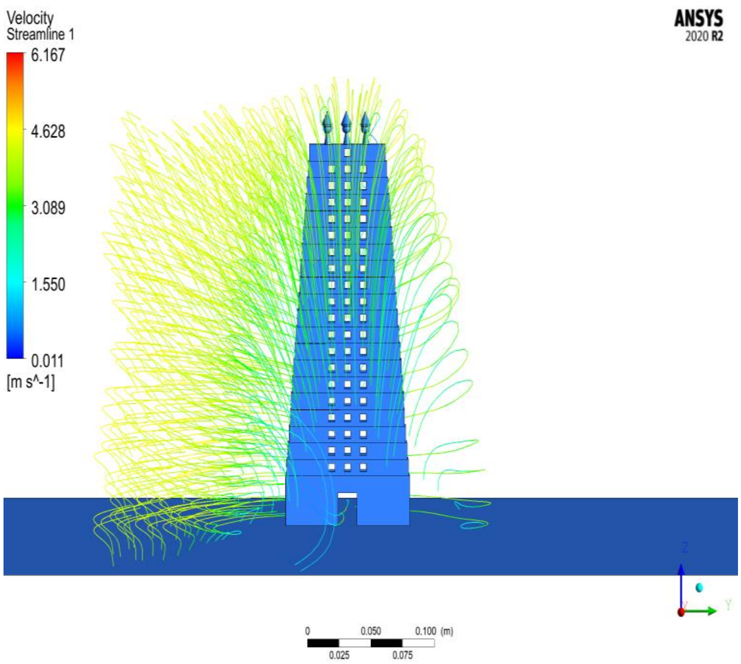

Figure 7.3. f Velocity streamline front view-- With Kalasam with vent

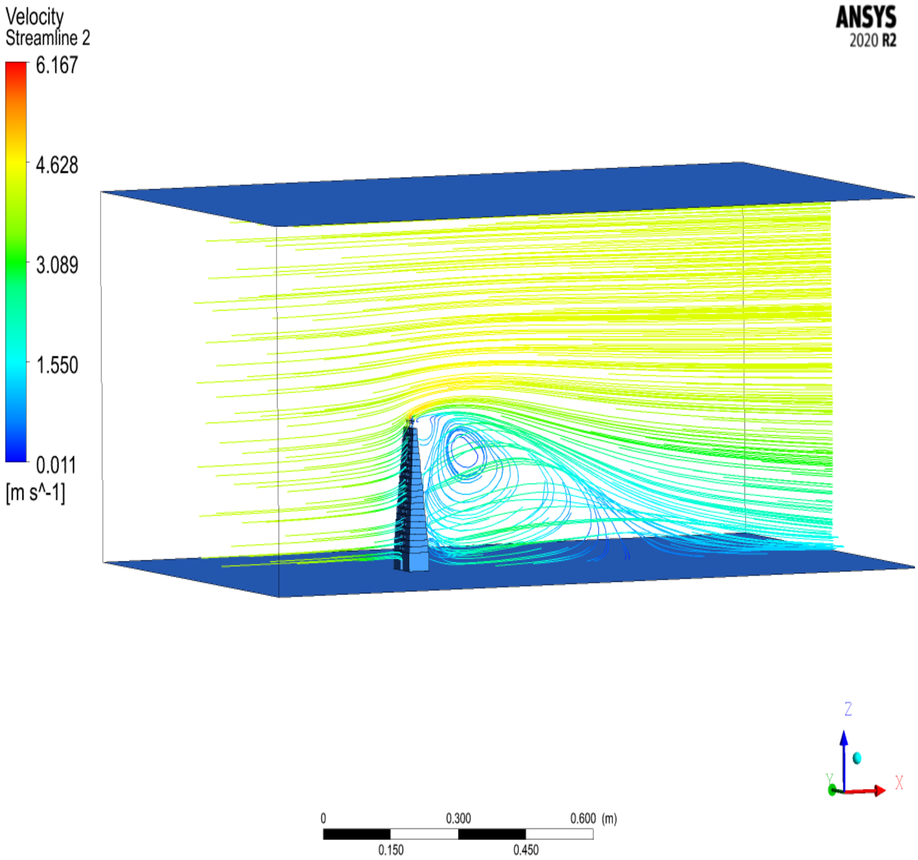

Figure 7.3 g Velocity streamline isometric view- With Kalasam with vent

Figures 7.3.a,7.3. b,7.3.c,7.3.d,7.3.e,7.3.f,7.3.g shows variation near the Kalasam region in peak and flow separation near walls, fluctuations are major near the Kalasam region, pressure is lesser in leeward compared to windward, viscous dissipation and band formation is observed near the Kalasam

7.4 WITHOUT KALASAM WITHOUT VENT-CFX:

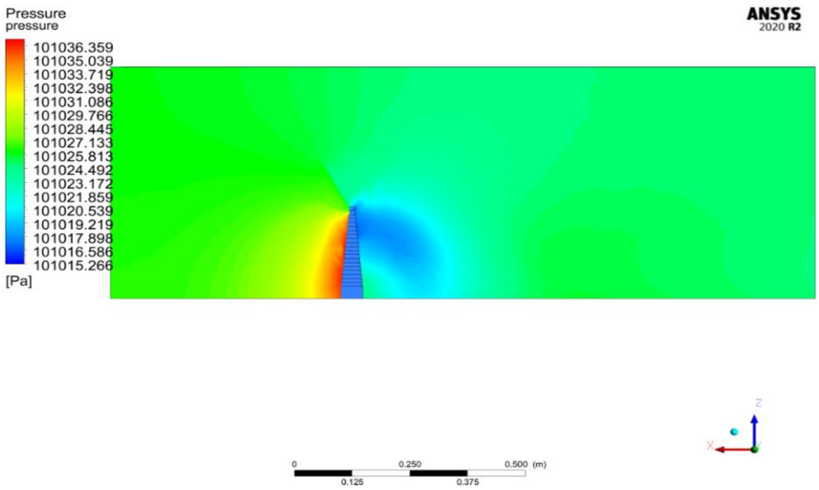

Figure 7.4a Pressure contour - Without Kalasam without vent

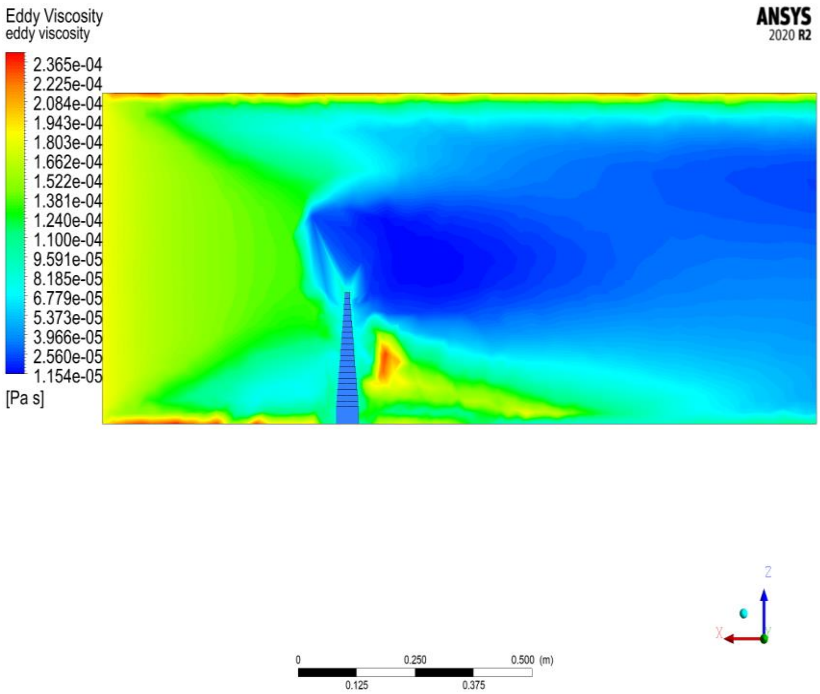

Figure 7.4 b Eddy viscosity contour- Without Kalasam without vent

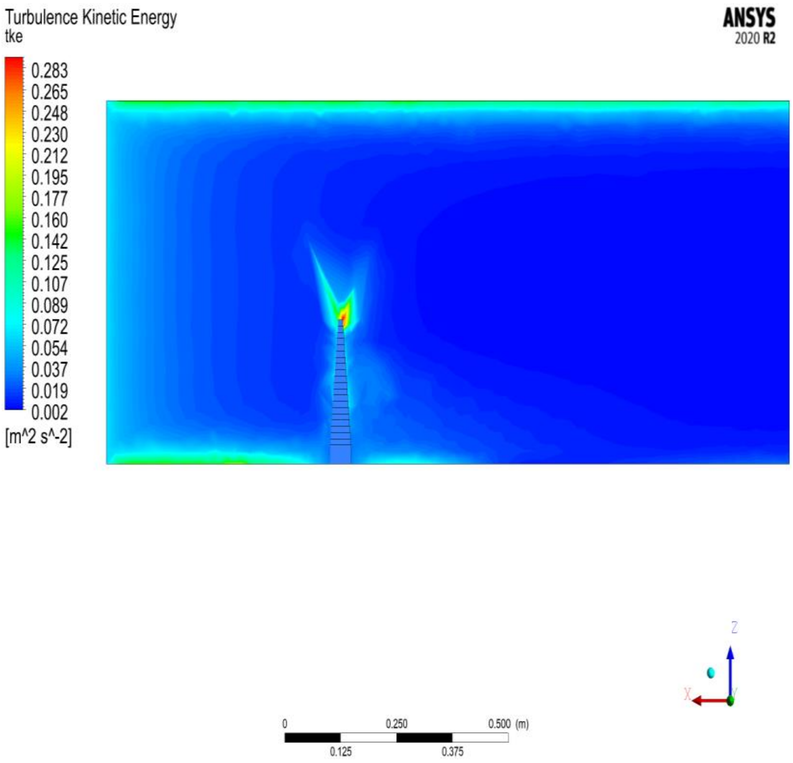

Figure 7.4 c Turbulence kinetic energy contour- Without Kalasam without Vent

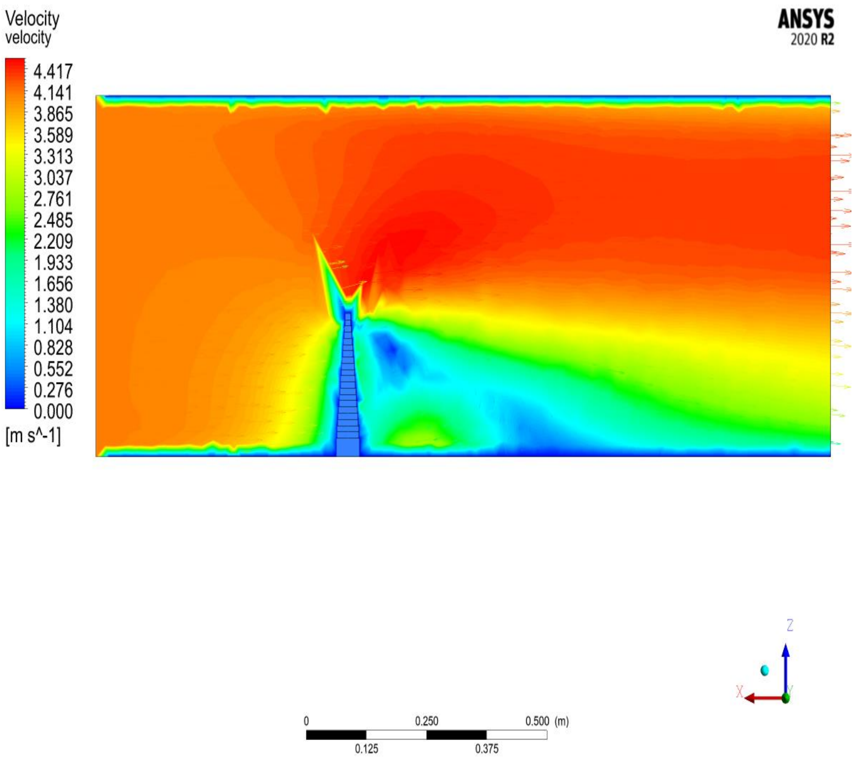

Figure 7.4 d velocity contour- Without Kalasam without vent

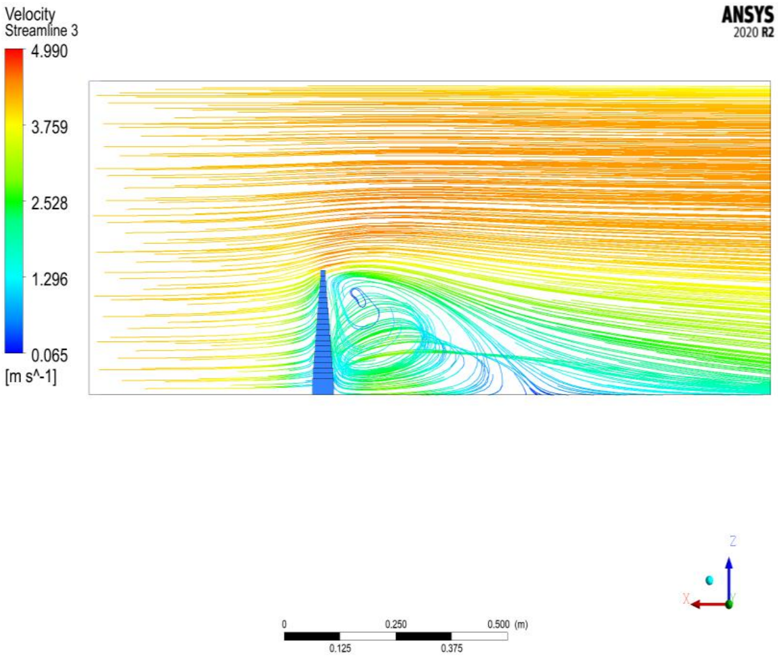

Figure 7.4 e Velocity streamline - Without Kalasam without vent

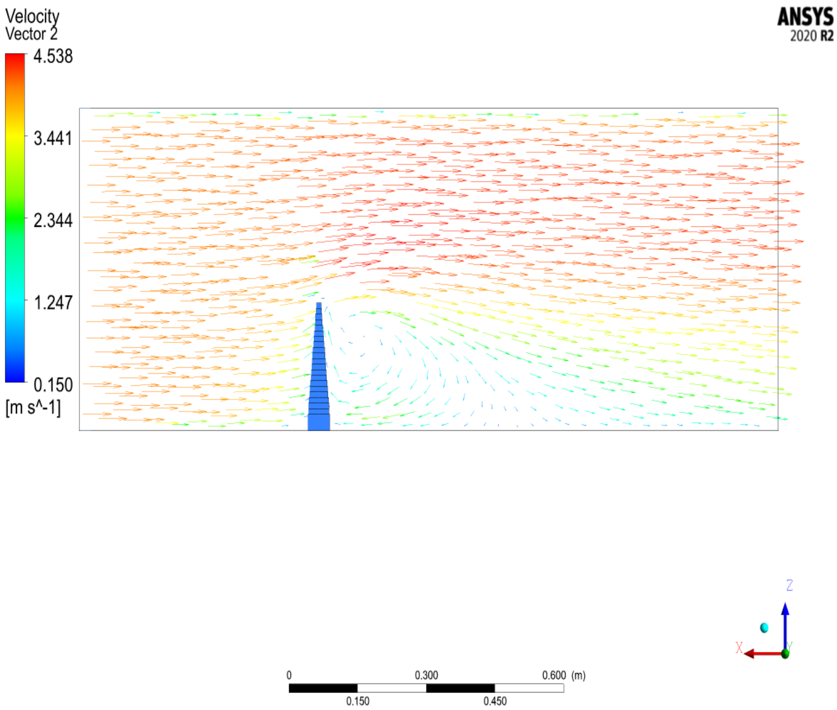

Figure 7.4 f Velocity vector - Without Kalasam without vent

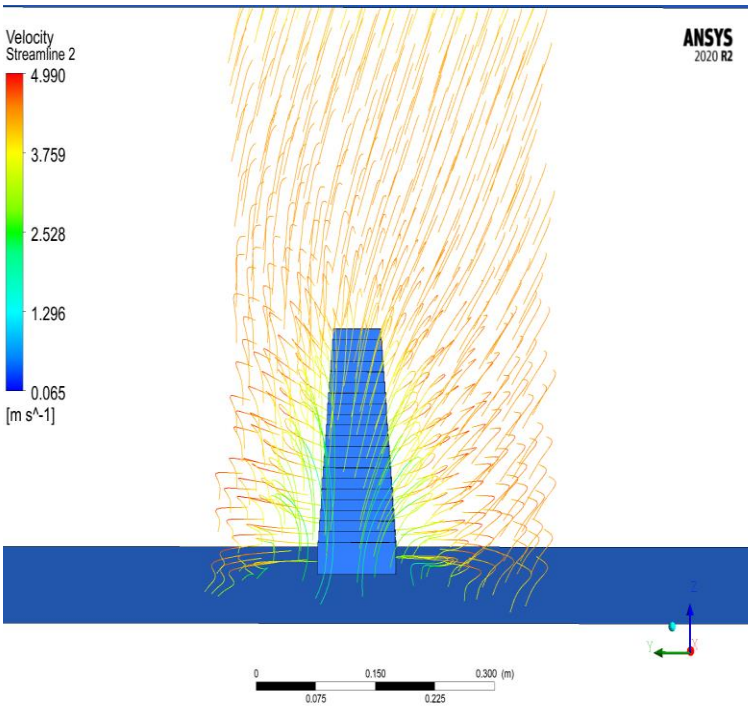

Figure 7.4 g Velocity streamline front view - Without Kalasam without vent

Figures 7.4.a, 7.4.b, 7.4.c, 7.4.d, 7.4.e, 7.4.f, 7.4.g represents the combination of contours of various aspects with respect to different parameters for without Kalasam without vent temple structure

CHAPTER 8

EXPERIMENTAL SETUP

FABRICATION:

Figure 8.1 Fabricated Model – wood

Figure 8.2 Scaled down temple model –with Kalasam with vent

The above figures 8.1 and 8.2 are the fabricated wooden model

PRESSURE MEASUREMENT TECHNIQUE:

Figure 8.3 With Kalasam with Vent Pressure Measurement, Experimental setup

The above Figure 8.3 is the experimental setup used for pressure measurement that is carried out on with Kalasam with vent temple structure.

Figure 8.4 without Kalasam without vent Pressure Measurement Technique, Experimental Setup

The above figure 8.4 is the experimental setup of a temple structure without Kalasam without a vent for pressure measurement.

PRESSURE MEASUREMENT TECHNIQUES IN LOW-SPEED WIND TUNNEL:

Measuring pressure is one of the main experimental procedures followed in wind tunnels. Once pressure measurement is done other parameters can also be obtained. One of the common techniques of measuring static pressure is connecting stationary ports to the orifice drills which are perpendicular to the wall of the test section. The readings are taken through the manometer and pressure measured by the orifice is noted.

Various pressure measuring devices are used in measuring pressure such as liquid column manometer, pressure transducers, and pressure gauges with static elastic elements. In this research, we have used (liquid column manometers) u tube manometers, and multiple manometers. The working principle behind these manometers is when pressure is sensed it gets balanced by the liquid column. Some commonly used liquids include water and mercury. To measure total pressure pitot tubes are widely used. When pitot static tube is placed for measurement Turbulence, Velocity Gradient, Viscosity, Vibration effect, Misalignment are influenced.

The pressure measurement technique is observed on two different taper temple models and explained with two different case studies. The first case study is observed with vent and Kalasam, the second case study is studied by excluding Kalasam and vent in aspect of both windward and leeward sides of the temple. Experimental setup for two different case studies has been included below.

CHAPTER 9

EXPERIMENTAL RESULTS

9.1 Pressure Measurement and C_p Graphs

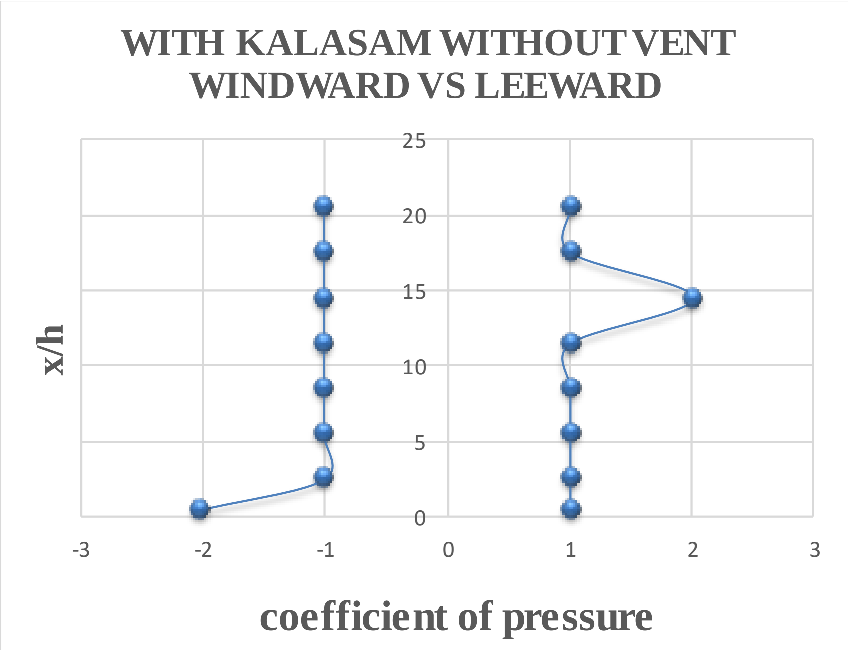

Figure 9.1 a with Kalasam without vent – cp vs x/h graph

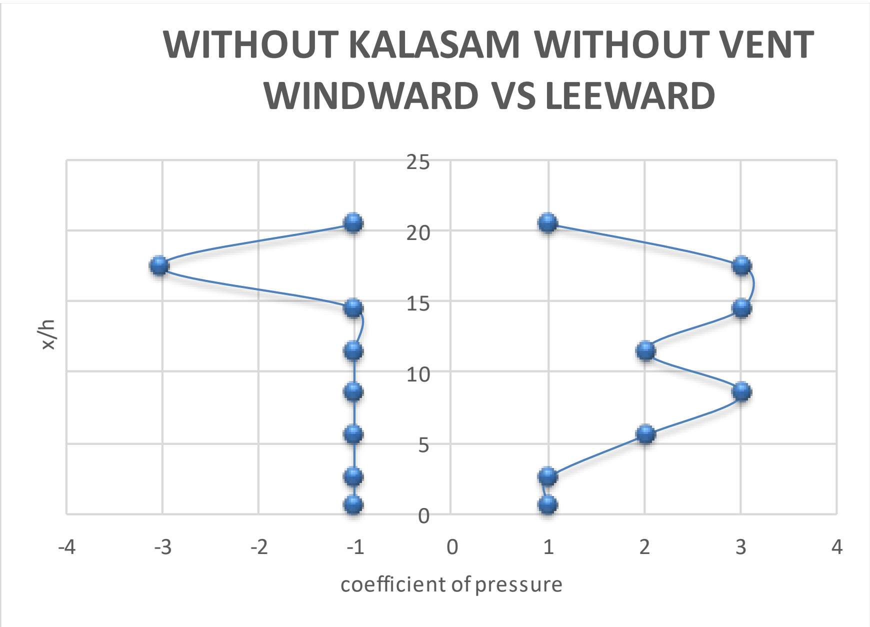

Figure 9.1 b without Kalasam without vent- cp vs x/h graph

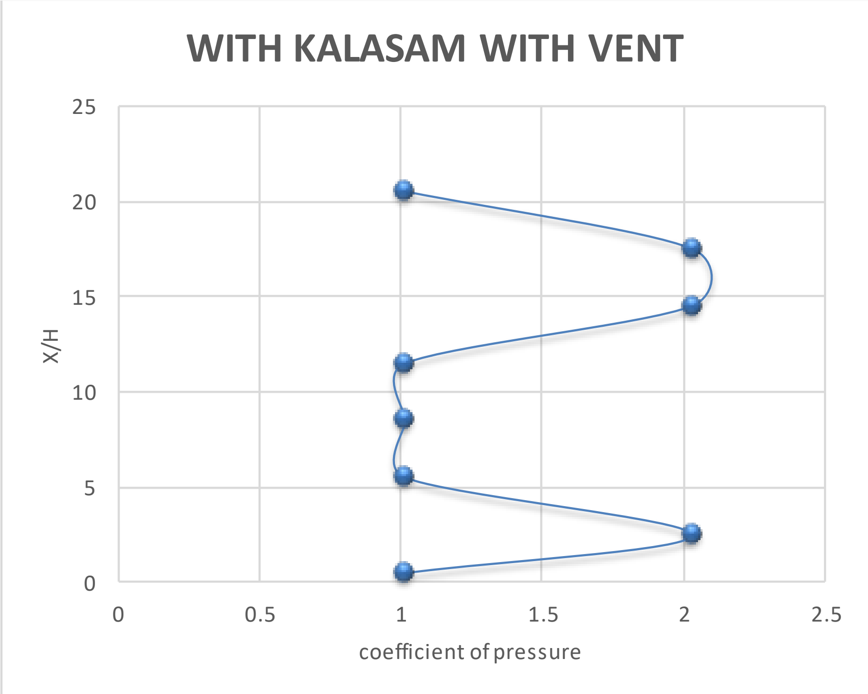

Figure 9. 1c with Kalasam with vent – cp vs x/h graph

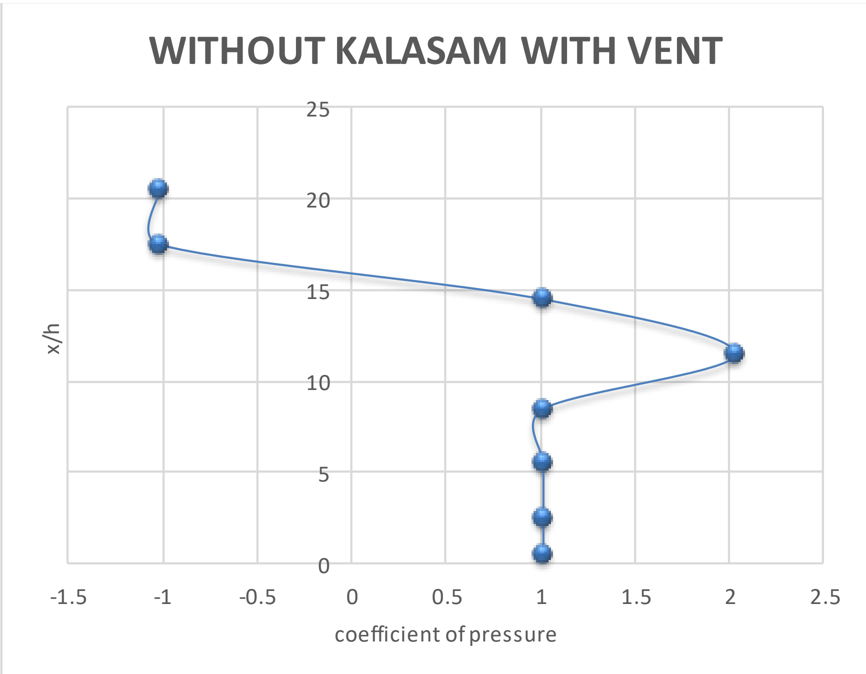

Figure 9.1 d without Kalasam with vent – cp vs x/h graph

The above figures (9.1.a,9.1. b,9.1c,9.1d) depict the relationship between the coefficient of pressure and x/h values with reference to the altitude in various cases such as with Kalasam with vent, without Kalasam without vent, without

Kalasam with vent, with Kalasam without vent. the above graphs are useful in obtaining knowledge regarding the pressure force acting on structure and variation in pressure force with changes in shape and surrounding environment.

From the above case studies, we can confirm that the existing temple with Kalasam with vent sets the best example compared to other modified structures by creating a counterbalancing force that ensures overall stability, structural support, and serviceability of the temple. The model without Kalasam without vent records uneven pressure distribution over the temple which does not support building stability and can be a major responsible phenomenon for structural damage, especially during disasters. It is observed that the CP value is higher on the windward face than on the leeward face favouring stronger wind force only towards the front face at a greater level and not reverted on the Leeward face. This phenomenal condition complies with the building to generate a bending force that un-stabilizes the structure

Though two different case study models do not change with building shape, there is only external modification but still, there is a drastic change in the coefficient of pressure measurement which indirectly explains the importance of vent and Kalasam along with taper and setback structure for a temple. The following experimentation depicts the importance of Kalasam and vent that is incorporated into the taper structure.

9.2 FLOW VISUALIZATION TECHNIQUE:

9.2.a. THREAD FLOW VISUALIZATION:

Figure 9.2 a Thread flow visualization technique using short thread on temple structure - With Kalasam with vent

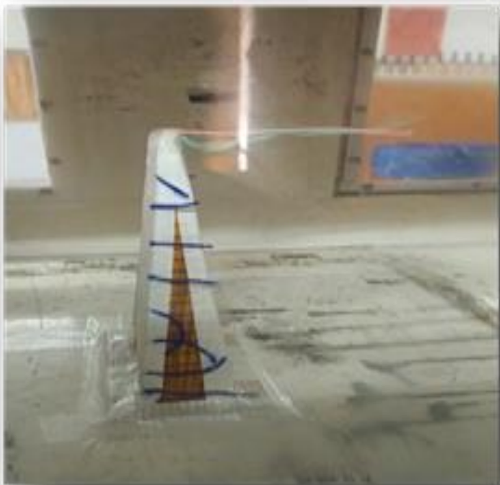

Figure 9.2 b Thread flow visualization technique using short thread on temple structure – Without Kalasam without vent

Figure 9.2 c Thread flow visualization technique using long thread on temple structure - With Kalasam with vent

Figure 9.2 d Thread flow visualization technique using long thread on temple structure - Without Kalasam without vent

Figures 9.2a and 9.2.b give clear visualization of corner effects using short threads. the flow is observed in the corners and on the top region.

Figure 9.2.c and 9.2.d represent the flow separation and recirculation near the corners and Kalasam region using long threads.

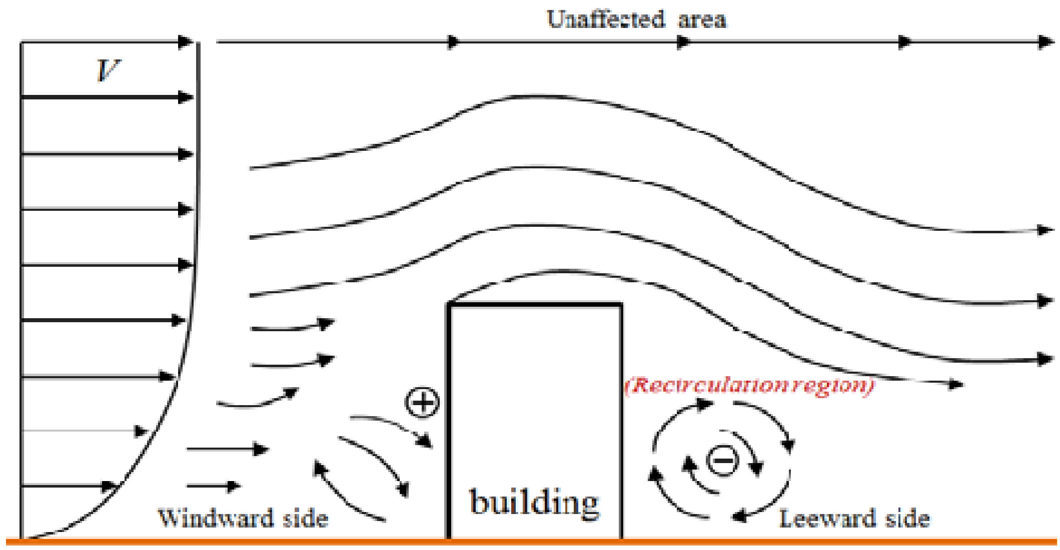

Figure 9.2 e .wind flow around a rectangular building

Figure 9.2.e.describes the wind flow pattern around a rectangular building where the recirculation occurs immediately after the wake region. The flow direction on the leeward side tend to be in similar direction due to core shape of the rectangular building.

9.3 SMOKE FLOW VISUALIZATION

Figure 9.3 a Smoke flow visualization technique on temple structure – windward side

Figure 9.3 b Smoke flow visualization technique on temple structure – leeward side

The above figures 9.3. a and 9.3.b depicts the smoke flow visualization that shows the flow separation near the wake region.

9.4 OIL FLOW VISUALIZATION:

Figure 9.4 an Oil flow visualization technique – side view

Figure 9.4 b Oil flow visualization technique – front view

Oil flow visualization technique are shown on Figures 9.4.a and 9.4.b where the flow path is traced by using high viscous oil and saw dust particles.

CHAPTER 10

CONCLUSION

Flow over a bluff body is severe and complex to maintain stability and increase the serviceability of a bluff body that is high rise building could be achieved by minor and major aerodynamic optimizations.

The importance of Kalasam and vents that essentially cuts down and reduce the vortex shedding that is formed either side of the building which is ensured by a stable structure. Eventually the presence of Kalasam and vents balances the flow around the structure and gets aerodynamic modifications along with flow pattern study. Thus, it is concluded that apart from aesthetics these optimizations would increase the span of temple and provides adequate natural ventilation.

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