FLOW SIMULATION OF ICON CITY CABLE TUNNEL VENTILATION

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KUALA LUMPUR

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RESEARCH REPORT SUBMITTED IN FULFILLMENT OF THE REQUIREMENT FOR THE MASTERS DEGREE OF MECHANICAL ENGINEERING

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UNIVERSITY OF MALAYA

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FLOW SIMULATION OF ICON CITY CABLE TUNNEL VENTILATION

ABSTRACT

The main concern in this project is the study and develop a ventilation system for Icon City Cable Tunnel. This is due to the fact the cables inside the tunnels generates heats as much as approximately 60^0C and these cables are laid in a 67.35-metre-length with 3 meter diameter tunnel. By using the Air Change Per-Hour ("AC/Hr") with the tunnel designed, the velocities and air flow in tunnel were determined. To simulate the air flow at the interior of the tunnel, draw a 3D geometry by using Solidworks software. The velocities acquired had been used in the ANSYS Computational Fluid Dynamics software to determine the temperature at the mid of the tunnel at numerous velocities to decide the suitable speed and air flow for the tunnel ventilation system. The ambient temperature took as 33^0C which the common temperature of the region is where the tunnel is proposed to be built. All the results and findings are in the Conclusion and Recommendation section in this report.

ANALISIS PENYALURAN UDARA BAGI TEROWONG KABEL BAWAH TANAH MENGUNAKAN PENGIRAAN DINAMIK BENDALIR

ABSTRAK

Keutamaan diberikan dalam projek ini ialah mengkaji dan membangunkan sistem pengudaraan untuk Terowong Kabel Ikon City. Ini disebabkan oleh fakta kabel-kabel dalam terowong menghasilkan haba sebanyak kira-kira 60^0C dan kabel-kabel ini dibentangkan dalam 67.35 meter panjang dengan terowong diameter 3 meter. Dengan menggunakan Air Change Per-Hour ("AC / Hr") dengan terowong yang direka, halaju dan aliran udara di dalam terowong ditentukan. Untuk mensimulasikan aliran udara di pedalaman terowong, lukiskan geometri 3D dengan menggunakan perisian Solidworks. Halaju yang diperoleh telah digunakan dalam perisian ANSYS Computational Fluid Dynamics untuk menentukan suhu pada pertengahan terowong dengan pelbagai halaju untuk menentukan kelajuan dan aliran udara yang sesuai untuk sistem pengudaraan terowong. Suhu sekitar mengambil 33^0C yang suhu biasa di rantau ini adalah di mana terowong dicadangkan untuk dibina. Semua hasil dan penemuan berada di bahagian Kesimpulan dan Rekomen dalam laporan ini.

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I deeply appreciate the guidance of my project manager and discipline engineers. I wish to thank them for patient explanation of basic principles, for providing new ideas and for spending time to discuss my problems, it is really important for my study. Finally, a special thanks to my dearest parents, my wife and my siblings for the continuous motivation all the way.

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LIST OF SYMBOLS AND ABBREVIATIONS

XLPE	:	Cross-Linked Polyethylene Cable
CAD	:	Computer Aided Design
CAD	:	Computational Fluid Dynamics
HV	:	High Voltage
UHV	:	Ultra-High Voltage
Q	:	Flow Rate
Vi	:	Inlet Velocity
Vol	:	Volume
k V	:	Kilo Volt
AC/Hr	:	Air Change Per-Hour
$\Delta\theta_S$	:	Difference in surface Temperature
K_A	:	Thermal Conductivity

CFM	:	Cubic Feet Per-Minute
Ft^3	:	Cubic Feet
A	:	Cross Section Area of Tunnel
De	:	Diameter of Cable
n	:	no of conductor within cable
$\lambda 1$	:	Ratio of Losses in Metallic Sheet
$\lambda 2$	:	Ratio of Losses in Armor to Conductor
T1	:	Thermal Resistance between Conductor and Sheet
T2	:	Thermal Resistance between Metallic Sheets
T3	:	Thermal Resistance of outer covering
h	:	Heat Dissipation Coefficient
da	:	Metallic Sheet Outer Diameter
Wd	:	Dielectric Losses

U_o	:	Voltage from Phase to Ground
C	:	Capacitance
Di	:	Conductor Outer
ε	:	Insulation Emissivity

LIST OF FORMULA

CHAPTER 1: INTRODUCTION

1.1 Introduction

In the process of upgrading their living standards and engineering capabilities, cities are very involved. The demand for services such as electricity, network connectivity, heat, steam and sewerage is steadily increasing and needs upgradation. This need has resulted in an increasing number of utility tunnels, mostly in urban cities, in the subsurface climate. These tunnels are commonly found in model climate countries, especially in very cold countries where burial is not feasible under frost soil. Nowadays, in order to avoid disruption caused by repetitive construction, repair and upgrading of cables and pipes in direct burial, these tunnels are becoming favored and favorite for the majority of service providers in tropical climate countries. In addition, this method is also undoubtedly the best way to maintain and upgrade in the future.

The ventilation system will be one of the most critical factors to be considered in constructing these tunnels before construction. This will be the challenge for the design engineers, particularly when the tunnel transmits high-voltage cables and auxiliary equipment that must be held at certain temperatures. The ventilation or cooling system must be constructed taking into account both the high demand for energy and the ambient temperature. The system must also be able to achieve adequate airflow through either natural or forced ventilation to eliminate the power cables heat emission. The air flow design must be able to permit permanent human presence in the tunnel or only depending on the purpose or requirement for maintenance purposes.

Figure 1.1: Utility tunnel, **(**http: https://www.ancon.co.uk)

1.2 Problem Statement

The human movement and cables may be vulnerable due to heat without a proper ventilation system. Ensuring that the cables are not affected by temperature in the tunnel and safe human movement in the tunnel for control, repair and upgrading is necessary for maximum airflow in the tunnel in order. To investigate the best temperature condition during full load, different air flow configuration will be simulated by using CFD (ANSYS Fluent) in steady state condition.

1.3 Objective

Designing, simulating and evaluating underground cable tunnels with consideration of air change per hour, air velocity and volume to establish an appropriate air flow to maintain tunnel temperature.

i. To analyze appropriate temperature

ii. To determine appropriate air change per hour (AC/hr)

iii. Fan pumping power needed

1.4 Scopes

The aim of this research project to model an underground cable tunnel with desired parameters, then configure with various inlet velocity to determine the best air flow to extract the heat generated from the cable.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

The purpose of this study is to conduct numerical simulation study in order to determine the necessary air flow during full load in a high voltage cable tunnel to allow human presence. During full load, different air flow configurations are simulated to investigate the best temperature state in the tunnel.

The basic principle of tunnel ventilation is to provide fresh air and remove the exhaust air from the tunnel afterwards. The exhaust air can be collected via a portal where a ventilation outlet such as a stack opens the tunnel path to the surrounding environment.

Ventilation of tunnels is necessary for a range of reasons. Ventilation typically preserves sufficient air quality, controls the transmission of smoke in case of fire, and reduces air temperatures to reasonable limits. The role of ventilation is linked to the form of tunnel involved. Cable tunnels require refrigeration, smoke control and some exchange of air.

2.2 Type of Ventilation Systems

Alternative tunnel ventilation systems are available, including transverse, semi-transverse and longitudinal ventilation systems. Due to their low construction costs, longitudinal ventilation systems are usually selected for short tunnels with a length of 3 km or less.

i. Longitudinal Ventilation

ii. Semi-Transverse Ventilation

iii. Full Transverse Ventilation

2.2.1 Longitudinal Ventilation

Longitudinal ventilation consists of new air pumped to the inlet and compressed air removed from the outlet. The amount of waste in the tunnel is increasing as this is the air flow path and as cars pass from one side to the other they continue to generate pollutants. The design of the longitudinal ventilation system shall be determined by the permissible amount of tunnel pollution. The way this is controlled is by ensuring that the volume of fresh air at the end of the tunnel is properly filtered. Cars can cause this volume of air, and it's called the piston effect.

Ventilation fans will increase the air flow in longer tunnels in situations where the speed of traffic is insufficient to generate sufficient portal ventilation to keep the level of pollutants below the permissible level. (Roads and Maritime Services, 2014)

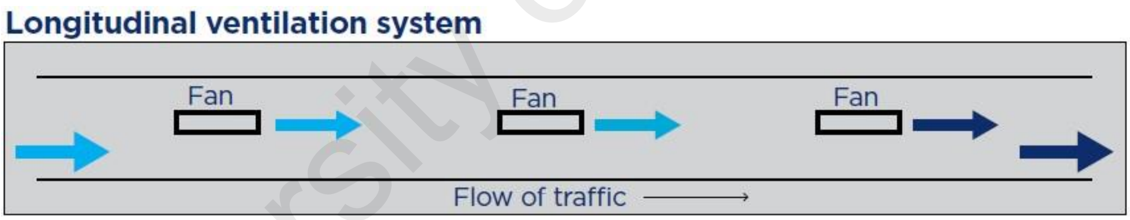

Figure 2.1: Longitudinal Ventilation System (Roads and Maritime Services, 2014)

2.2.2 Transverse Ventilation

Transverse ventilation operates on the same elimination principle as longitudinal ventilation, but fresh air is provided throughout the tube and waste gas is eliminated. The system requires two tunnel-length ducts, one for new air supply and another for to remove wasted polluted air. Such ducts could be either big or small, or narrow and high in the pipe. Transverse ventilation was used in the earlier days where longitudinal ventilation would not efficiently handle tunnel contaminant concentrations resulting in much higher levels of contaminants through tunnels. Transverse ventilation is also efficient in trans-directional tunnels (where cars ride in the same tunnel in both directions). In these driving conditions, the effect of the piston is cancelled and the concentrations of contaminants are more evenly distributed along the tunnel length. (Roads and Maritime Services, 2014)

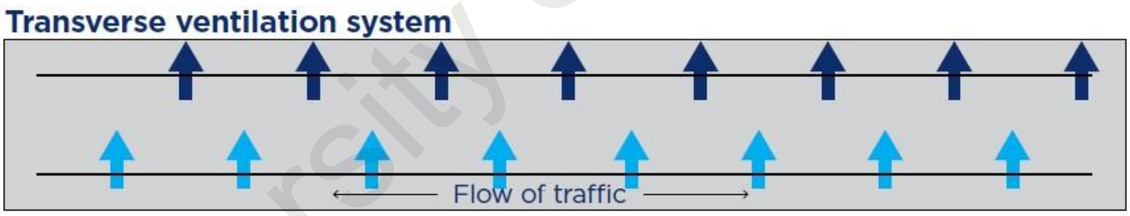

Figure 2.2: Transverse Ventilation (Roads and Maritime Services, 2014)

2.2.3 Semi Transverse Ventilation

Semi-transverse air circulation is a mixture of longitudinal and transverse ventilation. Clean air could be supplied from even the door and pumped continuously through the tube across the tunnel length. Optionally, clean air could be provided continuously across the tunnel through a mile-long pipe and can be drained through the portals or through a tunnel pile. (Roads and Maritime Services, 2014)

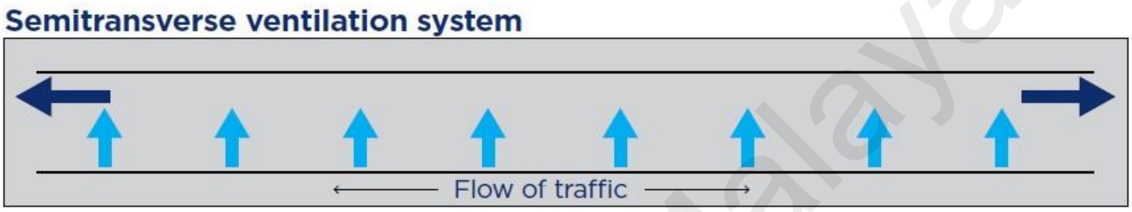

Figure 2.3: Semi Transverse Ventilation (Roads and Maritime Services, 2014)

2.3 Thermal comfort

Thermal comfort is a state of mind demonstrating pleasure with the thermal environment. Thermal comfort is different for each individual because of its subjectivity. It is maintained when it is allowed to dissipate the heat generated by the human metabolism at a rate that maintains the body's thermal balance. Any additional heat gain or loss generates considerable discomfort. Essentially, the heat produced must be equivalent to the heat lost in order to maintain thermal comfort. It has long been recognized that the sensation of warm or cold relies on more than the temperature of the atmosphere. Yes, there are six main variables for thermal comfort:

- Ambient temperature
- Radiant temperature
- Relative humidity
- Air motion
- Metabolic rate
- Clothing insulation

Comprehension of these six variables is essential when planning and designing a building air conditioning system to make informed decisions. It is equally important, however, to understand how these systems affect the energy load of a building. (Thermal Comfort: Designing People)

2.4 SolidWorks

The parts of the SOLIDWORKS software are the basic building blocks. Assemblies, called subassemblies, contain parts or other assemblies. A SOLIDWORKS model is a 3D geometry that defines the edges, faces and surfaces of the model. The SOLIDWORKS software allows you to quickly and accurately design models. SOLIDWORKS models are:

• Defined by 3D design

• Based on components

SOLIDWORKS is using a 3D approach to layout. While creating a piece, you build a 3D template from the original drawing to the final result. From this model, to create 3D assemblies, you can create 2D drawings or mate components that consist of parts or subassemblies. 2D drawings of 3D assemblies can also be created. You will imagine it in three dimensions while constructing a prototype utilizing SOLIDWORKS, the way the template appears once it is made. (Introducing SolidWorks)

2.5 ANSYS (Fluent)

There is so many computer program ANSYS FLUENT that used by ANSYS. One of the software programs is FLUENT (Computational Fluid System Software). FLUENT could be a progressive computer program in advanced geometries to model fluid flow and heat transfer. FLUENT offers complete mesh flexibility, determining problems with unstructured mesh that can be generated with relative ease by advanced geometries. Mesh is graded as two-dimensional triangular / quadrilateral, three-dimensional / hexahedral / pyramid / wedge, and mixed mesh.

With FLUENT, you will find your own answer. The language of the C computer is used to program FLUENT and to use the computer language's capabilities and abilities. The program was made possible by all the dynamic distribution of memory, productive information structures, and adaptable solver control. FLUENT can also act as a single simultaneous system constructed of qualified operation, intrinsic command and tailored to new machine or device environment conditions. In addition, all the skills need to define the solution and produce the results in FLUENT is an adaptable Computational Fluid Dynamic (CFD) technology that enables simulation of heat transfer, fluid motion, friction and reactions. The software has high-performance computing capabilities and is capable of modeling two-dimensional and three-dimensional structures capable of turbulent, transient, laminar, incompressible, compressible, and steady behaviour. FLUENT can also create flows in a gas or liquid state when editing fluid / solid properties. (ANSYS:Fluent)

CHAPTER 3: METHODOLOGY

3.1 Introduction

The research technique is followed to conduct calculations of ventilation velocities based on the shift in air per hour and to perform multiple cases of study of computational fluid dynamics on the system. The primary objective of this chapter is to address the theoretical concept in this project and to evaluate the air flow analysis approach and techniques in tunnels.

3.2 Data Collection

Table 3.1 tabulates the details of the predetermined data. Mathematical model and mathematical calculations based on heat transfer equations are developed using these specifications. The following steady state heat transfer research related to an underground tunnel's interior cooling. The model measurement of the air flow based on Icon City's specifications and data. In the formula, multiple air change per hour (AC/HR) was replaced to measure the suitable air flow. The primary data for this analysis are the tunnel length, manhole diameter, manhole height, amount of cable in the tunnel and the building material.

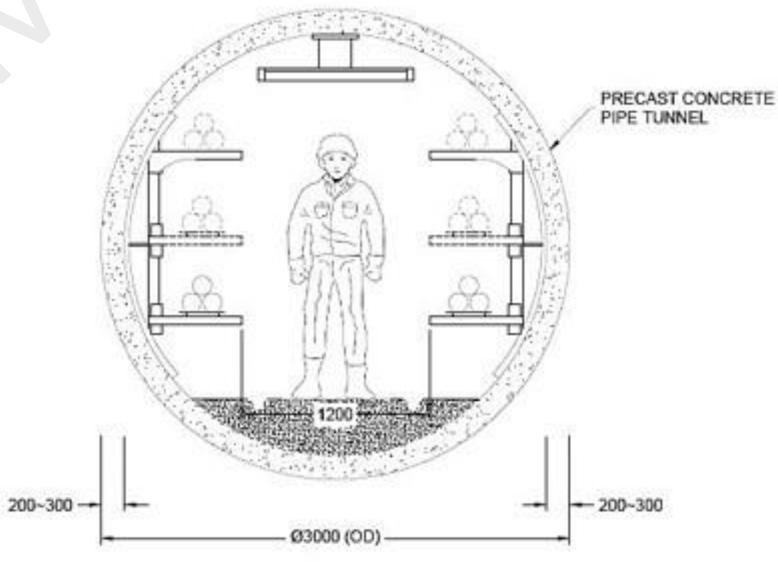

Figure 3.1: Tunnel Cross Section View

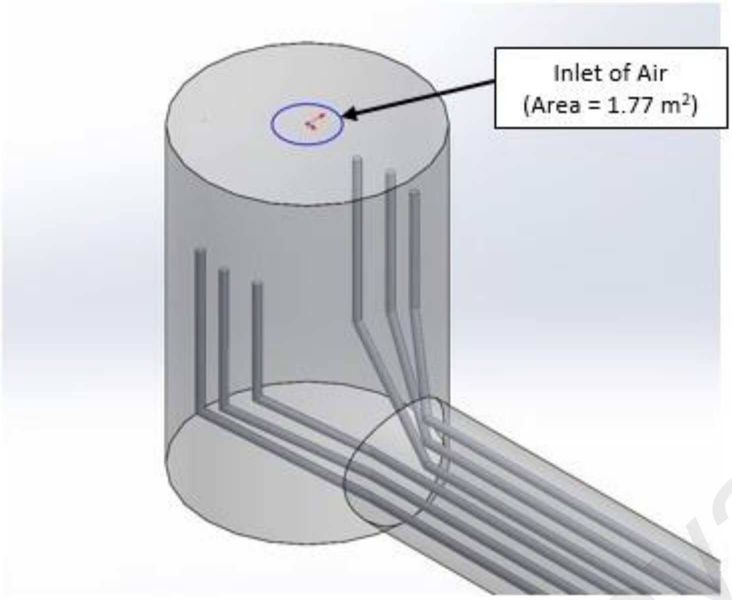

Figure 3.2 : Tunnel Inlet Area

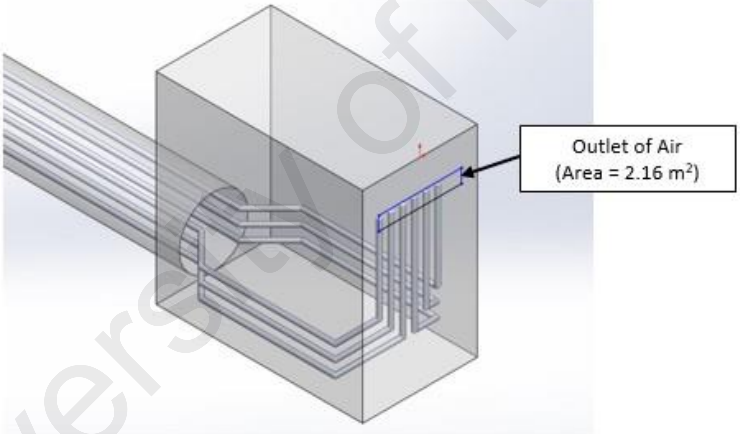

Figure 3.3 : Tunnel Outlet Area

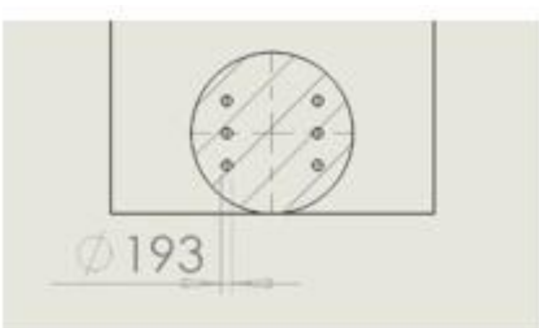

Figure 3.4 : Cable Diameter

Table 3.1: Parameter of Study

No	**Specifications**	
1	Manhole Diameter	1.5 meters
2	Tunnel Length	67.35 meters
3	Tunnel Height	7 meters
4	Tunnel Diameter	3 meters
5	Number of cables	18 x 1C
6	Cable Type	132KV 1C XLPE 1200mmsq CU
7	Cable Diameter	193mm
8	Ambient Temperature	33^{0}C
9	Cable Temperature (Assumption)	60^{0}C

Table 3.2: Meteorological Data

Temperature Min/Max by Malaysian Meteorological Department

Station ID	**Station**	**Minimum (°C)**	**Maximum (°C)**
48603	Alor Setar	24.0	30.1
48642	Batu Embun	23.6	34.2
48670	Batu Pahat	24.7	30.0
48601	Bayan Lepas	24.0	29.9
96441	Bintulu	23.9	33.5
48602	Butterworth	25.4	31.6

48632	Cameron Highlands	16.2	22.4
48604	Chuping	23.5	30.2
48617	Gong Kedak	23.8	32.0
48625	Ipoh	24.8	32.8
96420	Kapit	24.3	35.2
96467	Keningau	23.2	33.5
48672	Kluang	24.0	33.2
48615	Kota Bharu	25.4	30.7
96471	Kota Kinabalu	26.6	34.7
48616	Kuala Krai	23.6	34.5
48651	Kuala Pilah	22.5	31.6
48618	Kuala Terengganu	25.2	33.2
48657	Kuantan	23.7	33.0
96413	Kuching	24.7	33.3
96477	Kudat	25.5	30.2
96465	Labuan	24.8	33.7
48600	Langkawi	23.6	30.8
96450	Limbang	24.4	34.8
48623	Lubok Merbau	23.5	32.3

48665	Melaka	23.5	31.8
48674	Mersing	23.4	24.9
96449	Miri	26.2	35.5
48649	Muadzam Shah	22.5	32.9
96448	Mulu	24.6	37.6
48648	Petaling Jaya	25.2	33.4
96469	Ranau	22.2	31.6
96491	Sandakan	25.5	31.6
48679	Senai	23.7	33.9
48650	Sepang (KLIA)	24.4	31.7
96421	Sibu	25.0	34.4
48620	Sitiawan	23.7	33.4
96418	Sri Aman	24.0	35.0
48647	Subang	25.2	33.1
96481	Tawau	23.9	31.7
48653	Temerloh	23.0	34.0

Source:http://www.met.gov.my/en/web/metmalaysia/observations/surface/minmaxtemperature

3.3 Calculations

The tunnel air temperature and learning takes place in the center of the tunnel. This analyzes the effects of different velocities of airflow and ambient temperatures. The velocity of ventilation is calculated based on the air change per hour (ACHR). The geometry design used is a simplification of the actual concrete tunnel cable designed for precasting.

3.3.1 Air Change Per Hour Calculation

Air Change Calculation for simulation:

Volume = 39,022.55 ft^3

Air Change Per Hour Formula (Formula 3.1),

$$AC/Hr = \frac{60 X CFM}{Vol}$$

Air Flow Cubic Feet Per Minute Formula (Formula 3.2),

$$CFM = \frac{AC/Hr X \ Vol}{60 min}$$

The value of Flow rate (CFM), will be substituted in the equation below to find the value of V (velocity) m/s

$CFM = V \ X \ A \ X$ 2118.88

$$V = \frac{CFM}{A \ X \ 2118.88}$$

The result/value obtained are tabulated in the table below;

Table 3.3: Air Change Per Hour, Flow Rate, Velocity Inlet

AC/Hr	Q (ft^3/min) or CFM	VelocityInlet(m/s)
5	3251.88	0.87
10	6503.76	1.73
20	13007.52	3.47
30	19511.27	5.20
40	26015.03	6.94
50	32518.79	8.67
60	39022.55	10.40

3.3.2 Cable Surface Temperature

Excess Cable surface temperature given by, $\Delta\theta_s$ is the difference in temperature between the ambient temperature and the cable surface temperature. $\Delta\theta_s$ may be calculated iteratively using the equation below (Formula 3.3).

$$(\Delta\theta_s)_{n+1}^{1/4} = \left[\frac{\Delta\theta + \Delta\theta_d}{1 + K_A(\Delta\theta_s)_n^{1/4}}\right]^{0.25}$$

Since, $\Delta\theta_d = 0.0002227$ and $\Delta\theta = 60$, $K_A = 0.476844549$,

$$(\Delta\theta_s)_{n+1}^{1/4} = \left[\frac{60 + 0.0002227}{1 + (0.476844549)(\Delta\theta_s)_n^{1/4}}\right]^{0.25}$$

Iteration to stop when, $(\Delta\theta_s)_{n+1}^{1/4} - (\Delta\theta_s)_n^{1/4} \leq 0.001$

Iteration	Initial $(\Delta\theta_s)^{1/4}$	New $(\Delta\theta_s)^{1/4}$	Error|New-Initial|/ Initial
1	2	2.354096992	17.70%
2	2.354096992	2.305814313	2.05%
3	2.305814313	2.312109887	0.27%
4	2.312109887	2.311284127	0.04%
5	2.311284127	2.311392354	0.00%
6	2.311392354	2.311378168	0.00%

Therefore, the iteration is stopped with:

$$(\Delta\theta_s)^{1/4} = 2.311284127$$

Solving, results with:

$$\Delta\theta_s = 28.54^oC, \; \theta_s = 28.54 + 30.0 = 58.54^oC$$

The steady state cable surface temperature is expected to be 58.54 ^oC with a core temperature of 90 ^oC and an ambient temperature of 33 ^oC.

Dependent parameter calculations:

Calculating K_A (Formula 3.4),

$$K_A = \frac{\pi D_e^* h}{(1+\lambda_1+\lambda_2)}\left[\frac{T_1}{n} + T_2\ (1+\lambda_1) + T_3\ (1+\lambda_1+\lambda_2)\right]$$

D_e^* = 110.86mm = 0.11086m

n = 1 (single conductor within cable)

λ_1 = 0.0041998

λ_2 = 0

T_1 = 0.4233 K.m/W

T_2 = 0 K.m/W

T_3 = 0.07808 K.m/W

h = 2.740446

K_A = 0.476844549

Calculating $\Delta\theta_d$ (Formula 3.5),

$$\Delta\theta_d = W_d\left[\left(\frac{1}{1+\lambda_1+\lambda_2}-\frac{1}{2}\right)T_1-\frac{n\,\lambda_2\,T_2}{1+\lambda_1+\lambda_2}\right]$$

W_d = 1.061x10^{-3} W/m

λ_1 = 0.0041998

λ_2 = 0

T_1 = 0.4233 K.m/W

T_2 = 0

$\Delta\theta_d$ = 2.227x10^{-4} ^{0}C

Detailed Sub-Calculations

λ_1 = ratio of losses in metallic sheath to conductor = 0.04575/10.89337

λ_1 = 0.0041998

λ_2 = ratio of losses in armour to conductor in this case, with no armour installed, **λ_2 = 0.**

T_1 = Thermal Resistance between one conductor and sheath

$$T_1 = \frac{\rho_T}{2\pi}\ln\left[1+\frac{2t_1}{d_c}\right]$$

Thermal resistivity for XLPE, ρ_T = 3.5 K.m/W

Thickness of layer between conductor and metallic sheath, t_1 = 0.0247m

Conductor Diameter, d_c = 0.0434m

T_1 = 0.4233 K.m/W

T_2 = Thermal Resistance between metallic sheath and armour in this case, with no armour installed, **T_2 = 0**.

T_3 = Thermal resistance of outer covering (serving)

$$T_3 = \frac{\rho_T}{2\pi} \ln\left[1 + \frac{2t_3}{d_a}\right]$$

Thermal resistivity for XLPE, ρ_T = 3.5 K.m/W

Thickness of XLPE jacket, t_3 = 0.00725m

Metallic sheath outer diameter, d_a = 0.09636m

T_3 = 0.07808 K.m/W

Heat dissipation coefficient, h

$$h = \frac{Z}{\left(D_e^*\right)^g} + E$$

From Table 2 of IEC 60287-2-1, for three cables in trefoil, installed on non-continuous brackets, ladder supports or cleats with D_e^* not greater than 0.15m (case under study = 0.11086m).

Z = 0.96

E = 1.25

g = 0.20

$D_e^* = 0.11086\text{m}$

h = 2.740446

Dielectric losses, $\mathbf{W_d = CU_o^2\tan\delta = 1.061x10^{-3}}$ **W/m**

Voltage from phase to ground, $U_o = 76{,}210$ V

$\tan\delta = 0.001$

Capacitance, $C = \dfrac{\varepsilon}{18\ln\left(\dfrac{D_i}{d_c}\right)}10^{-9} = 1.8275\times10^{-10}$ **F/m**

Insulation outer diameter, $D_i = 0.0928\text{m}$

Conductor outer diameter, $d_c = 0.0434\text{m}$

Insulation emissivity, $\varepsilon = 2.5$

3.3.3 Fan Pumping Power

The following is a basic formula for calculating the horsepower required to drive the ventilator or blower component. This formula does not account for any specific fan or blower's speed, density or airflow characteristics (Formula 3.6),.

$$HP = \frac{CFM \times PSI}{229 \times \text{Efficiency of Fan}}$$

HP = Horsepower CFM = Cubic Feet per Minute

PSI = Pound per Square Inch Efficiency Of Fan = %/100

3.4 Solidworks and Ansys (Fluent)

Solidworks software used to draw the desired parameter 3D model. ANSYS (Fluent) used to solve and analyze fluid flow problems. The cable tunnel design that was derived from the specification and calculation was tested using CFD software to determine the appropriate airflow. The optimum mesh was generated and used to set the governing parameters. Many cases have been tested to generate an efficient flow of air.

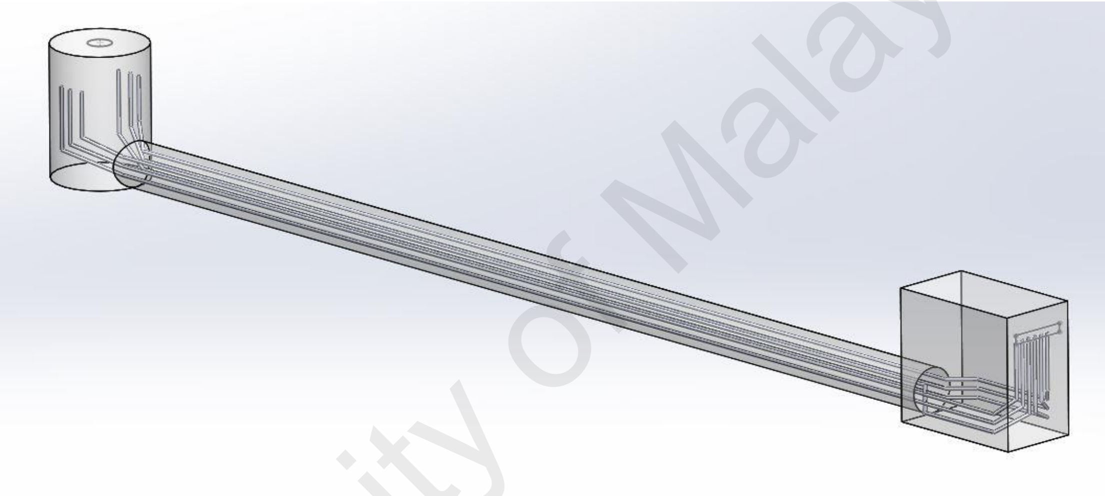

Figure 3.5: Isometric view of tunnel and cable geometry

Figure 3.6: Side view of tunnel and cable geometry

3.4.1 Design Mesh

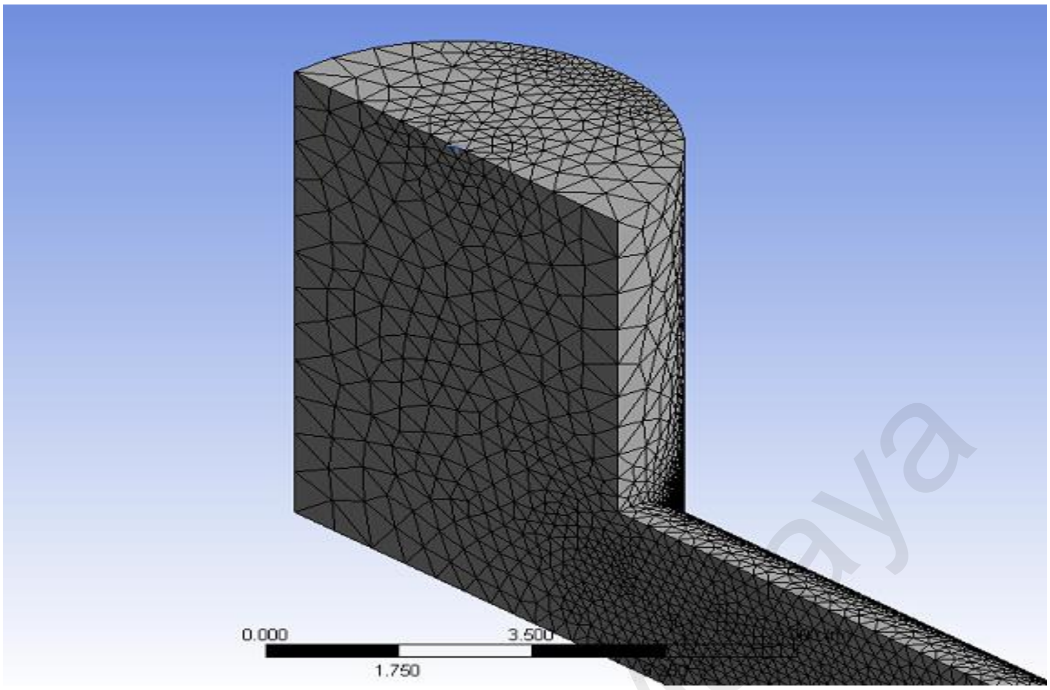

Figure 3.7: Tunnel Cross Section Geometry Inlet Mesh Model

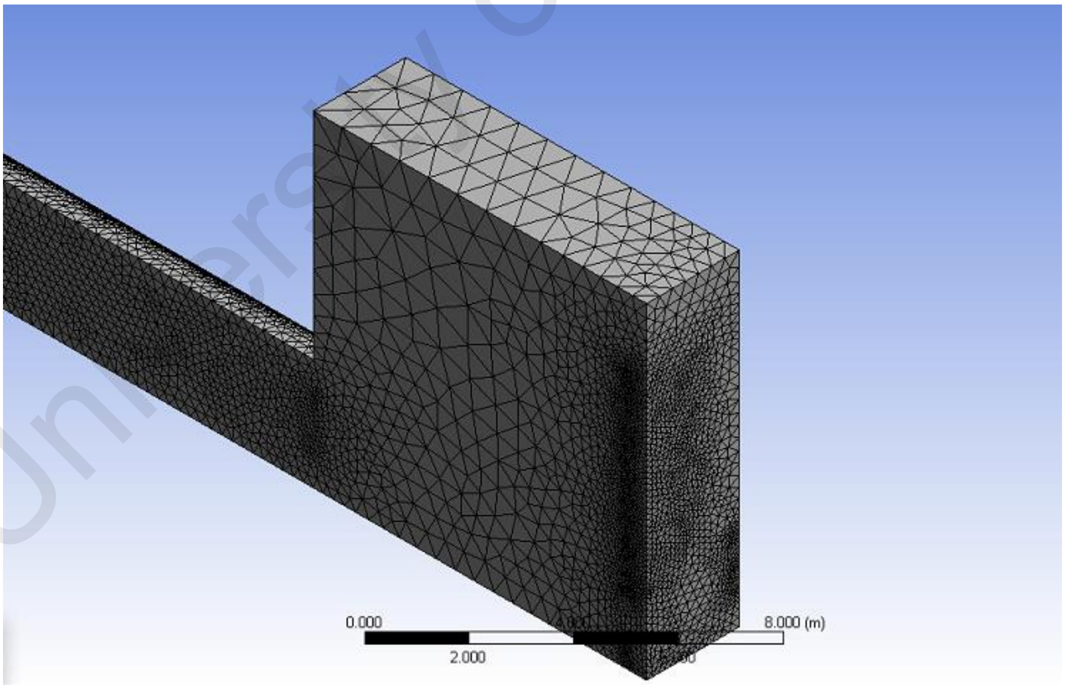

Figure 3.8: Tunnel Cross Section Geometry Outlet Mesh Model

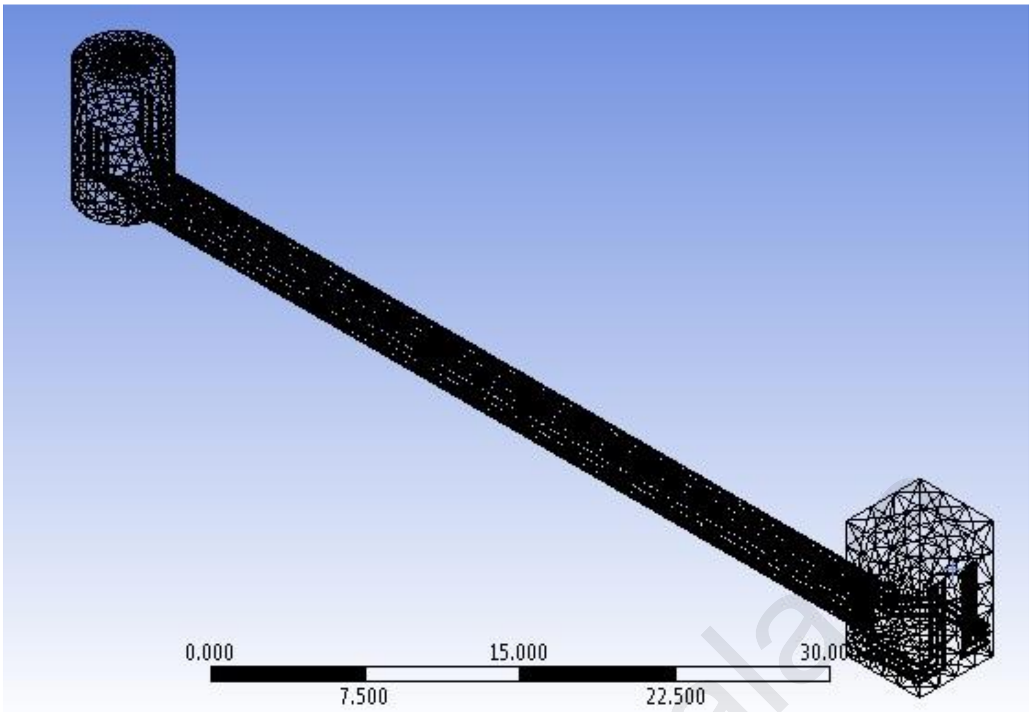

Figure 3.9: Mesh Isometric View

The tunnel geometry has been meshed in CFD as per statistics in the table below

Table 3.4: Mesh Statistics

Number of Nodes	931670
Number of Elements	844667
Min Size (m)	0.04
Max Size (m)	2
Average of Skewness	0.4124

3.4.2 Boundary Condition

The ambient temperature is set at 33°C in this simulation process, and four different speeds, 2 m/s, 4 m/s, 8 m/s, and 12 m/s, have been flowed through the manhole inlet. These parameters have been tested to find the mid-point temperature of the tunnel and to determine the best flow.

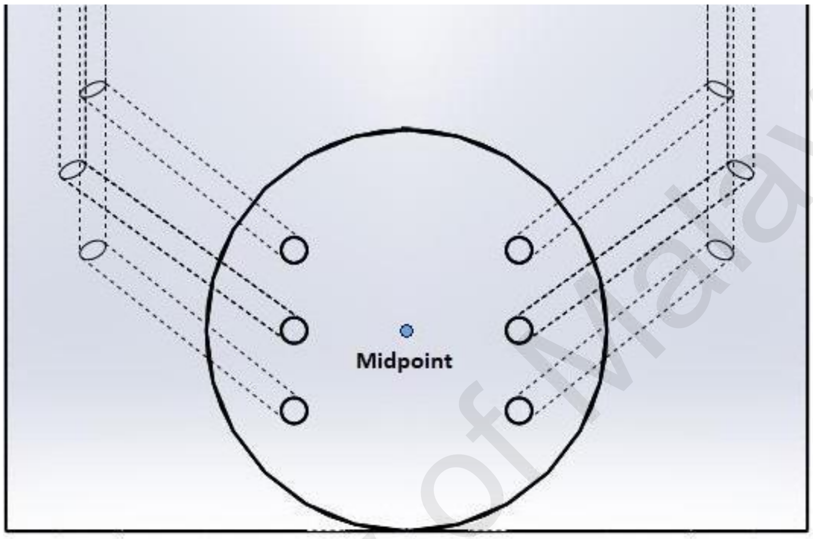

Figure 3.10: Mid-Point temperature

The simulation model indicates the maximum temperature produced by the cable is 60 ° C, while at the inlet air reduces the heat at the midpoint to create an appropriate environment for the presence of humans.

CHAPTER 4: RESULTS AND DISCUSSION

4.1 Introduction

The findings will be used as a basis for guidance for improvements in the cable tunnel ventilation system design technique to achieve desired temperature. Here are summarized the findings of the review discussed in the previous chapter. Findings include the high-voltage cable tunnel's temperature and velocity study. Simulation are used to assess the optimal ventilation system for air flow.

4.2 ANSYS(Fluent) Results

AMBIENT TEMPERATURE = 33 ^{O}C

Temperature difference from ambient temperature with different velocity:

Table 4.1 : CFM and Temperature Difference

Velocity of Air at Inlet (m/s)	**Diameter of Inlet (m)**	**Flow Rate of Air at Inlet (ft^3/min)**	**Temperature of Air at Midpoint (^{O}C)**	**Temperature Difference (^{O}C)**
2	1.5	7520.74	35.51	2.51
4	1.5	15041.49	34.80	1.80
8	1.5	30082.98	34.78	1.78
12	1.5	45124.47	34.74	1.74

Position of the cut-sections for results.

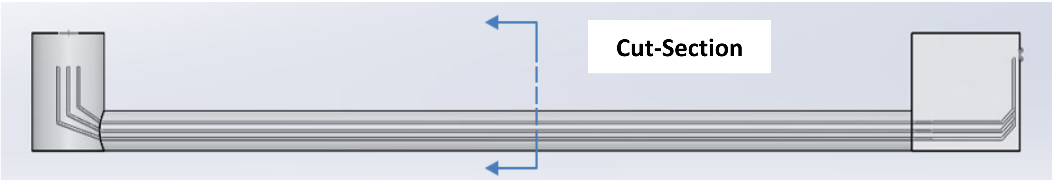

Figure 4.1: Cut section of temperature contour

Temperature Contour at 33°C , V= 2 m/s

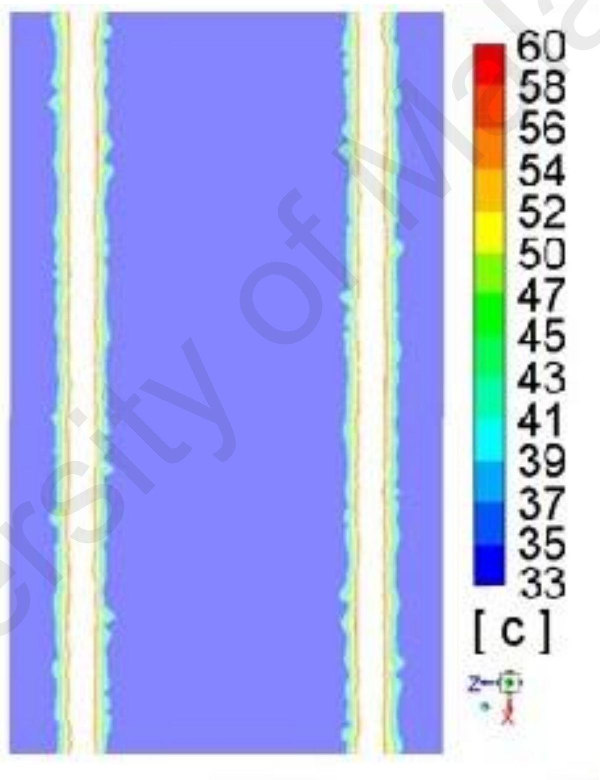

Figure 4.2: Temperature Contour at Top-View of tunnel, 2m/s

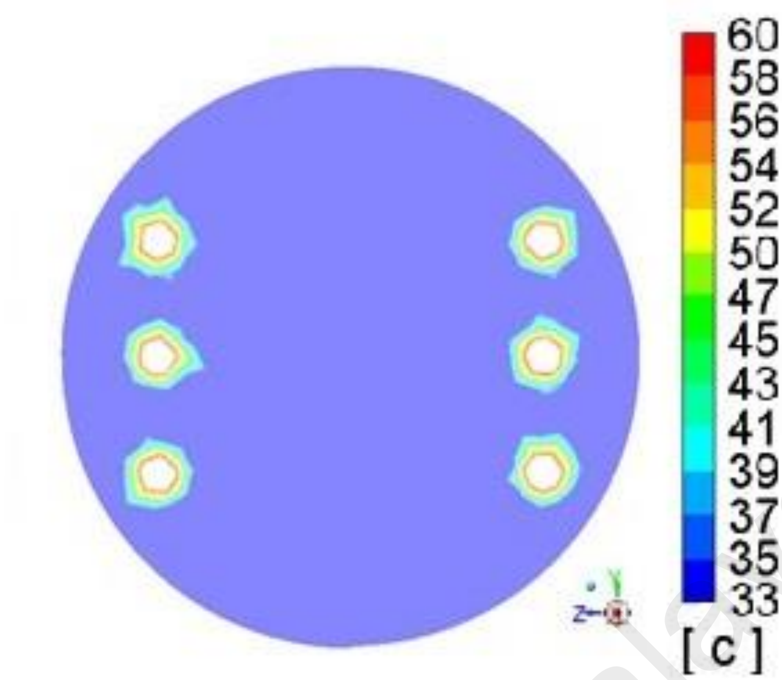

Figure 4.3: Temperature Contour at Cross-Section of tunnel, 2m/s

Temperature Contour at 33°C , V= 4 m/s

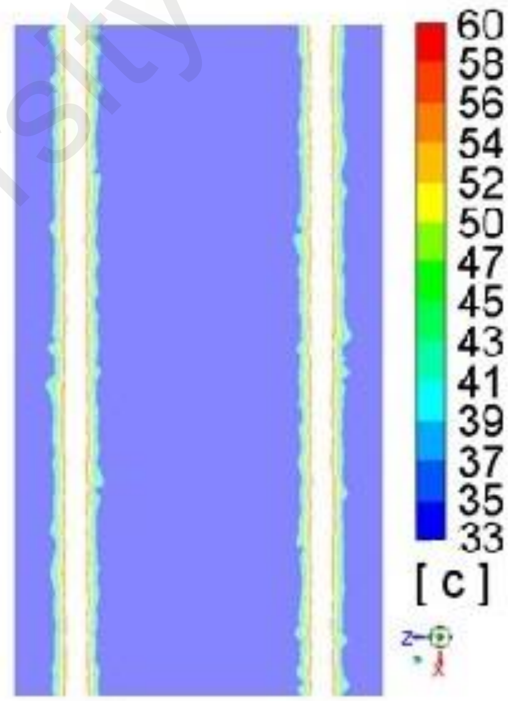

Figure 4.4: Temperature Contour at Top-View of tunnel, 4m/s

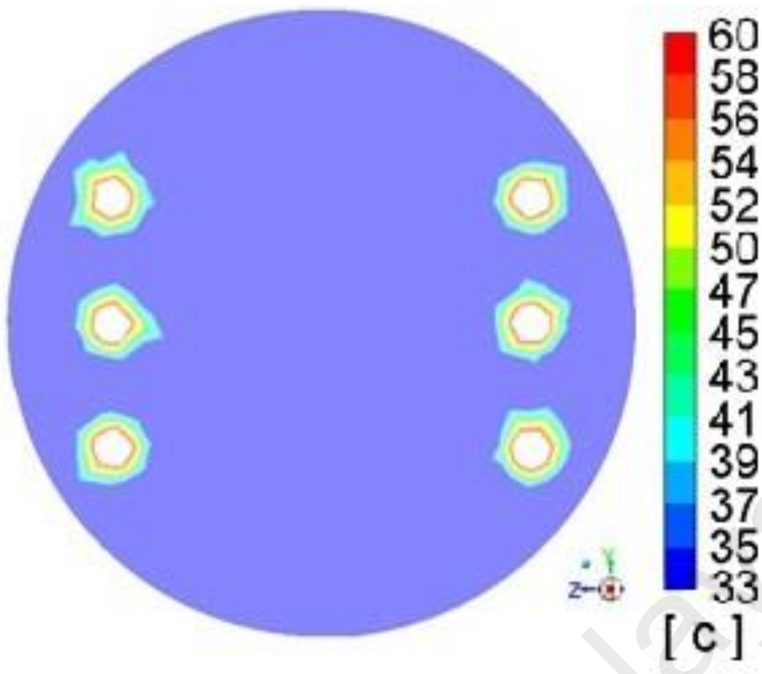

Figure 4.5: Temperature Contour at Cross-Section of tunnel, 4m/s

Temperature Contour at 33°C , V= 8 m/s

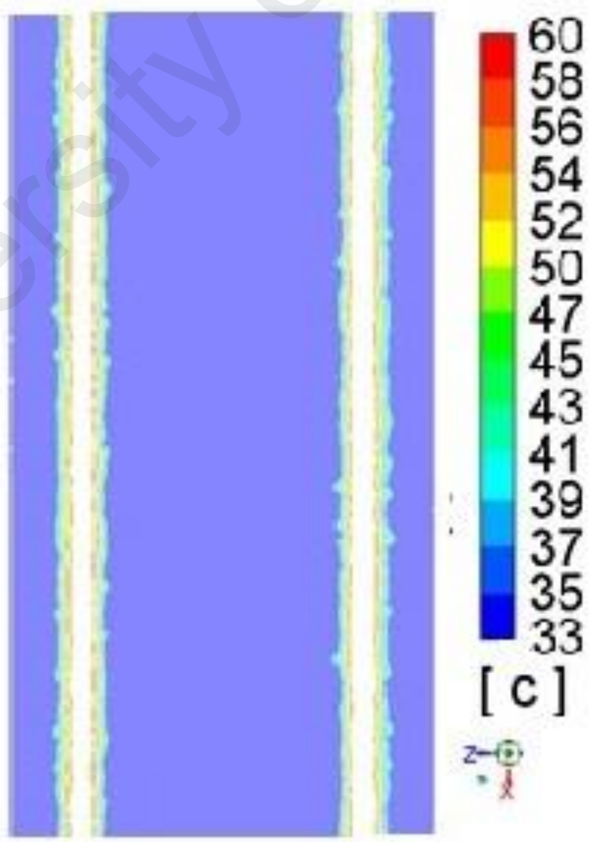

Figure 4.6: Temperature Contour at Top-View of tunnel, 8m/s

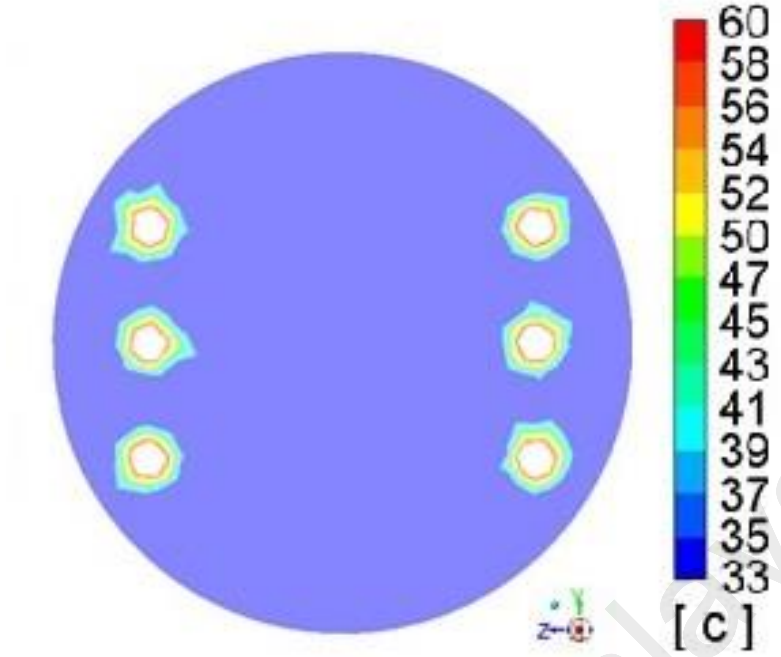

Figure 4.7: Temperature Contour at Cross-Section of tunnel, 8m/s

Temperature Contour at 33°C , V= 12 m/s

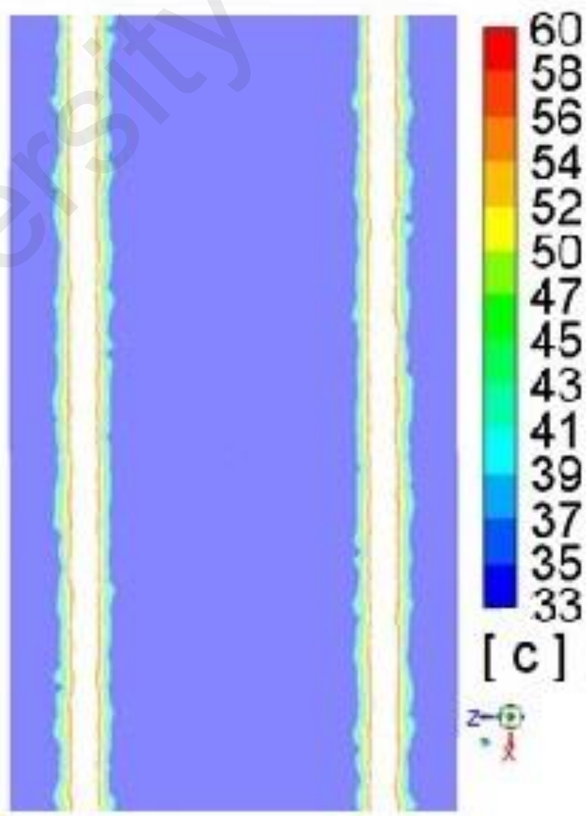

Figure 4.8: Temperature Contour at Top-View of tunnel, 12m/s

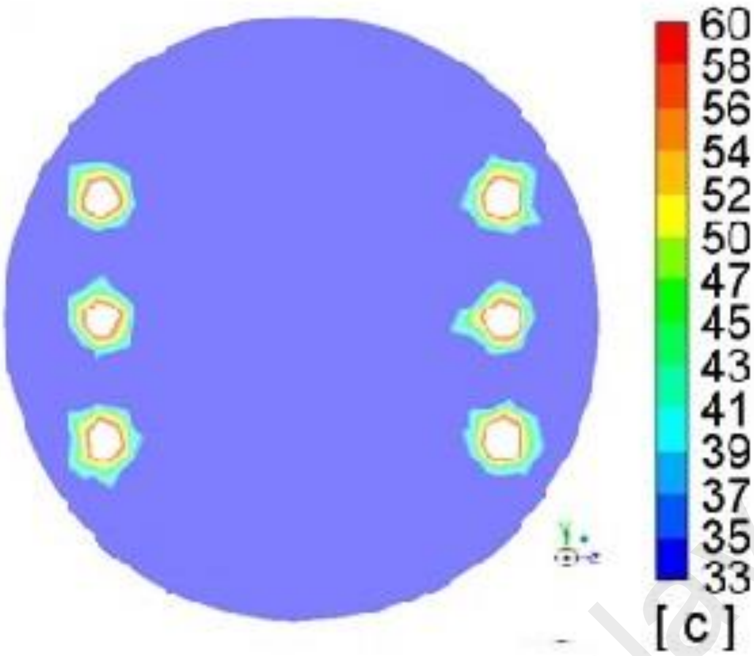

Figure 4.9: Temperature Contour at Cross-Section of tunnel, 12m/s

Table 4.5: Results Tabulation

Velocity of Air at Inlet (m/s)	**Q (ft^3/min) or CFM**	**AC/Hr**	**Average Mid-Point Temperature difference (°C)**
2	7520.74	12	2.51
4	15041.49	23	1.80
8	30082.98	46	1.78
12	45124.47	69	1.74

4.3 Fan Pumping Power

Based on the simulation results above, 4m/s air velocity will be the suitable air velocity for the cable tunnel. 229.43 pascal @ 0.0333psi of static pressure obtained from the 4m/s velocity simulation.

$$HP = \frac{CFM \times PSI}{229 \times Efficiency\ of\ Fan}$$

Therefore,

Assume efficiency of fan is 80%.

HP = (15041.49 x 0.033) / (299 x 0.8)

= 2.09 Hp

4.4 Discussion

The planned cable tunnel building site is located in the Icon City area of Petaling Jaya. Petaling Jaya has an average ambient temperature of 33.4°C base of Malaysian Meteorological Department. The reference temperature will be 33°C for this study.

Inlet velocity temperature of 12 m/s has the lowest variations in temperature due to high inlet velocity and its temperature different is the nearest to ambient temperature. Therefore, it might be the easiest way to remove the heat generated by the cable during full load. For inlet velocity 4 m/s and 8 m/s the variations in the CFM range between 15041.49 ft3/min but the difference in temperature is very small. Even if the temperature difference is not the best for 4 m/s inlet speed, it would be a very efficient choice when it comes to CFM.

CHAPTER 5: CONCLUSION AND RECOMMENDATION

5.1 Conclusion

For a total of four different inlet velocities, 2 m / s, 4 m / s, 8 m / s and 12 m / s, the simulation was carried out. The ambient temperature will be 33.4^0C, depending on the location of the cable tunnel. The primary analytical temperature was 33^0C. The study of the CFD model and the result, temperature, air shift and the CFM play a major role in deciding an acceptable inlet speed for the underground cable tunnel.

This inlet velocity and CFM will be more efficient compared to the other three given the small difference in temperature because the CFM is low for this temperature and this would be the most cost-effective choice. Depending on CFD testing, the mid-point temperature of 33^0C nearest to the average ambient temperature of the region can be reached. This temperature is achieved with 4 m/s inlet speed and 15041.49 CFM.

5.2 Recommendation

In respect to the 33^0C ambient temperature measurement, it is feasible to use the 4 m/s inlet velocity in 15041.49 CFM for any potential tunnels without and can achieve the thermal comfort to human who doing maintenance work in the tunnel.
Based on the 4 m/s inlet velocity and 15041.49 CFM, the recommended needed fan pumping power is 2.09 horsepower.

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