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Ventilation Duct Design in Temporary Ventilation System During Tunnelling Construction

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Abstract: In tunnel construction, there a lot of dust and gases were produce from excavation activities. It is essential to have temporary ventilation system to provide fresh air for workers inside the tunnel during construction. Current technology they used ventilation duct that connected to axial fan to blow fresh air from outside of the tunnel inside of the tunnel. The bigger size of ventilation duct contributed to scratch the duct and take a lot of space along the tunnel. Other works such as locomotive movement may be limited due the bigger size of ventilation duct. Therefore, in this paper studied on how to reduce ventilation duct sizing for Western Tunnelling Package (WTP) in Australia. In this study I used Reynolds Number method to identify how much to reduce for better ventilation duct to supplied enough air inside the tunnel. Logically, if diameter of ventilation duct become smaller the pressure flow inside the duct become higher. For future idea, I also give a suggestion to put fan in the middle of ventilation duct to pump more air for a better air flow inside the ventilation duct.

Keywords: Temporary Ventilation System, Axial fan, Ventilation Duct, Tunnel Boring Machine

1. Introduction

In Tunnel Operation, a lot of work has been done, such as excavations, loading of excavated materials, mucking, drilling, blasting, and shotcreting. From these activities, many gases and dust are forming, which is unfit for breathing. Therefore, it is essential to have a temporary ventilation system for workers inside the tunnel during excavation where as to provide sufficient environment for

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respiratory purpose inside the tunnel. The bigger ventilation duct sizing is the issue for workers to move along the tunnel. Therefore, the probability of a damaged ventilation duct is extremely high since it is made of canvas. To reduce the size of the pipe, other factors will also affect for example the length of the tunnel, the diameter of the tunnel and also the number of workers who need to be in the tunnel during construction activity. Other than that, the requirement of air flow and air pressure in ventilation duct should be consider to minimize the sizing of ventilation duct. The aim of study in this paper is:-

- To identify the factors that affect the sizing of ventilation duct.
- To analyze the factors affected using Reynold Number method.
- To compare and validate based on different diameter of ventilation duct.

2. Temporary Ventilation System

2.1 Temporary Ventilation System

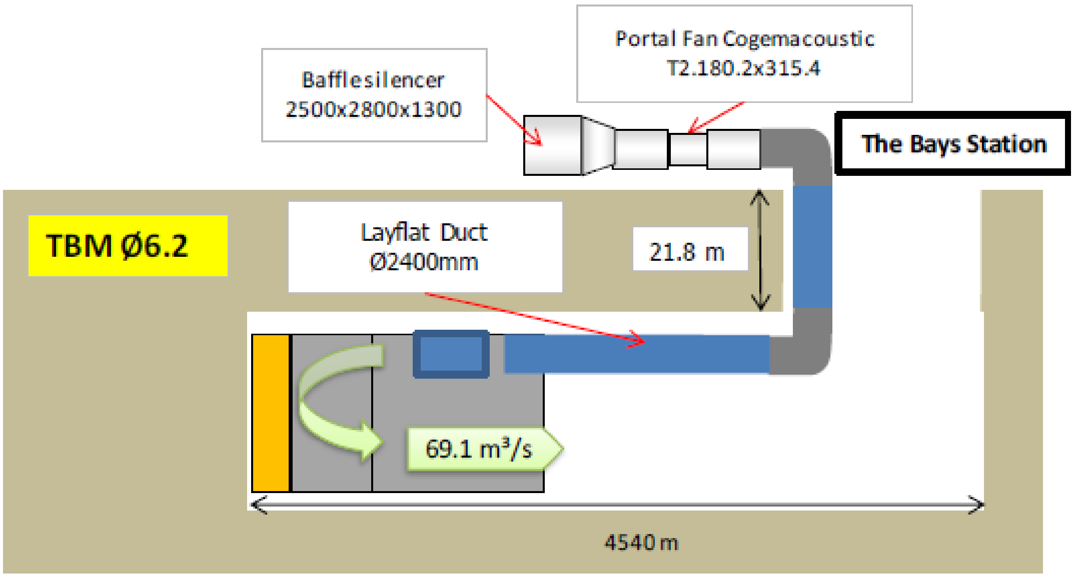


Figure 1: Temporary Ventilation System

Temporary Ventilation System consist of axial fan that connect to ventilation duct and ventilation duct will be installed along the tunnel until cutterhead of Tunnel Boring Machine. [2]

2.2 Reynolds Number Methods

Reynolds Number investigate experimentally is the transition of flow from the orderly king that called “laminar flow” to the more chaotic type of flow termed “turbulent flow”. Reynolds established that the change in the nature of the flow occurs when a certain combination of the parameters in the flow crosses a threshold. This combination was named the “Reynolds number.” Reynolds number were defined as,

$$Re = \frac{DV\rho}{\mu} = \frac{DV}{v} \qquad Eq.\ 1$$

$D = flow\ in\ a\ circular\ tube\ of\ diamater$

$V = average\ velocity$

$\mu = dynamic\ viscosity\ of\ the\ fluid$

$\rho = density\ of\ the\ fluid$

$v = \frac{\mu}{\rho} =\ the\ kinematic\ viscosity$ [3]

2.3 Equations

Based on Reynolds Number method this is how to calculate air flow and air pressure in ventilation duct.

2.3.1 Calculation of Air flow

a) Based on manpower and diesel operated machine in the tunnel

$$Q_1 = [(q_a \times N) + q_b]\,\lambda \qquad Eq. 2$$

q_a — min quantity of air per person, 1.5 m^3/min

q_b — min quantity of required for diesel operated machine, 4m^3/min/kW

N — people inside the tunnel, (TBM and Cross Passage team)

λ— safety coefficient, 1.2

b) Allowed minimum speed taken into consideration

$$Q_2 = V \times S \qquad Eq. 3$$

V — air velocity, 18m/min (0.3 m/s: Safe Work Australia Guidelines)

S — area of cross section.

c) Actual Volume

$$Q_{max} = \max\ \{Q1, Q2\}$$

Leakage of air ducts should be taken into consideration

$$Q = Q_{max} / (1- \beta)^{L/100} \qquad Eq. 4$$

β – air leakage coefficient/ 100m, 0.01

L – max length of air ducts, 11 000m will be adopted

2.3.2 Calculation of Air Pressure

a) Diameter of ventilation Duct

$$V_p = Q / (60 \times \pi \times j^2) \qquad Eq. 5$$

d — diameter of air duct,

ρ — density of air, 1.184 kg/m^3

V_p — average speed inside air ducts, m/s

b) Pressure loss due to resistance of air ducts

$$P_d = \lambda \times L/d \times \rho \times V_p^2 /2 \qquad Eq. 6$$

L —maximum length of air ducts, 11000 m

d —diameter of air duct, 1.4 m

ρ—density of air, 1.184 kg/m^3

V_p —average speed inside air ducts, m/s

λ—friction coefficient of air ducts, 0.015.

c) Pressure loss due to resistance of tunnel

$$P_D = \lambda \times L/D \times \rho \times V_T^2 / 2 \qquad \textit{Eq. 7}$$

$$V_T = Q / (60 \times \pi \times D^2 /4) \qquad \textit{Eq. 8}$$

L—maximum length of air tunnel, 11000m

D—inner diameter of tunnel, 6.2m

V_T—average wind speed in tunnel, m/s

λ—friction coefficient of tunnel interior surface。

$$V_T = Q / (60 \times \pi \times D^2 /4) \qquad \textit{Eq. 9}$$

2.3.3 Air Pressure requirement for Ventilation Fan

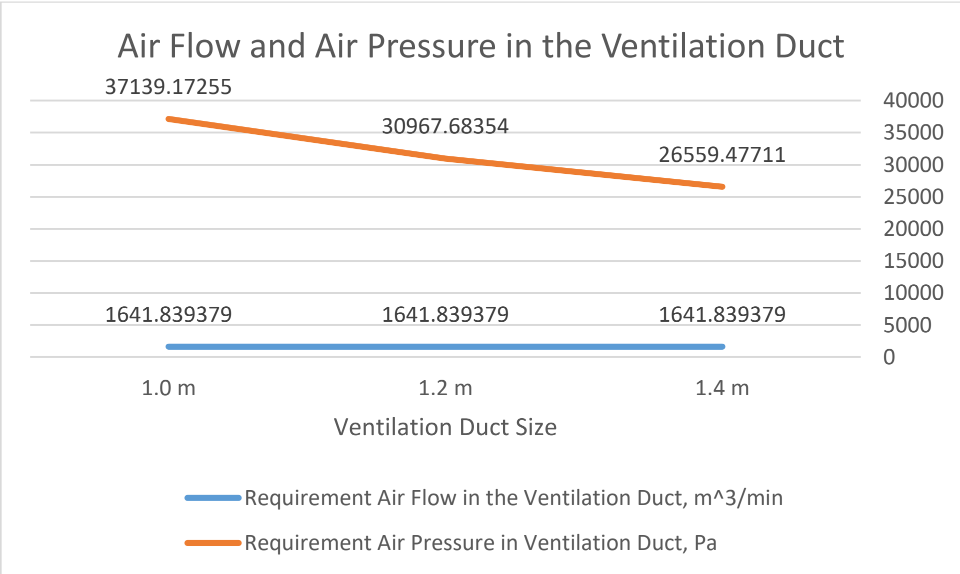
$$P = P_d + P_D) \times \lambda \qquad \textit{Eq. 10}$$

λ – Safety coefficient, 1.2 [1][2]

3. Results and Discussion

Using Reynolds Number methods, here the data for using different sizing of ventilation duct.

3.1 Results



Figures 2: Graft of air flow and air pressure using different size of ventilation duct

Figure 2 shown the result of air pressure if we used different size of ventilation duct. The result shown, air pressure will be increase due to smaller size of ventilation duct.

3.2 Discussions

Based on Figures 2 we known that the pressure will become hinger if we used smaller size of ventilation duct. The higher pressure not suitable for ventilation duct. This is because the material that used for ventilation duct is canvas. Ventilation duct that made form canvas is easy to store compare other type of material.

Higher pressure inside the ventilation duct can be dangerous become it can tear the canvas. Other than that, it is not suitable and beyond requirement for worker to work near high pressure area.

4. Conclusion

Based on my research on sizing of ventilation duct we can conclude that there a pros and cons to reduce sizing of ventilation duct. The pros are the worker will have a better space to move easily while construction. The cons are the workers need to works near high pressure area. So, based on my finding and reading we can reduce the sizing of ventilation duct but not too much because it may damage the canvas. Reducing ventilation duct also can cut our budget for ventilation duct. For further research the pressure inside ventilation duct can be the issues because on this paper just technically research on the sizing of ventilation duct. It also helps to classify how much size we can reduce for better pressure inside the ventilation duct during construction activities. The additional of fan inside the ventilation duct also can be an issues of air pressure inside ventilation duct.

Human body can hold 1 atm external pressure in our daily life. [5] Our limit as normal human body can hold maximum 100 atm pressure but it depends on human health. High pressure can cause disease on human body such as rupture of air drum, hard to breath, loss of balance and etc. [4] Based on the result from pressure rising it not more than 1 bar pressure so normal human body can work near the ventilation duct with 37139.17 Pa. So, we can used 1.0 diameter of air duct.

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This research was made possible by findings from Gamuda and issues that occur while construction. The authors would also like to thank the Faculty of Engineering Technology, University Tun Hussein Onn Malaysia for its support.

Appendix A

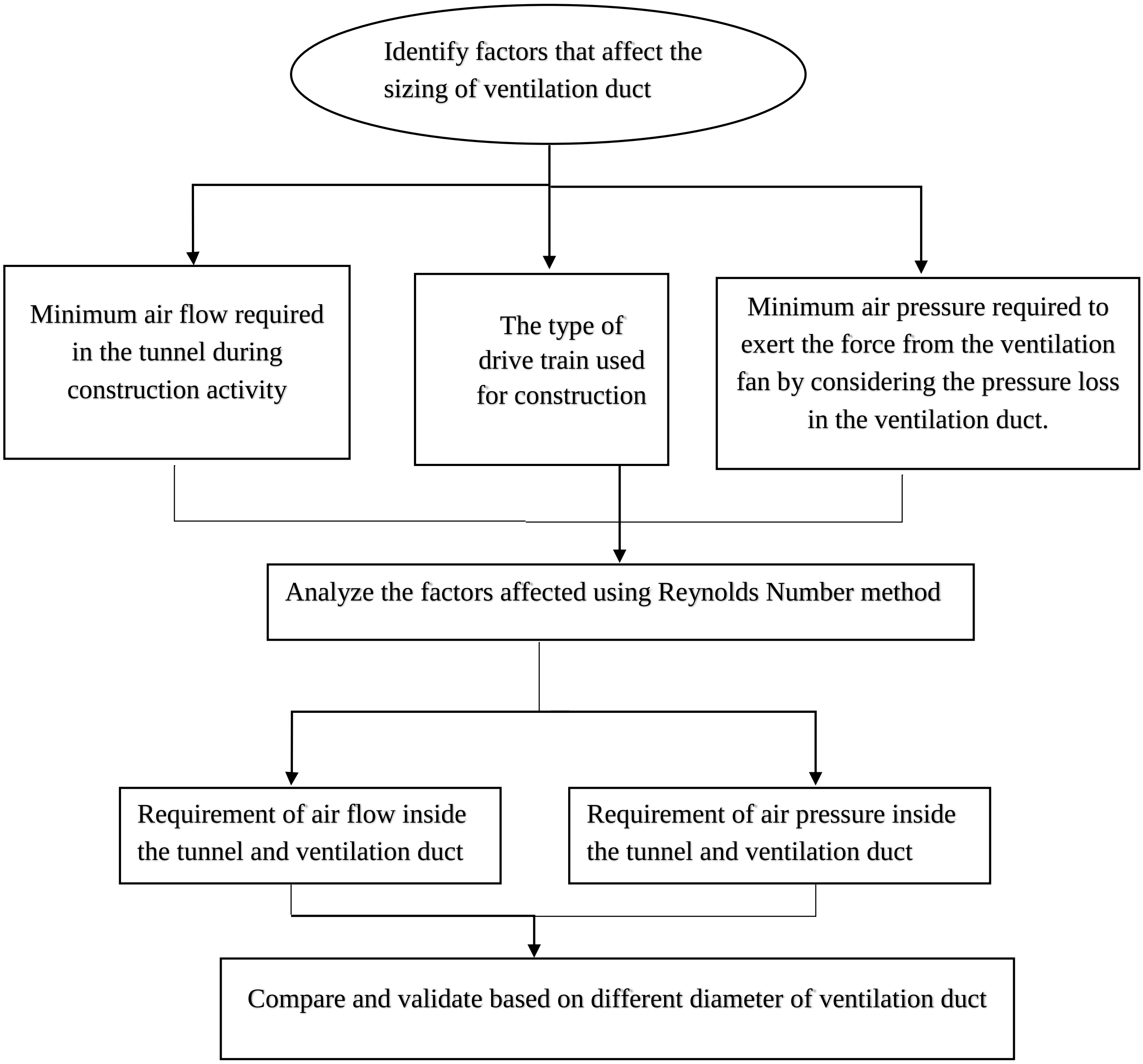

Figure 3: Flow Chart for Methodology

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