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# *Investigation of Effective Parameters on Critical Ventilation Velocity in Underground Tunnels*

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## *ABSTRACT*

Due to the importance of safety in underground tunnels and the health of passengers in emergency modes, analysis and simulation of fires in tunnels and design of an appropriate and efficient ventilation system to reduce damages of fire hazards is necessary. Longitudinal ventilation system is widely used in tunnel ventilation. Critical ventilation velocity in longitudinal system is the amount of airflow necessary to prevent back layering of smoke and heat to upstream of fire region. The lower air velocity leads to influence of smoke and heat of fire to the fire upstream, and resulting in reduction of visibility and fresh air in the tunnel. In critical velocity, smoke and heat move to the downstream of the tunnel and provide fresh air and a safe passage for passengers to escape. The aim of this research is to investigate the critical ventilation velocity and effective parameters on it. CFD simulation were performed in this paper to study the critical ventilation velocity by using the code FDS. Effects of fire source shape, vehicle such as a train inside the tunnel, tunnel geometry and slope on the critical ventilation velocity were investigated.

***KEYWORDS:***

Tunnel Fire, Critical velocity of Ventilation, Back Layering

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## 1- INTRODUCTION

In recent years, tunnel firings such as Baku and Daegu Metro show importance of fire and smoke ventilation in tunnels [1]. Initiation of fire in tunnel produces a huge amount of smoke, which moves to the ceiling due to the buoyancy effect and spread out in both sides. The task of tunnel ventilation system in this critical mode is to push the smoke into one side, and make a safe passage for passenger escape or rescue team. Thus the true selection of capacity of tunnel HVAC system is very important to prevent the back layering of the smoke. The minimum velocity of air flow in tunnel, which leads to overcome to the back layering of smoke to the upstream, is named as critical velocity. Critical velocity is dependent to some parameters such as heat release from fire source, air flow temperature and thermal capacity, tunnel shape and slope [2]. Determination of critical velocity is under focus of many researchers. First, Thomas introduced an empirical relation for critical velocity due to the Froude number as [3]:

$$V_c = k\left(\frac{gQH}{\rho_0 C_p T_0 A}\right)^{1/3} \quad (1)$$

After him, Oka and Atkinson [4] corrected this relation for different heat releases. Atkinson and Wu [5] studied the effects of tunnel slope and introduced a modified relation. Wu and Bakar [6] studied on the tunnel cross section, using a scaled model. They suggested to use the effective hydrolic diameter of tunnel as lenth parameter in critical Velocity.

In this paper the effects of some parameters such as fire source width and length, occupation of tunnel with train, fire height and tunnel section and slope have been studied using FDS code.

## 2- MODELING

The scheme of heat release rate (HHR) of fire due to time is plotted in Figure 1. It can be seen that HHR is increasing with time from fire initiation and reach to the fully developed fire state. After it fire is decreasing due to finishing of material. In this paper study and design of tunnel ventilation is considered at the critical zone of fully developed fire.

Critical velocity is determined with Estimation of back layering using temperature sensing on a tunnel ceiling as shown in Figure 2.

## 3- RESULTS

The effects of fire source width and length on critical velocity is shown in Figure 3 and 4. The fire source parameters are increased considering the fixed heat release rate. It can be seen that critical velocity is decreased with increasing of fire width, which may be due to the decrease of smoke density, in comparison with the stated formula. This behavior is repeated

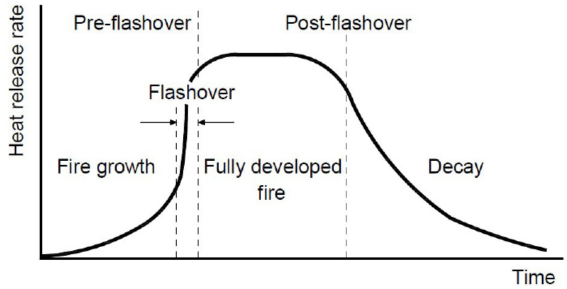


**Figure 1. Heat release rate**

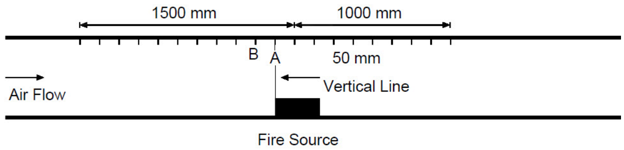


**Figure 2. Position of temperature and velocity measurement in model**

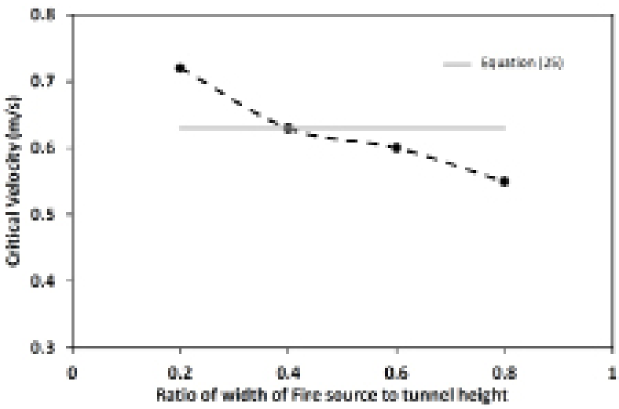


**Figure 3. Variation of critical velocity with fire source width**

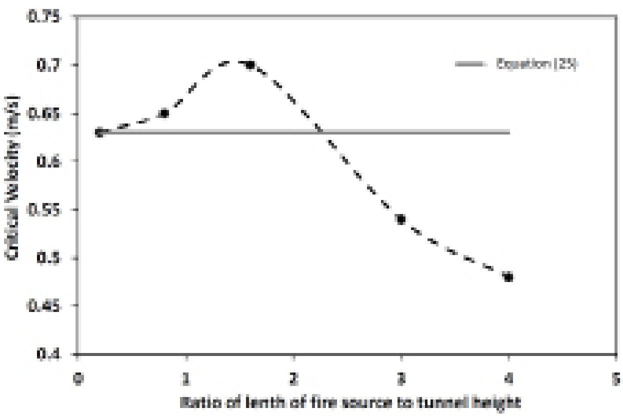


**Figure 4. Variation of critical velocity with fire source length**

in increase of fire length after an increase in critical velocity, which is due to the concentration of smoke in front of air velocity.
In Table 1, critical velocity of four fire sources with different cross sections and constant heat release rate are presented.

**Table 1. critical velocity for fire sources with different cross-section**

| Fire source Length*width | Critical Velocity(m/s) | Critical Velocity. (25)Eq (m/s) |
|---|---|---|
| 25*100 | 0.6 | 0.63 |
| 50*50 | 0.69 | 0.63 |
| 100*25 | 0.72 | 0.63 |
| 200*12.5 | 0.77 | 0.63 |

The effect of tunnel cross section aspect ratio is shown in Figure 5. It can be seen that theoretically there is a critical point which the critical velocity is maximum due to the tunnel aspect ratio. But the limitations of tunnel constructions must be considered.
The effect of height of fire source in tunnel is shown in Figure 6.

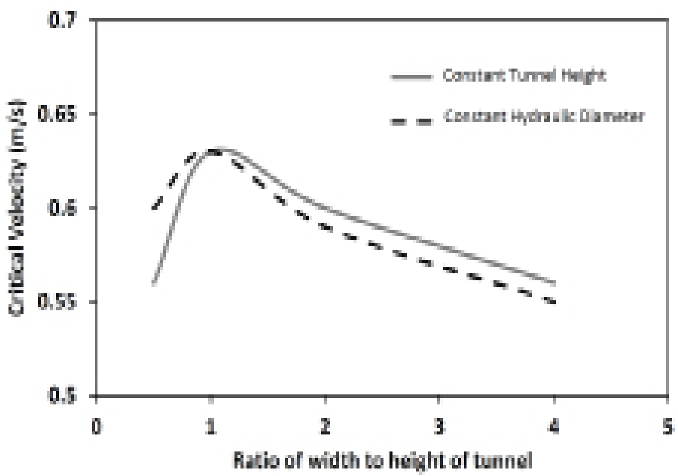


**Figure 5. Variation of critical velocity with tunnel aspect ratio considering fixed tunnel height and effective diameter**

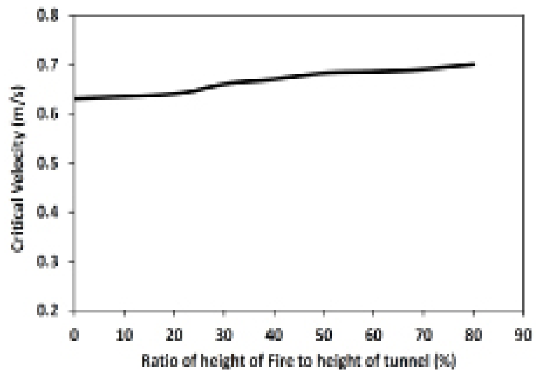


**Figure 6. Effect of height of fire source in tunnel**

## 4- CONCLUSION

The effects of fire source parameters such as width and length of fire, occupation of tunnel with train, fire height and tunnel cross section and slope on the critical velocity of ventilation have been studied using FDS code. The Results have been compared with the available relations. Totally it can be told that the relations most be improved to cover variations of some tunnel dimensions in estimation of critical velocity and the hydraulic diameter of tunnel is introduced for implementation on the new relations.

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