The 2017 World Congress on
Advances in Structural Engineering and Mechanics (ASEM17)
28 August - 1 September, 2017, Ilsan(Seoul), Korea

Experimental Study on the Automatic Monitor System for Fire Suppression in Double-Deck Tunnel

Jin-Ouk Park[1], *Yong-Ho Yoo[2], Byoung-Jik Park[3], Hwi-Seung Kim[4] and Sang-Heon Park[5]

[1), 2), 3), 4)] *Korea Institute of Civil Engineering and Building Technology, Hwaseong-si, Gyeonggi-do, Korea*
[5)] *Dong-Il Engineering Consultants, Songpa-go, Seoul 05800, Korea*
[2)] *yhyoo@kict.re.kr*

ABSTRACT

As one of the solution to deal with the economical and environmental problems caused by excessive traffic load in metropolitan area, a deep underground road has been emerged and a double-layer tunnel which has the advantage in using the space effectively and cost reduction by reducing the excavation section is under development. But because of the structural characteristics of a double-layer tunnel that divides a single section into the middle slab for using as up line and down line, life safety system design shall be differentiated from that for the typical road. Particularly, smoke density in fire tends to become thicker than the typical road tunnel because of reduced tunnel height, causing the smoke layer to descend faster. Given such phenomenon has direct effect on passenger's safety, fire suppression and ventilation system in a double-layer tunnel must be the important factors to be considered. This study thus is intended to develop the automatic foam fire extinguishing system that is able to deal with the fire from the beginning stage till fire suppression stage. To that end, a system was developed to spray the water to the longest possible distance at a low tunnel height and limited fire water pressure and a full scale fire test was conducted to verify the performance of the equipment.

1. Introduction

The loss resulting from traffic congestion in downtown Seoul and Metropolitan area reaches to trillions of Won every year and moreover such loss is on the rise now. . (Y.H. Yoo, 2008)

As part of the way to deal with such problems, a deep underground road scheme is underway in advanced countries including Europe, thereby solving the traffic

---

[1)] Senior Researcher
[2) 3) 4) 5)] Researcher

congestion as well as securing the green zone at the ground level. And at the same time, a double-deck tunnel scheme such as A86 East tunnel in France, Fuxing tunnel in China and SMART tunnel in Malaysia is considered for reasons of comprehensive benefits including minimized excavation section and improved construction efficiency which will lead to enhanced cost efficiency, stability and constructability. (Y.H. Yoo 2008, H.G. Kim 2004)

Korea in line with such a tendency also has reviewed to apply a double-deck tunnel to road tunnels. But as the tunnel is semi-closed structure, fire, when occurred in tunnel, reduces the visibility due to smoke spreading while the air diffusion is limited, raise the temperature rapidly and reduces the oxygen concentration, thereby threatening the life of the passengers and causing the damage to the structure, facilities and vehicles. (Y.K.Yoon, 2011)

As a double-deck tunnel has relatively lower height than the typical tunnel, the risk by the fire is higher and the resulting damage is more severe than other tunnels. A double-deck tunnel has the higher level and lower level which are in operation together and thus the particular fire-resistant slab that can withstand for hours while another level suffers the fire. But the study on safety of a double-deck tunnel has yet start and even the study in foreign countries is very limited.

In this study, as part of the solution to cope with the particular fire risk in a double-deck tunnel, automatic fire extinguishing system to delay the fire spreading from the early stage of the fire till fire suppression at the final stage was developed first and for the performance test, a full-scale fire test was conducted and the result was reviewed and compared.

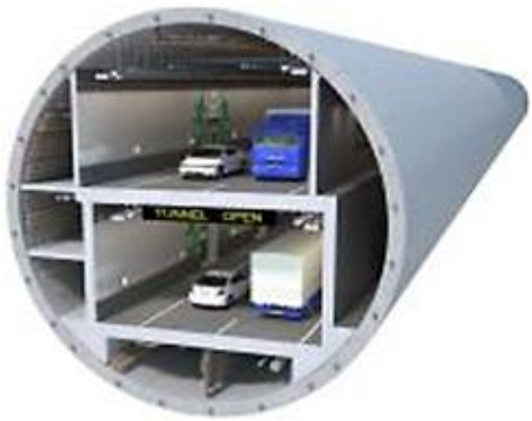

Fig. 1 Structure of double-deck tunnel

Fig. 2 fire extinguishing equipment of various facilities

2. Fire suppression test using automatic fire extinguishing system

A trail product was manufactured for the purpose of developing fire suppression system to delay the fire spreading from the early stage of the fire till fire suppression at the final stage in a double-deck tunnel depending on situation, and a full-scale fire test was conducted to verify the performance.

2.1 Automatic fire extinguishing system

Automatic fire extinguishing system developed in this study is as shown Fig. 3, 4 and the material used is copper alloy casting (CAC401) and the system comprises of sprayer, pump station and water tank (5 ton) and the sprayer is divided into the driving part and control part. A driving part has a spray head and body and three motors are provided to spray and vertical and horizontal movement of the body. Control part has three buttons as seen in Fig. 3 so as to control the spray vertically and horizontally with the flow capacity of 1,000LPM and terminal pressure 5 bar and maximum spray range up to 45m. Automatic fire extinguishing system will be further developed to have automatic control system based on location data from the fire detection system so as to spray the water automatically and suppress the fire at early stage.

2.2 Performance test

For the performance test of automatic fire extinguishing system, 2 cases of a full-scale fire test was conducted and the detail thereof is as follows.

In Case 1, fire extinguishing system was set 30m away from the fire source and according to fire scenario, fire was ignited on driver seat to simulate the fire in vehicle and the system started spraying (directly) in 2 minutes to suppress the fire.

In Case 2, fire extinguishing system was set 10m away from the fire source and according to fire scenario, fire was ignited on battery seat to simulate the fire in engine room and the system started spraying (directly) in 4 minutes to suppress the fire.

Fig. 3 Automatic monitor system

Fig. 4 Pump station and water tank (5ton)

3. Test result

3.1 Case 1: vehicle fire started from driver seat (30m away from fire extinguisher system)

This test was conducted to verify the performance at the maximum distance allowed at a 40m-long tunnel building at the Korea Institute of Constriction and Technology (10m was used to install the system). Given the characteristics of vehicle fire, maximum caloric value was expected in 100 to 150 seconds after ignition (J.O Park, 2016) and thus the system started spraying the fire water in 115 seconds. As expected flame was developed to the ceiling from the seat and the water was sprayed at 1000L/minutes and consequently, fire at the bottom of the vehicle and seat was mostly suppressed within 2 minutes so as to prevent the fire from spreading to engine room. Fire on ceiling of the vehicle which is difficult to suppress because of the water spray in parabolic form, making it difficult to reach, was also prevented from spreading to engine room. But considering the increased control range at the long distance, control motor with sufficient precision will be required for precise spray at early stage.

(a) The system started spraying (directly) and terminal pressure

(b) 115sec : Start of water injection

(c) 238sec : Fire suppression at bottom inside vehicle

(d) 355sec : Stop of water injection

Fig. 5 Real scale fire test for passenger car (CASE 1)

3.2 Case 2: vehicle fire started from engine room (10m away from fire extinguisher system)

This test was conducted to verify the performance at 10m and to simulate the fire in engine room, ignition was made on battery connection. Given the late spreading than the fire in vehicle, the system started spraying in 260 seconds after ignition at 1000L/minutes. The flame visible was suppressed in 10 seconds after spraying and since the part of fire in engine room was not visible, spray (direct) was lasted for a minute and consequently the fire was quickly suppressed which was attributable to injected water into the gap on hood and engine room which were set for the test. The shorter the distance the more precise water spray was achievable, making the fire suppression maximized.

(a) Ignition position and terminal pressure

(b) 256sec : Start of water injection

(c) 265sec : Fire suppression at engine room

(d) 320sec : Stop of water injection

Fig. 6 Real scale fire test for passenger car (CASE 2)

4. Conclusions

In this study, automatic fire extinguishing system designed to delay the fire spreading at early stage as well as to suppress the fire finally depending on situation was developed in a bid to cope with the particular characteristics of the fire in a double-deck tunnel for fire safety and the performance was verified through the full-scale fire test. In case of the fire inside the vehicle, it effectively suppressed the fire on seat (at the bottom inside the vehicle so as to constrain the fire from spreading to engine room as well as isolate the fire on ceiling which is difficult to suppress which resulted in preventing the fire from spreading to other parts of vehicle.

In case of fire in engine room, the fire was successfully suppressed within 10 seconds by the water penetrated into the engine room through the gap. Such results indicated the importance of precise water spray and the fire occurred in damaged engine room as a result of vehicle collision would be efficiently suppressed by the water penetrated through the gap.

Acknowledgement

This research was supported by Development of Design and Construction Technology for Double Deck Tunnel in Great Depth Underground Space (14SCIP-B088624-01) from Construction Technology Research Program funded by Ministry of Land, Infrastructure and Transport of Korean government.

References

Y. H. Yoo, H. J. Shin and C. H. Nam (2008), "The study of ventilation system during fire in road tunnel with bi-directional or congested unidirectional traffic", *Proc. Summer Conference of the Society of Air-Conditioning and Refrigerating Engineers of Korea*, 474-479.

J. K. Yoon (2011), "A Study of the Heat Release Rate of Tunnel Fires and the Interaction between Suppression and Longitudinal Air Flows in Tunnels", *Ottawa-Carleton Institute of Civil and Environmental Engineering*, Canada.

H. G. Kim and C. W. Lee (2004), "A study on the relationship among traffic accidents, fire occurrences and tunnel characteristics in local road tunnels", *Journal of Korean Tunnelling and Underground Space Association*, **6**(3), 199-211.

M. K. Cheong, M. J. Spearpoint and C. M. Fleischmann (2008), "Design Fires for Vehicles in Road Tunnels", *Proc. 7th International Conference on Performance-Based Codes and Fire Safety Design Methods*, 229-240.

J. O. Park, Y. H. Yoo, H. S. Kim and B. J. Park (2016), “Experimental Study on the Fire Behavior in Double Deck Tunnel", *Fire Science and Engineering*, **30**(2), 75-80.