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Early Response System and Improvement of Fire Safety Performance In Dae-gu Subway Disaster.

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Abstract

Dae-gu subway fire was the largest fire accident in 30 years of Korean subway history which culminated in 339(192 death, 147 wonded) casualties and 520 million won financial loss. There are reasons for this catastrophic Dae-gu subway accident. First of all, inadequate preparation of fire fighting system for early prevention, and failure of communication between train drivers and operation controller caused substantial delay in evacuation process, allowing fire to propagate to another rolling stock approaching from opposite direction. Secondly, extremely inflammable and toxic nature of interior materials of rolling stock made passengers suffocate badly during evacuation and also made fire propagate to the adjacent train. Thirdly, lack of capacity of smoke control equipments, hydraulic extinguishers and emergency guide lights to adapt to big scale fires meant the existing emergency facilities were inadequate.
This paper proposes to discuss defects in the current emergency systems and offers solutions such as fire-proof rolling stock cabin materials and detailed improvement plans of subway safety facilities for prevention of further fire accidents like Dae-Gu fire.

1. Introduction

Dae-gu subway incendiary fire was a very rare accident. It was initiated by a person with mental disorder. This accident resulted in 192 deaths and 147 injuries with 520 million won's (109M₩ rolling stocks, 411M₩ subway station) of financial loss.

The possible causes of this massive fire accident can be analyse from three different perspectives. Firstly, the subway emergency operation system had been neglected,

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ignoring possibilities of fire in the rolling stock cabin because it never happened before in Korean subway history. Dae-gu fire could not have been foreseen and was responded with inadequate early prevention methods.

Secondly, although the rolling stocks were constructed using a selection of non-flammable materials, they were still rather susceptible to fire.

Lastly, fire control and evacuation systems such as smoke controls, detection systems and hydraulic extinguishers were ineffective because of the large scale of heat flux and impaired visibility by thick smoke and particles in the air.

It is worthwhile to review the current emergency response system chronologically and from multiple perspectives of different scenes of the accident. This paper will particularly analyse emergency response system between operation controller and driver and will suggest that non-flammable cabin materials of rolling stocks and better subway fire safety facilities need to be introduced.

2. Chronological overview of the accident

The fire was deliberately set by igniting 4 liter gasoline in a pet tube container at 9:52 AM. It is estimated to have taken approximately 8 minutes to burn down the entire rolling stock compartment. From the result it can be seen that the first 8 to 10 minutes of the accident was a very critical time, as an effective early stage response could have reduced the extent of the damage that was caused by the fire.

The chance of reducing the damage by fire or even avoiding the accident would have been greater (approx 5-6 times) if the emergency operation system had been correctly set up and operated effectively, and if the driver and the operation controller made quick judgments and reacted spontaneously towards the outbreak of fire.

For instance, at 9:52 the passengers at 1079 had opportunity to physically suppress the arson from setting fire. The 1080`s driver could have stopped the vehicle when it approached the neighbouring terminal when he noticed the smoke.

The operation controller and both drivers could have let the doors of the rolling stock open for immediate evacuation, but due to hesitation and indecision, more casualties resulted. At 9:54 the fire alarm reported to the operation controller. However, he ignored it because he took it as a false alarm. At 9:56 the 1080 train from the opposite direction arrived next to the burning compartment of the rolling stock 1079 and fire spread from 1079 to 1080 at 9:59.

Between 10:00 and 10:06, the power supply was cut down at the rail, platform and the entire station area as the fire grew bigger, making the situation more difficult to control.

The fire brigade attempted to access platform at 10:00 but they failed to get down to the underground levels because of impaired visibility and breathing disorder due to thick toxic smoke.

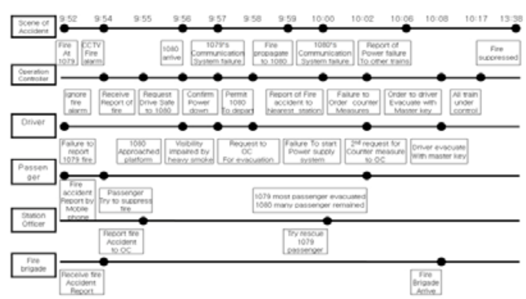

Figure 1. Accident situation stages.

3. Emergency Response System

3-1 Dae-gu Subway fire case

Dae-gu subway fire can be analysed in two stages: fire at rolling stock at platform and extension of fire in rolling stock in tunnel.

In the first stage, the driver should have reported the fire to the operation controller and waited for an appropriate order before moving the train to the nearest station.

He also should have informed the situation to the passengers and attempted to extinguish the fire when the rolling stock arrived at the platform, with the aid from the subway fire brigade unit, while at the same time conducting spontaneous evacuation for passengers.

Also the drivers should have attempted to suppress fire with passenger by using potable foam extinguishers upon operation controller`s command. The driver should not have, moreover, moved the train without a command from the operation controller.

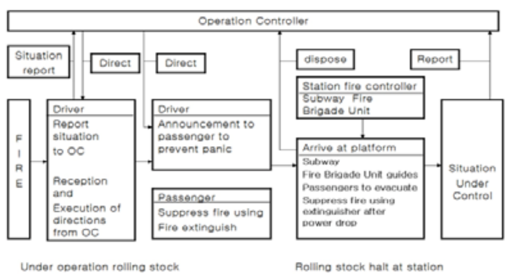

Figure 2.Emergency response for fire at rolling stock.

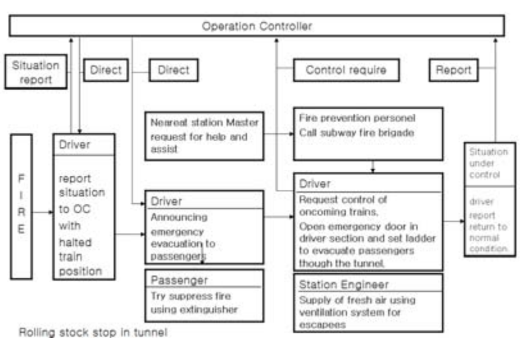

Figure 3.Emergency response for rolling stock in tunnel fire.

3-1 Comparison between Daegu fire and Nagoya Subway fire

The study of Japanese emergency response procedure shows that most of early response judgement and action is made by the driver. He orders shut down of a power transformer and departure of stationed trains at the neighbouring station, while at the same time calling fire brigade and police.

This is followed by operation controller's order for passenger evacuation, and then order to the driver to attempt to suppress fire.

In the meanwhile the stationmaster and staffs close the entrance to the station and rescue the wounded.

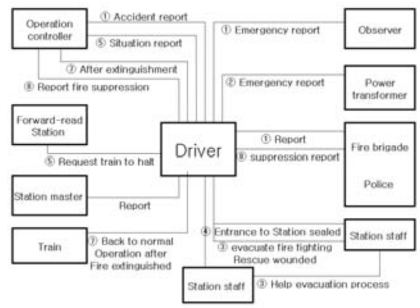

Figure 4.Nagoya subway fire emergency response procedure.

By contrast, Dae-Gu emergency system relies heavily on the driver's action, needing him or her to attempt suppressing fire first, before evacuating passengers.

In Japanese system passenger evacuation comes first. Of course the driver should follow operation controller`s order, but mostly situations are such that driver's judgment is more prevalent than the order from the operation controller.

This is so because the Japanese emergency manual indicates drivers have more responsibility than anyone else at the scene of the accident. This is something the Korean subways safety and emergency manual need to follow as a guideline for better safety response in the future.

4. Analysis of Fire propagation, Fire protection and evacuation facilities

4-1 Fire propagation

Initially, the fire at Dae-Gu subway started by use of 4 liters of gasoline. The fire was lit on seat cushion, climbing through side wall. Soon after the ignition the flame reached ceiling and engulfed entire cabin followed by fire simulation FDS 3.1

Approximated, the fire developed beyond control within 220 seconds, and in the next 200 seconds engulfed the entire compartment.

The propagation of fire from one compartment to another is assumed to have been caused by the opened connection door with its cover tent and broken windows. On the other hand, fire propagation from 1079 to 1080 was accelerated by the rush of air caused by the 1080 train approaching the platform within the narrow tunnel space. It took 2 minutes and 15 second to propagate the fire to another rolling stock since the 1080 arrived at platform. The total firepower from the rolling stocks is estimated to be about 10~20MW. This estimation is made through investigating cracks, peelings and exposures of re-bar from concrete ceiling. Such structural damage happens only under extreme conditions of long time exposure to 500℃ of thermal heat.

The major reason for the fire propagation can be attributed to the interior materials used in the rolling stocks. The ceilings and interior side walls consist of FRP; the floor is PVC(KSM3305); seat cushion is urethane foam(FMVSS302); and heat insulating material, polyethylene (KSM3808, FMVSS302).

The ignition point of these materials is approx 320~399℃, which is 60~140℃ lower than wood stocks. In terms of chemical composition these materials contain CO 10 times more than wood stocks. They also contain highly toxic material of HCN and produce, upon ignition, micro-particles of high density shoot compound.

Presumably these interior materials for rolling stocks met the required KS (Korean Standard) for fire radiation capability during the initial stages of manufacturing. However, these standards were not adequate in accurately assessing the fire power in actual situations, as toxicity and smoke quantity had not been accounted for.

4-2 Analysis of Fire safety facilities

- *Fire extinguisher*

The usual practice is that two ABC type potable dry chemical extinguishers are located at each rolling stock compartment. It seems that when the fire expanded and propagated so quickly because it was initiated by large amount of liquid gasoline, deliberately set, these fire extinguishers could not provide effective measures to control the fire.

- *Indoor hydrant*

The underground (3rd level) indoor hydrant is located every 25 meters along the platform. There was no sign of its use, mostly due to lack of training and knowledge of how to use it by station operators and drivers in case of fire emergency.

- *Smoke control*

Most victims were presumably killed by suffocation through toxic smoke inhalation. The smoke control system did not work properly because the fan cover melted down with exposure to high temperatures. Hence, only the air ventilation ducts collected smoke particles, however, this was insufficient as the duct size was too small.

- *Fire shutter*

The fire shutter between subway entrance and the shopping center at underground level one is made up of rolling steel fire door type. When the evacuated passengers reached the subway entrance to escape, the fire shutter automatically functioned, and blocked the way out.

Many people died and suffocated right at this scene of accident, where they could have safely escaped if the fire shutter did not block their way out. People could have escaped through a small secondary emergency exit, which was installed at the corner of the shutter. However, the exit door only opened in one direction and casualties resulted.

Although Korean subway station's fire protection system standards did not fulfill international standards, even ISO, NFPA and BS codes only consider the fire power in the case of a fire in one compartment of the rolling stock. Hence, following international standards would not have helped in responding to the fire at Dae-Gu subway station, as the fire spread to all twelve compartments. We believe this is a matter to be considered for future developments in international standards.

4-3 Problems of communication and evacuation facilities.

A more critical problem that resulted in further difficulty in this emergency case was the communication failure between the driver and the operation controller which resulted in delay of their judgments and lost chance in early stage of successfully having the situation under control. Clear and immediate communication with full appreciation of severity of the situation is really important in emergency situations. The emergency guide light and search light could not have been noticed by evacuees properly for impaired visibility in thick smoke and also because the evacuation guide signage on the ceiling melted down due to exposure to high heat radiation.

5. Future directions for safety improvement

To build more effective and proper emergency response systems in response to fires like Dae-Gu fire, the Subway Safety Task Force suggests following counter measures.

5-1 Protection / response improvement

- Introduction and improvement of manual emergency response training
- Driver's license renewal system.
- Safety guards and patrol on each platform and train.
- Certification of safety standards of subway stations
- Public education of safety procedures and safety issues (e.g. how to escape from railway vehicles, manually)

5-2 Legislative reform of Safety system

- Safety management regulations for urban railway plan
- Reform rolling stock safety standards
- Set new safety standards for subway station and tunnel
- Set up Accident Inspection Committee and safety organizations

5-3 Safety improvement

- Automatic suspension system in response to approaching vehicles
- Improve safety standards of interior materials; improve fire extinguisher quality
- Universalized manual emergency door system and interphone systems
- More funding for collision, derailment and fire safety tests at lab

5-4 Strengthen emergency facilities

- Multi-communication system between train, station, operation controller and CCTV
- Smoke control, hydraulic extinguisher
- Improve standards of induction light, emergency light and tunnel evacuation facilities

6. Conclusion

In conclusion, early stage response to the fire is very crucial since it can prevent the accident once and for all with ease. However, once the fire expands to grow bigger beyond control, it is inevitable that there will be many casualties as a result. Therefore, the priority here is to improve and prepare better early stage prevention mechanisms in case of fire, which can be accelerated by legislative reform.

The plan should be feasible in terms of both cost and technicality. The Korean government should invest $1308M (USD) to proceed with 75 newly recommended improvement plans and regulations during the next 5years period, including primarily the change of interior fittings of existing subway rolling stocks.

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