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REPORT

Investigation into the fire in the Heinenoordtunnel on 21 May 2014

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1. INTRODUCTION

On May 21th 2014 a truck crashed into a wall of the Heinenoord tunnel near Barendrecht, The Netherlands and caught fire. The truck driver died in the accident and two people who were involved in the accident got injured. The tunnel was closed for traffic for almost 19 hours. This caused a 100 km long traffic jam in the area of Rotterdam.

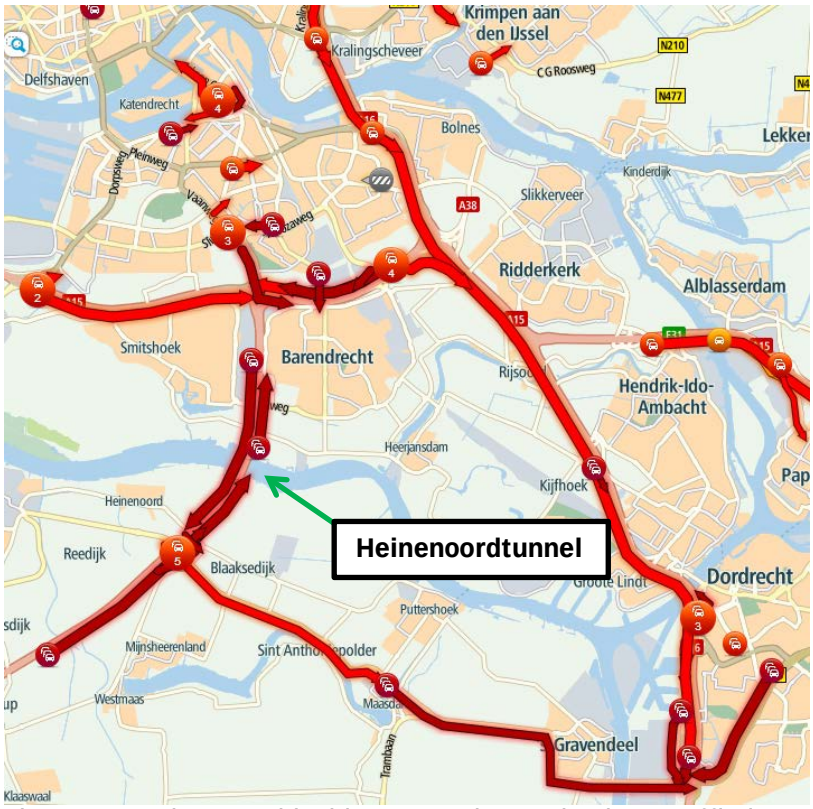

Figure 1 The tunnel incident caused a 100 km long traffic jam. (source: www.hulpverleningsforum.nl)

Efectis (on its own initiative) responded to the incident on May 21th and started an investigation with the permission of the owner of the tunnel, Rijkswaterstaat and the Rotterdam-Rijnmond Fire Department. Although Rijkswaterstaat allowed Efectis to investigate this fire and this report was reviewed by Rijkswaterstaat, they are not responsible for the contents of this report.

1.1 PURPOSE OF THE INVESTIGATION

Efectis investigated the fire to collect data about tunnel fires, to analyse the fire development and to assess the performance of the tunnel lining and the effect of the longitudinal ventilation system.

1.2 DESCRIPTION OF THE INVESTIGATION

Efectis investigated the fire on site at the tunnel on May 21th around 17:45hr. Pictures of the damage were taken and information from the Fire department was obtained.
Through contacts at Rijkswaterstaat, the Fire department and the contractor Imtech[1], more information was gathered about the incident, the damage and the performance of fire safety measurements.

[1] Involved in tunnel repair

Based on information about the fire load and the duration of the fire, the heat release rate was estimated.

The performance of the fire fighting equipment in the tunnel and the efficiency of the fire departments attempt to fight the fire are not a part of this investigation.

2. INFORMATION

2.1 THE HEINENOORDTUNNEL

The Heinenoordtunnel was opened in 1969 as part of the highway A29 near Barendrecht[2].
The tunnel is an immersed tunnel under the river "Oude Maas" that was built in sections of 8,8 meter high, 30,7 meter wide and 115 meter long and gives room to 2x3 traffic lanes. The tunnel has a length of 614 meters and is used by ±85.000 motor vehicles/day[3].

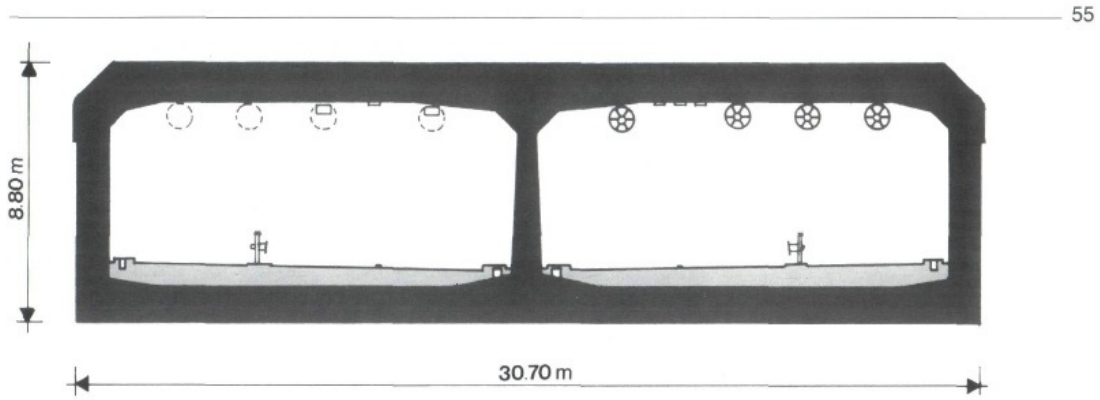

Figure 2 Cross section of the tunnel (The lanes and the barrier in picture are not up to date. The tunnel has 3 highway lanes. The concrete barrier is placed near the wall in the middle of the tunnel to provide an escape path)[4]

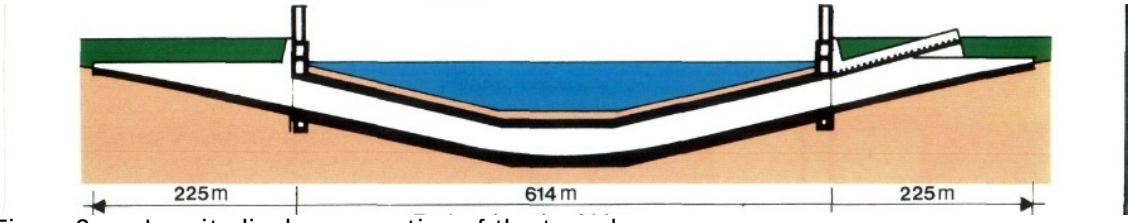

Figure 3 Longitudinal cross section of the tunnel

Along the wall in the middle of the tunnel concrete barriers are placed on both sides to create an 1,25 meter wide evacuation path. Every 100-125 meters an escape door is positioned in the middle wall.

The tunnel is, amongst others, equipped with a longitudinal ventilation system, a public address system, emergency phones and fire hoses. The lights on the tunnel roof are made of LED's. Illuminated green signs point to the nearest escape door and the fire fighting equipment.

[2] http://www.wegenwiki.nl/Heinenoordtunnel
[3] Statistics from 2010
[4] Tunnels in the Netherlands : underground transport connections, Ministry of Infrastructure and Environment

Figure 4 Fire fighting equipment and escape route signs

2.2 THE INCIDENT

At 13:30:51 on May 21th the Fire department was alarmed for a fire in the tunnel. According to an eye witness[5] a tyre of the truck (a Mercedes-Benz Actros 1841 LS[6]) involved in the accident blew up. The truck zigzagged and drove into the concrete barrier and the tunnel wall on the left side. After hitting the wall the truck turned over and caught fire. In the crash the truck hit another car (Ford Fiësta, 2013). The truck slided while burning over approximately 100 meters through the tunnel and stopped blocking 2,5 lanes of the tunnel. The car that was hit by the truck turned upside down right behind the truck. The driver and passenger of the car got out on their own with severe (burn) injuries. The truck driver died in the accident.
Figure 5 gives an impression of the situation short after the accident. Figure 6 gives an impression of the amount of smoke produced by the fire.
The truck stopped near the middle of the tunnel. Traffic in front of the truck was able to exit the tunnel. The traffic behind the truck came to a halt. Through the PA system people were instructed to leave their car and exit the tunnel. The eye witness is a public bus driver who entered the tunnel right behind the truck. He describes a calm evacuation. According to the bus driver people were following instructions.

According to the camera images from the tunnel, the fire lasted for about 31 minutes. The cabin of the truck, the container floor, the truck tyres, the (diesel) fuel and the front of the car were consumed by the fire. The cargo load of the truck in the 40'container consisted of drums filled with salt, stacked on wooden pallets. Most of the wooden pallets and the drums were consumed by the fire. The salt was still in the container.

[5] http://youtu.be/5WRKdVZAaKc (The eye witness is a public bus driver who entered the tunnel right behind the truck.)
[6] Fire department Rotterdam-Rijnmond / Rijksdienst voor het wegverkeer

Figure 5 Picture of the fire in the tunnel. (source: Twitter account Richard Hoogeveen, @RichardMaasdijk)

Figure 6 Smoke at the tunnel south exit (source: www.hulpverleningsforum.nl)

Figure 7 gives an impression of the situation in the tunnel after the accident.

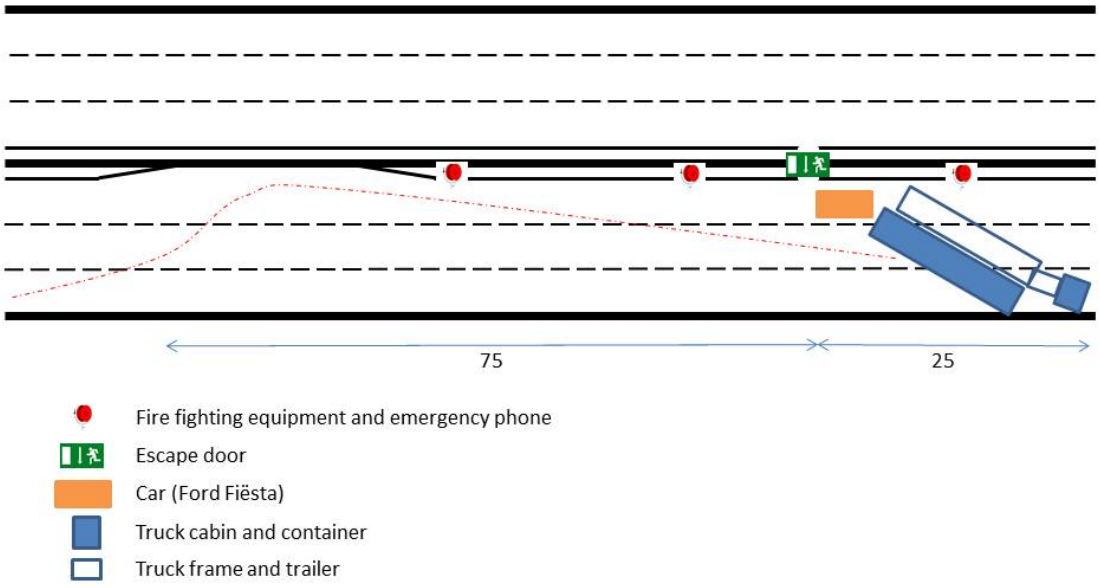

Figure 7 Schematic situation in the tunnel after the accident

Figure 8 Remains of the truck cargo load.

2.3 OTHER INFORMATION

2.3.1 Fire load

The fire load consisted of the truck and trailer and half the car.
The following information was obtained about the truck and the trailer.
Truck:

Brand: Mercedes-Benz
Type: Actros 1841 LS
Fuel: diesel (430 litre)
Empty weight: 7150 kg
Tare weight: 7250 kg
Gross weight: 18600 kg
cylinder capacity: 11946 cm3
Power: 300 kW (408 hp)

Parts of the truck like the dashboard are made of plastics. Based on information from Daimler-Mercedes a maximum of 8% of the truck consists of plastics and other material than metal, tyres and fuel.
The tyres are mainly made of rubber with a mass of about 70 kg (estimated). There were 6 tyres on the truck.

Trailer and container:
3 axles = 6 tyres
Wooden floor (trailer floors are constructed out of bamboo or laminated wood). For this investigation the floor is assumed to be constructed out of laminated wood with a thickness of 30mm. Most floors are constructed of hardwood[7]. For this investigation a density of 700 kg/m^3 is assumed)
Estimation of the cargo load:

- 20 Euro-pallets
- 360 cardboard or fibre drums filled with salt (The empty drums are estimated to weigh about 3 kg each)

Car:
For the car an average amount of energy based on earlier research[8] is used.

Object	**Mass (kg)**	**Total Energy (MJ)[9]**
Plastics on the truck	572	17.732
Tyres on the truck	420	11.760
Diesel fuel	360 (worst case)	15.120
Trailer floor	590	9.912
Trailer tyres	420	11.760
Trailer load (pallets)	480	8.380
Trailer load (cardboard or cellulose fibre)	1.080	17.604
½ Car (Ford Fiësta)	n/a	2.625
Total		94.893

2.3.2 Tunnel protection and damage to the tunnel

The tunnel roof and the upper parts of the walls are protected with a 27,5 mm thick PROMATECT-H lining. The lining is mounted in 1990. The longitudinal tunnel ventilation system was on during the fire. The picture in figure 5 shows that the part of the tunnel behind the truck is clear of smoke, while flames are visible in the entire tunnel cross section. Smoke is pushed to the tunnel exit on the south side (figure 6). The damage patterns on the

[7] Information about the construction of containers was obtained from CETEM Containers (www.cetem.com)
[8] CTICM, ARBED Recherches, TNO, July 1998, Demonstration of real fire tests in car parks and high buildings. Daniel Joyeux, August 1997, Natural fires in closed car parks.
[9] Deel 2: Toepassingsinstructie BVB 2007, bijlage A, Save, April 2007.

wall next to the truck cabin also indicate the influence of longitudinal ventilation. Figure 9 gives an impression of the damage pattern on the tunnel wall. The damage extends in the direction of the airflow.

Figure 9 Damage pattern on the tunnel wall

The red lines in figure 9 give an indication of the shape of the damage.
In the direct vicinity of the truck cabin the concrete wall showed damage due to spalling. A maximum spalling depth of 2,5 cm was measured (figure 10). The concrete showed a buff discolouration, which indicates temperatures[10] reached more than 1.000 °C. The discolouration of the concrete was only visible around the cabin and can be explained by direct flame impingement.

[10] Principles of Fire Investigation, Institution of Fire Engineers, Roy A. Cooke, Rodger H. Ide, 2006

Figure 10 Spalling of concrete

Figure 11 The tunnel lining directly over the cabin shows a clean burn.

Directly over the cabin and in front of the cabin a clean burn pattern was visible on the tunnel lining. The lining has a black appearance along the length of the tunnel (this is probably due to sooth from traffic) . Due to the fire the black layer of sooth directly above the cabin of the truck was burned off.
Figure 11 gives an impression of the lining on the tunnel wall and roof directly over the cabin. In this picture you can see the remains of a speaker of the PA system. The speaker was consumed by the fire.

An indication of the thickness of the smoke layer in the tunnel during the fire can be found in figure 9. The black rectangle on the left side of the picture is an escape route sign. This sign is totally covered in sooth, which indicates that the smoke layer was at least as low as 1,2 meters above the road surface. In figure 11 a sign above a fire extinguisher placed on the tunnel lining is not covered in sooth (on the bottom right side of the picture). This gives an indication that there was no or just a thin smoke layer on the up wind side of the truck.

In figure 12 the damage to the barrier and the left tunnel wall due to the crash is visible.

Figure 12 Damage to the barrier and the left tunnel wall due to the crash

On the tunnel roof a lighting system was installed consisting of LED lights. Most part of this lighting system was still working after the fire. Some parts were melted or soothed. In figures 13 and 14 the damage to the lighting system is visible in an overview of the accident area in the tunnel.

Figure 13 Overview from behind the truck. Large parts of the lighting system are on after the fire

Figure 14 Overview from the front side of the truck

The contractor who repaired the tunnel after the fire stated that the electric wiring behind the PROMATECT-H tunnel lining showed no damage.

3. ANALYSES

3.1 HEAT RELEASE RATE

Based on the duration of the fire and the estimated amount of materials consumed by the fire it is possible to calculate the heat release rate during the fire.
From the analysis in paragraph 2.3.1 a total amount of energy of 94.893 MJ was present in the tunnel. Most part of this "fuel" was consumed by the fire. Part of the pallets in the container were still visible. The amount of fuel burned is estimated to be 90%.
The heat release rate is calculated based on a total amount of energy 85.404 MJ.

Efectis was allowed to watch the video footage from the CCTV system in the tunnel. In this video it is visible that the fire grew quickly (within one minute) directly after the crash. This rapid fire development can only be explained by a ruptured fuel tank. The hypothesis of a ruptured fuel tank is confirmed by the fact that just after the crash a reflecting surface (pool of fuel) is visible between the truck and the car behind the truck (based on video footage).
The fire department was alarmed at 13:30:34 and the first attempt to extinguish the fire was made around 13:46. It is estimated that between the crash and the alarm 2 minutes passed by.
The previous analysis leads to a fire curve that grows to a maximum in 1 minute and maintains about the same rate of heat release (HRR) during 18 minutes. The fire lasted for a total of 31 minutes.
Within the remaining 12 minutes the fire decayed and was extinguished by the fire department.
The peak output of the fire is estimated to be between 50 and 65 MW. In figure 15 the estimated fire curve is given.

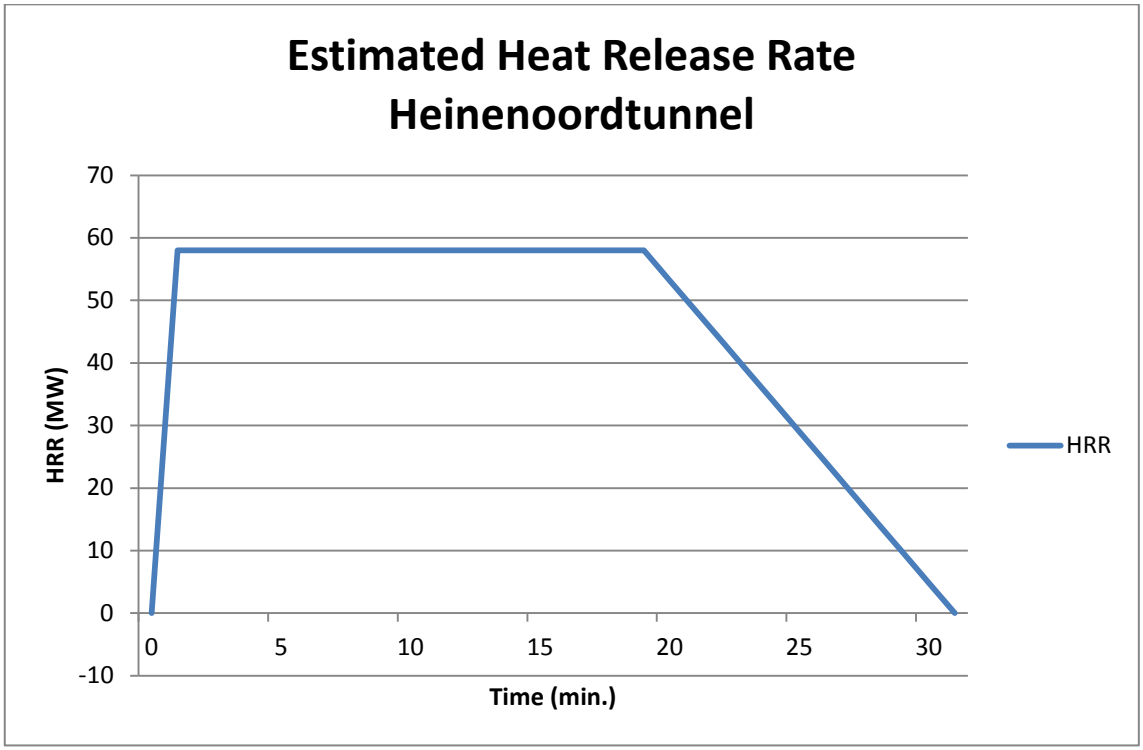

Figure 15 Estimated fire curve

3.2 PERFORMANCE OF THE TUNNEL LINING

From within the tunnel the PROMATECT-H lining showed no visible damage. After editing the photo used in figure 11 it became visible that some parts of the tunnel lining were cracked. It is not possible to determine whether these cracks are a result of the fire or were present in the lining before the fire occurred.

3.3 PERFORMANCE OF THE LONGITUDINAL VENTILATION SYSTEM

On the video footage no back layering of smoke is visible. The smoke stain on the tunnel ceiling and walls indicate that the ventilation system in the incident tube was functioning properly. The fire department communication was hindered by the sound level of the ventilation system.
It is safe to state that the ventilation system in the incident tube was functioning the way it should during the fire.

Almost no heat damage occurred beyond 40m from the fire (downstream). Up to 60 m beyond the burning truck there was more damage and pollution to the installations in the tunnel. Although all systems remained functional, the damage and smoke pollution in and on the installation makes a replacement in due time over a total length of 200 m necessary.
The tunnel cross section behind the burning truck was filled with smoke which indicates a laminar flow through the tunnel cross section.

3.4 EVACUATION

The evacuation is visible on the video footage. On youtube an interview with a bus driver, who stopped right behind the accident, can be found (reference in paragraph 2.2).
Traffic stopped directly behind the truck and the car involved in the crash. At first some cars backed up and one van turned around.
The professional drivers (two public bus drivers) initiated an evacuation and through the PA system people were told to leave their car and exit the tunnel. The evacuation went calm and in order.
The two victims in the car managed to escape the burning vehicle. When the fire department arrived they walked towards the fire truck and were treated for burn injuries by the first arriving fire fighters.

4. CONCLUSION

The PROMATECT-H tunnel lining protected the tunnel during the fire. The tunnel lining was still in place and performed as expected.

The estimated heat release rate of the fire (max. 58 MW) and the duration of the fire is below the design criteria of the tunnel.

The longitudinal ventilation system mixed smoke and cool air which led to relative low temperatures just behind the burning truck and prevented heat damage to the tunnel lining and the functionality of the tunnel installations. Further downstream the installations were more damaged and polluted which makes replacement in due time necessary.
The ventilation system prevented smoke from flowing upstream and made a safe evacuation and safe fire fighter operations possible.

The P.A. system made a smooth evacuation possible. The incident made clear that the presence of professional drivers helps in an emergency situation to speed up the evacuation.

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