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Tunnel Fire in Heinenoord Road Tunnel, The Netherlands: Safety Installations Response and Human Behaviour

On 21 May 2014, an accident occurred in the Heinenoord Road Tunnel resulting in a fire of approx. 50 MW. The tunnel surveillance cameras recorded the event, which has made it possible to analyse not only the accident itself but also the events following the accident. This article describes these events and analyses the behaviour of the people present in the tunnel at the time of the accident, the actions taken by the tunnel operator and the response of the tunnel safety installations. Based on the analysis, lessons are drawn regarding human behaviour during evacuation and the role and the effectiveness of the tunnel installations.

Brand im Heinenoord Straßentunnel, Niederlande: Sicherheitstechnik und menschliches Verhalten

Am 21. Mai 2014 ereignete sich ein Unfall im Heinenoord Straßentunnel, der ein Feuer von rund 50 MW auslöste. Die Überwachungskameras im Tunnel zeichneten das Ereignis auf, wodurch es möglich wurde, nicht nur den Unfall selbst, sondern auch die Folgeereignisse nach dem Unfall zu analysieren. Dieser Artikel enthält eine Beschreibung der Ereignisse und analysiert das Verhalten der im Tunnel zum Zeitpunkt des Unfalls anwesenden Personen, die vom Tunnelbetreiber ergriffenen Maßnahmen und die Reaktionen der Tunnelsicherheitseinrichtungen. Aus der Analyse werden Erkenntnisse über das menschliche Verhalten während Evakuierungen und die Rolle und Wirksamkeit der Tunneleinrichtungen abgeleitet.

1 The accident

On 21 May 2014, an accident occurred at 13:28 in the Heinenoord Road Tunnel (Highway A29) near Rotterdam in The Netherlands, resulting in a fire of approx. 50 MW.

The accident was caused by a tyre collapse (Figure 1) resulting in a driver losing control of his truck. Due to the loss of control, the truck hit the barrier and the tunnel wall and burst into flames almost immediately (Figure 2). The truck was carrying 20 t of salt (KCl) and a considerable amount of fuel (diesel). As can been seen in Figure 2, a car with two people inside was caught up in the accident. The two people in the car were able to rescue themselves, but unfortunately the truck driver lost his life.

2 The Heinenoord Road Tunnel

2.1 General information

The Heinenoord Road Tunnel is an immersed tunnel under the River Oude Maas close to Barendrecht, a suburb of the city of Rotterdam. The tunnel, with a total length of 1,064 m, was

Figure 1 Tyre collapse

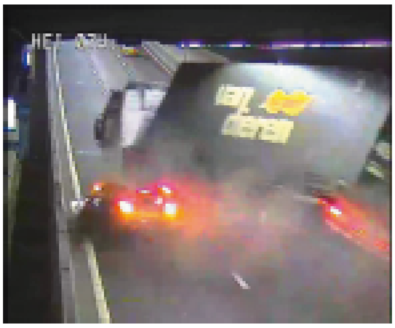

Figure 2 Accident happening

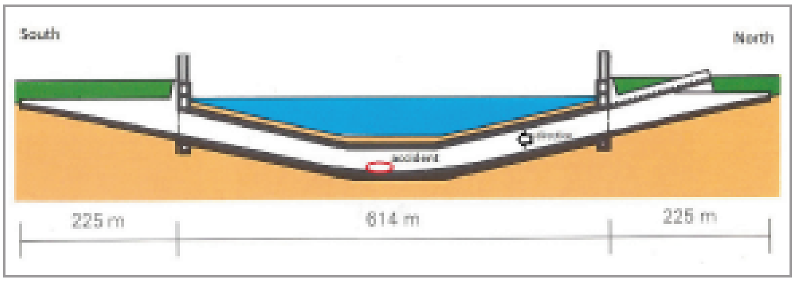

Figure 3 Longitudinal section (west tube) of the Heinenoord Road Tunnel

commissioned in 1969 and has a closed section of 614 m. The total width of the tunnel is 30.70 m accommodating two tubes, each with a width of 13.75 m. There is no service tunnel between the two tubes. The original use of the tunnel also included slow traffic but this was changed in 1994 after the construction of a separate tunnel for slow traffic. After completion of this new tunnel, the cross-section of the Heinenoord Road Tunnel was converted into a highway tunnel with 2 x 3 lanes.

Today approx. 41,000 vehicles per direction use the tunnel each day. The tunnel is a Category D tunnel, which means bulk transportation of petrol and diesel oil is prohibited. Figure 3 shows the longitudinal section of the tunnel.

Unlike most other Dutch road tunnels, the two tubes are only separated by a wall, so the escape route, when the emergency doors inside the tunnel are used, leads directly from one tube into the other. The emergency exits are located at no more than 100 m intervals. When an accident occurs in one of the tubes, the other tube will be closed during the execution of safety procedures to provide a safe area for people who use the doors. To make sure there is a safe escape route even when there is still traffic, barriers are placed in both tubes as can be seen in Figure 4.

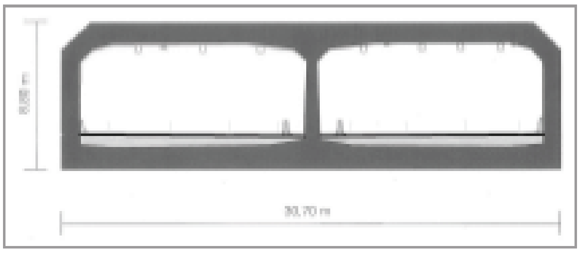

Figure 4 Cross-section of the Heinenoord Road Tunnel

2.2 Tunnel installations

The Heinenoord Road Tunnel is equipped with a number of installations of which the most important are:

- Longitudinal mechanical ventilation,
- Visibility sensors for smoke detection,
- Traffic motion detection (stopped vehicles, drivers in the wrong direction, etc.) using cameras,
- Traffic lights and boom barriers to prevent cars from entering the tubes in case of emergency,
- CCTV for monitoring the tunnel,
- A fire repression system consisting of a water reservoir and pumps, fire hoses and Storz connections at the emergency posts,
- PA System for broadcasting an evacuation message in the incident tube,
- HF/C2000, this system provides access to the communication network for emergency responders. It also sends the message that is broadcast over the PA system to car radios by "overruling" regular broadcasting.

The tunnel is also subject to Motorway Traffic Management. A motorway traffic control centre, situated in Rhoon, is responsible for managing processes like traffic management, tunnel safety management and emergency and contingency planning for the Heinenoord Road Tunnel and nine other tunnels in the region.

3 The events following the accident

3.1 General

As the Heinenoord Road Tunnel has two separate tubes, each of which is used in one driving direction only, a certain amount of natural airflow is present. Due to this "natural ventilation", the smoke and heat flow starts in the preferred direction, meaning downstream where there is no traffic present. The cars downstream of the accident were able to continue because there was no congestion. Very soon the mechanical ventilation took over and forced smoke and heat out of the tunnel, providing protection against smoke and heat for those present upstream including the car that is involved in the accident. Also a number of measures are implemented due to the fact that the tunnel operator starts the emergency procedure by pushing the accident button for the tube in which the accident occurred.

3.2 Tunnel operator

By pushing the accident button, the tunnel operator sets in motion a number of automated actions:

- Ventilation in both tubes switches to the maximum level and the direction of the ventilation in the non-accident tube is changed to the same direction as the accident tube. This prevents smoke being drawn into the non-accident tube.
- The tunnel is closed in both directions; the non-accident tube is emptied and available for the emergency services and as a safe haven for people using the emergency doors.
- The tunnel lighting is set to maximum and highlighting of emergency doors is activated.
- The audio system of the tunnel starts broadcasting an evacuation message.

The tunnel operator informs the emergency services about the accident and tries to gather as much information as possible about the accident using the cameras.

3.3 People inside the tunnel

Based on information provided by the cameras in the tunnel, close to the accident and at the tunnel portal, the following observations can be made.

3.3.1 Close to the accident (crash happens t = 0 sec)

The car closest to the accident stops after a distance of approx. 18 m. After only 5 sec, the driver opens the door of the car and is gone after 19 sec. The driver obviously is aware of the danger and has little doubt what to do; the car is left behind, some personal belongings are taken and the driver flees (Figure 5).

All other vehicles inside the tunnel also come to a standstill and no further accidents occur. During the next minutes, the following events occur:

- A motorcyclist close to the accident is in doubt what to do. He rides closer to the accident, turns several times but finally decides to leave the tunnel on his motorcycle after almost 2 min (Figure 6).
- Close to the accident, two busses and several trucks are present. After 30 sec, the first people from the busses are seen to evacuate. After approx. 40 sec, the first cars start trying to reverse, which they do while people are already fleeing by foot to the tunnel portal using the traffic lanes. At first, nobody uses the evacuation route provided behind the barrier although the moving cars are creating an unsafe situation. Only when they come closer to the tunnel portal do some of them start to use the evacuation route behind the barrier. After approx. 1 min, cars are still trying to reverse and after 1.5 min people still seem to be in doubt what to do with their cars. They are reluctant to leave their car inside the tunnel or close to the accident.
- The truck is burning but thanks to the forced ventilation, no smoke and very little heat – only heat due to radiation – is present upstream of the accident. People seem to be unaware of the potentially dangerous situation caused by the fire. On the videos, it can be seen that truck drivers have to urge people in cars to leave their cars behind and evacuate the tunnel (Figure 7).

Figure 5 Passenger of car closest to accident flees

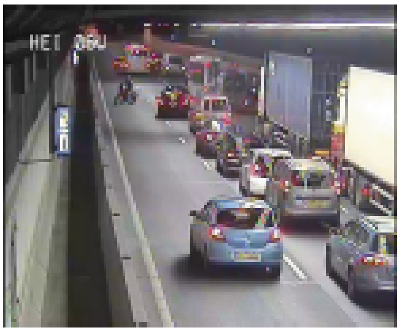

Figure 6 Motorcyclist in doubt

3.3.2 At the tunnel portal

At the time of the accident, the number of vehicles using the tunnel was moderate compared to rush hour. The traffic flow comes to a stop at the portal after approx. 15 sec (Figure 8).

Already after 40 sec, the first vehicles try to reverse and after 1 min and 40 sec the first people who were inside the tunnel at the location of the accident arrive at the tunnel portal, some of them now using the evacuation route behind the barrier (Figure 9).

4 Human behaviour: what do we see?

Observation of the behaviour of the people inside the tunnel and in sight of the accident show that little to no panic occurs.

The person closest to the accident (approx. 18 m) takes very little time to assess the situation as dangerous (5 sec), makes a quick decision to flee and is gone after 19 sec.

Other drivers, who have stopped inside the tunnel and also at a relatively close distance from the accident (approx. 30 m), have a good view of the situation and are in doubt. One curiosity is that the motorcyclist is clearly in doubt whether to help, leave the tunnel or instruct people. It is almost 2 min before the motorcyclist leaves the tunnel on his bike. Several drivers are reluctant to leave their cars and try to get away from the accident by reversing or turning their cars.

A great difference can be noticed regarding the behaviour of individual and professional drivers (busses and trucks) present near the accident location. The bus drivers almost immediately start in-

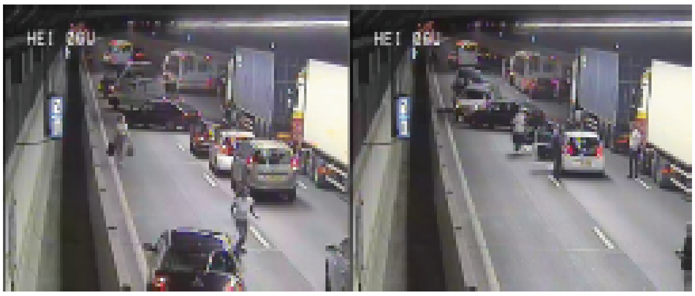

Figure 7 Cars trying to reverse, people fleeing and drivers in doubt

Figure 8 Tunnel portal at t = 0 sec (accident) and t = 15 sec when traffic stops

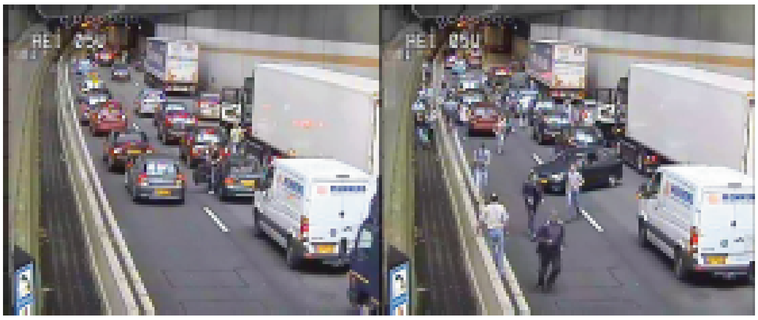

Figure 9 People arriving form the accident at the tunnel portal

structing their passengers to evacuate the bus and leave the tunnel. Only 30 sec after the accident occurred, the bus passengers were outside the bus and have started to walk towards the tunnel portal.

When the evacuation is viewed in more detail, the following can be noticed:

- Only after instruction by the professional drivers or from the tunnel speaker system do people inside the tunnel start to flee.
- There is a clear tendency to secure property: individuals fleeing are carrying bags and car drivers try to reverse or even take their cars with them when leaving the tunnel.
- This causes dangerous situations for the people fleeing by foot.
- Everybody is walking towards the light i.e. the tunnel portal. Only in the last part do they start using the space behind the barrier. Nobody uses the escape doors.
- After 1 min and 40 sec, the first people who were inside the tunnel close to the accident reach the tunnel portal. They have covered a distance of approx. 300 m.
- Also at the tunnel portal, various drivers try to reverse or even turn their cars, which led to the situation that emergency response units encountered cars driving in the wrong direction while trying to get to the accident.

How effective are the tunnel safety installations?

- Separate driving directions are not only important for road safety but also for tunnel safety because it makes longitudinal ventilation possible.
- Longitudinal ventilation is an effective tool to facilitate evacuation, to prevent escalation and facilitate the emergency services during repression.
- Longitudinal ventilation in this situation is thus effective to:
  - Safeguard people upstream of the accident
  - Limit damage to the tunnel due to rapid extraction of smoke and heat, which is beneficial for the availability of the tunnel after the accident. However it should be noticed that although heat and smoke were extracted by the ventilation system, some damage to the tunnel did occur, not at the location of the accident but damage to cables, lighting and PA system further downstream was observed and required repair
- Instructions over the loudspeaker system are necessary and effective to influence the behaviour of drivers when evacuation is required.

5 Final remarks

As expected based on earlier evaluations of tunnel fire accidents (Mont-Blanc Tunnel, Tauern Tunnel), little panic occurs after an accident takes place but people need clear instructions to initiate an evacuation process and to be persuaded to leave their personal belongings behind. The longitudinal ventilation is effective, at least for this type of fire and magnitude (approx. 50 MW) to safeguard people upstream of the accident and provide time for safe evacuation. The extended tenability of the situation close to the accident however leaves people in doubt what to do; whether to flee or to help. Again clear instructions are needed to initiate the evacuation process.