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Tank Trailer Fire in the Skatestraum Subsea Road Tunnel – Lessons Learnt and New Safety Measures

This paper describes lessons learnt from the tank trailer fire in the Skatestraum subsea road tunnel but also important relevant lessons from other large incidents in similar tunnels. The paper describes safety strategies and new regulations for the tunnels in Norway as a result of such incidents.

Brand eines Tankwagens im Skatestraum Unterwassertunnel – Erkenntnisse und verbesserte Sicherheitsmaßnahmen

In diesem Beitrag werden die Erfahrungen aus dem Brand eines Tankwagens im Skatestraum Unterwassertunnel dargelegt und in Bezug gesetzt zu anderen schweren Unfällen in Tunneln ähnlicher Größe. Des Weiteren werden Sicherheitsstrategien und neue Regelungen für Tunnel in Norwegen vorgestellt, die in Folge solcher Vorfälle erarbeitet wurden.

1 Introduction

In recent years, there have been several serious tunnel fires in Norway. Two of the latest incidents occured in the summer of 2015. One of them started with technical problems in a large vehicle with 16.500 l of gasoline (transport with dangerous goods), and led to a major fire with extensive damage in Skatestraum tunnel, a subsea Tunnel in western Norway.

The second major fire occured in Gudvanga Tunnel (Figure 1), which resulted in injuries to people, and damage to vehicles and the tunnel.

Figure 1 *Gudvanga tunnel 2015*

2 The Oslofjord Tunnel lessons

In 2017 Norway experienced another large fire incident, but this time in the Oslofjord Tunnel. The fire, type of vehicle and the amount of damage of the tunnel are similar to the large incident that occured in that tunnel in 2011, when several people were seriously injured (Figure 2).

In 2011 the Norwegian Investigation Board provided the following recommendation [1] to the responsible agencies regarding Oslofjord tunnel:

"The investigation into the fire in the Oslofjord tunnel on 23 June 2011 has shown that the preconditions for the self-rescue principle were absent as a result of the tunnel's safety equipment and emergency preparedness solution, resulting in several road-users being trapped in the smoke. The Accident Investigation Board Norway (AIBN) points out the lack of a comprehensive assessment of the interaction between information to road-users, safety equipment, ventilation solution/smoke control, firefighting and safe road-user evacuation (self-rescue) as a basis for the tunnel's emergency preparedness plan. The Accident Investigation Board Norway recommends that the Norwegian Public Roads Administration, along with the Norwegian Directorate for Civil Protection and the fire department, reviews and updates the emergency response plans for long single-lane tunnels, including the Road Traffic Centre's routines in the event of fire, to safeguard the preconditions for the self-rescue principle."

The Norwegian Public Roads Administration and other agencies agreed with the safety recommendations.

Following the fire in 2011, the Norwegian Public Roads Administration, in cooperation with the emergency services, wanted to be better prepared for the various events that could occur in the tunnel.

It was important to make good use of time by detecting fire early, closing the tunnel, alerting emergency services, getting early smoke control and initiating alert and evacuation of road users. Furthermore, the Norwegian Public Roads Administration stated that safety equipment should make it easier to evacuate a smoke-filled tunnel. Consequently, LED lights were installed and 25 evacuation rooms were created. Several probability-reducing measures were also installed.

The Accident Investigation Board issued the following statement after the last fire in Oslofjord tunnel (May 2017) [2]:

Figure 2 Fire incident in the Oslofjord tunnel on June, 23rd, 2011

"Course of events, fire location and the types of vehicle involved were similar to the fire in 2011. Findings were made that suggested that engine breakdown caused this fire as well. This will be investigated further in the preliminary investigations. Fire extinguishing and evacuation seems to have worked as intended at this fire, and the damages to other road users were not severe. Installed aids and evacuation chambers seem to have contributed to this outcome."

Much indicates that the use of technology to detect fire early, initiate early closure of the tunnel, alert the motorists in the tunnel about evacuation and LED light leading to evacuation chambers have been effective measures to reduce the consequences of fire in such a tunnel. In this case the road tunnel manager defines evacuation chambers (with no access to the outside) to be a safe zone, and an effective measure to make sure that the principle of self-rescue is maintained.

This is the first tunnel in Norway with evacuation chambers. There are restrictions in the tunnel safety directive [3], which states that such evacuation rooms shall not be built.

The lessons learnt from this fire will definitely open up a discussion about how to design effective counter measures for tunnels with special characteristics like high gradient.

Norwegian Public Roads Administration have started a survey to investigate key challenges with evacuation chambers and they will document whether these chambers can be used in road tunnels in the future.

3 What causes severe fires in tunnels?

Heavy vehicles are overrepresented in the statistics of fire in Norwegian road tunnels, and this is especially true for tunnels with a high gradient. Technical problems were more than twice as frequently the cause of fires and instances of fires in heavy vehicles than in light vehicles says the Institute of Transport Economics, Norwegian Centre of Transport Research [4]. 40 % of the fires in tunnels in Norway happen in tunnels with a gradient higher than 5 %.

Norway has experienced several large fires in the last seven years, and several of these can be directly linked to high gradient in or before the tunnel. The Norwegian Public Roads Administration is well aware of these facts.

Today, regulations and requirements for tunnel gradient in the tunnel are more stringent than ever. There are several projects that had to redesign the tunnel in order to achieve a lower gradient.

4 How is the overall safety picture?

Risk is the probability of an incident occurring and the consequence of such an incident. Probability of an incident is linked to, among other things, traffic volume, traffic congestion and special characteristics of the tunnel.

Consequences can be significantly worse in the case of a road tunnel, while the characteristics of the tunnel will also affect the consequence.

Fire emergency preparedness in the area can also affect the consequences of the outcome of a fire.

Smoke is the main problem in a fire incident and the opportunity to reach a safe zone, is essential for the consequences of an incident.

4.1 Self-rescue

Fire in a building will give those in the building a reasonable opportunity to escape to a safe zone. It is a short distance in most cases. In a tunnel, you have to escape from your location to the portal outside of the tunnel. If there is an escape tunnel, this can be used. For long one-tube tunnels the safe zone may be several kilometers away which often undermines the principle of self-rescue.

The AIBN has in its investigations questioned whether the road authorities have adequately facilitated the tunnels so that the road users have a real chance to evacuate on their own in a tunnel fire (self-rescue).

4.2 New strategy

Such incidents with such experiences demand action from the authorities. The Norwegian Public Roads Administration (NPRA), in cooperation with the Norwegian Directorate for Civil Protection (DSB), has conducted seminars and meetings with both internal and external stakeholders fokusing on emergency preparedness and cooperation between agencies and stakeholders.

The NPRA, DSB, emergency services, rescue services, researchers, advisers, producers and suppliers have contributed their knowledge, and the NPRA has listened to advice and noted input. The NPRA finds that there is great commitment and a new strategy [5] for tunneling has become an important part of upgrading the road network in Norway.

The principle of self-rescue applies to all tunnels, but it poses a challenge in long single tube tunnels and especially tunnels with a high gradient. Serious incidents that challenge the self-rescue principle are primarily incidents with high fire impact and a rapid smoke development, mainly incidents involving heavier vehicles. Fire in vehicles in shorter road tunnels challenges the principle to a lesser extent than fire in vehicles in road tunnels with longer distances for evacuation. A high gradient, which affects the ability to control the smoke, can make evacuation difficult and therefore affects the possibility of self-rescue. Technical problems due to weakness in a heavier vehicle and/or lack of knowledge and experience with the driver, are major causes for such incidents.

In its new strategy, NPRA aims to reduce the probability of an incident occurring, be well prepared for different scenarios, as well as utilize time well by detecting fire early, closing the tunnel, alerting emergency services, getting early smoking control and launch notification to the road users and start evacuation. Furthermore, safety equipment shall make it easier to evacuate in a smoke-filled tunnel, if road users are caught in the smoke.

Safety in tunnels is affected by many conditions, such as technical, organizational and human nature, and the interaction between these. This applies to prevent incidents from occurring but also applies to prevent or minimize harmful effects of such incidents.

Knowledge of interaction between people, technology and organization is crucial for the tunnel safety. Optimizing the interaction between people, technology and organization is important for a well-functioning and effective self-rescue. The interaction can be decisive when it comes to damage and the overall consequences of an incident.

The Traffic Control Center's operators and emergency services will, by implementing various measures and communicating with road users, play a key role in organizing and assisting in such a way that self-rescue is done as effectively as possible. Systems and routines must as far as possible be simple and predictable for those involved. Simplicity and predictability reduce the likelihood of malfunctions. Coordination and interaction between the Traffic Control Centre operators and emergency services must be determined in advance as far as practicable, agreed on in a contingency plan and practiced regularly. This is especially important for a Traffic Control Centre in charge of 250+ tunnels.

5 Dangerous goods and lessons learnt from the Skatestraum tunnel incident

The fire in the Skatestraum Tunnel started with technical problems in a large vehicle with 16.500 l of gasoline (transport with dangerous goods) and led to a major fire with extensive damage.

Similar potential for damage as in the previous fires was also present at the fire in the Skatestraum Tunnel, and the fire reminded the public of another risk potential: the hazard of dangerous goods in tunnels.

The Accident Investigation Board in Norway (AIBN) [6] commented:

"The fire escalated so quickly and sparked so much energy that it was a very short window of time available for evacuation. AIBN therefore recommends the introduction of restrictions on the transport of dangerous goods based on a risk assessment of each individual tunnel."

The different design features are important, especially in subsea tunnels.

The investigation revealed weaknesses in the tunnel design and the ability to resist the spread of fire (Figure 3). The steep gradient in the tunnel helped the fire to spread over a wide road surface area and the tunnel's drain system was not designed to handle the amount of petrol that leaked out (Figure 4).

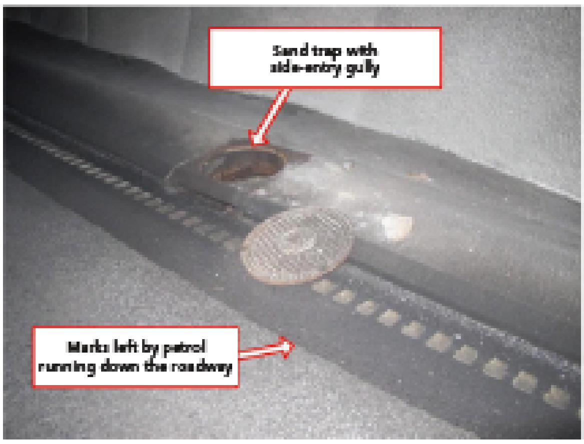

Figure 4 Sand trap with side-entry gully where the petrol ran past (photo: AIBN)

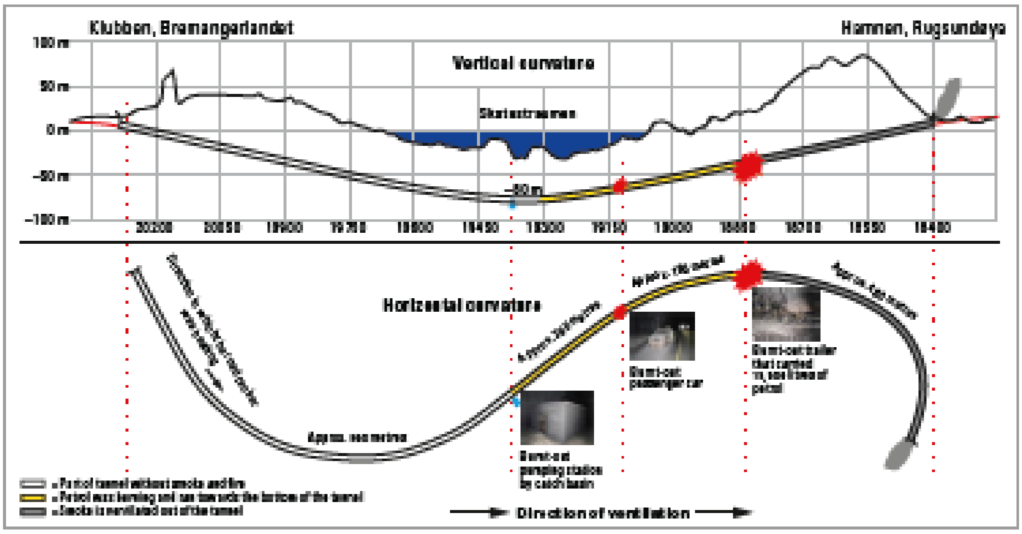

Figure 3 The tunnel's vertical and horizontal curvatures and overview of the fire incident (illustration: AIBN/NPRA)

This is one of many learning points from the fire in the Skatestraum Tunnel. In upgrades of corresponding tunnels a much larger capacity is added in the drainage solutions as a result from this incident.

References

[1] Rapport om brann i vogntog på Rv 23, Oslofjordtunnelen, 23. Juni 2011 (AIBN).
[2] Preliminary article on fire in Oslofjord tunnel on May 2017 (AIBN).
[3] Directive 2004/54/EC of the European Parliament: Minimum safety requirements for tunnels in the Trans-European Road Network, 2004.
[4] Vehicle fires in Norwegian road tunnels 2008-2015 – The Institute of transport economics, Norwegian Centre of Transport Research.
[5] Report 427: Measures to improve fire safety in vulnerable road tunnels (NPRA).
[6] Report on fire in tank trailer in the Skatestraum tunnel in Sogn and Fjordane on 15 July 2015 (AIBN).