FIXED FIREFIGHTING SYSTEMS IN ROAD TUNNELS - GENERAL REQUIREMENTS AND CAPABILITIES

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ABSTRACT

Firefighting systems are increasingly being constructed and operated in road tunnels in a wide range of countries. However the reason for use is varies greatly from system to system; in the end it comes down to the choice of system. In 2014, ASFINAG is constructing the first firefighting system on the highway network in Austria in the City Tunnel near Bregenz. By 2017 at least one more system will be constructed – the one in the Arlberg Road Tunnel. So far two systems have already been fitted in Austria, one in the Felbertauern Tunnel and one in the Mona Lisa Tunnel.

The plans and choice of system have been discussed and decided with a focus on the latest guidelines and technologies; parameters such as route availability, maintenance frequency, pressure levels, water volumes, the drainage system, etc. were the crucial basic factors. Since the “Fixed Extinguishing Systems” data sheet did not set any binding guidelines in Austria, the new RVS 09.02.51 Fixed Firefighting Systems was created for ASFINAG’s efforts based on the previous data sheet.

1. ASFINAG AND FIXED FIREFIGHTING SYSTEMS

In future, ASFINAG – the constructor and operator of the major road network in Austria – will construct firefighting systems in tunnels due to cost-efficiency issues. The first system will go into operation in 2014 with the City Tunnel near Bregenz, which is approx. 1.3km in length. In years to come, the intention is to investigate and assess more tunnels in accordance with the prevailing requirements – a further project has already been secured with the Arlberg Road Tunnel.

The reasons for constructing firefighting systems are complex. In addition to general points such as improving self-rescue and supporting firefighters in their fighting of fires, the detailed principle of operation is as follows:

- Reducing temperatures
- Reducing heat radiation
- Preventing fires from spreading
- Reducing the heat release rate
- Influencing the concentration of smoke gas

In its projects, ASFINAG primarily strives to improve fire safety for the structure in question, whereby any added value (rescuing people, etc.) will of course also be used for positive assessment.

The cost-effectiveness of a project is assessed by comparing active (firefighting system) and passive (fire protection panels) fire prevention. The costs of the entire life cycle are referred to here – so not just the construction costs, but also the costs for operation (staff, energy, maintenance, repairs, etc.).
2. CLASSIFYING FIXED FIREFIGHTING SYSTEMS

On an international scale there is a very wide range of manufacturers with very diverse philosophies regarding the design and technique behind firefighting systems. The following classification may help to develop a system here:

**Table 1: Classifying Fixed Firefighting Systems**

<table>
<thead>
<tr>
<th>System</th>
<th>Extinguishing agent</th>
<th>Water-foam requirement</th>
<th>Nozzle pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water deluge</td>
<td>Water</td>
<td>8-15mm/min</td>
<td>1-5bar</td>
</tr>
<tr>
<td>Water mist</td>
<td>Water</td>
<td>4-7mm/m² per min</td>
<td>Low pressure P ≤ 12.1 bar</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Medium pressure P &gt; 12.1 bar</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>and ≤ 34.5 bar</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>High pressure P &gt; 34.5 bar</td>
</tr>
<tr>
<td>Air foam</td>
<td>Mixture of water and foam</td>
<td>~ 6mm/m² per min</td>
<td>1-2bar</td>
</tr>
</tbody>
</table>

Classifying the water mist systems into low, medium, and high pressure corresponds with classification in accordance with NFPA 750.

A differentiation is made between water deluge systems and water mist systems in accordance with DIN CEN/TS 14972 and NFPA 750.

According to NFPA 750, the DV₀.99 characteristic diameter describes the diameter of the drops that fall below the size of 99% of the released volume of water. The CEN is defined in accordance with the DV₀.9 diameter with a proportion of 90%. Water mist systems are associated with cases where DV₀.9 < 1mm; where DV₀.9 > 1mm, it is a sprinkler- and/or water spray system. NFPA 750 differentiates between three classes of water mist systems based on the DV₀.99 characteristic diameter.

**Table 2: Differentiation between water mist- and sprinkler/water spray systems**

<table>
<thead>
<tr>
<th>Class I</th>
<th>Class II</th>
<th>Class III</th>
</tr>
</thead>
<tbody>
<tr>
<td>DV₀.99 ≤ 200µm</td>
<td>200µm ≤ DV₀.99 ≤ 400µm</td>
<td>400µm ≤ DV₀.99 ≤ 1000µm</td>
</tr>
</tbody>
</table>

3. REGULATION AND GUIDELINES

The construction of firefighting systems in tunnels is fundamentally not regulated in Austria. The revised RVS 09.02.51 Fixed Firefighting Systems thus specifies how they must be constructed and what should be taken into account in the process. The important thing here is that in Austria only high-pressure water mist systems may be used in accordance with this Guidelines. The following points are also cited:

- Design principles
- Adding additives
- Spray specifications
- Criteria
- for release
- Operational aspects
- Verifying and testing
Thus RVS 09.01.45 Construction Fire Protection is significant if a firefighting system is constructed for fire prevention in structures. It cites the procedure for calculating the necessary level of protection – in other words, the amount of time in which the structure must stand firm in a fire.

Table 3: Overview of the various levels of protection

<table>
<thead>
<tr>
<th>Level of protection</th>
<th>Duration of exposure to fire</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>None</td>
</tr>
<tr>
<td>1</td>
<td>30 min</td>
</tr>
<tr>
<td>2</td>
<td>90 min</td>
</tr>
<tr>
<td>3</td>
<td>120 min</td>
</tr>
</tbody>
</table>

In this guideline, a heavy good vehicle tank accident involving diesel fuel, within which a pool size of 100m² is used, is taken as a basis for fire load. Therefore, as a result of these standards, a firefighting system for use in construction fire protection in Austria must be measured beyond the standards stated in RVS 09.02.51.

Controlling this fire load using a firefighting system (in this case, a high-pressure spray mist system) was verified in 2008 in the Runehamar Test Tunnel in Norway. During these trials, solid- and liquid fires with various fire loads were created. Among other things, it was possible to successfully complete a trial with a 100m² diesel pool (corresponding to a fire load of 200MW) and an applied volume of water of approx. 4L/min and m².

Moreover, it must be verified in Austria that the measures also achieve the desired success and justify substituting passive construction fire protection methods using risk analysis in accordance with RVS 09.01.31 – Tunnel – Risk Analysis Model.

It goes without saying that we at ASFINAG are also guided through the planning stages by other international standards and guidelines and/or studies, such as:

- SOLIT² – Safety of Life in Tunnels
- DIN CEN/TS 14972 – Fixed Firefighting Systems
- NFPA 750 - Standard on Water Mist Fire Protection Systems

4. CITY TUNNEL FIREFIGHTING SYSTEM

The City Tunnel in Bregenz is a 1,311m-long tunnel on the approach road to the A14 Rheintal highway for Bregenz, the regional the capital of Vorarlberg. The tunnel was approved for traffic in 1984. The traffic operates in this single-tube tunnel in a bi-directional way. The standard section includes a 7.50m-wide lane with 0.85m-wide shoulders on both sides; it has a clearance of 4.70m.

The ventilation system consists of longitudinal ventilation (jet fans) with exhaust air extraction in a ventilation cavern which is positioned about a third of the way up the tunnel section.

The need to adapt the City Tunnel with fire protection is a result of the EU-Directive (in Austria STSG) which has set a deadline for 04.30.2019 at the latest. The reason for this is that the tunnel is being overbuilt, in particular in the section of open cut tunneling. This is why a significant amount of the neighboring buildings have been put at risk should a major incident with fire occur.
After the technical and safety equipment was completely redeveloped in 2007, a conceptual study revealed that subsequently installing a firefighting system was the most economic option. If passive construction fire protection had been installed, all of the tunnel equipment would have had to be dismantled and reconstructed – this is no longer necessary in the current system.

The implemented investigations have resulted in protection level 2 for the City Tunnel in accordance with RVS 09.01.45, which means designing a 90-minute service life for the firefighting system. With water exposure of 4L/min and m², this means:

- Constructing a 450m³ water container
- Constructing a pumping station with a motor capacity of 430kW
- The required volume of water in operation is approx. 60L/sec
- Constructing the water distribution system in the tunnel
- 23 remotely-operated valve stations for actuating the sections
- Adapting the tunnel drainage system

5. ARLBERG ROAD TUNNEL FIREFIGHTING SYSTEM

The Arlberg Road Tunnel is the longest road tunnel in Austria. The tunnel system, which is approx. 15.5km in length (including galleries) was put into operation as a bi-directional traffic tunnel in 1978. The Arlberg Road Tunnel has transverse-ventilation with supply air- and exhaust air ventilators in a total of 6 ventilation zones.

Between 2014 and 2017, the supply air duct was also fitted as an escape route in addition to the existing 8 escape and emergency routes between the road and rail tunnel – a similar design to the Felbertauern Tunnel. This requires constructing a total of 37 sets of collectors from the driving area into the channel above. It is also intended that the tunnel will be fitted with a firefighting system in order to curb the risk of the subceiling collapsing in the event of a fire.

The standards set in RVS 09.01.45 – Construction Fire Protection, SOLIT² and RVS 09.02.51 – Fixed Firefighting Systems are used as a guide when designing the minimum firefighting system’s operating time. These standards specify that it should be designed for 120 minutes. This is also confirmed by fire fighters’ working times as they arise in practice. During a fire incident on January 16th, 2013, the emergency services took approximately 12 minutes to get to the tunnel portal and a total of 22 minutes to reach the location of the fire. The entire chain of events was as follows:

<table>
<thead>
<tr>
<th>Step during the incident</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Detecting the fire and alerting the emergency services</td>
<td>0 min</td>
</tr>
<tr>
<td>Triggering the firefighting system (delayed in accordance with RVS 09.02.51)</td>
<td>5 min</td>
</tr>
<tr>
<td>Time until the firefighters reach the tunnel portal</td>
<td>12 min</td>
</tr>
<tr>
<td>Reaching the start of the traffic congestion</td>
<td>16 min</td>
</tr>
<tr>
<td>Reaching the fire location and beginning of the extinguishing works</td>
<td>59 min</td>
</tr>
<tr>
<td><strong>TOTAL TIME TAKEN FOR FIREFIGHTERS TO REACH THE FIRE</strong></td>
<td><strong>59 min</strong></td>
</tr>
</tbody>
</table>
In accordance with the SOLIT\textsuperscript{2} planning guide, the water supply must be enough to last double the timespan that the emergency services require to reach the fire (with due regard to the most unfavorable conditions such as traffic jams, etc.). In the Arlberg Road Tunnel’s case, this timespan is therefore 118 minutes; this is covered by the requirements stated in the Guideline for Construction Fire Protection.

The water is supplied via both portals due to the extraordinary length of the Arlberg Road Tunnel. In turn, the following are details of what is required with water exposure of 4L/min and m\textsuperscript{2}:

- Constructing 2 water containers, at 350m\textsuperscript{3} each
- Constructing 2 pumping stations with a motor capacity of 280kW each
- The required volume of water in operation is approx. 60L/sec
- Constructing the water distribution system in the tunnel
- 147 remotely-operated valve stations for actuating the sections

Once the tunnel drainage system in the Arlberg Road Tunnel will be completely renovated, the additional volumes of water do not need to be adjusted as a result of the firefighting system.

6. CONCLUSION

When comparing international standards, it is clear that the basic approaches for the use of firefighting systems varies widely. Some countries, such as Australia, already specify an obligatory construction. Due to differing systems, in ASFINAG’s experience the focus during the development stages is above all on the safety objective. For example, several systems are possible for supporting firefighters in the event of a fire; this is not the case if the focus is on protecting the structure.

From the operator’s perspective, it would be preferable if the standards and guidelines could be made more internationally uniform. On a national scale, there are still great differences and differing approaches to the function and operation. This in turn has significant impacts on the individual manufacturers on the market, who need to adapt to the respective standards; this involves high levels of effort and spending.

7. REFERENCES

[3] RVS 09.01.31 – Tunnel – Risk Analysis Model, Forschungsgemeinschaft Straße, Schiene, Verkehr (Research Team for Road, Rail, and Transport), Vienna, 2013 draft version
[5] RVS 09.02.51 – Fixed Firefighting Systems, Forschungsgemeinschaft Straße, Schiene, Verkehr (Research Team for Road, Rail, and Transport), Vienna, 2013 draft version
[7] SOLIT\textsuperscript{2} – Safety of Life in Tunnels, SOLIT\textsuperscript{2} Research Consortium, Cologne, Germany, 2012