Fire Protection of Underground Facilities with innovative Water Mist Systems

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• SOLIT² Research Program Review
• Objectives
• Partners
• Project in General
• (first) Results
• Future Works
Aims of FFFS in tunnels

- Fire Suppression and reduction of fire spread
- Improvement of self-rescue conditions
Water Mist FFFS in road tunnels

- Easier and safer work for rescue services (fire brigade, etc.)
- Reduction of damages on the building structure
- Compensation of other safety measures???
Compensation: Costs vs. Safety Level

Today’s accepted safety measures (prescriptive): Increasing Safety Level → higher costs
Increasing Safety Level → same costs
Same Safety Level → less costs
European Roadtunnels with WN-FFFS

- Virgil (Virgolo) Tunnel, A22 Brenner Highway
- A 86, Paris
- M30 Ring road, Madrid
- Felbertauerntunnel
- A73 Roertunnel
- New Tyne Crossing (NTC), Newcastle
- ...

More are in planning and tender process.
Guidelines and Standards

• UPTUN 251: “Engineering Guidance for Water Based Fire Fighting Systems for the Protection of Tunnels and Subsurface Facilities”

• NFPA 502 (2008): “Standard for Road Tunnels, Bridges, and Other Limited Access Highways”

• PIARC: “Road Tunnels – An Assessment of Fixed Fire Fighting Systems (FFFS)”
Potential for compensation

Compensatory Measure:

*Measure that ensures the same level of protection than with standard measures required by guidelines or state-of-the-art.*

- Increase the efficiency of ventilation systems
- Improvement of self-rescue conditions
- Fire suppression and temperature reduction
- Improvement of fire brigade intervention
Reduction of Temperatures / Reduction of damages
Improvement of self-rescue conditions

Prescriptive based analysis

<table>
<thead>
<tr>
<th>Min./Max. concentration at breathing height Vol%</th>
<th>Fixed Limit Value for 30 min. exposure Vol%</th>
<th>Free burning Fire (150 MW) Vol%</th>
</tr>
</thead>
<tbody>
<tr>
<td>O₂ 19.41</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>CO₂ 1.53</td>
<td>6-7</td>
<td>7-9</td>
</tr>
<tr>
<td>CO 0.22</td>
<td>0.14 – 0.16</td>
<td>0.4 – 3.0</td>
</tr>
</tbody>
</table>

Performance based analysis

Fractional Effective Dose according ISO 13571

\[ FED = \Delta t \sum_{i=1}^{n} \sum_{t_1}^{t_2} \frac{C_i}{(C_{t_1})_{t_1}} \Delta t \]
Compensation of safety measures by FFFS
Integration of FFFS into a holistic tunnel safety system

- Run time: 10/2010 – 09/2011
- Supported by the German ministry of economy and technology
- Budget: ~ 4 Mio €
- Large scale fire test program in 2011
- Workshop/Conference in 2011
- Scientific advisory board

Information at www.solit.info
• State of the art analysis
• Potential of Compensation
Simulation /
Base data for risk analysis
• Effects of FFFS
• Economical Evaluation (LCC)
• Integration and Engineering Guidance
SOLIT² - Partners

FFFS, Project Manager
Engineering, Simulation, Compensation

Engineering, Simulation, Literature
Economical Evaluation, Integration
Integration, Reliability, Guidance

Full Scale Fire Tests
Measurments, Data evaluation
SOLIT² - Test Program

- 34 full scale fire tests (at least)
- Consumed water ~ 1200 m³
- Class A / Class B fires
- 3700 liters Diesel
- 80 files measuring data, 0.5 GB
- Longitudinal ventilation, semi transversal ventilation
- Video data, ~ 67 GB
- 0 – 6 m/s air velocity

TEST PROGRAM - SOLIT² RESEARCH PROGRAM

<table>
<thead>
<tr>
<th>Week</th>
<th>Tunnel Rent</th>
<th>Date</th>
<th>Testnumber</th>
<th>Scenario</th>
<th>Ventilation</th>
<th>FFFS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Mo 21.05</td>
<td>110528-1</td>
<td>Truck with cover</td>
<td>Longitudinal TEO m/s</td>
<td>Layout 1</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Do 22.05</td>
<td>110524-1</td>
<td>Truck without cover</td>
<td>Longitudinal reduced TEO m/s</td>
<td>Layout 1</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Mo 21.05</td>
<td>110526-1</td>
<td>Pool 30 MW</td>
<td>Longitudinal TEO m/s</td>
<td>no FFFS</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Do 22.05</td>
<td>110527-1</td>
<td>Pool 100 MW</td>
<td>Longitudinal TEO</td>
<td>Layout 1</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Fr 27.05</td>
<td>110527-2</td>
<td>Pool 100 MW</td>
<td>Longitudinal reduced TEO m/s</td>
<td>Layout 1</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Sa 28.05</td>
<td>110527-3</td>
<td>Pool 100 MW</td>
<td>Longitudinal TEO</td>
<td>FFFS with 1 - 2 m distance b</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Su 29.05</td>
<td>BREAK</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

12.10.2011
SOLIT² - Measurements
Institute for applied fire safety research

SOLIT² - Measurements

12.10.2011

16
SOLIT² - Measurements and Testing

60MW pool fire
Results - Efficiency

- Truck Fire 150MW - temperatures 10 m behind fire Load

Temperature development in the fire zone at the point of ignition (U005) as comparison.
Results - Efficiency

- Truck Fire 150MW - HRR
Results - Efficiency

- Development of fire
  - Extinguishment of fire
  - Cooling of surfaces
  - Reduced heat flux
  - Reduction of back layering
Results – Compensation Ventilation

• Thermal imager film
Results – Compensation Structural Protection

- Components
  - Concrete plate on ceiling
  - Main pipe
  - Section pipe with nozzles
  - Section valve with insulation box

- Location
  - In the fire zone and between fire load and target
Results – Compensation Structural Protection

• Temperatures of section valve box
Results – Compensation Structural Protection

Temperatures Concrete Plate

![Graph showing temperature changes over time for concrete plate samples TE 01, TE 02, TE 03, TE 04, TE 05, and Gastemperatur um Betonplatte.](image)

- TE 01 - 4,0 cm
- TE 02 - 3,0 cm
- TE 03 - 2,0 cm
- TE 04 - 1,0 cm
- TE 05 - 0,2 cm
- Gastemperatur um Betonplatte

12.10.2011
Results – Operation Conditions

- Operation conditions
  - *Within the activated water mist sections*
    - Visual range: up to 4 m
    - Possible orientation by light sources: yes
    - Influence of heat radiation: low

  - *During the fire suppression*
    - Possible distance to suppress the fire manually: 2 m
    - Suppression of the fire by the water mist system: strong
Comparison of HPWM vs. Deluge

- HPWM
  - Better barrier for temperatures and heat radiation

- LP
  - Flames hit ceiling
## Comparison of HPWM vs. Deluge

<table>
<thead>
<tr>
<th>Safety Objectives</th>
<th>HPWM</th>
<th>LP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Layout 1</td>
<td>Layout 2</td>
</tr>
<tr>
<td>Fire protection of tunnel architecture</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reduced ceiling temperatures</td>
<td>from 10 m behind FL</td>
<td>from 10 m behind FL</td>
</tr>
<tr>
<td>Reduced heat flux</td>
<td>✓ ✓ ✓</td>
<td>✓ ✓ ✓</td>
</tr>
<tr>
<td>Prevention of fire spread</td>
<td>✓ ✓</td>
<td>✓ ✓ ✓</td>
</tr>
<tr>
<td>Before fire load (upstream)</td>
<td>Fire fighter’s access/ Self rescue</td>
<td>✓ ✓ ✓</td>
</tr>
<tr>
<td>Behind the fire load (downstream)</td>
<td>Fire fighter’s access</td>
<td>✓ ✓ ✓</td>
</tr>
<tr>
<td></td>
<td>from 40 m behind FL</td>
<td>from 10 m behind FL</td>
</tr>
<tr>
<td></td>
<td>Self rescue</td>
<td>✓ ✓</td>
</tr>
<tr>
<td></td>
<td>from 60 m behind FL</td>
<td>from 40 m behind FL</td>
</tr>
</tbody>
</table>

- ✓ ✓ ✓ fully fulfilled
- ✓ ✓ fulfilled to a limited extend
- ✓ barely fulfilled
Comparison of HPWM vs. Deluge

- Example Heatflux

![Graph comparing HPWM ST, LP 12 mm/l/min, LP 6 mm/l/min over time]

Time [hh:mm:ss]

HF [W/cm²]

12.10.2011
Conclusions

- FSSS are accepted as state of the art measure to improve safety in tunnels
- Until today the systems are used as additional safety measure
- The major aim of FFFS in future is either reduce costs with the same safety level or improve safety with same costs as today
- SOLIT² focuses on the integration and compensation
- SOLIT² will generate data as base for risk analysis
- SOLIT² will publish a engineering guidance
- Assumption: Transfer of findings on other underground facilities
Thank you very much for your kind attention!