Natural Ventilation of a Short Road Tunnel – Application of FDS+EVAC

Katie McQuade-Jones and Matt Bilson
WSP USA
DECK PARK
OVERBUILD
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Section 11.1.1:
Emergency ventilation shall not be required in tunnels less than 3280 feet in length, where it can be shown by an engineering analysis that the level of safety provided by a mechanical ventilation system is equaled or exceeded by enhancing the means of egress or the use of natural ventilation.
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How do we show equivalent level of safety quantitatively?
## EXISTING SHORT TUNNELS

<table>
<thead>
<tr>
<th>Name</th>
<th>Length (m ft.)</th>
<th>Urban / rural</th>
<th>Traffic</th>
<th>Year</th>
<th>Ventilation</th>
</tr>
</thead>
<tbody>
<tr>
<td>I5 Tunnel, Seattle, WA</td>
<td>167 (547)</td>
<td>U</td>
<td>Uni</td>
<td>1988</td>
<td>Natural</td>
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<tr>
<td>Dyer Avenue, New York</td>
<td>168 (550)</td>
<td>U</td>
<td>Bi</td>
<td>*</td>
<td>Mechanical</td>
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<tr>
<td>Rockville, Intercounty Conn, Maryland</td>
<td>195 (640)</td>
<td>R</td>
<td>Bi</td>
<td>2010</td>
<td>Natural</td>
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<tr>
<td>Pasadena, I210, California</td>
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<td>Uni</td>
<td>2003</td>
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<td>U</td>
<td>Uni</td>
<td>2010</td>
<td>Mechanical</td>
</tr>
</tbody>
</table>
DEFINING LEVEL OF SAFETY

NFPA 502 Section 11.2.2:

In all cases, the desired goal shall be to provide an evacuation path for motorists who are exiting from the tunnel and to facilitate fire-fighting operations.
DEFINING LEVEL OF SAFETY

NFPA 502 Section 11.2.2:
In all cases, the desired goal shall be to provide an evacuation path for motorists who are exiting from the tunnel and to facilitate fire-fighting operations.

— Use tenable egress path criteria to demonstrate safety
— Traditional methods use visibility > 10 m to define tenability
— For some fire scenarios in short tunnels, might not be able to show visibility of 10 m (e.g. fuel tanker fire)
TENABLE EGRESS PATH CRITERIA

— Traditional methods use visibility > 10 m to define tenability
— For some fire scenarios in short tunnels, might not be able to show visibility of 10 m (e.g. fuel tanker fire)
— Fractional effective dose (FED) and fractional irritant concentration method
— Track FED of toxic gases and heat exposure
— Track FIC of toxic gases
— Set criteria so more susceptible occupants can self evacuate
TENABLE EGRESS PATH CRITERIA

— Toxic gas FED based on Purser’s equation (used in EVAC)
— Heat exposure FED calculated based on NFPA 502 Annex B equations
  — Output visibility and temperature profiles to calculate this for a theoretical occupant

— To be considered a passing result:
  — Toxic gas FED < 0.3
  — Heat exposure FED < 0.3
  — Toxic gas FIC < 0.3
SCENARIO SCHEMATIC

- Cross passage door
- Fire vehicle
- Stopped passenger car

← +2% grade, 5.5 m/s adverse wind
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**SCENARIO SCHEMATIC**

- **Fire vehicle**
- **Stopped passenger car**
- **Cross passage door**
- **Exit**
- **Entrance**

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- Dangerous goods vehicle (DGV) fires versus heavy goods vehicle (HGV) fires
- Quantity of egress doors
- Length of tunnel (600 ft. and 1000 ft.)
- 2 lane vs. 6 lane tunnels

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+2% grade, 5.5 m/s adverse wind

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FIRE SCENARIO

Fire heat release rate curves

FHRR (MW)

Time (min)

DGV

HGV
COMBUSTION REACTION

— Emissions from an experimental vehicle fire used as a basis (Lonnermark and Blomqvist)
— Reaction included: CO, NO₂, HCN, HCl, SO₂, C₃H₄O, and CH₂O, soot
— All species included in FDS+EVAC FED/FIC calculation
# RESULTS SUMMARY

<table>
<thead>
<tr>
<th>Length (m)</th>
<th>Lanes</th>
<th>Design fire</th>
<th>Provisions to meet NPFA 502 with natural ventilation</th>
</tr>
</thead>
<tbody>
<tr>
<td>180</td>
<td>2</td>
<td>HGV</td>
<td>Portal egress</td>
</tr>
<tr>
<td>180</td>
<td>2</td>
<td>DGV</td>
<td>Additional egress doors</td>
</tr>
<tr>
<td>180</td>
<td>6</td>
<td>DGV</td>
<td>Portal egress</td>
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<tr>
<td>305</td>
<td>2</td>
<td>HGV</td>
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<td>6</td>
<td>DGV</td>
<td>Additional egress doors</td>
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VISIBILITY AT 2.4 M ABOVE ROADWAY

- +2% grade, 5.5 m/s adverse wind
- Fire vehicle
- 180 m tunnel, HGV fire
- Slice taken at 310 seconds (last occupant exits)
SECTION VIEW OF TEMPERATURE

— 180 m tunnel, HGV fire
— Slice taken at 310 seconds (last occupant exits)
VISIBILITY AT 2.4 M ABOVE ROADWAY

+2% grade, 5.5 m/s adverse wind

Fire vehicle

Entrance

Exit

Visibility (m)

0.0 1.0 2.0 3.0 4.0 5.0 6.0 7.0 8.0 9.0 10.0

— 180 m tunnel, DGV fire

— Slice taken at 335 seconds (last occupant exits)
RESULTS SUMMARY

— Results are consistent with recent work by Purser, suggesting that occupants can move through visibilities of 2 m for 20-60 minutes

— Can use this quantitative approach to form a basis for approval by the authority having jurisdiction (AHJ)
## SIMULATIONS

<table>
<thead>
<tr>
<th>Case number</th>
<th>Ventilation</th>
<th>Egress doors</th>
<th>FHRR (MW)</th>
<th>Tunnel length</th>
<th>Lanes</th>
<th>Max. FED, toxic gases</th>
<th>Max. FED, heat</th>
<th>Max. FIC</th>
<th>Pass/fail</th>
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<tbody>
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<td>FEM-01-01</td>
<td>Natural</td>
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</tbody>
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