Cross-Passages in Rail Tunnels - Technical & Legal Requirements

Dr Fathi Tarada
Mosen Ltd
Motivation

• Cross-passages are specified in many tunnels to facilitate self-rescue and intervention
• Construction can be technically challenging and expensive
• To what extent are such cross-passages legally required?
Overview

• Standards & practice
• Challenges in design & construction
• Legal requirements and tests
• Example application
Metro Tunnel Cross-Passages

- Underground Trainway
- Cross Passageway
- Station
- PSD Return Door
- Platform Public Area

≤ 500 m
## Rail Tunnel Cross-Passage Spacing

<table>
<thead>
<tr>
<th>Standard</th>
<th>Territory</th>
<th>Maximum Cross-Passage Spacing (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NFPA-130</td>
<td>North America / International</td>
<td>244</td>
</tr>
<tr>
<td>AS 4825</td>
<td>Australia</td>
<td>240</td>
</tr>
<tr>
<td>TSI</td>
<td>Europe</td>
<td>500</td>
</tr>
<tr>
<td>SFSRTS</td>
<td>Singapore</td>
<td>250</td>
</tr>
</tbody>
</table>
Rail Tunnel Walkway
Genesis of NFPA-130 Guideline

- NFPA-130 based on 800 feet (244 m) cross-passage spacing
- Derived from the MARTA (Atlanta) Subway project.
- Distance people could walk downstream of a train fire site before flashover occurred and made the downstream environment untenable
# European Rail Tunnel Projects

<table>
<thead>
<tr>
<th>Project</th>
<th>Country</th>
<th>Maximum Cross-Passage Spacing (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gotthard Base Tunnel</td>
<td>Switzerland</td>
<td>312</td>
</tr>
<tr>
<td>Brenner Base Tunnel</td>
<td>Austria - Italy</td>
<td>333</td>
</tr>
<tr>
<td>Mont d'Ambin Base Tunnel</td>
<td>France - Italy</td>
<td>333</td>
</tr>
<tr>
<td>Lötschberg Base Tunnel</td>
<td>Switzerland</td>
<td>333</td>
</tr>
<tr>
<td>Eurotunnel</td>
<td>UK - France</td>
<td>375</td>
</tr>
</tbody>
</table>
Crossrail, London

• The London Crossrail scheme has cross-passages at approximately 500m spacings, with a maximum spacing of up to 693m, after negotiation with the London Fire Brigade.
Crossrail, London
Challenges in Cross-Passage Construction

- Urban environment with existing buildings, foundations and piles
- Pre-existing tunnels and underground spaces
- Airport runways sensitive to settlement
- Soft ground tunnelling
- River-crossing tunnels
Legal Requirements

• Focus on common law countries (UK, Australia, Singapore)
• Outline of civil law requirements in Europe
Risk Assessment - 1

• Management of Health and Safety at Work Regulations (1999):

• “Suitable and sufficient risk assessments”
Risk Assessment - 2

- The Regulatory Reform (Fire Safety) Order 2005:
- Duty on the “responsible person” to make a suitable and sufficient assessment of the risks to which relevant persons are exposed.
Good Practice

• Health and Safety Executive, UK: risk mitigation measures established by “good practice” should be considered as a means of discharging the duty-holder’s duty of care.

• Guidelines and standards can be considered “good practice” which establish a baseline risk level.
Alternative Measures

• Article 2.3.6 of EU Regulation No 402/2013:
  • “Where an alternative approach is not fully compliant with a code of practice, the proposer shall demonstrate that the alternative approach pursued leads to at least the same level of safety”
Common Law

*Edwards v National Coal Board* [1949]:

“... a computation must be made by the owner in which the quantum of risk is placed on one scale and the sacrifice involved in the measures necessary for averting the risk (whether in money, time or trouble) is placed in the other, and that, if it be shown that there is a gross disproportion between them – the risk being insignificant in relation to the sacrifice – the defendants discharge the onus on them”
Cost / Benefit Ratios

• Cost/Benefit ratios in safety submission to Health & Safety Executive for the 1987 Sizewell B Inquiry:
  • Up to 3 for workers
  • Up to 2 for low risks to public
  • Up to 10 for high risks
Risk Assessment Process

- Start
- Definition of the system
- Hazard identification
  - Probability analysis
  - Consequence analysis
- Risk estimation
- Risk criteria
- Risk evaluation
- Risk reduction
  - (additional) safety measures

Acceptable risk?
- Yes: Stop
- No: (additional) safety measures
Typical Frequency-Consequence Diagram

- **Frequency (per year)**
- **Consequences (Incapacitated People)**

**Kingsway F-N Effect of Fire Suppression**

- **Current Design**
- **Line of Acceptance**
- **Line of Irrelevance**

**ALARP Zone**

- **Line of Acceptance**
- **Line of Irrelevance**
Departures from Standards

• Existing design forms baseline risk (e.g. Australia, EU’s Common Safety Method)
• Alternative designs can pass the test if integrated risk is the same or less
Fire Scenarios

• Majority of train fires will be small (< 5 MW)
• Evacuees will preferably walk upstream of the ventilating airflow (into safety)
• Evacuees walking downstream of the fire are unlikely to survive for large fires, regardless of cross-passage spacing
Cost/Benefit Ratios

• Very low risk of train fires
• Cost/Benefit ratios for additional cross-passages typically $>> 10$
  – Do not merit legal enforcement on the basis of cost/benefit
• BUT other mitigation measures may be necessary to reduce the level of risk to ALARP
Potential Mitigation Measures

• More fire-resistant rolling stock
• Heat detection at portals (for brakes & transformers)
• Fire suppression (infrastructure or rolling stock)
• Fire and smoke detection
• Smoke ventilation
Summary

• Standards for cross-passage spacing imply a certain ‘baseline risk’

• If spacing is increased:
  – Marginal increase in life safety risk
  – Other measures may be required

• Reduction in spacing generally not justifiable from Cost/Benefit perspective
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