RED
Fire and Facade Consultants

HKIE Fire Division 9th Annual Symposium

Fire Tests for Tunnels

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Agenda

Section 1: Introduction

Section 2: Fire Testing of Tunnel Lining

Section 3: Q & A

Section 1

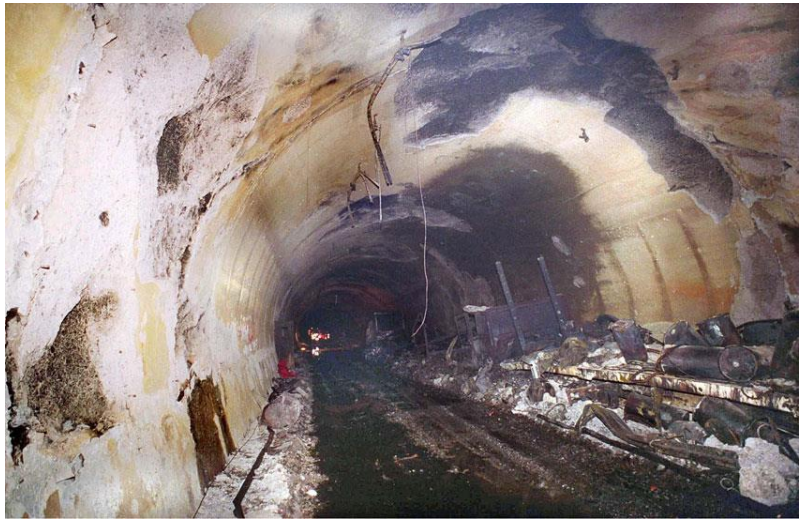
Introduction of Tunnel Fire

Introduction – Why do we need to concern?

- **Road Tunnel and Train Tunnels**
- **Long distance enclosure**
- **Large fire size – temperature > 1,300 ^{o}C**
- **Concrete spalling (using of High Strength concrete)**
- **Loss of structural strength**
- **Tunnels may be collapsed**

History - Disaster

- Tunnel fire at Mont Blanc Road Link
  - Connection tunnel for France / Italy
  - 11.4 km long Single-tube, two-lane, bi-directional road tunnel
  - 39 dead
  - Intense fire with temperature up to 1,300 ^{o}C
    - Serious concrete spalling
    - Reinforcement exposed and lost strength



History - Disaster

- **Tunnel fire at Gotthard Tunnel**
  - **In Switzerland**
  - **16.9 km long Single-tube, two-lane, bi-directional road tunnel**
  - **11 dead**
  - **Intense fire with temperature up to 1,200 ^{o}C**
    - **Fire spread of 300 m**
    - **Serious concrete spalling**
    - **Reinforcement exposed and lost strength**

Tunnel Fire – What will happen?

- **Vehicles are mobile fuel tanks**
  - **Fire Sizes:** **Cars ~ 5 MW**
    Buses ~ 20 MW
    Trucks ~ 30-100 MW
    Tankers ~ 300 MW
- **Maximum temperature climbs up to 1,300 ^{o}C quickly**
- **Long duration – Fuels and enclosed environment**

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Tunnel Fire – Suitable Design

- Smoke Extraction System
- Provision of Refuge
- Control of Fire Spreads
- Prevention of Concrete Spalling
  - Intervention of Fire Brigade (Safety issue)
  - Loss of Structural Strength (Collapse of tunnels)

Tunnel Fire - Spalling

- **Concrete spalling during fire**
  - **Hinder the intervention of fire brigade**
  - **Spalling concrete may harm the evacuees and firemen**
  - **Spalling causes exposure of re-bars**
    - **Re-bars at high temperature will loss strength**
    - **Structural unstable causes the collapse of tunnel**
  - **Leads to leakage of water**

How dose Spalling happen?

- Concrete heat up
  - Causes Drainage and Evaporation
  - Causes Steam Pressure
  - Leading to Explosive Crackings
- High Strength Concrete (HSC) is particularly prone to spalling
  - Always uses for tunnel linings
  - Reduces pore volume
  - Lower permeability to release steam pressure
- Fire testing developed to give measures of tunnel lining under tunnel fire

Passive Fire Protection

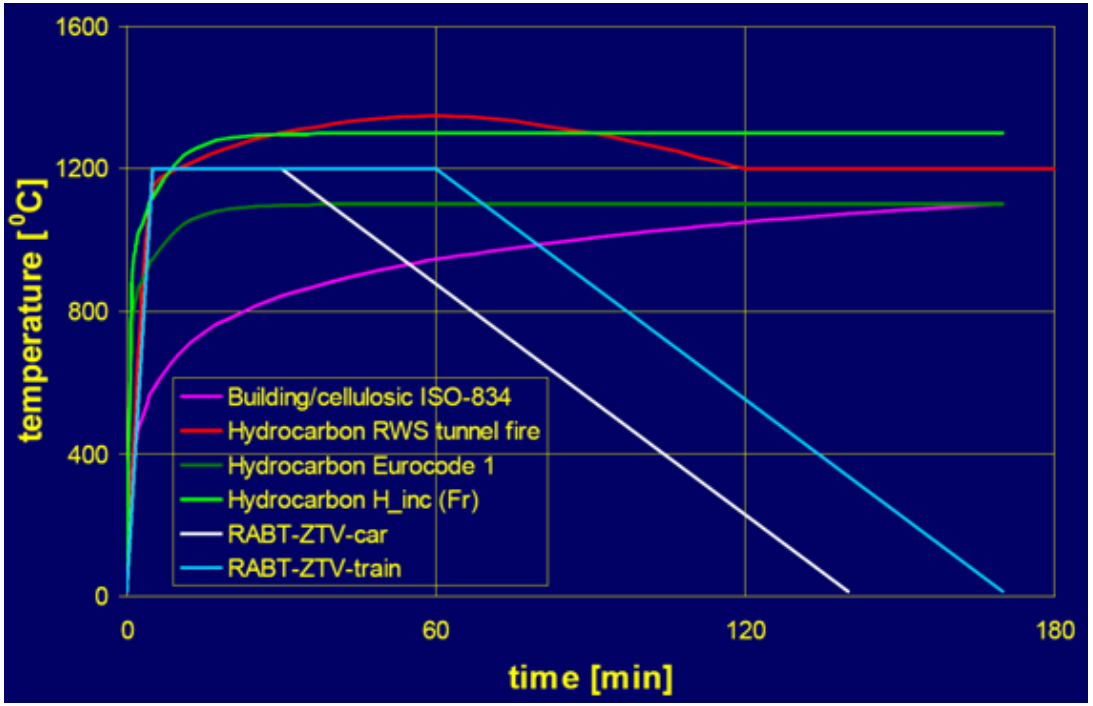
- **Passive Fire Protection applied to protect tunnel structures**
- **Insulation materials to prevent exposure to high temperature**
- **Applied materials need to remain intact throughout the heating condition**

Section 2

Fire Testings of Tunnel Linings

Commonly used heating curves

- Standard ISO 834 heating curve
- HydroCarbon (HC) heating curve
- RABT/ZTV heating curve
- MHC heating curve
- RWS heating curve

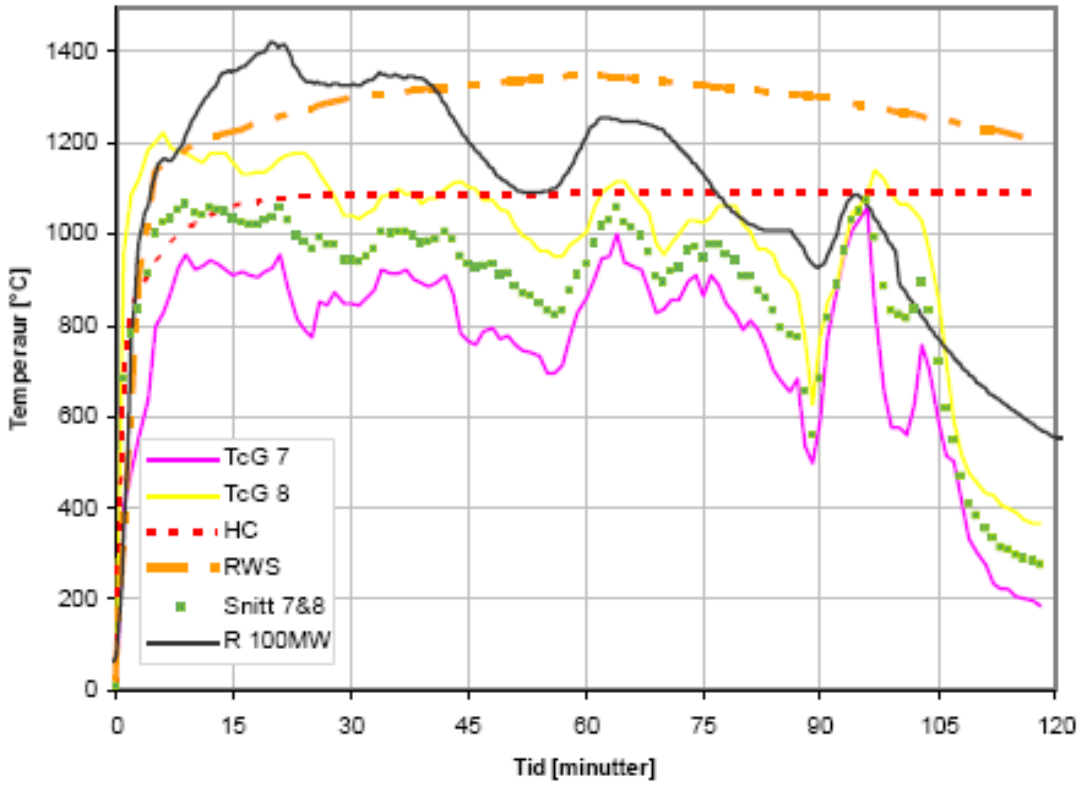


How to work out the heating curve

- **Real scale fire or full scale fire tests**
  - **UPTUN Fire test in Runehamar test tunnel**
    - **Shows the measured HRR higher than expected from normal HGV-goods**
    - **Up to 200 MW**
    - **Fire spread to vehicles 100 m downstream**
  - **Full scale test by NPRA**
    - **A small tanker-sized pool with sizes of 40 m^2, approx. 11 litres diesel**
    - **Generate temperature up to 1,400 ^oC**

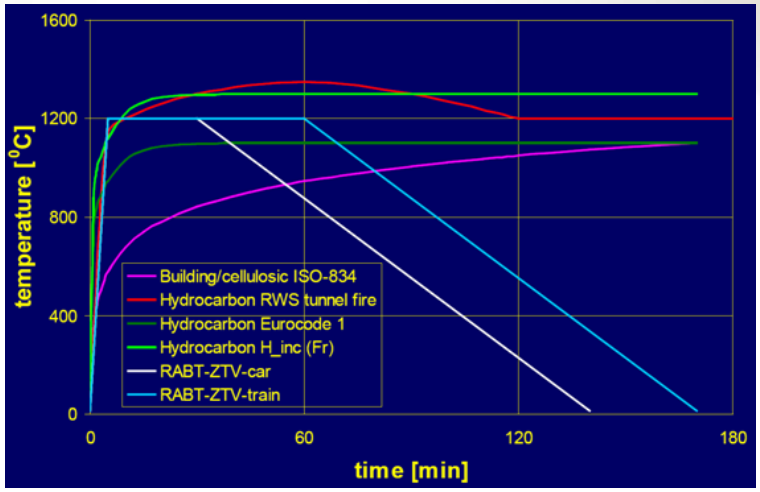
Result from the full scale test

- **The result of full scale test of 40 m^2 diesel**



Commonly used heating curve

- **RWS Curve**
  - much rapid heating at the initial
  - Higher maximum temperature up to 1,350 ^{o}C at 60 minutes.
  - Constant at 1,200 ^{o}C after 120 minutes
- **ISO curve**
  - Less rapid heating at the initial
  - Temperature is 945 ^{o}C at 60 mins, 405 ^{o}C lower compared to RWS
  - Continuous increasing throughout the test
- **Rapid temperature rise cause temperature shocks to concrete**
- **Concrete starts to melt at temperature higher than 1,300 ^{o}C**



Purposes of fire tests

- **Fire test to check**
  - **If Spalling of concrete occurs and how serious?**
  - **If insulation lining is used, what is the performance?**
    - **Insulation performance**
      - **Concrete start to melt at temperature higher than 1,300 ^{o}C**
    - **Ability of the insulation lining remains intact throughout the test**

Fire Test Furnace

- Vertical Furnace with 4 m high by 3.4 m wide

- Horizontal Furnace capable to test loadbearing building elements

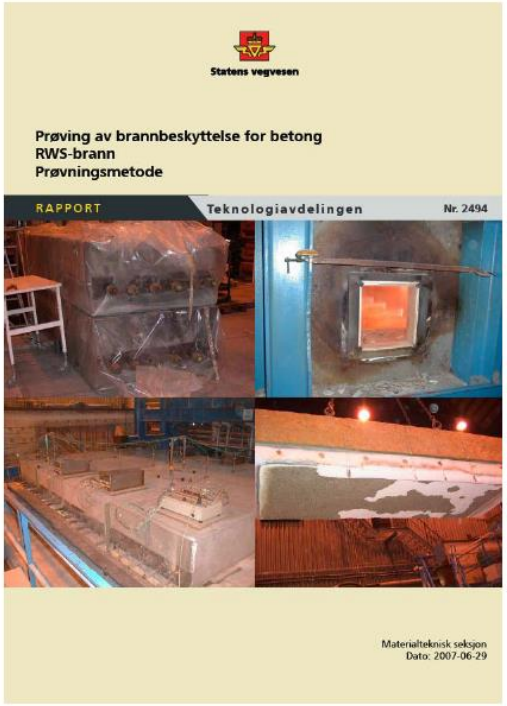
Fire testing using RWS

Fire protection of the Immersed Bjørvika Tunnel – new test method

- Development of our own test method for fire protection of concrete in RWS
  - Based on fire testing of large concrete elements
  - RWS-proven systems failed in the larger scale test
- Compressive stress of 11 MPa
- High quality concrete (m=0.40, B55)
- Sealed curing, min. 3 months old
- Relatively large test elements (1.2 x 3.6 x 0.6 m^3)
- Sprayed systems must be anchored with stainless steel mesh and bolts
- Board systems must have at least two joints
- 16 TCs for temperature at interface and at reinforcement

Statens vegvesen

Norwegian Public Roads Administration



- **Source from the Internet**

Fire testing using RWS

- **Source from the Internet**

Q and A Section

- **Thank you for your attention!!**