Fire Protection of Tunnel Joints

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Motivation

• Conwy Tunnel in Wales, UK was constructed in 1986 – 1991
• The immersed tube tunnel did not have any fire protection between its joints
• This project was commissioned to rectify the deficiency
Agenda

• Conwy Tunnel and its joints
• Passive fire protection criteria
• Fire protection scheme
• Fire tests
• CFD calculations
• Installation
Conwy Tunnel and its joints
Conwy Tunnel

- Cut-and-cover portal sections:
  - East 260m
  - West 120m
- Immersed tube tunnel: 710m
- Overall length: 1090m
Tunnel location
Locations of tunnel joints

CONWY TUNNEL WESTERN CUT & COVER SECTION(A55 855)

CONWY TUNNEL IMMERSED SECTION (A55 850)

CONWY TUNNEL EASTERN CUT & COVER SECTION(A55 845)
Typical as-built tunnel cross-section
Original element soffit joint
Original element internal wall joint
Passive fire protection criteria
Design criteria

• RWS time-temperature curve
• Up to 335mm from the joint: maximum interface temperature <350ºC after 2 hours’ fire exposure + no spalling
• Average temperature of 120ºC or less at the gasket material (Omega seal)
• Fixing system should not fail during 2 hours of fire exposure
Challenges
Challenges

• Seasonal movements of the elements with respect to each other (up to 9.5 mm)
• Significant misalignments between the element edges vertically (up to 65mm) and rotationally
Fire protection scheme
Key Design Aspects

• Passive fire protection calcium silicate fibre boards (trade name “Promatect-T”)
• Bagged layers of insulation in element voids
• Paint (trade name “Ceramicoat C”) to protect boards from water ingress
• Slotted holes to allow for seasonal movement
• Machined packing boards to allow for misalignments
• Composite steel/cement impact protection sheets (trade name ‘Durasteel’)
Fire tests
Fire tests undertaken

CSTB, France:

• Vertical (wall) element joint
• Horizontal (soffit) element joint
• Vertical (wall) dilation joint
Vertical (wall) element joint - 1
Vertical (wall) element joint - 2
Horizontal (soffit) element joint - 1

Rear “Closure” PFP Boards and Mock Omega Seal

Joint Insulation Omitted for Clarity

Fixings Omitted for Clarity

Board Movement Expansion Gap

Fused Block 500.00

60.00

15.00

80.00

530.00

60.00
Horizontal (soffit) element joint - 2

Fixing Detail (NTS)

Type “A”

Type “B”

Type “C”
Vertical (wall) dilation joint - 1
Vertical (wall) dilation joint - 2
Compressive Stress

• Load of 1750kN applied centrally to the slab provided a uniform compressive stress of 9.3N/mm$^2$ across the section.

• The load was displaced to give an eccentricity of 14mm, which gave a combined (axial + bending) compressive stress of 12.5N/mm$^2$ on the front face of the unprotected test slabs.
Measured Results

• The three fire tests confirmed that all the passive fire protection criteria had been satisfied
CFD calculations
Purpose of CFD calculations

• To verify the CFD calculations by comparison to experimental results
• To account for the various types of joints and their particular layouts
Movement of Liquid Water and Vapour

- Calculated through the passive fire protection board & concrete
- Essential for obtaining good predictions with experimental results
Test B Board Interface Temperatures

Temperature (°C) vs. Elapsed Time (Min)

- CFD Board/Concrete
- Measured TC20
- CFD TC20
- Measured Board/Concrete
Test 2 Predicted Temperature through Test Sample at 2 hours
Installation
Review

• Conwy Tunnel and its joints
• Passive fire protection criteria
• Fire protection scheme
• Fire tests
• CFD calculations
• Installation
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