LA DURABILITÉ DE LA PRÉCONTRAINTE EXTÉRIEURE

Journée Technique
Vendredi 27 septembre 2018
FNTP – 3 Rue de Berri, 75 008 PARIS
HAMMERSMITH Flyover Post-Tensioning Repair Overview, the British Approach
HAMMERSMITH Flyover Post-Tensioning Repair Overview, the British Approach
Hammersmith Flyover Importance

Transport for London Road Network

Hammersmith

M4 West

England & Wales

A4

Heathrow

Olympic Park
Hammersmith Flyover Importance

Transport for London Road Network

- 16 spans
- 622m elevated length
- Max box depth 2.75m
- Min box depth 1.98m
- Typical span = 42m
- 80,000 vehicles / day
- Post-tensioned pre-cast
- Bridge Owner-Transport for London (TfL)
Technical Specifics

Structural Form

- Strands in individual ducts to post-tensioning anchorages in deck
- External tendons in grout boxes each side of internal webs
- Tendons in grouted ducts in box soffit
- Roller bearing in pits below ground level
- Location of lower deviators
- Roller bearing in pits below ground level
Technical Specifics

Structural Form
Technical Specifics

Original Prestress Layout

- Sloping sections are external to concrete section in “grout boxes”
- Mid span sections grouted in 4 large ducts (12 strands)
- Individual grouted strand at anchors
- 19 Wire Strand
## Prestress Deterioration

### Timeline (1)

<table>
<thead>
<tr>
<th>Year</th>
<th>Event Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1961</td>
<td>Hammersmith Flyover opened</td>
</tr>
<tr>
<td>1962</td>
<td>Heated road surface decommissioned</td>
</tr>
<tr>
<td>1990s</td>
<td>PTSI programme commenced</td>
</tr>
<tr>
<td>Late 1990s / Early 2000s</td>
<td>Works to reduce water ingress – manholes sealed and rewaterproofing</td>
</tr>
<tr>
<td>Late 2000s</td>
<td>Intensive PTSI and assessment (40T)</td>
</tr>
<tr>
<td>2010</td>
<td>Installation of monitoring</td>
</tr>
<tr>
<td>2011</td>
<td>Propping installed on one critical span</td>
</tr>
<tr>
<td>23^{rd} Dec 2011</td>
<td>Flyover closed to all traffic</td>
</tr>
</tbody>
</table>
Prestress Deterioration

Condition of Tendons
Prestress Deterioration

Condition of Tendons
Prestress Deterioration

Corrosion Locations

Corrosion concentrated at transition from external in “grout boxes” to conventional internal
## Prestress Deterioration

### Timeline (2)

<table>
<thead>
<tr>
<th>Date</th>
<th>Event Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>7(^{th}) Jan 2012</td>
<td>Flyover opened to 7.5T vehicles</td>
</tr>
<tr>
<td>23(^{rd}) Dec 2011</td>
<td>Flyover closed to all traffic</td>
</tr>
<tr>
<td>7(^{th}) Jan 2012</td>
<td>Flyover opened to 7.5T vehicles (2 lanes)</td>
</tr>
<tr>
<td>Jan – May 2012</td>
<td>Phase 1 strengthened constructed to partially strengthen 5 spans</td>
</tr>
<tr>
<td>30(^{th}) May 2012</td>
<td>Flyover fully reopened to all traffic (40T)</td>
</tr>
<tr>
<td>27(^{th}) July 2012</td>
<td>London 2012 Opening Ceremony</td>
</tr>
<tr>
<td>Late 2012</td>
<td>Phase 2 strengthening project commenced</td>
</tr>
</tbody>
</table>
## Monitoring & Investigation

### Methods Used

<table>
<thead>
<tr>
<th>Acoustic Emission</th>
<th>Intrusive Investigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Very Effective</td>
<td>- Targeted at specific locations</td>
</tr>
<tr>
<td>- Did not work during Phase 1 (emergency partial strengthening)</td>
<td>- Identified that virtually all failures at interfaces</td>
</tr>
<tr>
<td>- Filtering now improved</td>
<td>- Cannot see all wires</td>
</tr>
<tr>
<td>- Only tell you changes; not what has occurred already</td>
<td>- Results have to be extrapolated</td>
</tr>
</tbody>
</table>
Monitoring & Investigation

Risk – Prestress eventually becomes completely ineffective

- Need to ensure it is safe in the meantime
- Determine:
  - Current Condition Factors; how much of the original prestress is effective
  - Estimated deterioration rate and hence future Condition Factor
- Lower bound approach; same factor applied to whole unbonded length
- We know some rebonding occurred
Monitoring & Investigation

Indirect Methods – Monitoring Strain (less accurate)

Gauges span two in-situ joints
Prestress Replacement

Client Technical Requirements

- 120 years design life for all new construction
- 60 years residual life on existing structure
- Existing PT system redundant
- New PT to be replaceable
- Design to contemporary design standards/codes
- Use of Building Information Modelling (BIM)
Prestress Replacement

Client Technical Requirements

- 120 years design life for all new construction
- 60 years residual life on existing structure
- Existing PT system redundant
- New PT to be replaceable
- Design to contemporary design standards/codes
- Use of Building Information Modelling (BIM)
Prestress Replacement

Summary of Key Challenges

- Critical London arterial route – Roads above and below must remain open during works
- Highly constrained site with high density residential, commercial, community and transport
- Limited geometry – internally and externally
- Allow full future replacement
Prestress Replacement

Geometry – Internal & External

1.5m x 2.5m
Prestress Replacement

Geometry – Highway Clearances

5.03m
Prestress Replacement

Keep London Moving
Prestress Replacement

Location
Prestress Replacement

Phase 1 Strengthening

- Emergency strengthening of the 5 worst affected piers before London Olympics.
- Ramboll not involved.
- Road closures needed.
Prestress Replacement

Phase 2 Strengthening Concept
Prestress Replacement

Phase 2 Strengthening Concept
Prestress Replacement

Short Tendons – System

- **PROBLEM** – Cannot use grouted system.
- Grout installed before tendons stressed; temporary propping of tendon needed until tendons stressed; busy gyratory system; long term road closures *not an option*.
- **SOLUTION** – Use un-grouted, incrementally installed strands!
Prestress Replacement

Short Tendons – System

- 7-Wire Strand; fpk = 279kN
- Midspan Tendons = 22 Strands
- Capping Tendons = 13 Strands

Corrosion Protection

- Hot dipped galvanised strands
- Semi-bonded extruded polyethylene sheath
- Space between wire and sheath filled with petroleum wax

Or (Cohestrand)

- Hot dipped galvanised strands
- Bonded extruded polyethylene sheath
- Space between wire and sheath filled polybutadiene resin
Prestress Replacement

Short Tendons – Cable Stay Technology Anchorage
Prestress Replacement

Short Tendon – Blister Design

- Reinforced concrete anchors would have rebar crowding & tolerance problems
- Phase 2 blisters are more complicated and need to be more compact.
- PROBLEM!
Prestress Replacement

Short Tendon – Blister Design

- Ultra High Performance Fibre Reinforced Concrete (UHPFRC) – Ductal®
- Very high compressive strength 130N/mm²; Tensile strength 10N/mm².
- Unreinforced enabling lighter, more compact shape.
- Improved installation safety & maintained clearances.
- Avoided the reinforcement fixing tolerance and congestion experienced on Phase 1.
- Little design guidance; designed by testing.
Prestress Replacement

Short Tendon – Blister Design

- Prestress anchor (bar and tendon) load transfer testing.
- Confirmation of behaviour of blister anchor zones when stressed.
- Test-bed constructed in Freyssinet factory.
- Near full scale testing of complete blister and friction interface.
- Flat jack used to replicate tendon jacking force.
Prestress Replacement

Short Tendon – Blister Design
Prestress Replacement

Short Tendons – System

Blister Post-Tensioning Bars

• High Tensile Steel Bars; yield stress = 1200 N/mm²
• Maximum Diameter M52 (47mm)

Corrosion Protection

• Tubes and caps filled with petroleum wax
Prestress Replacement

Long Tendons - Anchors
Prestress Replacement

Long Tendons - Anchors
Prestress Replacement

Long Tendons - Anchors
Prestress Replacement

Long Tendons – System

- 7-Wire Strand; fpk = 279kN
- 6 x 37 Strand Deviated Tendons
- Maximum strand length 350m length

Corrosion Protection

- Wax filled HDPE Duct
- Un-sheathed galvanised strand
- Individual strands cannot be destressed and removed. Necessary compromise to design requirements.
Prestress Replacement

Existing Prestress – Deactivation

- **Almost** possible to replace prestress without deactivating the original.
- Philosophy of **Progressive Strengthening** employed. No existing prestress removed until strength replaced.
No traffic during first deactivation. Relaxed later.
Exclusion zone plus plywood boxes to protect operatives.
Re-anchoring was not instantaneous, the wires crept back in the concrete for several hours.
Prestress Replacement

Confined Spaces!
Acknowledgements

True Collaborative Team Effort!