Runcorn Viaduct

Refurbishment 2017-2018

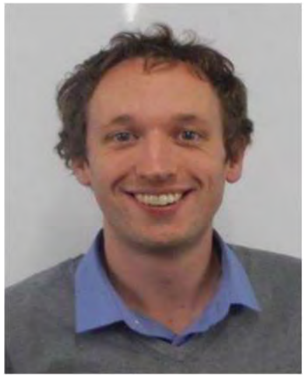
Introduction

- Structure Overview and History
- Project Overview
- Phase 2 Refurbishment Works
- Future Bearing Replacement – Initial Feasibility Study

Speakers

Richard Johnson MEng (Hons) CEng MICE
Rail Engineering Manager (North) for Buckingham Group Contracting Ltd.

Richard has over 19 years' experience in the rail industry as CRE/CEM on a range of projects across the North. He specialises in bridge and multi-disciplinary projects and has taken a leading role in several ECI schemes.



Marc Fletcher MEng (Hons) CEng MICE
Contractor's Responsible Engineer for Buckingham Group for the Runcorn Viaduct Refurbishment Works.

Marc has over 10 years' civil engineering design consultancy and construction experience across a range of national and local rail projects.

Runcorn Rail Bridge

RUNCORN RAIL BRIDGE
150 YRS • 1868-2018

- Carries overhead electrified twin track Liverpool spur of West Coast Mainline (WCML) between Runcorn and Widnes
- Crosses the Mersey estuary at a pinch point between Runcorn and Widnes.
- The bridge is part of a much longer viaduct which continues on both sides of the estuary.
- Grade II* Listed structure
- Designed by William Baker and opened in 1868.

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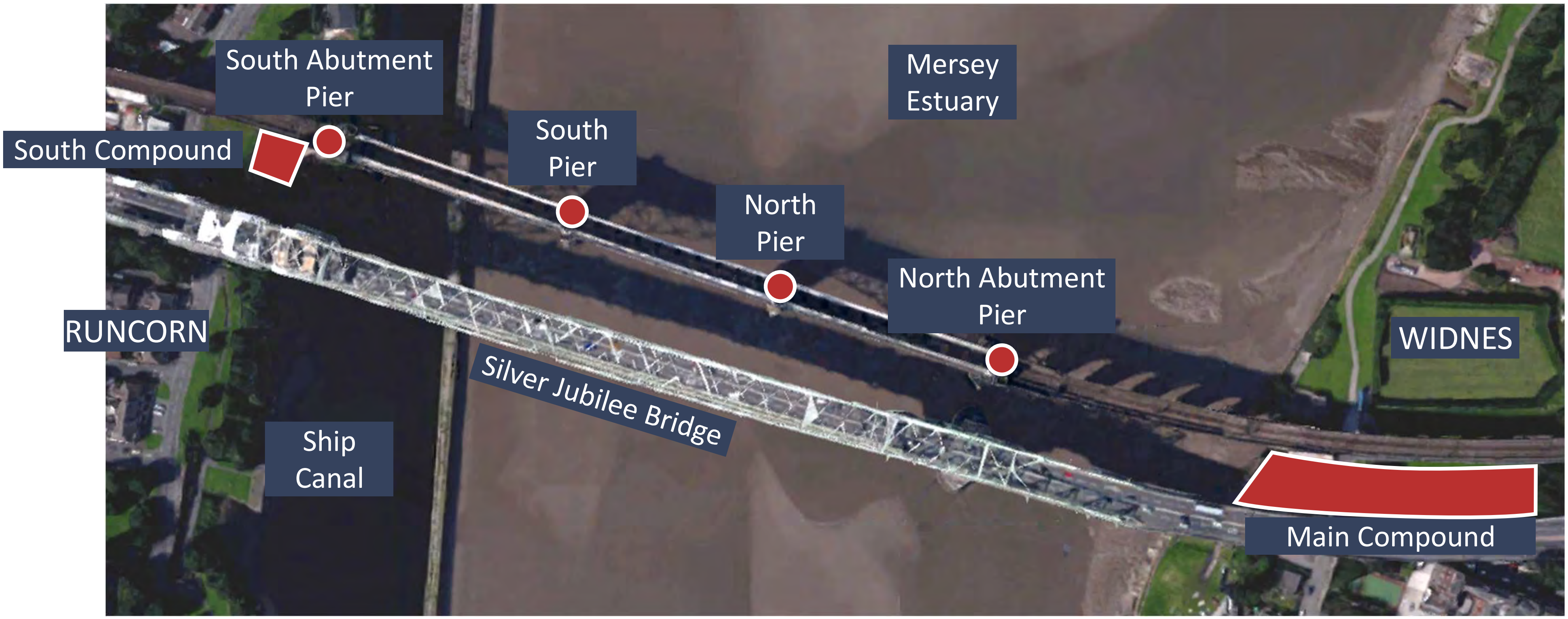
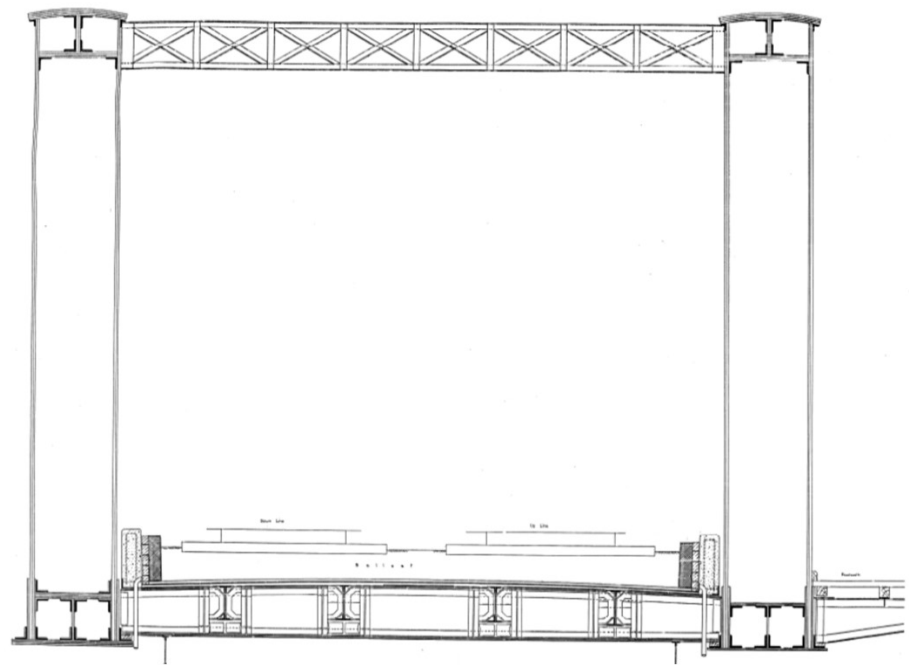
Runcorn Rail Bridge



Runcorn Rail Bridge

- 3 Span Wrought Iron Lattice Truss Through Bridge
- 305ft (93m) spans with 75ft (23m) clearance to soffit required for shipping on the Mersey and Ship Canal
- Each span comprised of 2 lattice trusses formed from twin box section chords and wrought iron latticework.
- Deck formed from wrought iron plate with cross-girders and rail bearers
- Sandstone piers and abutments (with voids) constructed on bedrock



History

- Construction commenced in 1863 and the bridge opened to traffic in October 1868
- First bridge crossing of the Mersey Estuary
- East Walkway originally open to public as alternative route to ferry
- East Walkway closed to public in 1960's when the adjacent road Runcorn Road Bridge opened (now called Silver Jubilee Bridge).

Image courtesy of Network Rail

RUNCORN RAIL BRIDGE
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Construction

RUNCORN RAIL BRIDGE
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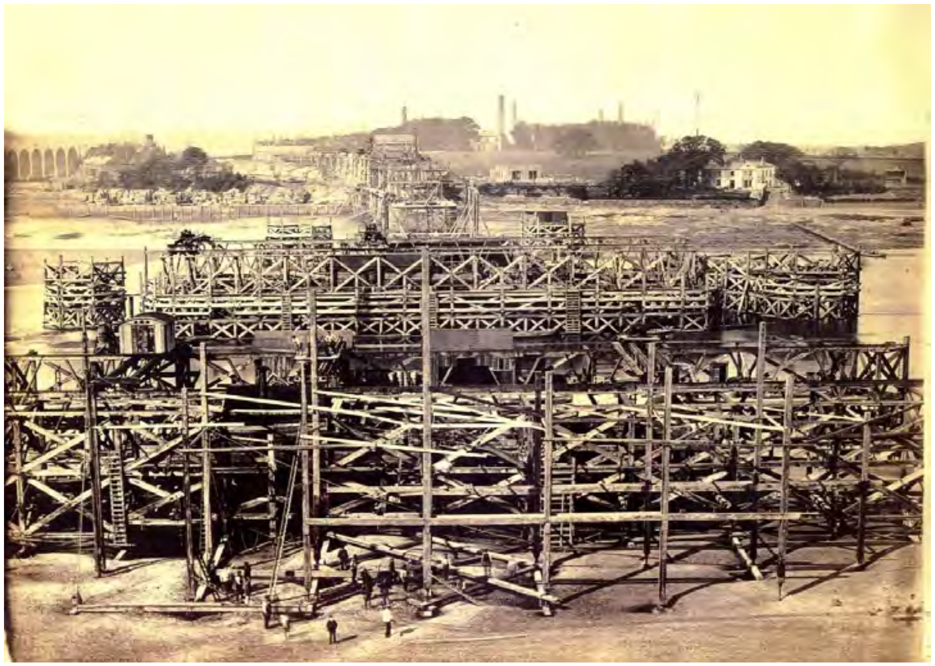

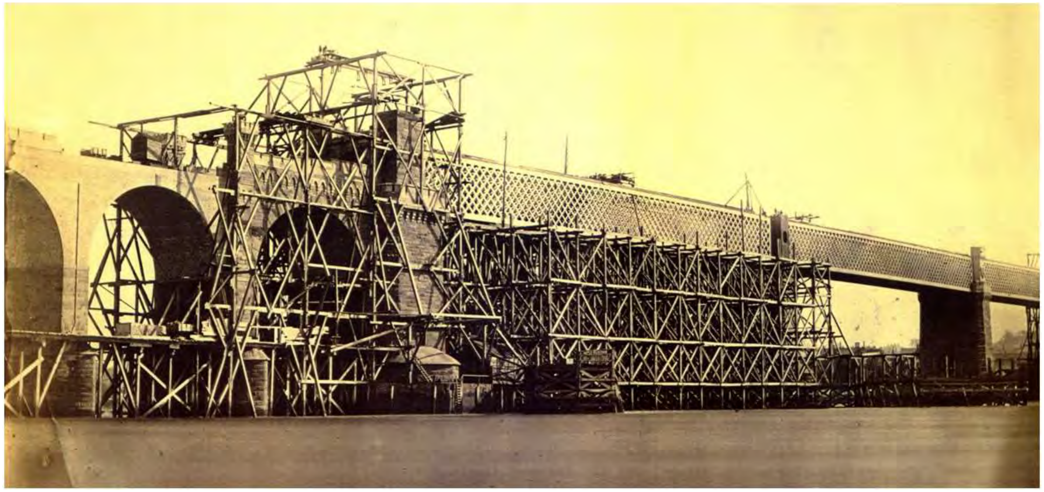

Images courtesy of Network Rail

Construction

Image courtesy of Network Rail

Project Timeline

Phase 1 (2015-16)	• Visual and intrusive investigations • Structural Assessment using Finite Element Model • 3D survey using combination of drone and ground measurements
Phase 2 (2017-8)	• East Walkway Refurbishment • Stone Turret Waterproofing • Pier Fender Refurbishment
Phase 3 (>2024)	• Bearing replacement (Initial work in 2015/16)

Phase 1 – SI and Assessment

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- Bridge condition inspection by roped access
- 3D survey using combination of drone and ground measurements
- Intrusive works in the piers
- Structural assessment using 3D FEA models
- Initial feasibility of bearing replacement
- Identified urgent maintenance required to East Walkway, Fenders and drainage system. Historic navigation bell at risk of being lost

3D Survey and Model

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Phase 2 – Partial Refurbishment

- Replace/refurbish the cast iron walkway parapets like-for-like
- Refurbish and repaint the cantilever walkway and elevation of the east bottom chords
- Waterproof the top surface of all the bottom chords
- Waterproof the stone ‘turrets’ at each end of the bridge and repair/replace the drainage
- Remove or stabilise the ‘Navigation Bell’ on the South Pier
- Refurbish the timber fenders on the piers, replacing rotten/missing timbers and selective renewal of the metal banding

Phase 2 – Project Team

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Client
Network Rail (Infrastructure Projects)

NR Air Operations
&
PDG Helicopters

Client
INOVYN (11kV Cable Route Repairs)

Principal Contractor
Buckingham Group Contracting

Steelwork and Painting
Taziker Industrial

New Parapet Castings
Shakespeare Foundry

Off-Site Refurbishment
NL Williams

Designer
Arcadis

Fenders
Carmet Marine

Marine Safety
Safety Training International

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Phase 2 - Interfaces

- Marine Management Organisation
- HM Coastguard
- Manchester Ship Canal Company (Peel Holdings)
- Crown Estate
- Halton Borough Council
- Liverpool John Lennon Airport (ATC)
- NR IP Signalling – Weaver to Wavertree Resignalling Project
- Balvac (Silver Jubilee Bridge Refurbishment)
- Inovyn (11kV cable route – vital power supply)
- Local school and residents

Site Constraints

- Difficult access
- Adjacent Silver Jubilee Bridge refurbishment worksite
- Manchester Ship Canal (2 or 3 ships per day)
- Mersey Estuary – high tidal range and fast flows with tidal bore on spring tides. Dangerous mud flats at low tide
- No safe access to trackbed whilst trains running. Only access is 2m wide walkway on eastern elevation.
- Compounds located in residential areas
- 11kV Inovyn cable – unplanned supply interruptions costly

Safety and CDM

- Works involved four ‘Schedule 3’ risks from CDM 2015
  - Lead exposure during blasting
  - All works above or adjacent to fast tidal flows
  - Works adjacent to 25kV OLE and 11kV power supply (INOVYN)
  - Assembly/dismantling of heavy cast iron parapet elements (up to 450kg)
- Very constrained site and limited opportunity for mechanical lifting equipment
- West Coast Mainline so limited track access
- Adjacent Balvac worksite – co-ordination of water based activities and safety boats
- All activities meticulously planned with subcontractors and co-ordinated by BGCL

Temporary Works

- 3no. 90m length suspended scaffolds with full encapsulation for grit blast and paint.
- Load assessment by Arcadis.

Temporary Works

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Temporary Works

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- 2no. 20m high Loading bays (one each end of structure) and 'Haki' staircases.
- Scaffold jetties in the estuary and ship canal for safety boat
- Turret access scaffolds

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Design Close Call

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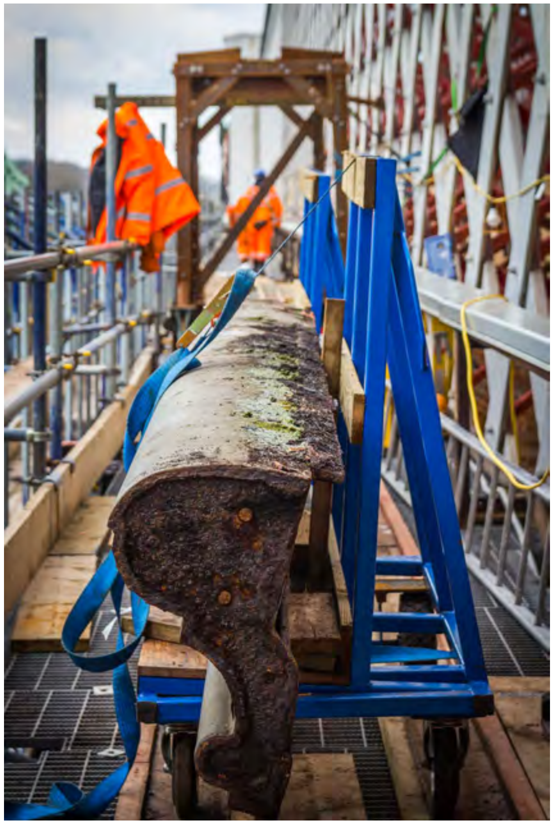
- During works a risk was identified where personnel were leaning out to move the cast iron elements due to limited clearance between hoists and scaffold handrails
- Scaffold design revised to increase clearance and provide attachment points for inertia reel harnesses
- Longer 'Niko Rail' with longer projections to avoid manual effort
- Alternative hoists used to reduce clearance required

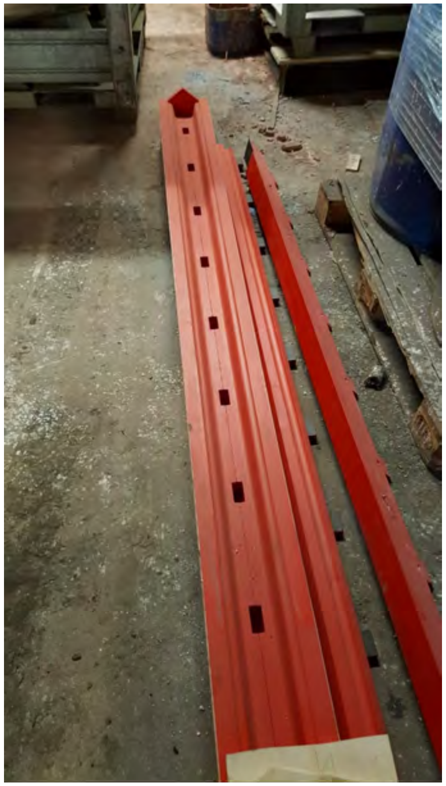
Cast Iron Parapets

- Each parapet ‘bay’ formed from 6no. Interlocking elements: Top Rail, Lattice Half Panels, Bottom Rail, Bullnose and post.
- The ‘bullnose’ is the heaviest element with each weighing 450kg
- Over 500 elements of cast iron to be removed and reinstated/replaced
- All elements formed from brittle 1860’s grey cast iron. Many elements had previously fractured and could not be reused.
- Replacement elements formed from Spheroidal Graphite (SG) Ductile Iron.
- Alternative lighter materials ruled out at early stage of design by Network Rail.



Parapets - Casting

- November 2017 – initial elements removed from the structure to start production of ‘pattern’ at Shakespeare Foundry, Preston
- Pattern is a reusable timber replica of the element to be cast. The replica has to be around 2% larger than the final element to allow for heat shrinkage
- Pattern making is a skilled carpentry task and takes several weeks



Parapets – Casting

- Pattern is used to make sand moulds, these can be ‘boxed’ or ‘boxless’ (‘boxless’ requires less floor space but is more expensive)
- ‘Sand Core’ used for creating internal voids
- A new mould is made for each individual component

Parapets – Casting

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- Molten iron temperature carefully controlled to prevent ‘blow out’ of mould (too hot) or internal voids (too cold)
- Casting left in mould for hours/days/weeks depending on volume to prevent warping or fracture
- Bullnose cooling time was 36 hours and was the most difficult to cast
- Concerns over warping of intricate lattice panels

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Parapets - Casting

- Once removed from the mould, the elements require ‘fettling’ to remove runners and create a surface finish
- Need to define surface finish standard at start of contract using BS EN 1370:2011.

Parapets- Casting

- First trial erection in Feb 2018, second trial in April 2018 before full production run
- Large area of floor space required for elements limits production rate
- Typically produced 25 elements per week, limited by floor space

Parapets- Finishing

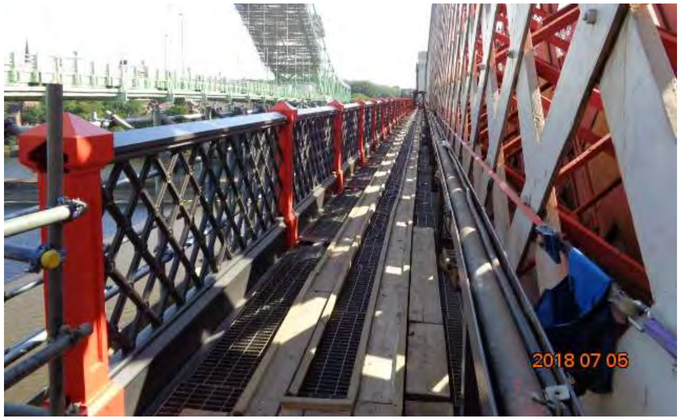
- Elements transferred from Foundry to Painters (NL Williams in St Helens)
- Local filling required to rectify minor defects such as blow holes
- Initial issues with surface finish resolved by changing paint setup
- Full M24 paint system required 1 week per item (completed in batches of up to 30)

Parapet Removal / Installation

- Steelwork repairs/painting to the cantilevered support beams before reinstating parapets
- All items individually lifted around 15m using loading bay hoists
- Transported over 200m on trolleys by hand (500kg total weight)
- Able to install up to 6 bays (30 elements) per day but limited by production rate of foundry.
- High risk activities with detailed planning and regular reviews

Parapet Installation

- Bespoke lifting frames critical to successful implementation
- Trolleys and runways used to transport elements from loading bay to working area.
- Challenging logistics to avoid working above the fender refurbishment works.

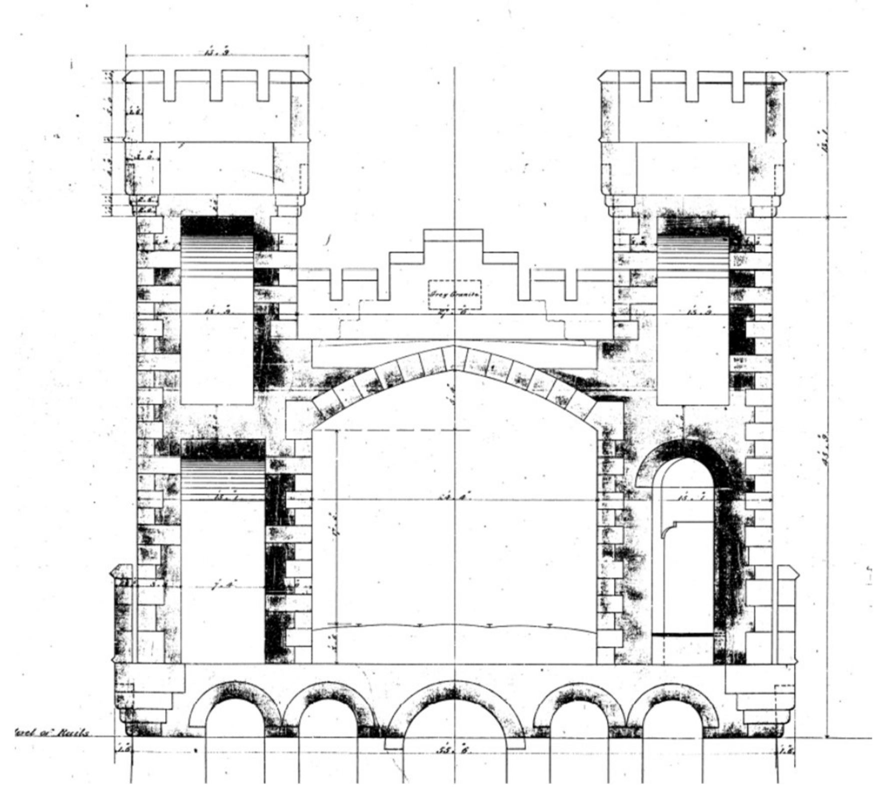


Steelwork Repairs

- Modifications to cantilever beam ends to allow tolerance for fixed size castings
- Steelwork repairs to beam ends for parapet fixings

Turret Waterproofing

- Difficult access to stone turrets up to 20m above rail level (over 40m above the Mersey)
- Only possible during weekend blockades with full isolations
- Co-ordination with Weaver to Wavertree project to identify access opportunities
- Roped access to replace external drainage pipes and clear debris from bearing shelf



Turret Waterproofing

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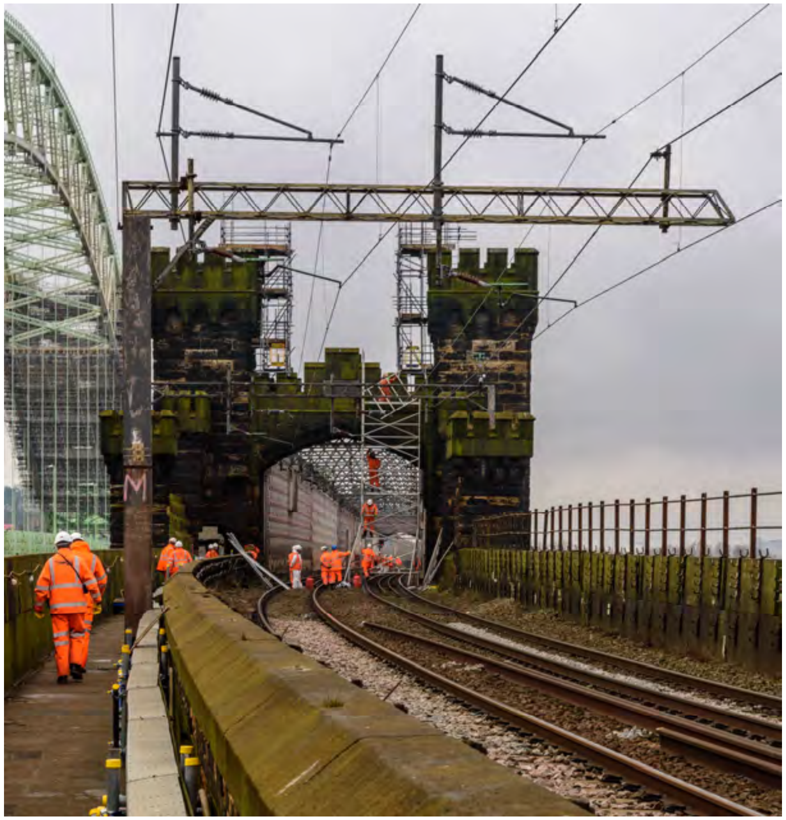
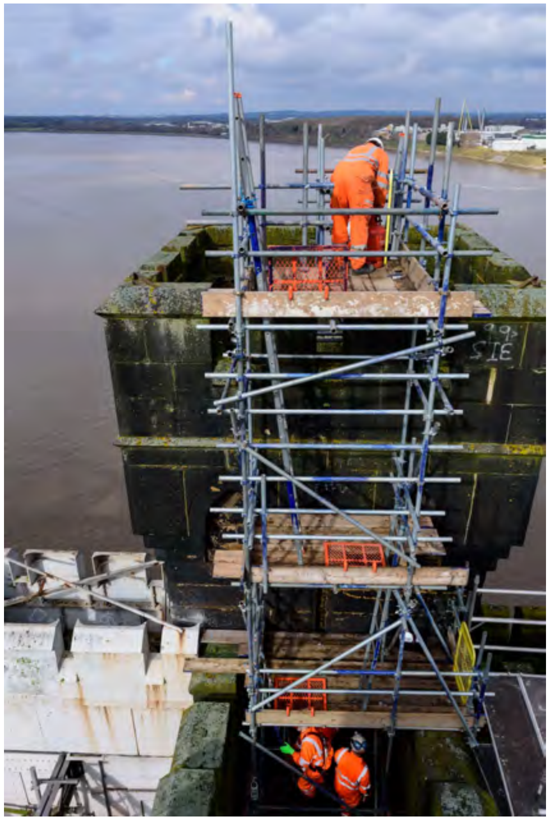


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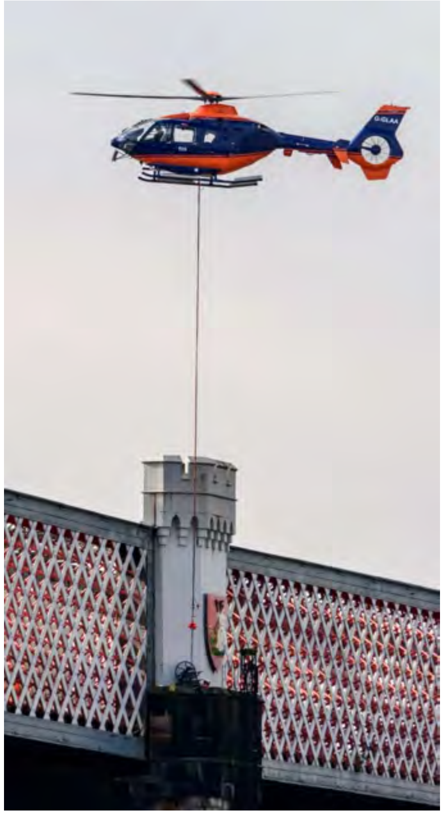
Runcorn Viaduct – Navigation Bell

- Inaccessible location made repair difficult and expensive
- Future maintenance challenging
- Removed using helicopter organised via NR Air Operations

Navigation Bell

- Lift could only be undertaken during full possession and isolation of overhead electrification
- 30 minute planned window with Liverpool John Lennon Airport (approx. 5 miles from bridge)
- Exclusion zone around entire bridge and watercourse below (including shipping on Canal)
- 2 months of planning with NR Air Operations and their partner PDG Helicopters
- 500kg maximum lift weight, every kilogram to be accounted for



Helicopter Lift

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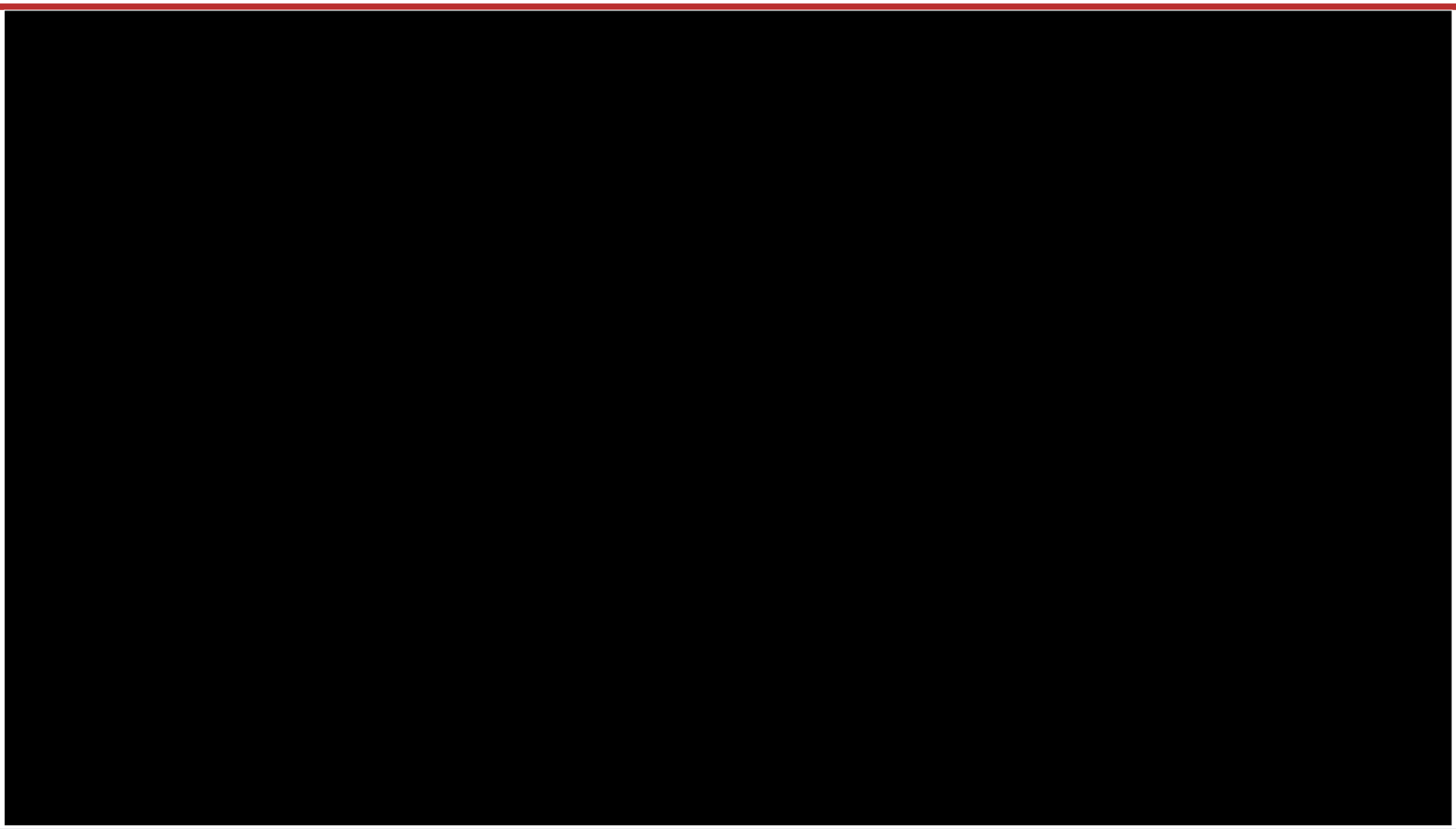

Navigation Bell

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- After removal, the bell was refurbished and donated to Halton Borough Council by Network Rail
- Listed Building Consent Condition required the Bell to be put on public display if removed.
- Bell exhibition unveiled at Brindley Theatre, Runcorn in October 2018 to coincide with 150 year anniversary of bridge opening

Pier Fenders

- Refurbishment of Fenders
  - New Sustainably Sourced Ekki Hardwood – 350kg for largest pieces
  - Each piece cut to suit
  - Stainless Steel Anchors
  - Steel bands

Pier Fenders

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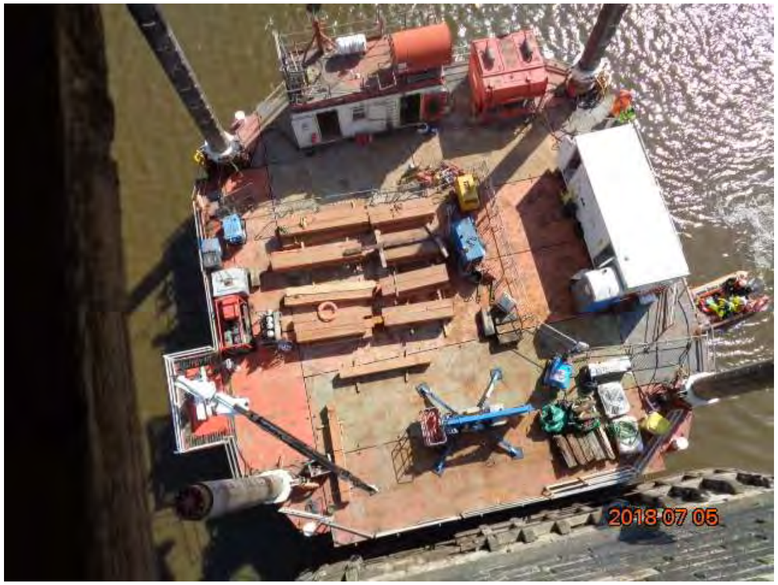
- Challenging marine environment with high flow rates (incoming tide 2 hours, outgoing tide 10 hours)
- Dry river bed for 6 hours every 12 hours



Pier Fenders

- No maintained navigable channel between Liverpool Airport and Runcorn Bridge
- Challenging navigation due to shifting sandbanks and shallow depth
- 24hrs to travel 16km due to narrow tidal windows

Pier Fenders

- 18m x 18m modular jack-up barge with hydraulic legs to allow working surface level to be partially independent of tides
- Full welfare facilities on board
- 12 hour shifts to suit the tides. Barge manned 24 hours a day, 7 days a week for 7 weeks
- Only accessible at high tide by boat from Widnes 'Public Jetty'
- Fatigue management

Pier Fenders

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- Jack-up rig could only be moved and re-supplied at high tide
- Tug boat follows the high tide to the bridge bringing new materials
- Tug pushes the barge against the incoming/outgoing tide to maintain control
- At least one leg of the barge in the river bed at all times to prevent barge drifting
- Tug boat leaves site on outgoing tide with waste materials

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Pier Fenders

- All regular crew required STCW competency to work 'at sea' in the estuary (Personal survival, fire fighting etc)
- Visitors and specialists allowed when escorted by crew
- Rig too large for arch spans and adjacent to Jubilee Bridge. Slower workboats, more dependant on tides (no jack-up facility)
- Shallow water depth – risk of damaging workboats

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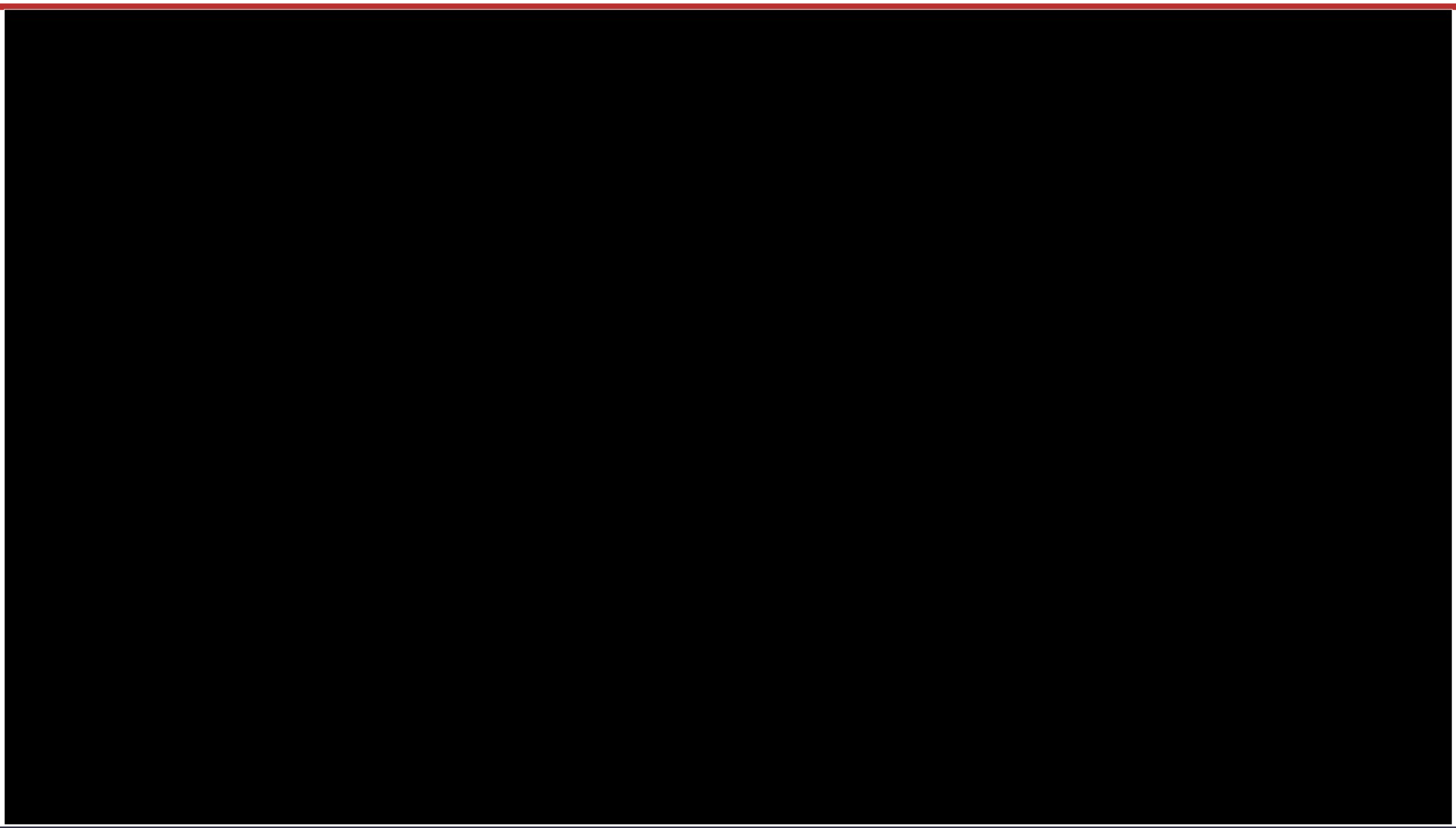
Pier Fender Timelapse



Bearing Replacement

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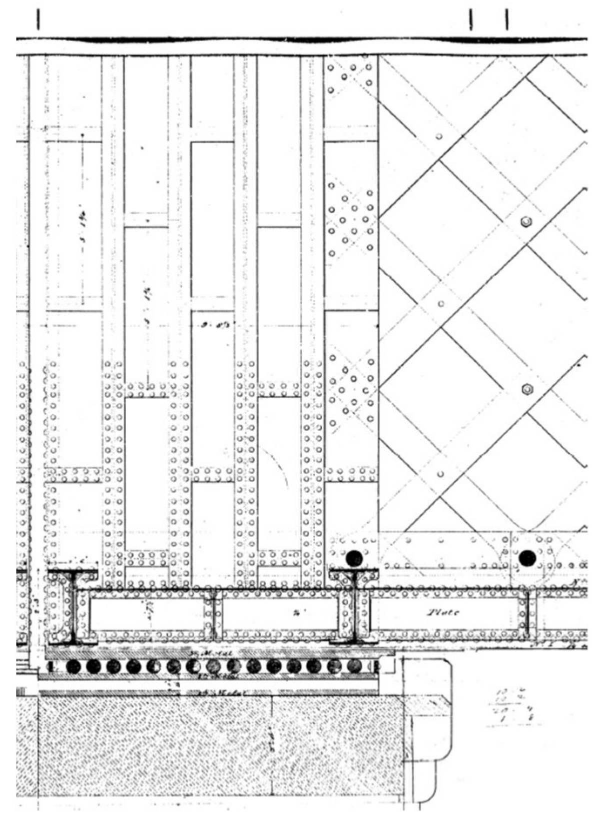
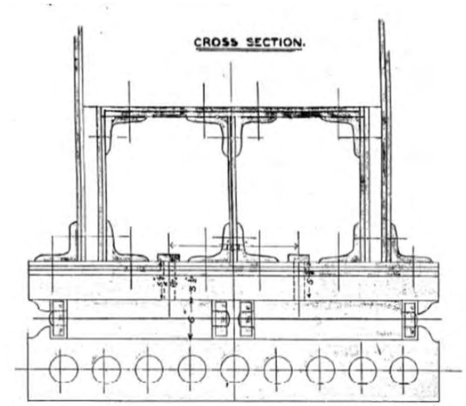
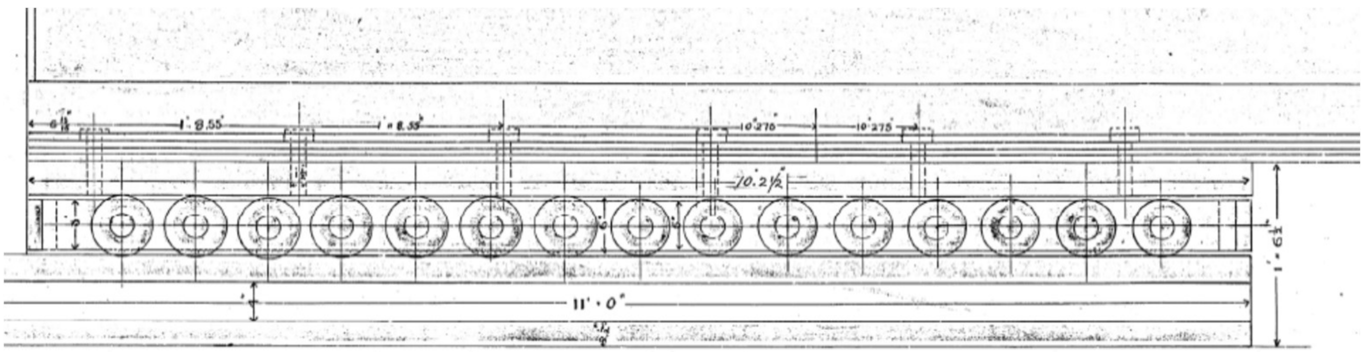
- The bridge is intended to be articulated as three simply supported spans with roller bearings located over the piers and a fixed point on the south abutment pier.
- There is limited longitudinal continuity at deck level through the rail bearers
- Cellular box structure over the bearings at each end to increase shear strength
- Ends of structure covered by decorative cast iron panels



Bearing Replacement

- Roller bearings comprise a series of iron rollers which appear to have seized and may have deformed
- Seized bearings are causing the piers and adjacent viaduct spans to deflect.
- Large cracks in the piers appear to vary seasonally with temperature



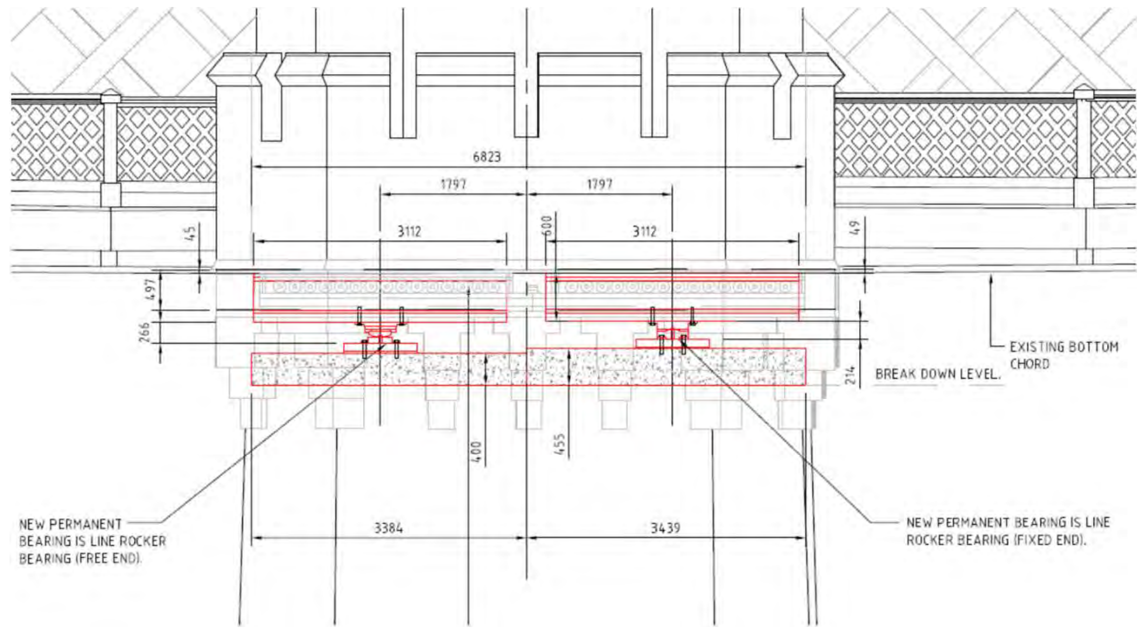


Bearing Replacement

- Bridge inspections and monitoring has found large cracks in the pier masonry which appear to vary seasonally with temperature
- The cracking in the substructure is a long standing issue
- The bridge has been assessed as adequate for current and future loading in present state despite the seized bearings
- Bearing replacement would be high cost, high risk operation
- Alternative, lower cost/risk option, would be to repair the substructure damage and carry out additional ongoing maintenance

Bearing Replacement

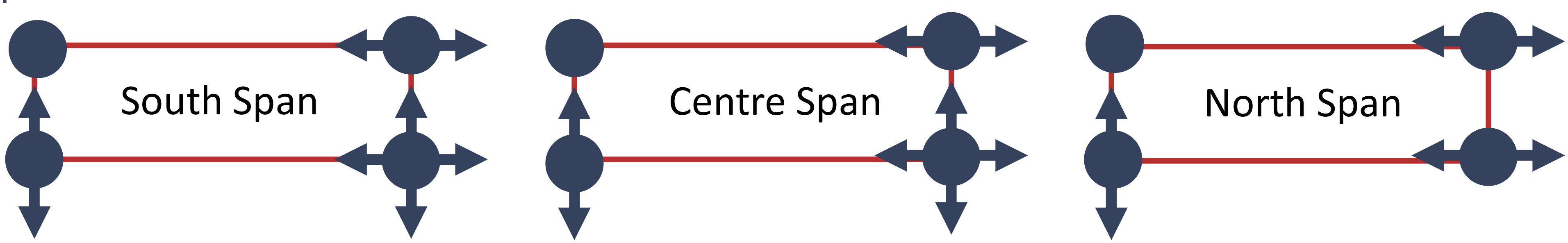
- Proposed structure articulation would change the structure to three independent simply supported spans.
- New stainless steel line rocker bearing proposed to maximise design life



Articulation

Existing

Proposed



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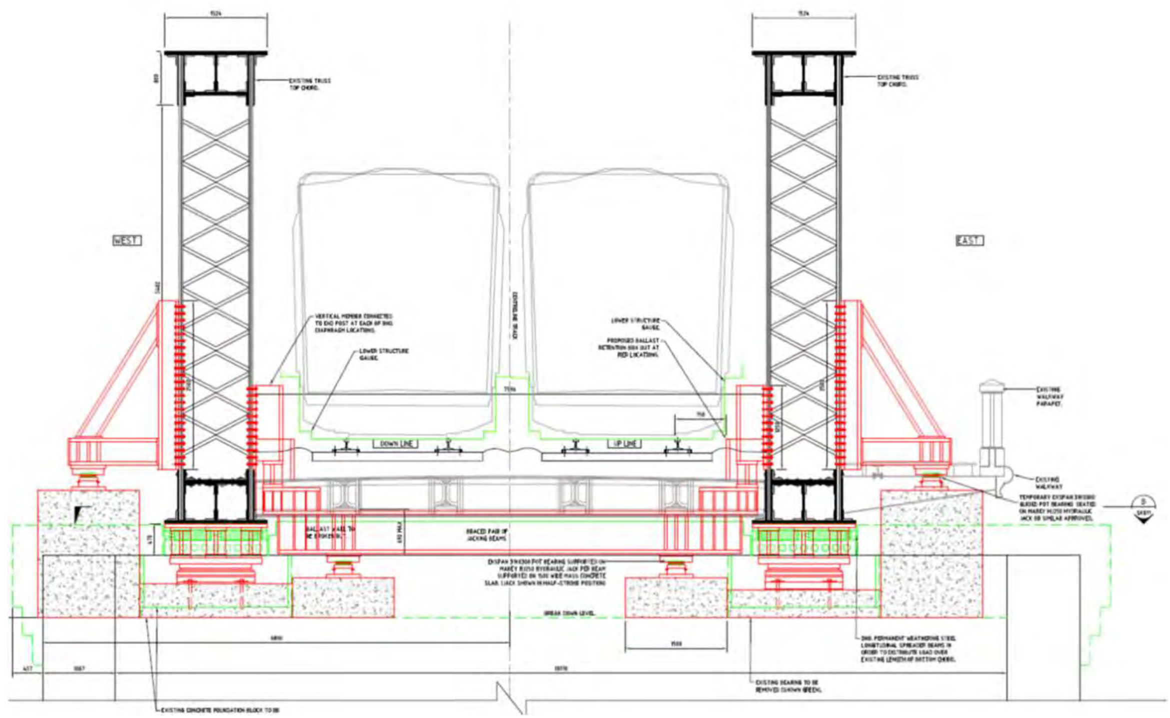
Bearing Replacement

- Proposal to replace the existing bearings with modern bearings
- Lattice structure adjacent to bearings has low shear strength as structure not intended to be jacked. Bearing replacement not considered by original designers.
- Strengthening of lattice structure required to provide jacking/lifting points



Bearing Replacement

- Early feasibility discussions between BGCL, Network Rail, Arcadis and Freyssinet
- Substantial temporary works with many options considered including ‘mining’ of the existing bearings to allow new bearings to be installed.

Bearing Replacement Options

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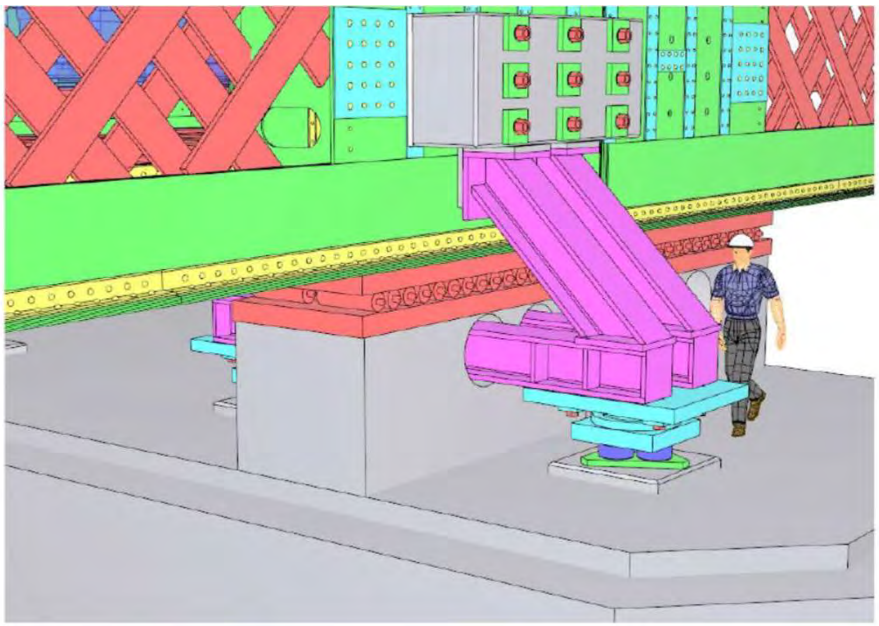
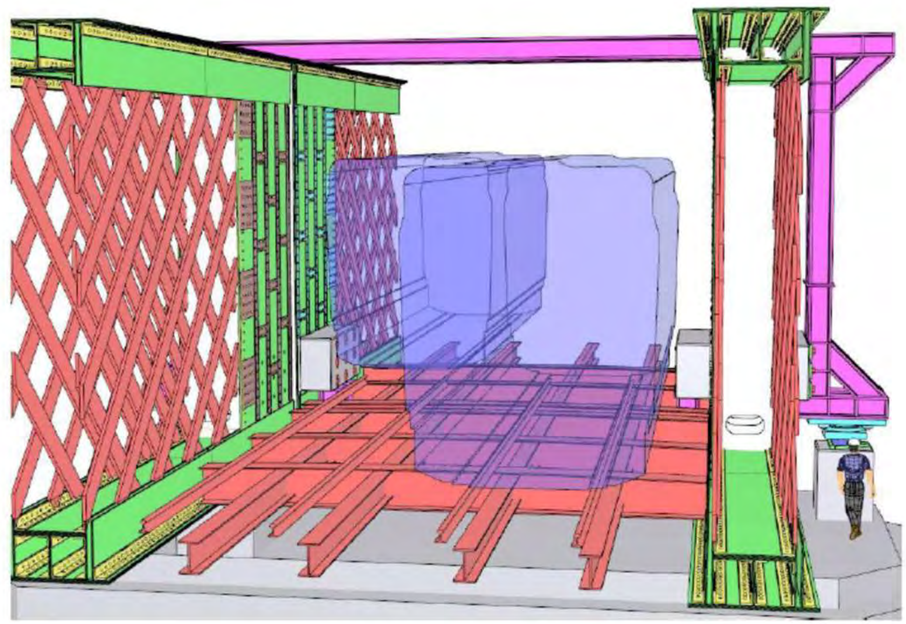
- Hydraulic Jacking with modifications to existing bearing shelf





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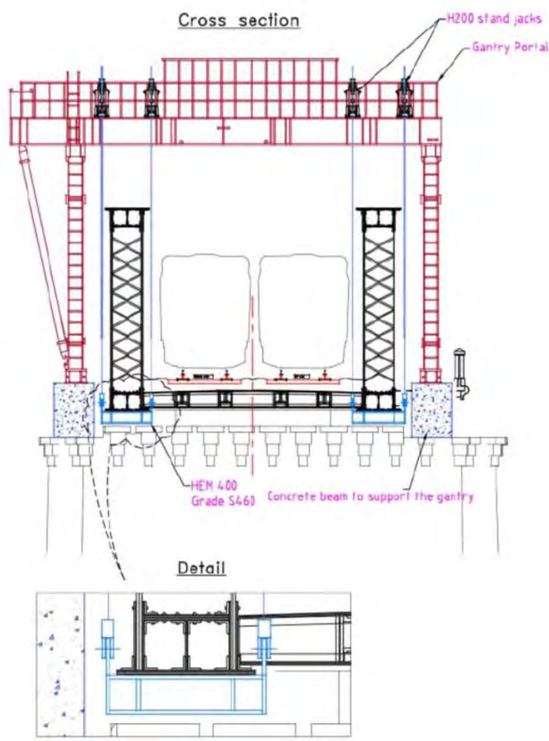
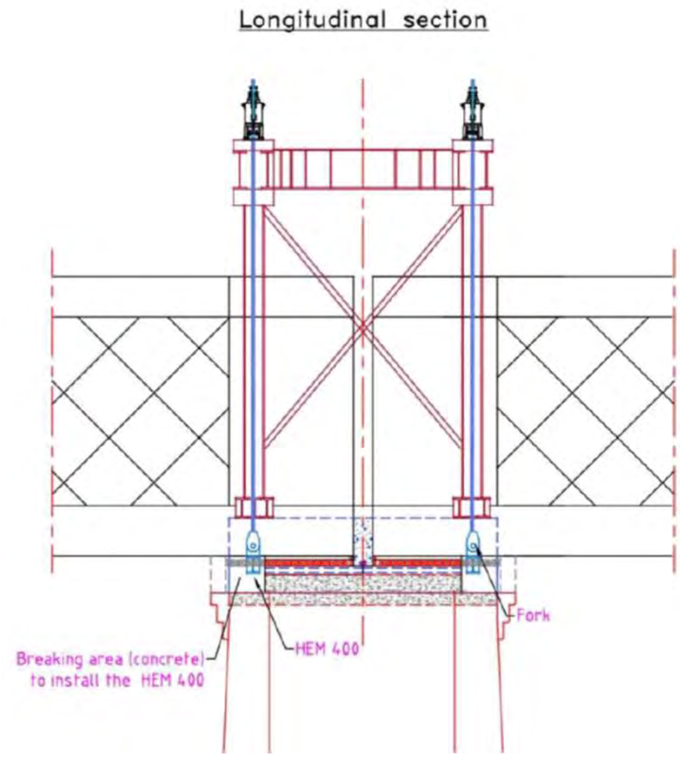
Bearing Replacement Options

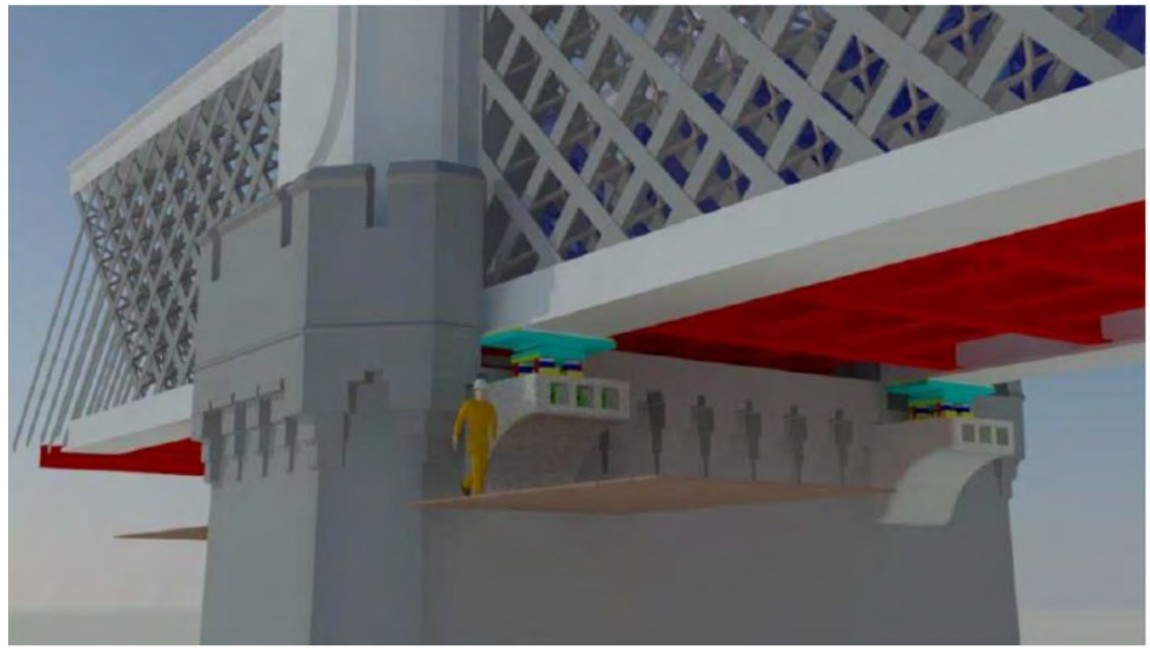
- Strand Jacking





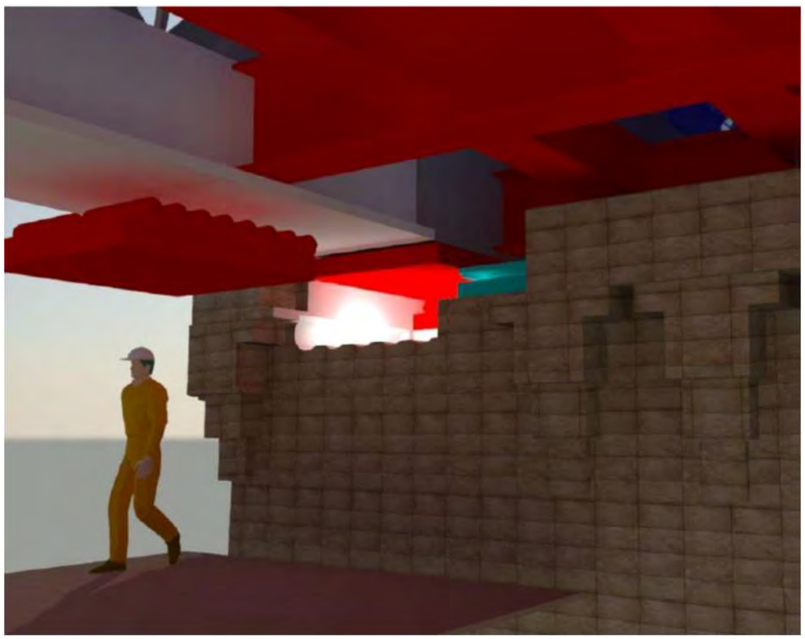
Bearing Replacement Options

- High Performance Concrete (HPC) corbels



Bearing Replacement Options

- Progressive bearing replacement (“mining”)



Bearing Replacement

- Works likely to require the bridge to be temporarily lifted to allow access to the bearings
- Strategic location on WCML limits opportunities for long blockade.
- Long viaducts each side of bridge limit options for temporary track alignments
- Safety of operating trains whilst bridge is in jacked position to be considered
- Due to seized bearings, current stress state is difficult to determine and behavior of bridge during jacking/lifting challenging to predict
- Additional bridge monitoring required to validate 3D FEA model

Summary

- Runcorn Bridge is likely to remain an important strategic asset for the foreseeable future
- Phase 2 works have secured the immediate future of the structure
- Phase 2 works were challenging due to the constrained site with multiple interfaces
- Like for Like replacement of cast-iron parapets was a complex activity
- Bearing replacement is a high cost/risk activity and there is a case for adopting an enhanced maintenance regime to manage the seized bearings

Thank You

Contact
Richard Johnson
Email: richard.johnson@buckinghamgroup.co.uk