Repair and strengthening of masonry arches.

Network Rail’s Experiences

Is strengthening necessary?

Brian Bell, Network Rail
Presentation outline

• Arch bridges
• Deterioration and repair
• Strengthening
  – Considerations
  – Techniques
• Further reading
• A new development
Each arch bridge is unique.
181’ (approx 60m) main span, 169’ (approx 55m) above watercourse

main spans 128’ (39m), rise 24’ (7m)

Network Rail
37 semi circular brick arches, 1475’ (450m) long (contains 11m Dutch bricks)
sometimes do funny jobs ...
and can be picturesque!
• They tend to very long lasting

• But they do suffer from wear and tear
Natural deterioration
Repair methods - repointing

Pointing mortar must be weaker than masonry in arch
Repair methods - grouting
Repair methods – patch repair

Try to match physical properties of the new units with those of the existing units.
Repair methods – patch repair

Try to match physical properties of the new units with those of the existing units.
Ring separation
Repair method - through ring stitching
Pier/abutment movement
Pier/abutment movement
Pier/abutment movement
Repair methods - underpinning
Spandrel movement
Repair methods – pattress plates
Parapet damage
Repair methods – repair/upgrade
## Inadequate capacity

<table>
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<th>Structural defect and location</th>
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| Concrete saddle      | Replacement of existing fill material with a reinforced concrete saddle, to which the spandrel walls and extrados are sometimes stitched using structural ties, aiming to create a composite structure with enhanced stability and to facilitate waterproofing repairs. | Inadequate overall load carrying capacity of arch barrel in conjunction with spandrel wall and waterproofing failures. | - no change to appearance as hidden  
- facilitates other repairs/parapet upgrades/waterproofing  
- enhanced live load capacity | - traffic disruption during construction  
- relative cost  
- increase in crown depth | Effective implementation and inspection/maintenance will enhance structural performance in line with the strengthening or repair design life. | Used |
| Prefabricated liners | Structural lining (normally corrugated steel or precast concrete liners) are installed beneath the existing arch structure to provide a secondary support mechanism within an existing deformed or deteriorated arch | Inadequate overall live load carrying capacity of arch and/or abutments where depth of fill over the arch barrel is excessive. This can also address spandrel wall and waterproofing failures. | - no change to appearance as hidden  
- facilitates other repairs  
- enhanced live load capacity | - traffic disruption during construction  
- relative cost  
- increase in crown depth | Existing structure assumed to be redundant with liner designed to take full dead and live loading. | Used |
| Retro-reinforcement  | Installation of additional structural reinforcement to the arch barrel aims to increase its structural capacity while not reducing structure clearances or significantly affecting the bridge’s appearance. | Inadequate overall load carrying capacity of arch barrel. | - repairs hidden  
- much less disruption than saddle/slab Reconstruction  
- relative cost  
- speed of implementation | - Independent verification/validation of analysis, design, installation, fatigue and durability of systems | Effective implementation will allow the structure to support specific enhanced loadings | Some railway authorities do not accept this method |
| Relieving slab       | Installation of a horizontal reinforced concrete slab over the plan area of the arch, extending over the abutments. Aims to improve live load carrying capacity of the arch while eradicating the generation of additional horizontal thrust from the arch into the abutments at springing level. | Incompetent existing fill material or inadequate overall load carrying capacity | - no change to external appearance  
- enhanced live load capacity | - traffic disruption during construction  
- relative cost  
- increase in crown depth possible | Effective implementation will allow the structure to continue to perform as originally designed with increased capacity. | Used |
| Sprayed concrete lining | Application of structural sprayed concrete to the arch barrel intrados to repair and strengthen arches which are suffering from major defects such as arch barrel distortion, deteriorated masonry and severe cracking. | Inadequate overall carrying capacity | - little disruption to traffic flow over the bridge  
- enhance load carry capacity  
- reinforcement can be incorporated | - alter appearance  
- reduces opening under the bridge  
- cannot inspect condition of original arch barrel | Spayed concrete provides strengthening mechanism for weakened deteriorated structures. | Used |
| Thickening surfacing | Provision of an additional thickness of surfacing distributes the live loads more evenly through the arch and can result in higher live load capacity for the structure. | Inadequate overall live load carrying capacity of arch barrel | - possible enhanced live load capacity  
- relative cost | - traffic disruption during construction  
- structure life expectancy unaffected by works  
- further maintenance works may be required | Improved performance and capacity of original structure | Used |
Strengthening considerations

- Consider carefully before specifying
  - Can foundations take increased loading?
  - Are load paths within arch altered?
  - Will arch be stiffer afterwards?
  - Are suppliers’ published claims reliable?
  - Will arch be unacceptably weakened as part of installation process?
Laboratory test method
Strengthening - concrete saddle

Saddling video
Strengthening - prefabricated liners
Strengthening – near surface reinforcement
Strengthening – through arch reinforcement
Other methods

- Relieving slab
- Sprayed concrete
- Thickening surface
Recommended reading

CIRIA report C656 available for free download or purchase from www.ciria.org
Chapter 4.5 describes repair and strengthening techniques for arch bridges.

Appendix C looks at strengthening in more detail.

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“project reports”
Thank you