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

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Each arch bridge is unique

Small …

daring designs …

main spans 128’ (39m), rise 24’ (7m)

181’ (approx 60m) main span, 169’ (approx 55m) above watercourse

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long...

37 semi circular brick arches, 1475’ (450m) long (contains 11m Dutch bricks)

sometimes do funny jobs …

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and can be picturesque!

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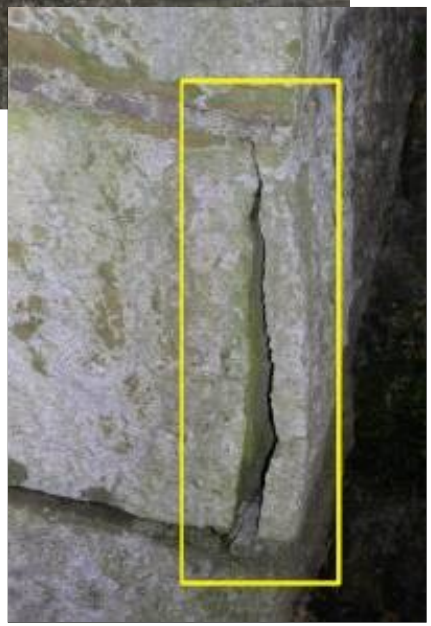
- They tend to very long lasting
- But they do suffer from wear and tear

Natural deterioration



Damage

Repair methods - repointing

Pointing mortar must be weaker than masonry in arch

Repair methods - grouting

Repair methods – patch repair

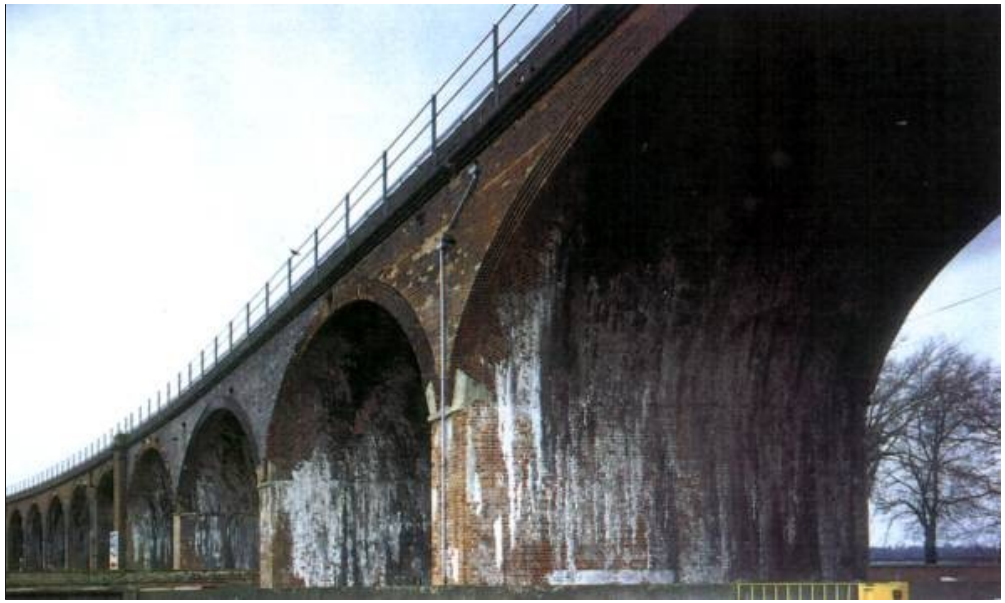
Try to match physical properties of the new units with those of the existing units

Repair methods – patch repair

Try to match physical properties of the new units with those of the existing units

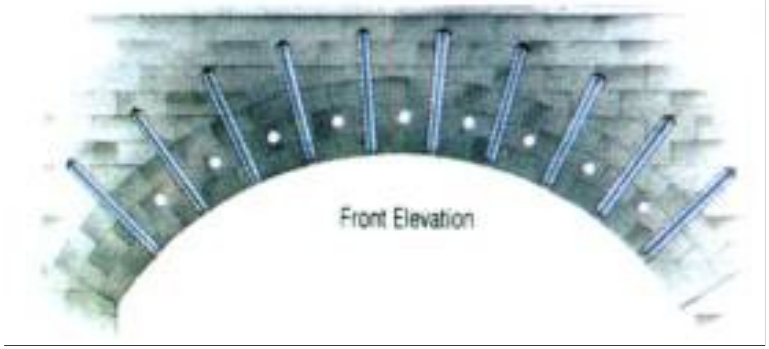
Ring separation

Repair method - through ring stitching



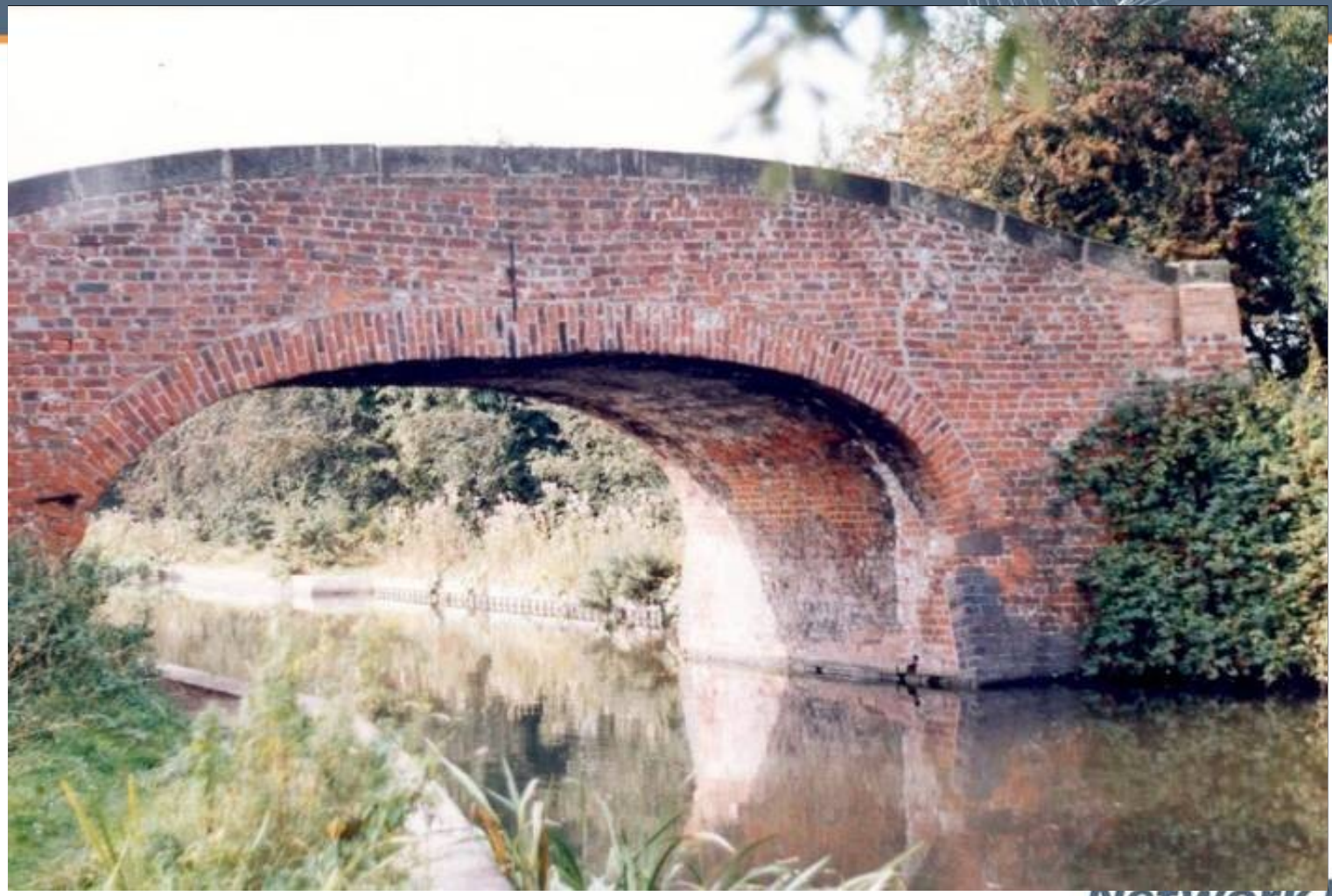
Section through arch

Plan view of stitching anchors

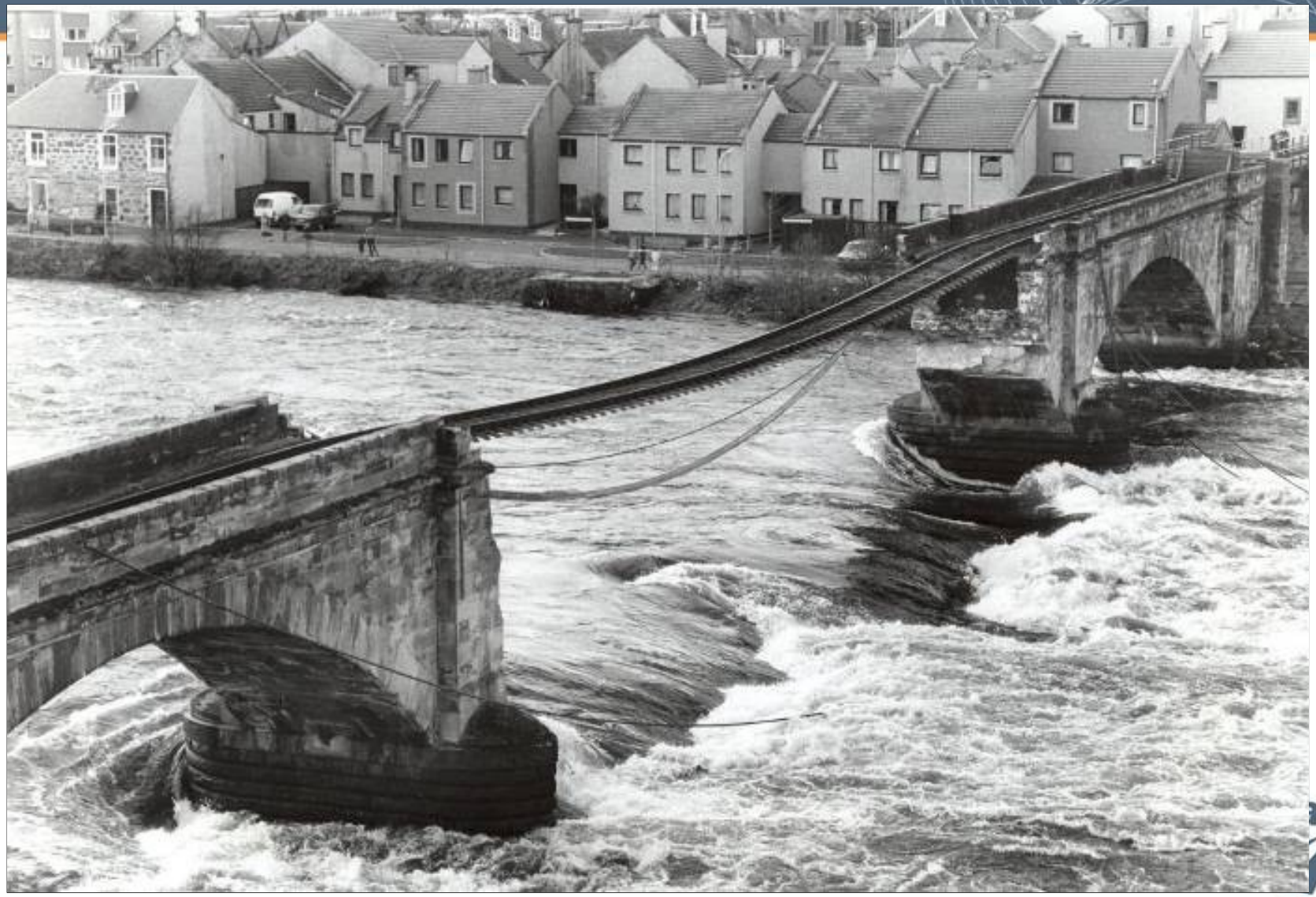


Front Elevation

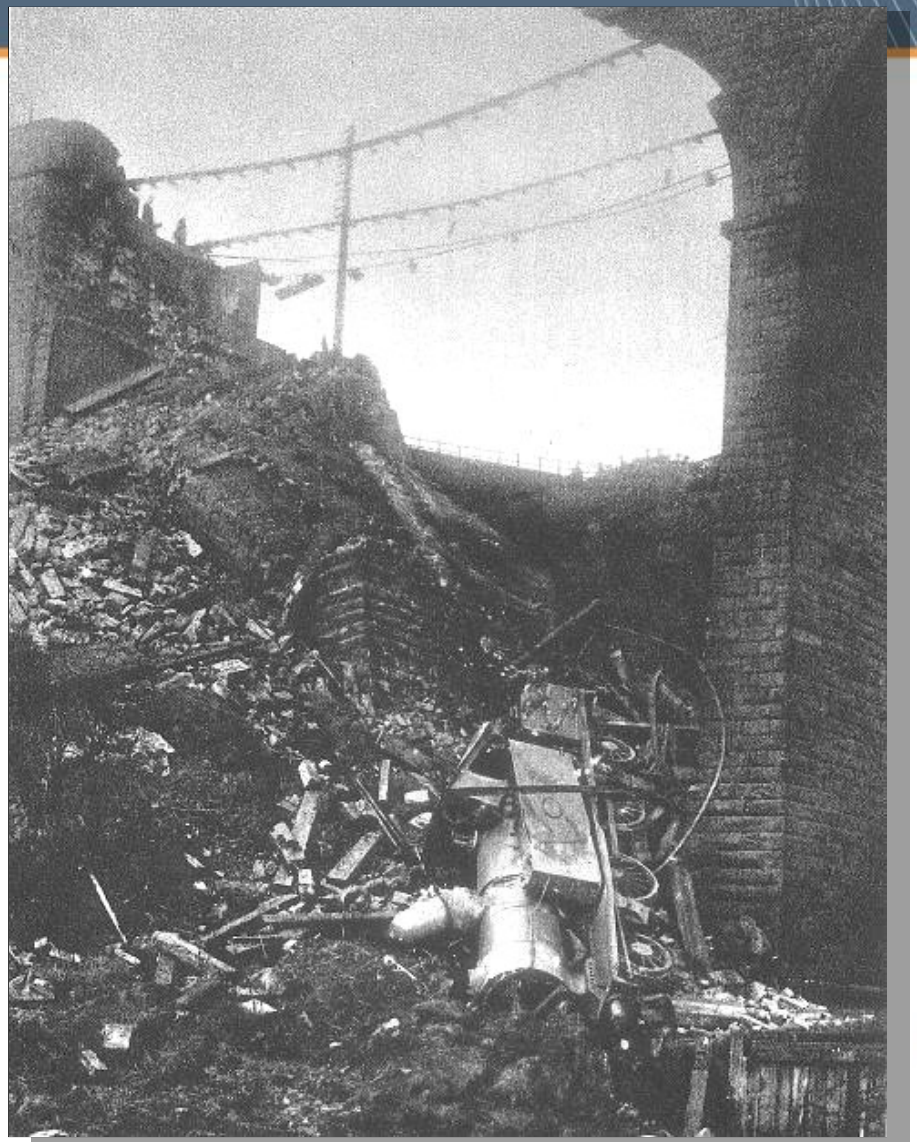
Pier/abutment movement



Pier/abutment movement



Pier/abutment movement



Repair methods - underpinning

Spandrel movement

Repair methods – pattress plates

Parapet damage

Repair methods – repair/upgrade

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Inadequate capacity

Method	Summary	Structural defect and location	Advantages	Disadvantages	Performance	Experience with existing railways
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 re pairs/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 incorporate	• 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?

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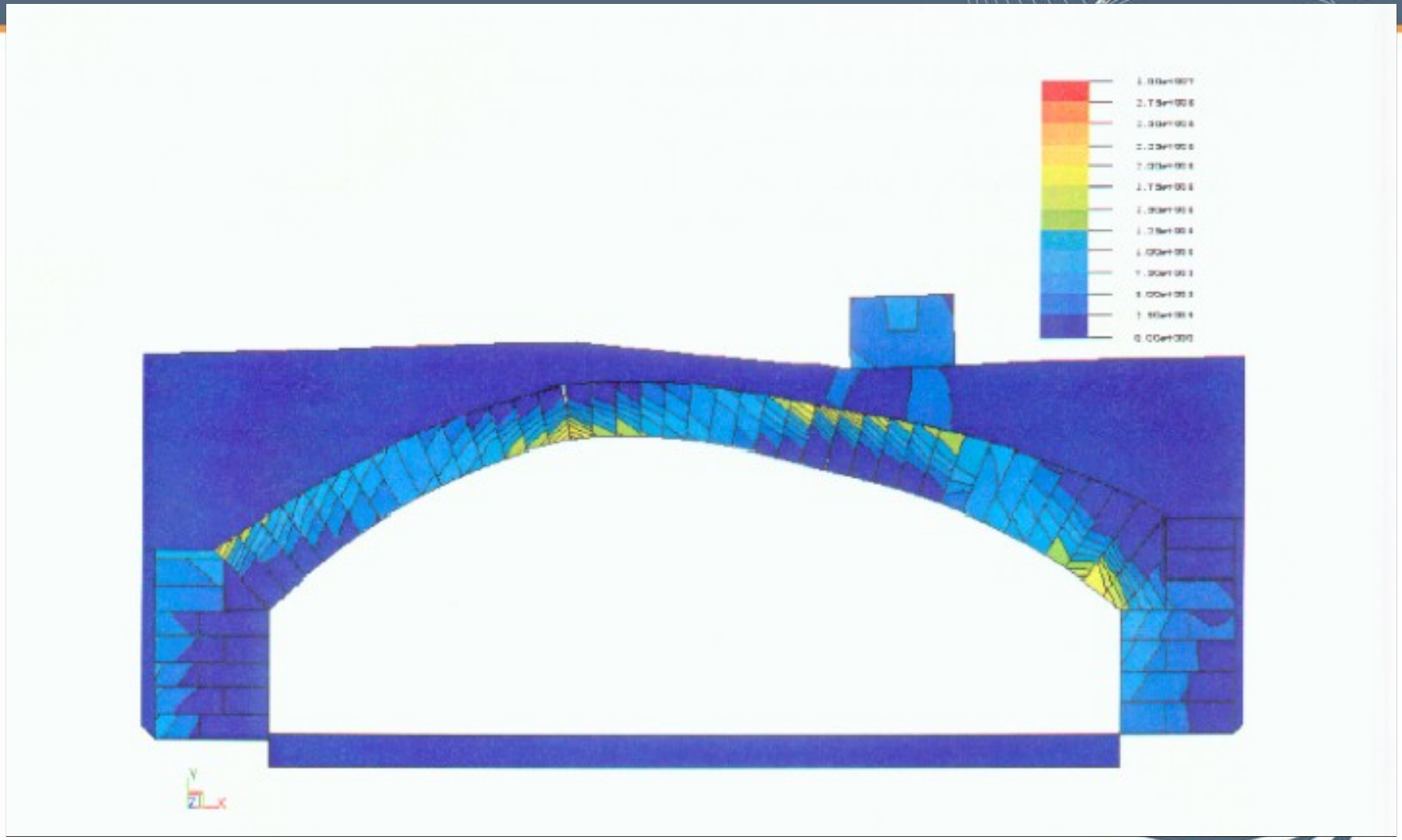
Laboratory test method



Strengthening - concrete saddle

Saddling video

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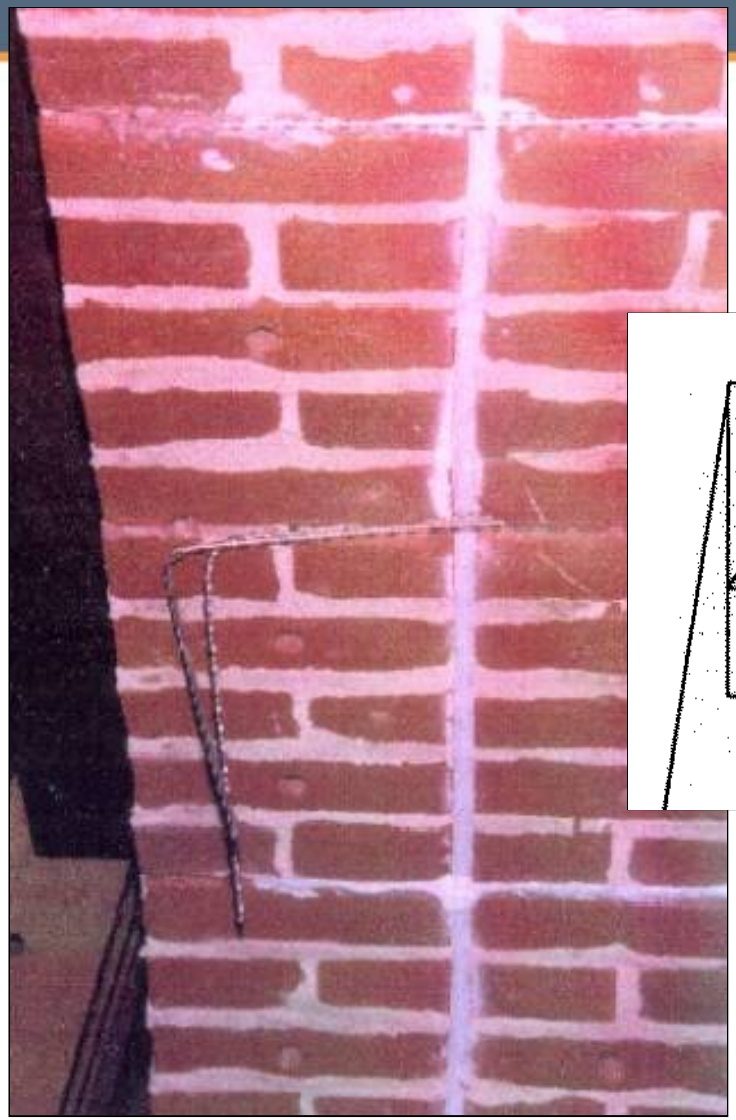
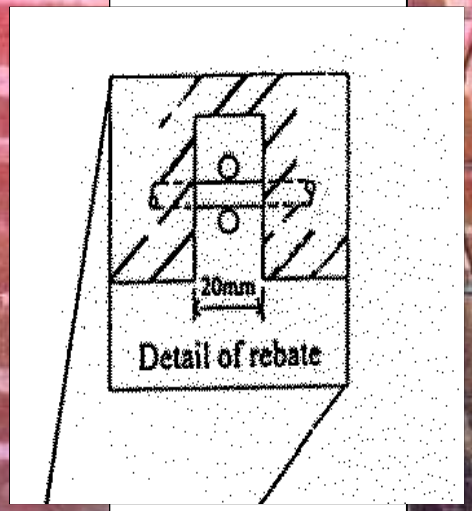
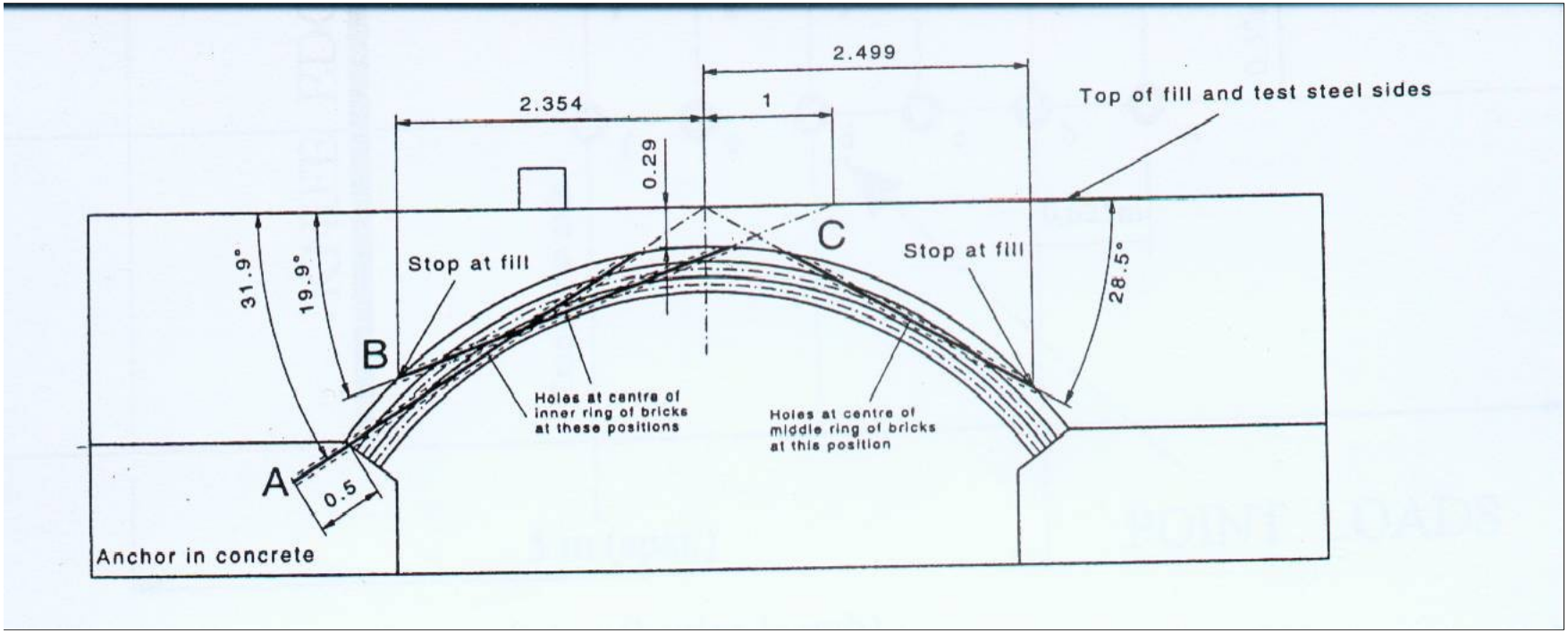
Strengthening - prefabricated liners

Strengthening – near surface reinforcement





Strengthening – through arch reinforcement



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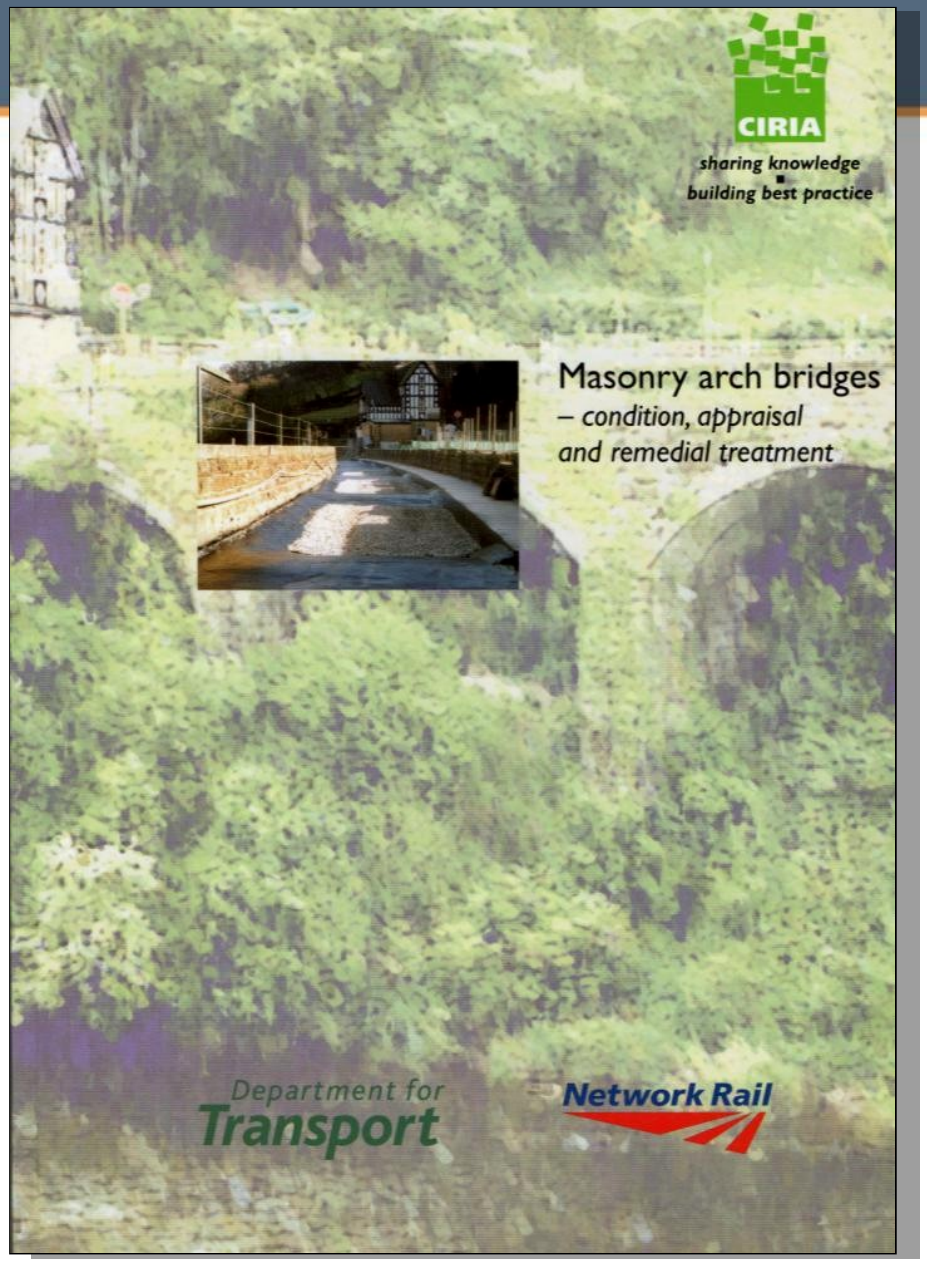
Other methods

- Relieving slab
- Sprayed concrete
- Thickening surface

Recommended reading



CIRIA report C656 available for free download or purchase from

www.ciria.org

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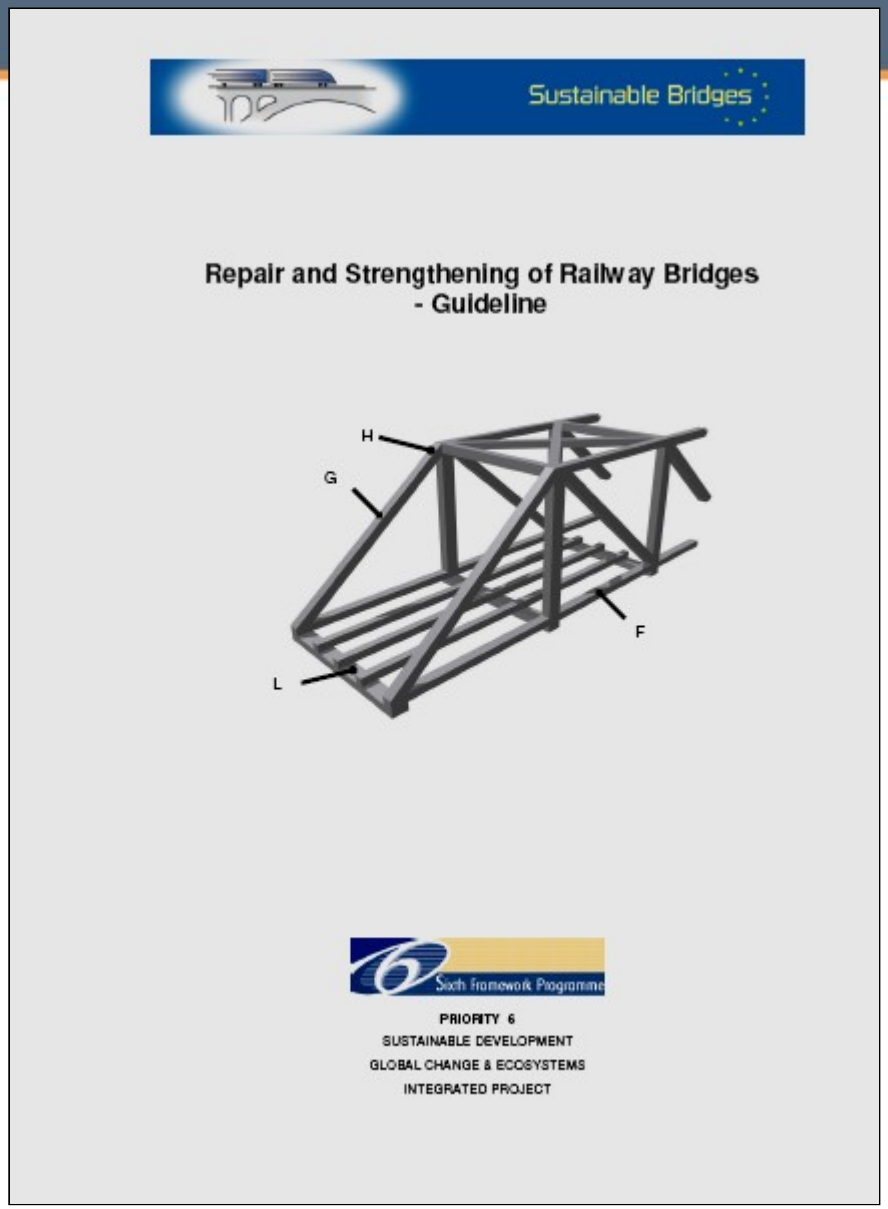
The Sustainable Bridges Report



- Chapter 4.5 describes repair and strengthening techniques for arch bridges
- Appendix C looks at strengthening in more detail

www.sustainablebridges.net

"project reports"

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Thank you