Inspection, Assessment and Strengthening of TII Masonry Bridges

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Irish Heritage

Significant heritage and cultural identity with masonry arch bridges. TII have a policy of retain and repair, rather than replace. TII bridges as old as 14\textsuperscript{th} century
Assessment Standards

- TII new Standards website will be launched soon; names of Standards will change to reflect new organisation
- Currently access Standards through nrastandards.nra.ie
- NRA BD21/14 Assessment of Road Bridges and Structures
- NRA BA16/14 Assessment of Road Bridges and Structures
- NRA BD79/14 Management of Substandard Road Structures
- NRA BD101/14 Structural Review and Assessment of Road structures
- NRA BD86/15 Assessment of Road Bridges and Structures for the Effects of Abnormal and Exceptional Abnormal Load Vehicles using SV and SOV Load Models
- Stage 1 Assessment of Sub-standard Road Structures (internal document)
- Stage 2 Assessment of Sub-standard Road Structures (internal document)
PI and Inspection for Assessment

Principal Inspection - Primarily addresses structure condition issues
- Report on the condition of each bridge component and significance of structural defects
- Use previous inspection report to monitor the change in condition of components and defects
- Make recommendations for repairs or Special Inspections
- Make recommendation for structural assessment if necessary due to deterioration
- Identify year of next inspection (max 6 years)

Inspection for Assessment – Primarily addresses structure capacity issues
- Accurate measurement of key dimensions of structure and carriageway
- Record information which affect condition factors & other parameters for assessment
- Signs of distress which affect structural capacity: cracks, loss of mortar, deformation, missing/dropped stones
- Look for evidence of backing/haunching – leaching at top of haunching
- Look for previous strengthening methods saddling, tie-bars & patress plates etc
Typical Assessment Procedure

Stage 1
- Screening assessments for 40/46T GVW – efficient consistent approach required for large bridgestock
- Use of Modified MEXE and Archie-M assessment methods
- No site testing undertaken
- Assumptions of arch barrel thickness behind voussoir face stone

Stage 2
- Structures failing Stage 1 tested with trial pits/cores to establish actual arch barrel thickness and depth of backing/haunching if present
- Structures re-assessed using actual barrel thickness and haunching test results – significant pass rate
- Sensitivity analysis – if the arch still fails, would enhanced condition factors (repointing, haunching construction) result in assessment pass?
Polyurea injection resin trial

Presence of haunching may strengthen the bridge

Repointing the arch barrel may strengthen the arch

Castlegar Bridge

8 (64-tonne ISO*) impact axle 3 @ 6682 mm

Span 1

GammaF dead load: 1.00
GammaF superimposed: 1.00
GammaF live load: 2.38
GammaF load effect: 1.00
GammaM material: 1.00

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Bridge Management Options—failed structures

Theoretical Analysis

- Further assessment using more refined analysis and better structural idealisation
- Stage 3 assessment using specialist techniques including bridge-specific assessment live loading, reliability-based assessment methods or load testing

Other Factors to Consider

- Does the Principal Inspection state that structural repairs are required?
- If defects are present (loss of mortar, cracking, leaning spandrel wall, etc) they will need repair regardless of whether the structure passes further assessment
- Repairing the defects and undertaking strengthening methods within a single contract may offer good bridge management
- When considering undertaking significant structural repairs to a bridge following recommendations in a PI, a bridge manager may decide to undertake a structural assessment to ascertain load-carrying capacity first to ensure that both condition and load-carrying capacity needs can be addressed at the same time
Arch Bridge Defects

Spandrel Wall Separation

• Not uncommon – spandrel wall stiffens edge of arch and the barrel flexes resulting in shear
• Circumferential cracks are not necessarily significant
• Higher risk if evidence of spandrel wall leaning, or centrifugal forces if bridge on bend, or if the crack is proved by monitoring to be ‘active’ rather than ‘historic’
• Crack stitching may result in a further shear crack along line of Stitching bars
• Tie-bars and patress plates will prevent further outward movement of spandrel wall
• Repointing cracks alone is of no benefit
Arch Bridge Defects

Bridge on hairpin bend in road
Arch Bridge Defects
Arch Bridge Repairs
Water-related Defects

- Scour – Erosion of riverbed and foundations to bridge substructure. TII Standard for hydraulic assessment and analysis of riverbed material for scour susceptibility to be published soon.

- Soft verges lead to washout of fines in spandrel backfill and washout of mortar in arch barrel
Arch Strengthening – Saddle and Sprayed Concrete

- Arches which fail assessment may be strengthened by concrete saddle which increases the thickness of arch barrel
- TII seldom use this method – disruptive, relatively expensive, unsympathetic
- Sprayed concrete to arch intrados – popular in 70’s and 80’s but often ill-considered. Thin layer achieves very little. Unsympathetic and unsightly. Unclear whether masonry joints are full. Retains water leading to durability defects freeze/thaw etc
Masonry Repair with Lime Mortar

- TII undertook significant testing of lime mortars to develop a Specification for masonry reconstruction and repointing on all masonry arch bridges
- Lime mortar has higher flexural strength than cementitious mortar therefore accommodates the thermal and load-induced movements of the arch barrel
- Repairs in sympathy with the character, history and heritage of the structure, which was constructed using lime mortar
- Use of Natural Hydraulic Lime (typically NHL5) and well-graded sand in keeping with Conservation best practice
- NRA Specification Series 2400 – materials, curing, finishing, cold-weather working etc.
Vehicle Restraint Systems

- Difficult to make masonry arch bridge parapet and safety barriers compliant with EN1317
- Masonry parapets may be reinforced or unreinforced BS6779, NRA BD52
- When designing masonry arch bridgeworks parapets can be reinforced with concrete core to facilitate connection to safety barrier
- Can design barrier in front of parapet if constraints allow although unsightly
- Engineers Ireland VRS training course