Bath and North East Somerset Council

FEASIBILITY REPORT - CLEVELAND BRIDGE

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JULY 2022

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Bath and North East Somerset Council

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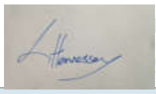
Signature	 Hennessey, Liam (liam.hennessey) 2022.07.06 12:22:22 +01'00'
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EXECUTIVE SUMMARY

Introduction

Originally built-in 1826, Cleveland Bridge and the four adjoining former toll houses are of unique construction, possessing architectural, aesthetic, historic and cultural values. It is an important strategic river crossing within Bath and a crucial link for the city. Various structural modifications have been carried out to the bridge throughout its lifetime, which have resulted in a complex structural arrangement that presents a unique set of challenges in terms of structural assessment, maintenance and operation.

The current structural system that forms the highway deck was built in 1929 and consists of four reinforced concrete, modified Pratt truss girders with a two-way tapering deck that forms the top chord of the truss. The bottom chord of the truss is supported at each abutment by a series of hanger bars connected to transversely spanning steel beams resting on five mass-concrete piers. The footways either side of the highway are supported via steel portal frames with longitudinal joints at their interface with the road deck. The original cast iron arches have been retained as non-loadbearing elements for heritage reasons.

Various inspections conducted from 2014 to 2022 identified numerous defects in the concrete truss and deck. Identified defects have been repaired and the structure has been extensively refurbished as part of the ongoing site works. To facilitate the safe management of the structure and the refurbishment works a series of temporary traffic weight limits, temporary closures and single lane operation have been implemented.

In January 2022, potentially significant defects were identified within a number of the eight structural support groups, each of which comprises 11 hanger bars, with one bar group (Truss 4 North) being particularly badly affected. These defects were characterised by localised section loss to the hanger bars as a result of corrosion. The structure relies entirely on the hanger bars to support its self-weight and imposed traffic loadings. An initial analysis undertaken based on spot measurements and assumed corrosion profiles suggested there was a significant risk of a tensile overload of the worst affected bars, leading to the introduction of the current loading limit and traffic management arrangements as mitigation measures. Currently, the structure has a lane closure with temporary traffic signals restricting access to the east side of the structure (upstream side) and is subject to an 18 tonne vehicle weight limit.

The implications of the hanger bar defects established the need to consider the immediate and longer-term options for the structure. A range of possible options have been considered in terms of its management in a manner appropriate to its heritage significance and its importance as a strategic link.

Discussion

As with any study of this type, a broad range of options have been appraised considering factors such as level of use, cost, timescales, complexity of the associated works, heritage constraints, local and strategic significance and local stakeholder interests (e.g. emergency services). The initial options considered within the study included:

1. Do Nothing
2. Installation of a structural monitoring system

3. Retaining the bridge in service for non-motorised users only
4. Implementation of a passive failsafe support system
5. Implementation of an active, alternative support system
6. Demolish the structure
7. Deck replacement
8. Bridge replacement
9. Installation of a temporary bridge above the existing deck

Clearly several of the above would not be viable from a heritage point of view and others would involve longer term solutions requiring strategic decisions regarding broader economic and regional network operational viability.

As a result, the recommendations fall into two streams:

a. An immediate response to allow the structure to be safely brought back into service as rapidly as possible.

b. Development of a longer term, strategic solution that would accommodate both local and regional network functional requirements.

Very recently, more accurate information on the degree of section loss to the worst effected group of bars has become available. The castings made from the impressions taken from the hanger bars to the north end of truss No. 4 have allowed us to establish the level of section loss suffered by each bar with a much higher level of confidence than was previously possible by taking spot measurements with callipers. Having taken this new information into account within the assessment process, our assessment and internal checking teams have reached similar conclusions in terms of the hanger bar utilisations under Normal Traffic (up to 44 tonnes). The assessment indicated a borderline pass with a margin of less than 1%, whereas the check suggests a borderline failure with a margin of approximately 2%. This marginal result makes it clear that the worst affected set of bars are at the limit of their capacity under factored normal traffic static loading but are still comfortably within their elastic limit under unfactored loads. There does however remain a possibility that cyclic loading may present a fatigue risk, but there is a significant degree of uncertainty associated with trying to quantify that risk analytically.

The fact that there are 8 groups of hanger bars with 11 bars in each group means that there is a high degree of redundancy within the support system. This has both positive and negative implications. On the positive side, it means that prior to the development of a global failure mechanism, there will be measurable redistribution of load both within and between hanger groups. Conversely however, it means that it is not possible to definitively evaluate the in-situ tension in any single bar using basic statics and equilibrium. This is further complicated by the fact that the joints between the deck and the abutments appear to be closed and in close contact. This, along with the longitudinal interface between the road deck and adjacent footways, introduces further uncertainty in terms of understanding the load-paths from the deck into the substructure.

Should the monitoring system identify a change in the bridge response characteristics that cause concern, such as non-recoverable displacements or the onset of a significant degree of load redistribution between the truss hanger bars, it would be prudent to provide a passive support system, as noted in Option 4, which would allow the controlled transfer of the support loads into the abutment. This would take the form of a thin elastomeric pad positioned beneath the lower hanger connection that would only begin to take up load from the deck in the event of the onset of failure within a group of hanger bars. The elastomer would initially be installed such that the articulation of the structure is unaffected whilst the integrity of the hangers remains intact.

Whilst the monitoring system will allow the bridge to be opened to Normal Traffic once fully operational, if it were acceptable from an operational point of view, the bridge could initially be opened under a temporary load restriction of, say 18 tonnes under two way traffic. This would be a reasonable, precautionary measure once the monitoring system has been installed and is in the early stages of data acquisition and whilst the design of a passive support system is being progressed.

Recommendation

The combination of the above factors has led us to conclude that the structure is monitoring appropriate in accordance with CS 470. The installation of an intelligent, remote monitoring system identified as Option 2 above, would allow informed management decisions to be taken based on real time data. Recently developed machine learning technology would allow early detection of the onset of changes in the characteristic 'fingerprint' response of the structure and enable the introduction of control measures to ensure public safety in a considered, timely and measured way.

The deployment of such a system does not imply that a failure of the hanger system is inevitable. It does however provide ongoing confidence that this complex and important heritage crossing remains safe once brought back into service, whilst not affecting the fabric of its construction or risk changing its structural behaviour. An intelligent monitoring system could be deployed relatively quickly and allow the structure to be brought back into service following a brief, initial period of monitoring under test loads. From previous experience we would anticipate that the system could be capable of starting to gather data within a period of 4 weeks after an order is placed with a preferred supplier, followed by a further 4 weeks of software development in order to benchmark and 'fingerprint' the system to structure specific characteristics and establish trigger thresholds and reporting protocols. This would be a highly specialised system and in view of the available timescales for deployment, it is likely to be appropriate to make use of similar current, proven technology that has very successfully been deployed on a heavily trafficked underbridge on the M4. Whilst we have had preliminary discussions with that supplier, we are not in a position to confirm the delivery timescales suggested above, primarily because of the lead-in time for the supply of the instrumentation.

Additionally, we recommend a package of works be prepared in parallel, that could be rapidly implemented at some point in the future to provide an alternative load path to the hangers, should the monitoring system identify non-recoverable displacements or the onset of a significant degree of load redistribution between the truss supports. This would take the form of a passive support system as noted in the discussion above.

In the longer term a deck replacement scheme should be developed to provide a crossing that is compliant with current design and operational standards.

1 INTRODUCTION AND CONSTRAINTS

PROJECT DETAILS

Name of project:	Cleveland Bridge Major Maintenance Scheme
Name of structure:	Cleveland Bridge
Structure reference no.:	76007

1.1 INTRODUCTION

Cleveland Bridge and the adjoining Four Former Toll Houses is a Grade II* listed structure. The structure spans the River Avon, linking the A4 (London Road) in Walcot on the north side of the Avon, with the A36 in Bathwick, via Bathwick Street. The bridge has been significantly altered since its original construction, with much of its superstructure being replaced, although its original Bath stone abutment, cast-iron parapet and arch ribs remain in place.

The original single-span bridge was built in 1827 to span the River Avon. It comprised a cast-iron deck with arches supporting the deck between the two Bath stone abutments. At the cast iron springing point, the arch ribs bear onto cast-iron spreader plates set flush into recesses in the abutment. The abutments also form party walls with four Georgian stone lodges which are situated at the corners of the bridge, and which would have served as toll houses.

Prior to 1929, a 5-ton weight limit was in force for the bridge, structural calculations showed that the bridge was inadequate for the then contemporary Class A loading. A new deck and supporting system was designed by the F. P. Sissons M.Inst.M. & Cy.E. who was City Engineer for Bath at that time. Significant construction works were carried out by Lotz and Kier to enhance the capacity at this river crossing, by introducing four reinforced concrete, modified Pratt truss girders with a two-way tapering deck. The system of trusses is supported at the abutment by a series of groups of hanger bars via a transverse steel beam arrangement resting on five mass-concrete piers. The trapezoidal-prismatic mass-concrete piers are supported by a reinforced concrete cill beam, that is cast onto the original abutments with steps cut into the masonry to form a mechanical key between the two materials.

The historic record drawings suggest that there was originally a concrete casing to the hanger bars, which appears to have been removed in August 1989 to allow their condition to be investigated. The bars were found to be in good condition and later were protected with a paint system and petroleum impregnated tape, enabling future inspection of what was previously a hidden critical element. A fine mesh was installed to attempt to keep birds out of the chamber and a mass concrete screed with drainage channels were added to the chamber floor.

A full structural assessment was carried out prior to 1992. The trusses were considered adequate for 40t loading but the footways and parapets of the bridge were deemed not to be adequate to sustain accidental and impact loads. In 1992, new footways were constructed, comprising twin steel portal frames supporting new reinforced concrete footway slabs with cast-in utility ducts and the original cast-iron parapets were retained. These portal frames were supported at the arch springing level via pin bearings. Custom cast iron trief kerbs were installed to deter vehicles from loading the footway.

In 2014, CAN Structures Ltd carried out a roped access inspection, recording a series of defects. These defects were reported in the Principal Inspection Report by CH2M Hill dated March 2014. This was followed by proposed refurbishment recommendations reported by CH2M Hill in the Cleveland Bridge Repair Strategy dated May 2015. The proposed refurbishment works included repairs to the deck slabs and masonry abutments, repainting the footway beams, waterproofing and installation of protective coating systems.

In 2017, WSP undertook a desk study of all available information along with a comprehensive programme of investigations with the aim of developing a package of refurbishment works.

In order to evaluate sequencing of concrete repairs, a structural assessment was undertaken in 2018-19. Through this assessment, it was identified that the structure was provisionally substandard in terms of the deck slab capacity. The slab was found to have a flexural inadequacy for 44T and 32T loads and it was proposed that pultruded fibre reinforced polymer (FRP) strengthening elements should be applied to the underside of the deck to address this shortfall.

A further roped access inspection was carried out in December 2019 to identify whether any further deterioration had occurred since the previous inspection. WSP issued their Principal Inspection report in February 2020.

A repair package was prepared and released for tender in 2019 and a contractor was subsequently appointed to undertake the repair works in early 2020. The works were predominantly within areas of restricted access beneath the complex array of structural elements within the deck structure. Most of the work activities demanded the use of skilled labour working within a confined environment. As a result of the emergence of the COVID-19 virus in early 2020, the scheme was deferred into 2021.

During the refurbishment works between 2021 and 2022, the need for a series of concrete repairs was identified and appropriate mitigations were implemented. Following the erection of the access scaffolding to facilitate the concrete repair works, a significant defect was identified in January 2022, one of the eight groups of hanger bars that support the deck. Potentially significant section loss and possible necking of the hanger bars was identified that had not been reported in previous inspections.

At the time of writing in May 2022, the FRP strengthening of the deck has been completed and all other concrete repairs are progressing and approaching completion. The remaining works comprise painting, resurfacing, installation of galvanic anodes and repairs to the Bath stone abutment are ongoing.

1.1.1 REPORT PURPOSE AND SCOPE

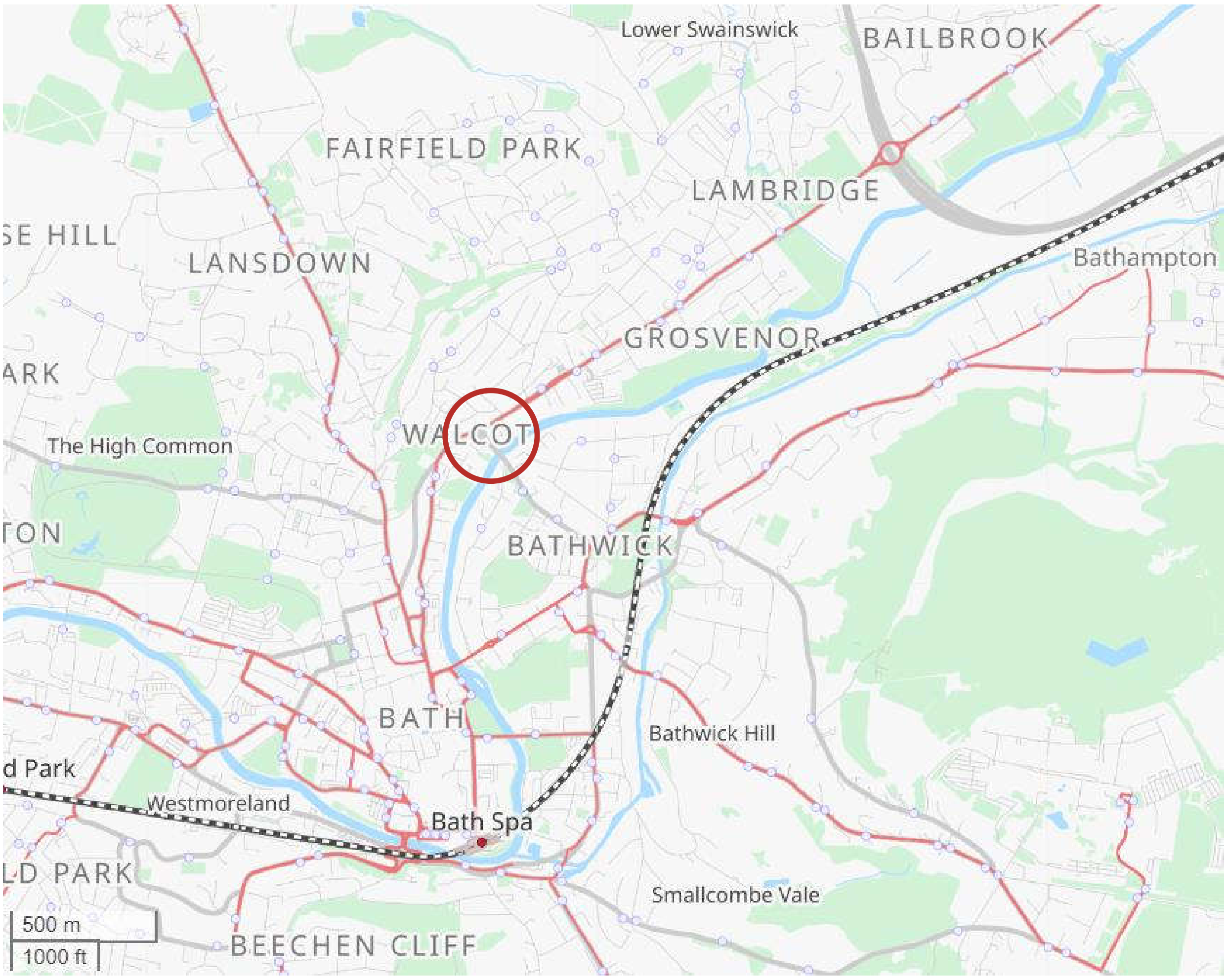
The purpose of this report is to outline the broad range of possible strategies available to extend the service life of the bridge, minimise or remove existing weight restrictions and conserve the structure in a manner appropriate to its heritage significance and strategic importance.

The scope of this report is limited to the possible strategies for the future management of Cleveland Bridge based on information and findings obtained to date. Should any further defects be identified in the future as part of refurbishment works or inspection, then the findings of this report should be reconsidered. Furthermore, this is a feasibility report based on structural analysis and assessment work undertaken to date; therefore, this report should be reviewed if development of the detailed design shows that selected options are unfeasible.

1.1.2 LOCATION

Cleveland Bridge is located to the northeast of Bath city centre of (Easting 375335, Northing 165661). The Site Address: Cleveland Bridge, Bath, BA1 5DH.

Figure 1-1 – Bridge Location (circled) © OpenStreetMap 2022.



It sits within the Bath World Heritage Site (WHS) and the Bath Conservation Area. The bridge is a strategic crossing of the river Avon within Bath and as such, an important link within the city. Cleveland Bridge is an important element of Bath's World Heritage status.

1.1.3 SCHEME DESCRIPTION

Following the discovery of the defects associated with the hanger bar elements, WSP have proposed emergency interim measures for the management of the structure to ensure the safety of its users, which have been implemented by Bath and North East Somerset Council.

In April 2022, WSP were commissioned by Bath and North East Somerset Council to consider strategies, potentially including strengthening of the hanger bars and associated elements with a primary aim of safely returning the structure to an operational status.

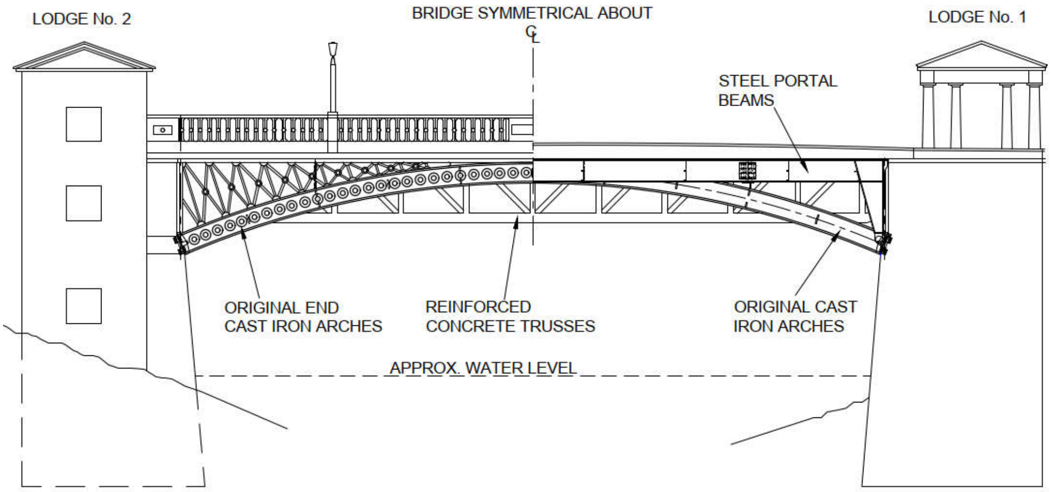
Options considered included the installation of an alternative support arrangement for the deck truss system and/or the ongoing management of a substandard structure in accordance with the Design

Manual for Road Bridges, specifically *CS 470 - Management of sub-standard highway structures*.

1.1.4 DESCRIPTION OF EXISTING STRUCTURE

Figure 1-2 illustrates the complex make-up of the superstructure with the adjoining abutments and lodge buildings.

Figure 1-2 - schematic of the bridge arrangement. Elevation on the left and a developed section on the right.



The single-span structure consists of three different construction forms, as described in Table 1-1:

Table 1-1 - Structure form descriptions.

Element	Description	Loading	Support at abutments	Transverse members
Reinforced concrete truss	4 reinforced concrete modified Pratt truss girders with a 2-way tapering highway slab.	Traffic and Self-Weight	Supported at the abutment by groups of hanger bars via transverse steel beam assemblies that rest on mass concrete piers within the abutment chambers.	Transverse members connect each truss between the bottom booms in bays 3, 5, 8 and 10 shown on Drawing number 00160 and 00171.
Steel portal frame	2 steel portal frames support a reinforced concrete slab within each footway	Pedestrian and Self-Weight	The portal frames are supported at each abutment on pinned bearings. The bearings are fixed at the abutments by rock anchors.	Transverse interior bracing between web plates on each portal frame.
Cast iron arches	7 lattice arch ribs	Self-Weight only	Supported at each abutment with an abutment plate.	The cast-iron structure is braced between each of the lattice arch rings

The bridge is a single-span structure with no skew. Effective spans are as follows:

- Portal frame – 30.27m
- Cast iron arches – 30.79m
- Reinforced concrete truss – 34.75m

1.2 CONSULTATIONS AND REQUIREMENTS

The following bodies have been considered and had early engagement throughout the development of proposed options.

Table 1-2 – Summary of consultees.

Consultee	Requirements
Bath and North East Somerset – Client	Set project expectations and scope.
Bath and North East Somerset – Highways Authority	Maintain the bridge in a safe operational state for public use
Bath and North East Somerset – Planning Authority	Consider requirements regarding Listed Building Consent.
Bath and North East Somerset – Ecology	Potential ecological effects of the proposed works.
Historic England	Consider requirements regarding Listed Building Consent.
Environment Agency	Consider potential impacts on the watercourse and flooding risk.
Local stakeholders	Will need to be involved in consultations and notified when any proposed works would be carried out.

1.3 GEOLOGY

Record drawings (00151) indicate a spread foundations with mass, block masonry founded on bedrock.

The foundations are buried and could not be directly examined in previous inspections given their make-up, however, there are no visible signs of distress or movement recorded to date.

Few of the remedial strategies considered would significantly alter the load path from the existing abutment arrangement.

1.4 LOADING

The bridge has had a series of temporary traffic weight restrictions and operational lane closures to facilitate the safe management of the structure and the remedial works undertaken to date. Currently, the structure has temporary traffic signals operating to allow a single lane closure to the east (upstream) side of the deck.

The options identified should be evaluated for characteristic traffic actions for normal or restricted traffic using both Assessment Live Load (ALL) model 1 or 2, as appropriate, in accordance with the Design Manual for Road Bridges, specifically CS 454 *Assessment of Highway Bridges and Structures*.

The history of the bridge construction and modification is complex, so a series of tests have been commissioned in order to evaluate the in-situ loads on the hanger bar elements. These are described in the report by Full Scale Dynamics, reference FSD1286/1, titled *'Estimation of tension in hanger bars in Cleveland Bridge'*.

1.5 ENVIRONMENT

The bridge site and the River Avon are the subject of significant ecological considerations. Bats use the River Avon as a navigation corridor and the river and its banks host otters, foxes and other wildlife. The impact of the developed options should consider the ecology of the surroundings across the River Avon and the heritage significance of the unique structure.

The following reports are available:

- Environmental Constraints Report (Report No. 76007-WSP-RPT-ECO-001)
- Preliminary Ecological Appraisal Report (Report No. 76007-WSP-RPT-ENV-001)

An Environmental Impact Assessment should be carried out for further works involved in the developed strategy. Environment Agency permits should be reconsidered in light of the proposed solution. Consultation with the local planning authority and ecologists will be necessary considering the location of the structure within the Bath World Heritage Site (WHS) and the Bath Conservation Area.

1.6 LAND AND PROPERTY

The site is owned by Bath and North East Somerset Council and the necessary access within the site for the selected option should therefore be easily facilitated. However, there are four adjoining properties with long term leases from the Bath and North East Somerset Council. Their properties have walls and cellars adjacent to the structure where any groundworks could potentially be required. For some of the more disruptive options, the extent of the site may increase to facilitate associated groundworks. Land records should therefore be reviewed at these locations.

Local stakeholders to the works should be consulted ahead of the proposed works.

1.7 OTHER CONSTRAINTS

Age of structure

Danish engineers Olaf Kier and Jorgen Lotz formed J Lotz and Kier and were early pioneers of reinforced concrete design and construction when they constructed the reinforced concrete bridge in 1929. At that time, reinforced concrete was fairly novel with William Leslie Scott publishing the guidance of the time *'Reinforced Concrete Bridges: The Practical Design of Modern Reinforced Concrete Bridges'.* Common issues of the era regarding durability are apparent on this structure, including low cover and likely marine sourced aggregates, given the discovery of shells in the aggregate mix. For context, we would expect a modern structure to be designed for a 120-year design life.

It is considered that the bridge is approaching the end of its practical service life insofar as the main load bearing structure is more than 90-year-old. However, with ongoing structural management and sustained maintenance investment the unique structure could be preserved.

Complex structural arrangement and behaviour

The bridge structure consists of three distinct but intertwined construction forms that have been significantly altered across its lifespan. In 2022, it has been further altered by the introduction of fibre reinforced polymer strengthening to the concrete highway deck.

The overall bridge articulation and its global behaviour are complex as a result of the interfaces between the different sections of deck and there are significant uncertainties in terms of historic construction sequences and processes. Testing and analysis to date suggest that there are anomalies in the distribution of support reactions that cannot be definitively explained. This may be contributed to by the development of friction at the interfaces of the various joints between discrete deck sections, the presence of multiple transverse bracing systems or the action of the cast iron arches that have timber wedges stabilising them against the concrete slab intermittently along their span.

Testing to date suggests that the distribution of forces within the structure is complex, with the north abutment carrying roughly 30% less load than the south abutment. Estimated values of the tensile forces within each hanger bar and hanger bar group across the structure (based on dynamic testing) vary considerably. Monitoring also suggested that there is a degree of redistribution of loads between hanger bars. Further information is available in report reference FSD1286/1, titled '*Estimation of tension in hanger bars in Cleveland Bridge*'.

Impact on emergency services

The bridge, along with Pulteney Bridge and Batheaston Toll Bridge, which are Grade I and II listed structures respectively, connects the Avon Fire & Rescue Service to the city and surrounding areas. As such, it is a vital link that must remain in service to ensure that key emergency services can be maintained within acceptable response times.

2 OPTIONS

2.1 DISCUSSION OF OPTIONS CONSIDERED

A spectrum of available management, rehabilitation, construction, and decommissioning works are discussed below.

1. Do Nothing

The outcomes of our structural analysis, based on recently confirmed, more accurate information on the degree of section loss to the worst effected group of bars has indicated a borderline pass of the critical hanger bars with a margin of less than 1%, whereas the check suggests a borderline failure with a margin of approximately 2% under Normal Traffic (up to 44 tonnes). This marginal result makes it clear that the worst affected set of bars are at the limit of their capacity under factored normal traffic static loading. However, there does remain a possibility that cyclic loading may present a fatigue risk, but there is a significant degree of uncertainty associated with trying to quantify that risk analytically. If the structure remains in service, the condition of the hanger bars will continue to deteriorate and as such, a 'do nothing' approach is not considered tenable.

2. Installation of a monitoring system

The fact that there are 8 groups of hanger bars with 11 bars in each group means that there is a relatively high degree of redundancy within the support system. This has both positive and negative implications. On the positive side, it means that prior to the development of a global failure mechanism, there will be measurable redistribution of load both within and between hanger groups. The installation of an intelligent, remote monitoring system, would allow informed management decisions to be taken based on real time data. Recently developed machine learning technology would allow early detection of the onset of changes in the characteristic 'fingerprint' response of the structure and enable the introduction of control measures to ensure public safety in a considered, timely and measured way.

The deployment of such a system does not imply that a failure of the hanger system is inevitable. It does however provide ongoing confidence that this complex and important heritage crossing remains safe once brought back into service, whilst not affecting the fabric of its construction or risk changing its structural behaviour. An intelligent monitoring system could be deployed relatively quickly and allow the structure to be brought back into service following a brief, initial period of monitoring under test loads. From previous experience we would anticipate that the system could be capable of starting to gather data within a period of 4 weeks after an order is placed with a preferred supplier, followed by a further 4 weeks of software development in order to benchmark and 'fingerprint' the system to structure specific characteristics and establish trigger thresholds and reporting protocols.

The structure is therefore considered to be monitoring appropriate in accordance with CS 470.

3. Retain the bridge in service for non-motorised users only

There are several subsets of the monitoring approach in conjunction with other management options which look to manage the decline of the structure. With an appropriate monitoring system in place, there may be opportunities to close the bridge fully to vehicular traffic and open it as a pedestrianised area for non-motorised users. An example of this being a success is the High Line in New York. This option would be at detriment to an important strategic link within Bath, but there are possible opportunities to extend the River Avon Trail and consider biophilic design to adopt more urban greenery.

4. Implement a passive failsafe support system

The installation of a Passive Failsafe Support comprising a reinforced concrete [or Ultra-High-Performance Fibre Reinforced Concrete (UHPFRC)] plinth below the bottom chord incorporating an elastomeric bearing would allow the controlled transfer of the support loads into the abutment, in the event of a plastic extension of the hanger bar system. The provision of failsafe supports would ideally be accompanied by long term monitoring in order to understand whether load is shed from any of the hanger bar clusters. Should such behaviours be detected, an inspection would be required to identify whether unanticipated distress has occurred because of the associated redistribution of loads.

5. Implement an active alternative support system

An active support system would transfer load into a plinth and bearing assembly similar to that proposed above through the use of sacrificial flat jacks. The flat jack will be encased in concrete or grout to provide long term durability. The load transfer would be directly controlled and therefore remove the need for long term monitoring. However, this option will require rigorous evaluation and may require additional strengthening works to the deck slab and other structural elements as a result of load redistribution during the jacking process.

6. Demolish the structure

In view of the key strategic and unique heritage status of the structure, this option is not considered to be tenable.

7. Deck replacement

A deck replacement could be considered, but there are numerous complications and constraints associated with the existing substructure that will make the construction process extremely challenging, such as the four toll houses and cellars immediately adjacent to the bridge, multiple services within the footway and its setting in a busy urban environment. A replacement deck system would weigh less than the existing structure and therefore be less demanding on the existing substructures.

The superstructure and part of the substructure (mass-concrete abutment-piers) could be demolished, the original cast iron elements could be retained and a more modern composite deck comprising steel beams or trusses with a concrete deck slab could be installed.

An alternative consideration for the cast iron elements would be that they could be retained and reused in a more appropriate location in view of their historic importance (e.g. a footbridge across the river). This would avoid some of the historic complications that have arisen because of the 3 different construction types intertwined within the existing structural arrangement.

8. Bridge replacement

A bridge replacement in an alternative location may be appropriate. There have been historic proposals regarding possible bypasses, e.g., Bristol and Bath to South Coast (2004) which are not considered in this report.

9. Temporary bridge over the top of the existing

This option would require the installation of a temporary modular bridge (or similar) supported beyond the extent of the existing bridge. Typically, such temporary structures have very limited fatigue lives and require a disproportionate level of maintenance input. This, alongside the challenges associated with accommodating the increased support reactions and the changes to the vertical and horizontal highway geometry within the approaches mean that a temporary overbridge solution is not considered to be viable.

2.2 VIABLE OPTIONS

Of the above 9 potential options, only Options 2, 4, 5 and 7 are considered to be viable moving forward. Options 2, 4 and 5 can be implemented within relatively short timescales in order to bring the structure back into service and remove the existing traffic restrictions. In terms of the long term viability of the crossing, Option 7 will need to be developed but must be seen as a medium to longer term solution (ideally circa 20 year timescale) to be considered within the context of the broader transportation and economic development plans within the region.

2.3 APPEARANCE

Cleveland Bridge forms an important element of the World Heritage Site (WHS). It is a Grade II* listed structure, listed as *Cleveland Bridge and Four Former Toll Houses,* located within the WHS and the Bath Conservation Area.

The adoption of Options 2,4 or 5 would have no obvious external visual impact.

2.4 DURABILITY/DESIGN LIFE

The main load bearing structure is more than 90-year-old and has been subject to multiple repair regimes since its construction. The proposed solutions should be considered in light that the repair scheme in 2021 and 2022 has repaired the majority of the structure to a good standard. The coating systems and galvanic anodes installed within the concrete elements of the structure will increase durability of the structure as a whole (excluding its supports), likely requiring its next major maintenance cycle in 20-30 years.

The envisaged outline durability/design life of developed options are listed as follows:

Option 2 - Installation of a monitoring system

The structure has deteriorated at the truss end supports and they will gradually deteriorate further with time under ongoing traffic loading which poses a potential risk of fatigue damage within the damaged areas of the hanger bars. Further corrosion of the hanger bars should be prevented through the application of an appropriate corrosion protection system. Implementation of a monitoring regime will not have any direct impact in terms of increasing the overall durability of the structure, but it would provide clear and reliable data on which to make future operational and maintenance decisions that safely retain the structure in service. The monitoring system will need to be regularly maintained in order to ensure its continuing functionality whilst the structure remains in service.

Option 4 - Implement a passive failsafe support system

A failsafe support system will only become active only should the existing hanger bars begin to redistribute or shed load. Elastomeric bearings are widely used within the industry and will have a design life of at least 25 years. The use of a UHPFRC material within the plinths would provide a highly durable and low maintenance support system.

Option 5 - Implement an active alternative support system

At a component level, this option would be similar to Option 4 but would include the incorporation of a sacrificial flat jack within the support assembly. The UHPFRC plinths would provide protection to the jacks but would inhibit visual inspection.

Option 7 - Deck replacement

Installation of a new, modern bridge deck would provide a design life of 120 years subject to appropriate routine inspection and maintenance to replace serviceable components.

2.5 RECOMMENDATION

The combination of the above factors has led us to conclude that the structure is monitoring appropriate in accordance with CS 470. We therefore recommend the installation of an intelligent, remote monitoring system identified as Option 2 above, which would allow informed management decisions to be taken based on real time data.

Additionally, we recommend a package of works be prepared in parallel, that could be rapidly implemented at some point in the future to provide an alternative load path to the hangers, should the monitoring system identify non-recoverable displacements or the onset of a significant degree of load redistribution between the truss supports. This would take the form of a passive support system as described in Option 4 above.

In the longer term a deck replacement scheme, as described in Option 7 should be developed to provide a crossing that is compliant with current design and operational standards.

3 SIGNATURE PAGE

THE ABOVE IS SUBMITTED FOR ACCEPTANCE

Signed	Hennessey, Liam (liam.hennessey) 2022.07.06 12:22:49 +01'00'
Name	Liam Hennessey
Position held	NEC3 Project Manager
Engineering qualifications	MEng (Hons) CEng MICE NECReg
Name of organisation	WSP
Date	06th July 2022

PREFERRED OPTION AGREED

Signed	MPJohnson
Name	Mike Johnson
Position held	Structures Manager
Engineering qualifications	IEng AMIStructE
TAA	South Gloucestershire Council (On behalf of Bath and North East Somerset Council)
Date	11/07/2022

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