

Claydon Canal Bridge

CS 470 Management Of Sub-Standard Structures Report

December 2025



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F01	Initial issue	KB	BD		21/10/2024
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F03	Reviewed and re-issued following updated assessment	KB	BD		03/12/2025
F04	Reviewed by OCC	RPC			12/12/2025

Executive Summary

Claydon Canal Bridge is a single span brickwork arch bridge which carries Claydon Road over the Oxford Canal in the north of Oxfordshire. The structure is Grade II listed and currently has a signed 3-tonne weight limit. There is a historic 5t axle Traffic Regulation Order, which does not align with the current signed restriction. There are no physical measures preventing heavy goods vehicles crossing over the bridge.

Claydon Canal Bridge is in poor condition with extensive spalling of brickwork at the intrados of the arch. This has resulted in a reduced arch barrel thickness being assumed lowering the capacity of the bridge, for which the 3t weight restriction signage appears to have been erected in response to this. The cause of this deterioration is believed to be primarily due to water ingress and movement through the brickwork accompanied with freeze-thaw action. Deterioration may be exacerbated by frequent overloading by agricultural vehicles. Deterioration of the brickwork is expected to continue without intervention.

A new assessment of the structure has been completed in November 2025 which now finds that the structure has 13-tonne capacity (and FE Group 1 (17t for a twin axle Fire Engine with a particular maximum axle load and spacing)). This assessment uses arch geometry determined from a 3D scan completed in 2022 and updated arch barrel thickness determined during 2024 investigation works, and an arch barrel thickness reduction factor to account for the spalling at the intrados lowering the capacity. The bridge was found to have a marginal failure for 18-tonne loading, and an adequacy factor around 0.74 under 40-tonne loading.

The greatest risk health and safety risk associated with the structure in the short-term is spalling debris and bricks dropping out from the arch barrel onto people using the canal and its towpath beneath the bridge. In the long-term, the greatest risk is continued deterioration of the arch barrel progressively reducing the bridges safe load carrying capacity.

This CS 470 risk management review of this sub-standard structure recommends that a 13t structural weight restriction (with an exemption for Group 1 Fire Engines) is implemented. The signage of this restriction being supported by an appropriate Traffic Order such that it can be legally enforced to help improve compliance. This then helping reduce the progressive deterioration of the bridge. Alternative strengthening has been considered, for which Listed Building consent for this Grade II Listed building has been rejected.

Additionally it recommends that water leakage through the arch barrel is reduced by resurfacing over the structure with impermeable asphalt. The existing concrete verge and kerbs should also be sealed to help prevent surface water penetrating the arch barrel. The carriageway resurfacing should include smoothing out the carriageway surface and hump over the bridge's arch as far as is practical, to help reduce the dynamic loading from vehicles passing over the bridge, and reducing the incidents of vehicles grounding out.

Whilst this construction work is carried out it is also recommended that missing brickwork pointing be replaced and the section of damaged bridge parapet be repaired. There are also cracks in the arch barrel at the interface with the bridge's spandrel walls which are recommended to be sealed and infilled with lime mortar injection. These proposed modifications to this Grade II Listed Structure, excluding the provision of the structural weight restriction will be subject to obtaining Listed Building Consent.



Structure name:	Claydon Canal Bridge				
Structure Ref.	No.: 244				
Assessment/ Review	Stage:	Stage 1 Assessment	Stage 1 Assessment	Strengthening proposal 2024	Stage 1 Assessment
	Date:	1969/70	2015	2024	2025 Nov
	Report reference:	'0244 Claydon A of M & B A B' (on county BMS)	'RING Assessment – notes to accompany output' (on county BMS)		
	Assessed capacity:	7.5-tonne	10-tonne	10-tonne	13-tonne (& FE Group1)
	Sub-standard status:	Yes	Provisionally yes	Provisionally yes	Yes
Interim Measure Feasibility Assessment	Date:	N/A	N/A	October 2024 (issue F01 of CS 470)	November 2025 (issue F03 of CS 470)
	Structure 'Immediate Risk' or 'low risk provisionally sub-standard'?	N/A	N/A	Low risk provisionally sub-standard structure	Low risk sub-standard structure
	Structure monitoring appropriate?	N/A	N/A	Monitoring appropriate, but unlikely to be of any benefit	Monitoring appropriate, but unlikely to be of any benefit
Interim Measures Proposal	Date:	N/A	N/A	Interim measures proposal sent to C&RT on 20/09/2023	November 2025 (issue F03 of CS 470)
	Recommendations:	N/A	N/A	<u>Short term:</u> Fix mesh to intrados to capture loose material (rejected). <u>Long term:</u>	13t (FE Group 1) TRO, carriageway resurfacing, general mortar and brickwork repairs, lime mortar injection to cracks.
Interim Measures Approval	Date:	N/A	N/A	24/10/2023	
	Approval/ Rejection:	N/A	N/A	Mesh interim measures rejected by C&RT	
Actions	Implementation date:	28/12/1970	N/A	N/A	
	Details/ref.:	Prohibition of track laying vehicles	N/A	N/A	
	Provisional finish date for monitoring:	5-ton axle weight limit	N/A	N/A	
	Removal Date:		N/A	N/A	
Documentation:	Form used:	Weight TRO	N/A	870060-MIL-SBR-244-RA-CB-0042 CS 470 Report	



	Date:	28/12/1970	N/A	Issue F02 03/2025	
Additional notes:		3-tonne weight limit signage installed at unknown date		Strengthening proposal LBC submitted to Cherwell DC on 24/06/2024, not approved.	

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1 General Details – CS 470

1.1 Structure name and assessment reference

Claydon Canal Bridge, OCC No.244. (Also referred to by the Canal & Rivers Trust C&RT as Oxford Canal Bridge Field No.145 and locally as ‘Dog Poo Bin Bridge’).

1.2 Location, route and county/area

Claydon Canal Bridge, Claydon Road, Claydon, Cherwell, OX17 1FD

Coordinates	446525E , 250020N
Grid Ref.	SP 46525 50020
What3Words	///schooling.pine.processor

1.3 Assessing organisation

Assessed:	M Group
Checked:	M Group (Cat 0 check)
Latest assessment date:	November 2024

1.4 Structure type, form, span, skew

Claydon Canal Bridge has a single span brickwork arch which carries Claydon Road over the Oxford Canal. The structure is located approximately half a mile east from the village of Claydon in Cherwell, Oxfordshire. The bridge shall be referenced as spanning in an east-west direction over the canal which has a north-south alignment.

A topographical survey and 3D scan of the structure was completed in 2022 which found the structure to have an average span of 4.2m at the assumed arch springing level with no noticeable skew. The mid-span rise of the arch is approximately 1.65m above the assumed springing level.

A trial hole was dug in the carriageway over the crown of the arch as part of investigation works in 2024 which confirmed the depth of fill over the back of the arch to be 118-138mm. This also allowed the thickness of the arch to be confirmed at 480mm (which differs from the voussoir thickness).

The main arch barrel is constructed from soft red brick with a header course at the intrados and two stretcher courses behind. Historic brickwork and render/mortar repairs to the arch barrel are evident. The voussoir brickwork consists of three stretcher courses with notched red bricks at the intrados and the 3rd course consisting of a protruding blue brick drip mould.

The abutments are constructed from blue engineering bricks in English Bond. The wing walls, spandrel walls, and parapet are all constructed from red bricks in English Bond. The parapets are 450mm thick and topped with shaped bricks in rowlock.

1.5 Obstacle crossed and facility carried

Obstacle crossed:	Oxford Canal
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Facility carried: Claydon Road (C-Road)

1.6 Estimated cost of permanent strengthening/replacement works

An arch strengthening scheme consisting reinforced concrete spray-lining was designed and tendered by Milestone which was found to cost approximately £230k including traffic management and fees as of September 2024.

Alternative strengthening and replacement options shall also be considered below. Note that any cost estimates are indicative only - the actual cost can only be determined through tender. The costs given are not quotes for the works required.

Complete arch reconstruction in brickwork, with existing spandrel walls, parapets, and abutments retained. This option is not feasible as it could not be completed within the canal winter closure periods.

Reconstruction of the carriageway above would require approximately 170m length of carriageway on the approaches to be regraded with the earth retaining elements likely required. Estimated cost approx. £1m.

Arch replacement with a pre-cast arch. Existing voussoirs, spandrel walls, abutments, and parapets to remain. New foundations behind existing abutments. This option would require an approximate 170m length of carriageway on the approaches to be regraded with the earth retaining elements required. Estimated cost approx. £750k.

Arch over-slabbing or saddling. This option would require approximately an approximate 190m length of road to be regraded on the approaches with the earth retaining elements required. Estimated cost approx. £800k.

Replacement of inner course in brickwork. Estimated cost approx. £250k.

2 Assessment Progress

2.1 Level of assessment reached

In 1970, a MEXE assessment of the arch was completed based on arch barrel thicknesses equal to voussoir thicknesses.

In 2015, an updated assessment was completed using LimitState RING, which is a two-dimensional rigid block upper-bound mechanism analysis software. The voussoir thickness was taken as the arch barrel thickness.

In 2023, a strengthening scheme was designed consisting of reinforced concrete spray-lining to the intrados to bring the structure up to 40-tonne and SV-80 capacity. Historic England raised an objection to the Listed Building Consent and Cherwell District Council did not approve the application.

In 2025, Claydon Canal Bridge was formally assessed and checked as a Cat 0 structure using updated structure information from investigation works to inform management of the structure.

2.2 Assessed capacity

Summary of assessment findings to date:

1970 MEXE assessment with 381mm arch barrel thickness ^[1] :	7.5-tonne
2015 RING assessment with 381mm arch barrel thickness ^[1] :	10-tonne
2025 assessment with updated structure information and 60mm spalling at the intrados:	13-tonne & FE Group 1

[1] The 2024 investigation works found that the arch barrel thickness is 480mm, larger than the 381mm voussoir thickness assumed in historic assessments.

2.3 Date of assessment

Most recent assessment and check was completed in November 2025.

2.4 Provisionally sub-standard or sub-standard

The structure is assessed as sub-standard to 40-tonne highway loading.

The structure in its existing condition has been assessed as having 13-tonne and FE Group 1 capacity. The structure has marginal failure under 18-tonne loading.

The structure currently has a signed 3-tonne weight limit on both approaches to the structure and advanced signage at the junctions at the end of the road.

2.5 Description of anticipated mode of failure, including progression from local overstress to global collapse mechanism

Global Failure

Under normal traffic loading, spandrel wall cracking in the arch barrel may be expected as a result of the difference in stiffness between the more flexible arch barrel and stiff spandrel walls. Significant spandrel wall cracking separating the main arch barrel from the voussoir sections is present.

The intrados of the structure has extensive spalling which is thought to be largely due to freeze-thaw action and possibly movement of moisture through the brickwork. The structure will continue to degrade, the intrados will continue to spall, and the overall condition and capacity will gradually decrease with time.

If the condition of the structure continues to degrade and/or the bridge is loaded with over-weight vehicles, the arch may progress to form a global failure mechanism. Flexural failure would initially be characterised by transverse cracks indicating the formation of hinges. Cracks widths would start narrow and may be difficult to observe at the intrados, particularly with the rough spalled surface. Cracks may only open up during loading.

If overloading continues, eventually the cracks would become significant in width indicating that plastic hinges are forming. At this point, there may be deformation of the arch barrel. During deformation, longitudinal shear stresses between the courses of brickwork may exceed the bond strength causing ring separation and/or sliding. This would weaken the arch making it more susceptible to failure.

Eventually, the bridge would progress to form a full traditional 4-hinge arch collapse mechanism. This would be characterised by significant cracking at the hinge locations and deformation/cracking of the carriageway surfacing due to the low depth of fill. Deformations may not be visible at the elevations due to separation of the arch barrel from the spandrel wall and voussoir sections. As the structure approaches the ULS, the deformations associated with a failure are often so large that the structure becomes unusable and is closed prior to complete collapse.

Local Failure

Another possible collapse mechanism is punching shear. The depth of fill over the back of the arch at the crown was found to be very shallow at 118mm to 138mm meaning that wheel loads may create concentrated loading. However, the arch is multi-ring with a mixture of header and stretcher courses which will increase the arch's resistance to punching shear reducing the risk.

The spalling intrados creating debris has previously been a concern as posing a risk to towpath and canal users passing under the bridge. The 2024 investigation works consisted of removing loose brickwork and mortar from the intrados which found the brickwork and mortar to be generally soft and friable, and easily removed. Until intervention, the condition of the arch barrel can be expected to deteriorate. Small fragments may continue to fall from the arch onto the towpath and into the canal. This will progressively weaken the arch.

Consideration should also be given to the possibility of header bricks debonding and dropping out. Although the surface of the brickwork was found to be soft and friable, the investigation works found that the header bricks generally seemed well-bonded.

2.6 Description of distress (if present)

There is evidence of spandrel wall cracking at the interface between the intact brickwork at the voussoir and the main arch barrel. The exact width, depth, and extents of this cracking are difficult to determine due to spalled arch barrel and historic mortar repairs over the crack.



Figure 2-1: Photo of arch barrel close to north elevation along interface between voussoir and main arch barrel section [2024].

The main arch barrel has approximately 60-80% spalling across its total area at the intrados. The depth of spalling varies from minor surface and pointing loss to a maximum measured spall depth of 95mm at the north end of the arch barrel. (Areas of spalling may penetrate deeper than the values measured with a tape). This is likely largely due to freeze-thaw action and movement of moisture through the brickwork. The rate of deterioration may be exacerbated by frequent usage of the structure by over-weight vehicles (such as agricultural vehicles) which may be causing the structure to flex under loading.

Previous inspections have found evidence of dropped spalled material on the towpath as shown in Figure 2-3. It is unlikely that a towpath user will be struck by falling debris, but the fragments on the towpath may create a trip hazard which poses an increased danger due to the canal immediately adjacent.

There is evidence of historic brickwork repairs and render/mortar repairs as seen in Figure 2-2. The brickwork repairs around the springings generally appear to have been successful as the brickwork is clearly in significantly better condition than the rest of the arch barrel which has extensive spalling.

Historic render/mortar repairs have been unsuccessful and are spalling off. Where the render is spalling, it appears to be taking brickwork and mortar behind with it. The render repairs may also be masking defects and deterioration of the brickwork underneath. The brickwork around the outside of render repair areas also appear to be deteriorating at a quicker rate than the rest of the brickwork which indicates that the render/mortar is changing how moisture moves through the structure, impacting the rate of deterioration.

The trial hole in the carriageway over the crown of the arch completed as part of the 2024 investigation works found no waterproofing, so moisture ingress is likely. There is no positive drainage system - drainage over the structure appears to be provided by the steep fall over the hump-back to grips and soft verges off the structure. The verges over the structure are concrete.



Figure 2-2: Intrados of arch barrel, historic repairs in stretcher bond visible above the blue brick abutments on the right of the photo [2024].



Figure 2-3: Evidence of dropped material from the intrados [2019].



Figure 2-4: South end of arch barrel [2024].



Figure 2-5: 95mm spalling depth measured at north end of arch barrel near crown [2024].

There are missing and damaged bricks to the voussoir close to the south-west springing as can be seen on left of Figure 2-6. There is severe brickwork section loss at the north-west end of the arch where 10no. voussoir bricks above the springing have 50-80% section depth loss as shown in Figure 2-8. These defects are likely the result of canal boat collisions/scraping with the structure. Defects to the voussoir and spandrel wall sections of the arch are unlikely to affect the bridge's capacity due to the spandrel wall cracking separating the voussoir from the main arch barrel.



Figure 2-6: South elevation of Claydon Canal Bridge [2021].



Figure 2-7: North elevation [2019].



Figure 2-8: Close-up of north-west end of arch barrel [2019]

The abutments are generally in good condition. There is extensive vertical cracking and general deterioration of the masonry at the north end of the east abutment as shown in Figure 2-9.

The wing walls, spandrel walls, and parapet are generally in moderate condition with extensive efflorescence to the surface. There is stepped cracking at the base of the south-west wing wall as shown in Figure 2-10. This may be indicative of settlement of the west abutment. There are other areas of general mortar loss, brick displacements, and cracking around the structure.

The parapet was struck in 2024 by purportedly local district verge grass cutting works. This caused an area of 2.1m x 0.45m of parapet brickwork to fall onto the west bank and into the canal. A section of parapet is therefore missing as shown in Figure 2-12. Although there is no official footway over the structure, it is still used by pedestrians meaning there is a 2.4m length section of parapet which is significantly sub-standard.

The carriageway over the structure is humped with scrape marks in the road from undercarriage scrapings, visible on the left of Figure 2-11. Undercarriage scrapings might be indicative of larger, and therefore heavier vehicles which may be overweight using the structure.



Figure 2-9: North-east abutment [2024].



Figure 2-10: South-west springing and wingwall showing stepped cracking in brickwork [2022]



Figure 2-11: Parapet over the structure (prior to damage in 2024), concrete verge, and carriageway with undercarriage scraping marks [2021]



Figure 2-12: Section of damaged parapet [2024].

3 Consideration of risk posed by structure in current state

3.1 Discussion

As per CS 470 appendix A4 the aim of this section is to “include discussion of likelihood and consequence of collapse, likelihood of warning signs and degree of safety implied by latest assessed capacity” considering the factors outlined in CS 470 Cl. 3.2:

- 1) *the consequence of failure;*
- 2) *nature of the structural weakness;*
- 3) *any corresponding signs of distress;*
- 4) *the possibility of hidden distress;*
- 5) *condition data;*
- 6) *the sensitivity of the structure to the applied loading;*
- 7) *the recent load history of the structure; and*
- 8) *the level of assessment completed.*

Risk of global failure

Complete (catastrophic) collapse is unlikely. In the case of overloading and/or continued degradation, a slow progressive flexural failure would be expected with the structure reaching its serviceability limit state from large deformations before ultimate limit state failure, allowing the structure to be closed before complete collapse. Global collapse is not thought to be an imminent risk at this stage.

From the perspective of highways management, closure of the road would not have a severe impact on the local road network, although there are currently other local road closures due to HS2 works.

From the perspective of canal users, global collapse is deemed unlikely, and even less likely that a canal boat would be situated directly under the arch. From the perspective of canal network management, collapse of the structure would require closure of the canal. This would have a big impact on the canal network as the Oxford Canal is a primary route.

The nature of the structural weakness is the general deterioration of the arch barrel which is gradually reducing the capacity of the structure. If deterioration continues, eventually a critical point may be reached. The spalling also makes inspection and identification of arch barrel defects difficult to spot which increases the risk. No signs of the formation of a failure mechanism have been observed.

Hidden distress is therefore entirely possible. It is also possible that cracks only open up during loading. Inter-ring separation may be present. A hammer tap survey completed as part of the 2024 investigation works found the arch barrel to have large areas of hollow sounding brickwork. It was not clear if this was due to inter-ring debonding or the soft friable surface of the brickwork. The assessed capacity relies on full bonding between the courses.

The current signed weight limit is lower than the assessed capacity which greatly reduces the risk. However in terms of recent load history, agricultural vehicles greater than 3 tonnes are known to use the structure meaning that the weight limit is not entirely effective. There are no physical restrictions or deterrents for overweight vehicles.

Risk of local failure

In its current state, the structure will continue to deteriorate and small fragments of brick and mortar would be expected to spall off onto the towpath and into the canal. The 2024 investigation works found the header bricks at the intrados to be generally well bonded, so the risk of header bricks dropping out should be considered low. This risk may increase as the general condition of the arch barrel worsens.

The likelihood of fragments or a brick striking canal or towpath users are low, and even lower for fragments large enough to cause injury. However, a greater risk would be dropped debris causing a trip hazard on the towpath, for which the danger is increased due to the canal immediately adjacent.

Other Risks

The section of missing parapet poses an increased risk of falls from the bridge deck. Although there is no official footway over the structure, the bridge is still used by pedestrians. The parapet is of sub-standard height anyway so this existing risk is further increased.

Loose brickwork has already been removed from the damaged area to reduce the risk of brickwork falling onto canal users. There is an increased risk that adjacent brickwork has been loosened as a result of the strike causing further bricks to drop from the parapet.

3.2 Is the structure and 'Immediate Risk Structure'?

Cl. 3.2.1 states the signs of immediate risk structures, which the structure in question shall be assessed against.

The structure has a 3-tonne signed weight limit, while the assessed capacity is 13-tonnes (with condition factors). There are no signs of imminent failure or signs of distress associated with either a non-ductile global failure mode or the formation of a failure mechanism.

Local failure is more likely to occur in the near future (i.e. next 5-10 years). Debris on the towpath does create a hazard but it is not indicative of an immediate risk structure.

Generally, with respect to the criteria given in Cl.3.2.1, this structure is *not* currently assessed as being an 'immediate risk structure'.

3.3 Is the structure a 'low risk provisionally sub-standard structure'?

Assess the structure in relation to criteria set out in Cl. 4.4.1.

Even if no interim measures are applied, global failure is still expected to be progressive over time as the structure continues to deteriorate. The capacity may continue to diminish as spalling continues until a critical state is reached. It is hoped that intervention measures will have been agreed with Historic England, the Local Planning Authority, and Canal and River Trust before a critical state occurs. The overall risk of global failure is currently low.

Spalling of brickwork and mortar will likely continue and the risk of dropped/spalled material remains. The overall likelihood of a local failure is low (such as a dropped brick). This risk is likely to increase as the general condition of the arch barrel worsens.

In the context of the highway network, the consequence of failure of Claydon Canal Bridge is at the lower end. The adequacy factor at 40-tonne live loading is assessed as 0.74 which is within the partial factors applied to loads.

At this current point in time, the structure satisfies the criteria set out in CS 470 Cl.4.4.1 such that it may be considered a 'low risk sub-standard structure'. However, without intervention it can be expected that the structure will continue to deteriorate progressively increasing the risk.

4 Appropriateness of monitoring

4.1 Discussion

This discussion is focused around criteria given in CS 470 Cl. 6.9, with any structure-specific considerations and recommendations made.

Claydon Canal Bridge is easily accessible and inspectable under the structure, with a safe access route from the carpark adjacent. Visual inspection of the full arch barrel can be made from the towpath. Much of the arch barrel requires access pontoons/barges in the canal to get within touching distance.

Failure is anticipated to be gradual over time which usually lends itself to being monitoring appropriate. There is the possibility of hidden defects that may not be monitored/identified through inspection alone.

The severely spalled arch barrel makes arch cracking and deformations very difficult to identify by eye. If cracks are identified, crack gauges could be used to monitor movements. Due to the accessibility of the structure, there is the possibility that any equipment installed could be tampered by members of the public.

4.2 Is the structure monitoring appropriate?

The structure should be considered monitoring appropriate.

Whether there is benefit and/or value in monitoring is discussed in Section 6.

5 Options for load mitigation and safeguarding interim measures

For each option, the following issues as appropriate have been given consideration:

- 1) *operational and cost implications;*
- 2) *other implications.*

Note that any cost estimates are indicative only based on past experience.

5.1 Option 1 – Do nothing

The lowest cost option in the short term would be to do nothing, but would most likely in the longer term be the highest cost option. The structure would continue to be inspected through the county's GI and PI regime. Justification for this would be through the fact that there is already a signed weight limit in place which is well below the assessed capacity which reduces the overall risk, even if there are no physical measures to prevent overweight vehicles using the structure.

The greatest risk in the short-term is that brick fragments and units may drop from the arch barrel creating a hazard to canal and towpath users. In the long-term, the arch barrel should be expected to continue to deteriorate, progressively weakening the structure.

'Do nothing' may be an appropriate short-term management strategy proportional to the risk, until a permanent solution is agreed with the Local Planning Authority. This would not be an effective long-term management proposal, from a health and safety or whole life cost point of view.

5.2 Option 2 – Width restriction

The bridge has been assessed as 13-tonne capacity. Despite the signed 3-tonne weight limit, it is thought that over-weight agricultural vehicles are still using the structure which is likely contributing to its deterioration. Implementing a physical width restriction would help enforce a 3t weight restriction and protect the structure from over-loading.

The spalling to the arch barrel is thought to be predominantly from moisture movement and/or freeze-thaw action, though over-loading may be exacerbating or accelerating deterioration. A physical width restriction would not significantly reduce the risk of local failure such as brick fragments/mortar and units dropping from the spalled arch barrel intrados.

Constructing a width restriction requires some careful consideration with respect to its placement due to the hump in the road, steep approaches to the structure, limited onward visibility, and carpark location. There is a significant risk that determined farmers/locals may attempt to remove or cause damage to any physical restrictions as has happened elsewhere in the county.

Overall, it cannot be seen how this option can be practically implemented to provide significant benefit.

5.3 Option 3 – CCTV

To enforce a weight limit supported by an appropriate Traffic Order (as an alternative to physical restrictions), CCTV (with or without ANPR technology) could be installed on the approaches to the bridge to act as a deterrent to overweight vehicles.

There is no live electrical feed over/near the structure so CCTV is not readily implementable. Cameras may also be prone to vandalism. While this solution may provide some deterrent to overweight vehicles, the structure is expected to continue to deteriorate providing no long-term benefit.

5.4 Option 4 - Weight limit review and TRO

The structure has a current assessed safe load carrying capacity of 13-tonnes, but has an existing signed 3t structural weight restriction in place which is not supported by an appropriate Traffic Order. The signage and Traffic Order therefore need to be amended.

Structural weight restrictions should not unduly restrict the movement of vehicles on the highway, such that their needs to be appropriate justification for their implementation based on the structures assessed load carrying capacity. There are two parts to this assessment process. Firstly, to determine the safe load carrying capacity, using conservative assumptions where more detailed information cannot be practically obtained. Then to consider appropriate risk mitigation measures taking into account the risks associated with these measures and balancing these against the likelihood and severity of the potential adverse consequences of the structure being overloaded.

Structural weight restrictions should generally be viewed as a short term measure as these do not completely remove the risk of the structure from being overloaded as signage is often ignored. Enforcement assists, but is only carried out after the restriction has been breached, and with the limited resources available only a small proportion of those breaching the restriction are likely to be caught. When caught this is advertised to deter others.

In the longer term the structure ideally needs to be strengthened or replaced, but this is a Grade II Listed structure for which its historic heritage is wished to be preserved and modifications to it require Listed building Consent. A solution which helps preserve and minimises the changes to the structure to achieve this has been proposed, but Listed Building consent for this has not been granted. A longer term weight restriction may therefore be required in this instance, which is not particularly unusual for Listed Buildings, where modifications may adversely affect its perceived historic significance.

The structural assessments indicates that the bridge currently has an approximate 25% reserve of capacity above its conservative safe assessment load carrying capacity, such that further deterioration of the arch barrel can be afforded to occur before its re-assessed safe load carrying capacity falls below 13t, which makes this proposed weight restriction appropriate for an extended period of time.

5.5 Option 5 – Arch barrel mesh/netting

This option involves fixing netting or a mesh to the intrados of the arch to catch any falling bricks/debris to prevent them from falling onto people on the towpath or in the canal. Mesh works were previously planned by Milestone/OCC and were rejected by the C&RT as they had concerns that safeguarding measures would be implemented without a plan for a permanent solution.

This option remains the most effective for protecting canal and towpath users against falling and fallen debris which is the most likely imminent risk. Installation of mesh to the intrados of the structure would introduce a risk of boats or people snagging on the mesh and causing injury to persons or damage to the structure. This was one of the reasons that the C&RT rejected the mesh installation proposal.

Proceeding again with this solution would be effective at managing the risk of local failure in the short-term, but also carries the same risk of non-acceptance by the C&RT. This option alone would not be an effective long-term management option.

5.6 Option 6 – Road Closure

A road closure could be implemented to eliminate the risk of overweight vehicles using the structure. The overall disruption to the road network would be low, although other local road closures are already in place due to HS2 works local to the area.

The overall risk of the structure is currently low, and there is already a signed 3-tonne weight limit. Closure of the road is therefore not deemed proportionate to the level of risk posed.

5.7 Option 7 – Waterproofing

The spalling is thought to be predominantly from moisture movement and/or freeze-thaw action. Waterproofing measures may help slow the rate of deterioration by greatly reducing surface water ingress through the brickwork from the carriageway.

This is thought to be best achieved by laying impermeable asphalt over the structure, and sealing any joints and cracks in the concrete verges and kerbs (or replacing them). This could be achieved with a road closure less than a week long and probably without Listed Building Consent, and would help manage the structure in the long-term.

5.8 Option 8 – Mortar repairs

Consideration has been given to completing mortar repairs to the structure.

Firstly considering the arch barrel, historic mortar repairs have not been successful, and where the mortar is now spalling it is taking the surface of the brickwork behind with it too. Spalling is to both bricks and mortar joints, and is extensive throughout the intrados of the arch barrel. It is not obvious where mortar repairs can be completed and to what benefit. Lime-based mortar could be injected into the spandrel wall cracking to help slow the rate of deterioration at that interface and reduce the risk of bricks adjacent to the crack dropping out.

Secondly considering the rest of the structure, there are a number of cracks and areas of pointing loss around the abutments and spandrel walls. If works are being completed to the structure (such as parapet reconstruction), there would be value in completing general mortar and brickwork repairs elsewhere to help prolong the bridge's life.

6 Options for monitoring interim measures

If the structure is monitoring-appropriate, for each option, the following issues should be considered:

- 1) *description of monitoring regime;*
- 2) *effectiveness of monitoring regime with reference to anticipated failure mode;*
- 3) *risk of collapse;*
- 4) *risk of damage at loads lower than the collapse load;*
- 5) *operational and cost implications;*
- 6) *other implications.*

6.1 General inspections

Although the structure has good accessibility for inspections, the spalling to the intrados makes visual identification of cracks and deformations difficult. It would therefore be proposed to monitor the structure through a general inspection ensuring at least one inspection every two years.

The purpose of the general inspection would be to identify through visual inspection if there are any obvious or alarming changes to the structure, such as significant new cracks and movements/deformations. The inspections could also serve to check the towpath for fallen debris and remove it.

Monitoring through general inspections may form part of an effective short-term management strategy until a permanent solution is determined. The structure would be expected to continue to deteriorate in the longer term so monitoring is not considered an effective long-term strategy.

6.2 Higher frequency monitoring

A higher frequency and objective monitoring regime could be implemented. The primary purpose would be to frequently visually inspect the structure to identify any changes such as cracks and deformations. This would be supplemented with monitoring equipment such as crack gauges to track any movements.

The monitoring regime would be at frequency intervals every 3-6 months in order for it to provide benefit over general inspections. This would require some engineering resource (time and cost) which would detract from the completion of other tasks and other schemes. Overall, there does not appear to be much benefit in this.

7 Recommended interim measures

The greatest risk to the structure in the short-term is spalling debris and bricks dropping out from the arch barrel. In the long-term, the greatest risk is continued deterioration progressively reducing the capacity of the arch.

After everything, installing mesh/netting to the arch to capture any loose material still appears to be the most sensible way of mitigating the short-term risk while a permanent proposal is determined. The original reinforced concrete spray-lining remains the most effective permanent strengthening measure that works around the scheme constraints. Both of these have been rejected by third parties so alternative structural management arrangements must be sought.

Firstly, it is proposed that the weight restriction is amended to its current assessed load carrying capacity of 13t (with an exemption for Group 1 17t Fire Engines) and this be supported by an updated TRO, such that this restriction can be legally enforced.

A primary cause of the arch barrel spalling is believed to be moisture ingress and movement of water through the structure. It is therefore proposed that the carriageway over the structure is resurfaced with impermeable asphalt to waterproof the arch. The existing kerbs and concrete verges should also be sealed as part of the scheme. (Consideration could be given to replacing them instead, although this may then require upgrading the parapets).

At this stage, no provisions for positive drainage are envisaged as the longitudinal fall due to the hump-back of the bridge appears adequate to allow water to run-off quickly. As part of the scheme, the approach gradients and carriageway vertical alignment is recommended to be reviewed to bring them up closer to current standard as far as practical. Full compliance is likely to be impractical due to the require significant regrading on the approaches with earth retaining elements, for which the cost would be disproportional to the benefits gained.

It is also recommended that whilst the above works are taking place that the section of parapet that has been knocked is re-built, together with general structure repointing, brickwork repairs and lime mortar injection to the spandrel wall cracks.