Claydon Canal Bridge

Assessment Criteria

Doc. Ref. 870060-MGH-SBR-244-AC-CB-0045

Contents

1 Project Details

Client:	Oxfordshire County Council
Name of project:	Claydon Canal Bridge Assessment
Structure reference:	OCC No. 244 C&RT Bridge No. 145
Easting, northing:	446525 , 250020
Grid reference:	SP 46525 50020
Road carried:	Local authority single carriageway single lane road with passing places; 'C' class road informally known as 'Claydon Road'
Obstacle crossed:	Oxford Canal and towpath
Existing restrictions:	3T signed weight limit
Structure category:	Cat 0 structure (to CG 300)
Project summary:	Claydon Canal Bridge is a single span brickwork arch bridge which carries Claydon Road over the Oxford Canal. The structure is Grade II listed and currently has a signed 3-tonne weight limit.

In 2023, Milestone (now M Group) planned safeguarding works consisting of fixing mesh to the intrados of the structure to capture spalling/dropped material and prevent it from striking towpath/canal users. This proposal was rejected by the Canal and River Trust and was therefore never implemented.

In 2024, Milestone submitted an application to the Local Planning Authority for a strengthening proposal which would increase the capacity of the structure to full highway loading and eliminate the risks associated with spalling at the intrados. Historic England raised an objection to the Listed Building Consent (LBC) and Cherwell District Council did not approve the LBC application. As such, the structure remains unstrengthened and without any safeguarding measures.

The existing structure shall be assessed to determine an assessed capacity to help inform a CS 470 interim measures report and to inform recommendations for the management of the structure. This structural assessment should take into consideration the condition of the structure and any structural defects that could affect the assessed capacity.

2   Description Of Structure

Claydon Canal Bridge is a single span brickwork arch which carries Claydon Road (C-road) over the Oxford Canal. The bridge shall be referenced as spanning in an east-west direction over the canal which has a north-south alignment.

The arch has a brick voussoir approximately 380mm thick and consists of 3 rings of brickwork in rowlock. The outer ring is constructed from blue engineering bricks which protrude from the face of the spandrel wall to form a brick mould.

Investigation works completed in January 2024 was found that the main arch barrel brickwork differs from that to the voussoir. The inner ring of brickwork at the intrados consists mainly of red bricks in header coursing, which is backed with 2 rings of brickwork in stretcher course. This coursing arrangement may differ in areas of historic repairs. The original unspalled arch barrel thickness is 480mm.

A topographical survey and 3D scan of the structure was completed in 2022 which allowed an idealised arch profile to be determined for the purposes of structural analysis which is shown in Section 6. The span of the structure was found to be on average 4.19m with a mid-span rise of 1.65m above the notional springing point. The total depth of fill above the crown was found to be 120mm in a trial hole completed as part of investigation works in 2024.

The width of the structure is 5495mm. On the topside of the structure, the north and south parapet are 450mm thick. The north concrete verge is 540mm wide, the carriageway is 3350mm wide at the crown, and the south concrete verge is 700mm wide. The carriageway has a severe humped profile over the arch.

At the intrados of the arch, there is severe longitudinal spandrel wall cracking to the arch barrel 600mm in from the north elevation and 710mm in from the south elevation which separates the main arch barrel from the spandrel wall sections. The width of the arch barrel between the spandrel wall cracks is 4185mm.

60-80% of the main arch barrel has spalling and/or surface weathering to the intrados. The investigation works found that the deepest spall depth which could be measured with a tape measure was around 95mm with an average spall depth of around 40-60mm. It is likely that there is spalling and cracking beyond these measured depths.

3   Parts Of Structure To Be Assessed

The structural assessment shall include:
- Arch barrel

The following elements are outside the scope of this assessment:
- Parapets
- Spandrel walls
- Abutments
- Foundations

4   Standards Used For Assessment

4.1   DMRB

CS 454 - Assessment of highway bridges and structures

CG 300 - Technical approval of highway structures

CS 458 - The assessment of highway bridges and structures for the effects of special type general order (STGO) and special order (SO) vehicles

4.2 Eurocode

None.

4.3 Other

Ciria C800 - Guidance on the assessment of masonry arch bridges

5 Method Of Analysis

The arch barrel shall be assessed using upper-bound plastic mechanism analysis. An example of such methodology is using Limitstate:RING 4.0, which is a two-dimensions rigid block upper-bound mechanism analysis software. The Limitstate:RING analysis model is an iterative optimisation problem to find critical hinge locations and critical collapse mechanism at the lowest load for any given loadcase. Both global multi-hinge collapse mechanisms, and local sliding and yielding failures are considered in the assessment model. The collapse mechanisms considered by the software are shown in Figure 5-1.
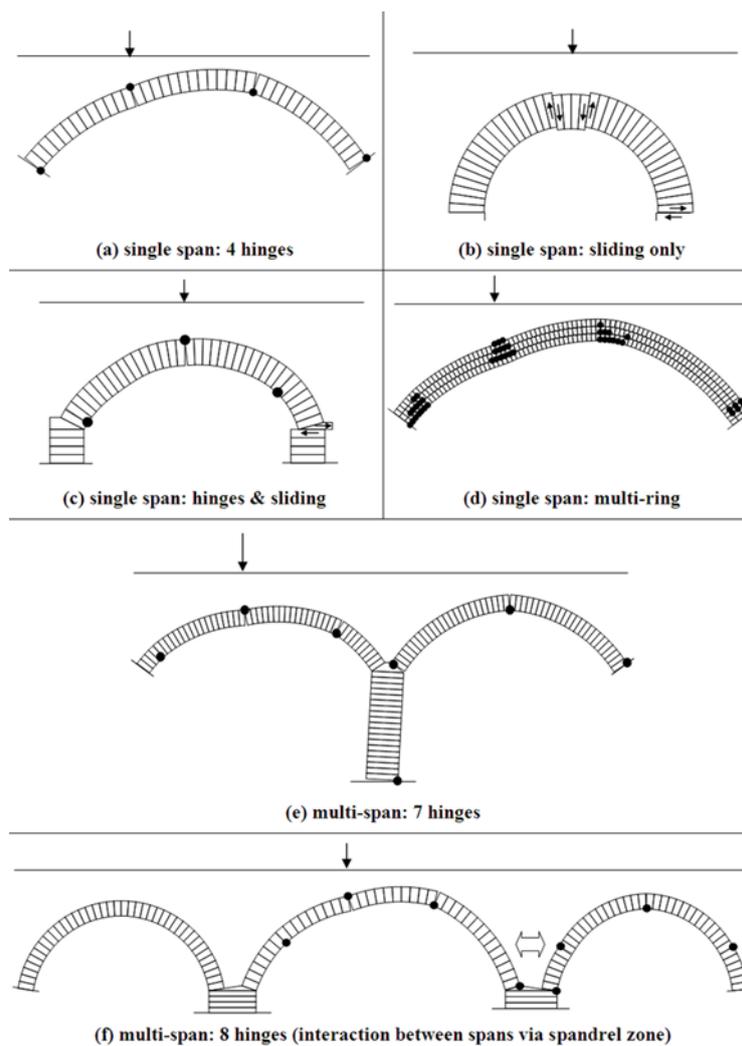

Figure 5-1: Failure modes considered by LimitState:RING.

6 Description and Diagram of Idealised Structure to be Used for Analysis

The arch's geometry shall be defined from the arch profile surveyed during the 2022 topographical survey, for which key dimensions are shown in Figure 6-1.

The depth of fill above the crown shall be determined by the carriageway profile over the structure relative to the arch which is shown in Figure 6-1 and Figure 6-3. The minimum depth of fill at the crown is given in Table 6-1. The carriageway has a severe humped profile over the arch which shall be considered in the structural analysis model.

The overall structure width shall be taken as 5495mm. The effective width for applied axle loads shall be calculated in accordance with CS 454 Cl.7.7.6 considering the effect of the longitudinal spandrel wall cracks to the arch barrel located at 600mm in from the north elevation and 710mm in from the south elevation which may curtail the effective width.

The effect of spalling and mortar loss to the intrados arch barrel should be considered in the assessment model. 60-80% of the barrel has spalling and/or surface weathering. The investigation works found that the deepest spall depth which could be measured with a tape measure was around 95mm with an average spall depth of around 40-60mm.

Key dimensions for assessment are summarised in Table 6-1.

Table 6-1: Key dimensions for assessment.

| Property	Value	Unit	Source
Arch span	Geometry input as per Figure 6-1		2022 topographical survey
Arch rises			
Arch barrel thickness	480	mm	Unspalled thickness determined from 2024 investigation works
Min. depth of fill above crown	120	mm	Carriageway profile as per Figure 6-1 and Figure 6-3
Carriageway surfacing thickness	80-90	mm	2024 investigation works
Overall structure width	5495	mm	2022 topographical survey
Arch barrel width between cracks	4185	mm	2024 investigation works
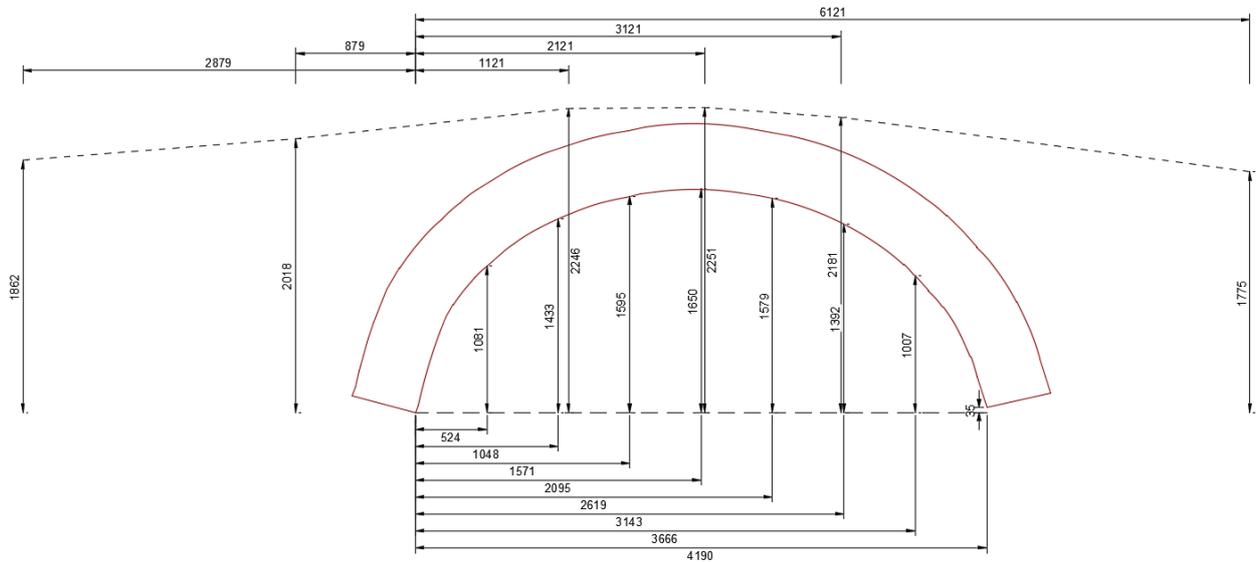
Figure 6-1: Arch profile geometry for assessment.
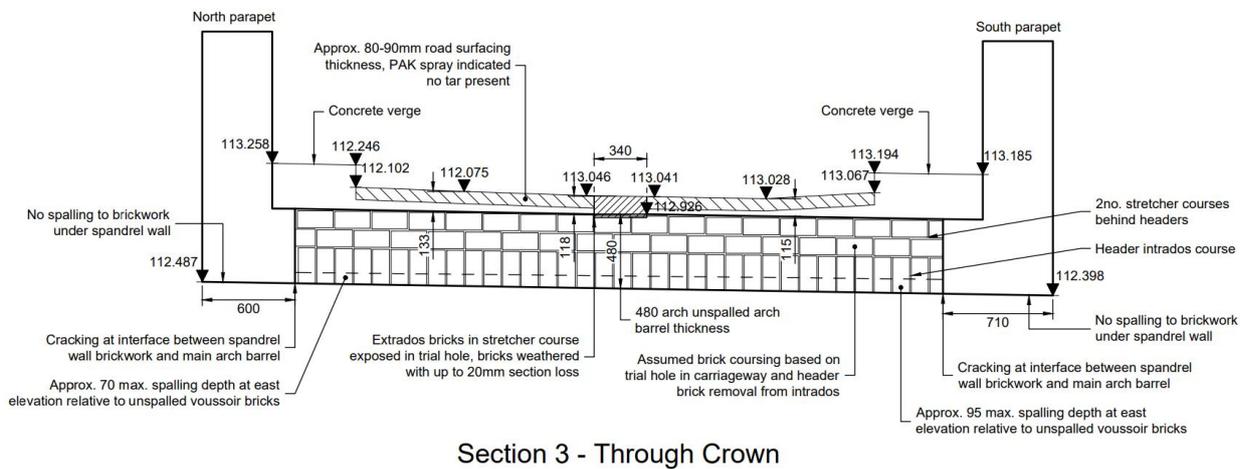
Section 3 - Through Crown

Figure 6-2: Excerpt from 2024 investigation works survey drawing - transverse section through arch at crown (not to scale once embedded within this document).
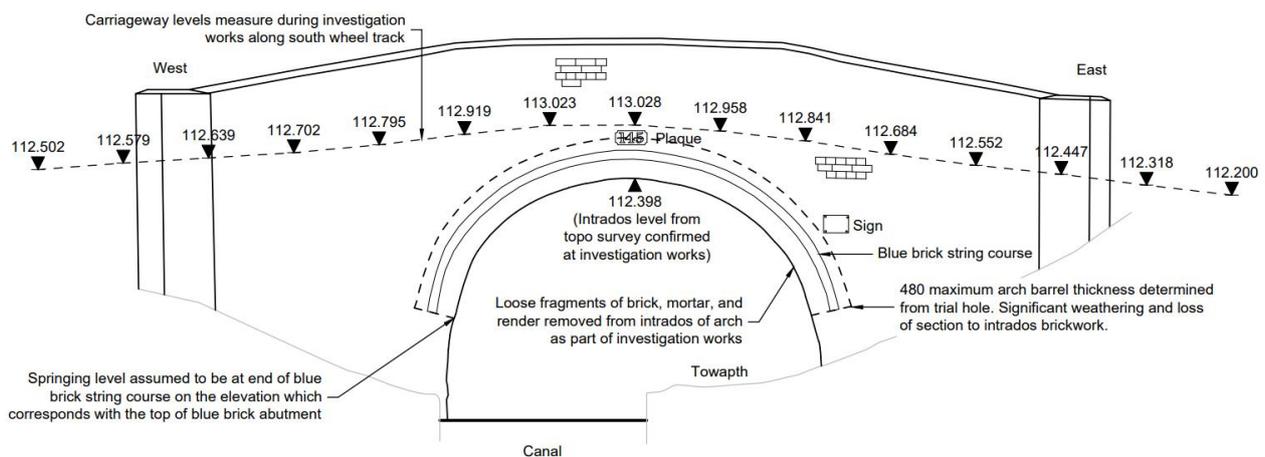
Section 1 - South Elevation

Figure 6-3: Excerpt from 2024 investigation works survey drawing – south elevation of structure showing carriageway profile (not to scale once embedded within this document).

7 Assessment Actions

7.1 Permanent Actions

The following permanent actions may be considered:
- Structure self-weight
- Fill and surfacing self-weight
- Soil active, at-rest, and passive earth pressures on the arch

Material weights shall be taken from CS 454. Material properties for calculation of permanent actions are given in Table 8-1.

Partial factors for permanent actions shall be determined and applied in accordance with CS 454. These partial factors are summarised in Table 8-2.

7.2 Actions Relating to Normal Traffic Under AW Regulations and C&U Regulations

The structure shall be assessed for characteristic traffic actions comprising of single axle, double axle, and triple axle bogies as listed in Table 7.3.1a of CS 454. These are to be modified by the following factors:

1. Load capacity factor of 1.2 to avoid further distress, C_{min} from CS 454, Clause 7.2.
2. Partial factor for traffic actions at ULS of 1.5, γ_{fl} to CS 454, Table 3.4.
3. Impact factor of 1.8 to CS 454 Cl.5.9a assuming dynamic/impact effects may develop. Factor applied to the critical axle only.
4. Traffic flow factor of 0.9 to CS 454, Cl.5.9b.
5. Lane factor of 1.0 to CS 454, Cl.5.9c.
6. Partial factor for load effects at ULS of 1.0, γ_{f3} to CS 454, Cl.3.9 for masonry structures.
7. Due to the significant hump over the bridge, axle lift-off shall be considered for double and triple axles, to CS454 Table 7.3.1b.

Horizontal braking and acceleration loads shall not be considered. Centrifugal forced shall not be considered.

7.3 Actions Relating to General Order Traffic Under STGO Regulations

If the structure is found to be adequate for 40-tonne normal traffic loading to Section 7.1, the structure shall be assessed for special order SV-80 traffic loading. An SV-80 triple-axle load model to CS 458 Fig.3.8 shall be applied modified by the following factors:

1. Load capacity factor of 1.8 to avoid further distress, C_{min} from CS 454, Clause 7.2.
2. Partial factor for traffic actions at ULS of 1.1, γ_{fl} to CS 454, Table A.1.
3. Overload factor of 1.2 applied to the critical axle, and 1.1 applied to all other axle, to CS 458 Cl.3.33.
4. Dynamic amplification factor of 1.16 to CS 458 Cl.3.35.

8 Material Properties

Material properties for the assessment are given in Table 8-1. Partial factors for permanent actions and material strengths are summarised in Table 8-2.

Table 8-1: Material properties for assessment.

Property	Value	Unit	Source
Masonry engineering brick unit weight	2200 21.6	kg/m^3 kN/m^3	CS 454 Table 4.1.1a 'Engineering bricks'
Masonry compressive strength	3.5	MPa	CS 454 Figure 4.2.7a 'wirecut' brick with 1:3 lime mortar[1]
Coefficient of friction for masonry	0.6	-	
Fill unit weight	1920 18.8	kg/m^3 kN/m^3	CS 454 Table 4.1.1a "Hardcore fill" value.
Fill angle of friction, ϕ	35	°	Granular fill (2024 investigation works), assume no cohesion, assume fill is reasonably well compacted
Cohesion, c	0	kPa	
Load dispersion cutoff angle	26.6	°	CS 454 Cl. 7.3.5
Surfacing unit weight and thickness	23.1 80	kN/m^3 mm	CS 454 Table 4.1.1a "Hot-rolled asphalt".
Angle of load dispersion through surface fill	26.6	°	CS 454 Cl. 7.3.5

Table 8-2: Partial factors for materials.

Factor	Value	Source
Dead load factor, γ_{fL}	1.0	CS 454 Table 3.4 – assumed to be favourable
Material factor for crushing strength, γ_m	1.0	Set to 1.0 in accordance with Ciria C800 Table 7.7.
Material factor for sliding resistance, γ_m	1.0	CS 454 does not give a partial factor for sliding.