Essex Highways

Boxted Bridge Report

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18 May 2021

FAO: Vasileios Papadimas

Boxted Bridge Assessment Report

Following on from our initial proposal via email dated 08.04.2021, we are pleased to attach our report for the above project.

CBUK have undertaken a desk top study of Boxted Bridge and engaged expert opinion from a partner organisation Cass Hayward. Together, we discussed the only viable repair and refurbishment option, detailed in the CH report below and additionally the replacement of the bridge.

In our experience, refurbishment can be a cheaper option, but only marginally. When risk is analysed and appropriate allowances are made in mitigation, the refurbish option then becomes on paper the most expensive option. Our experience demonstrates that risk allowances are almost always called upon to undertake unforeseen and hidden defects.

With regards to hidden defects, the nature of the construction of Boxted Bridge presents us with this very issue – hidden defects. The concrete make up of the deck covers structural elements and their vital connections thus eliminating thorough inspection and most importantly any less intrusive means of repair other than removing the concrete. In order to clear sufficient concrete to uncover connections and steel elements for replacement would virtually render the bridge deck unsound resulting in a requirement to remove the entirety of the deck. By the time this is achieved and hidden defects exposed the monies thus far expended would have been far better directed to a sympathetically designed replacement.

During any refurbishment, over and above the actual costs and intrusive repair works required, are other peripheral issues to be addressed. Works on site, in-situ for the repair and refurbishment are more disruptive to the local population and travelling public. A new structure can be prepared while the existing structure still affords passage and right of way for stakeholders and it is therefore our conclusion that the most cost effective and lowest risk solution for Essex Highways is to replace the bridge.

I hope you find all to be satisfactory and we look forward to your response.

Yours faithfully
for **Cleveland Bridge UK Ltd**

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1. Introduction/objective

This document follows receipt of an email from Jim Mawson (Cleveland Bridge UK Ltd) requesting Cass Hayward view of the feasibility of repair of Boxted Bridge from both a practicability and economic viewpoint.

After some initial email exchanges, it was determined that this should be carried out as a desk study only (no site inspection), based predominantly on a Principal Inspection (PI) report prepared for by Essex County Council by Ringway Jacobs in March 2018.

In the event that refurbishment is not considered economically feasible, Cass Hayward have been asked to outline a reconstruction option, for further consideration.

This report fulfills the above objectives.

2. Information received.

Cass Hayward have prepared this report from the information contained within the Boxted Bridge (ECC BR0059) Principal Inspection report prepared for by Essex County Council by Ringway Jacobs in March 2018.

The Principal Inspection report contains some details of the history of the structure together with text description of inspection findings. A general arrangement of the bridge is included together with two drawings showing defect locations. A large number of photographs show details of condition. References in this document to numbered photographs relate to those in the PI report.

It appears that the bridge was built in 1903 (so will be wrought iron or early steel). Inspection records only date back to 2012. A 1992 assessment is reported to have found the deck to have a live load capacity of 3 Te though this rating was ‘with reservations’ regarding edge beam effective length/U-frame action. The assessment recommended that the structure be restricted to 3 Te GVW though it is understood no weight restriction was implemented and none exists to date.

Based on the most recent inspection the condition of the bridge is reported by Ringway Jacobs as ‘POOR’ and the BCI risk ranking is ‘HIGH’.

Whilst the PI describes the defects qualitatively there is no quantitative report of their extent in respect of measured loss of section. For example, main girder bottom flange corrosion is noted as ‘severe’ but there may be locations within the span where ‘severe’ might be tolerable, as long as it’s cleaned up and further decay is prevented. For this reason it is not possible to be unequivocal in the assessment of remaining strength of the structure.

It is, however, possible to review the types of decay, the probable causes, and the practicability issues that would be raised in seeking to effect refurbishment works to rectify the defects in general terms. In this manner we have formed a view of the overall feasibility of the refurbishment activities.

3. Refurbishment – principle defects.

On review of the PI we consider the principal areas requiring attention are:

3.1. Decay to deck elements.

On many ‘half through’ bridges of this type it is common to see major decay above deck level including to exposed parts of main girders (particularly outer main girders), but relatively little decay to structural elements within the soffit. The underside of a bridge is often in remarkably good condition.

This is not the case on Boxted bridge.

Significant (‘severe’) decay is described under PI section 5.2, illustrated by photographs 1.1.27 to 1.1.37 inclusive, and 1.2.1 to 1.2.30 inclusive, and others. This type of decay, spread over much of the plan area of the bridge deck infers failure of the waterproofing system.

The arrangement of the deck is a little unusual. It is trapezoidal in plan, being wider at the south abutment than the north, and has an effective square span of 12.50 m. It comprises riveted plate girders as primary supports with cross girders spanning transversely but only over the 'middle half' of the plate girder span. The cross girders stabilise (prevent buckling) of the edge girders by means of their connection to the main girder and the formation of U-frames – but only over this central region. Support for the deck over the remaining 'outer quarter' at each end of the span is by a system of longitudinal rolled I-beam/channels, spanning onto each abutment. This grillage of steelwork is then completed by concrete infill on 'buckle plates' that span between bottom flanges of cross girders and other steelwork. All of this steelwork is important for the performance of the bridge, including the cross girder to main girder U-frame connections.

The buckle plates are shallow and will likely have been placed as permanent formwork resting on the flange angles and unable to take arch thrust. The concrete fill would however arch, being cast against the cross-girder webs. In this arrangement the concrete will tend to crack directly above each cross girder. Any water from the roadway that is not otherwise collected and redirected by the waterproofing system would percolate down the ends of the buckle plates and corrode the flange edges and between doublers and flange. The waterway under could also have encouraged corrosion.

It is apparent from the description and photographs that this has happened extensively over the deck – likely over a long period of time. We must also consider what further decay has taken place within the deck structure that we cannot see – particularly what else has decayed?

3.2. Rust distortion of main girder flange splice plates and cross girder doubler plates.

These defects are shown on photographs 1.1.9-1.1.11 (main girder top flange) and 1.2.1-1.2.4 (cross girders in bridge soffit).

Cusp and curl distortions (by 'rust jacking') is likely due initially to excessive rivet edge distance which appears to be at least 4 inch. Also the longitudinal spacing which appears more than "custom and practice" 4 inch (needs confirmation). Excessive spacings – likely coupled with insufficient corrosion protection – allows rust decay to commence, which then expands (each 'layer' of rust by a factor of at least three) over time, 'jacking' the plates apart.

Although the cross-girder doublers are distorted they are apparently intact otherwise, though rivet capacity may have been eroded. Imminent failure of the bridge floor under light traffic seems unlikely with only 1m close spacing of cross girders due to redundancy, but this is still a serious defect. Cross girders which support the stringers towards the ends of the bridge are likely to be vulnerable to traffic overload.

Whilst main girder top flange plates could be removed fairly easily (subject to strength and temporary support requirements) we have concerns over what we would find under them, and subsequent repair requirements.

In respect of the cross-girder doubler plates, the presence of the buckle plates above the cross girder bottom flanges hampers (or makes impossible) the removal of the existing fixings. Removal of these doubler plates as part of refurbishment would require some element of propping/temporary support which on this bridge would need to be effected from above due to the presence of the river under.

We can see no practicable way of replacing cross girder doublers by bolting without demolishing most of the floor. Welding would be technically difficult and high risk, with the existing early steel (to be confirmed) being of variable quality and not always suitable for welded repairs.

We consider that if refurbishment is to be attempted, it would be more economic to replace the cross girders leaving only the main girders to be repaired. Of greater concern is likely to be the vulnerability of the main girders to accidental impact. See below.

3.3. Longitudinal edge channel.

The longitudinal channel that makes up the deck in the ‘outer quarter span’ regions (photos 1.2.19 – 1.2.30) is also cast into the deck and is in very poor condition. Concrete cast against the inside of the web and the top of bottom flange makes it difficult to replace/strengthen in any practicable manner.

3.4. Main girder vulnerability.

Apart from any inadequacy in supporting the vertical loading by lack of U-frame restraint and the condition of the steel/splices generally, the main girders are vulnerable to accidental impact.

U-frame restraint can only be achieved in the central 6m length of the bridge span where cross girders exist. Details of the cross girder/main girder connections are not shown and would be vital in establishing U-frame strength and stability.

At the abutments it would appear that restraint is only available from gravity resistance of the main girder to overturning, noting that the bottom flange appears to be only about 250mm wide (unless connected to a wider spreader plate or other stabilising arrangement).

There appears to be evidence of vehicles colliding with the main girders.

The risk of girder instability from accidental vehicle impact appears to be serious because:

- Lack of overturning resistance at the ends of the main girders. Torsional resistance at supports is required as part of the system that provides structural strength in bending.
- Little or no verge width or kerb upstands
- Curvature of the road approach and vertical profile.
- Narrow width of the road, allowing limited space for oncoming vehicles to pass

These deficiencies would not be allowed in a structure designed to modern standards. A short-term option might be to impose single lane use by traffic lights, but this is deferring the problem, not addressing it.

4. Refurbishment – illustrative option.

In general terms, prior to implementation of any refurbishment scheme it is essential to establish the present capacity of the key bridge elements, to determine which are critical to strength. From this a decision can be made on retention/feasibility and a refurbishment design can proceed. Also, the current and future traffic use should be considered to decide whether the bridge needs to be widened, provided with footways or services, or if other improvements to its arrangement need to be made.

On Boxted bridge it is clear that the deck is severely decayed and that it’s form of construction (presence of buckle plates and concrete against items requiring repair) makes local repair impracticable and uneconomic. There is also a risk that there is severe decay in parts that are covered, and cannot be inspected.

For illustrative purposes we have developed a refurbishment option involving retention of the main girders only – subject to capacity checks outlined above. The option is shown in sketch BOXTED -1 (appendix A), and described in principle below:

4.1. Sketch BOXTED -1 shows reuse of the existing main girders, but with the floor replaced. This assumes that the girders are found on blast cleaning to be in repairable condition, and subject to capacity check (non-linear buckling analysis) requiring measurement of straightness and twist. The present splice plates to the flanges would be replaced with others of increased capacity. Local repairs to any decayed areas would be required.

4.2. The bridge floor would be replaced in a similar layout to the existing using composite UC sections. Intermediate U-frame stiffness would be achieved by rigid TCB connections (possibly to new stiffeners) within the raised verges.

4.3. The work would involve stabilisation of each main girder followed by removal of the existing deck. This itself would need careful consideration of method including protection to the waterway etc. Normal demolition of the floor concrete would be hindered by the buckle plated soffit.

We tentatively suggest firstly stripping off the surfacing for recycling. The floor concrete would then be partly broken out to reveal tops of the cross girders local to the main girders. Longitudinal sling beams could be laid to span 6m onto the existing "end" cross girders and connected by bolts or clips to the 5 others. Concrete local to the main girders would be removed to allow the cross girders and buckle plates to be cut, leaving stubs to the main girders avoiding damage to the connections. The centre part of the floor could then be lifted out. The end sloping sections would then be lifted out in a similar manner. Main girders would be removed and taken to works for cleaning up, repair and trial fitting to the new cross girders.

4.4. Whilst the main girders were being refurbished and fitted to new deck steelwork at works, the abutments would be cleaned off, repaired as necessary and adjusted (level reduced) to prepare them to receive the refurbished structure.

4.5. The girders would be supported by steel "sit-on" trimmers rigidly connected to new bearing stiffeners on the refurbished girders. This would provide rigid end U-frames to stabilise against buckling and provide impact resistance. The trimmers would have inboard disc bearings beneath to provide load distribution via precast sills onto the existing abutments.

4.6. On return to site the main girders would be repositioned outwards on the sit-on trimmers to provide verges say 450mm wide with Trief kerbs 300mm high to protect against accidental collision with the girders. The existing pilasters would be rebuilt in front. Appearance of the bridge in elevation and from the road would be largely unchanged.

4.7. This could be considered a ‘heritage restoration’ of an interesting structure in keeping with its rural setting.

It is emphasized that during blast cleaning of main girders it is normal for other defects to be uncovered, or present defects to become more evident/extensive. ‘Scope growth’ is likely (and high risk) and suitable budgetary allowances need to be made against any option of this type. Allowance for new main girders would be prudent – resulting in, effectively, reconstruction.

The cost of the above refurbishment scheme will be significant and will result in a (professionally) ‘patched up’ bridge. Theoretical design life (fatigue endurance) will be zero years for the existing main girders, though life to next painting maintenance would be 20-25 years based on shop application of a modern corrosion protection system.

We would not recommend this option unless local support for retaining the bridge for historical reasons becomes an issue.

5. Reconstruction option

Appendix B includes sketches BOXTED-3 sheets 1 and 2 illustrating a reconstruction option.

Reconstruction of the superstructure (assuming the existing road geometry) would probably be most economic using a composite steel/concrete deck comprising stiffened wide bottom plate with fabricated tees over. This avoids soffit permanent formwork and requirement to thread rebar through the webs, a tricky process once the edge girder is in place.

The stiffened plate would be curved in elevation to reflect the shape of the required road profile. It is common to fabricate from weathering steel (at least for the soffit plate) to reduce whole life costs, though painted carbon steel is also an option. If weathering steel is adopted, the Council could still chose to paint the steel exposed on elevation, for aesthetic reasons.

Delivery to site would be in longitudinal sections, each spanning from abutment to abutment. The outer sections could be delivered with parapet plinths cast onto the outer tees at works, thus providing a degree of edge protection/stiffness for site works. Splice steel sections together (from above – no welding) and then infill remainder on site with concrete. Install waterproofing, surfacing, kerbs, services (check requirement but duct locations can usually be provided through dedicated bays) and parapet.

Parapets would depend on containment standard adopted (N2?) and would be mounted on upstands to the deck units. Widening of the deck to provide minimum 450mm wide edge verges would be desirable and could be achieved by mounting the new bridge deck onto precast cill units secured onto the existing abutments. A small overhang of the new cills on the existing abutments would likely be required, as illustrated on BOXTED -3 sheet 2 of 2.

Bearings would likely be elastomeric pads (or strip) along each cill beam. During detailed design we would need to consider possible introduction of a shear key between deck and cill beam(s) to resist horizontal loads.

The vertical road profile and splay plan geometry would be likely to preclude use of proprietary prestressed beam decks in this instance.

Aspects including river flow, scour of foundations, repairs of the substructures and headroom restriction would also need to be taken into account.

6. Conclusion

For the reasons given in the preceding sections Cass Hayward consider that replacement should be the preferred option.

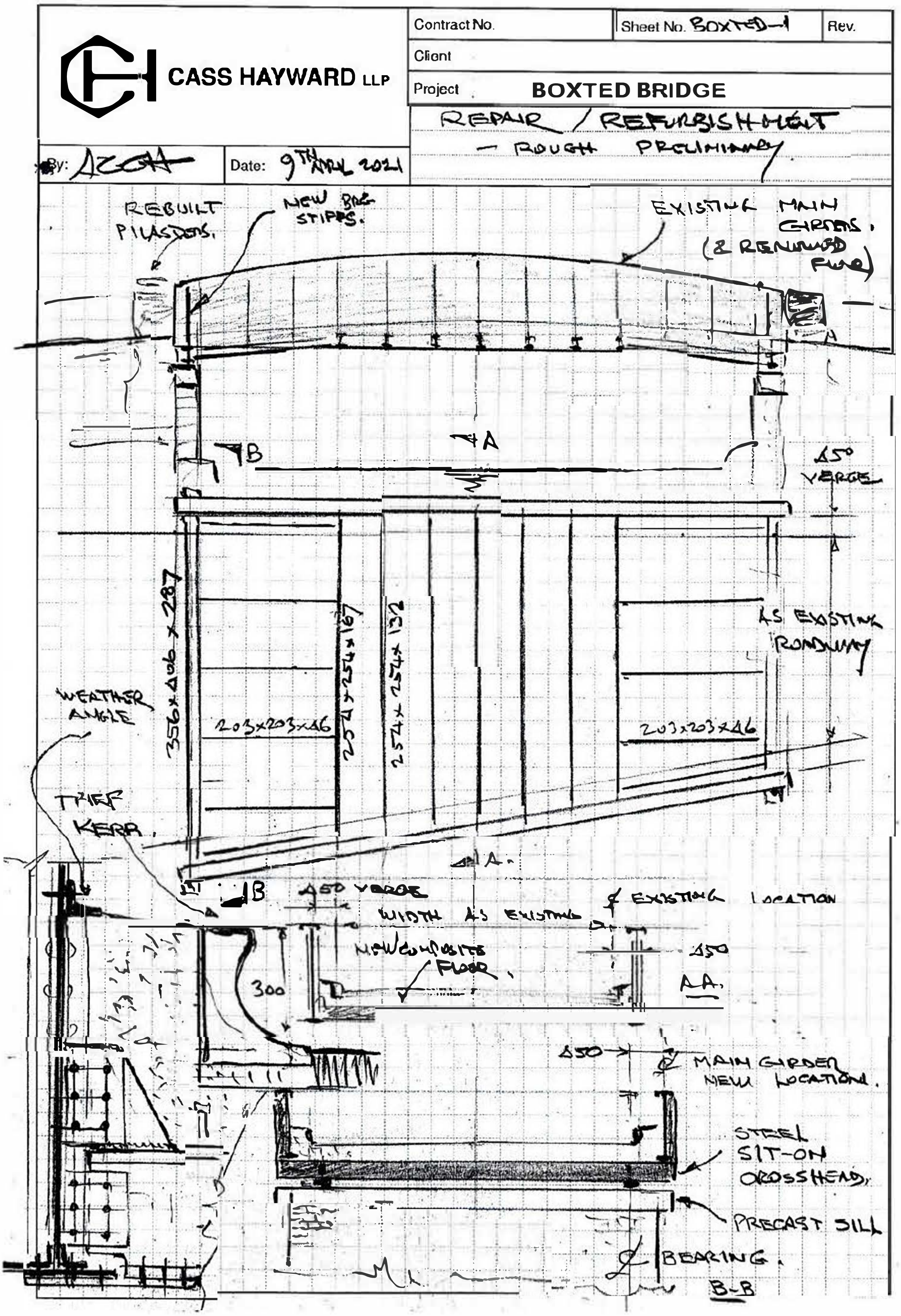
Repair of cross girders, U-frame connections and stabilising or strengthening of the main girders is probably impracticable or uneconomic compared with reconstruction of the superstructure, based on present knowledge.

Refurbishment would, as a maximum, retain the existing main girders but these would still require removal and refurbishment at works, whilst they are fitted to a new deck. This would cause a much longer period without a bridge in place (or with an expensive temporary bridge in place), whilst refurbishment talks place. This may not be acceptable to the local community.

Reconstruction will provide a new structure, probably cheaper, with design life (fatigue endurance) of 120 years.

Appendix A

Sketch of refurbishment option



Contract No.	Sheet No. BOXTED-1	Rev.
Client		
Project	BOXTED BRIDGE	

CASS HAYWARD LLP

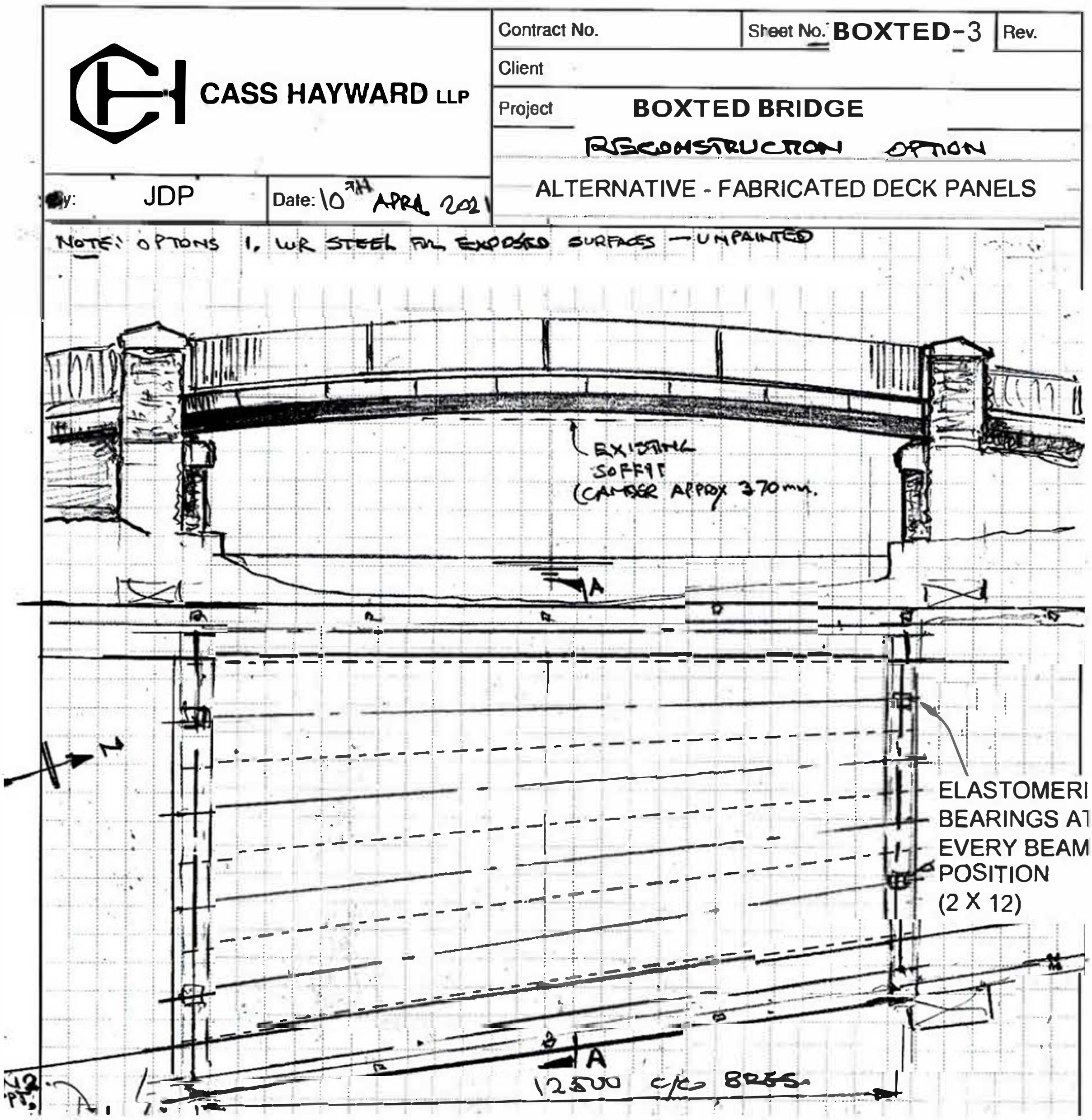
By: AZGH

Date: 9TH APRIL 2021

REPAIR / REFURBISHMENT
– ROUGH PRELIMINARY

Appendix B

Sketches of reconstruction option



CASS HAYWARD LLP

Contract No.
Sheet No. BOXTED-3
Rev.
Client
Project BOXTED BRIDGE
RECONSTRUCTION OPTION
ALTERNATIVE - FABRICATED DECK PANELS
By: JDP
Date: 10TH APRIL 2021

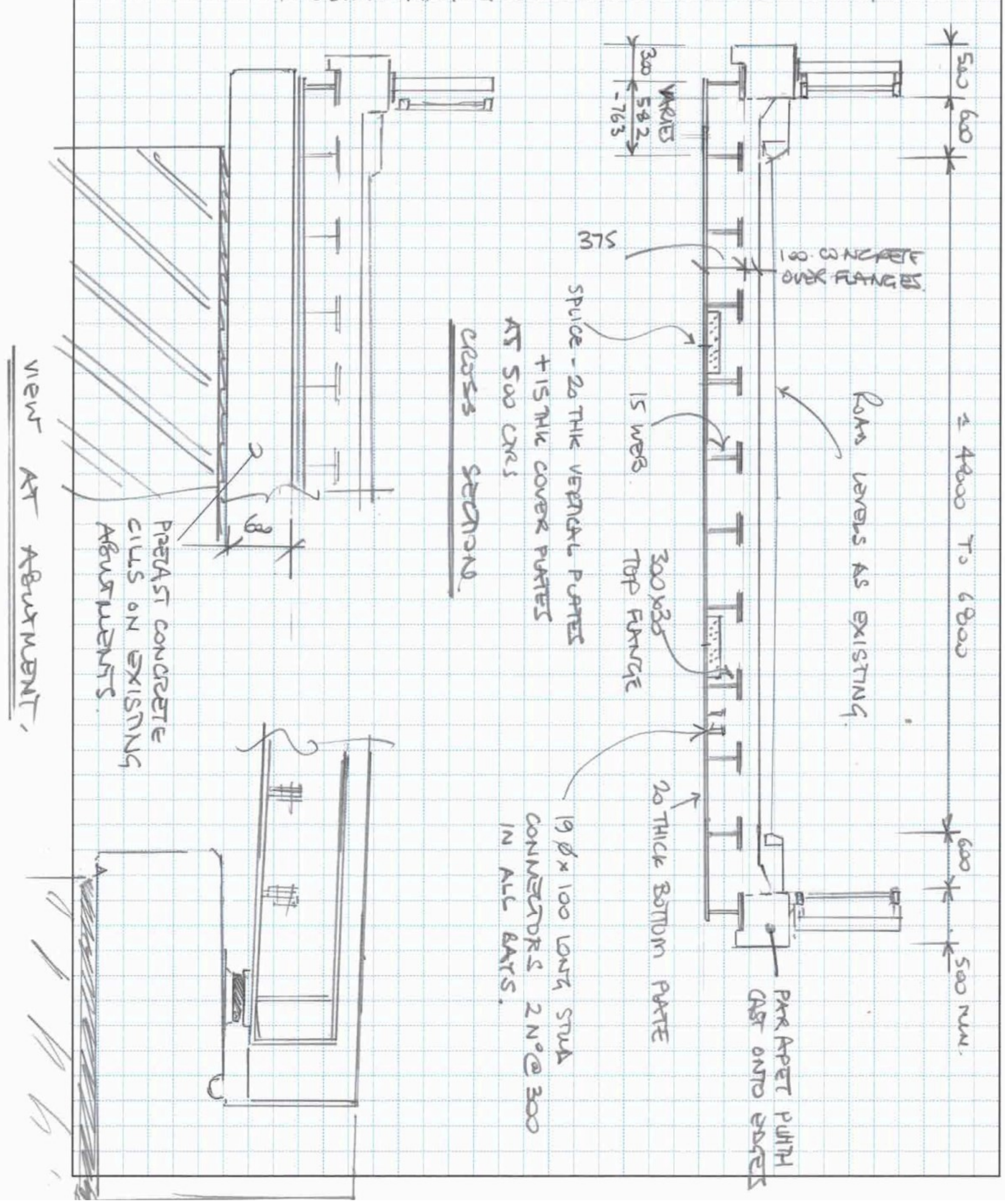
NOTE: OPTIONS 1, WR STEEL FOR EXPOSED SURFACES — UNPAINTED

PLAN

CASS HAYWARD LLP

Contract No.	Sheet No. BOXSTED 3 - 2	Rev.
Client		
Project BOXTED BRIDGE		
FULL WIDTH DECK PANEL		
By: JZP	Date: 4/21	

PRELIMINARY & SUBJECT TO DETAIL DESIGN



CLEVELAND BRIDGE UK

at a glance

- Established in 1877, based in Darlington, England
- Proven track record of design, fabrication and installation of multifaceted steelwork projects.
- Combined group fabrication capacity of 170,000 tonnes per annum.
- Commitment to the highest quality standards throughout the business.
- Full suite of capabilities, from turn-key solutions to provision of product-specific services across multiple sectors.
- Highly experienced engineering team, offering design, value engineering, project and site management expertise.
- Commitment to working with local partners, providing training, experience and employment opportunities.
- Commitment to minimising environmental impact and adherence to international environmental standards.

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