Dead Dog Basin Footbridge

Inspection and Assessment Report

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Version Control

Version	Date	Author	Checker	Reviewer	Approver	Changes
01	**12/11/21**	**W Fenner**	**V Dudley Bow**	**A Branch**	**A Branch**	**Draft report**
02	**17/12/21**	**W Fenner**	**V Dudley Bow**	**A Branch**	**A Branch**	**Finalised report**
03	**03/02/22**	**W Fenner**	**V Dudley Bow**	**A Branch**	**A Branch**	**Updated with client comments**

Contents

1 Introduction

Arcadis were commissioned by Canal and River Trust to undertake an inspection and assessment of Dead Dog Basin Footbridge including material and paint testing. The structure was inspected on 23rd September 2021 with dry and warm weather conditions. The access was conducted with the use of a work boat and scaffold tower provided by the Canal and River Trust (CRT).

An inspection of the footbridge was undertaken by Arcadis on 23rd September 2021 with dry and warm weather conditions. Material and paint testing was also carried out by ESR Technology. The bridge is owned by The Canal and River Trust and carries the towpath over the entrance to Dead Dog Basin alongside Regent's Canal.

Functional Location:	RE-004-030
Asset Name:	Bridge 21 Dead Dog Basin
Grid Reference:	528613, 184061
Post Code:	NW1 7DZ

The following sources were consulted as part of the inspection:

- Previous Principal Inspection report dated July 2010.

A change in condition grade from C to D was undertaken in 2013 following the Principal Inspection in July 2010 and a further inspection in 2012. The significant corrosion of the parapets and lateral deflection of the northern parapet triggered the change in condition and priority works.

2 Structure Description

The bridge is a single span structure and consists of two edge I girders supported by masonry/brick abutments with approach/retaining walls to the ramps of red and blue stock brickwork. There are double tie rods on both edge I girders. The original deck between the I girders was removed and replaced with a new deck arrangement to accommodate National Grid cable troughs and comprise 4No. 400 x 180 mm steel 'I' beams arranged in pairs. Each pair of beams has been boxed in to form cable troughs. A shallow, steel deck tray 80mm deep filled with asphalt is bolted to the upper flanges of the main beams to form the towpath surface. The decking/walking surface is of tarmac and the parapets are steel with lattice infills between the outer beam and handrail. The outer I girders which support the parapets are structurally independent from the deck elements supporting the footpath. The downstream approach ramp is of brick paving for the lower half, and tarmac for the upper half which continues over the length of the bridge to the upstream ramp to meet the towpath. The boundary walls are of brickwork with rounded stone top cappings.

The new deck was constructed in 1977, the parapets predate the current deck and the construction date is unknown.

Available record drawings are provided in Appendix A

3 Inspection Report

3.1 Detailed Condition Report

3.1.1 Deck Elements

The primary deck element comprises two original cast iron girders located at the edges of the deck with four steel beams arranged in pairs supporting shallow, steel deck trays to form two cable troughs. Support brackets are located every 500mm along the length of the bridge connecting the cable trough beams to the cantilevered section of the deck plate.

Defects noted on site are as follows:

Original cast iron girders

- Delamination caused by general surface corrosion is noted along the entire length of both the canal side and basin side edge I girders. (See Photos 1 – 3).
- Full thickness section loss in the lower flange to the canal side edge I girder measured approximately 65mm in width at the midspan. (See Photos 4 – 5).
- Full thickness section loss in the lower flange to the canal side edge I girder toward the west abutment measured approximately 70mm in width and 30mm into the flange. (See photos 6 – 7)
- Pitting to the web on the basin side edge I girder toward the west abutment. (See photo 12)

Steel beams and cable troughs

- The steel beams have minor corrosion on the edges of the flanges and minor deterioration of paintwork throughout. (See Photos 8 – 9).
- The shallow, steel deck trays between the steel beams have deteriorating coating possibly caused by damp conditions when the coating was applied. (See Photo 10)
- Pigeon guano at the top of the flanges of the steel beams.
- Corrosion to the base plates of the support brackets, in some cases causing minor section loss of base plate. (See photo 11)

Tie Rod

Tie rods are installed to both the canal side and basin side edge I girders via a clamp on the ends of the span.

- Surface corrosion to the tie rod clamp I sections and bolts on the basin side I girder. (See photo 13).
- The tie rod on the basin side I girder is providing no structural support to the deck and moves side to side with little applied force.

3.1.2 Load bearing substructure

Foundations

- Foundations were not visible for inspection; no signs of any movement or settlement were found at the time of the inspection

Abutments

Both abutments are of masonry construction.

- Corner sections have been broken away by possible boat impact on both abutments. (See photo 14 – 15).
- Vegetation and moss are growing from the brickwork. This can also be seen in photos 14 – 15

3.1.3 Durability elements

Waterproofing

It is not known if any waterproofing layer is applied to this structure.

3.1.4 Safety elements

Access/ Walkways

Access to the footbridge is provided by ramps to the east and west of the structure. The east ramp is surfaced with tarmac and cobblestone and the west ramp with tarmac only.

- Minor vegetation growth along the footpath at the base of the wall on the basin side of the ramps. (See photo 16-17).
- Loss of tarmac surfacing to the east ramp. (See photo 18)
- Areas of graffiti to both ramps. (See photos 19-20).
- Approximately 250mm wide hole to the east ramp where it meets with the bridge deck at the base of the canal side ramp parapet. Light is visible through this hole and has accumulated minor debris and detritus. (See photo 21)
- Approximately 150mm wide hole with cracking to the surfacing of the east ramp where it meets with the bridge deck at the base of basin side ramp parapet. Light is visible through this hole and has accumulated minor debris and detritus. (See photo 22).
- A lateral crack in the east ramp approximately 1m away from the bridge deck

East Ramp wall and parapet

- Extensive graffiti to the boundary wall. (See photo 23)
- Loss of mortar to the boundary wall. (See photo 24)
- Bridge parapet is connected to the ramp parapet via a staple connection. (See photo 25)
- Minor graffiti and loss of mortar to the ramp parapet. (See photo 26).

West Ramp wall and parapet

- Extensive graffiti to the boundary wall. (See photo 27)
- Loss of mortar and brick to the boundary wall. (See photo 28).
- Vegetation growth to the boundary wall. (See photo 29).
- Algae staining to the ramp parapet. (See photo 30).

Bridge Parapets

The parapets consist of a steel T-section bolted to the top flange of the edge girders . Lattice work is bolted to the web of the T-section at the bottom and to another T- section at the top upon which the handrail is attached. The bridge parapet is then bolted to the ramp parapets via L - plates either side of the lattice work.

- Significant rusting and delamination of the base T-section at the basin side leading to some section loss and missing bolts that should connect to the edge I girder. (See photo 31 – 33).
- At the east end, basin side parapet, replacement bolts have been used to secure the end L – plates to the parapet but are now loose making the end of the parapet unsecured and loose. (See photo 34).
- Lattice work is generally in reasonable condition on both sides of the bridge with deterioration of paintwork and rusting at the bolted connections. (See photo 35).
- Top rails are in reasonable condition with minor deterioration of paintwork. There are signs of delamination on the canal side edge, however, the canal side edge parapet is generally in better condition than the basin side parapet. (See photo 36 - 37).
- General detritus, moss and algae on the bottom T – sections of both parapets.
- Basin side parapet is loose and can be moved back and forth with little applied force. (See photo 38).

- Positioning of the parapets in relation to the masonry approaches has become misaligned. (See photo 31)

3.1.5 Other elements

West wingwall

- Loss of brick and mortar at the far west end of the wingwall. (See photo 39).
- Significant vegetation and algae growth at the gap between the brickwork and capping stones. (See photo 40).

East wingwall

- Loss of brick and mortar at the far east end of the wingwall. (See photo 41).

3.2 Key defects affecting stability of the parapet

The north parapet is noticeably unstable. The primary defects contributing to this instability is the corrosion of the base T section and the loss of connection to the masonry walls at either end. There is a significant difference in condition between the two parapets. The difference being that it appears that the T section at the base of the lattice members on the south side has been replaced more recently as there is very minimal corrosion, however, the corrosion on the same element on the north parapet is extensive and connection has been almost lost between the cast iron beam and the parapet. Our assessment is that the north and south T sections have a condition factor of 0.2 and 0.9 respectively.

3.3 Inspection photos

***Photo 1**: Corrosion of north side edge I girder*

***Photo 2**: Delamination of northside edge I girder*

***Photo 3**: Delamination of southside edge I girder*

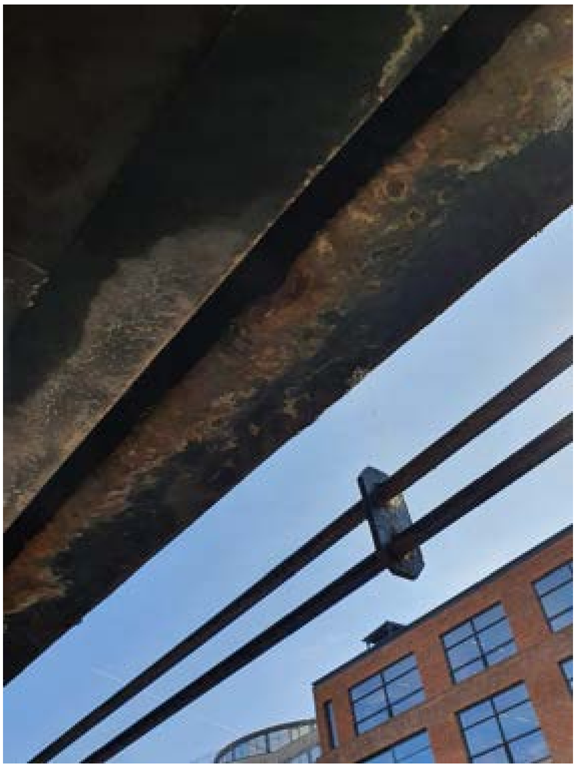


***Photo 4**: Full thickness section loss of bottom flange of canal side edge beam*

***Photo 5**: Full thickness section loss of bottom flange of canal side edge beam*

***Photo 6**: Full thickness section loss of bottom flange of canal side edge beam towards west abutment*

***Photo 7**: Full thickness section loss of bottom flange of canal side edge beam towards west abutment*

***Photo 8**: Edge of flange corrosion of central beams*

***Photo 9**: Deterioration of paintwork to central beams and cable trough trays*

***Photo 10**: Deterioration of paintwork to cable trough trays*

***Photo 11**: Corrosion to the base plate of the support brackets*

***Photo 12**: Pitting to the web on the basin side edge I girder*

***Photo 14**: Damaged brickwork to east abutment*

***Photo 13**: Corrosion to tie rod clamp and bolts*

***Photo 15**: Damaged brickwork to west abutment*

***Photo 16**: Vegetation growth on the east ramp*

Photo 17*: Vegetation growth on the west ramp*

Photo 18*: Loss of tarmac surfacing on the east ramp*

Photo 19*: Graffiti on west ramp surfacing*

Photo 20*: Graffiti on east ramp surfacing*

***Photo 21**: Hole on east ramp canal side*

***Photo 22**: Hole on east ramp basin side*

***Photo 23**: Graffiti to the boundary wall on east ramp*

***Photo 24**: Loss of mortar to the boundary wall on the east ramp*

***Photo 25**: stapled connection - canal side parapet*

***Photo 26**: Minor graffiti and loss of mortar to the ramp parapet*

***Photo 27**: Graffiti to the boundary wall on the west ramp.*

***Photo 28**: Loss of mortar and brick to the boundary wall.*

***Photo 29**: Vegetation on the boundary wall on the west ramp.*

***Photo 30**: Algae on the west ramp parapet.*

***Photo 31**: Rusting of the base T-section on the basin side parapet.*

***Photo 32**: Rusting of the base T-section on the basin side parapet.*

***Photo 33**: Rusting of the base T-section on the basin side parapet.*

***Photo 34**: Replacement bolts on the L plate of the basin side parapet east side.*

***Photo 35**: Lattice work on basin side parapet*

***Photo 38**: Alignment of parapet has moved away from the deck structure*

***Photo 36**: Delamination of top rail on canal side parapet*

***Photo 37**: Delamination of top rail on canal side parapet*

Photo 39*: Loss of brick and mortar on west wing wall*

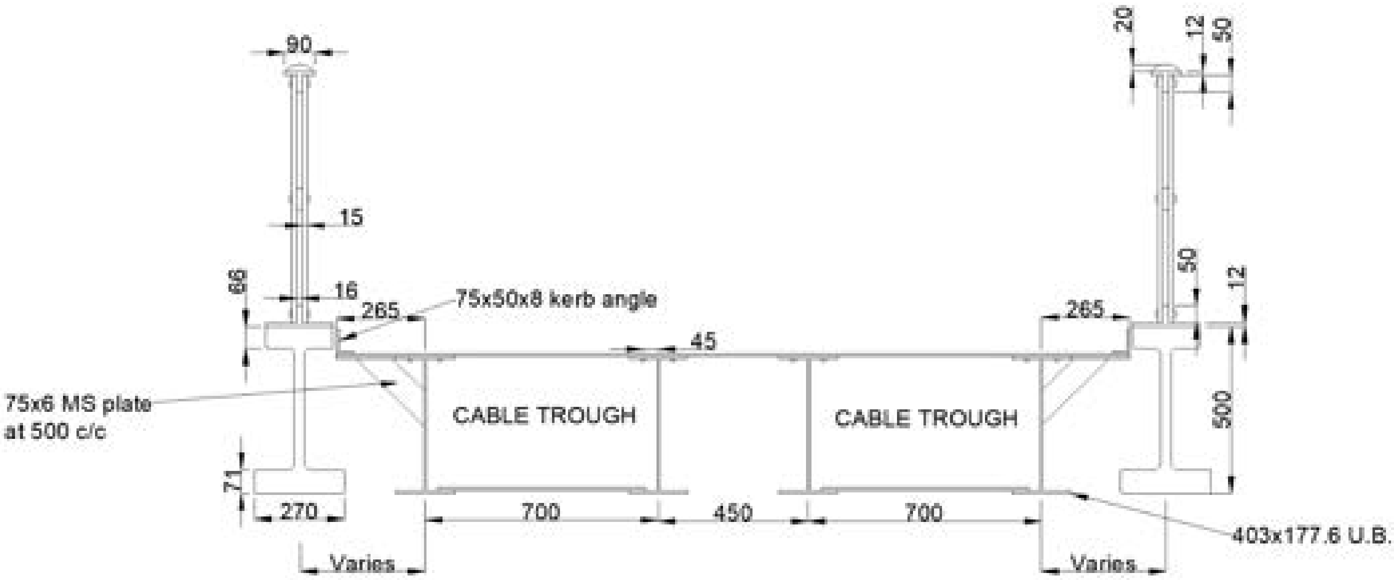
Photo 40*: Vegetation and algae growth on the west wingwall*

***Photo 41**: Loss of brick and mortar to the east wingwall*

3.4 Dimensions

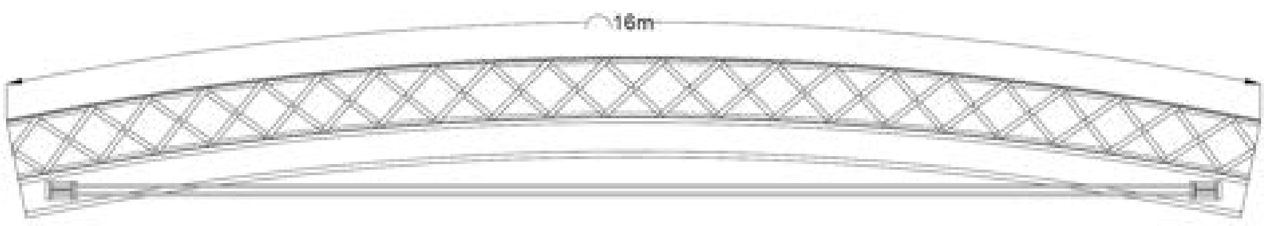
All dimensions in mm

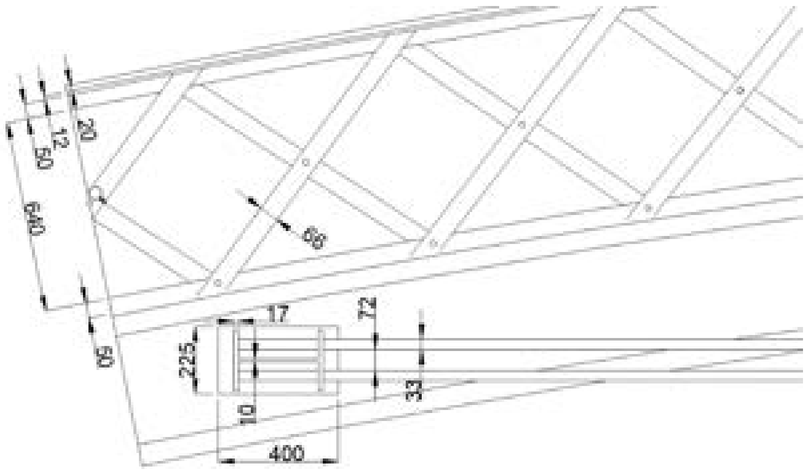
3.4.1 Cross section view



3.4.2 Elevation view

From west to east, canal side





4 Material Testing

ESR Technology Ltd carried out a site visit on the 23rd of September 2021 to (RE-004-030) Dead Dog Basin Footbridge. The aim of the visit was to conduct an examination to identify the material of construction of various areas of the bridge structure and to collect paint samples for subsequent laboratory analysis. The identification of the material of construction was made using Replication Metallurgy (RM). Paint samples were removed from the various areas of the bridge and initial qualitative analysis consisted of Energy Dispersive X-ray (EDX) analysis to determine the presence of lead.

A total of six areas were subjected to RM and paint analysis, they are listed as follows;

- Area 1 – Handrail
- Area 2 – Horizontal top
- Area 3 – Horizontal bottom
- Area 4 – Vertical side
- Area 5 – Lattice work
- Area 6 – Archway

4.1 Results

The materials of the individual elements were identified as follows:

- Area 1 – Handrail – **Wrought Iron**
- Area 2 – Horizontal top – **Carbon Steel**
- Area 3 – Horizontal bottom – **Carbon Steel**
- Area 4 – Vertical side – **Wrought Iron**
- Area 5 – Lattice work – **Wrought Iron**
- Area 6 – Archway – **Grey Flake Cast Iron**

The paint testing showed presence of lead in all 6No. samples however testing showed that asbestos was not present.

A full description of the analysis and results is provided in report ESR/NCT/6621/4640/Issue 1 in Appendix B

5 Assessment

5.1 Reason for Assessment

A change in condition grade from C to D was undertaken in 2013 following a Principal Inspection in July 2010 and a further inspection in 2012. The significant corrosion of the cast iron parapets and lateral deflection of the northern parapet triggered the change in condition and Priority Works. Below is list of the affected areas at the structure.

- The original cast iron beam elements have corroded significantly. This is particularly apparent at the parapets where section losses are present. It should be noted that the outer beams provide no structural purpose other than to support the parapets.
- The northern parapet on the basin side is loose and is becoming detached.
- The masonry and brickwork substructure elements require remedial works (veg removal, pointing works and masonry patch repairs)
- Voids are in the surfacing where it interfaces with the end of the bridge deck. Full section loss can also be seen in the steelwork in addition to further deterioration of surfacing in the surrounding area.

5.2 Assessment Criteria

A linear elastic analysis was used to assess the outer parapet members and the steel deck members in accordance with CS 454. The parapet and deck structures were assessed independently.

Structural geometry and member sizes are based on information recorded during the recent inspections as well as available records.

A 3D space-frame model has been used to carry out the global analysis with the use of MIDAS computer software. The main girders are modelled as beam elements.

Loading has been applied in accordance with CS 454 and includes the following:

1. Self-weight of structural elements
2. Superimposed dead load from non-structural elements
3. Pedestrian loading
4. Parapet loading (transverse loading)

5.2.1 Materials

Characteristic strength of steel

The structural steel is assumed to be grade 43A according to BS 4360 as shown on drawing 78/1732. This grade of steel has a tensile strength of 430 MPa and yield strength of 240 MPa.

Characteristic strength of cast iron

It is assumed that the characteristic strength of the cast iron parapet girder has the following properties, according to the Historical Steel Handbook:

Ultimate strength in Tension -	6 tons/sq.in.
Ultimate strength in Compression -	32 ton/sq.in
Ultimate strength in Shear -	8 tons/sq.in.

Characteristic strength of wrought iron

It is assumed that the characteristic strength of the wrought iron sections of the parapet have the following properties, according to the Historical Steel Handbook:

Ultimate strength in Tension -	21 tons/sq.in.
Ultimate strength in Compression -	16 ton/sq.in
Ultimate strength in Shear -	20 tons/sq.in.

5.2.2 Idealised diagram

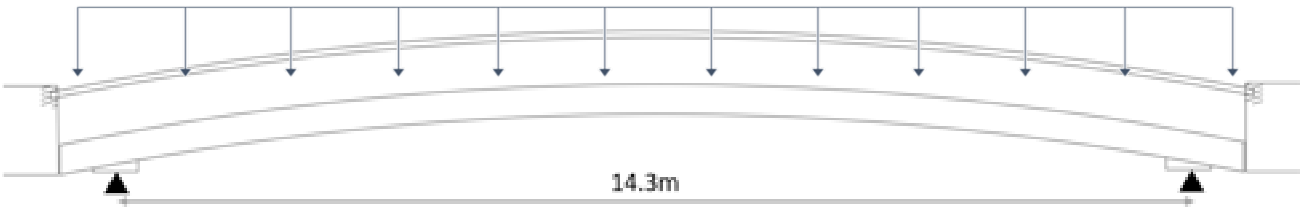


Figure A Idealised structure for the main deck

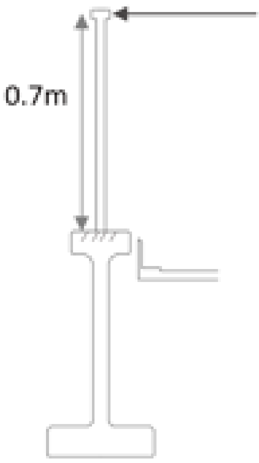


Figure B Idealised structure for parapet

5.3 Assumptions

The following assumptions have been made in undertaking this assessment:

- An additional 10% has been applied to the steel structural element self-weight to account for fixing plates, bolts etc.
- A conditional factor of 1 has been used, for all elements excluding the cast iron girder, to demonstrate the capacity following the completion of remediation works. A condition factor of 0.8 has been used for the cast iron girder.
- The parapets have a suitable bolted lateral connection into the masonry approach walls at both ends.

5.4 Assessment Results

The parapet and the deck have been assessed assuming a condition factor of 1 to represent the condition following refurbishment of the bridge. It should be noted that cast iron elements were assessed for compressive and tensile stresses only in accordance with CS 454 Clause 8.1.

Table 1 Results for cast iron girder

Structure	Element	Load check	Permissible stress allowance (N/mm^2)	Load effects (ULS) (N/mm^2)	Utilisation	Comments
Parapet	Cast iron girder	Compressive stress	154	27.13	18%	PASS
		Tensile stress	46	27.25	59%	PASS

Table 2 Results for steel and wrought iron elements

Structure	Element	Load check	Assessment Resistance	Load effects (ULS)	Utilisation	Comments
Parapet	Carbon Steel Lower 'T'	Bending	27.6 kNm	4.6 kNm	17%	PASS
		Shear	177.8 kN	4.4 kN	2%	PASS
	Wrought Iron Lattice	Bending	0.8 kNm	0.3 kNm	37%	PASS
		Shear	149 kN	1.2 kN	1%	PASS
	Caron Steel Upper 'T'	Bending	5.7 kNm	4.6 kNm	81%	PASS
		Shear	177.9 kN	4.4 kN	2%	PASS
Deck	Steel beams	Bending	288.6 kNm	191.7 kNm	66%	PASS
		Shear	549 kN	60.4 kN	11%	PASS

6 Repair Recommendations

As discussed in Section 5 the majority of the bridge elements are in reasonable condition. The key area of concern is the north parapet which is very unstable when applied with a small amount of force. The key elements which need consideration are the ‘T’ sections which connect the parapet to the cast irons girders beneath and the connections into the masonry at either end of the deck.

It should also be noted that the existing parapet is also below 1.15m as required by BS 7818. To make the parapet fully compliant it would need to be completely replaced however the Grade II listing of the parapet prevents this course of action.

The following maintenance/repair works are recommended to the bridge:

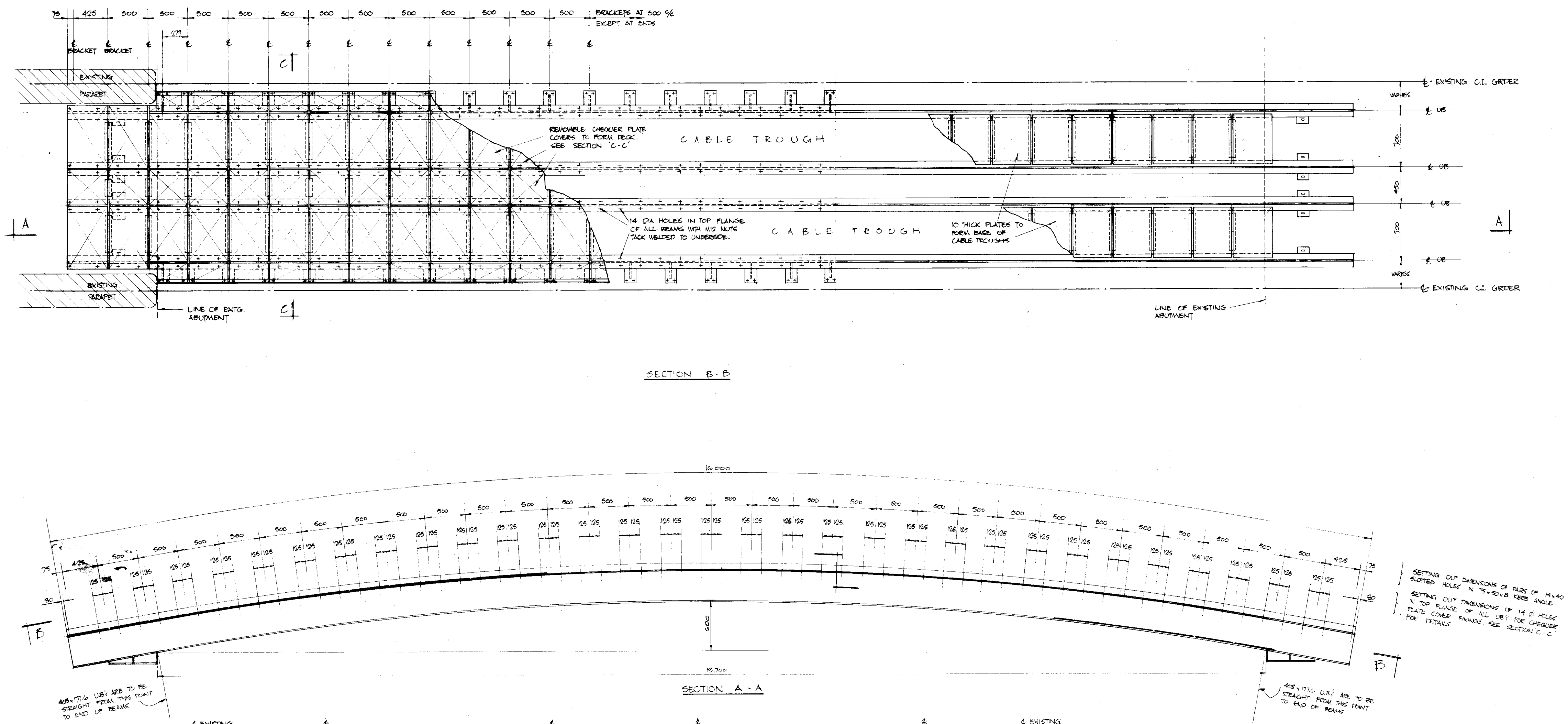
- Replacement of the lower ‘T’ section on the north parapet
- Reinstatement of the bolted masonry connections on the north and south parapet.
- Removal of all corroded material and failed paint systems across the entire bridge
- Repainting of all elements on the bridge
- Repointing and replacement of missing masonry on approaches
- Laser scanning of the bridge prior to removal of any elements

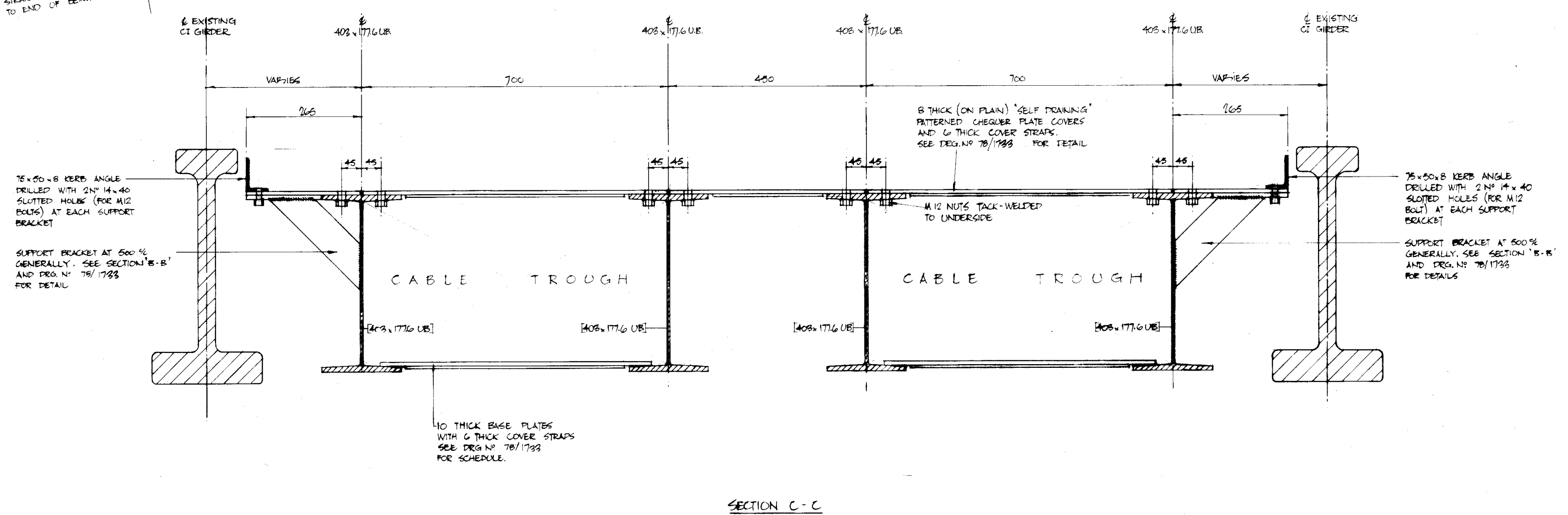
It is recommended that the north parapet is completely removed from the structure to enable the refurbishment. As the south parapet is in much better condition the refurbishment to the existing sections could largely be carried out in-situ, however, the quality of the refurbishment may be improved if the parapet was also removed. The top T section of the south parapet has corroded quite significantly in some places and forced the top domed part of the handrail upwards, this does not currently impact the loading capacity of the parapet but if allowed to continue to corrode it may cause issues in the future. It is recommended that if possible, the top handrail section is removed and the T section replaced. Alternatively, the handrail could be left as is and repainted as part of the overall painting scheme. It would need to be monitored for any deterioration over time and may need to be repaired in future if the condition worsens.

Paint testing showed that lead is present on all parts of the parapet, therefore any parts of the parapet that are to be refurbished in-situ will need to be fully encapsulated to prevent any release of hazardous material into the canal.

Appendix A

Record Drawings



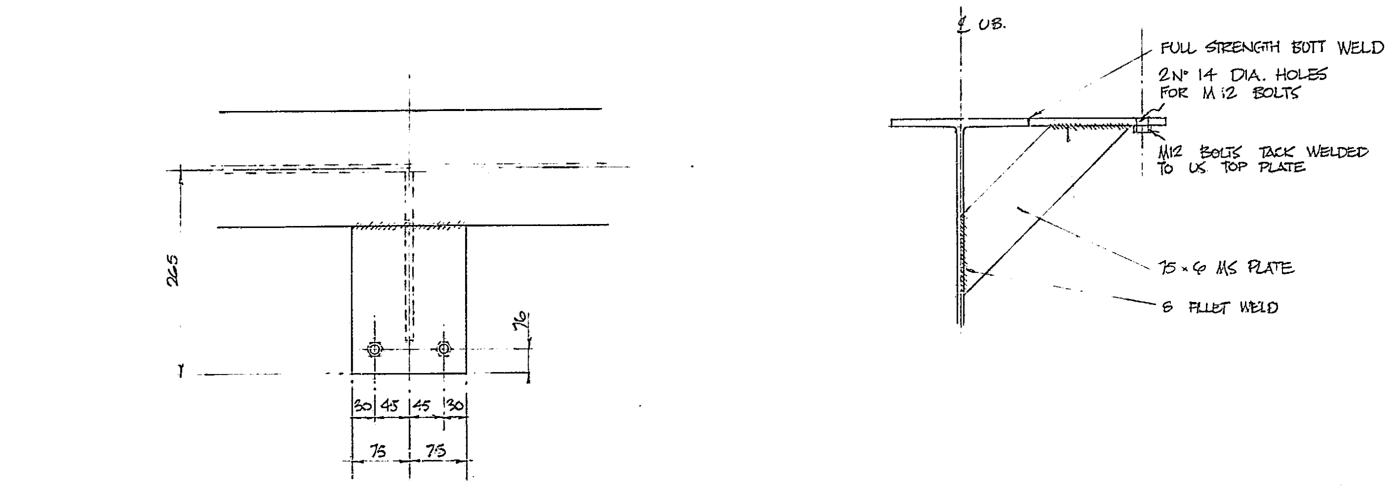


GENERAL NOTES

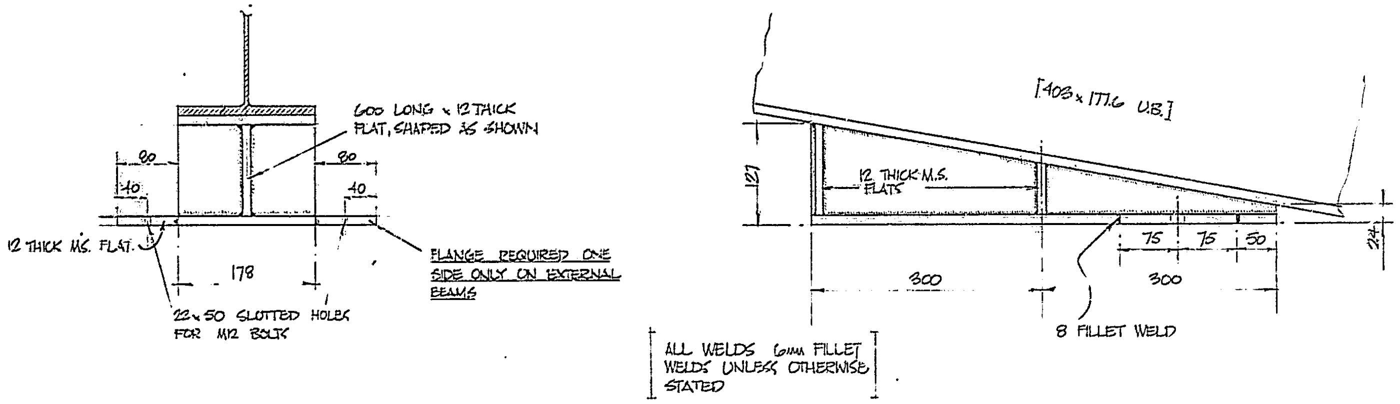
1. STEEL SHALL CONFORM TO BS. 4360 Pt 2 GRADE 43 A
2. GENERAL CONSTRUCTION SHALL BE IN ACCORDANCE WITH BS. 449 Pt 5
3. ALL PARTS OF THE STRUCTURE INCLUDING ALL NUTS WASHERS BOLTS, FITTINGS ETC. TO BE GALVANISED (AFTER ALL WELDING CUTTING AND HOLING) IN ACCORDANCE WITH BS. 729 Pt 1
4. THE SIZE OF FILLET WELDS GIVEN ARE LEG LENGTHS
5. FOR DETAILS OF BRIDGE ABUTMENTS AND APPROACH TROUGHS SEE DRG. Nº 78/1734

B	RISE OF BRIDGE WAS 620.	AJM 15.12.77	A	MINOR AMENDMENTS.	AJM 22.9.77	

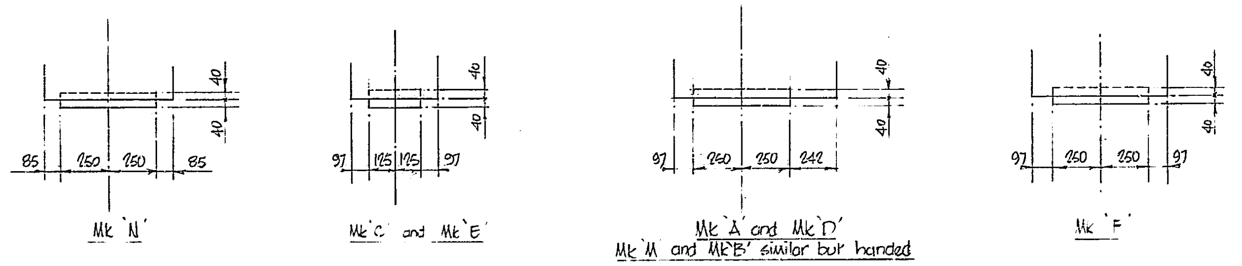
CONTRACT OR T.R.I. NO. TC/NT/F...		CENTRAL ELECTRICITY GENERATING BOARD	TRANSMISSION DIVISION
LOCATION: N.THAMES/ S.E REGION		DETAILS OF GOODS SHED BASIN BRIDGE (SHEET 1)	ST JOHNS WOOD / ~~WEST~~ HAM
SCALE: 1:200 1:50			
DRAWN	M.B.C.		78/ 1732
CHECKED	A.J.M. 30/6/77		
APPROVED	[illegible] 30/6/77		



DETAIL OF SUPPORT BRACKETS



DETAIL OF BRIDGE BEARING



DETAIL OF COVER STRAPS

CABLE TROUGH BASE PLATES		
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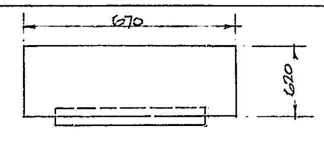
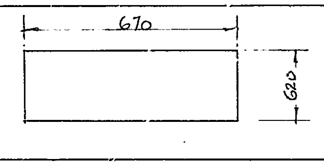
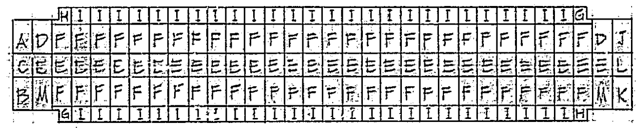
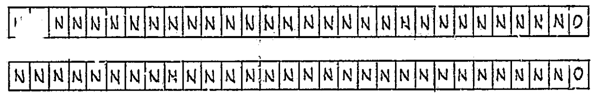
Mk 'N'	54	
Mk 'J'	2	

NOTES:-
BASE PLATES TO BE 10 THICK PLATES WITH 6 THICK COVER STRAPS



LAYOUT OF CHEQUER PLATES



LAYOUT OF [illegible] S

CHEQUER PLATE COVERS		
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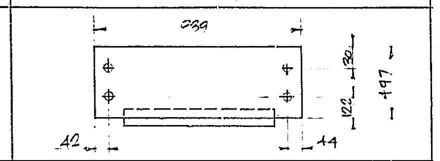
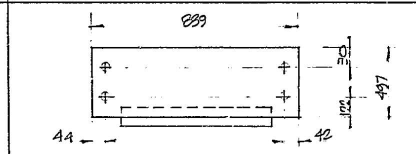
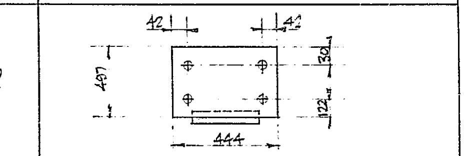
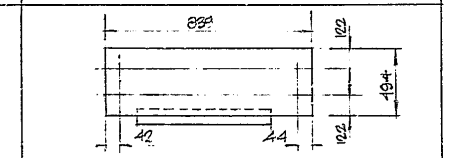
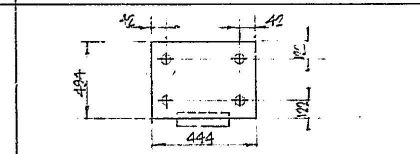
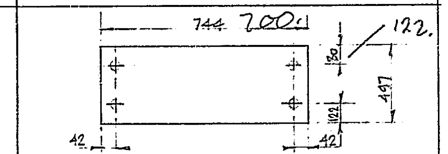
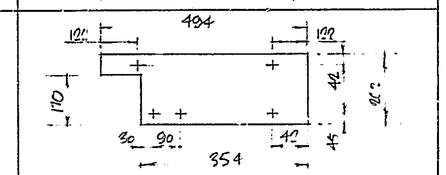
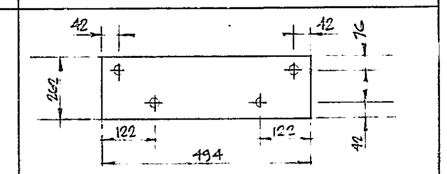
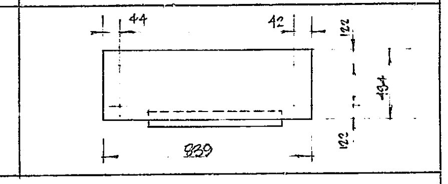
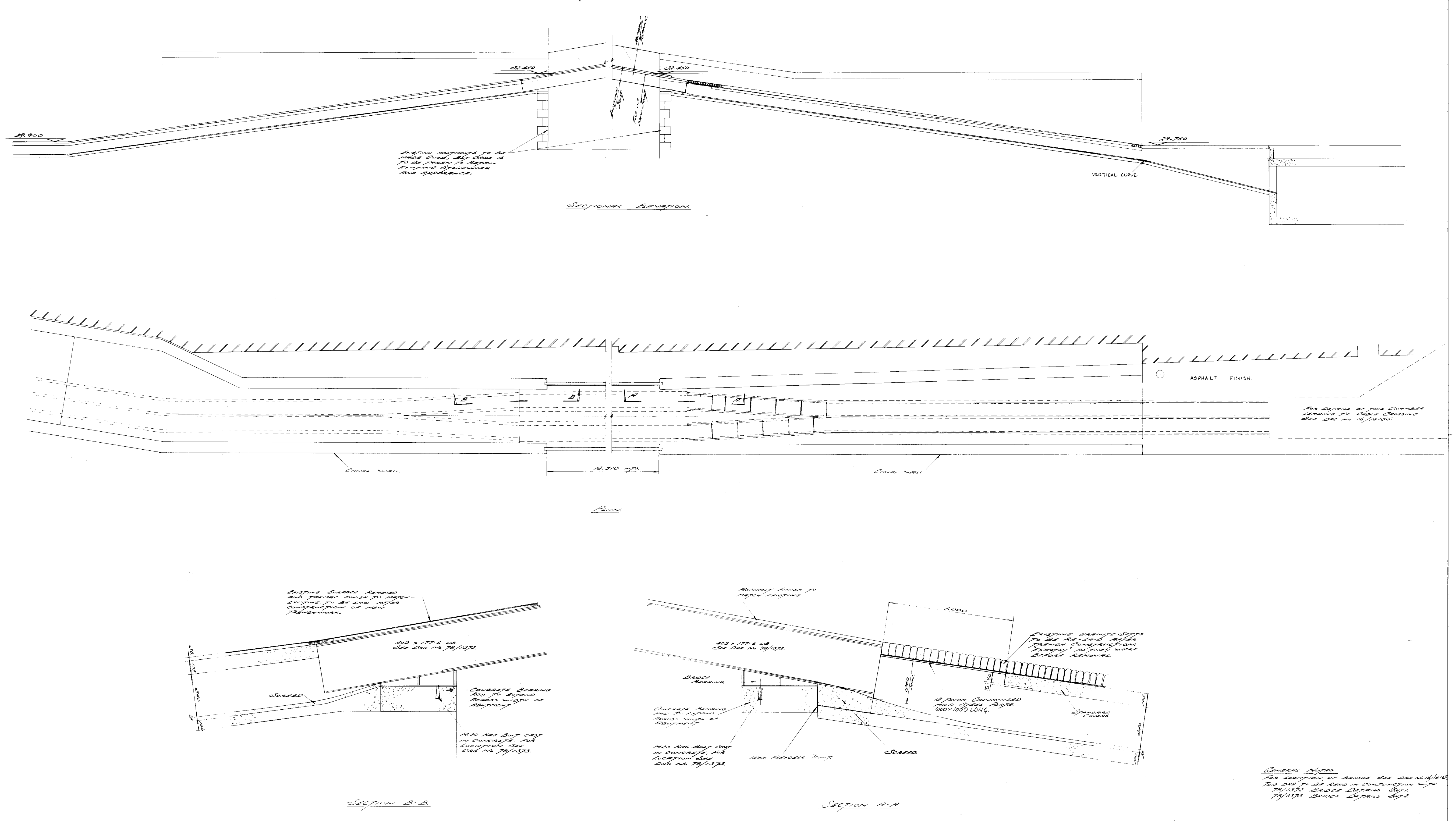
Mk 'A' (Mk 'K' similar but without cover strap)	2	
Mk 'B' (Mk 'J' similar but without cover strap)	2	
Mk 'C' (Mk 'L' similar but without cover strap)	2	
Mk 'D'	2	
Mk 'E'	30	
Mk 'F'	56	
Mk 'G' Mk 'H', similar but opposite hand)	2	
Mk 'I'	26	
Mk 'M'	2	

NOTES:-
1. EACH COVER TO BE DRILLED WITH 4 N° 16 × 25 SLOTTED HOLES.
2. COVERS TO BE 6 THICK (ON PLAIN) 'SELF DRAINING' CHEQUER PLATE

A	MINOR AMENDMENTS	AJM 22.9.77	CONTRACT OR T.R.I. No. TC/NT/F5754	CENTRAL ELECTRICITY GENERATING BOARD.
			LOCATION N.THAMES/S.E.REGION	TRANSMISSION DIVISION.
			SCALE: 1:5 1:20	ST JOHNS WOOD / WEST HAM
			DRAWN M.R.C.	DETAILS OF GOODS SHED BASIN BRIDGE (SHEET 2)
			CHECKED A.J.M. 30/6/77	78/1733
			APPROVED [signature] 30/6/77	

78/ 1734



General Notes
For location of bridge see Drg No. 16/1613.
This Drg to be read in conjunction with
78/1372 Bridge Details Sht 1.
78/1373 Bridge Details Sht 2.

B.	Redrawn	B.J.C. 12.78	A	Minor Amendments	A.J.M. 22.7.77	

CONTRACT OR T.R.I. NO.	TC/NT F3754	
LOCATION:	N. Thames/S.E. Region	
SCALE:	1:50 1:10	
DRAWN	BVC	
CHECKED		
APP'D.		

CENTRAL ELECTRICITY GENERATING BOARD. TRANSMISSION DIVISION.

Details of Goods Shed Basin Bridge

Sheet 3.

St Johns Wood West Ham

NN 78/1734

Appendix B

ESR Testing Report

Dead Dog Basin Footbridge Materials & Paint Assessment (RE-004-030)

ESR/NCT/6621/4640/Issue 1

A report prepared for Arcadis Consulting (UK) Ltd

November 2021

ESR Technology
Engineering, Safety & Risk

Authorisation Sheet

Report Title:	Dead Dog Basin Footbridge Materials & Paint Assessment (RE-004-030)
Customer Reference:	14055393
Project Reference:	NCT0001947 (MA6337)
Report Number:	ESR/NCT/6621/4640
Issue:	Issue 1
Distribution List:	File (1 copy), QA (1 copy), Arcadis (1 PDF copy)

Author:	Mr Tim Gould	November 2021
Reviewed:	H Hunter	November 2021
Authorised:	E H Davies	November 2021

National Centre of Tribology

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Registered in England and Wales, No. 05462871

Contents

Appendices

1.0 Introduction

Arcadis Consulting (UK) Ltd requested ESR Technology Ltd carry out a site visit on the 23rd of September 2021 to (RE-004-030) Dead Dog Basin Footbridge. The aim of the visit was to conduct an examination to identify the material of construction of various areas of the bridge structure and to collect paint samples for subsequent laboratory analysis.

The identification of the material of construction was made using Replication Metallurgy (RM). Paint samples were removed from the various areas of the bridge and initial qualitative analysis consisted of Energy Dispersive X-ray (EDX) analysis to determine the presence of lead.

A total of six areas were subjected to RM and paint analysis, they are listed in the points below and highlighted in Figure 1 and Figure 2;

- Area 1 – Steelwork – Handrail
- Area 2 – Steelwork – Horizontal top
- Area 3 – Steelwork – Horizontal bottom
- Area 4 – Steelwork – Vertical side
- Area 5 – Steelwork – Lattice work
- Area 6 – Steelwork – Archway

A summary of the results is shown in Section 3.0. A more detail description of the analysis and a photographic record of the areas tested is shown in Section 4.0. A full photographic record including optical micrographs and EDX spectra from the paint sampled and analysed from each area is shown in the Appendix.

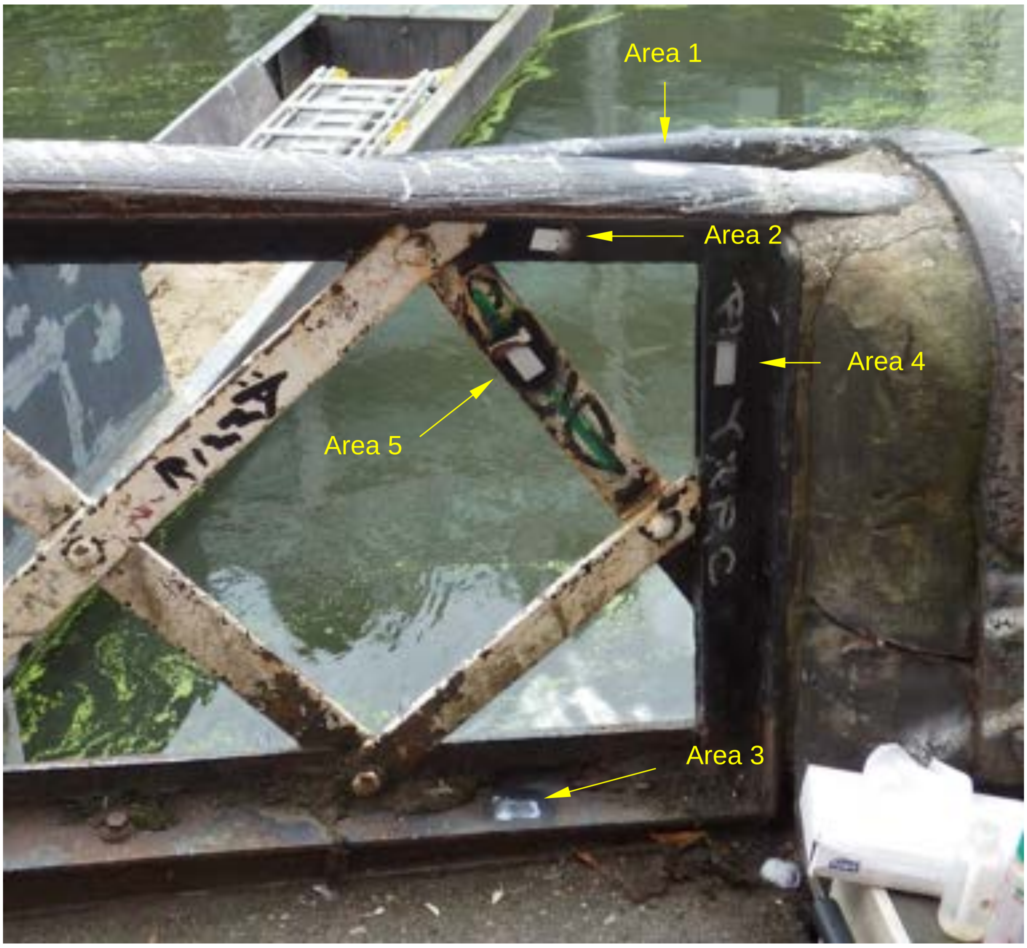


Figure 1: Overview of Areas 1 to 5 showing locations of RM testing and paint samples.

Figure 2: Overview of Area 6 showing approximate location of RM and paint samples.

2.0 Scope of work

The following scope of work was agreed to assist the investigation.

- Site visit to London (full day)
- Paint pull-off tests to measure adhesion if required (included in the site visit).
- On site metallography and replication of the identified areas of the steel work. This will identify the type of material such as grey cast iron, nodular cast iron, wrought iron or carbon steel.
- If a small steel sample can be retrieved this will also be analysed.
- Hardness measurements on suitable surfaces.
- Collection of representative samples of paint from the identified areas. The collected samples will be analysed to determine the composition and type of paint.
    - SEM / EDX analysis of paint to determine chemical elements present qualitive)
    - A full quantitative analysis will determine the concentration of toxic metals in the paint for waste classification purposes – to include Lead, Aluminium, Arsenic, Cadmium, Chromium, Hexavalent Chromium, Zinc and Copper in mg/kg and paint type.
- Upon completion of the work, the findings shall be summarised in a technical note with results and our conclusions.

3.0 Summary of Results

A total of six (6) paint samples were collected from Dead Dog Basin Footbridge (RE-004-030) on the 23rd of September 2021. The paint samples consisted of steelwork paint collected from multiple locations around the footbridge.

All six individual samples were analysed using EDX analysis, this shows the chemical elements present on the paint surface and whether lead (Pb) was present, the EDX results are listed in Table 1.

One sample was selected for fully quantitative analysis (ICP-OES) to gather information on asbestos and hazardous metals content, also shown in Table 1. This was an amalgamation / combination of paint from all of the areas.

The combined paint sample was also analysed by FTIR and it consisted of several layers and ranged from 550 microns to 1010 microns thick. The black samples leached bitumen and also contained alkyd and urethane alkyd layers.

The FTIR trace of the analysed paint sample is shown in Figure 3.

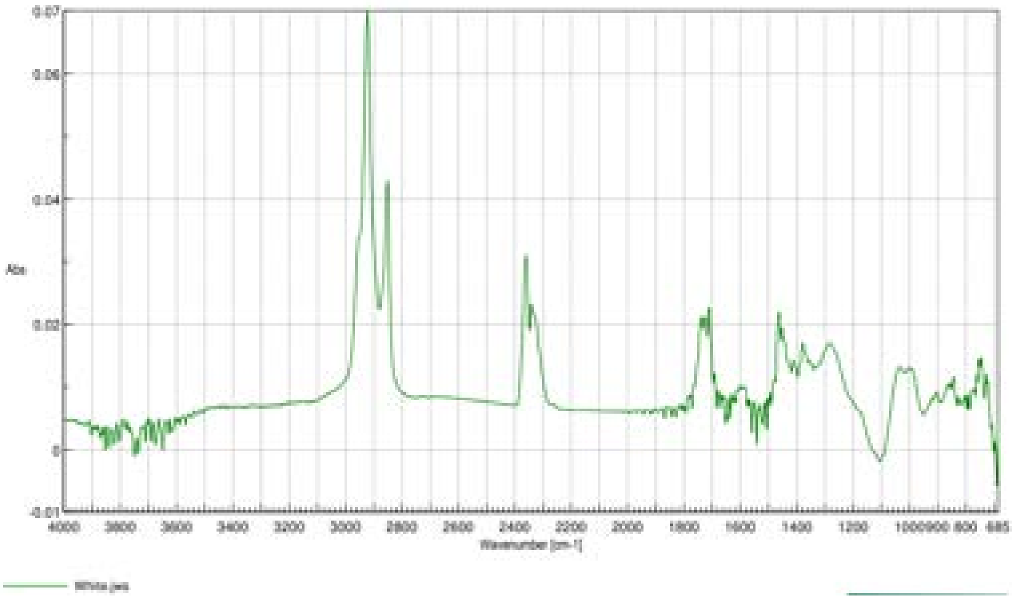


Figure 3: FTIR traces of the combined samples for a quantitative chemical analysis.

Area	Steelwork	Main chemical elements	Lead detected (Y/N)	Asbestos	Hazardous Metals Analysis (mg/kg)						
					Arsenic	**Aluminium**	**Cadmium**	**Chromium Chrome VI**	**Copper**	**Lead**	**Zinc**
1	Handrail	C, O, Cl, Al, Si, P, S/Mo, K, Ca, Cr, Fe, Pb. C, O, Al, Si, Ca, Ti. C, O, Al, Si, P, S/Mo, Ca, Fe, trace Pb. C, O, Al, Si, S/Mo, Ca, Fe. C, O, Al, Si, P, S/Mo, Cl, Ti, Fe, Pb. C, O, Al, Si, P, S/Mo, Ca, Fe, trace Pb. C, O, Si, P, S/Mo, Fe, Pb. C, O, Al, Si, S/Mo, Ca, Ti, trace Fe and Zn. C, O, Na, Mg, Al, Si, P, Ca, Ti, trace Fe and Zn.	**Y**								
2	Horizontal top	C, O, Na, Mg, Al, Si, P, S/Mo, Ca, Ti, Fe, Zn trace Pb. C, O, Al, Si, Ca, Ti, trace Fe. C, O, Na, Mg, Al, Si, P, S/Mo, Cl, K, Ca, Ti, Fe, Zn, Pb. C, O, Na, Mg, Al, Si, P, S/Mo, Cl, K, Ca, Ti, Fe, Zn, Pb. C, O, Na, Al, Si, P, S/Mo, Cl, K, Ca, Ti, Fe, Zn, Pb. C, O, Al, Si, Ca, Ti, trace Fe. C, O, Al, Si, S/Mo, Ca, Ti, Fe, Pb. C, O, Al, Si, S/Mo, Ca, Ti, trace (Fe, Zn, Pb)	**Y**	ND	ND	85	ND	18	11	27,000 (2.7%)	745
3	Horizontal bottom	C, O, Al, Si, Ca, Ti, trace Fe. C, O, Al, Si, P, S/Mo, Ca, Ti, Fe, Pb. C, O, Al, Si, P, S/Mo, Cl, Ca, Fe, Pb. C, O, Al, Si, P, S/Mo, Cl, K, Ca, Ti, Fe, Zn trace Pb. C, O, Na, Mg, Al, Si, P, S/Mo, Ca, Ti, Fe, Zn, Pb. C, O, Al, Si, S/Mo, Ca, Ti, trace Fe. C, O, Si, S/Mo, Ca, Ti. C, O, S/Mo, Ca, Ti, Fe, Pb. C, O, Al, Si, S/Mo, Ca, Ti, Fe, Pb. C, O, Al, Si, P, S/Mo, Cl, K, Ca, Ti, Fe, Pb.	**Y**								
4	Vertical side	C, O, Na, Mg, Al, Si, P, S/Mo, Ca, Ti, Zn trace Pb. C, O, Na, Si, S/Mo, Ti, Fe, Pb. C, O, Al, Si, S/Mo, Ca, Ti, Fe, trace Pb. C, O, Al, Si, S/Mo, Ca, Ti, Fe, Pb	**Y**								

5	Lattice work	C, O, Al, Si, S/Mo, Ca, Ba, Fe, Pb. C, O, Al, Si, S/Mo, Ca, Ba, Fe, Pb. C, O, Al, Si, Ca, Ti, trace Fe. C, O, Al, Si, P, Ca, Ti, Fe trace Pb. C, O, Al, Si, S/Mo, Ca, Ti, Fe, Pb	**Y**
6	Archways	C, O, Al, Si, S/Mo, Mn, Fe. C, O, Al, Si, S/Mo, Mn, Fe, Pb. C, O, Al, Si, S/Mo, Mn, Fe, Pb. C, O, Al, Si, P, S/Mo, Ca, Mn, Fe, Pb. C, O, Al, Si, P, S/Mo, Ca, Mn, Fe, Pb.	**Y**

Table 1: Summary of hazardous metals paint analysis results. ND = not detected.

	Area	Material	Hardness (Hv)	Observations
1	Handrail	Wrought iron	138	Hardness increased over other areas, possible due to large thickness of section compared to other areas. Microstructure typical of wrought iron
2	Horizontal top	Carbon steel	108	Carbon content, estimated from the visible pearlite content appears fairly low, section relatively thin which can reduce hardness readings
3	Horizontal bottom	Carbon steel	120	Carbon content, estimated from the visible pearlite content appears greater than for Area 2, potentially reason for increased hardness
4	Vertical side	Wrought iron	119	Microstructure typical of wrought iron, section relatively thin which can reduce hardness readings
5	Lattice work	Wrought iron	121	Microstructure typical of wrought iron, section relatively thin which can reduce hardness readings
6	Archways	Grey flake cast iron	172	Microstructure typical of grey flake cast iron, very thick section

Table 2: Summary of RM, hardness testing and general observations.

4.0 Replication Metallurgy and Paint Analysis

Replication Metallurgy (RM)

The areas to be examined were prepared by grinding to a 1200 grit finish using several grades of silicon carbide grinding papers. The surfaces were then cleaned and polished to a one-micron finish before being etched using a Nital solution (to reveal the microstructure).

Replicas were then taken of the microstructure using acetate sheets; these were then positioned on glass slides for an examination using optical microscopy. A record of the micrographs taken from each area are shown in the appendices.

Portable Scleroscope hardness measurements were also taken at the various locations.

Paint Sampling & Analysis

Samples of paint were taken from five of the six areas; Area 1 - handrail exhibited little to no visible paint able to be removed, the finish of the handrail was very smooth, dimpled and worn. The top surface of the handrail had bowed upwards, likely from expansion caused by the gross general corrosion of the underside of the handrail; this enabled some remnants of the debris to be collected in lieu of a conventional paint sample.

Paint sampling consisted of removing visible paint flakes from each area; each area exhibited regions of corroded steelwork causing some of the remaining paint to detach and flake off. Several regions of Area 3 – horizontal bottom showed gross general corrosion with some areas exhibiting severe material loss, this enabled some of the steelwork to be removed along with the paint samples, this was used to confirm the RM.

A photographic record of the paint sampled from each area; the flakes prepared for EDX analysis along with the corresponding EDX analysis spectra are shown in the Appendix.

A summary of each area is presented in the following sections.

4.1 Area 1 – Steelwork - Handrail

Area 1 comprised of the top horizontal domed handrail, shown in Figure 4. The general appearance of the handrail was degraded. The top surface was very smooth and dimpled, typical of a high touch-traffic area. The top surface of the handrail had bowed upwards, caused by the gross general corrosion between the top and bottom sections of the handrail, highlighted in Figure 5.

As no paint was able to be removed from the top of the handrail, some of the corrosion debris between the top and bottom handrail sections was sampled, some of this debris contained remnants of paints previously applied to the area.

SEM/EDX analysis showed lead to be present, primarily on the reverse side of the corrosion debris, indicating that the paint remnants did contain lead.

RM, Figure 11, showed the handrail material to be a wrought iron. The micrograph shows the typical elongated large dark coloured slag inclusions in a ferrite matrix.

Hardness measurement of Area 1 showed it to be ~138Hv, typical of this type of material.

Figure 4: Overview of Area 1.

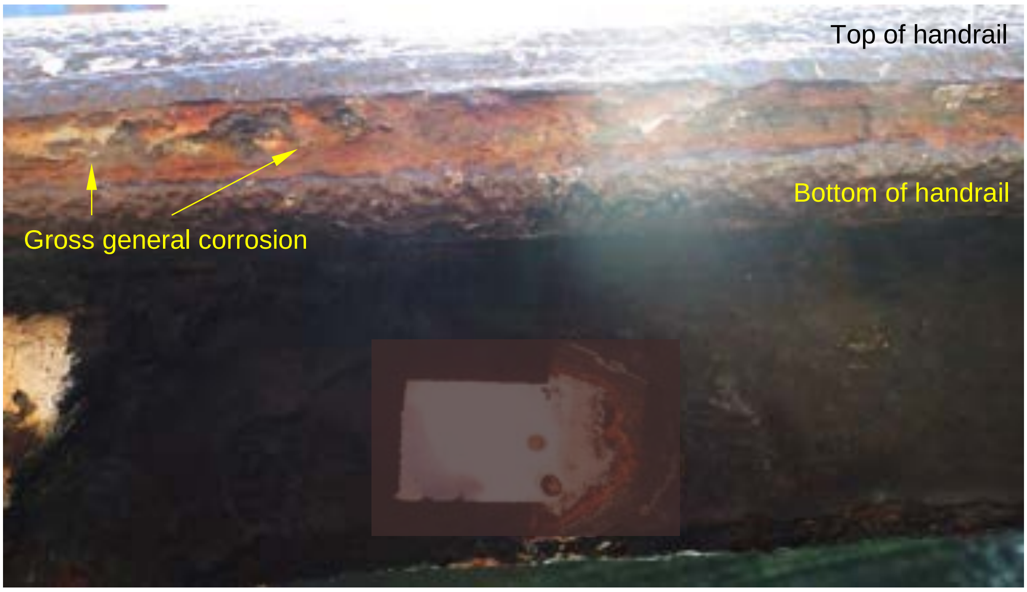


Figure 5: Detail of Area 1 – Handrail showing oxide jacking of top of handrail due to gross general corrosion.

Area 1	Detail
Material of construction	Wrought iron
Lead detected in paints	Yes
Hardness	138Hv

Table 3: Summary of RM, EDX analysis and hardness measurement.

4.2 Area 2 – Steelwork – Horizontal top

Area 2 comprised of the top horizontal bracketed steelwork, shown in Figure 6. Similar to other areas of painted steelwork, the general condition in this location was poor; the paint surface was rough and undulating indicating a degraded paint layer with a degree of corrosion under the paint. The visible paint had detached and flaked off in several areas and general corrosion to the steelwork was observed.

SEM/EDX analysis of paint removed from the top horizontal steelwork showed lead to be present.

Visual examination of the sampled paint flakes, along with the area subjected to RM shows multiple paint layers to be present. Also clearly visible is an orange paint layer, EDX analysis of this showed high concentrations of lead, suggesting the orange layer is an old leaded primer. Only traces of lead were detected on the topmost black paint layer, likely transferred from the high lead content layers underneath.

RM, Figure 15, showed the horizontal top steelwork to be a carbon steel material. The micrograph shows a typical ferrite / pearlite microstructure. The quantity of pearlite visible in the micrograph suggests a relatively low level of carbon rather than a high caron steel.

Hardness measurement of Area 2 showed it to be ~108Hv, typical of this type of material.

Figure 6: Overview of Area 2.

Area 1	Detail
Material of construction	Carbon steel
Lead detected in paints	Yes
Hardness	108Hv

Table 4: Summary of RM, EDX analysis and hardness measurement.

4.3 Area 3 – Steelwork – Horizontal bottom

Area 3 comprised of the bottom horizontal bracketed steelwork, shown in Figure 7. Similar to other areas of painted steelwork, the paint condition in this location was poor. Greater areas of exposed corroded steelwork were visible, indicating a greater degradation of the paint. This was likely aided by the fact this area was located horizontally and at the bottom of the structure creating a flat area to hold water and contain mosses and plant life which will in turn contain and hold moisture increasing corrosion.

SEM/EDX analysis of paint removed from the bottom horizontal steelwork showed lead to be present. The greatest concentrations were detected in the underlayers rather than the topmost layers, indicating the use of old leaded primers or undercoats.

RM, Figure 19, showed the horizontal bottom steelwork to be a carbon steel material. The micrograph shows a typical ferrite / pearlite microstructure. The quantity of pearlite visible in the micrograph suggests a medium level of carbon rather than a low carbon level as seen in Area 2. Figure 20 shows a laboratory prepared metallurgical sample taken from a detached fragment near to the bottom steelwork; the micrograph confirms the RM, the structure is a ferrite / pearlite microstructure. A difference in the level of pearlite is noted, this could be due to the difference in orientation between the RM and the removed sample.

Hardness measurement of Area 3 showed it to be ~120Hv, typical of this type of material.

Figure 7: Overview of Area 3.

Area 1	Detail
Material of construction	Carbon steel
Lead detected in paints	Yes
Hardness	120Hv

Table 5: Summary of RM, EDX analysis and hardness measurement.

4.4 Area 4 – Steelwork – Vertical side

Area 4 comprised of the vertical side bracketed steelwork, shown in Figure 8. Similar to other areas of painted steelwork, the paint condition in this location was poor with regions of general corrosion of the underlying steelwork visible.

SEM/EDX analysis of paint removed from this area showed lead to be present. The greatest concentrations were detected in the underlayers rather than the topmost layers, indicating the use of old leaded primers or undercoats.

RM, Figure 24, showed the vertical side steelwork to be a wrought iron material. The micrograph shows typical elongated large dark coloured slag inclusions in a ferrite matrix.

Hardness measurement of Area 4 showed it to be ~119Hv, typical of this type of material.

Figure 8: Overview of Area 4.

Area 1	Detail
Material of construction	Wrought iron
Lead detected in paints	Yes
Hardness	119Hv

Table 6: Summary of RM, EDX analysis and hardness measurement.

4.5 Area 5 – Steelwork – Lattice work

Area 5 comprised of the lattice work between the horizontal and vertical bracketed steelwork, shown in Figure 9. Similar to other areas of painted steelwork, the paint condition in this location was poor. Exposed and corroded steelwork was visible on the edges of the lattice sections showing localised degradation of the paint (where the existing paint would likely either be thinner or be exposed to a greater degree of weathering). Overall, the paint on the lattice work was in a similar condition to the paints observed in other areas.

SEM/EDX analysis of paint removed from the lattice work showed lead to be present. The greatest concentrations were detected in the underlayers rather than the topmost layers, indicating the use of old leaded primers or undercoats.

RM, Figure 28, showed the lattice work to be a wrought iron material. The micrograph shows typical elongated large dark coloured slag inclusions in a ferrite matrix.

Hardness measurement of Area 5 showed it to be ~121Hv, typical of this type of material.

Figure 9: Overview of Area 5.

Area 1	Detail
Material of construction	Wrought iron
Lead detected in paints	Yes
Hardness	121Hv

Table 7: Summary of RM, EDX analysis and hardness measurement.

4.6 Area 6 – Steelwork – Archway

Area 6 comprised of the supporting archways underneath the bridge shown in Figure 10. Similar to other areas of painted steelwork, the paint condition in this location was poor. Large areas where the paint had degraded and spalled away exposed corroded steelwork underneath. The surface of the paint was very rough and undulating and the corroded surface underneath also very rough and textured, more so than that observed in other areas.

RM showed the horizontal steelwork to be a grey flake cast iron material.

SEM/EDX analysis of paint removed from the supporting archway showed lead to be present. The greatest concentrations were detected in the underlayers rather than the topmost layers, indicating the use of old leaded primers or undercoats.

RM, Figure 32 and Figure 33, showed the Archways to be a grey flake cast iron material. The micrographs show graphite flakes in a pearlite / ferrite matrix with small islands of phosphide eutectic, typical of an old grey flake cast iron.

Hardness measurement of Area 6 showed it to be ~172Hv, typical of this type of material.

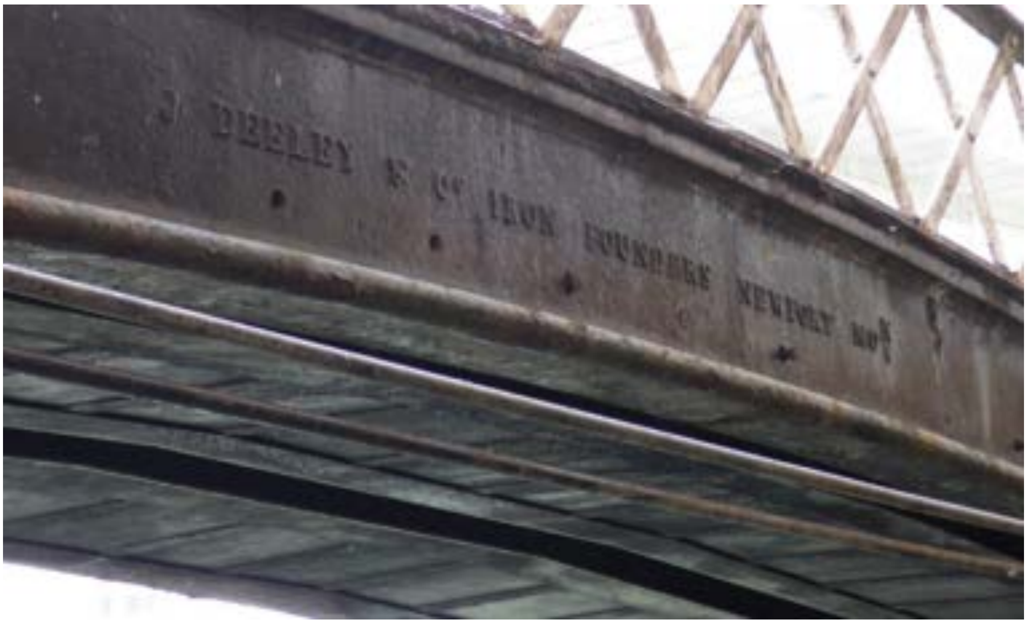


Figure 10: Overview of Area 6.

Area 1	Detail
Material of construction	Grey flake cast iron
Lead detected in paints	Yes
Hardness	172Hv

Table 8: Summary of RM, EDX analysis and hardness measurement.

6.0 Discussion / Conclusions

ESR Technology Ltd carried out a site visit on the 23rd of September 2021 to (RE-004-030) Dead Dog Basin Footbridge for Arcadis Consulting (UK) Ltd. The site visit was to carry out metallurgical replication (RM) of the steelwork and collect paint samples for subsequent laboratory analysis.

Initial qualitative analysis will consist of SEM/EDX analysis to determine the presence of lead, and further quantitative ICP analysis (one sample) to determine the quantity of hazardous elements present in the paint and if possible, the paint type.

Six locations around the bridge were chosen for analysis by Arcadis. The areas consisted of:

- Area 1 – Steelwork – Handrail
- Area 2 – Steelwork – Horizontal top
- Area 3 – Steelwork – Horizontal bottom
- Area 4 – Steelwork – Vertical side
- Area 5 – Steelwork – Lattice work
- Area 6 – Steelwork – Archway

The examination has shown:

- The metallurgical replication revealed the microstructure of the steels. Most engineering steels consist of a pearlite / ferrite grain structure whereas cast irons have free graphite in the form of flakes or spheres. Wrought iron generally is mostly ferrite with large slag type inclusions. Stainless steels are generally bright with clear grain boundaries. The areas consisted of:
    - Handrail, Vertical side and Latticework were manufactured from wrought iron.
    - Horizontal top was manufactured from a low carbon steel.
    - Horizontal bottom was manufactured from a medium carbon steel.
    - Archways were manufactured from a grey cast iron (graphite flakes in a pearlite / ferrite matrix with small islands of phosphide eutectic).
- The SEM EDX analysis found the majority of the paint contained typical chemical elements of C, O, Ca, S, Cl, Mg, Al, Si, P, Ti, Fe and Zn.
- The additional heavy metal Pb was found in all of the locations, primarily in the primer or undercoat. Traces of chromium were also found on the handrail. Barium was found on the lattice work.
- The guidance contained within The Control of Lead at Work Regulations 2002 issued by the Health and Safety Executive (HSE), states that working with materials containing less than 1% lead (10,000mg/kg) is not likely to result in significant lead exposure.
- The analysis showed that the conglomerated paint sample contained 2.7% lead (27,000mg/kg), this is above a threshold that is normally classed as hazardous.
- Some painted areas where lead was detected will contain less than 1%, below the hazardous threshold; however, inhalation of dust particles containing lead should always be avoided.

- No asbestos, arsenic or cadmium were found in any of the paint samples examined.
- The combined paint sample was also analysed by FTIR. It consisted of several layers and ranged from 550 microns to 1010 microns thick. The black samples leached bitumen and also contained alkyd and urethane alkyd layers.

Appendix 1 Area 1 - Steelwork - Handrail

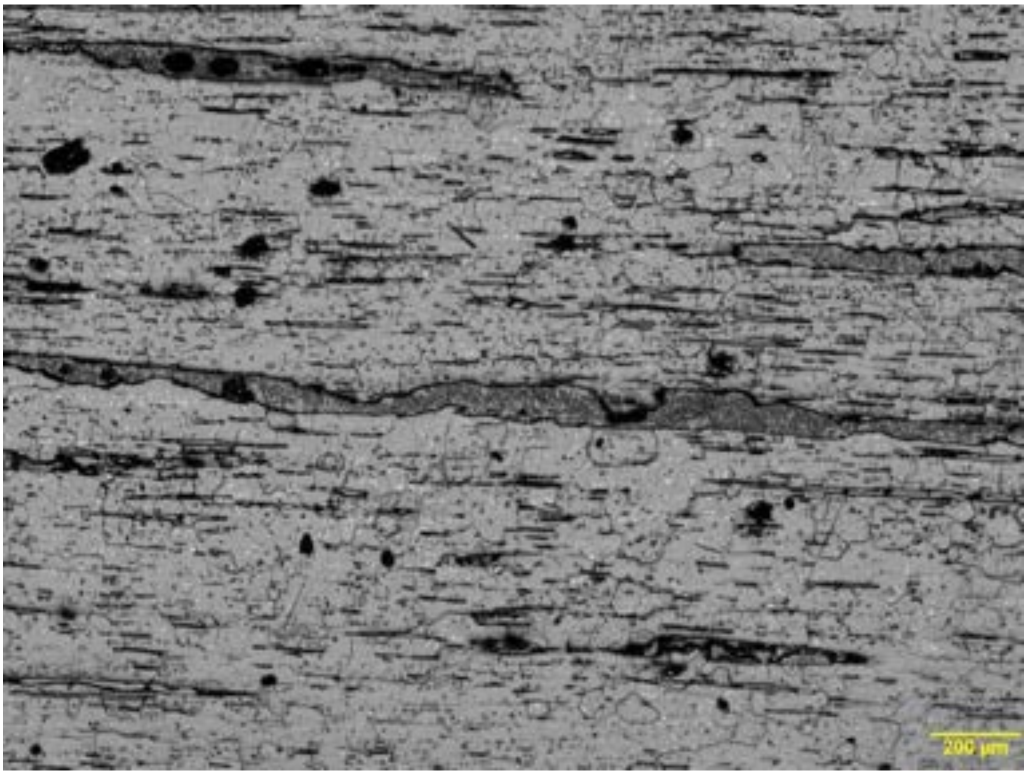


Figure 11: Etched RM micrograph showing typical wrought iron microstructure.

Figure 12: Paint sample collected from Area 1.

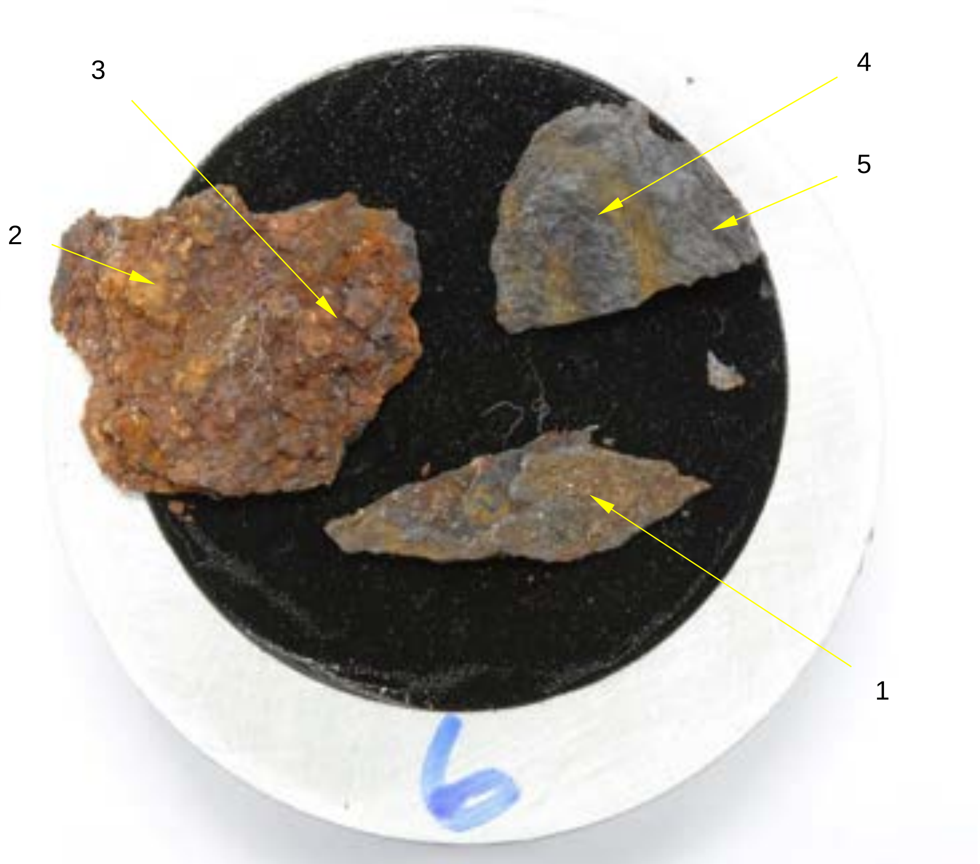
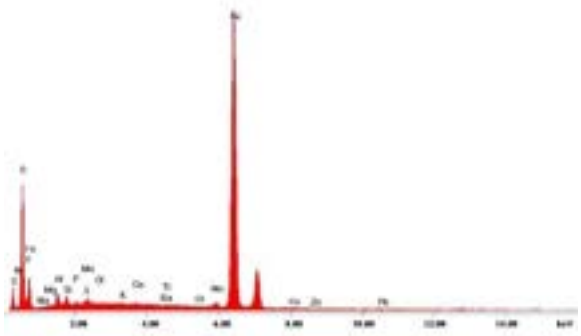


Figure 13: Paint from Area 1 examined using EDX analysis, showing analysis positions.



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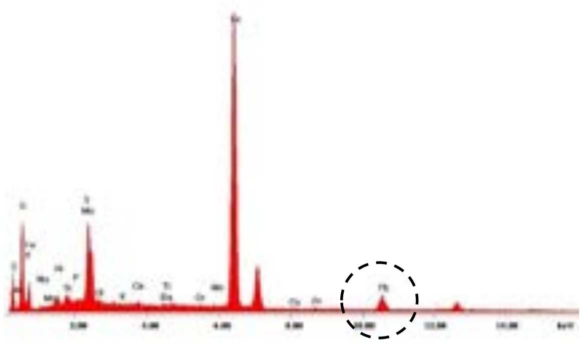

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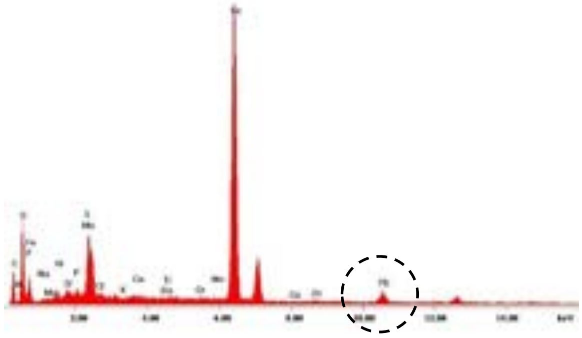

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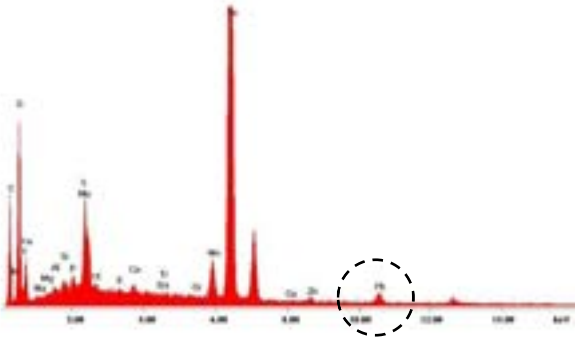

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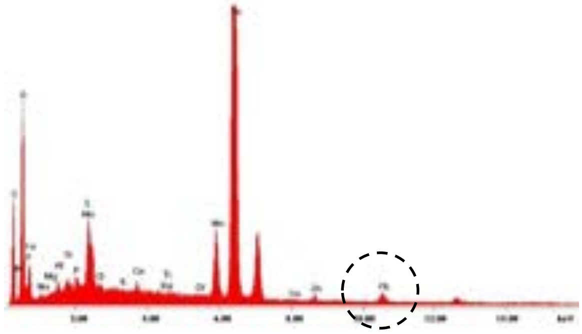

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Figure 14: EDX spectra of numbered analysis positions from paint sample.

Appendix 2 Area 2 – Steelwork – Horizontal top

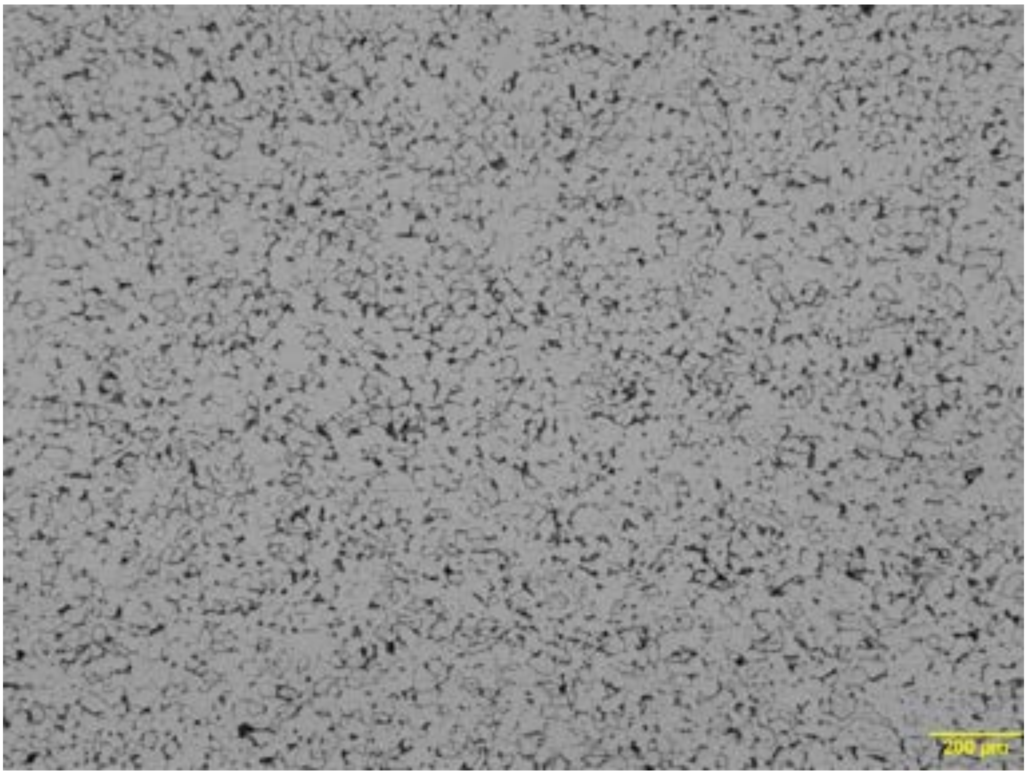


Figure 15: Etched RM micrograph showing typical carbon steel microstructure.

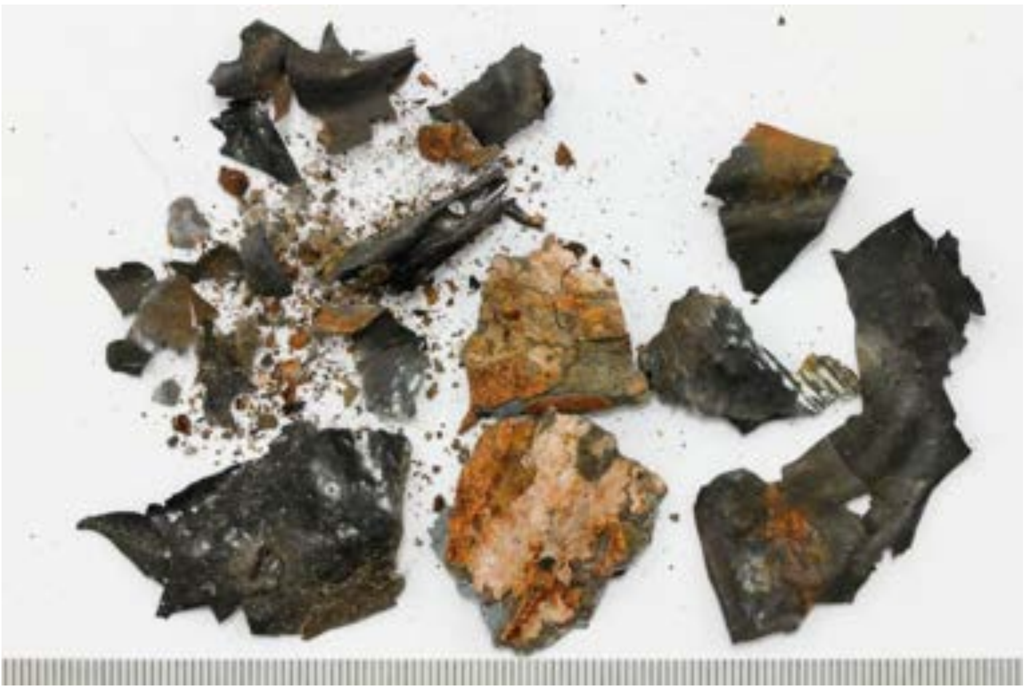


Figure 16: Paint sample collected from Area 2.

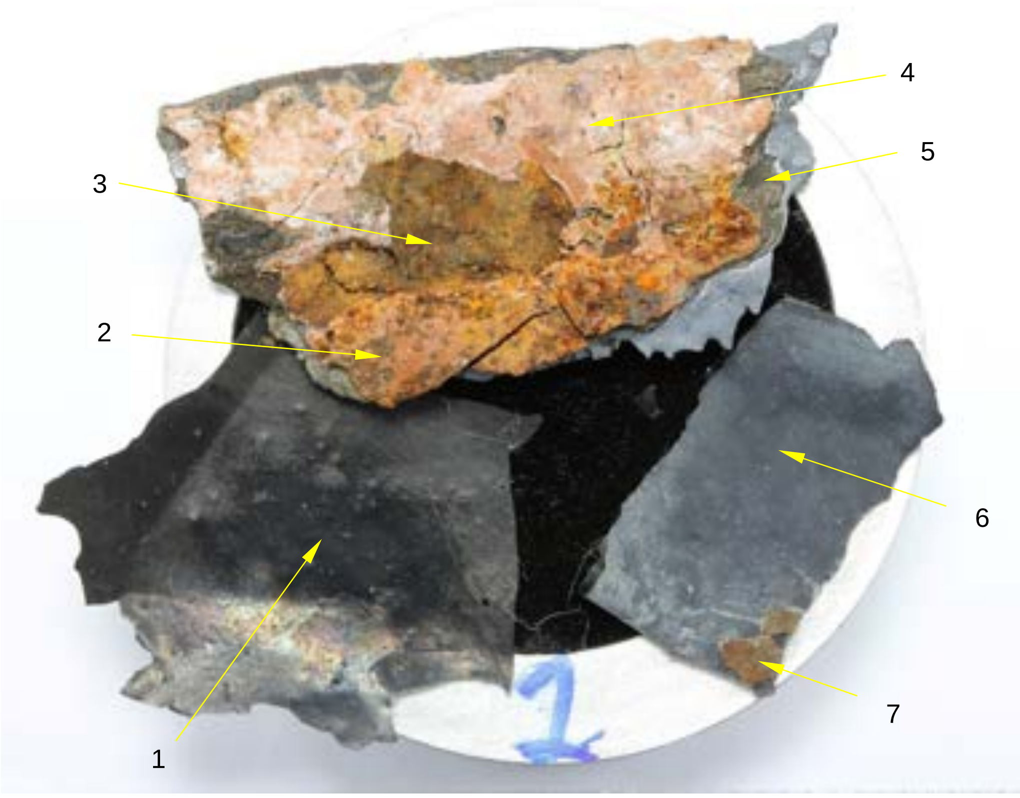
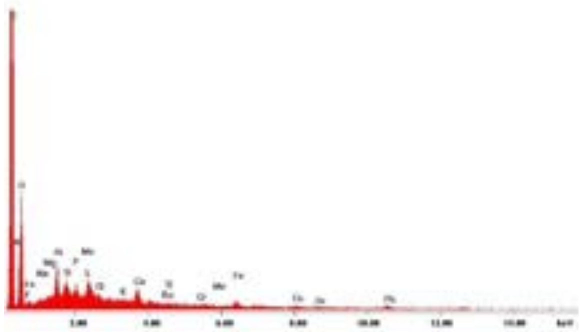
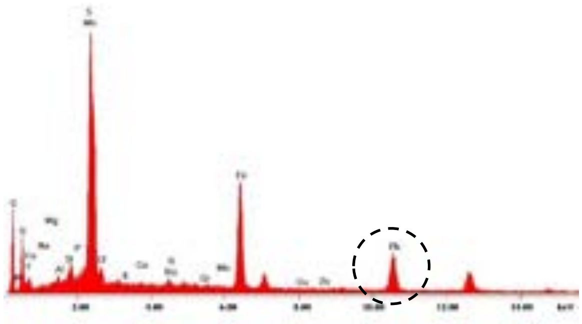


Figure 17: Paint from Area 2 examined using EDX analysis, showing analysis positions.



1



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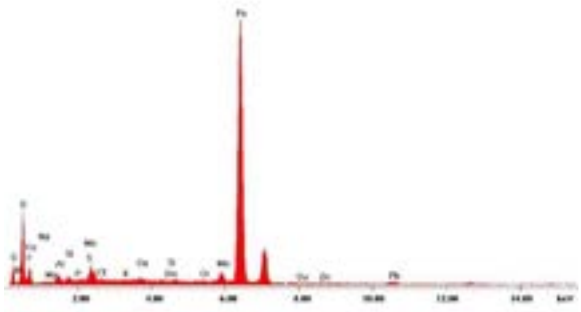

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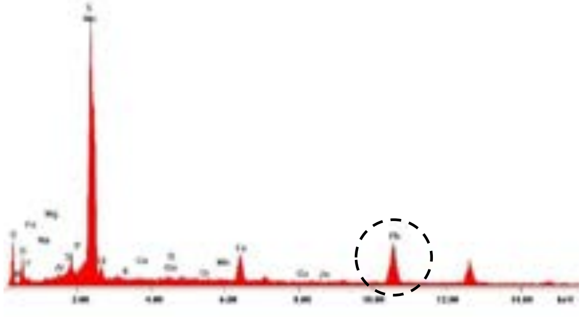

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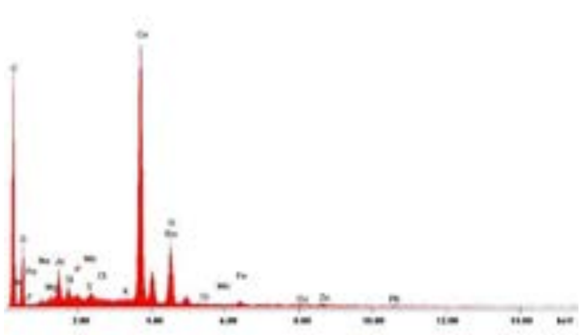

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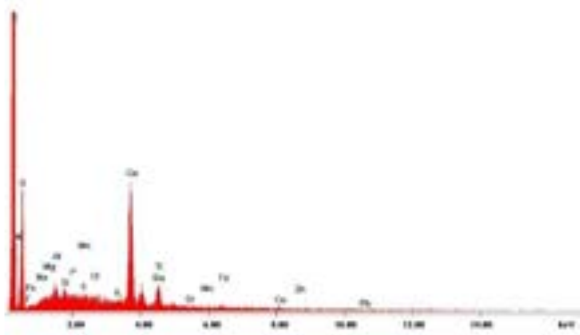

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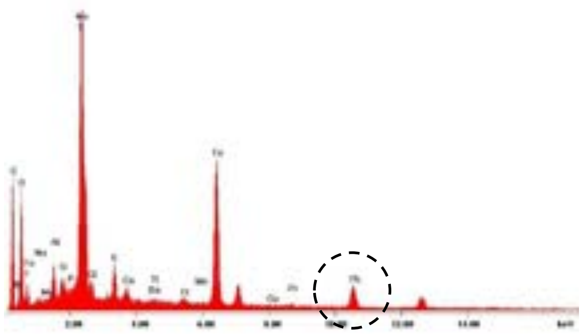

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Figure 18: EDX spectra of numbered analysis positions from paint sample.

Appendix 3 Area 3 – Steelwork – Horizontal bottom

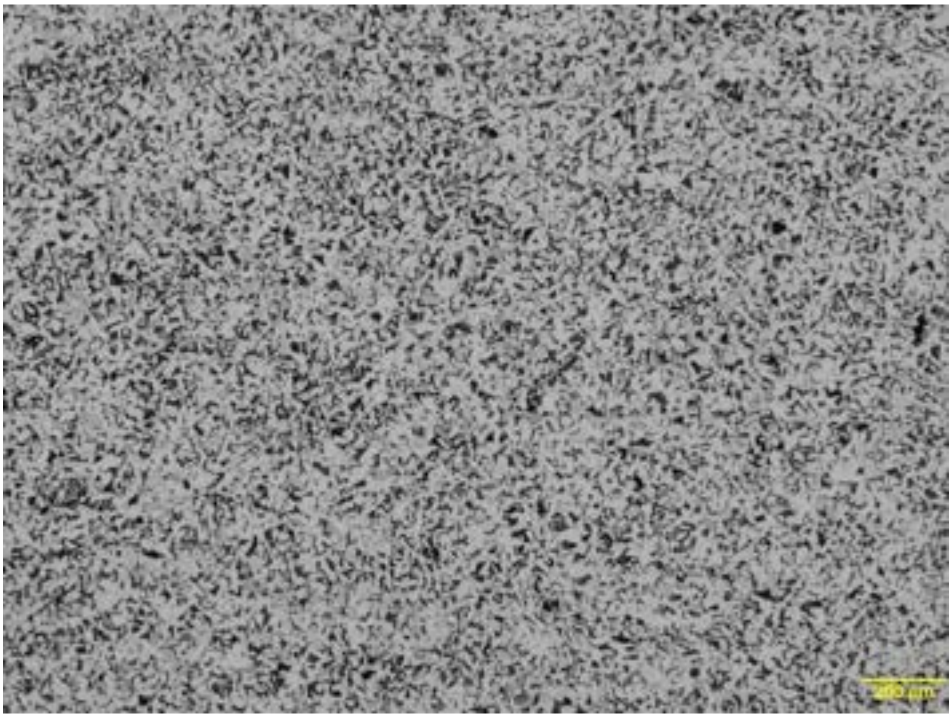


Figure 19: Etched RM micrograph showing typical carbon steel microstructure.

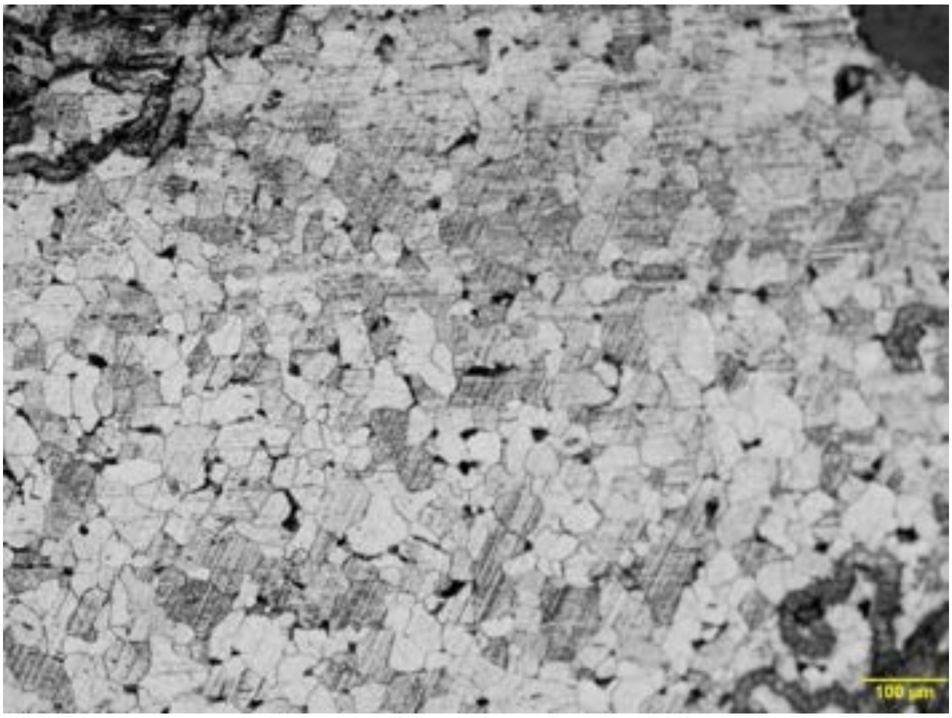


Figure 20: Etched micrograph of sample removed from structure, showing typical carbon steel microstructure.

Figure 21: Paint sample collected from Area 3.

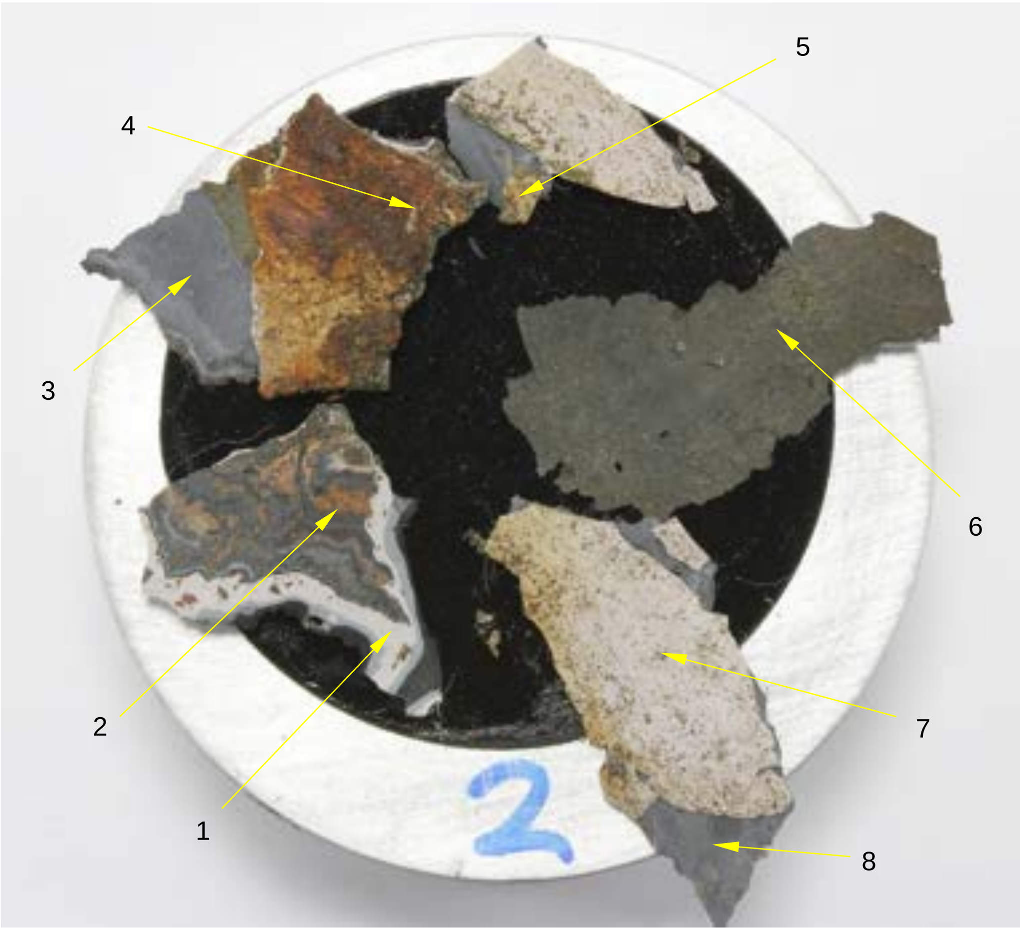


Figure 22: Paint from Area 3 examined using EDX analysis, showing analysis positions.

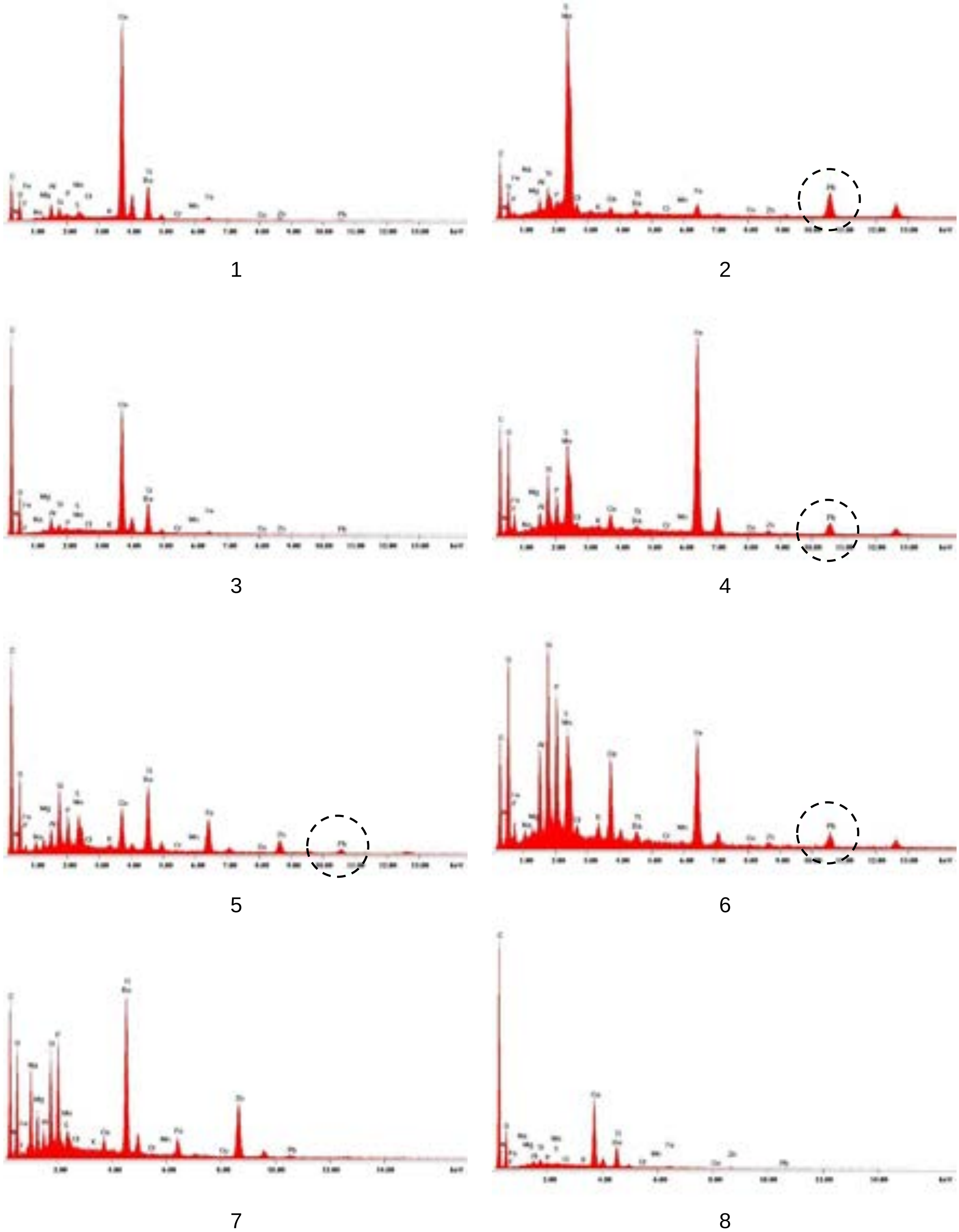


Figure 23: EDX spectra of numbered analysis positions from paint sample.

Appendix 4 Area 4 – Steelwork – Vertical side

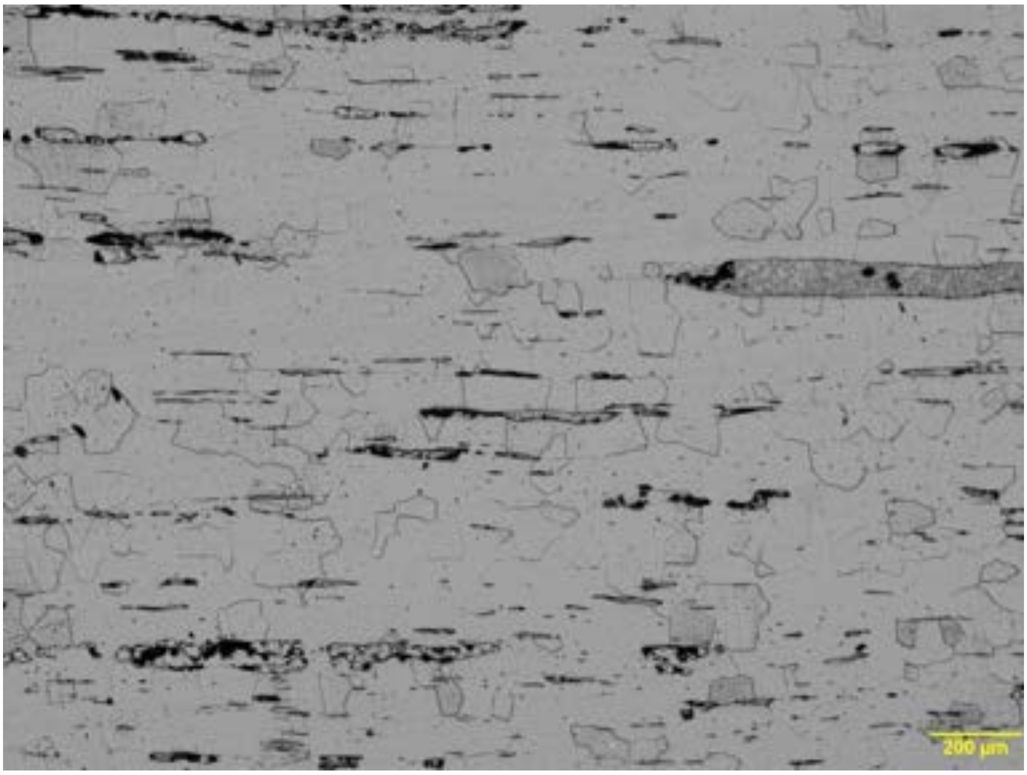


Figure 24: Etched RM micrograph showing typical wrought iron microstructure.

Figure 25: Paint sample collected from Area 4.

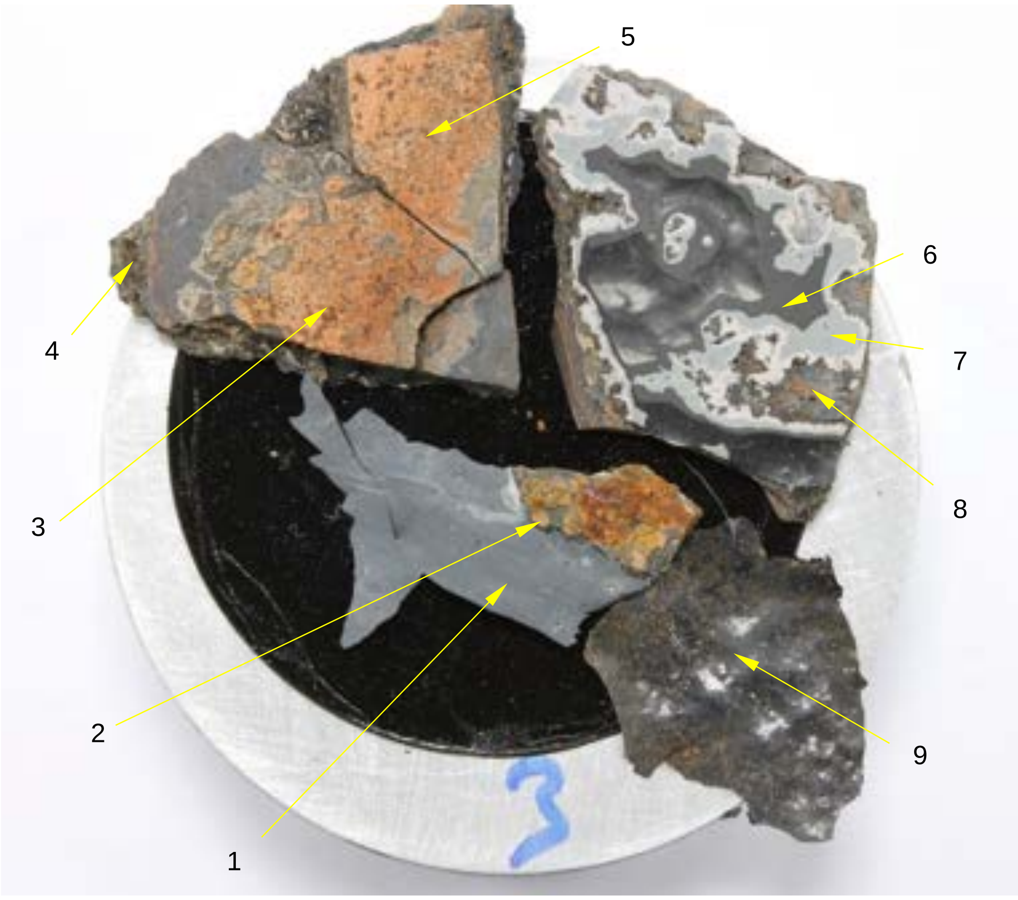
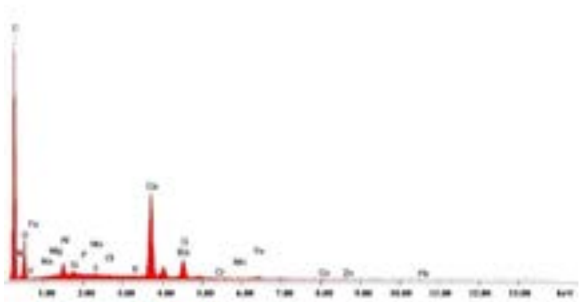


Figure 26: Paint from Area 4 examined using EDX analysis, showing analysis positions.



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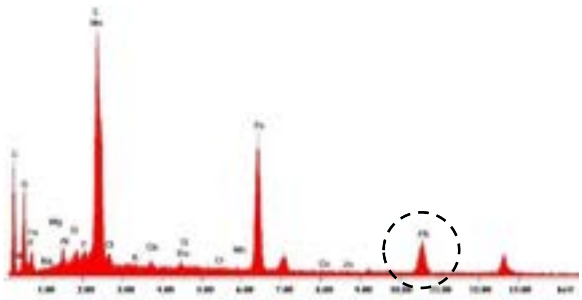

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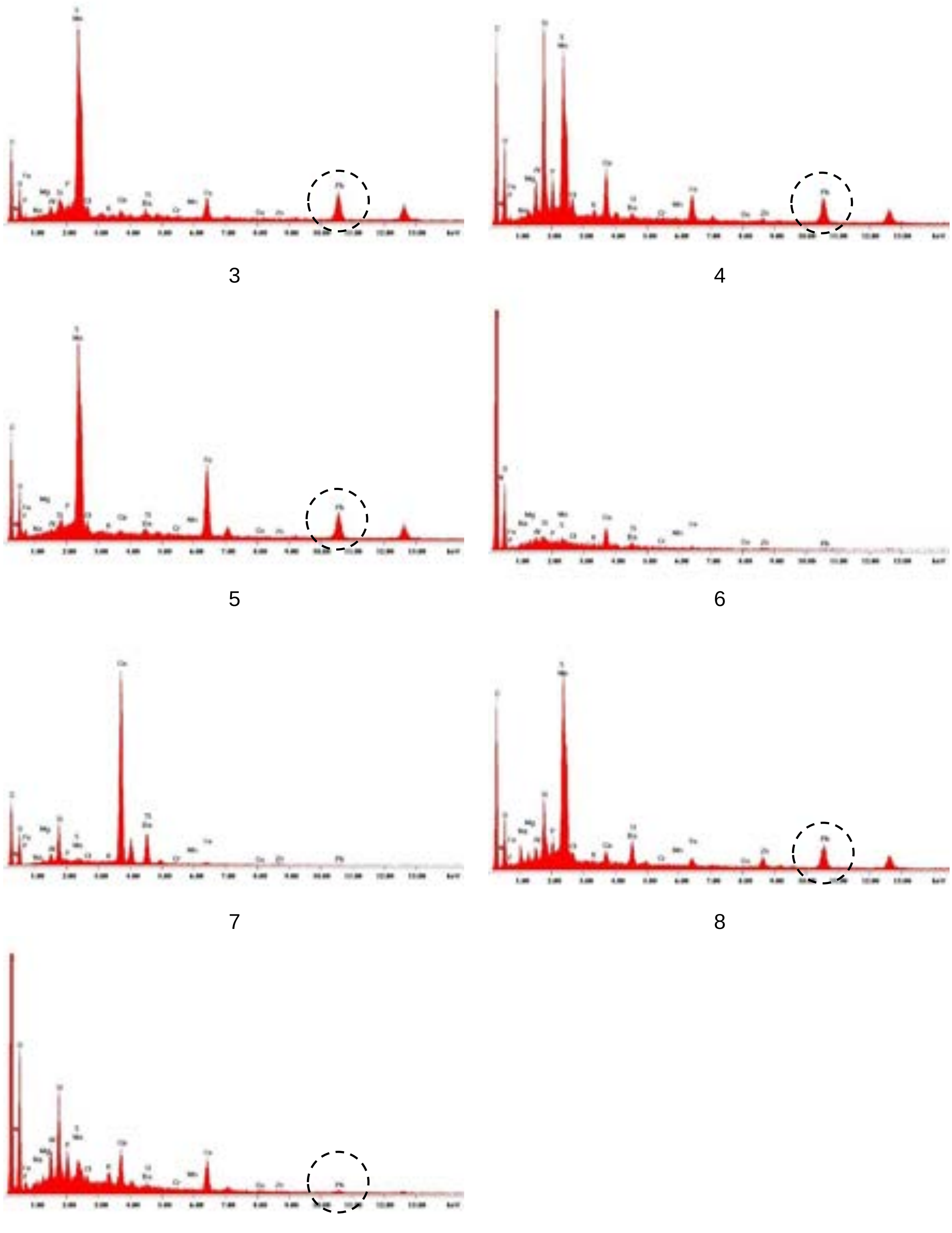


Figure 27: EDX spectra of numbered analysis positions from paint sample.

Appendix 5 Area 5 – Steelwork – Lattice work

Figure 28: Etched RM micrograph showing typical wrought iron microstructure.

Figure 29: Paint sample collected from Area 5.

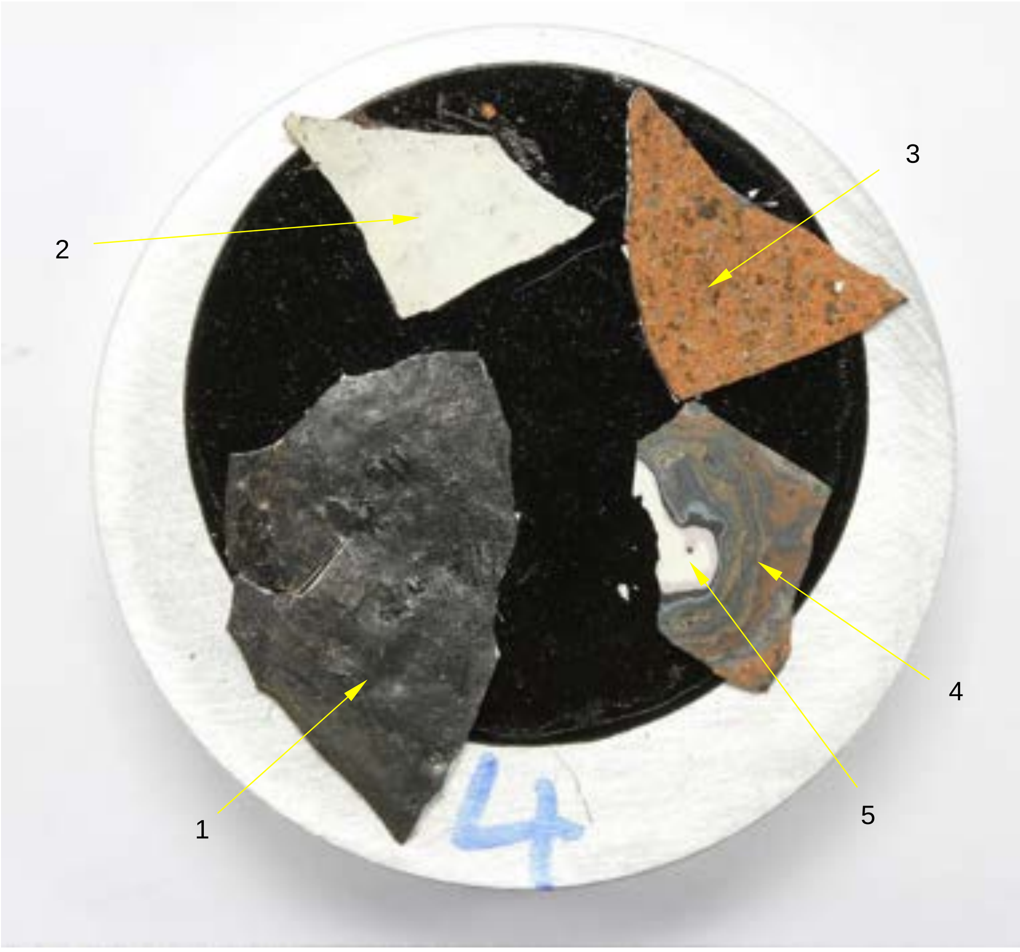
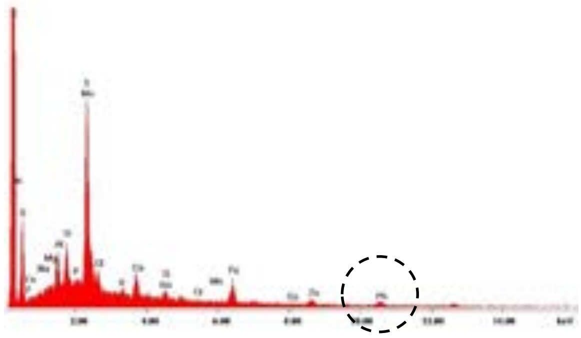


Figure 30: Paint from Area 5 examined using EDX analysis, showing analysis positions.



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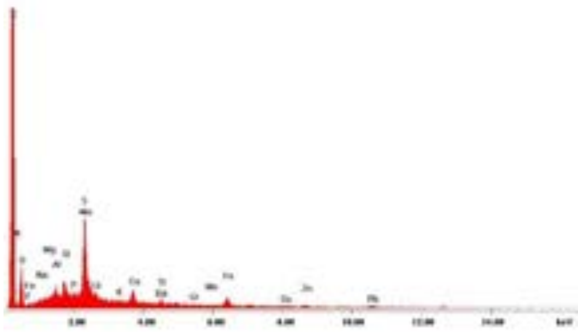

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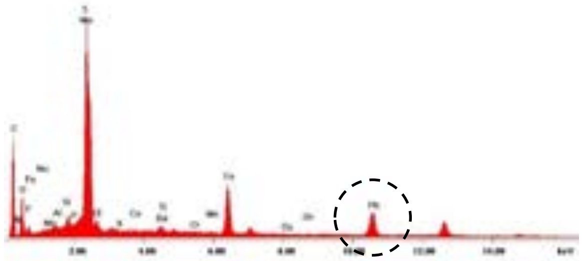

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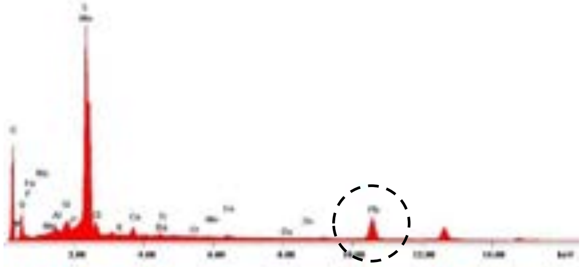

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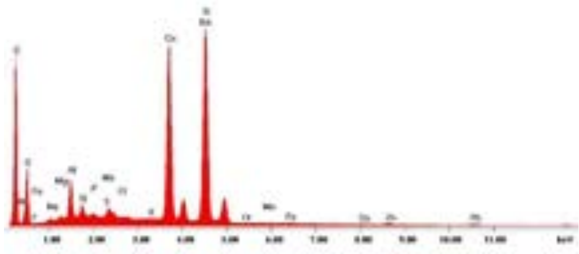

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Figure 31: EDX spectra of numbered analysis positions from paint sample.

Appendix 6 Area 6 - Archway

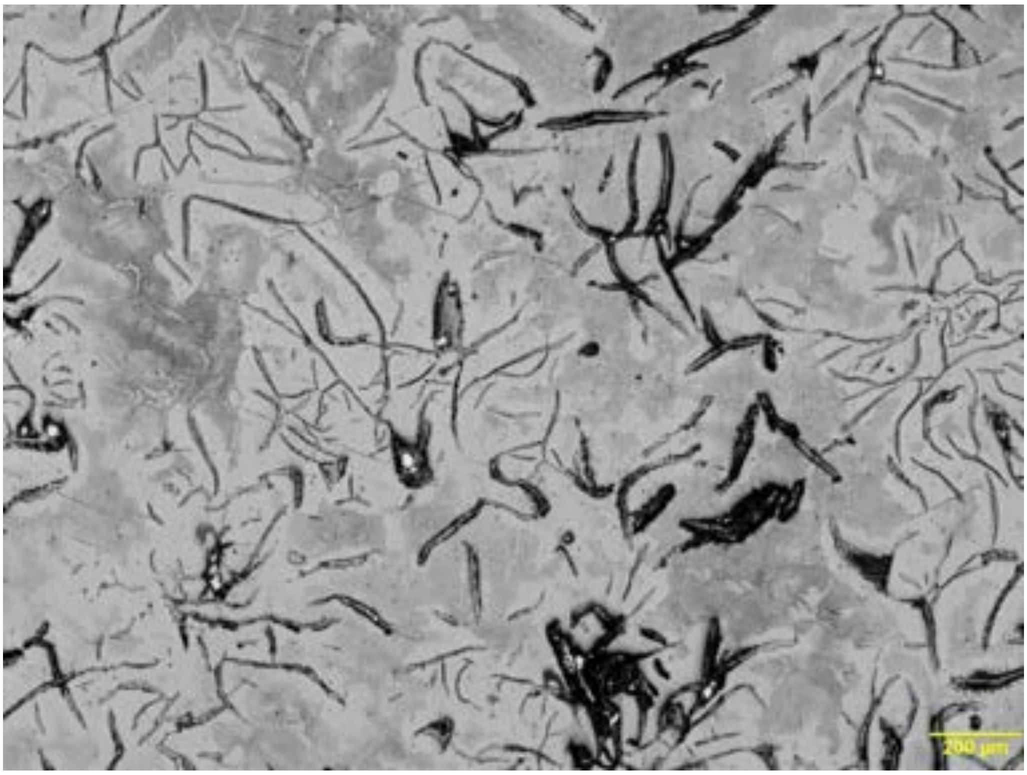


Figure 32: Etched RM micrograph showing typical grey flake cast iron microstructure.

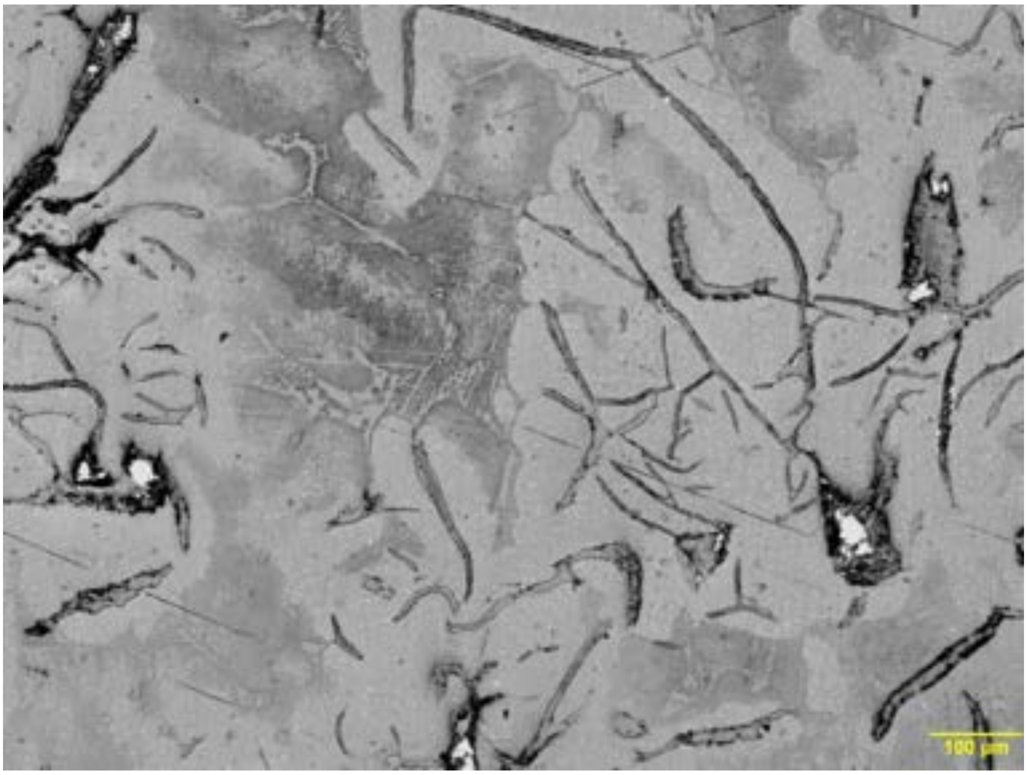


Figure 33: Etched RM micrograph showing typical grey flake cast iron microstructure.

Figure 34: Paint sample collected from Area 6.

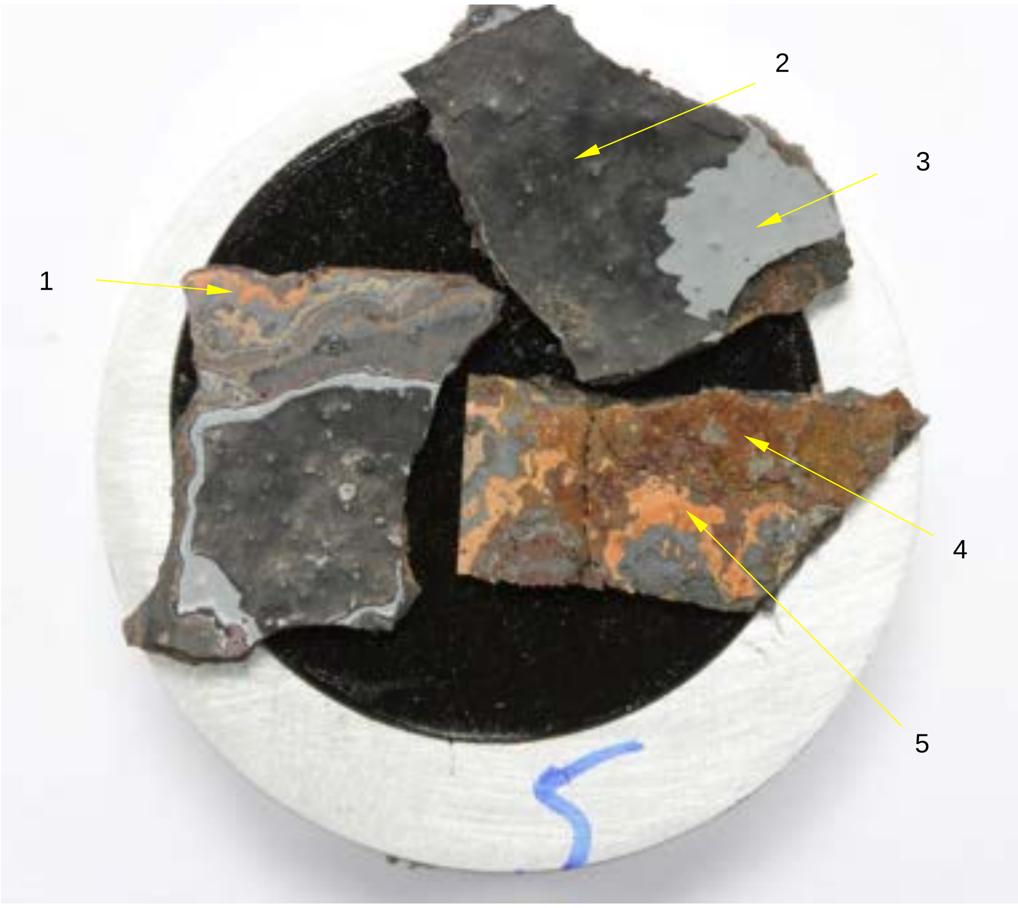
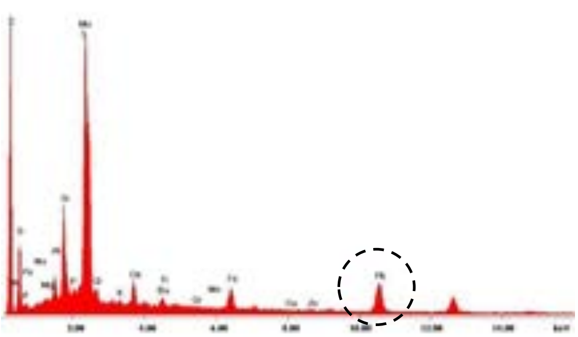


Figure 35: Paint from Area 6 examined using EDX analysis, showing analysis positions.



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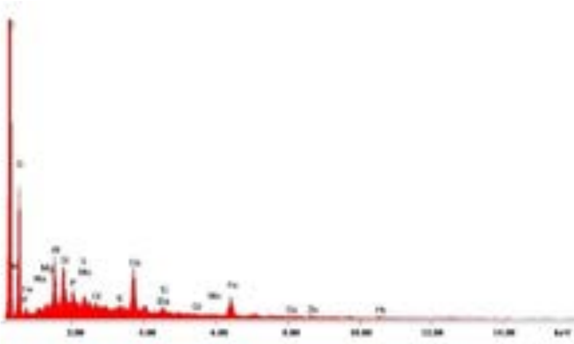

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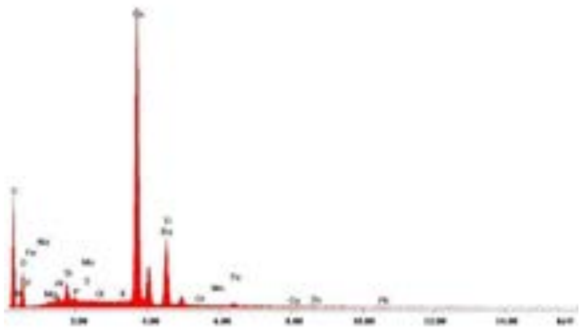

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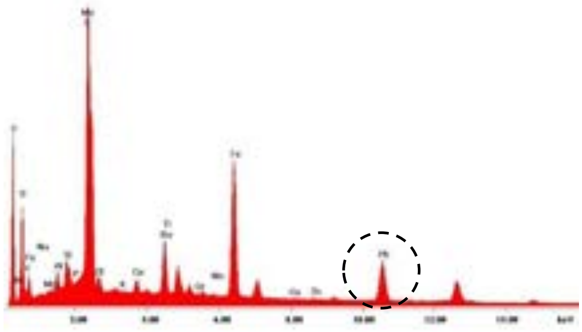

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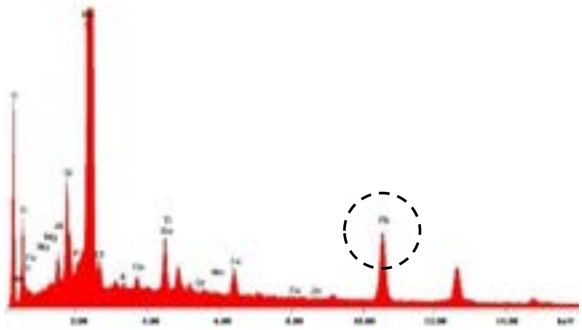

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Figure 36: EDX spectra of numbered analysis positions from paint sample.

Appendix C

Assessment Calculations

ISSUE	TOTAL SHEETS	AUTHOR	DATE	CHECKED BY	DATE	APPROVED BY	DATE	COMMENTS
1	13	Shahed Mortazavi	13/01/2022	Vita Dudley Bow	31/01/2022	Andrew Branch	03/02/2022	
Signature		Shahed Mortazavi		Vita Dudley Bow		Andrew Branch		
1								
2								
3								

SUPERSEDES DOC No	DATE

DESIGN BASIS STATEMENT (Inc. sources of info/data, assumptions made, standards, etc.)

Methodology

As provided in the assessment report

Materials

As provided in the assessment report

Assumptions

Calculations are based on information/details provided in drawings 78/1732,1733,1734 and from dimensions taken on site.

Surface thickness are assumed due to lack of sufficient information from the existing drawings.

Codes & Standards

- CS 454
- CS 456
- BS 7818

References

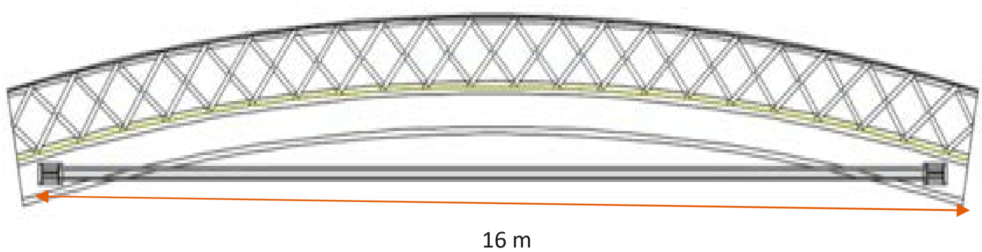
Drawings: 78/1732, 78/1733, 78/1734

REFERENCE	CALCULATIONS	OUTPUT

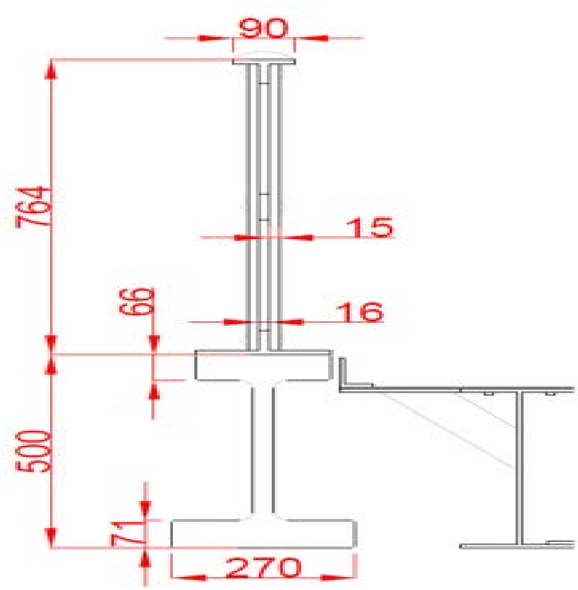
1. Introduction

The bridge is a single span structure and consists of two main outer beams supported by masonry/brick abutments with approach/retaining walls to the ramps of red and blue stock brickwork. There are double tie rods on both outer beams. The original deck between the main beams was removed and replaced with a new deck arrangement to accommodate National Grid cable troughs and comprises 4No. 400 x 180 mm 'I' beams arranged in pairs. Each pair of beams has been boxed in to form cable troughs. A shallow, steel deck tray 80mm deep filled with asphalt is bolted to the upper flanges of the main beams to form the towpath surface. The decking/walking surface is of tarmac and the parapets are steel with lattice infills between the outer beam and handrail. The downstream approach ramp is of brick paving for the lower half, and tarmac for the upper half which continues over the length of the bridge to the upstream ramp to meet the towpath. The boundary walls are of brickwork with rounded stone top cappings.

2. Geometry of parapet Structure



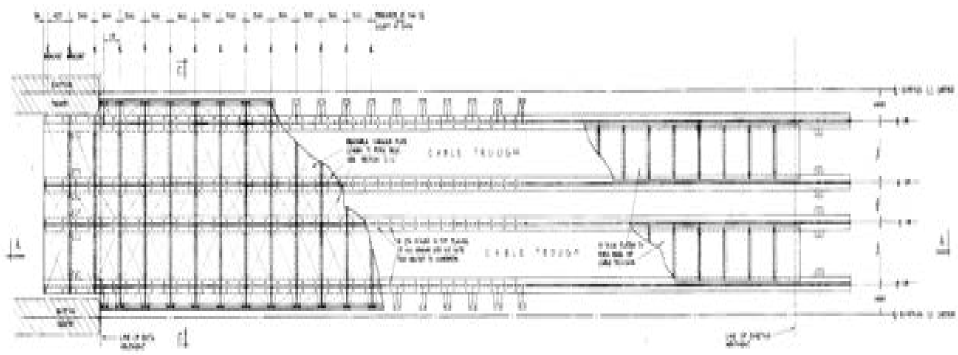
Elevation of the parapet



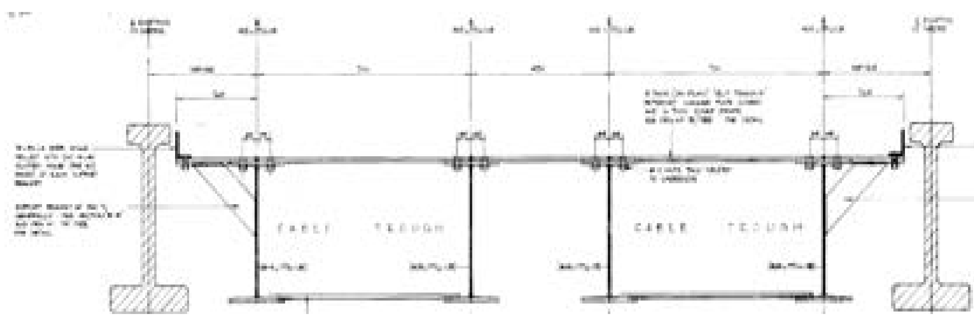
Cross section of the parapet

REFERENCE	CALCULATIONS	OUTPUT

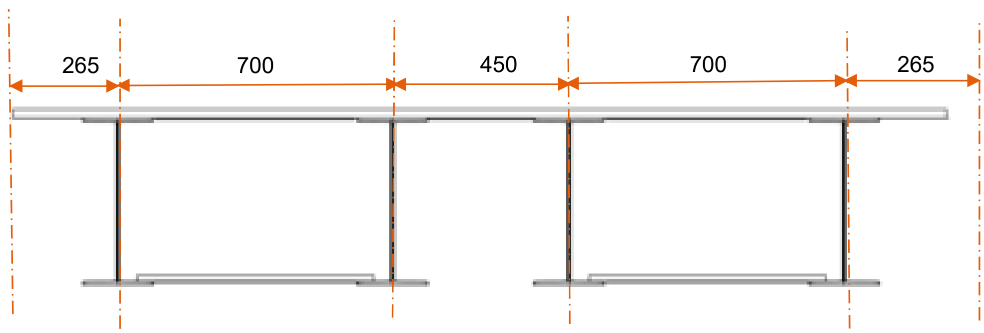
3. Geometry of the deck Structure



Plan of bridge

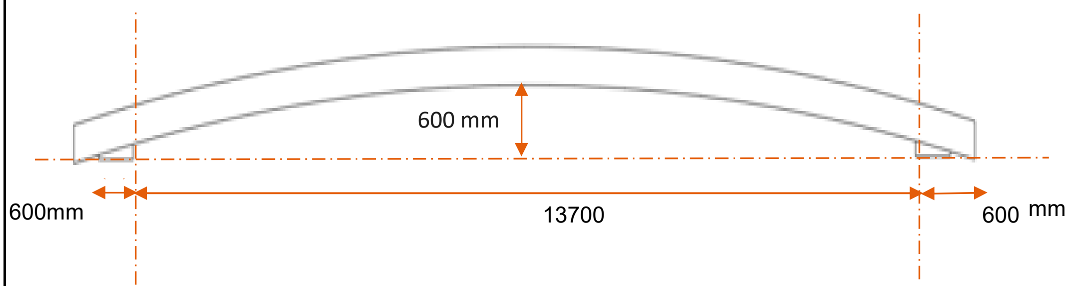


Cross section of the bridge



REFERENCE	CALCULATIONS	OUTPUT

Spans

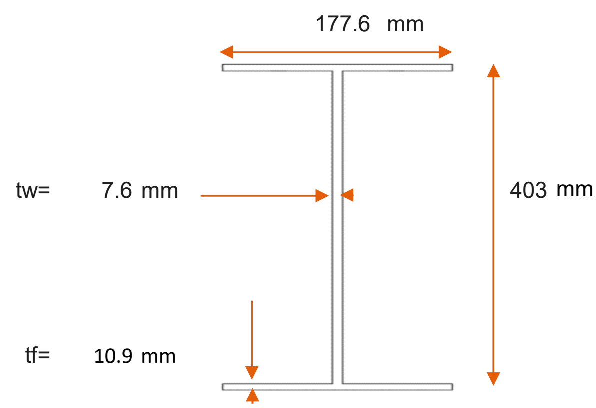


CS 454
6.6

The effective span should be taken as the distance between the centroids of the bearing pressure diagrams.

b =	600	mm	Clear span l	=	13700 mm
			Eff. span le	=	14300 mm
					14.3 m

Typical Section size



SUBJECT **Assessment of Dead Dog Basin Footbridge Parapet & Deck**

REFERENCE	CALCULATIONS					OUTPUT
	4. Material & section properties					
	Unit Weights					
CS 454 Table 4.1.1a	Structural Steel			=	78.5 kN/m^3	
	Asphalt			=	23.0 kN/m^3	
	Cast iron			=	72.0 kN/m^3	
	Wrought iron			=	77.0 kN/m^3	
	Material Strengths					
	$f_{yk,steel}$			=	344 N/mm^2	
	f_{ck}			=	15 N/mm^2	
the Historical Steel Handbook Table 2.1	fy, cast iron			=	93 N/mm^2	
	fy, wrought iron			=	324 N/mm^2	
	Elastic modulus					
	Steel			=	210000 N/mm^2	
CS 454 CS 456	Cast Iron			=	90000 N/mm^2	
	Wrought Iron			=	190000 N/mm^2	
CS 454 Table 3.4	**Load Factors**					
	YfL	Steel	ULS	=	1.05 (Comb 1)	
	YfL	Deck Surfacing	ULS	=	1.75 (Comb 1)	
	YfL	Footway & cycle track loading	ULS	=	1.5 (Comb 1)	
Appendix A Table A.1	YfL	Cast iron	ULS	=	1.00 (Comb 1)	
CS 454 3.9 AIP	Yf3			=	1.1	
	Condition factor	Full structure excl. cast iron beams		=	1	
		Cast Iron girders		=	0.8	
	Material's Cover					
	At Footway:					
Drawings 78/1734	Depth of Asphalting			=	38 mm	
	Chequer plate cover thickness			=	8 mm	

REFERENCE	CALCULATIONS				OUTPUT
AIP	**5 Permanent actions on parapet beam**				
	5.1 Dead Load				
	Self weight of the cast iron beam				
Midas Model	Beam area	=	0.004	m2	
	Unit weight	=	72.00	kN/m^3	
	Beam length	=	16	m	
	Beam self weight	=	0.32	kN/m	
	Self weight of the T section bottom				
Midas Model	T area	=	0.003	m2	
	Unit weight	=	78.50	kN/m^3	
	T length	=	16	m	
	T self weight	=	0.25	kN/m	
	Self weight of the T section top				
Midas Model	T area	=	0.002	m2	
	Unit weight	=	78.50	kN/m^3	
	T length	=	16	m	
	T self weight	=	0.15	kN/m	
	Self weight of the Lattice infills section				
Midas Model	Lattice area	=	0.071	m2	
	Number	=	44		
	Thickness	=	0.015	m	
	Unit weight	=	77.00	kN/m^3	
	Lattice self weight	=	3.62	kN/m	
BS 7818	**5.2 Live Load**				
	Assumed Design Loading — Class 2: normal duty guard rail				
Table 2	Longitudinal members(rails) — nominal	=	700	N/m	

REFERENCE	CALCULATIONS	OUTPUT

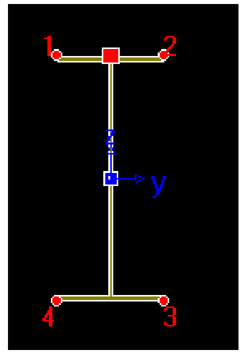
6. Permanent actions on steel deck

6.1 Dead Load

Historic Steel book Table 3.14

Self weight of the steel beam 406x178x54

Depth of cross-section	h=	402.6	mm
Web depth	hw=	380.8	mm
Width of cross-section	b=	177.6	mm
Depth between fillets	d=		
Web thickness	tw=	7.6	mm
Flange thickness	tf =	10.9	mm
Radius of root fillet	r =	0.0	
Cross-sectional area	A=	68.3	cm2
Second moment of area (y-y)	I y=	18580	cm4
Second moment of area (z-z)	I z=	922.0	cm4
Elastic section modulus (y-y)	Wel,y =	103.8	cm3
Elastic section modulus (y-y)	Wel,y =	922.8	cm3



Self weight of the steel beam

Area = 0.0068 m2

Density = 78.50 kN/m^3

0.536 kN/m — Midas will consider

Self weight of the Cover plate

Density = 78.50 kN/m^3

Length = 16 m

Width= 2.38 m

Thickness= 0.014 m (Drawings 78/1732)

1.10 KN/m2

Self weight of the asphalt

Density = 23.00 kN/m^3

Width= 2.38 m

Thickness= 0.038 m

0.874 KN/m2

Total dead load = 2.0 KN/m2

Maximum width of deck over single beam= 482.5 mm = 0.4825 m

Dead load on middle beams 0.95 kN/m

incl 10% for connections 1.05 kN/m

6.2 Live Load

CS 454 5.32 — Pedestrian Width = 2380 mm = 2.38 m

Table 5.32a — Pedestrian live load = 5 kN/m2

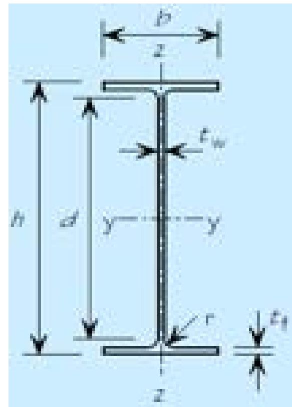
REFERENCE	CALCULATIONS	OUTPUT

7. Deck's steel beam classification of cross-section

The deck steel beam 406x178x54

Historic Steel book Table 3.14

Depth of cross-section	h=	402.6	mm
Web depth	hw=	380.8	mm
Width of cross-section	b=	177.6	mm
Depth between fillets	d=	380.8	mm
Web thickness	tw=	7.6	mm
Flange thickness	tf =	10.9	mm
Radius of root fillet (Assumed)	r =	0.0	mm
Cross-sectional area	A=	68.3	cm2
Second moment of area (y-y)	I y=	18580.0	cm4
Second moment of area (z-z)	I z=	922.0	cm4
Elastic section modulus (y-y)	Wel,y =	922.8	cm3



BS EN 1993-1-1 5.5 table 5.2

$\varepsilon = \sqrt{\frac{235}{f_y}} = \sqrt{\frac{235}{275}} = 0.92$

Outstand flange: flange under Uniform compression

$c = \frac{(b-t_w-2r)}{2} = \frac{177.6 - 7.6 - 2 \times 0}{2} = 85.0$ mm

$\frac{c}{t_f} = \frac{85}{10.9} = 7.8$

The limiting value for Class 1 is

$\frac{c}{t} \leq 9\varepsilon = 9 \times 0.92 = 8.319746$

7.7982 ≤ 8.32

Therefore, the flange outstand in compression is Class 1.

Internal compression part: web under pure bending

c = d = 380.8 mm

$\frac{c}{t_w} = \frac{380.8}{7.6} = 50.11$

The limiting value for Class 1 is

$\frac{c}{t} \leq 72\varepsilon = 72 \times 0.92 = 66.56$

50.11 ≤ 66.56

Therefore, the web in pure bending is Class 1.
Therefore the section is Class 1 under pure bending.

OUTPUT: Section is Class 1

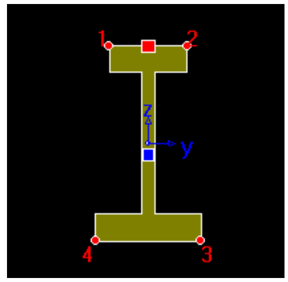
REFERENCE	CALCULATIONS	OUTPUT
	8. Deck - I sections Moment and Shear check	
BS EN 1993-1-1	**Bending resistance, M**	
	Section modulus Wpl, y-y = 922.8	
6.2.5	$M_{c,Rd} = \frac{W_{pl} f_y}{\gamma_{M0}}$ = 288.6 kN-m	
	γ_{M0} = 1.1	
Midas Model	Maximum bending moment My = 191.7 kN-m	
BS EN 1993-1-1 6.2.5	$\frac{M_{Ed}}{M_{c,Rd}} \leq 1.0$ $\frac{191.73}{288.58} \leq 1$ = 0.66	Utilisation 66% OK
	Shear resistance, V	
6.2.6	$V_{pl,Rd} = \frac{A_v (f_y/\sqrt{3})}{\gamma_{M0}}$	
	For a rolled I-section with shear parallel to the web the shear area is:	
	$A_v = A - 2bt_f + (t_w + 2r)t_f$ but not less than $\eta h_w t_w$	
	Av = 3041.2 mm^2 = 0.0030 m2	
BS EN 1993-1-1 6.2.6	Vpl,Rd = 549.1 kN	
Midas Model	Maximum shear Vz=Ved = 60.4 kN-m	
	$\frac{60.42}{549.09} \leq 1$ = 0.11	Utilisation 11% OK

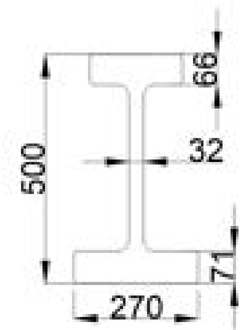
REFERENCE	CALCULATIONS	OUTPUT

9.Cast iron beam

Midas Model

Area	43986.0	mm^2
Asy	26975.0	mm^2
Asz	16000.0	mm^2
Ixx	46028230.0	mm^4
Iyy	1610305000.0	mm^4
Izz	161449000.0	mm^4
Cyn	135.0	mm
Cym	135.0	mm
Centre Y	135.00	mm
Centre Z	222.30	mm





10. Cast Iron Beam stress check

CS 454 cl 8.1 — Cast iron members shall be assessed by verifiying that the stresses do not exceed permissible values.

CS 454 8.3 — The total compressive stress in cast iron shall not exceed 154 Mpa

Max compressive stress in Midas model = 27.13 Mpa So — OK

8.4 — The total tensile stress in cast iron shall not exceed 46 Mpa

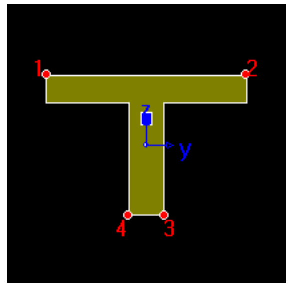
Max tensile stress in Midas model = 27.25 Mpa So — OK

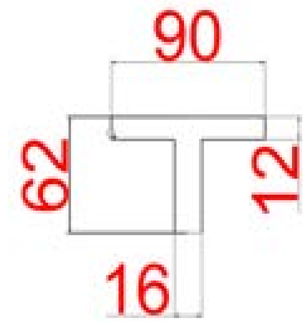
REFERENCE	CALCULATIONS	OUTPUT

11.Parapet's top T section

Midas Model

Area	1880.0	mm^2
Asy	900.0	mm^2
Asz	992.0	mm^2
Ixx	119026.3	mm^4
Iyy	621277.7	mm^4
Izz	746066.7	mm^4
Cyn	45.0	mm
Cym	45.0	mm
Centre Y	45.00	mm
Centre Z	42.81	mm





BS EN 1993-2

Bending resistance, M

Major axis

Section modulus $W_{pl,}$ y-y = 14513 mm³

cl 6.2.5

$$M_{c,Rd} = \frac{W_{pl} f_y}{\gamma_{M0}}$$ = 4.99 kN-m

γ_{M0} = 1

Midas Model — Maximum bending moment My = 0.37 kN-m

Utilisation 7% OK

Minor axis

Section modulus $W_{pl,}$ z-z = 16579 mm³

cl 6.2.5

$$M_{c,Rd} = \frac{W_{pl} f_y}{\gamma_{M0}}$$ = 5.70 kN-m

γ_{M0} = 1

Midas Model — Maximum bending moment Mz = 4.62 kN-m

Utilisation 81% OK

BS EN 1993-2 6.2.6

Shear resistance, V $$V_{pl,Rd} = \frac{A_v (f_y/\sqrt{3})}{\gamma_{M0}}$$

where

$$A_v = A - bt_f + (t_w + 2r)\frac{t_f}{2}$$

Av = 896.0 mm^2
= 0.00090 m2

Vpl,Rd = 177.95 kN

Midas Model — Maximum shear Vy=Ved = 4.42 kN

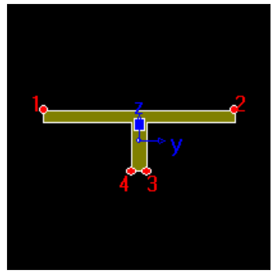
Utilisation 2% OK

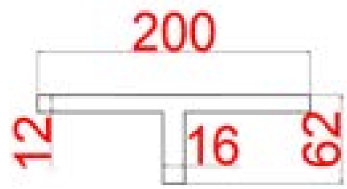
REFERENCE	CALCULATIONS	OUTPUT

12. Parapet bottom T section

Midas Model

Area	3200.0 mm^2
Asy	2000.0 mm^2
Asz	992.0 mm^2
Ixx	182386.2 mm^4
Iyy	772066.7 mm^4
Izz	8017067.0 mm^4
Cyn	100.0 mm
Cym	100.0 mm
Centre Y	100.00 mm
Centre Z	48.25 mm





BS EN 1993-2

Bending resistance, M

Major Axis

Section modulus $W_{pl,}$ y-y = 16001 mm^3

6.2.5 — $M_{c,Rd} = \frac{W_{pl}f_y}{\gamma_{M0}}$ = 5.5 kN-m

γ_{M0} = 1

Midas Model — Maximum bending moment, My = 0.37 kN-m — Utilisation 7% OK

Minor axis

Section modulus $W_{pl,}$ z-z = 80171 mm^3

6.2.5 — $M_{c,Rd} = \frac{W_{pl}f_y}{\gamma_{M0}}$ = 27.58 kN-m

γ_{M0} = 1 — Utilisation 17% OK

Midas Model — Maximum bending moment, Mz = 4.62 kN-m

BS EN 1993-2 6.2.6

Shear resistance, V $V_{pl,Rd} = \frac{A_v(f_y/\sqrt{3})}{\gamma_{M0}}$

where

$A_v = A - bt_f + (t_w + 2r)\frac{t_f}{2}$

Av = 896.0 mm2
= 0.00090 m2

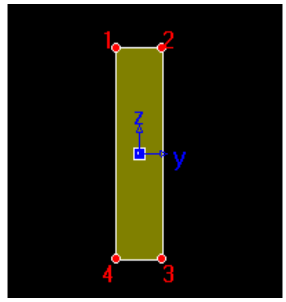
Vpl,Rd = 177.95 kN — Utilisation 2% OK

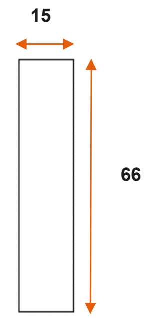
Midas Model — Maximum shear Vy=Ved = 4.42 kN

REFERENCE	CALCULATIONS	OUTPUT

13.Section properties

Parapet's Lattice infills section





Midas Model

Area	990.0	mm^2
Asy	825.0	mm^2
Asz	825.0	mm^2
Ixx	63621.1	mm^4
Iyy	359370.0	mm^4
Izz	18562.5	mm^4
Cyn	7.5	mm
Cym	7.5	mm
Centre Y	7.50	mm
Centre Z	33.00	mm

Bending resistance, M

Major axis

Section modulus, y-y = 10890 mm^3

BS EN 1993-2 6.2.5 — $M_{c,Rd} = \frac{W_{pl} f_y}{\gamma_{M0}}$ = 3.53 kN-m

γ_{M0} = 1

Midas Model — Maximum bending moment My = 0.41 kNm

Output: Utilisation 12% OK

Minor axis

Section modulus, z-z = 2475 mm^3

BS EN 1993-2 6.2.5 — $M_{c,Rd} = \frac{W_{pl} f_y}{\gamma_{M0}}$ = 0.80 kNm

γ_{M0} = 1

Midas Model — Maximum bending moment Mz = 0.29 kNm

Output: Utilisation 36% OK

6.2.6(1) — **Shear resistance, V** $V_{pl,Rd} = \frac{A_v (f_y/\sqrt{3})}{\gamma_{M0}}$

Vpl,Rd = = 151 kN

Av= 806.7 mm^2 = 0.0008 m2

Midas Model — Maximum shear Vz=Ved = 1.23 kN

Output: Utilisation 1% OK

BS EN 1993-1-1 6.2.6

$$\frac{V_{Ed}}{V_{c,Rd}} \le 1.0 \qquad \frac{1.23}{151.05} \le 1$$

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