

Castlefield Viaduct

Arup Report – 3 September 2021



Executive Summary

Report Content

Our input at this stage has been to support the development of the planning application.

This report contains:

- Records of our site visits, structural assessment and reviews of existing information
- Strategic MEP and lighting advice
- A record of Building Controls structural information requirements
- Sketch details of the proposed interventions and description of the engineering performance requirements
- Notes on the history and structural form of the viaduct
- A CDM hazard register is included at the end of the report

Conclusions and Recommendations

The scheme can make a valuable contribution to the UN Sustainable Development Goals, reactivate a well-loved historic structure and provide a much-needed amenity in central Manchester.

As the structure was designed for rail traffic it has significant capacity, only limited by corrosion. Highways England, who maintain the structure, have identified several repairs and these are contained in the 2020 Detailed Examination Report by Jacobs. We have highlighted those repairs which we recommend as part of the Pilot Park project.

The structure has been regularly inspected by Jacobs, most recently in 2020. This is except for Span 1 over the live railway. An inspection is recommended before the Pilot Park is implemented.

The deck-plates have limited spare capacity to support additional loads. New loads are to be placed directly onto the existing rail bearers and transverse fish belly beams.

An access route for mini construction plant has been incorporated into the design. This is 5 feet (1,524mm) wide and runs the length of the park, flanked on both sides by gravel infill, making the total access path width 4m.

Castlefield Viaduct

View from ground level



Recommendations

Design Development

Key elements of the design work for RIBA Stage 4 are:

- Dimensional survey of the existing structure.
- Confirming supplies and connections with the utility companies.
- Confirming the contamination and drainage strategy with Royal Haskoning.
- Developing a detailed engineering performance specification for the temporary building.
- Undertaking further assessment of the existing structure to satisfy Building Control requirements.
- Engaging with contractors and suppliers to test the scheme design and develop the construction details.
- Developing an outline construction sequence so the works can be implemented safely and cost effectively.
- As the project is to be procured traditionally, all design information is to be completed prior to tender.
- Consultation with all Stakeholders in relation to fire safety. Specifically, regarding a secondary egress route and access/egress requirements to and from the viaduct for occupants and the Fire Service in an emergency.
- Developing a detailed fire strategy report for the project to satisfy Building Control and local Fire Service.

Repairs for Phase 1

Structural

These repairs are recommended as part of the Pilot Park:

- Repair major losses of section to top boom of south truss of span 2.
- Clear shelf areas, removing saplings and replace heavily corroded bearing to west abutment.
- Repair minor losses of section to trusses and replace some connections.
- Remove all areas of corrosion to connections between main and transverse girders at decks 2-8, repair/repaint.
- Surface preparation and repair at bearing positions.

Drainage

These repairs are recommended as part of the Pilot Park:

- Replace drainage bracket to pier 4S and guttering brackets to soffit of span 2.
- Install drainage pipes to flooded bottom booms of spans 6S, 8N and 8S and re-examine elements.
- Remove all ballast from recently installed guttering system to span 5.

Further Inspections

As a priority we recommend a follow-up inspection is undertaken which covers Span 1 over the NR lines and the isolated areas (e.g. transverse stiffeners and areas of main girder lower flange corrosion) that were excluded from the 2020 detailed inspection. We envisage this will be undertaken by Jacobs, on behalf of Highways England, and that they will liaise with Network Rail.

If, for whatever reason, Jacobs are unable to undertake this inspection Arup could engage with Network Rail and undertake the survey in RIBA 4.

In either case, early engagement with Network Rail is recommended to secure permission and possession of the line.

We also recommend further investigation regarding repairs to key areas noted as concerns. since the 2010 Jacobs report, to discern the level of urgency for each:

- end web stiffeners of transverse (fish-belly) beams,
- top or bottom flanges of main truss bottom chords,
- main truss connection to the top of piers,
- flanges of the transverse beams (up to 12mm section loss).

To assist in finalizing the path details, it would also be useful to confirm the depth of ballast along the length of the path.

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Introduction

Commission

The Arup scope comprises three elements :

- 1) Building structures consultancy advice to inform the design for temporary structures as part of the pilot scheme, to ensure compliance with building regs and planning policy.
- 2) Strategic MEP advice to inform the design of the pilot scheme, to ensure compliance with building regs and planning policy.
- 3) Viaduct structural assessment to validate the capacity of the structure to accommodate proposed pilot park design.

UN Sustainable Development Goals

The project addresses the following UN SDGs:

Goal 3. Good Health and Well-being - by providing urban green space

Goal 11. Sustainable Cities and Communities - by providing urban green space and turning a liability into an asset

Goal 12. Responsible Consumption and Production - through specification

Goal 15. Life on Land - by increasing biodiversity

UN Sustainable Development Goals

The seventeen UN Sustainable Development Goals



Existing Information Review

Introduction

Several historic documents have been made available to the project team, including a full structural assessment undertaken by Jacobs in September 2010.

Jacobs Assessment (September 2010)

The assessment appears to be thorough and covers the key modes of potential failure anticipated. The assessment has been undertaken in accordance with BD21/01 and BD56/96 limit state principles but with no Finite Element modelling.

The key mode of potential failure identified is in the transverse girders at the support. These are typically provided with an end stiffener to resist web buckling, but it was noted that this has been entirely lost in places due to corrosion, particularly on the exposed north side of the structure.

The assessment has considered the complete loss of this end stiffener, with the compression forces assumed to be resisted by the web alone. As in the excerpts below, the capacity is significantly reduced as a result. This is particularly marked when any potential loss of web section is included.

The deck plates across the 6 ft span deck plates also show a low capacity of 3.1kPa, and for the 4 ft span 6.2kPa. Both would need to be strengthened to permit the proposed planters as well as crowd loading. 300mm of ballast has been assumed across the deck.

Main Girders

Position (Col – Col)	Girder length	Max dead load moment	Capacity	Live load udl capacity
EA - 3	144' – 0"	14746 kN.m	90053 kN.m	39.8 kN/m ²
3 - 5	71' – 3"	3364 kN.m	37153 kN.m	76.9 kN/m ²
5 - 7	167' – 6"	20781 kN.m	115373 kN.m	35.8 kN/m ²
7 - 9	83' – 0"	5432 kN.m	48889 kN.m	60.7 kN/m ²
9 - 11	127' – 6"	11741 kN.m	74232 kN.m	41.6 kN/m ²
11 - 13	175' – 0"	23136 kN.m	121705 kN.m	33.9 kN/m ²
13 – 15	149' – 0"	16516 kN.m	109042 kN.m	44.1 kN/m ²
15 - WA	144' – 0"	14746 kN.m	90053 kN.m	39.8 kN/m ²

Transvers Girders

Action	Location	Dead load effect with 12" ballast depth	Capacity	Live load udl capacity
Bending	Mid-span	717 kN.m	5040 kN.m	42.3 kN/m ²
Shear	Support	249 kN	1166 kN	26.0 kN/m ²
Buckling	Bearing stiffener	249 kN	1687 kN	40.8 kN/m ²
Buckling	Full section web alone	249 kN	494 kN	7.0 kN/m ²
Buckling	Web alone 25% corrosion loss	249 kN	243 kN	0

Deck Plates

	Dimensions	Permissible live load UDL	Permissible point load
Plate 1 (4 foot)	4.06 x 1.52m	6.2 kN/m ²	8.3 kN
Plate 2 (6 foot)	4.06 x 1.83m	3.1 kN/m ²	4.0 kN

NB – 300mm of ballast has been included in these values

Additional Calculations

In the appendices, to the assessment, there are some additional calculations by Jacobs on the capacity of the transverse girders to resist buckling. This clearly shows the significant contribution the stiffeners were making to the buckling resistance of the transverse girders.

Jacobs Recommendations (2010)

- There is a conclusion in the report that the ballast should be removed to prevent the ongoing build-up of vegetation. Poplar trees are believed to be growing up to 1.2m despite chemical treatment.
- Drainage gullies to be taken down due to extensive corrosion making them unstable. (These have now been replaced although some further maintenance is required.)



Typical Transvers Girder End Stiffener

The stiffener is the vertical plate, riveted to the web



Close up of Stiffener

Shows corrosion and loss of section

Royal Haskoning Documents

Drainage Assessment

Royal Haskoning report the existing drainage appears to have used transverse channel-shaped carriers beneath the bridge deck, connecting to downspouts fixed to the supporting columns. Gullies within the deck are provided along the length of these transverse channels but are currently buried under ballast. They note the existing drainage system is unlikely to meet modern standards for capturing runoff.

The Royal Haskoning recommended drainage strategy is to develop a concept that would maintain the current drainage principle in place whilst creating a suitable working surface suited for the proposed use. They suggest retaining the existing draining properties of the ballast and allowing water to percolate through any new surface into this and then carried away by the existing drainage system.

Flood Risk Assessment

The viaduct is noted to be at very low risk of flooding.

Land Quality Desk Study

Principally, they recommend leaving the existing ballast in place and providing new material in which to bed plants, etc.

Land Quality Interpretative Report

Their recent assessment concludes, the site soils potentially pose an unacceptable risk to site users and construction/maintenance workers. Paint scrapings indicate concentrations of metals that may pose an unacceptable risk to maintenance and construction workers.

They advise mitigation is required to reduce the risk and possible measures include; covering of the ground with temporary boarding, or similar, removal of ballast and soil or processing of the ballast to remove the soil matrix, refurbishment of the drainage network and raised planting beds.

Services and Utilities Information

Information on the services and utilities in the area is provided, although this all appears to be off-viaduct. There are no signs of any services or utilities carried by the viaduct.

Viaduct Drainage

Photograph and diagram of the drainage system

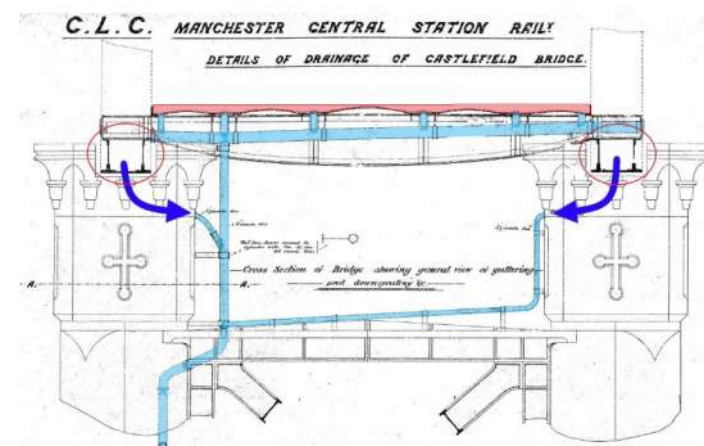


Figure 3-5: Section Through Viaduct with Additional Drainage Collectors Under Deck

Historic Drawings and Inspection Reports

A reasonable array of historic drawings are provided that appear to show most of the structure.

The viaduct is maintained by Highways England on behalf of the Historical Railways Estate.

A visual inspection was undertaken by Jacobs in 2018 which proposed that the drainage system be reinstated and “an approach” to the major repairs planned and considered, although no more detail is provided than this.

Detailed Examination Report (2020)

The examination from 7 Sept 2020 by Jacobs appears very thorough and the same as a “touching distance survey” Arup recommended following the initial walkover on 30 June 2021.

However, access could not be gained to Span 1, which sits over the live, electrified Network Rail lines. Further examination would be required to understand the condition of Span 1.

A set of recommendations are detailed on the cover page of the report by Jacobs with cost estimates for the repairs totalling £140,500.

Arup comments on the report and recommendations are:

- Apart from the repair/painting of corroded connections between main and transverse beams, the recommendations do not appear to including any significant re-painting of any of the defects despite including recommendations for: the removal of loose rust to pier trusses; repairs to minor section loss of piers; repairs to trusses.
- Despite noting defects in the main body of the report on these elements, there is no mention of recommended repairs to:
 - end web stiffeners of transverse (fish-belly) beams.
 - flanges of main truss chords (except top boom, S truss, span2) e.g. Span 4, item 7.
 - top of piers.
 - flanges of the transverse beams (up to 12mm section loss).
- There are various observations that relate to the bearing positions, but no repair specified – at minimum, surface preparation and repainting should be completed.

Existing Viaduct

View from the canal side



Detailed Examination Report Repairs

The detailed examination report by Jacobs (2020) includes a list of repairs and estimated costs. We have highlighted the items that are most likely to be required for the Pilot Park. This equates to £85,000 for structural works and £10,500 for drainage repairs of the £140,500 total.

As part of RIBA 4, it may be possible to demonstrate through engineering calculations that there is sufficient capacity for the proposed loading, despite the loss of section. In the meantime, it would be prudent to allow for a programme of repair work.

Item	Estimate
Repair broken stave to palisade fencing at E end of structure - PS £500	£ 500
Remove loose rust debris to isolated piers trusses, W abutment and span 8 ballast wall - P1 £8k.	£ 8,000
Replace drainage bracket to pier 4S and guttering brackets to soffit of span 2 - P1 £2k.	£ 2,000
Install drainage pipes to flooded bottom booms of spans 6S, 8N and 8S and re-examine elements - P1 £6k.	£ 6,000
Remove all ballast from recently installed guttering system to span 5 - P1 £2.5k.	£ 2,500
Repair major losses of section to top boom of S truss of span 2 - P1 £10k.	£ 10,000
Annually monitor widespread fractures to piers - P1 £n/a.	
Clean shelf areas, remove sapling and replace heavily corroded bearings to W abutment - P2 £15k.	£ 15,000
Stitch repair fracture to pier 1S column - P2 £15k.	£ 15,000
Remove root growth and vegetation to pier 3S, pier 4S and make good - P2 £1.5k.	£ 1,500
Repair minor losses of section throughout piers particularly at tops - P3 £20k.	£ 20,000
Ditto to trusses generally and replace odd connections - P3 £30k.	£ 30,000
Remove all areas of corrosion to connections between main and transverse girders at decks 2-8, repair/repaint - P3 £30k.	£ 30,000
	£ 140,500

Repairs and estimated costs from the detailed examination report

Site Visit Summary

Introduction

Arup visited the Castlefield viaduct on 30 June 2021 to conduct a walkover and observe the general condition of the steel structure. Approximately 150m of viaduct was inspected from below (on foot) and covered 4 main spans between piers.

Summary of inspection

The main observations noted significant section loss to:

- the end web stiffeners of the transverse fish-belly beams,
- discrete locations on the main bottom chords of the truss,

And significant corrosion was found on:

- Various soffit elements – deck plates, beams and trusses,
- Structural panels of the main piers.

Locations that could not be inspected were the top of the viaduct and the bearing points between:

- longitudinal rail-bearers and transverse beams,
- transverse beams and main trusses at each side,
- main trusses at each side and the pier heads.

Recommendations

Overall, the condition appears to be consistent with the previous consultant's inspection reports. Repairs have been advised in the 2020 Detailed Examination Report by Jacobs and these should be undertaken – timeframes to be decided through some further assessment.

Additionally, we recommend further assessment regarding repairs to key areas noted as concerns since the 2010 Jacobs report, to discern the level of urgency for each:

- end web stiffeners of transverse (fish-belly) beams,
- top or bottom flanges of main truss bottom chords,
- main truss connection to the top of piers,
- flanges of the transverse beams (up to 12mm section loss).

We recommend a follow up inspection which covers Span 1 over the NR lines and the isolated areas (e.g., transverse stiffeners and areas of main girder lower flange corrosion) that were excluded from the 2020 detailed inspection.

Underside of the viaduct

Image shows transverse fish belly girder and corroded stiffener



Building Control Planning Submission Requirements

Building Control Meeting

The team met with Alex Bremner of Manchester City Council Building control to discuss the planning submission requirements on 12 July 2021.

Planning Submission Requirements

For the structural condition and capacity of the viaduct superstructure and substructure (in addition to heritage or other planning considerations) the following documents in support of the planning application were requested:

DMRB - CS 450 - Principal Inspection for Assessment Report

CS450 sets out how the structural examination should be undertaken.

Proposed Action - Issue existing inspection report to MCC to confirm their acceptance. Note Span 1 over the Network Rail lines requires examination.

DMRB - CS 451 - Structural Review and Assessment Report

Proposed Action – A ‘Record of Structural Review Form’ (RSRF) has been prepared separately for issue to the BCO. This documents the history of the structure, past examinations and assessments, historic works, intention of the new scheme and any changes to form.

DMRB - CS 454 - Assessment Report

Further full numerical assessment of the viaduct.

Proposed Action – As there is already a wealth of information on the viaduct propose to MCC that this is undertaken post planning and if still required once they have reviewed C450 and C451 above.

DMRB - CG 300 - Appendix A - Approval in Principle

This provides the project details, design criteria, structural analysis proposals, geotechnical considerations and supporting information all in one place. This could be provided in a different format if it provided the design intent and supporting documentation.

Proposed Action – This is undertaken post planning.

View under the viaduct

View showing the soffit of the viaduct



Structural Engineering

Structural overview

The viaduct was designed specifically for rail loading directly onto the longitudinal rail beams along the viaduct. The deck plate spanning between the rail bearing beams does not have much spare capacity beyond carrying the self-weight of the ballast and some live load.

As a result, all loads, except pedestrian access, must be transferred directly to the longitudinal rail bearing beams.

Structural interventions

Locations with additional applied loads require a support structure to transfer the loads to the rail bearing beams.

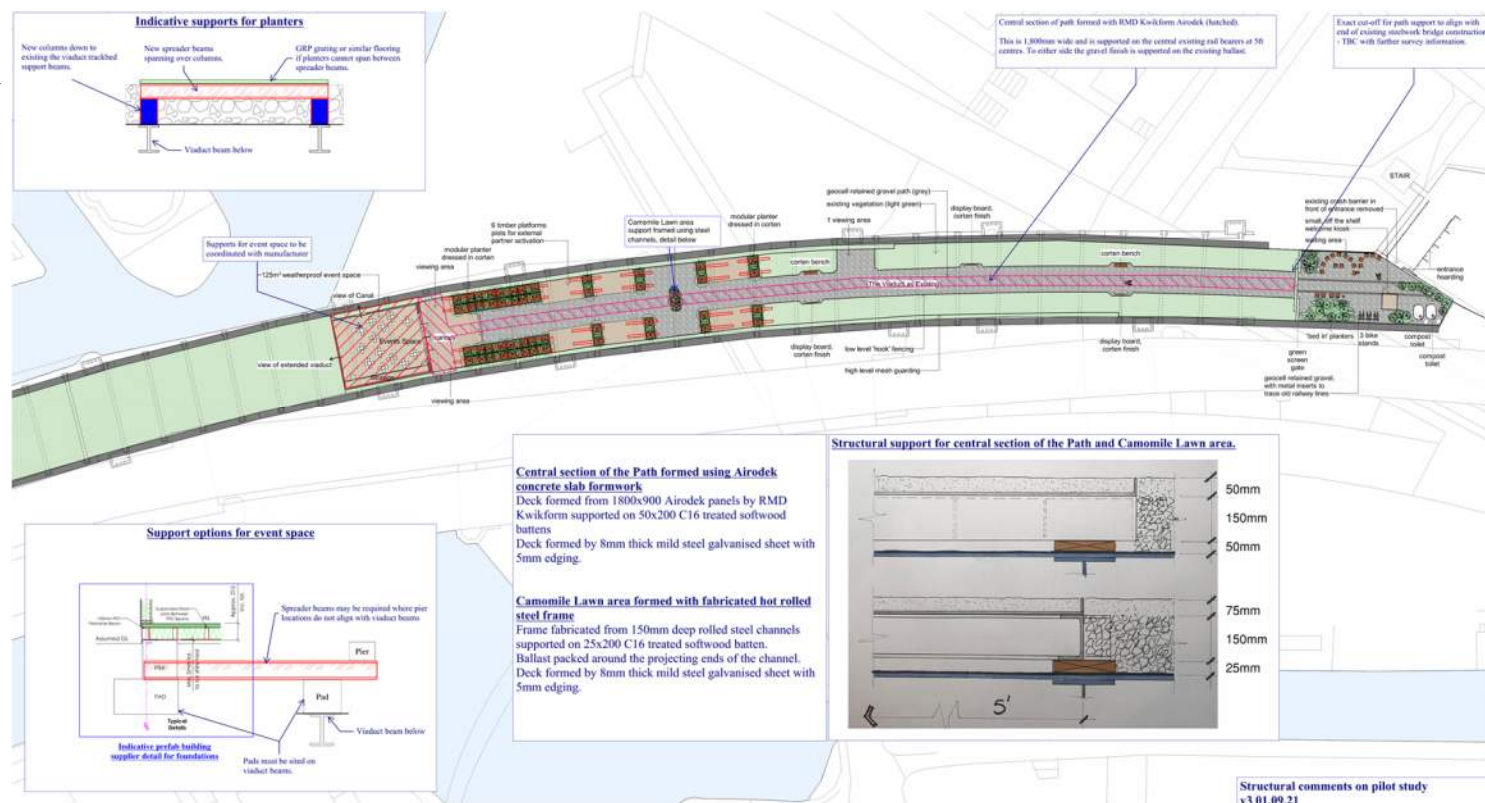
Locations of applied load are:

- path,
- discrete planters (indicative option outlined),
- event space building (indicative option outlined).

Solutions for all locations typically involve a structural beam to transfer load from point of application to point of support (rail bearing beam).

Note the proposed path does not allow for emergency vehicle access.

For further details and for the development of the path options, refer to the Path Options in Appendix 2 and Structural interventions in Appendix 3.



Proposed structural interventions

Access Path

Access Path

The path has a central higher capacity strip, for construction access and pedestrian access to either side.

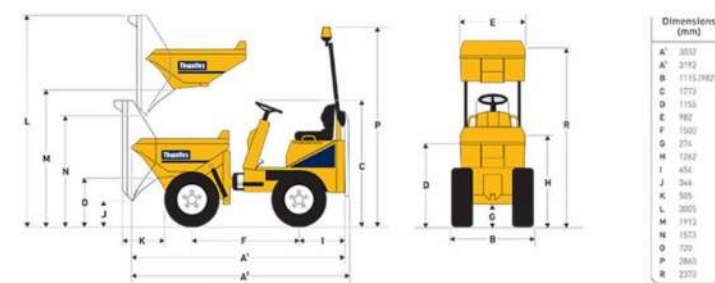
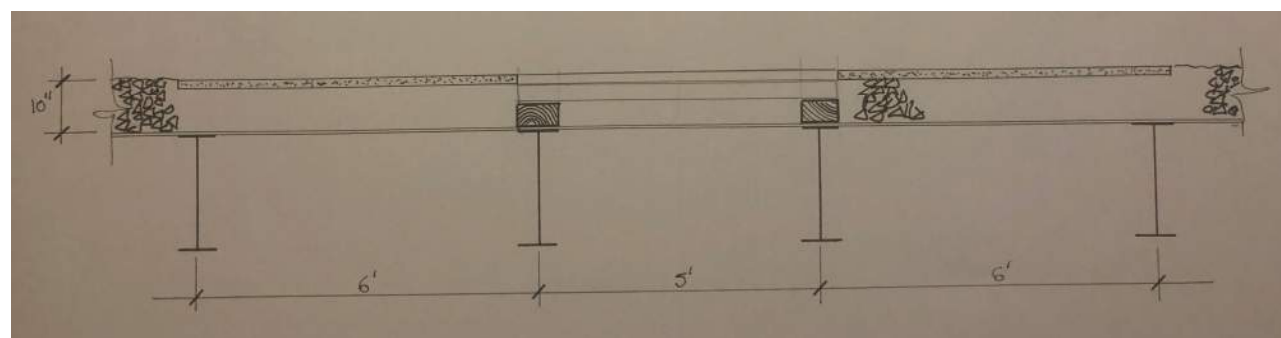
The path will be 4m wide. The central 1.8m will provide construction access and is to be constructed using reusable formwork panels. To either side gravel infill on top of the existing ballast will form the walking surface.

The 1.8m width will accommodate mini diggers and dumpers. Examples of which are shown opposite.

Services can be placed in conduit below the decking or placed in conduit to the site of the path.

Construction

- For the central construction access strip remove existing ballast and install timber battens above the rail bearers and the Airotek panels spanning between them. Finish with gravel cell infill.
- The treated softwood battens will run the length of the path and have gaps in them to allow drainage. They are not mechanically fixed to the historic fabric but sit on the asphalt/tar waterproofing to the deck plates.
- For the pedestrian access remove an equivalent depth of existing ballast to compensate for the addition of the gravel cell infill. Gravel cell infill is installed on top of the existing ballast.



*With optional narrow wheels

Path - Details

Central Construction Access Strip

Deck formed from 1800x900 Airodek panels by RMD Kwikform supported on 50x200 C16 treated softwood battens

Deck formed by 8mm thick mild steel galvanized sheet with 5mm edging, providing a 50mm deep tray for the gravel finish.

This is the proposed solution for this stage as it made from reusable components.

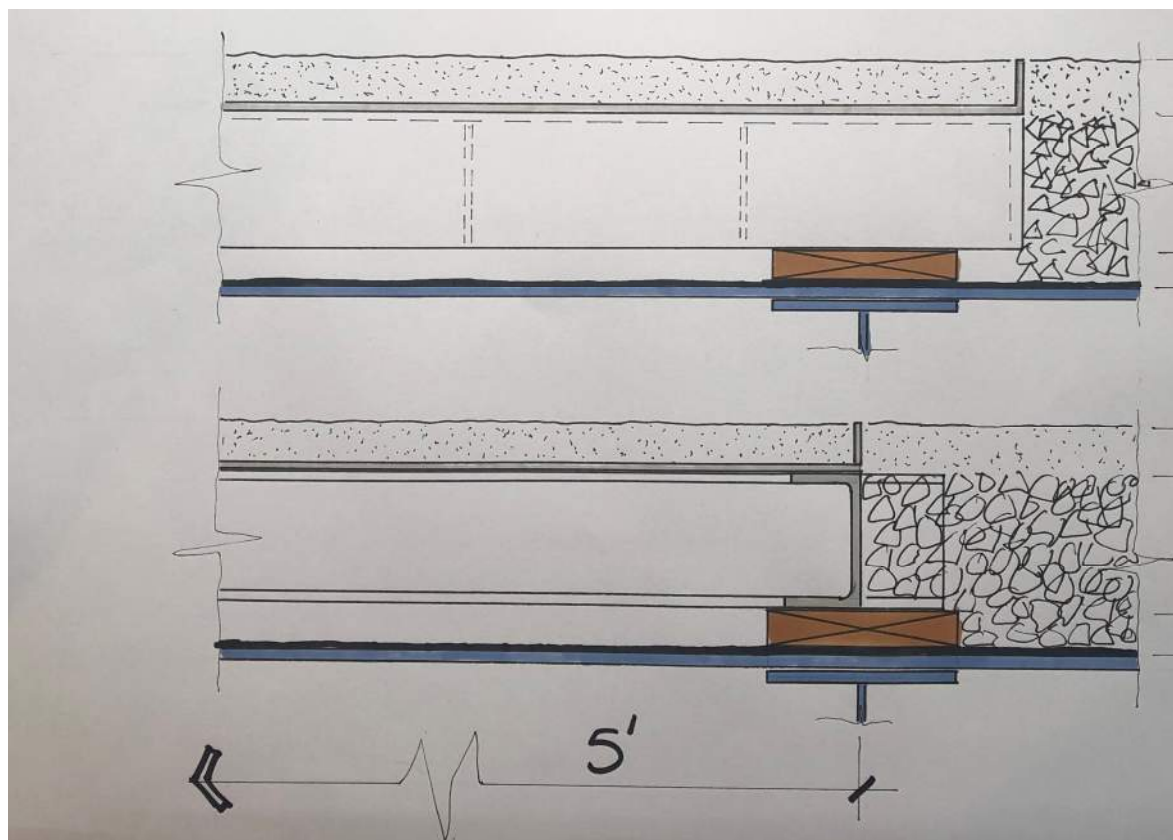
Details of the Airodek system are shown on the following sheet.

Camomile Lawn Area

Frame fabricated from 150mm deep rolled steel channels supported on 25x200 C16 treated softwood batten.

Ballast packed around the projecting ends of the channel.

Deck formed by 8mm thick mild steel galvanized sheet with 5mm edging, providing a 75mm deep tray for planting the Camomile lawn.

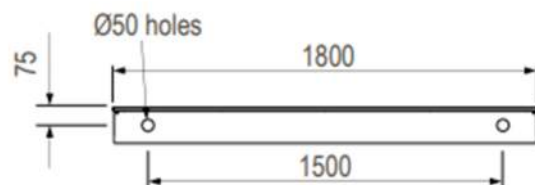


Airodek

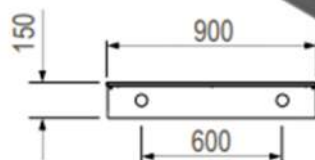
Airodek Panels

Manufactured from a welded, lightweight, powder coated, aluminium extruded frame with options of 9mm thick phenolic plywood or 10mm thick Alkus face material.

See Table Below for Allowable Slab Thicknesses

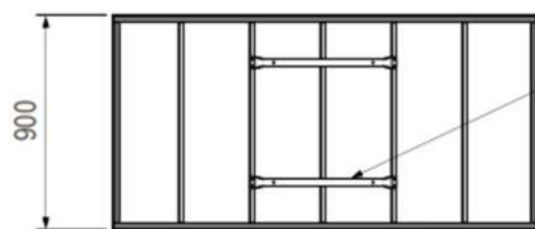


Side Elevation



Side Elevation

ribs @ 300mm ctrs



1800 x 900mm Panel Plan



900 x 900mm Panel Plan



End Elevation



Building Services Engineering - Electrical

Electricity Supply

The existing site does not currently have an electricity supply connection. However, surveys produced by Royal Haskoning have identified existing utility supplies in the vicinity of the site entrance in Beaufort Street and to the Bridgewater St Garage Carpark.

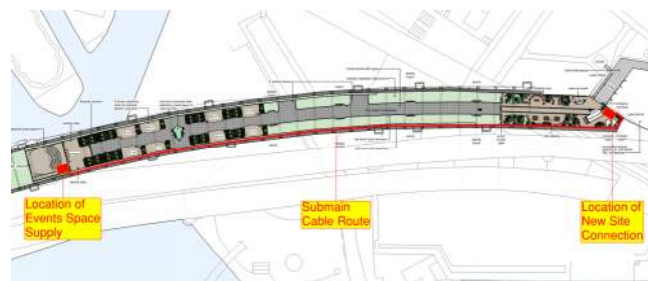
It is anticipated that a new single LV supply is required of less than 60kVA, connecting from the local ENWL network described above. It is proposed that a metered LV cut-out will be housed in an external feeder pillar near the site entrance to supply the site. This can be seen in the adjacent sketch.

The new site supply may provide power to several items listed below:

- External Lighting to Viaduct
- Food truck
- Events Space
- Welcome Kiosk

A budget quote connection application has been received from Electricity North-West Ltd (ENWL) based on these proposals which identifies capacity and feasibility to provide power described above.

Power will be provided in the events space via a new distribution board located in the back of house area. This will be supplied from a new LV armoured submain cable routed at low level along the length of the viaduct in a discreet location. See adjacent sketch.



Proposed Supply Locations

Electrical Services

The primary services required to the site are described below:

External Lighting will be required along the length of the viaduct to the park areas. This is described in further detail in the following pages of the report.

A power supply to the events space will be required to serve lighting and power in the building. The building is proposed to be modular in construction to allow ease of install and relocation in future if required.

Power shall be provided to allow cleaning of the space, electric heaters, ventilation, as well as to connect AV information screens for the visitors.

Powering the food truck will also negate the need for small generators and removing their exhaust fumes.

Electrical Services

The welcome kiosk will also require a power circuit served directly from the incoming supply feeder pillar point adjacent the entrance. Power will be provided to serve payment and ticketing facilities as well as an electric heater.

A self-contained food truck is currently proposed near the entrance to provide visitors with food and drink. The opportunity of providing a power point connection to electrically powered food services will be considered at the next design stage to avoid the need for on board generator to the truck which may provide a more sustainable solution.

A communications connection to the site is not currently proposed and 4g/5g connectivity to the welcome kiosk and events space is proposed to meet the needs of National Trust payment facilities and visitor Wi-Fi.

Requirements for automatic fire detection and emergency lighting to the development in line with BS 5839 and BS EN 1838 / BS 5266 will be determined at the next design stage in line with any fire strategy and building control requirements.

Electronic Security including CCTV and Access Control will be provided to meet the requirements of the National Trust practices. This will be developed during the design phase in line with any security strategy

Building Services Engineering – Lighting

Design Objectives

The key design objectives for the lighting design of Castlefield Viaduct are:

- Re-envision the viaduct from a majestic external daytime appearance to a night-time scene focused on activity within
- Create a magical experience which provides a different perspective in the hours of darkness
- Emphasise the historical function of the viaduct and storytelling, e.g. movement of locomotives
- Use lighting treatment to differentiate between the different zones along the viaduct
- Consider the viewpoints looking onto the viaduct and create intrigue for onlookers
- Interact with visitors, physically and digitally
- To consider the repurposing of the temporary lighting for the permanent scheme; circular design principles
- Use the lighting design to educate visitors
- Lighting to be aligned with Security requirements and strategy throughout design

Design Criteria

Artificial Lighting Guidance

The lighting will be designed with reference to with the following guides and standards, where appropriate:

- CIBSE SLL Code for Lighting
- CIBSE SLL Lighting Guide 6: Exterior environments
- CIBSE SLL Lighting Guide 14: Control of electric lighting
- British Standard EN 12464-2: Light and Lighting- Lighting of outdoor work places
- ILP Guidance Notes for the Reduction of Obtrusive Light GN01: 2020

Technical Requirements

- Minimise luminaire fixings to the structure
- Minimise light obtrusion
- Use luminaires of a suitable protection (IP) rating
- Minimise distraction to tram and train drivers
- Prevent lighting being seen from ground level

Building Services Engineering – Lighting

Lighting Concept

The lighting concept is formed by four elements:

1 Layers

A light touch to the lighting scheme with a base scheme of seating and planting illumination layered with portable lanterns which differentiates the different zones along the viaduct.

2 Playful

The lanterns engage with the public revealing elements that intrigue the individual. Handed out for the guided walk, the rechargeable lanterns act as an exploratory or guide light.

3 Movement

Free-flowing, flexible lighting integrated within the planting or from the lanterns matching those carried by visitors. The lighting to the viaduct is constantly changing with the movement of people, or plants in the breeze.

4 Tranquil

The lighting will transform the space into a different atmosphere in the hours of darkness. A subtle, low level lighting approach that provides a haven from the busy, bright city skyline.



Flexible planting illumination



Seating lighting



Lantern engagement



Integrated furniture lighting



Ground located lanterns



Natural planting illumination

Building Services Engineering – Lighting

Lantern Strategy

It is envisaged that the lanterns will be distributed to visitors within the welcome zone before entering the via the green screen gate to the 'viaduct as existing.' Once the guided walk is complete, the lanterns will be returned to the welcome kiosk to be recharged. The lanterns will serve a functional purpose as well as giving a unique and personal experience to all visitors.

The following design criteria form the key drivers for the lantern design:

- Functional glow-light to help guide visitors
- Lantern to take reference from locomotive history i.e. headlamps, signal lamps.
- Must be lightweight for children and adults to carry
- Battery powered lasting around five hours and recharged overnight within the welcome kiosk. The lanterns could be charged via solar panel; a solar cell installed onto each lantern or for increased power/reliability, the lanterns could be powered via a centralised solar panel system.
- Capable of repurposing lantern elements for the permanent scheme in the future.
- Use recyclable or reclaimed materials
- Opportunities for digital connectivity e.g. Bluetooth for an enhanced visitor experience and interactivity

It is anticipated that approximately 40 lanterns will be required.



Building Services Engineering – Lighting



Building Services Engineering - Mechanical

Building Regulations: Approved Document L2A (ADL2A) - Energy Efficiency requirements

In-line with the building regulations, temporary buildings do not need to conform to ADL2A energy efficiency requirements. A temporary building is considered any building that has a planned time of use of two years or less. As the proposed central building has a planned time use of 12-months, the building does not need to meet ADL2A energy efficiency requirements, however any new mechanical equipment installed will need to comply with the European ERP-Directive.

Mechanical Services - Central Building

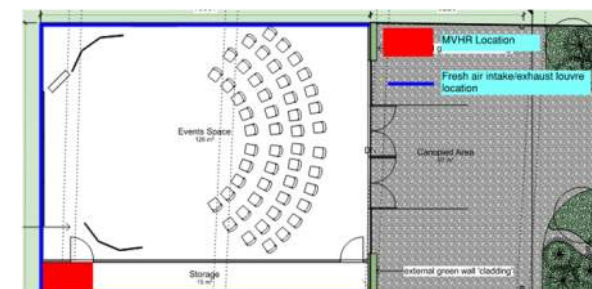
Heating - Heating will need to be provided in line with the recommendations stated within CIBSE Guide A (Table 1.5). Given the temporary nature of the space, it's recommended that local electric heating is installed as this will provide a cost effective solution. This can be in the form of electric radiant panels (long-wave), electric panel heaters or duct mounted heater batteries.

Cooling - It is envisaged that comfort cooling will not be required. The proposed space will need to be designed to meet the design requirements stated within TM52: The limits of thermal comfort: Avoiding overheating in European Buildings. An assessment will need to be undertaken at the design Stage to inform the project team of the minimum building design requirements to achieve compliance i.e. building fabric properties, local shading and minimum air change rates.

Ventilation - The proposed central building will need to meet the minimum ventilation requirements as outlined in Approved Document F. Assuming a maximum occupancy of 50 people (number of seats shown on floor plan) it is recommended that a vertically mounted mechanical ventilation heat recovery unit (MVHR) is installed to meet the ventilation requirements of the space, refer to figure 1 which indicates the proposed location. The MVHR unit will also require ductwork to a fresh air intake/exhaust louvre, it's proposed that any external louvers are located on either the North, South or West façade avoiding any modification to the East façade (entrance of the building).

Mechanical Services – Viaduct

Heating - The new viaduct entrance/café area does not require any form of heating due to it being an external space, however in areas where staff are to be stationed for a long period of time, i.e. welcome kiosk, it is recommended that local infrared heating is provided, this will provide staff with instant heat when required.



Proposed MVHR location

Building Services Engineering – Public Health

Public health Systems

The public health systems comprise of:

- Water services,
- Sanitary plumbing,
- Rainwater disposal.

In line with the aspirations of the proposed scheme, the public health systems have been developed to provide cost effective sustainable design solutions that are easy to operate and maintain.

Water Services and Sanitary Plumbing

It is not envisaged that a new cold-water supply will be required to serve facilities on top of the viaduct. Sanitary WC provisions will be provided utilising ecological WC's that do not require a water supply for flushing. Handwashing will be achieved via the use of anti-bacterial gels.

Drinking water will be provided via the use of bottled drinks supplied at designated vending points.

It is envisaged that any water required for cleaning sanitary provisions or other viaduct facilities will be brought up in a small mobile tank. The tank will be filled from a new mains cold water supply terminated at ground level. The new metered mains cold water supply will connect to a suitable connection point in United Utilities infrastructure.

The viaduct landscape planting will be selected to minimise regular watering or irrigation. Irrigation for the planting will be at optimum levels to ensure there is no residual water discharge and so there is a net neutral effect. Where irrigation is required, this will be achieved via the use of watering cans filled from a mobile water tank rather than via a piped irrigation system.

Rainwater Disposal

The drainage strategy for the Pilot Park is detailed by Royal Haskoning in section 4.1.1 of their Drainage Assessment.

This strategy is to use the existing system of transverse channel shaped carriers beneath the bridge deck that align with downspouts fixed to the supporting columns. Then gullies within the deck are provided along the length of these transverse channels but are currently buried under ballast.

The 2020 Detailed Examination Report report by Jacobs highlights some repair work is required and these repairs are highlighted in a previous section of this report.

Appendix 1

Site Inspection Report

Subject	2021-06-30 Castlefield viaduct walkover	Job No/Ref	282210-00
Date	30 June 2021		

ARUP

Contents

1	Introduction	1
2	General condition of the structure	2
3	Condition of the end web stiffeners	2
4	Condition of the deck plate spanning between rail-bearing beams	2
5	Review other points of interest for further consideration	3
5.1	Top flange of the main truss bottom chord	3
5.2	Bottom flange of the main truss bottom chord	3
5.3	Drainage channel locations	4
5.4	Cracks in piers	4
6	Summary of recommendations	4

1 Introduction

Arup visited the Castlefield viaduct (*Figure 1*) on 30.06.2021 to conduct a walkover and observe the general condition of the steel structure. The approximate extents of the section of viaduct inspected is indicated by the blue shaded areas on *Figure 2*. This accounts for approximately 150m, and includes 4 main spans between piers spread over two locations. The section between the two shaded area was reviewed but with reduced visibility. In attendance was Adam Morgan and Daniel Green. Conditions were dry, bright, partial cloud, approx. 19 degrees.

The structure was only accessible from below, so observations in this note are limited.



Figure 1 - Overview of viaduct

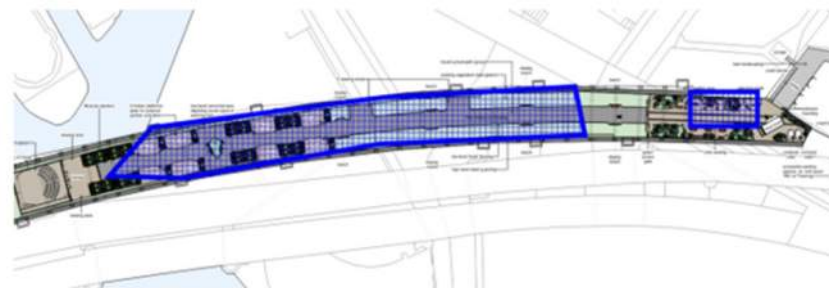


Figure 2 - Approximate extents of soffit review

The structure comprises deck plate spanning between longitudinal "rail bearers" supported by transverse fish-belly beams which span onto the top of the bottom chord of the main trusses on North and South elevations. The structure is expected to be structural steel, though possibility for wrought iron to be used instead of, or as well as, the steel.

From the desk survey of previous information, several points were identified for an initial understanding to review during the visit:

1. General condition of the structure.
2. Condition of the end web stiffeners – critical for structural capacity of the transverse fish-belly beams.
3. Condition of the deck plate spanning between rail-bearing beams.
4. Review other points of interest for further consideration.

Overall, it is recommended that a detailed structural condition examination is undertaken to review all aspects of the structure before any work is undertaken on the public space above. Particular attention should be made to:

- the end web stiffeners of the transverse fish-belly beams,
- the top surfaces and tight spaces at the pier heads,
- and the bearing points between:
 - longitudinal rail-bearers and transverse fish-belly beams
 - transverse fish-belly beams and main trusses at each side
 - main trusses at each side and the pier heads

Subject	2021-06-30 Castlefield viaduct walkover		
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2 General condition of the structure

Overall, the condition is 'satisfactory' with some discrete elements in 'poor' condition. Failure of the corrosion protection system is commonplace – refer to *Figure 3*. Surface corrosion is present across the structure, commonly in localised patches in the following five typical locations:

- Patches of the deck plate.
- The underside of each end of the fish-belly beams.
- The web stiffeners at each end of the fish-belly beams.
- Patches on any soffit element, including the transfer trusses between piers.
- Patches on the surface of, and seams between, structural panels of the main piers.



Figure 3 - General condition of the viaduct soffit

3 Condition of the end web stiffeners

The end web stiffeners, which align with the bearing point of the fish-belly beams onto the main trusses, are more exposed to the elements than others which is evident from the levels of corrosion. A proportion of end web stiffeners are significantly corroded and probable delamination of the section – refer to *Figure 4*.

The majority of end web stiffeners do not appear to have suffered more than minor surface corrosion.

From the limited observation points below, the other stiffeners also do not appear to have suffered more than minor surface corrosion.

It is recommended that a detailed measurement inventory of each stiffener is made to allow further assessment to determine the likely structural capacity of the beams at these locations.



Figure 4 - Example of significant corrosion and possible delamination of the end web stiffener on the fish-belly beams

4 Condition of the deck plate spanning between rail-bearing beams

The deck plate appears to be in reasonable condition. Surface corrosion is commonplace but from a distance, there does not appear to be any evidence of significant corrosion or section loss from the soffit.

It is recommended that the detailed structural examination of the viaduct includes trial pits in the ballast to observe the top side of the deck plate at several locations and at the positions of drainage points.



Figure 5 - Typical condition of the deck plate

Subject	2021-06-30 Castlefield viaduct walkover	Job No/Ref	282210-00
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5.3 Drainage channel locations

Three locations were observed between the metrolink surface carpark and the canal basin where new drainage channels had been installed since the 2015 Jacobs report – refer to Figure 8. At one location the down-pipe was leaking – refer to Figure 9 – the last rainfall appears to have been approx. 6.4mm 24hrs prior but followed a hot sunny day (21 degrees C).



Figure 8 - Example of new drainage channel



Figure 9 - Example of constant drip patch under downpipe joint.

5.4 Cracks in piers

Several cracks were observed in main structural piers that appeared to be more than simple surface paint cracks – refer to Figure 10 and Figure 11. It is understood that these columns have been infilled with mortared aggregate, which is likely to be the main structural element.

Further investigation e.g. NDT would be beneficial to understanding the significance and further work for these cracks.



Figure 10 – Location 1 - example of main pier crack



Figure 11 - Location 2 - example of main pier crack

6 Summary of recommendations

Overall, it is recommended that a detailed structural condition examination is undertaken to review all aspects of the structure before any work is undertaken on the public space above. Particular attention should be made to:

- the end web stiffeners of the transverse fish-belly beams – taking detailed measurements of each location,
- the top surfaces and tight spaces at the of the pier heads,
- and the bearing points between:
 - longitudinal rail-bearers and transverse fish-belly beams
 - transverse fish-belly beams and main trusses at each side
 - main trusses at each side and the pier heads
- the top and bottom flanges of the main truss chords - taking detailed measurements of section loss to allow further assessment of the implications of such section loss.
- trial pits in the ballast to observe the top side of the deck plate at several locations and at the positions of drainage points.

Main structural column cracks - further investigation e.g. NDT, would be beneficial to understanding the significance and further work for these cracks.

Appendix 2

Path Options

Path Options

Path Options

With no emergency options we have investigated three options for the central path.

Construction vehicle path

The central walkway is designed to accommodate construction vehicle loading and is finished with the gravel cell infill finish.

Note: in this instance emergency vehicles could be accommodated.

Pedestrian only path

A temporary construction track is removed when construction is complete and then a pedestrian only path with gravel cell infill finish is built.

Hybrid

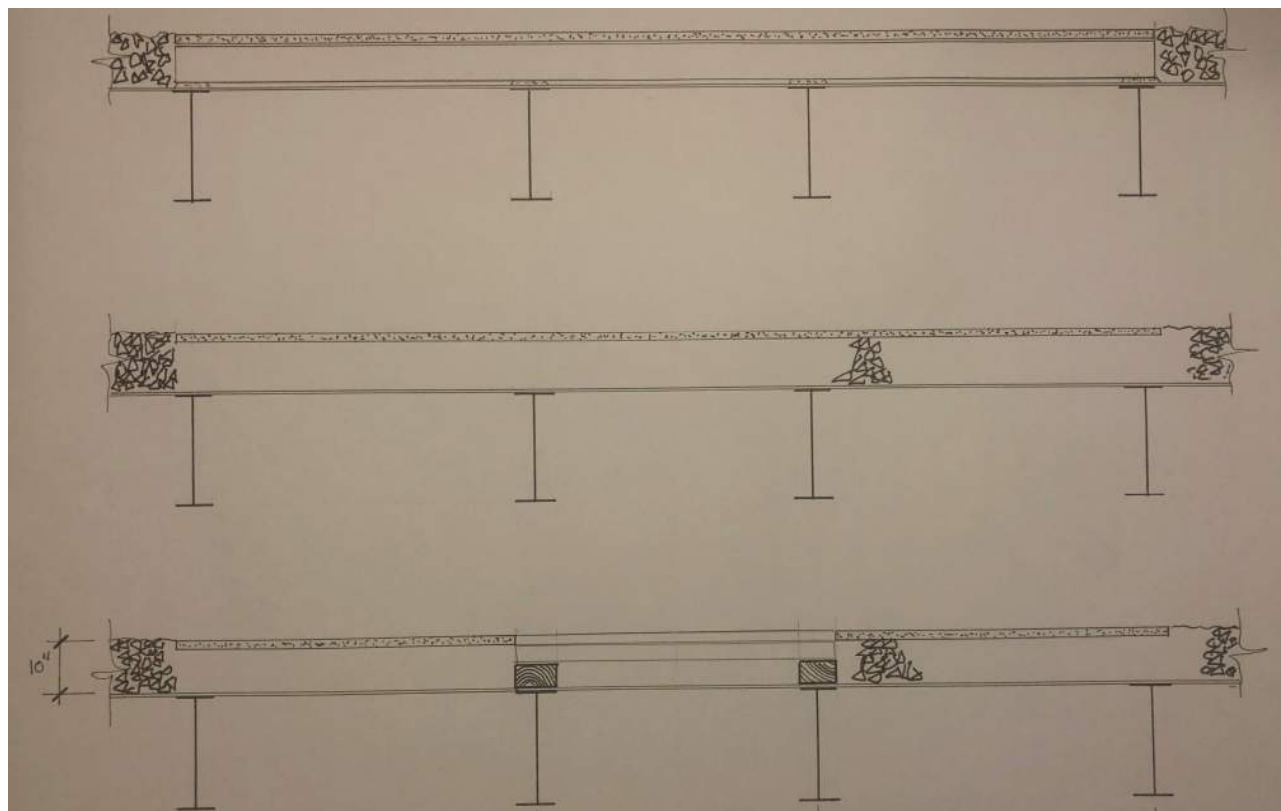
A section is designed for construction vehicle loading and the remainder is designed for pedestrian use only. Smaller construction plant, for example bobcat diggers and mini dumpers.

Path Construction Options

Top – Path for construction vehicles

Middle – Path for pedestrians only

Bottom - Hybrid



Path Options

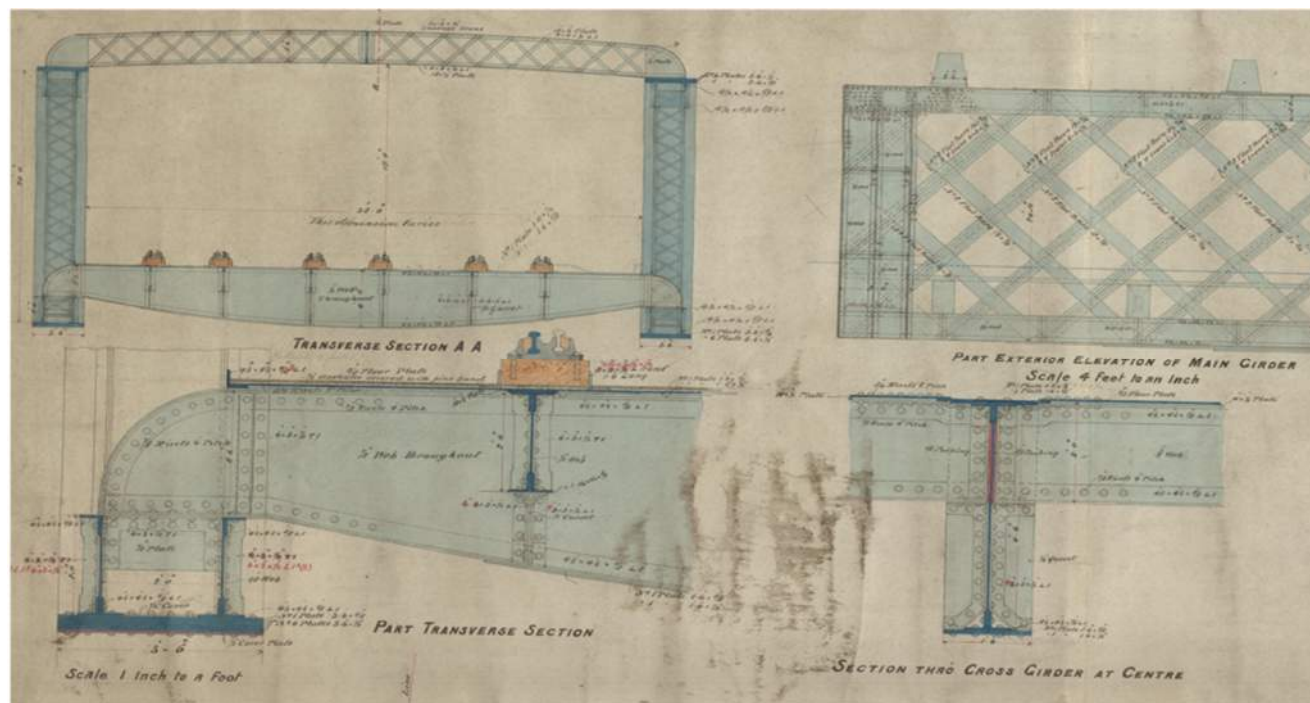
Existing Decking Construction

The existing decking is a 3/8" (9.4mm thick) riveted mild steel plate supported on transverse 'fish belly' beams and rail bearers.

The decking spans 5' (1,524mm) between rail bearers and 6' (1,829mm) between tracks.

The decking has approximately 25mm of asphalt as waterproofing, noted as tar in the Jacobs survey reports.

Before ballast was introduced the rails were originally supported on timber sleepers directly on top of the rail bearers.



Extract from Drawing No. 8

Path Options

Construction Vehicle Path

The central walkway is designed to accommodate construction vehicle loading and is finished with the gravel cell infill finish.

Note: in this instance emergency vehicles could be accommodated.

Construction

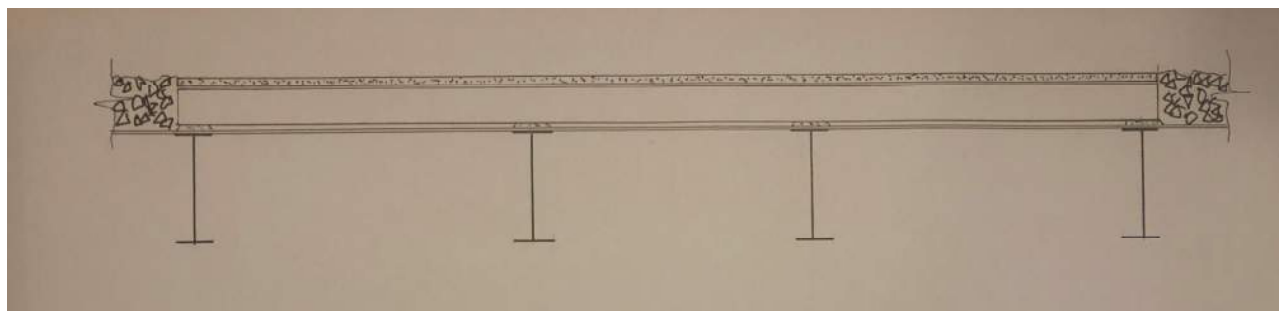
- Remove some of the existing ballast, exposing the existing deck to allow the installation of steel beams spanning between the existing rail bearers below.
- Steel beams bedded on a grout bed to so they can be brought to level.
- The steel beams supports a steel deck that in turn supports the gravel cell finish.
- Beams say 200 deep.

Allowable Uniformly Distributed Load

- Say 10kN/m^2 (could be up to the capacity of the primary beams at approximately 30kN/m^2)

Allowable Point Loads

- Say 15kN (to accommodate a wheel load from an ambulance)



Path Options

Pedestrian Only path

A temporary construction track is removed when construction is complete and then a pedestrian only path with gravel cell infill finish is built.

Construction

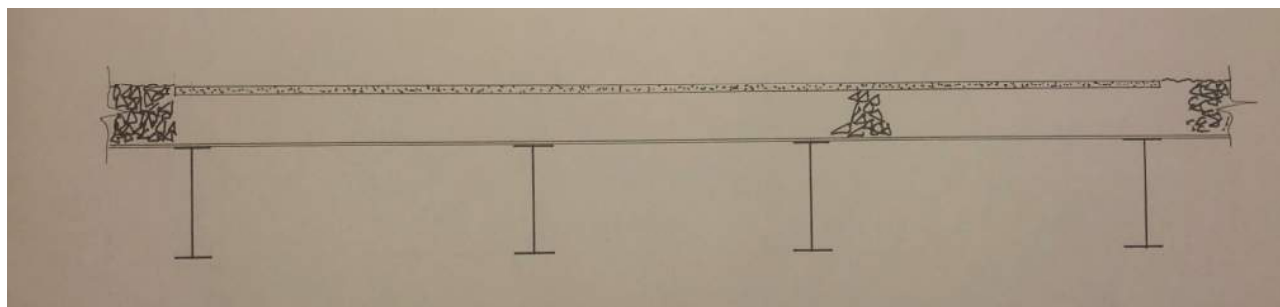
- An equivalent depth of existing ballast is removed to compensate for the addition of the gravel cell infill.
- Gravel cell infill is installed on top of the existing ballast.

Allowable Uniformly Distributed Load

- 3kN/m^2 (limited by the existing decking plates below)

Allowable Point Loads

- 4kN (limited by the existing decking plates below)



Path Options

Hybrid Path

A section is designed for construction vehicle loading and the remainder is designed for pedestrian use only. Smaller construction plant, for example bobcat diggers and mini dumpers.

Construction

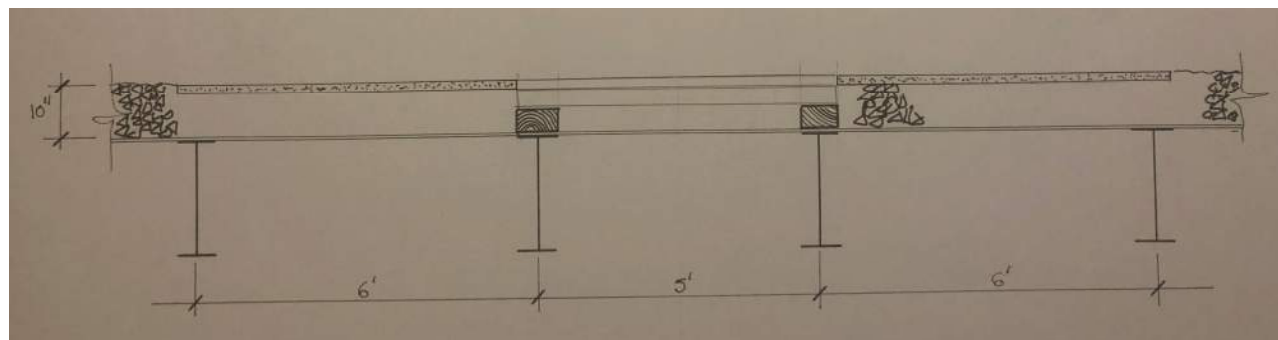
- In the central strip remove existing ballast and reinstate timber batten above the rail bearers and the Airodek panels spanning between them.
- The same gravel finish could be used for this strip, but it might be worth considering differentiating it as a maintenance route.
- Remainder of the path is constructed as the pedestrian path on the previous page

Allowable Uniformly Distributed Load

- Pedestrian areas - 3kN/m^2 (limited by the existing decking plates below)
- Construction Strip - Say 10kN/m^2 (could be up to the capacity of the primary beams at approximately 30kN/m^2)

Allowable Point Loads

- Pedestrian areas 4kN (limited by the existing decking plates below)
- Construction Strip - Say 10kN (No point in designing for an ambulance as the strip is too narrow)



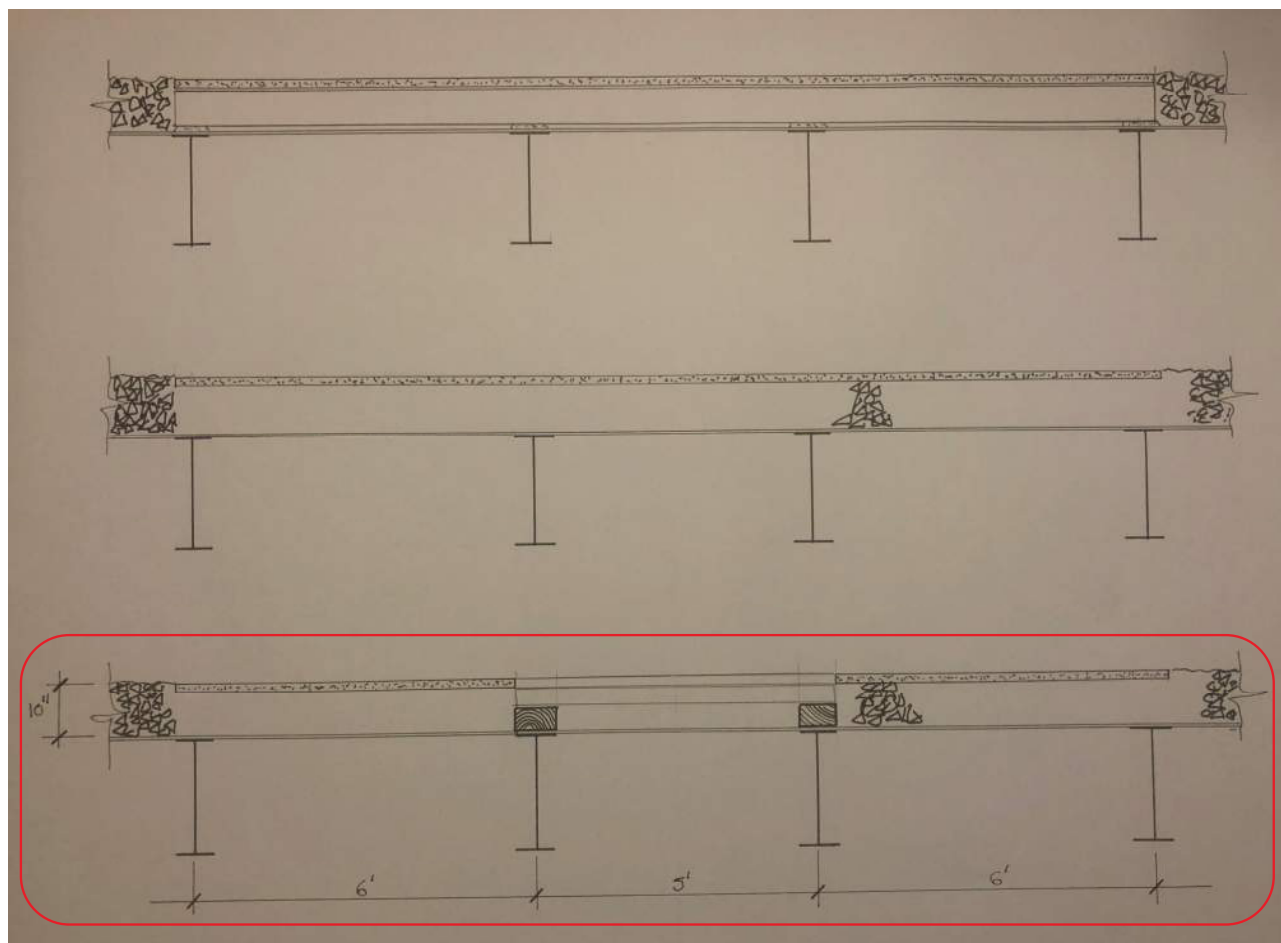
Path Options

Hybrid Path

The proposed solution for this stage is the Hybrid path with a central higher capacity strip and walking access to either side.

In developing the detail, shown on the following sheet, the sleepers have been removed and replaced with treated softwood battens. These will run the length of the path and have gaps in them to allow drainage. They are not mechanically fixed to the historic fabric but sit on the asphalt/tar waterproofing to the deck plates.

Services can be placed in conduit below the decking or placed in conduit to the site of the path. The latter would provide better access for maintenance.



Hybrid Path - Detail

1. Formwork soldier

225 deep Superslim formwork soldier 1.8m long by RMD Kwikform at 600mm centers spanning onto a 25x200 C16 treated softwood batten and 50x225 C16 noggins between.

Ballast packed around the projecting ends of the soldier.

Deck formed by 8mm thick mild steel galvanized sheet with 5mm edging.

2. Airotek – concrete slab formwork

Deck formed from 1800x900 Airotek panels by RMD Kwikform supported on 50x200 C16 treated softwood battens

Deck formed by 8mm thick mild steel galvanized sheet with 5mm edging.

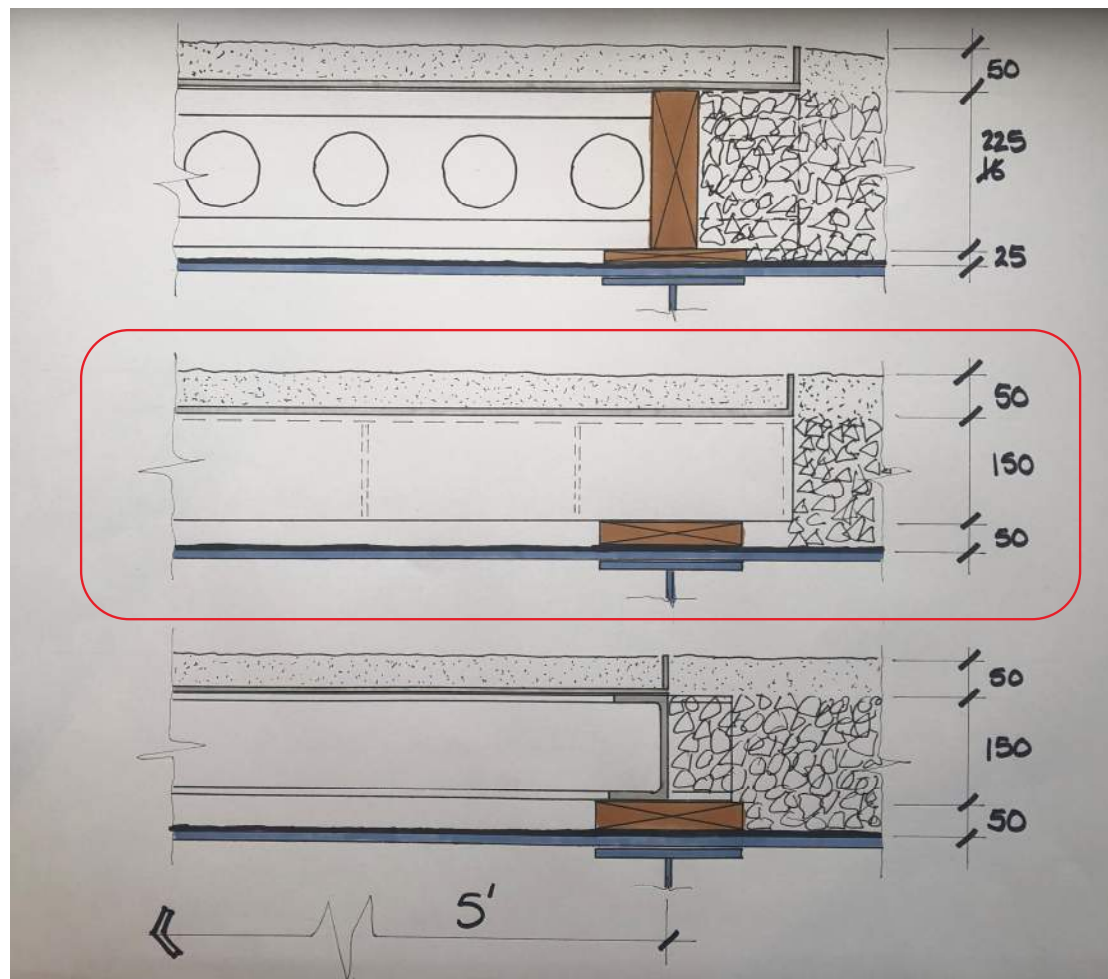
This is the proposed solution for this stage as it made from reusable components.

3. Fabricated hot rolled steel frame

Frame fabricated from 150mm deep rolled steel channels supported on 50x200 C16 treated softwood batten.

Ballast packed around the projecting ends of the channel.

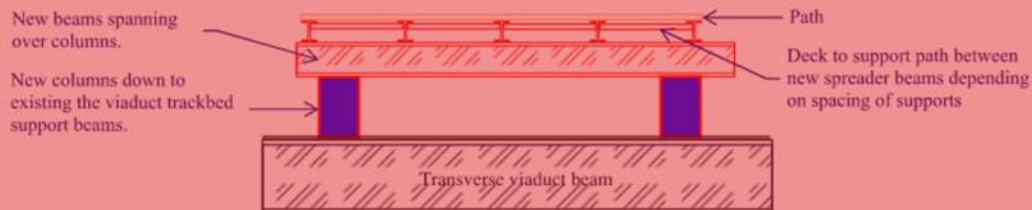
Deck formed by 8mm thick mild steel galvanized sheet with 5mm edging.



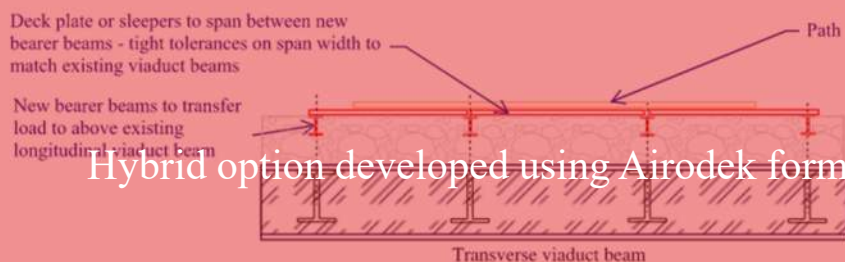
Appendix 3

Structural interventions

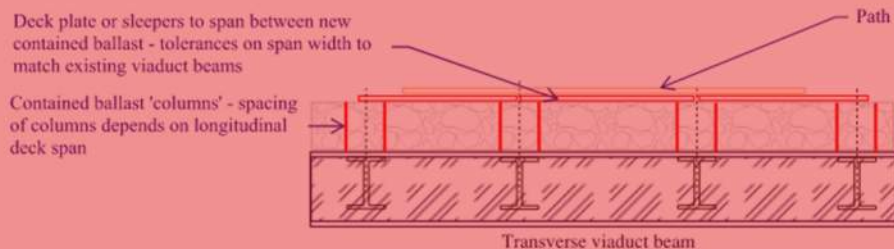
Options for path support



Option 1 - structural frame to transfer loads directly to viaduct beams



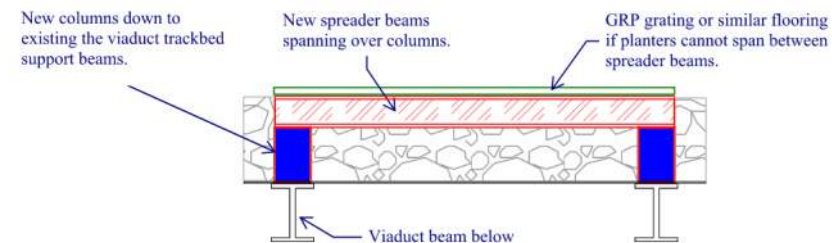
Option 2 - deck on longitudinal bearer beams



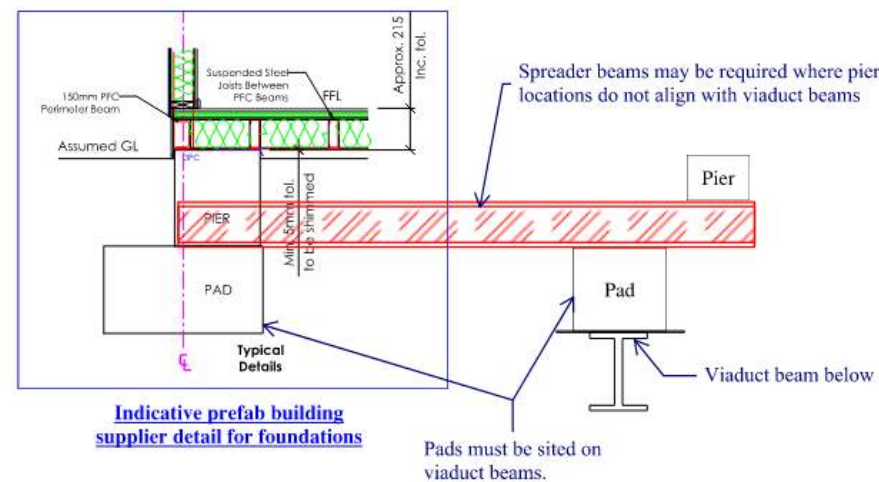
Option 3 - deck with containment of ballast above longitudinal bearer beams

Hybrid option developed using Airodek formwork

Indicative intervention for planter



Indicative intervention for event space



Structural Design Codes and Performance Criteria

Design Codes and Standards

The structural design codes and standards used shall be in accordance with current Building Regulations, Approved Documents and general best practice.

Relocation and Removal

The pilot park is to be designed as removeable, leaving the existing viaduct as found.

The event space is to be relocated to another National Trust property in Autumn 2023 when the Pilot Park closes.

Performance Criteria

The performance criteria are:

- A design life of 60 years for new-build elements, with life to first maintenance of 20 years.
- Provisions for robustness against disproportionate collapse shall be made in accordance with Building regulations Part A. The event space is classified as 2A.
- A temperature range to be considered for the new building structure of -5°C to +35°C for internal structure and -15°C to +40°C for external structure.
- Deflection limits for new-build structure shall be adopted in accordance with Eurocodes and to suit particular limits for cladding systems.
- Foundation settlements to new-build structure shall be less than 20mm.
- Fire resistance periods shall be determined by the relevant specialist, with integral or secondary fire protection provided as-required.

Below the viaduct



Design loads

General Loading

Dead and Superdead Loading

The existing and new-build structure will be designed to resist its self-weight, plus additional super-dead loads arising from floor finishes, services, ceilings, cladding and the like.

The magnitude of dead and super-dead loadings will be developed in conjunction with the architect as the design progresses.

Imposed Loading

Imposed loads are the variable component of the total load supported by the structure. They include the weight of people, loose furniture, fittings and the like.

The imposed loading allowances to be adopted in the design will reflect specific area-usage.

Key *uniformly distributed* imposed loading design allowances are:

- External walkway: 3.0kN/m²
- Event space: 5.0kN/m²
- Roof to event space: 0.6kN/m²

Emergency Vehicle Loading

Ambulance access is not required.

Using the national ambulance specification, the vehicle weight is 4,250kg and would impose an axle load of 30kN.

It is also assumed that fire engine access is not required, and that water facilities will be updated.

Barrier Loading

In accordance with BS 7818, the design load performance requirements for perimeter barriers will be:

- Design Class 2 for rails and posts according to Table 2 of BS 7818,
 - 700N/m applied to longitudinal members,
 - 700L N transverse load on vertical members,
 - 350L N longitudinal load on vertical members.
 - Where L is the intermediate post spacing.
- Class B (Normal Duty) infill panels according to Table 3 of BS 7818.
 - 1000N nominal load.



Appendix 4

History and Structural Form

History and Structural Form

Castlefield Viaduct

The Castlefield Viaduct was constructed from 1890, opening in 1893. This 370yard (330m) long viaduct has eight steel lattice girder spans and masonry arches at the approaches. The steel elements were constructed by Heenan and Froude and the masonry by M W Wormsley to the designs of W G Scott, chief engineer for the Cheshire Lines Committee. This note concentrates on the steel section, the main structural elements of which are:

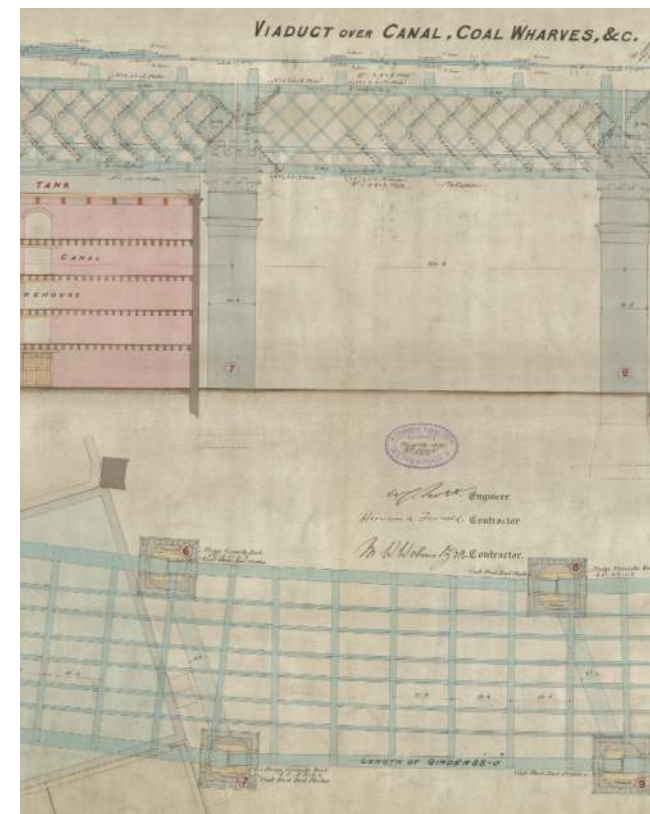
- Longitudinal girders supporting the rails typically spanning 13ft. 4in. (4m) between transverse 'fish belly' girders,
- Fish belly beams span transversely 38ft. (11.5m) to the inside face of the lattice trusses, across the full width of the viaduct on to lattice girders,
- The lattice girders are 20ft (approx. 6m) deep and span up to 175ft. (53m) onto cast iron cylinders, some 60ft. high,
- The cast iron cylinders are 10ft. 6in. (2.7m) diameter in the shaft and 13ft. 6in. (4.1m) at the base and are filled with masonry,
- Overhead, bracing links to the tops of the lattice girders together,
- Steel deck plates with waterproofing complete the structure.

Structural form

It was constructed against a background of structural material and technological development. The structural form being influenced by many factors including; physical constraints, the materials and technology available, local economic conditions and the designers and constructors experience.

The viaduct was required to carry trains into Manchester Central Station over the Bridgewater canal, coal wharves, warehouse and across the Manchester South Junction main line near Deansgate. These obstacle necessitating locating the girders at the same level as the trains rather than below it.

Extract from Original drawing No.7



Construction material

Following the development of the Bessemer Converter in 1856 and the Open-hearth furnace in 1867, enabling the economic production of reliable steel, the use of steel in construction became increasingly more widespread. In Britain by the 1890s steel had largely replaced wrought iron, perhaps hastened by the Tay Rail Bridge disaster in 1879. Although around the world some significant bridges and structures, such as the Eiffel Tower in opened 1889, continued to be constructed in wrought iron for another few decades.

In those early decades of steel construction, most production was for flat sheets or plate. There were limited types of rolled sections such as angles and this influenced the structural arrangement. The viaduct is mostly made from flat pieces of plate riveted together into larger sections or lattice trusses. The details show some small rolled angles have been used.

Rail bearers

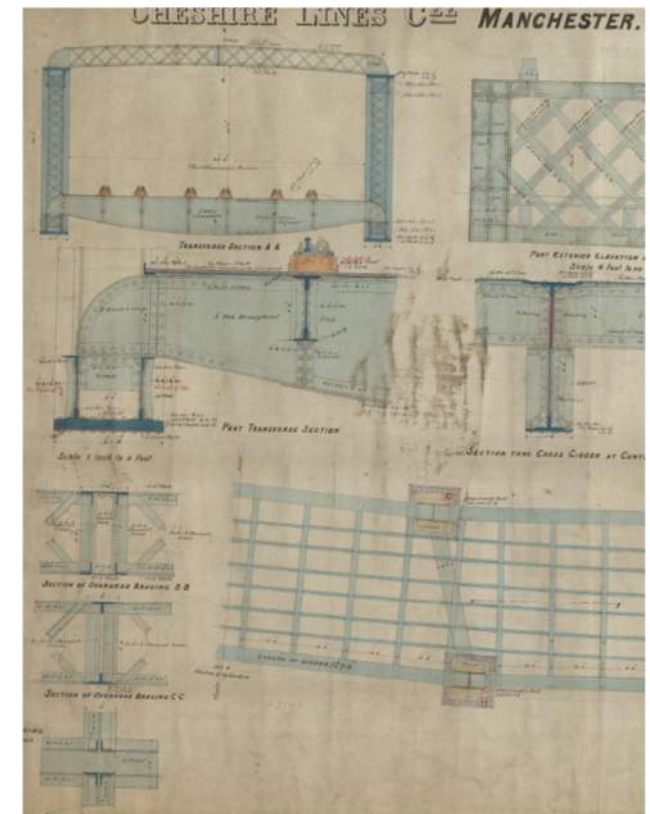
The rail bearers, supporting the rails, are made from plates and angles riveted together. They are constant depth as the material saved by making them deeper at midspan, where the forces are highest, was presumably less than the cost of the greater complication.

Fish belly girders

Load from the rail bearers is concentrated on 'fish belly' girders. These girders are so named because of the distinctive and attractive curved profile like the belly of a fish. Curving the bottom of the girder makes it deeper at mid span where the forces are highest, making it an effective use of material. Like the rail bearers the girder is made from steel plates and angles riveted together. However, because load is being concentrated on a larger girder the additional expense of making a girder with a curved bottom is paid for by the material saved, by reducing the depth near to the supports.

This can perhaps be illustrated by comparing the area supported by the longitudinal girder and the fish belly girder. Each rail bearer supports 6.6m^2 , whereas the fish belly girder supports 46m^2 . This is approximately seven times as much area, and if uniformly loaded with trains seven times the load.

Extract from Drawing No. 8



Lattice Girders

One of the most distinctive parts of the viaduct are the lattice girders. These form the sides of the viaduct and collect loads from the fish belly beams and transmit them to the cylindrical piers.

The lattice girders are 20ft. (6m) deep and 36in. (0.9m) wide beams with stacked steel plates forming the top and bottom or 'flanges', diagonal flats forming the sides connecting the two, all riveted together. It is a common structural system for the time, connecting smaller pieces of flat steel plate to carry heavy loads over longer distances. In this case up to 175ft. (53m). The evolution of this structural system is worth a short diversion as it helps to explain what each part is doing.

In 1820 Ithiel Town, of Connecticut America, patented a wooden truss system for use in bridges. This used crossed or a lattice of timber planks with over lapping timber planks for the flanges. It was known as Town's Lattice Truss or Town Truss and responded to the expanding railway networks need for bridges to be built quickly from readily available material and by unskilled labour.

In response to increasing loads and spans the lattice system was doubled forming a slender box in cross section. This development was patented in 1840 and retained the roof and roadway running within the depth of the girder.

The design was imported to Europe where it was adapted for use with wrought iron and steel flats. Rather than having the flat elements vertical for the top and bottom flanges these were laid flat, the connection formed with a small angle thus forming a wider, more stable box.

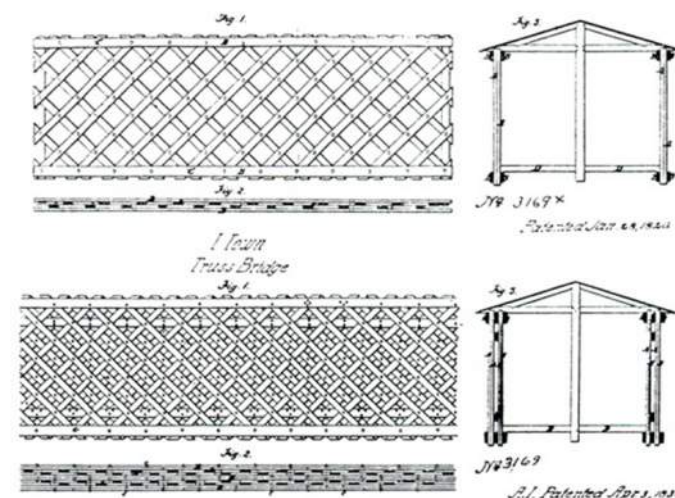
At the Castlefield Viaduct the top and bottom flanges were made up from stacked plates riveted together. Where the force in the flange was greatest, at mid span, more plates were used.

Following the theme of minimising the use of material, by only using it where it is needed, the lattice members vary. Towards the support, as the vertical load is progressively collected the diagonal members become wider in response to the increasing force.

Both the stacked flange plates and variation in the diagonals can be clearly seen on the drawings.

The ends of each lattice girder are seated on a lab of Shap granite to evenly distribute the concentrated load from the girder into the cylindrical pier. The drawings show each girder is separate from its neighbour. The gap presumably allowing for thermal movement in this 270yd. (330m) long structure.

Lattice Truss Bridge, Ithiel Town



Overhead bracing

Over the railway and trains there is bracing linking the lattice girders together.

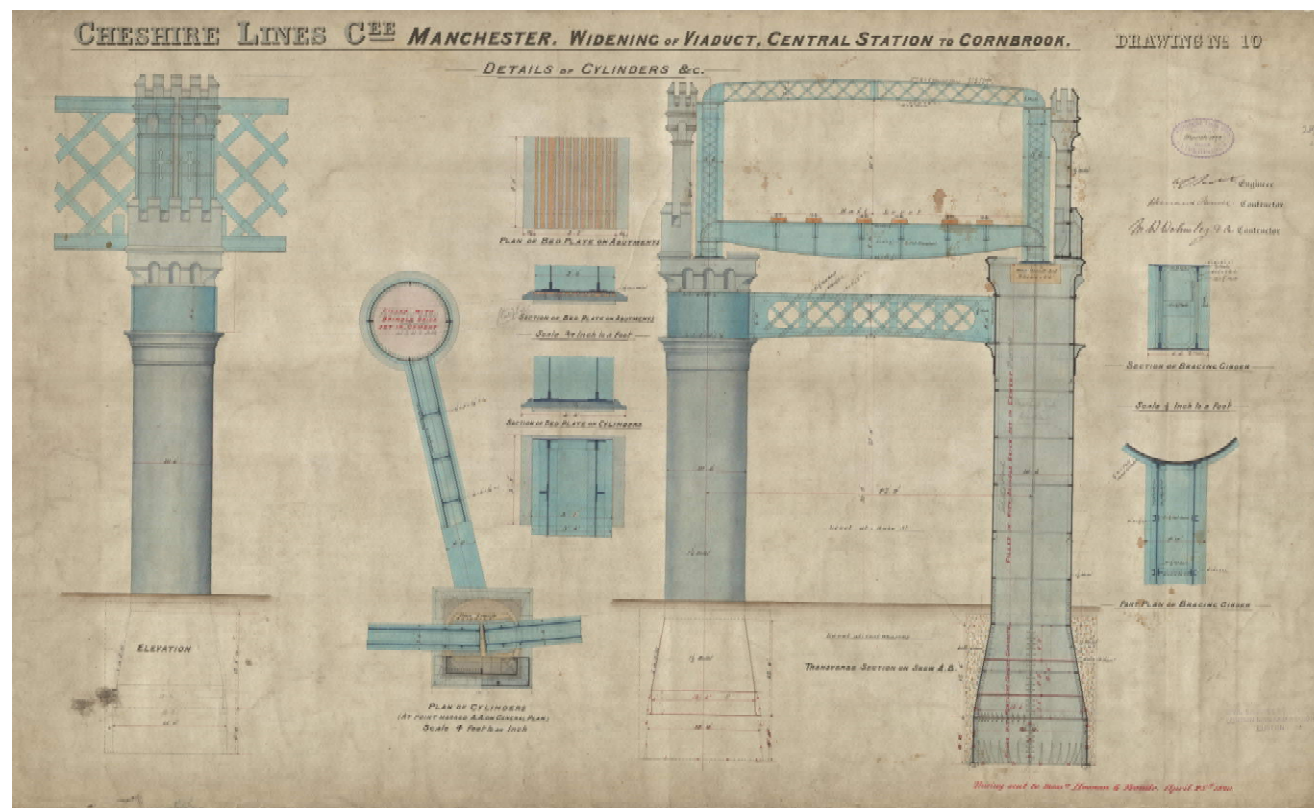
In the latter part of the nineteenth century Timoshenko notes in his History of Strength of materials that 'several failures of open bridges occurred in Western Europe and Russia'. In this context open means a bridge where the tops of the trusses are not connected.

The original bracing has been replaced but it will be performing the same function, to prevent the tops of the lattice girders from twisting and buckling of the top chord. This enables the lattice girder to support a higher load.

Piers

Cast iron cylinders were made in sections, bolted together, and filled with masonry in a cement mortar. The base of the cylinders is flared to spread the load from the viaduct over a greater area. They are founded on rock 20ft. (6m) below ground.

Drawing 10



Appendix 5

CDM Hazard Register

Register reference									
Project	Castlefield Viaduct					Job number	282210		
Package/Topic						Design stage	Planning		
Remember: Avoid – Reduce – Control and Communicate relevant information to others									
Date (+ initials)	Area/Location of Risk Exposure	Description of Hazard and Risk Exposure	Mitigation of Risk (Potential or Achieved)	A	R	C	Further Action	By	Status
16/08/21 GH	Existing structure	Corrosion of the structure reducing capacity.	Undertake repairs identified in the 2020 Detailed Examination Report.	A			Complete survey to span 1. Confirm with Highways England their plan for the refurbishing the structure.	Highways England/ Arup	Active
16/08/21 GH	Existing Structure	Deck plates have limited capacity for construction vehicles and materials	Central path has been designed for mini plant with a maximum point load of 10kN			C	Construct path from the accessible end and fence off the rest of the viaduct to prevent vehicle access.	Arup/ Contractor	Active
16/08/21 GH	Rail	Viaduct is above one and adjacent to another.	Cordon off the end of the viaduct to prevent contractors or public straying onto the live railway.			C	Develop method statement in collaboration with Network Rail	Contractor	Active
02/09/21 GH	Contamination	Ballast contaminated. Paint also presents a hazard to health.	Mitigation is required to reduce the risk. Possible measures include covering of the ground with a temporary covering, removal of ballast and soil or processing ballast to remove the soil matrix, refurbishment of the drainage network.			C	A remediation strategy to be completed to support the future redevelopment	Royal Haskoning/ Design Team	Active
16/08/21 GH	Existing Services	Some electrical services noted on the drawings hung below the viaduct.	Provide existing drawings to the contractor.			C	Contractor to undertake site survey to confirm presence/absence of services and terminate.	Contractor	Active
16/08/21 GH	Access	Access of emergency services during construction	Evacuate from one end without vehicles.			C	Develop method statement	Contractor	Active