
Jacobs
Trams to Granton, BioQuarter and Beyond
South East Corridor
South Bridge Structures Report
The City of Edinburgh Council
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NIDDRY STREET SOUTH
WHISKY ROW

Trams to Granton, BioQuarter and Beyond
South East Corridor - South Bridge Structures Report

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1. Introduction

1.1 Purpose

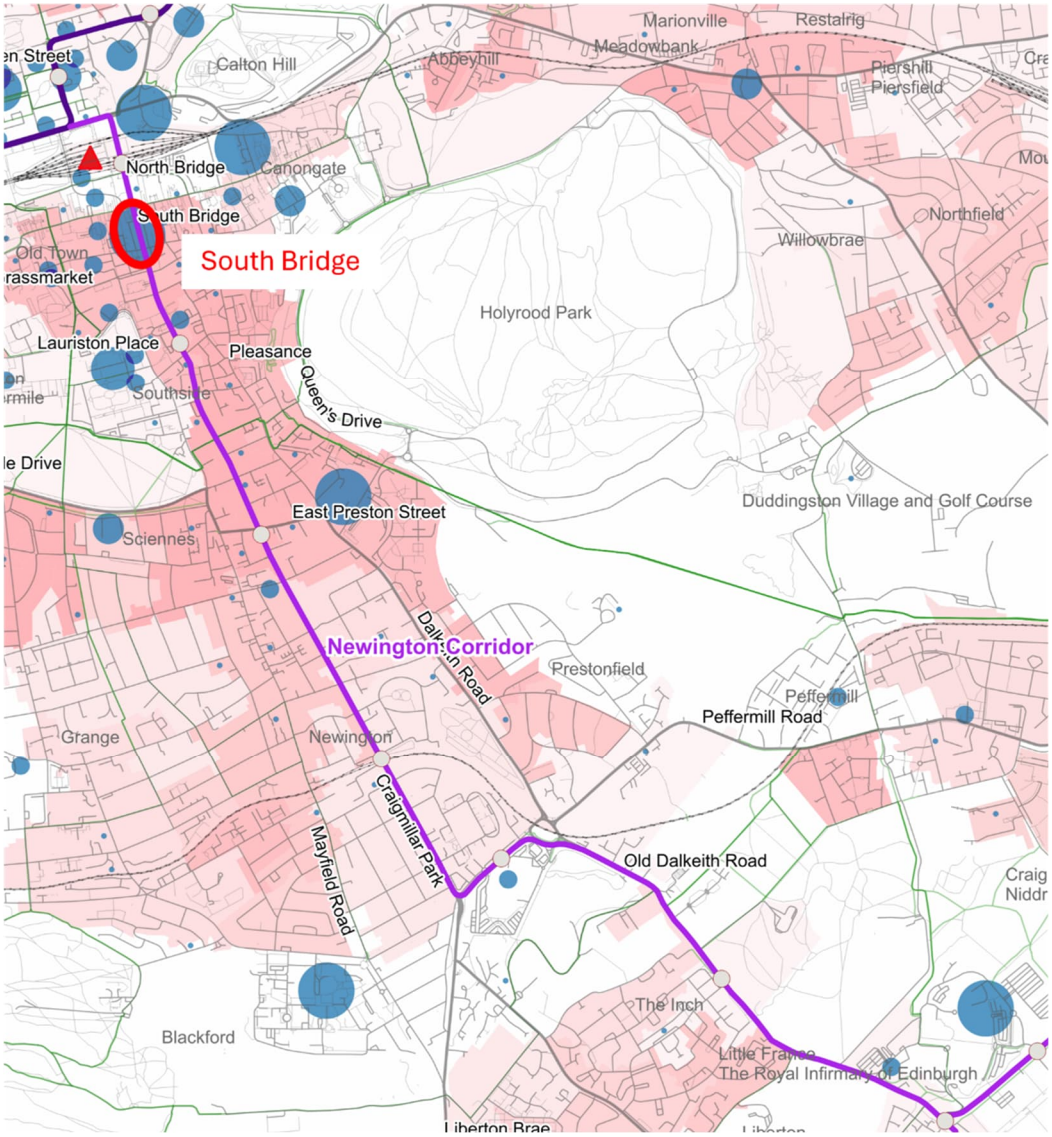
A north-south tram line is being considered as part of an expansion of the Edinburgh Tram network. Between the city centre and the south east, the proposed route would cross a number of recent and historic structures, one of these being South Bridge. This is a historic structure, built in the 1780s, and now substantially buried, with only the Cowgate span visible and accessible. This report considers the structural viability of operating trams across South Bridge.

The project is currently at Strategic Business Case and so considerations and recommendations are high level.

1.2 Location

The Southern Expansion of the Tram network would leave the existing route at Waverly Station. It will continue along Princes Street before turning right and traversing North and South Bridge, before continuing south along the A7 and A701 turning onto Lady Road by Craigmillar Park to Cameron Toll. The route will then proceed round the Northeast side of Cameron Toll shopping centre and along Old Dalkeith Road to the Royal Infirmary and BioQuarter. The South Expansion route is illustrated in **Figure 1.1**, with the location South Bridge circled.

Figure 1.1: South Bridge Location on the Proposed Southern Route



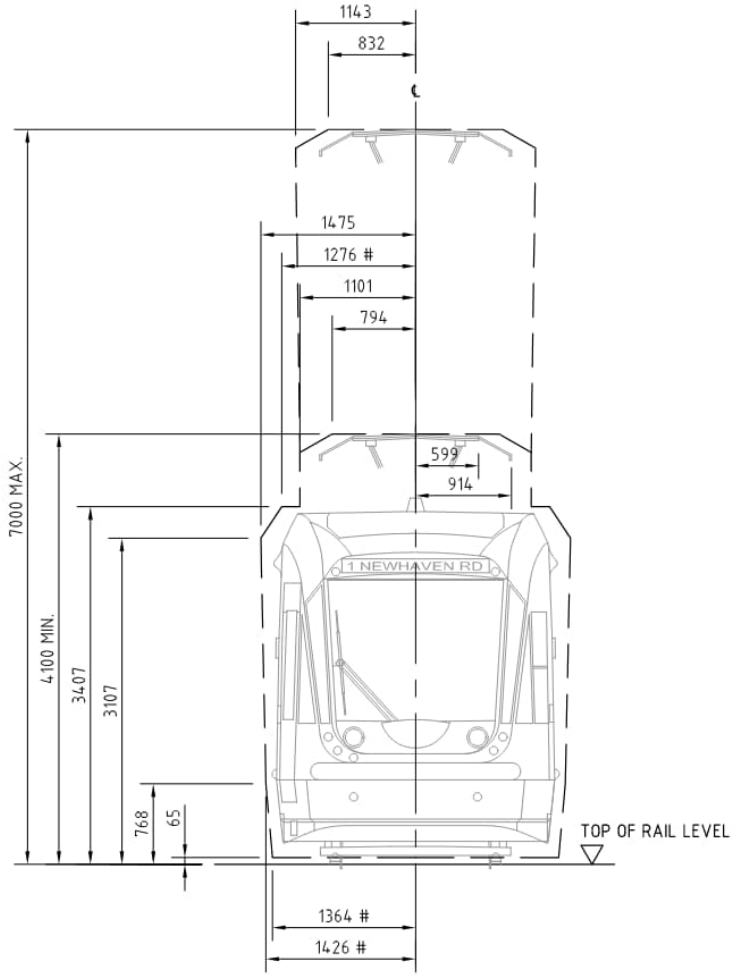
2. Scheme-Wide Considerations

It is anticipated that the proposed Southern route would align with the City of Edinburgh Council's policies and aims, with the expansion of the Edinburgh Tram network aligning to the Council's Mobility Plan. The following considerations under this section ensure that the proposed scheme meets its safety requirements, whilst its impact on the existing area remains beneficial to local community along the route.

2.1 Tramway Requirements

In keeping with the existing tramway clearances, the proposed scheme considers the dynamic kinematic envelope (DKE) for each tram, described in the Office of Rail Regulation's Guidance on Tramways document. This envelope factors in tolerances in the track gauge and alignment, while also making allowances for the effects of curvature. Clearances to other trams or structures are considered to be between the closets points of these envelopes. The dynamic kinematic envelope is shown in **Figure 2.1**.

Figure 2.1: Tram Dynamic Kinematic Envelope



2.2 Environmental

The area around South Bridge may be classed as a built-up urban environment with commercial properties at street level, and residential properties above. The form of the buried structure is know to comprise a series of stacked multi level arches although detailed records are not present. Condition mapping would need to be undertaken. Services would also need to be identified. In repurposing the carriageway for trams, the

opportunity exists to increase green spaces though this area with localised planting on the streetscape, just as has been done at similar locations along Leith Walk.

2.3 Local Heritage

South Bridge was constructed between 1785 and 1788, and designed to improve access between the Old Town and the South Side of Edinburgh by spanning the natural depression of Cowgate. Over time, the surrounding buildings concealed much of the bridge's structure, leaving only the Cowgate road span visible. This are is now a Conservation Area, with the structure and at least sixteen buildings on either side of its carriageway listed, as they remain from the 1780s expansion of the city. South Bridge and the associated housing developments are also recognised as a UNESCO World Heritage Site as being an *"outstanding and significant scheme in later 18th century town planning".*

This aligns with the design intent for the broader urban vision to modernize Edinburgh, replacing narrow, overcrowded streets with a more structured commercial district. South Bridge once completed became Edinburgh's first shopping street, marking the change to organised retail spaces rather than open-air markets.

The blockwork used in the construction is reportedly sandstone, sourced from various local quarries in Scotland.

3. Historical Data

3.1 Information Sources

South Bridge is a historical structure and therefore there is limited available information on the bridge. Jacobs undertook a thorough investigation to find existing drawings and research the history of the bridge was undertaken. The sources found and used in this report are detailed below:

Surveys and Inspections:

- Photos from the March 2016 Standing Building Recording of 85-87 South Bridge

Drawings:

- Large scale plan of South Bridge area before and after development (c1790), City of Edinburgh Council Architectural Drawings and Photographs https://canmore.org.uk/collection/76156
- Architectural drawing of the North and South Bridges, late 18th century, National Records of Scotland, 1790 https://catalogue.nrscotland.gov.uk

Written accounts, literature and images:

- National Record of South Bridge, (Canmore, 2024)
- National Record of South Bridge Link Bridge, (Canmore, 2024)
- Listing for South Bridge, (Historic Environment Scotland, 1970)
- The thread about the building of the South Bridge; a “remarkable feat of engineering and town planning” and one which you mostly cannot see (Arthur, 2023)
- Edinburgh Vaults (Palmer, Edinbrugh Vaults, 2024)

3.2 Missing Information

The information above has been useful in gaining an overview of the structure and its history. This gives an indicative understanding of its structural form and possible extents. It is noted that:

- Jacobs has not been provided with any inspection or monitoring reports for the structure. Therefore, its current condition is unknown. For the purposes of this report, it has been assumed that the structure is in fair condition and that there are no known major structural concerns.
- There is no available information on the foundations of the structure or their condition. Public geological maps and borehole logs are not available to give an indication of the expected ground conditions around the structure.
- The buried spans geometric and material properties, along with the actual exact extents of South Bridge have still to be confirmed.

4. Existing Structure

4.1 Overview

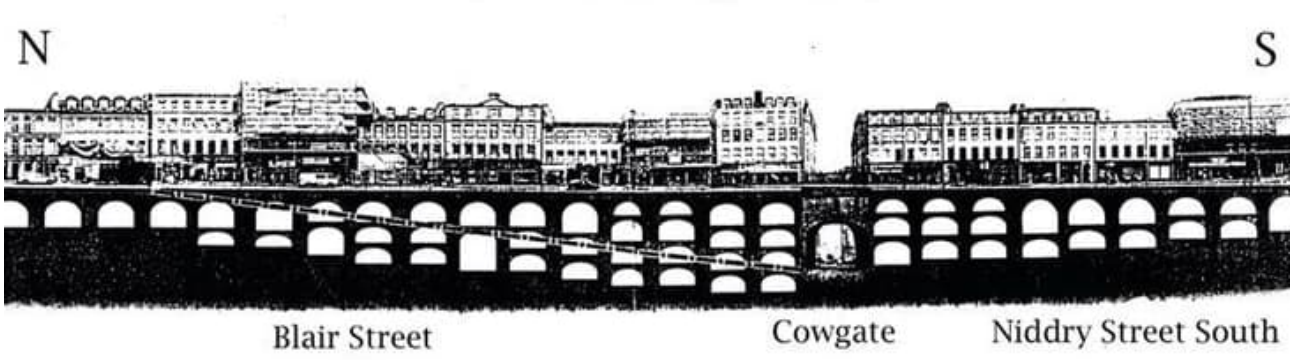
The historical records advise that South Bridge is a conventional multi-span masonry arch viaduct constructed in the 1780s and comprises nineteen spans (**Figure 4.1**). It was designed to link the Old Town's High Street with the expanding south side of Edinburgh, by spanning the Cowgate valley.

On either side of South Bridge the arches have been enclosed by full height buildings, with the high spans subdivided into vaults. These were originally intended for storage and workshops but were also used for housing and other activities. Today, basement level access into these vaults is either limited and/or restricted, with some utilised as social venues.

Referred to as the South Bridge Vaults, **Figure 4.2** provides an artists stylised illustration of what a sectional profile beneath South Bridge street may look like. Exact details have not been established.

Figure 4.1: Architectural Drawing Extract of South Bridge c.1790 (Source: City of Edinburgh Council)

Figure 4.2: Stylised Illustration of the Buried Structural Arrangement (Source: Mercat Tours 2024)



4.2 Site Description

Written accounts suggest that the bridge extends from Tron Kirk on High Street to the junction of Chambers Street. However, the architectural drawing available, shows the length of the bridge being shorter than this. It indicates that the arches start at the junction with Blair Street and extends as far as Chambers Street. This indicates that the length of the bridge could be anywhere from 160 to 230 metres, whilst alternative sources quote the bridge to be as long as 300 metres. In the absence of confirmatory data the extents of the bridge remain unknown. At street level, (**Figure 4.3**), the carriageway is approximate 16.5 metres in width and carries two central lanes of traffic with bus lanes on each verge. These are bounded by footpaths and the adjacent buildings.

Figure 4.3: South Bridge Street view (Looking North)

The bridges central span carries South Bridge (road) over Cowgate at grade, this avoids the natural depression of the Cowgate area. This vertical profile may be seen within **Figure 4.4**, which shows the street level of South Bridge (top left corner to middle right of image), with Blair Street running parallel and falling downhill to Cowgate.

Figure 4.4: Ariel view of South Bridge Denoting the Gradient Changes with Cowgate Below

4.3 Structural Form

4.3.1 Foundations

In the absence of construction drawings relating to the structural foundations, a review of the British Geological Society records was undertaken. This found no borehole records for the structure's foundations. Written records (Palmer, Edinburgh Vaults, 2024) suggests that the foundations reached 6.7 metres into the bedrock below the structure. It is not clear where this information originates however, the geology of the Old Town would be consistent with the record.

4.3.2 Piers

As with the foundations, there is currently no available information on the construction nor the material within these structural elements. Whilst they are likely to comprise masonry blocks sourced from local quarries, intrusive investigations would be required to confirm, the material strength and masonry classification.

4.3.3 Main Arch

The bridge is referenced as comprising 19 individual arches (Historic Environment Scotland, 1970). However, this needs to be confirmed, as an alternative drawing from the Canmore collection illustrates 16 individual arches. As neither drawing is dated, further investigation and surveys will be required to determine the exact number of spans and if some are of them are infilled. Again this is not presently known.

The depth of backing to the crown of each arch barrel is also unknown. Trial pits on South Bridge street would therefore need to be opened up to determine this depth and a classification of the backing material. This shall confirm the spatial depth to accommodate a buried tram track slab.

South Bridge has only one open span, and this crosses Cowgate Street. This is approximately 9.4 metres high and 9.1 metres wide, as shown in Figure 4.5. Significant staining and deposits of efflorescence was observed on the soffit of the arch. This suggests water from the carriageway above is seeping through the backing of the arch barrel. In addition, a longitudinal crack in the soffit of the arch barrel was noted. The presence of telltale gauges, confirms this defect is known and is being monitored by City of Edinburgh Council, although no records were forthcoming to determine its status.

Figure 4.5: Eastern Elevation of the Cowgate Arch (LHS), Longitudinal Arch Crack (RHS)

In 1929, the main Cowgate span was extended to the west by approximately 3.5 metres (**Figure 4.6**). The crown of the widened arch is lower than the existing arch to include a room linking the two adjacent buildings over Cowgate street. The Canmore records for 2004 suggest this link bridge comprises stone clad steel girders. No construction drawings have been found illustrating the structural arrangement.

Figure 4.6: West Elevation of the Cowgate arch

4.3.4 South Bridge Vaults

The either side of Cowgate Street, the buried arches of South Bridge are enclosed on both sides by buildings which were erected after the bridge was constructed. Rereferred to as the South Bridge vaults, they are not visible nor accessible from street level, only from the basements of the adjacent buildings. It has not been determined which buildings have direct access, although it is known that some of the arches are commercially used. **Figure 4.7** shows once such full height arch span, subdivided into different levels.

Figure 4.7: Exemplar image of a sub-divided span (Unusual Venues 2024)

No comprehensive survey detailing the access arrangements or the geometric profiles have been located. Although from the available information, the vaults are approximately 5.5 metres wide and have a varying height, it is known that some have been subdivided to create additional levels since the original construction of the principal masonry arch structure.

4.4 Structural Access

The open span is fully accessible from Cowgate Street.

The South Bridge Vaults are only accessible via the basement so of the adjacent buildings. It is unknown how many of the vaults are currently being used or are accessible. It is also likely that some of the flats in the buildings on either side of the bridge may have private unknown access to the vaults. Many of the vaults are interconnected with access between them, however some are anticipated to be isolated spaces with no interconnectivity.

4.5 Geotechnical Information

A review of the British Geological Society database found no available ground investigation records to inform the founding conditions of South Bridge structure. Bore hole records in proximity to the structure are available which support the position that the structure is founded upon rock.

4.6 Utilities

A large number of services are contained within the South Bridge carriageway. Due to it being a significant main road through the city with businesses and private flats, Gas; Water; Power; Streetlighting and Telecommunications etc. would be anticipated.

A utility survey would be required during the next phase of the project to determine the services present and their location.

4.7 Drainage

The structure has multiple stormwater drains located along its length. It is assumed that this water then goes through a drainage pipe, but it is unknown where the surface runoff water is ultimately transported to. Additionally, there are multiple gullies in the pavement which allow water from the guttering of the fronting buildings to be deposited onto the roadway.

During the next phase of the works these should be located and mapped.

5. South Bridge Tram Proposal

Multi-span masonry arch viaducts are known to be a robust solution for light rail and vehicle use. This is due to conventionally filled masonry arch structures providing excellent load distribution, making them ideal for supporting the combined weight of light rail and vehicular traffic. Provided the structural capacity of the structure can be determined, this will align with the intent for South Bridge, to carry two tram tracks in addition to existing vehicular and pedestrian traffic. By utilising a continuous buried track slab, dynamic loads such as traction and breaking forces, may be accommodated safely.

Whilst the spatial layout of the tramway along the bridge has not been finalised, it is assumed, that the double tram tracks will run centrally down the centre of the carriageway with OLE poles between. Normal vehicle and bus traffic will run either side of the trams or in a similar manner to Princes Street. It is assumed the current 2.0 - 2.5 metre footpath on either side of the carriageway will be retained and potentially widened.

5.1 Structural Form

The form of the existing structure is expected to be retained, with the tram tracks running flush along the existing roadway. Should the depth of backing permit, then the existing carriageway surface will be lifted and excavated down to arch crown level, with care taken to ensure no over excavation and damage of the arch barrels. However, should the depth of backing be found to be insufficient, then the final carriageway level shall be increased and the cross section reprofiled.

A separation membrane would be laid between the soffit of the proposed track form and the South bridge masonry arch crowns. This will ensure these elements are structurally separate. The reinforced concrete track form will be laid along the length of the deck, with services diverted to accommodate.

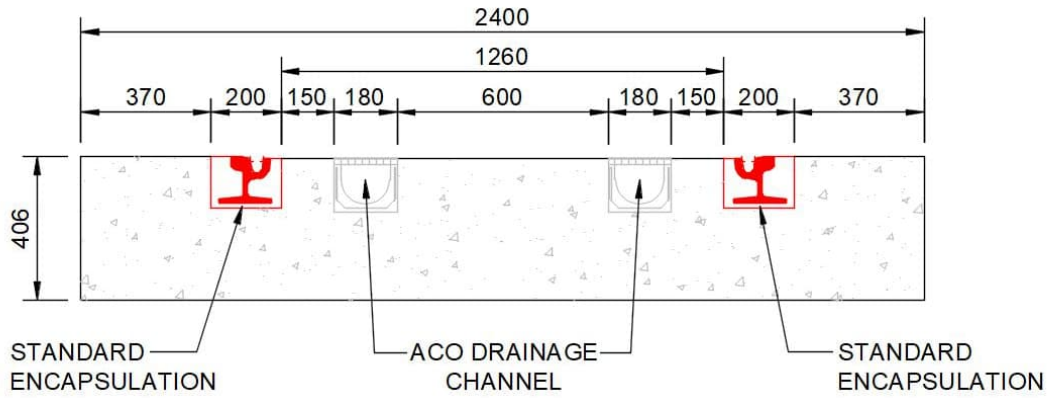
5.2 Proposed South Bridge Track bed and Track form

The tramway across the structure will consist of a double track line, with each track facilitating travel in one direction. These tracks will be standard gauge, with the tramway taking up approximately 6.5 metres of deck. The rails will be embedded within reinforced concrete track slabs to be flush with the adjacent vehicle running surface. The first stage of the slab construction will be a reinforced concrete pour across the whole width of the deck to function as a blinding layer to create a level top surface. This layer may include deeper shear keys to be poured transversely above the piers to allow a more even distribution of the longitudinal forces into the infill and subsequently the structure. The second stage of the reinforced concrete will then be poured with the embedded rails, this is the main track slab. It may be that two of these slabs are poured with a width of 2.4 metres each and normal road surfacing and tarmac is placed around them. Alternatively, the whole width of the deck may be covered in the second stage concrete pour, with this concrete making up the road surfacing. Both approaches have been deployed on the current route to Leith. In both cases, the first and second stage concrete need to have a minimum combined depth of 406mm.

The rails will be encapsulated, to provide vertical and lateral support to account for the dynamic loading from the trams. The concrete slabs will themselves be embedded within the granular fill layer, allowing the bridge deck to be raised to rail level. The longitudinal ACO drainage channels will provide drainage for the tramway, while also acting as derailment channels to prevent any derailed trams from colliding with the adjacent footpaths. A typical cross-section of a track slab is shown in **Figure 11**. This track slab section is based on the slabs used for the Edinburgh Trams network expansion to Newhaven. This is only indicative for this proposal, as a more refined design for the track slabs would be included as part of a detailed design for the structure.

As covered earlier, there is no available information on the construction depth between the road surface and the crown of the arch barrel. The historical information and drawings do not provide this level of detail. Therefore, further investigation is required. It should not be assumed that all the arches are the same elevation relative to the road level and therefore the construction depth should be established for all the arches.

Figure 5.1: Track Slab Cross-Section



5.3 Access to Structure

Existing access for walking wheeling and cycling, along with public and private vehicles will be accommodated within the reprofiled carriageway cross section.

5.4 Parapets/Guardrails

The parapets spanning the Cowgate span will be retained as parts of the works. It is assumed that no other parapets/guardrails will be installed, in keeping with the minimal street scape furniture of Princess Street. This shall be confirmed during the next phase.

5.5 Tram Utilities

Trams presently require Overhead Line Equipment (OLE) for power, with communication and signalling ducts also needed. The OLE would require additional vertical and lateral clearances and may be installed as per the existing network along Princes Street. These however could be negated were battery technology adopted to remove the need for additional overhead line infrastructure. The feasibility of this may be investigated along with the additional mass associated with such batteries, during the next phase.

5.6 Durability and Materials to be Used

Concrete construction is durable and would require minimal maintenance. The track slab would be grade C32/40 or C40/50 with ST2 blinding. All buried concrete surfaces will receive two coats of bitumen. The structure will be designed for a working lifespan of 120 years. The finishes used for the structure are displayed in **Table 5.1**, in accordance with MCHW Series 1700.

Table 5.1: Surface Finish Classes

Formed Surfaces		Unformed Surfaces	
F2	All other exposed surfaces	U5	Top of surface of deck (for waterproofing)
F1	Hidden surfaces	U1	Hidden unformed surfaces

The reinforced concrete elements will use grade B500B steel rebar in accordance with BS4449:2005. The nominal cover for the reinforcement bars will be sufficient to protect the rebar from corrosion across the 120 year life span.

5.7 Proposed Construction Sequence

The road running along South Bridge is a significant through route, therefore total closure may not be feasible. As successfully deployed elsewhere on the network expansion to Newhaven, some form of temporary one or two way running would be established. However, the road is 9.0 - 10 metres narrower than Leith Walk, where the traffic management during partial closure for the trams was challenging. Therefore, it may be advisable to close the road to allow a rapid construction work. This however would cause significant

disruption albeit for a shorter duration that works undertaken in parallel. It is therefore recommended that traffic management and be carefully considered during the next stage.

The construction sequences would be split into two stages: Advanced works, works at carriageway level.

5.7.1 Advance works

1. Excavate trial pits to determine the depth of backing over the crown of the South Bridge arches
2. Undertake a comprehensive utility and drain survey
3. Identify the location of the South Bridge Vault accesses
4. Undertake a 3D Laser LIDAR scan of the arch barrels and the Cowgate crossing access
5. Undertake a ground penetration RADAR survey of South Bridge and the basements facing South Bridge
6. Undertake dilapidation surveys of the adjacent properties
7. Undertake a principal Inspection for assessment of the structure and the accessible arch barrels
8. Undertake intrusive testing to determine the pier, arch barrel and abutment thicknesses in addition to the material strengths of the masonry and backing media
9. Complete a structural load carrying assessment of South Bridge, identifying any remedial works required.

5.7.2 Works at Carriageway level

1. Set-up site compound and install the traffic management
2. Established appropriate monitoring techniques for the vaults
3. Undertake repairs of the longitudinal crack within the Cowgate span
4. Divert all utilities along the footprint of the proposed tram track slab
5. Remove existing deck surfacing and excavate to required track slab depth, taking care not to damage underlaying arch barrels
6. Construct track slab, lay tracks and relay the reprofiled carriageway surfacing
7. Remove the traffic management and site compound and reopen the bridge.

5.8 Design Loads

To remain in accordance with the design loads used for the rest of the tram structures on the network, the design actions for South Bridge would be applied according to the amendments to BD 37/01 detailed in Sections 3.71 to 3.76 of Structures and Civil Engineering Requirements Specification for the Edinburgh Trams Network. This specifies that 0.5 of the Type RL loading model given in the now withdrawn BD 37/01 be used for the tram design.

This is recommended as no equivalent load model to RL is provided in the Eurocodes. This design load model will be subject to approval from the TAA and a departure from standard required.

It should be noted that braking and traction forces are much more significant in rail loading models, compared to similar vehicle models. This may result in tension and other unexpected forces acting through the bridge. A mechanism analysis would need to be undertaken to understand the failure mechanisms of the structure under tram loading. This may show that the current structure is not suitable to carry tram loading without additional works and strengthening.

The key documents to be used for design are:

- BD 37/01 Loads for Highway bridges
- ULE 90130-SW-SW-SPN-00049 V2 (Structures and Civil Engineering Requirements Specification for the Edinburgh Trams)

BS EN 1317 and CD 377 would be consulted for the parapet design.

In addition to the above, the design for South Bridge shall comply with the relevant parts of:

- Eurocodes and associated UK National Annexes
- British Standards
- Execution or Product Standards referenced in British Standards or Eurocodes
- Published Documents (PDs)
- The Design Manual for Roads and Bridges (DMRB)
- The Manual Contract Document for Highways Works (MCHW)
- CIRIA
- Disability Discrimination Act (DDA) 1995/Equality Act 2010
- Cycling by Design 2021
- Office of Rail Regulation Guidance on Tramways
- Edinburgh Tram Design Manual

5.9 Third Party Interfaces

The following Third-Party Interfaces have been identified:

- City of Edinburgh Council
- Transport for Edinburgh
- Historic Environment Scotland
- Key stakeholders such as business / property owners
- Utility companies
- Scottish Environment Protection Agency (SEPA)
- Nature Scot
- Sustrans

5.10 Checking Level

It is considered that due to the relative complexity of this form of structure, a full independent Category 3 level check would be required. This shall be confirmed by the TAA prior to commencement of the detailed design stage.

6. Recommendation

6.1 Recommendation

As part of the southern extension of the Edinburgh Trams network, this report has reviewed the information available with the view of considering the viability or otherwise of a Tram route utilising South Bridge. This 240-year-old multi-span masonry arch viaduct is a conventionally constructed arch, linking High Street with Nicholson Street, across the Cowgate. The study has considered the publicly available historical drawings and written records on the structure and the surrounding environment.

The overarching finding is that tram can be delivered across South Bridge. It is well established that multi-span masonry arch viaducts can accommodate actions arising from combined light rail and vehicle use. For South Bridge, providing that the structural capacity can be determined, and the defects pertaining to the Cowgate and any other span addressed, it is reasonable to anticipate the structure can be safely repurposed for use within a southern extension of the Edinburgh Tram network.

Nevertheless, given that the structure is large and old, significant further analysis is required. The record data reviewed by Jacobs has been found to be conflicting and can only be taken as indicative until confirmatory surveys and/or intrusive investigations are undertaken. From the overall length of the structure to the physical number of spans, or from the element thicknesses to the material strengths and backing material classification, further information is required.

With access to the buried spans restricted / limited by adjacent properties, the physical condition of the individual spans is unknown. No inspection records have been made available. To afford a better understanding of this structure's condition, the following work bank is recommended:

- **Radar Survey**

  Undertake a ground penetrating radio detection and ranging survey to inform upon the extents of the structure and any voids, to indicate the location of the arch spans.

- **3D Laser Survey**

  Create a digital twin of the existing asset by gaining access to the internal spans. This will establish the number of vaults, their extents and location in relation to the carriageway above. Additionally, all dimensions should be surveyed. A 3D map showing the full structure should be produced.

- **Condition/ Dilapidation Inspections**

  Complete a condition inspection of all the hidden vaults and the adjacent buildings to create a base line of the condition of these assets.

- **Utilities Survey**

  A detailed utilities survey should be undertaken at street level to map all existing services and their depths.

- **Drainage Survey**

  A detailed survey of the drains should be undertaken at street level to map all pipework, their falls and outlets.

- **Trial Pits**

  A series of deck level excavations over the crown of the deck arches should be undertaken to establish the available depth for a track slab, and the arch backing material.

- **Masonry Cores**

  Multiple cores of the masonry arch barrels, piers, spandrel walls and abutments both for the Cowgate and hidden spans should be taken to establish material properties.

- **Assessment of the Structure for Tram Loading**

  Undertaken an assessment of the structure to determine the structural capacity to carry tram loading and determine what if any strengthening measures may need to be incorporated into the permanent works.