HAMMERSMITH BRIDGE REPLACEMENT PROJECT: CAROLINE BRIDGE BY P&M Co. (GROUP 1)

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ABOUT HAMMERSMITH BRIDGE

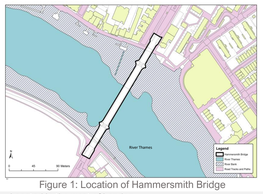


Figure 1: Location of Hammersmith Bridge

Located in the west of London
- The suspension bridge is in London Borough of Richmond, linking Hammersmith (north end) & Barnes (south end)

Grade II* listed bridge
- This bridge was constructed in 1984 to cater traffic of horses and carts during the Victorian Era.

The weakest bridge in London
- It can only support up to 7.5 tonnes, which is approximately around 22,000 cars and buses daily.

Numerous refurbishments and closure since 1990s
- Due to bombing, maintenance issues and structural hazards.
- The bridge has suffered overloading of vehicular traffic that it was not originally designed for.

Currently, the bridge is indefinitely closed for all vehicles, pedestrians, cyclists, and river traffic due to safety concerns.

CURRENT WORKS

Bridge was closed to all motorised vehicles

- Complete closure
- No public access of pedestrians and cyclists across the bridge
- No boats permitted to pass under the bridge

Sep. 2019

Apr. 2019 — **Aug. 2020**

Repairing works were undergone for the restoration of the bridge

PROBLEM STATEMENT

The development of microfractures in the existing bridge were detected by ultrasound sensors which have been installed in place

Further propagation of microfractures in the bridge footings caused by persistent heatwaves in 2019. Thus, the damage of the bridge pedestal becomes more severe.

The bridge pedestals are made of cast iron, a brittle material, that imposes higher risk of sudden collapse.

Fulham and Hammersmith council announced the full closure of the Hammersmith Bridge on 13th August 2020, since there is possibility of hidden cracks remaining in the bridge as it was poorly maintained over the years.

The chain links of the bridge are weak in sustaining the bridge.

DESIGN CONSIDERATIONS: DRIVERS AND CONSTRAINTS

SOCIOPOLITICAL ANALYSIS

Mayor of London
The reallocation of fund to support the residents during the COVID-19 pandemic causes most tenders to repair the bridge to be rejected. Priority is also given to other development projects, such as Crossrail 2.

Business
A survey involving 87 businesses in the Borough of Richmond was carried out and demonstrates the importance of having a time-efficient bridge solution to overcome the situation.

91% staffs feel affected by the closure of Hammersmith Bridge because they find it hard to travel to and from work

78% companies feel that the bridge closure deteriorates their annual turnover because sales are likely to decrease from less customers

79% suppliers and distributors rate the severity of the bridge closure from average to very severe impact (rating scale from zero impact to severe impact)

Local Community
The Richmond council consulted over 2700 residents to understand the importance of the bridge in their daily life.

67% of residents travel on the bridge using buses making buses as a prioritised means of transport for new bridge

Total of 79% of frequent users of the bridge with 47% of daily users and 32% of users who indicate as 'often' usage

79%

Rowing Council
The bridge closure has significantly disrupted the financial income of the rowing council. Annual massive events such as the Boat Race 2021 and the Great Race had to be cancelled. This further strengthens the need of having a safe long term bridge solution to reopen the river traffic.

CULTURAL ANALYSIS

The Hammersmith bridge is classified as a Grade II structure. Seven Grade II assets were identified within 200 metres from the bridge. There are also 3 main conservation areas identified and the Archaeological Priority Zones can also be seen in northern area of the bridge. Figure 2 shows the four proposed locations for the bridge that were considered.

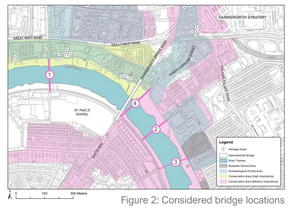


Figure 2: Considered bridge locations

ENVIRONMENTAL ANALYSIS

Air pollution
The emission of toxic gases from the construction may contribute to the air pollution. A 'Garden Bridge' concept inspired by the Ta'biat Bridge in Tehran is incorporated in the bridge design where small plants are grown to minimise the pollution.

Water pollution
Drainage system of the bridge will filter out large objects and contaminants that can pollute the river. Polluted water and contaminated liquids will be treated first before being discharged into the river.

Noise pollution
Sound dampening casing are installed on machines to avoid noise pollution during construction. Low noise paving materials and roadside noise barriers are included in the design to minimise noise during its service life.

STANDARDS & GUIDELINES USED

BS EN 1990-1—1 Actions on structure
BS EN 1991-1—1 Application on bridge design
BS EN 1992-1—1 Design of pylons, columns and deck
BS EN 1993-1—1 Design of cross and main girders
BS EN 1993-3—4 Road traffic actions on bridge
BS EN 1993-1-11 Design of cables
BS EN 10264-3 Design of cables

TRAFFIC ANALYSIS: NEW ROUTES

The northern entrance suffered from bus route changes - the new bridge's entrance is at Queen Caroline Street, as seen in figure 3. To accommodate for this development, Worlidge Street and Hammersmith Bridge Road will now be connected (which were unconnected previously).

More buses over bridge life span

Consequently, Worlidge Street will now only accommodate buses. As the southern entrance of Caroline bridge ends in the same location as Hammersmith Bridge's, the bus routes and bus stops will remain the same in that region.

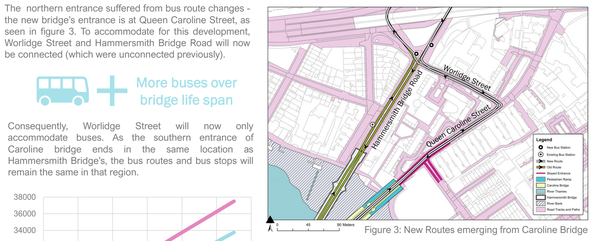


Figure 3: New Routes emerging from Caroline Bridge

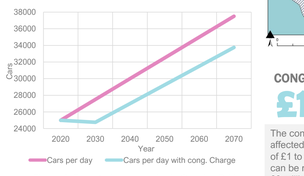


Figure 4: Expected cars per day in Caroline Bridge

CONGESTION CHARGE

£1-3 Figure 4 shows the expected number of cars the bridge is to experience per day with and without a congestion charge.

The congestion charge will discourage car use (as only private cars are affected) and promote public transport, cycling and walking. With a range of £1 to £3 per car crossing, the money raised from the congestion charge can be reinvested back for the bridge's maintenance, with an approximate £9 million made from just charging £1 per crossing.

ACCESS POINTS

Caroline Bridge is proposed to integrate into the site by connecting existing roads, Castelnau (south) and Queen Caroline Street (north). The bridge runs at an 8-metre vertical clearance from the river water surface, hence 4.4 metres above street level. Each entrance is elevated from street level with the following slopes:
- 1:22 slope for road lanes (vehicle and bike lanes)
- 1:12 slope for pedestrian footpath

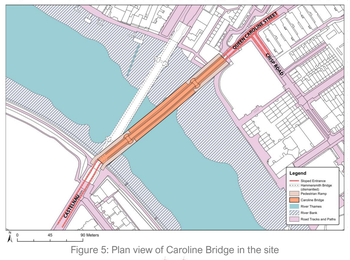


Figure 5: Plan view of Caroline Bridge in the site

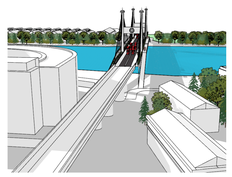


Figure 6: 3D Model of the north entrance

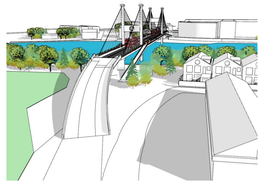


Figure 7: 3D Model of the south entrance

The north entrance of the bridge is located at the end of Queen Caroline Street where the bridge runs parallel to the street.

The south entrance of the bridge will be connected to Castelnau. The road lane will curve towards the alignment to provide a smooth navigation for the vehicle and the bike users.

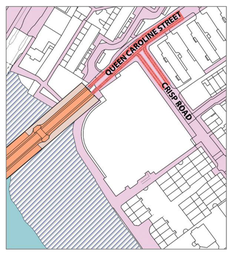


Figure 8: Plan view of the north entrance

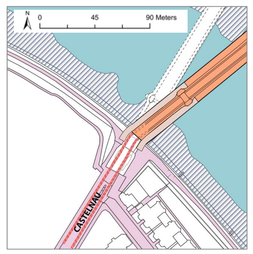
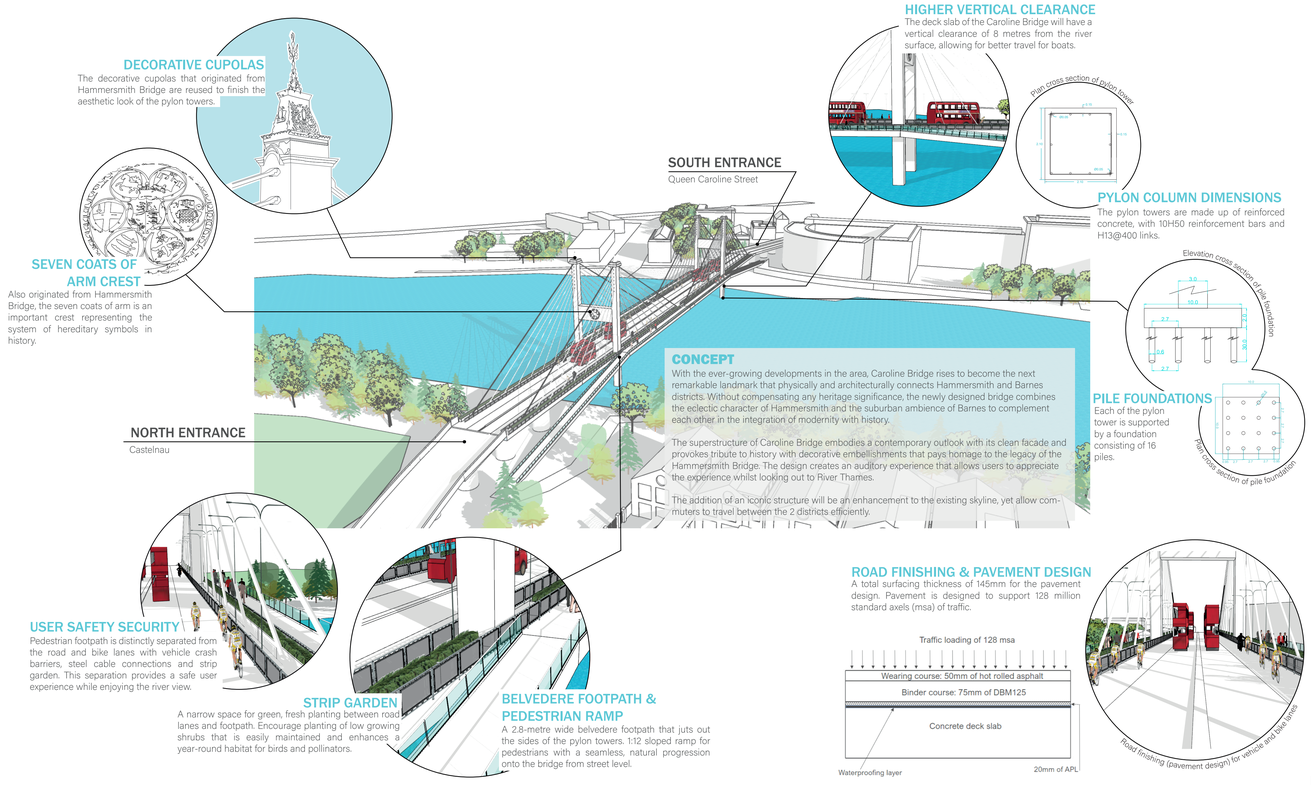


Figure 9: Plan view of the south entrance



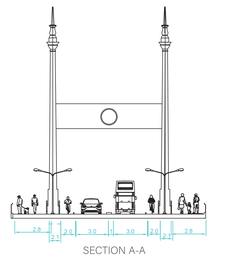
ROAD FINISHING & PAVEMENT DESIGN

A total surfacing thickness of 145mm for the pavement design. Pavement is designed to support 128 million standard axels (msa) of traffic.

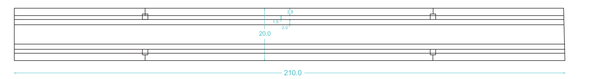
BRIDGE ELEVATION AND PLAN VIEWS, AND CONNECTION DETAILS

Caroline Bridge is a 20-metre-wide structure that will accommodate the following:
- Two 2.8-metre pedestrian footpaths (on both sides)
- Two 1.5-metre lanes for vehicle crash barriers and strip garden
- Two 2.0-metre bike lanes
- Two 3.7-metre road lanes

Additional notes:
- Vehicle crash barriers are installed between road lanes and footpaths, to prevent collision between the cyclist, pedestrian and the cables.
- For safety purposes and to prevent the collision between the bridge users, curbs are built between the bicycle lanes and the vehicle lanes, while vehicle crash barriers are installed to separate the cyclists and pedestrians.
- Adequate lightings and signages are placed between the barriers to ensure safety at night.

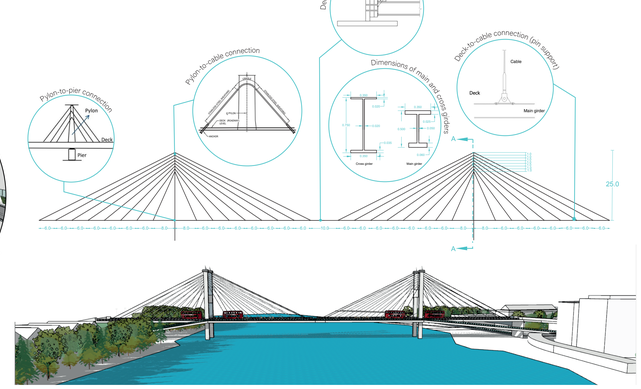


SECTION A-A



PLAN VIEW OF THE DECK SLAB

ELEVATION OF THE DECK SLAB WITH DIMENSIONS



LOAD PATH

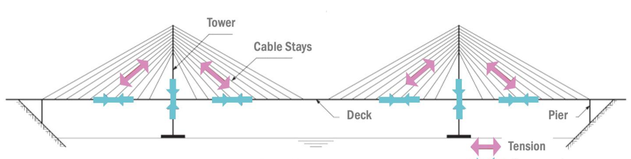


Figure 10: Load path

Deck → Cable → Pylon → Pier → Pile foundation → Soil

CONSTRUCTION SEQUENCE

The construction procedures are divided into six main stages. It is estimated that the bridge can be completed in 28 months.

Surface and subsurface investigation
Site investigation is carried out to study the soil properties and geology of the area. When it is ready for construction, warning signs and road barriers are put up for safety.

Construction of foundation
1. **Piled foundations are installed.** Drilling auger machine is used to bore into the soil until it reaches the required depth.
2. **Sealed cofferdam is placed.** Sheet piles are driven down into the soil by using a vibrating hammer.

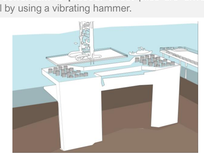


Figure 11: Construction of foundation

3. A temporary bridge is constructed to allow workers to access the cofferdam. The bridge can support low to medium loads such as concrete mixer and excavators.
4. **Dewatering and excavation of materials** within the cofferdam.
5. **Erection of concrete slab as a sealing cap** at the bottom of the cofferdam. Concrete is poured and anchored to the bored piles.
6. **Installation of pile cap** to support cranes and machines when installing the pylons.

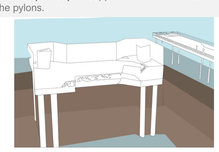


Figure 12: Installation of pile cap

Installation of pylon segments
Cranes are used to lift the pylon segments to its final position.

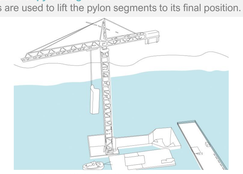
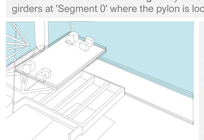


Figure 13: Installation of pylon segment

Installation of ladder deck
1. **Cantilever construction begins** by installing the main and cross girders at 'Segment 0' where the pylon is located.



2. **The ladder deck on each side of Segment 0 are installed** so that the forces are balanced for every new placing.
3. **Connection work** between girders at ladder deck is carried out while the jack still holds the deck in place.

Figure 14: Installation of ladder deck

Installation of precast slab and stay cables
1. **Precast slab and in-situ concrete are installed** on the ladder deck.
2. **Cables are connected** to transfer weight from the deck to the pylons and to the foundation.
3. **Crawler crane is used** to place the deck slab near the abutment.

Figure 15: Installation of precast slab and stay cables

Road finishing
The finishing starts off with road pavement. Street lighting will be installed, and green space will be created to enhance the landscape and improve the users' experience.

DURABILITY

Fire resistance
Fire risk is less acknowledged on bridge structures compared to buildings. However, the severity can still cause substantial damage to the bridge such as fire induced creep and local buckling. Strategies to mitigate fire risk includes:

1. Fire insulation in steel members
Cementitious sprays to reduce the thermal conductivity of steel

2. Adequate thickness of concrete cover
To protect steel structure from being exposed to fire and high temperature

Corrosion resistance

95% of structural damage in bridges is related to corrosion

Chemical erosion of metal that is mostly influenced by time of wetness and exposure to atmospheric pollutants. Chlorides and sulphates react with steel to form corrosive soluble salts.

1. Apply barrier coating
Protective paint

2. Apply waterproofing/sealer membrane
Between deck slab and driving surface to avoid water seepage

SUSTAINABILITY

The vision behind Caroline Bridge places great emphasis on creating a structure that is socially, economically and environmentally sustainable. A lot of consideration has been given to this aspect during the design phase to include sustainable aspects in the project. Stated below are some examples of sustainability features incorporated in the design.

- Instalment of bat & bird boxes in bridge deck
- Strip garden between road & footpath
- LED lighting system powered by solar panels
- Congestion charge to reduce traffic
- Comfortable and safe experience
- Durable & locally sourced materials
- Prefabricated structural components

COSTING

Majority of the cost is from the production and installation of materials (approximately £24.6mil). Whilst labour costs totalled to £5.8mil, hence the total budget of the project is £30.4 million.

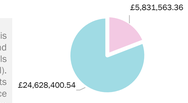


Figure 16: Breakdown of total costs

Breakdown of the non-labour costs can be seen in figure 17. It is important to note that this budget will be recouped over a period of by the money obtained from the congestion charges in a period of 3 to 4 years.

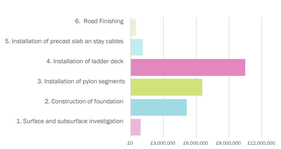


Figure 17: - Breakdown of non-labour costs