LIST OF REVISIONS:

Revision Number	Date of Issue	Author	Checker	Description of Changes
P01	15/10/2023	LH	LH	1.0
P02	22/10/2023	LH	LH	Incorporating comments received, references to supporting information and appendices included.

CONTENTS:

1.0 INTRODUCTION

This report is intended to summarise design development between Stage 3 design proposals (Planning and LBC consent), and Stage 4 (Technical Design and Tender).

It details design changes, provides a summary of further assessments and testing undertaken to inform Stage 4 technical design, and summarises Stage 5 approach and project risks that need to be addressed in Section 1 works.

[Refer to Purcell drawing MTR-PUR-01-ZZ-DR-A-2163 Section 1 of Phase 1 for further details].

It is intended to be read in conjunction with the Project Engineer;'s Cast Iron Report (produced by HOP - Appended), and is intended to contextualise this technical piece, and the additional testing reports that have been undertaken.

Project matters to be resolved during Stage 5 Section 1 testing include verifying the structural proposals, and close engagement with the Statutory Authorities to agree extents of re-cast and re-use of this important structure. The requirements to agree these matters are part of the reserved matters of the consent. Please refer to 'Volume 2 Appendix H3 Planning Condition Tracker'. This defines the responsibilities for discharge conditions. CI Items are Design Team led with input from the contractor.

Through Stage 4, several cast-iron elements have been tested in off-site facilities, although the extents of what could practically be undertaken pre-construction was limited to a number of ex-situ elements. So far this has not included trusses or columns. Thus further testing is needed when the initial dismantlement of several bay is undertaken in Stage 5.

The agreed parameters for appropriate live loading and in-use event management are to be formally agreed with B&HCC as asset owner and form part of the output of the additional testing during Section 1.

2.0 BASIS OF CI REPAIR/ RETENTION: STAGE 3:

Planning and listed building consent for the repair of the Phase 1 of madeira Terrace was granted on November 11 2022 (Application ref: BH2022/02577).

The cast iron structural elements form a critical aspect of the structure's heritage significance, and its overall function and purpose as a grandstand for spectators and outdoor events venue. Madeira Terrace overall is Grade 2* listed, and is on Historic England's Heritage at Risk Register. The structure is currently unsafe and is closed to the public.

The scheme to repair and restore the first phase of the terrace will start the process to remove this important heritage asset from the Heritage at Risk Register, and bring back into public use this important part of the Brighton Eastern Seafront.

The proposed restoration encompasses a number of initial steps:

- The careful removal of the in-situ concrete deck. The Contractor is required to provide a method statement for the removal of the concrete deck at Tender Stage. The proposed methodology is be reviewed and ultimately approved by the Design Team and the Statutory Authority prior to commencing dismantle. Please note Condition 6 of the Statutory Consent requires the method statement to be submitted and approved by the Local Authority.

The removal of the deck should be undertaken in a manner that preserves the cast-iron in-situ, to allow for careful dismantlement. The intention is to carefully release and remove the cast iron structure to a specialist cast iron foundry, assess and repair the cast iron elements, and re-instate them in their original positions. Temporary support designs should be prepared and submitted as part of the method statement, including proposals for temporary access and support of the remining in-situ structure.

Section 1 of the project relates to works to an initial tranche of 6no. arches (bays). The preferred location of the Section 1 works is marked on the plans [Refer to Purcell drawing MTR-PUR-01-ZZ-DR-A-2163 Section 1 of Phase 1]. The purpose of Section 1 is to allow the proposed methodology for dismantle, assessment and sequencing to be test-bedded ahead of roll out to the remainder. It is also to permit additional condition surveys and testing of the structure to be carried out, to verify initial testing and assumptions.

- Prior to commencing works, details of the proposed area for Section 1shall be submitted to the local authority for approval. (Condition no 5).
- Condition 7(a) requires that a full condition survey of Section 1 is carried out and submitted to the Local Authority including details of the method of dismantling the ironwork and condition of all elements.
- Condition 7(b) requires that prior to reconstruction of Section 1, a full methodology for repair and replacement detailing all interventions to be carried out is to be submitted to the Local Authority. The survey shall include a photographic Condition record of each component at the point of assessment, and post-repair, and record all repair interventions carried out, including elements of new fabric.
- The scheme shall be developed with the input of an ironwork specialist/ conservator, and any material deviation from the specification, as approved at Section 1, shall be agreed with the local authority.
- One no sample of each newly cast, cast-iron element is to be submitted and approved by the local authority.
- We anticipate a close collaboration with the Statutory Authorities (inc Local Authority Conservation Officer, Planning Officer and Historic England) during the Section 1 works, to arrive at an agreed specification for the repairs, which can be rolled out to the remainder of the structure.
- During Section 1, testing and analysis of the cast iron is to be undertaken – including material testing for tensile and compressive strength, and load testing. Refer to HOP 'Existing Ironwork Specification' (Appended).
- Tensile testing of cast iron from an ex-situ balustrade has been undertaken to inform the current proposals, the test results are appended.
- A Revit model of the structure is available. The project encompasses BIM protocols. The BIM model will be owned and updated by the Design Team, though can be made available to the contractor for collaboration and reference purposes. The contractor will provide information to the design team on the condition and repairs to the Cast Iron as the project progresses to allow the model to be updated accurately.

  The structural elements are tagged in the model. The tagging system is be utilised to identify the components of the structure, and to record defects and repairs on assessment. This is to enable tracking of the components, and the type of repairs that have occurred to aid future monitoring of the structural performance and ongoing maintenance.
- At the point of consent (stage 3 planning and LBC consent), a hierarchy of intervention to the cast iron elements was proposed; which accepts some elements will be re-cast wholesale, (deck, edge beams, spandrel connectors), while highly significant elements would be assessed and repaired if possible, if re-cast if deemed not suitable for re-instatement, once assessed on the bench. An summary of the approach extracted from the Design and Access Statement is copied below for ease of reference: (please note the full Design and Access Statement is available via the planning portal):

2.1.1 Structural Component v Rate of Intervention

ELEMENT	STRUCTURAL SIGNIFICANCE	ARCHITECTURAL [HERITAGE] SIGNIFICANCE	RATE OF INTERVENTION / CONSERVATION APPROACH
Concrete Deck	High	Low-Medium	Full Replacement
Deck beams	High	Low	Full Replacement
Principal [Lattice] Truss	High	Medium/High	Prioritise Repair
Column	High	High	Prioritise Repair
Edge Beam	High	Low	Replace if structurally necessary / uneconomic to repair
Spandrel Panel	Low	High	Retain
Keystone Mask	Low	High	Retain
Spandrel Connection piece	Medium	Low	Full Replacement [to revised profile to accommodate movement joint]
Balustrade	Medium	High	Prioritise Repair; then substitution; then replacement. Note that all sections to have adaptations to improve structural connections and compliance [guardrail height]
Gutter Section	Low	High	a) Substitution b) Full Replacement
Hopper	Low	High	a) Substitution b) Full Replacement to original profile

-

- During Stage 4 technical design, some further testing has been carried out on already ex-situ components, and non-destructive testing on in-situ structures. This has further informed the Stage 4 design.

3.0 STAGE 4: FURTHER TECHNICAL UNDERSTANDING AND TESTING

During Stage 4, some further testing on the cast iron has been carried out:

- Tensile testing of some sections of cast iron. (results appended)
- Bench assessments:

  A number ex-situ elements (albeit from the later part of the terrace at the western end) have been removed to a workshop, shot blasted to remove rust and previous paint layers, reviewed on the bench, defects identified and repairs made. This was considered a successful process as way to test the principle of bench assessment and repair. A sample of the condition records are appended to illustrate the assessment process.

  To date, this process has only been carried out to 2no spandrel panels, 2no balustrade infill panels and 3no balustrade stanchions and 2no Spandrel(Keystone) masks. Further testing and benchmarking of defects is thus required during Section 1 works, as described above.
- In-situ 'Dynamic Testing':

  This testing involved a vibration frequency being applied to the cast-iron in-situ and a response measurement being taken. From this process, an outline FE model can be interpolated. The dynamic test report is appended.
- A peer review of the cast iron detailed design was undertaken by a third party CARE-Accredited engineer, (Ed Morton of The Morton Partnership (TMP)), who also oversaw the dynamic testing process.

Stage 4 Proposals:

- The replacement of the concrete deck due its structural failure was anticipated and allowed for at Stage 3, and this remains unchanged. The new deck does not have embedded metal joists, these have been designed -out to reduce decay mechanisms in the future. Expansion joints in the deck have also been designed in at each truss position, to accommodate future thermal movement of the structure.

- Replacement of the concealed Edge beams was included at Stage 3 and this remains unchanged. The complete replacement of the edge beams allows for new splice connections to be located at structurally beneficial places.
- Replacement of the spandrel connectors was anticipated at Stage 3, and this remains unchanged.

Design development at Stage 4:

Some aspects of the design have evolved during Stage 4. Specifically:

- Introduction of wall-anchors into the cliff wall to stabilise the overall structure. These are tied at lattice truss positions and are incorporated into the new concrete deck, with little visual impact.
- New foundations have been designed, informed by trial pits at Stage 4.
- Balustrade stanchions: During Stage 3 it was intended to re-use the balustrade stanchions to the top deck. The Stage 4 design now allows to re-cast new balustrade stanchions. This is due to the increased height of the balustrade to meet a minimum of 1100mm. Various options for adaptation of the balustrade stanchions were explored, however the altered height changes means architecturally and structurally, it was preferable to re-cast to a new template that allows for a new bottom-rail to be incorporated. This minimises the gap at the base of the balustrade to max 100mm, to comply with current best-practice. The re-cast is due to the challenge of raising the balustrade height and incorporating this change of detail and the connection detail at the base, in a way that is architecturally sympathetic to the original. It should be noted that the existing cross-brace pattern of the balustrade panels does not meet current best practice in terms of the openings, but as the pattern is consistent across the Brighton Seafront and is an historic design, is not intended to be altered.
- Deck waterproofing: At Stage 3, the deck finish was proposed to be a natural stone aggregate finish, resin bound or bonded, in a buff colour. During Stage 4, the waterproofing on top of the deck has changed to a buff coloured asphalt. This is a thicker topping (approx. 60mm), and is typical of road-surface applications. The change is due to the critical nature of the waterproofing in terms of protecting the structure from water-driven decay. The asphalt finish was deemed to be more robust, giving longer lasting protection to the deck. Refer to the SE's specification for details.

Stage 4 testing and development:

- The tensile test results obtained were within the expected range for historic cast iron.
- The intention to test lattice trusses remains, with the preference to repair and re-instate. The TMP review and the subsequent Dynamic Testing (DT), suggest the re-use of the lattice trusses is structurally feasible and they are fit for purpose, once repaired to a good standard. The DT testing indicates the trusses are performing in tandem with the concrete deck, and thus the stiffness of the overall structure should be considered holistically, rather than relying entirely on structural performance of individual elements in isolation.

  The DT testing acknowledges and recommends that an 'ex-situ' truss is tested, as the DT results in-situ gave greater structural confidence than would be expected of a truss in isolation. Load testing of trusses (and other structural elements) is thus specified in the Section 1 works. Refer to the Structural Engineer's Information (HOP) –'Refurbishment of Existing Ironwork' (Appended).

  HOP, as Project Engineer have reservations about the ability to re-use the trusses, and thus the outcome from the testing during Section 1 is paramount to agreeing the manner to proceed.

  It should be noted that the testing to date suggests the diagonal cross member at the rear edge of the truss is working hard, and this is one key area of concern in terms of potential for re-use, which requires further testing. For the purposes of Stage 4, it has been assumed that if further testing so indicates this as a particular area of weakness, that additional localised strengthening of this member could be undertaken in the workshop, enabling re-use of the lattice trusses. This however, would involve alteration to the visual appearance of the repaired trusses. While this is likely a de-minimis alteration it needs to be considered at stage 5 in tandem with the Statutory Authorities.

  Any new trusses required by virtue of delapidation making then irreparable for re-instatement are detailed to match the existing. The key part of this is the presence of a stiffening plate along the top chord of the existing trusses, which new trusses are to replicate. Expansion joints have been designed

into the deck to accommodate thermal movement, and the deck detail and waterproofing at expansion joints is critical to safeguard the structure in the future. Refer to Structural Engineer's details.

- Balustrade infill panels: The intention to re-use and re-instate the existing balustrade infill panels, fixed to re-cast stanchions, remains. The ex-situ example assessment and repair noted above proved encouraging in terms of achieving a good standard of repair of the existing.

  That said, further ex-situ load testing is specified at Stage 4, and the Project Engineer retains reservations about the ability for re-use of these elements, until further testing is undertaken in Section 1.

4.0 RISKS AND CHALLENGES

Change to Structural Approach:

Although the client team have invested in further technical testing during Stage 4, some design items have not been able to be fully closed out. Thus Section 1 works allows for further 'off-site' assessment at Stage 5 following dismantlement of the Cast Iron structure. While it is typical for projects involving refurbishment of historic structures to require some work at stage 5 to confirm/resolve assumptions made at Stage 4, Section 1 of the project has been specifically introduced to enable this further assessment to take-place and be agreed in controlled manner, ahead of roll out the remaining structure.

A suite of technical tests have been undertaken during the design stage, and this has gone as far as is practically possible without the support of a main contractor in place. Until Section 1 works are commenced and off-site testing of more of the structure is possible, alteration of the structural approach cannot be ruled out, and close involvement of the Contractor, Design Team and Statutory Authorities at this stage is anticipated. That said, the design approach to the majority of the structure is agreed, the residual questions are limited to extents of re-use of cast iron, which will be confirmed on the load testing specified.

Use, Management and Derogations:

Modern Structural standards for dead and applied live loading have been applied when considering the Terrace. The Project Engineer thus recommends that a minimum 5kN/m2 live loading should be targeted for the terrace deck structure.

Problems invariably arise when trying to calculate the capacity of an historic structure to a modern standard it was not initially designed to. The review by TMP and subsequently the Dynamic Testing and other testing, supports the notion that the Terrace structure is suitable for its intended use, and has proved its ability to withstand high crown-load situations via its use over decades as a spectator grandstand (historic photos of events attest to this). That said, the testing to date acknowledges that a design load of 5 kN/m2 may be difficult to achieve.

The point is also made that at 5kN/m2, the deck would be so crowded as to be a danger to life, and thus structural failure due excessive crowd load is secondary to safe management of the structure at large events- as safe event management for protection of the public should be the first principle.

Subsequent engagement with B&HCC events teams has confirmed events would limit maximum number of people of the deck to numbers of around 150-250, due to the width of escape routes in case of evacuation, which is well below the numbers that would place the terrace at risk of crowd loading.

The recommendation of TMP is thus that a slightly lower live loading is accepted by B&HCC than would be typical, which accounts for the historic nature of the structure, and appropriate future use. This seems an appropriate response to safeguard the heritage asset and ensure public safety during events. This approach would require a derogation to be agreed formally, and the appropriate use of the structure to be communicated to event organisers in the future.

The precise live loading limits would need to be agreed following further testing, but a figure of around 4kN/m2 seems likely.

The agreement of the appropriate limits will to a large extent govern the extent of re-cast vs repair in the refurbished structure. It is the intention on receipt of further Stage 5 testing for the client consultant team to support B&HCC with the agreement of a suitable derogation report regarding the structure. The intention is for this to happen during Section 1 and the mechanisms are in place to undertake this.

Appendices: (Under separate cover):

A: HOP Iron Re-Use Strategy (Report)

B: HOP Refurbishment of Existing Ironwork (Report)

C: Tensile Testing Results (Data Sheet)

D: Dynamic Test Report – 11983ja-01_Madeira Terrace (Mann Williams)

E: Sample Inspection record sheets (CIWS)