

OVG Manchester

Structural Design Report

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Revision P02

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1 Executive Summary

1.1 Purpose of Document

This document is a header/preface document with a number of objectives:

- To provide a high-level overview of the structural design of OVG Manchester Arena.
- To clarify the organisation / hierarchy of the suite of structural documents on the project.
- To briefly introduce the content of each structural document and how they relate to the assumed tender packages.
- To highlight items requiring special attention.

This document must be read in conjunction with all documents within the structural document suite together with the information from the other engineering disciplines and the Architect. Any discrepancy between a specification or description document and its related documents and any drawings, shall be submitted to the Engineer for clarification.

It is deemed that the Contractor has inspected all specifications, is able to comply with them, and has allowed for all their requirements particularly, but not exclusively, in terms of cost and programme.

2 Design Status

Revision P02

The first draft of this document was issued on 1 May 2020. This revision is issued at the end of Stage 4a and is issued to accompany the project tender set. It serves as an overarching report to the Structural documents for the OVG Manchester Arena. The package status below is to provide a brief commentary of the design status at each issue of this document.

Substructure

Substructure information was developed to Stage 4a draft level early in the Stage 4a design stage. This advanced work was carried out to help inform pricing, which needs to account for the Subcontractor design of CDP items that we expect to take place from August 2020 onwards. A pile schedule with loads was issued at this stage to enable Contractor design of substructure elements, this has subsequently updated incorporating the southern landscaping structure and changes as a result of the lower bowl precast terracing.

Material specifications, waterproofing performance specification, and In-situ concrete description report have been issued as Stage 4a level information. An Approval in Principle document has also been produced for works adjacent to Alan Turing Way.

It is expected that the majority of Buro Happold's Stage 4b scope in relation to substructure will need to take place prior to novation to the main contractor – this is subject to instruction.

Superstructure

The superstructure is at a tender stage status whereby a more comprehensive suite of information has been compiled to enable the pricing process. At Stage 4a the drawing pack now includes 1:100 zone GA drawings at each level, additional key sections, and details. Tonnage and quantity information has been included within the Description Reports which should only be used as guidance in addition to the drawing suite.

During Stage 4a there has been some Contractor engagement which has highlighted some Value Engineering (VE) items. In some instances, where possible within the time frame, these have been included in the design, for example:

- Increased secondary beam spacing for large areas of the podium
- Reduced number of slab steps at L04 & increase beam spacing in plant zones
- Rationalised roof support framing to west end to simplify façade/MJ detailing
- Reduced numbers of stiffeners in the rakers
- L05 slab thickness reduction

More difficult VE items will require time post-4a to BH to carry out preliminary design to inform potential changes and formal instruction to carry out.

Structural Description Reports for each package have been compiled to help the Contractor understand the status of some specific areas, and to illustrate where the Package Contractors input may provide cost benefit.

A number of outline documents to aid costing have been produced for secondary items, including façade support steelwork and secondary steelwork. These are schematic only in terms of aiding costing and do not represent final design documentation due to the interfaces and reliance on co-ordination between packages and sub-contractors.

Roof structure

The roof design status is similar to the superstructure description above. At Stage 4a the drawing pack now includes 1:100 zone GA drawings at each level, additional key sections, and details. Tonnage and quantity information has been included within the Description Reports which should only be used as guidance in addition to the drawing suite.

The Roof Description Report will also provide commentary to some specific elements and additional information to assist the Contractor.

3 Structural Documentation

3.1 Introduction

This document, the Structural Design Report, heads up a suite of structural reports which have been split into different categories to facilitate the control of material for presentation and review for the Client and for distribution to the Main Contractor, Package Contractors and Sub-Contractors during the tender process. These categories are as follows:

- Global Structural Documents
- Structural Description Documents
- Structural Material Specifications

3.2 Document List

This report should be read in conjunction with all other tender and contract documents and drawings for the OVG Manchester project.

The Buro Happold structural report structure is shown in Table 3—1 Structural document suite below. This table should be considered as illustrative, rather than an exhaustive list.

Table 3—1 Structural document suite

Global Structural Documents	
BRA-BHE-ZZ-XX-RP-S-0100	Structural Design Report
BRA-BHE-ZZ-XX-RP-S-0200	Structural Basis of Design
BRA-BHE-ZZ-XX-RP-S-0301	Record of Significant Health and Safety Information
BRA-BHE-ZZ-XX-RP-S-0400	Retaining Wall Design Assumptions
BRA-BHE-ZZ-XX-RP-S-0500	Structural Movements and Tolerances Report
BRA-BHE-ZZ-XX-RP-S-0600	Structural Robustness and Systematic Risk Assessment
BRA-BHE-ZZ-XX-RP-S-0700	Structural Roof Loads - Rigging Criteria

Structural Description Reports	
BRA-BHE-ZZ-XX-RP-S-0210	Structural Description: In-situ Concrete
BRA-BHE-ZZ-XX-RP-S-0220	Structural Description: Superstructure – Precast Concrete – Bowl and Stairs
BRA-BHE-ZZ-XX-RP-S-0230	Structural Description: Superstructure Steelwork
BRA-BHE-ZZ-XX-RP-S-0240	Structural Description: Roof Steelwork

Structural Material Specifications	
BRA-BHE-ZZ-ZZ-SP-S-0100	Structural Concrete Specification
BRA-BHE-ZZ-ZZ-SP-S-0110	Structural Steelwork Specification [Incorporating Metal Deck Performance Specification]

BRA-BHE-ZZ-XX-RP-S-0202	Secondary Structure Elements
BRA-BHE-ZZ-XX-RP-S-0203	Façade support steelwork
BRA-BHE-ZZ-XX-RP-S-0250	Structural Performance Specification: Laterally loaded partition support

BRA-BHE-ZZ-ZZ-SP-S-0200	Below Ground Waterproofing Performance Specification
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Fire Reports	
BRA-BHE-ZZ-ZZ-RP-YD-0001	Fire Strategy
BRA-BHE-ZZ-ZZ-RP-YD-0002	Structural Fire Engineering Assessment

Geotechnical Specifications	
BRA-BHE-XX-XX-SP-CG-0001	Ground Investigation Specification
BRA-BHE-XX-XX-SP-CG-0002	Project Specification for Piling and Embedded Retaining Walls
BRA-BHE-XX-XX-SP-CG-0003	Specification for Earthworks

3.3 Global Structural Documents

The global structural documents include information about the general structural engineering requirements of the whole project. As such, these reports must be used in conjunction with all relevant packages for tendering purposes. This is especially important where packages have aspects of performance specification for design input by specialists (such as balustrades, access gantries, ceilings, facades, acoustic curtains, etc.).

3.3.1 Basis of Design

All of the content of this document is critical to the Final Design of the structural components. The basis of design document includes:

- Material properties
- Loading
- Performance Criteria

The material properties provide the design assumptions on the key materials and used within the structural calculations. Further material requirements are stated within the material specifications.

The loading section forms the largest part of this report and presents the loads which the structure is designed to withstand. These are based on an assessment of the weights of the various elements and a code-based assessment of live, thermal, snow, wind and notional horizontal loads.

The performance criteria set out the overall performance requirements for the structural elements.

In terms of assumptions, this document is critical and summarises a large amount of discussion and agreements and must be read with each Description Document.

3.3.2 Structural Roof Loads – Rigging Criteria (To be issued before handover)

This information is considered very important to the operation of the venue and as such it will be provided as a standalone document from the Basis of Design to give the Arena Operator a quick reference point while operating the

Arena. Prior to the issue of this document, similar information is included in the Basis of Design and Primary Roof Steelwork Structural Description documents.

3.3.3 Movement and Tolerance Report

This document records the anticipated movements of the structural elements designed by Buro Happold. This information is intended for design coordination use and for Client reference.

It also includes the requirements for the construction accuracy of structural trades. This section must be included in the Tender of all structural trades and then retained as a Contract document.

3.4 Structural Material Specifications

These documents present the detailed material specifications that the construction of the structure needs to follow in order to meet the requirements of the Client, codes and structural design intent.

3.4.1 Structural Concrete Specification

The Structural Concrete Specification defines criteria and performance requirements to which the works must be designed and provided. The concrete works of the OVG Manchester project are to be constructed in accordance with the requirements of:

- BS EN 13670: 2009 + Corrigenda 2015 Execution of Concrete Structures (and the UK National Annex)

BS EN 13670 requires the use of an execution specification and as recommended in NA.3 of the National Annex the NSCS edition 4 is to be used:

- National Structural Concrete Specification for Building Construction, Fourth edition complying with BS EN 13670: 2009 + Corrigenda 2015

This Structural Concrete Specification acts as the Project Specification as required by the NSCS and provides the information and requirements specific to the project. It records, by exception, any amendments to the Standard Specification of the NSCS considered necessary by the design team and is the part of the Specification where information is provided by the tenderer. The document is formatted to follow Sections P1 and P2 in the template provided with the NSCS.

3.4.2 Structural Steelwork Specification [Incorporating Metal Deck Performance Specification]

The Structural Steelwork Specification defines criteria and performance requirements to which the works must be designed and provided. The structural steelworks of the OVG Manchester project are to be carried out in accordance with BS EN-1090-2:2008 + A1:2011. The Structural Steelwork Specification document provides project specific requirements based on BS EN1090-2.

It presents the Execution Classes required for the various elements of the project and lists project specific variations split into different categories:

- Additional Information (as listed in A1 of EN1090-2)
- Options (as listed in A2 of EN1090-2)
- Preparation Grades

- Tolerance Classes
- Supplementary additions and modifications required for the OVG Manchester Arena Project

In addition to the main steelwork specification an additional section defines performance requirements for the design, supply and installation of steel decking and the design of composite slab where required for OVG Manchester.

3.5 Structural Description Documents

The structural description documents describe the key aspects of the design of the OVG Manchester primary structure. They have been written to support the information shown on the structural drawings and to assist the Contractor and their sub-contractors by providing them with a general understanding of the structure. They convey the structural systems employed, the design constraints, and information on interfaces with other aspects of the structure and the building in general. Any special areas which are considered different from the normal are also highlighted and explained.

The structure has been divided into a number of separate packages based on materials used and an assessment of likely sub-contractor division.

The documents for the pre-cast elements (bowl and stairs) and the laterally loaded masonry walls are written as performance specifications for contractor designed portions of the structure.

3.5.1 In-situ Concrete

The In-situ Concrete description document presents information for two packages:

- In-situ Concrete Substructure and Ground Floor
- In-situ Concrete Superstructure

The concrete package of works (for the concrete contractor) is anticipated to include the structural elements listed below. This is not an exhaustive list, and is provided for assistance purposes only:

- Reinforced concrete (RC) pile caps and ground beams
- RC and mass concrete spread foundations
- RC trench structures
- RC ground floor structures
- Build-up beneath the ground floor slab, including sub-base, blinding, gas & vapour proof membrane, below slab insulation, joints and sealants.
- RC cores
- RC walls
- Cast-in elements.

All elements within the Buro Happold design are shown within the Structural Revit model and on the structural drawings.

3.5.2 Superstructure Steelwork

The superstructure primary steelwork package of works is anticipated to include the structural elements listed below (and their joints/connections). This is not an exhaustive list, and provided for assistance purposes only:

- The structural frame above L00
- Rakers
- Stability elements, where not insitu concrete
- Steelwork forming overhangs
- Steelwork above the service yard
- Upper tier back of bowl and vomitory pre-cast support elements including columns, beams and shelf angles to slab and beam edges.
- Riser trimmer steelwork

All elements within the Buro Happold design will be shown within the Structural Revit model and on the structural drawings.

3.5.3 Roof Steelwork

The roof steelwork package of works is anticipated to include the structural elements listed below (and their connections). This is not an exhaustive list, and provided for assistance purposes only:

- Trusses.
- Top and bottom surface elements between trusses.
- In-plane bracing within the top and bottom surfaces.
- Purlins and decking, and the connections of purlins to top surface primary structure.
- Rigging grid and perimeter rigging elements; including any diagonal transfer elements.
- Catwalks and walkways.
- Bearings.
- Corrosion and fire protection paint systems.
- Local attachments at interfaces with façade packages.
- Fall arrest systems and their attachment to the primary structure.
- Secondary steelwork (dependent on final sub-contractor packaging).

All elements within the Buro Happold design are shown within the Structural Revit model and on the structural drawings.

3.5.4 Superstructure – Precast Concrete – Bowl and Stairs

The Bowl Pre-cast description sits within the Superstructure Pre-cast document and provides a structural description and specification of the pre-cast bowl elements. This document provides a structural description and specification of the bowl pre-cast elements for the OVG Manchester Arena and their interface with the primary structure to act as a performance specification for the Pre-cast Package Contractor to develop the design.

The final design, detailing and co-ordination of the pre-cast elements are the responsibility of the Pre-cast Package Contractor and the description document forms the basis on which the design should be carried out. This includes the reinforcement design and detailing with due consideration for installation and handling. The final design of the Pre-cast package is to be carried out in such a manner that it does not require change to the existing design of other elements of the works.

Elements which form part of the bowl precast are as follows: (This is not an exhaustive list, and provided for assistance purposes only):

- Terracing units
- Step blocks
- Parapet units
- End walls
- Arena floor tunnel walls
- Vomitory walls
- Vomitory bridge units
- Pre-cast walls and units associated with the upper tier accessible platforms
- Flat pre-cast units at the back of the bowl
- All other elements of Bowl pre-cast and their connections.

3.5.5 Pre-cast Concrete Stair Elements

The Stair Pre-cast description sits within the Superstructure Pre-cast document and provides a structural description and specification of the pre-cast stair elements. It describes the interface with the primary structure to act as a performance specification for the Pre-cast Package Contractor to develop the design.

The final design, detailing and co-ordination of the pre-cast elements are the responsibility of the Pre-cast Package Contractor and this document (alongside the other relevant structural and architectural documentation) forms the basis on which the design should be carried out. This includes the reinforcement design and detailing with due consideration for installation and handling.

Pre-cast stairs are found in the following locations:

- Core internal stairs
- Feature stairs (TBC)

- **Access stairs (TBC)**

The stairs are to be pre-cast since there are no finishes to the top surface and the soffit, as such the concrete will need to have an enhanced finish quality and connections should be concealed where possible. This is especially important for the feature stairs. Reference should be made to the architectural specifications for details on finish requirements.

3.5.6 Laterally Loaded Masonry performance specification

Within OVG Manchester Arena there are areas of masonry walls forming partitions, enclosures, and compartments, etc. These are generally formed from blockwork and are primarily located at Level 0. These masonry walls are categorised as 'non-load bearing' as they do not provide vertical support to any floors or other elements of primary structure. However, being within an Arena, a significant proportion of the walls are subject to lateral loadings from crowds, and internal wind pressures.

This specification [sets out](#) the performance criteria for masonry walls that have some element of structural design requirement, but do not form part of the primary structure of the buildings. This includes:

- Internal walls subject to lateral internal pressures
- Internal walls subject to loads from barrier or handrail actions

This performance specification [sets out](#) the minimum requirements for the loadings, materials, components and construction arrangement of the walls; and provides tender stage guidance to assist pricing. [This can be developed further to include 2D layouts of windposts if instructed in RIBA Stage 4b.](#)

4 Structural Drawings

Table 4—1 below, presents an overview of the structural drawings produced for the OVG Manchester Arena project to help navigate through these alongside the structural reports.

Table 4—1 Drawing List

Number	Title
Introduction Drawings	
BRA-BHE-XX-XX-DR-S-0001	General Notes
BRA-BHE-XX-XX-DR-S-0005	Structural Guidelines for MEP Openings
BRA-BHE-XX-XX-DR-S-0032	Superstructure Member Schedule
BRA-BHE-ZZ-ZZ-DR-S-0501	Overall 3D isometric View Sheet 1 Arena Bowl
BRA-BHE-ZZ-RF-DR-S-0502	Overall 3D isometric View Sheet 2 Arena Roof
Loading Drawings	
BRA-BHE-ZZ-xx-DR-S-0100 to 0190	Level xx - Loading Plan
BRA-BHE-ZZ-xx-DR-S-0200 to 0350	Level xx – Crowd loading GA's
Structural Plans	
BRA-BHE-ZZ-PL-DR-S-0700	Level PL (Piling) – General Arrangement
BRA-BHE-Zx-PL-DR-S-0701 to 0704	Level PL (Piling) - Zone Drawings
BRA-BHE-ZZ-FN-DR-S-0800	Level FN (Foundations) – General Arrangement
BRA-BHE-Zx-FN-DR-S-0801 to 0804	Level FN (Foundations) - Zone Drawings
BRA-BHE-ZZ-B1-DR-S-0900	Level B1 (Basement) – General Arrangement
BRA-BHE-Zx-B1-DR-S-0901 to 0904	Level B1 (Basement) - Zone Drawings
BRA-BHE-ZZ-GF-DR-S-1000	Level GF (Ground Floor) – General Arrangement
BRA-BHE-Zx-GF-DR-S-1001 to 1004	Level GF (Ground Floor) - Zone Drawings
BRA-BHE-ZZ-GM-DR-S-1050	Level GM (Ground Mezzanine) – General Arrangement
BRA-BHE-Zx-GM-DR-S-1051 to 1054	Level GM (Ground Mezzanine) - Zone Drawings
BRA-BHE-ZZ-xx-DR-S-xxx0	Level xx (01,02,03 etc.) – General Arrangement – (DR-S-1100 = Level 01, 1200 = Level 2 etc.)
BRA-BHE-Zx-xx-DR-S-xx01 to xx04	Level xx (01,02,03 etc.) - Zone Drawings – (ZA = Zone A, 1101 = Zone A Level 1)
Roof Plans	
BRA-BHE-ZZ-Rx-DR-S-1600, 1650, 1700	Level Rx – General Arrangement
BRA-BHE-Zx-Rx-DR-S-1x01 to 1x04	Level Rx - Zone Drawings
Superstructure Sections	
BRA-BHE-XX-ZZ-DR-S-3008	North Stand (GRID N08) Section
BRA-BHE-XX-ZZ-DR-S-3034	East Stand (GRID E04) Section
BRA-BHE-XX-ZZ-DR-S-3059	South Stand (GRID S09) Section
BRA-BHE-XX-ZZ-DR-S-3084	West Stand (GRID W08) Section
BRA-BHE-XX-ZZ-DR-S-3200	South to North & West to East Sections
Raker Sections	
BRA-BHE-XX-XX-DR-S-3301 & 3302	Raker Sections
Substructure Sections	
BRA-BHE-XX-XX-DR-S-3501 to 3506	Substructure Detail Sections
Roof Elevations	
BRA-BHE-ZZ-RF-DR-S-3801 to 3805	Roof Truss Elevations
Core Drawings	
BRA-BHE-Zx-ZZ-DR-S-4111 to 4173	Core Plans
BRA-BHE-Zx-ZZ-DR-S-4511 to 4574	Core Elevations
Substructure Details	
BRA-BHE-XX-FN-DR-S-5001 to 5003	Substructure Details
BRA-BHE-XX-GF-DR-S-5011 to 5012	Capping Beam & Buttress Wall Details
Ground Floor Details	

BRA-BHE-XX-GF-DR-S-5051 to 5052	Ground Floor Details
Superstructure Details	
BRA-BHE-XX-XX-DR-S-5101 to 5105	Superstructure Details
Superstructure Bowl Details	
BRA-BHE-XX-XX-DR-S-5151 to 5152	Superstructure Bowl Details
Roof Details	
BRA-BHE-XX-RF-DR-S-5201 to 5202	Roof Details
BRA-BHE-XX-RF-DR-S-5210 to 5213	Roof Bearing Schedule & Details
BRA-BHE-XX-RF-DR-S-5220 to 5221	Roof Structure Catwalk Details

5 Structural Overview

5.1 Substructure

Primary structural elements are supported on pile caps which spread loads to piled foundations.

The level of the ground floor requires excavation and results in the need for retaining structures around the majority of the perimeter of the building. These structures will retain material up to a maximum height of around 7 metres above the excavated level.

Contiguous piles are proposed as the permanent works retaining structure with a tanked RC internal basement wall around the entire perimeter.

5.2 Ground Floor

Ground floor structures are constructed of in-situ ground bearing reinforced concrete. In the event floor this is designed to resist high loading to maintain flexibility of use for the arena. [A number of smaller piles have been introduced during Stage 4A to reduce future settlements, together with increased ground slab reinforcement.](#)

5.3 Upper Floors

Plant and concourse floor plates are constructed from structural steelwork and composite deck floor. In some key service routes, there is a requirement for holes to maximise floor to ceiling heights.

5.4 Arena Bowl

Tiers are formed from steel rakers supporting pre-cast concrete terrace units. This approach maximises erection efficiency for the main frame. This approach also maximises repetition of detailing.

5.5 Stability System

The primary structure is divided into four quadrants by movement joints positioned through each stand. Refer to RP-S-0500 Movements & Tolerance Report for information. Each of the quadrants is stabilised by an insitu concrete core and localised steelwork stability elements.

5.6 Roof

The long span roof will be created from a series of planar trusses, spaced to match the superstructure grid below. This removes the need for any transfer structures to marry up the roof and bowl grids. The primary supports for the roof are on cores and on the primary steelwork around the perimeter.

5.7 Facade

The project is based on overall volumetric geometry of stacked staggered rectangular volumes. The façade consists of a precast concrete base plinth to the lower two floors, with incorporated doors and opening. The upper floors of mineral wool insulated composite panels with feature perforated aluminium cladding panels and incorporated

lighting. The top floor consists of an acoustically rated precast concrete façade to the back of bowl, and to the outer edge of the MEP zone includes a continuation perforated aluminium cladding facing an aluminium backing panel with integrated lighting and LED components.

6 Specific Technical Requirements

This section has been provided to emphasise a number of specific aspects of the OVG Manchester Arena structural design which require special attention. It is provided for assistance purposes and is not exhaustive.

6.1 Combined steel and concrete bowl construction

The structure comprises of both reinforced concrete (RC) and steelwork. It is therefore vitally important that the bowl steel contractor and the insitu concrete contractor understand each-other's packages, and the multiple interfaces between them.

6.2 Bowl Dynamics

As with all arena structures the performance of the bowl under dynamic crowd loading is critical in both vertical and horizontal directions. For the OVG Manchester Arena the dynamic performance of the bowl results from a combination of the steel frame elements and the pre-cast terrace units. Therefore, it is important to consider the design as a whole and not just individual elements.

6.3 Bowl Tolerances

Achieving the required sightlines for the Arena requires the steelwork sub-contractor and bowl pre-cast sub-contractor to work closely together with an understanding of each other's construction tolerances and deflections during the loading sequence to ensure accurate shimming is in place to produce the required bowl geometry in the final condition.

6.4 Foundation approach

The heavily loaded steel frame and concrete cores, including the steel roof predominantly supported from the cores, found onto deep piled foundations. Due to the loading and ground conditions piled foundations has been considered as the most cost-effective solution for the Arena.

Retaining structure is required around the perimeter of the building which is of structural significance. Various interfaces between packages will require understanding of details and construction programme of multiple Contractors.

6.5 Waterproof Membrane & Gas Protection

A waterproof membrane is required, in accordance with BRA-BHE-XX-XX-SP-S-0200. For gas protection requirements refer to BRA-BHE-XX-XX-RP-CG-0004.

6.6 Trenches

A large trench situated in the event floor slab provides services to a possible ice pad. [Final setting-out requirements](#) are TBC.

6.7 Movement Joints

The superstructure of the building is separated into self-stable portions by movement joints. These are included to reduce locked-in stresses within the floor slabs which occur due to thermal expansion and contraction.

6.8 Visual Concrete

Exposed concrete will play an important role in the internal appearance of OVG Manchester Arena. To this end, a large proportion of surfaces will be allocated a visual concrete status. Costs in these areas will therefore be higher than standard concrete construction (although it should be recognised that this approach minimises the need for additional finishes).

The extents and specification for areas of visual concrete will be defined in the Architects' tender drawings and specifications. The concrete mix design used to achieve the visual requirements should still comply with the structural requirements set out in the Buro Happold structural concrete specification, BRA-BHE-ZZ-ZZ-SP-S-0100.

For chamfer requirements refer to Architectural drawing and specification documents.

Some exposed concrete requires high level finish and flatness requirements. Refer to Architectural drawing information and specification documents. Also refer to the Buro Happold structural concrete specification.

6.9 West Atrium

Escalators and stairs are supported within a feature atrium in the West stand [which are supported on hanging secondary structure which BH are appointed for cost input only at this stage.](#)

6.10 Roof Primary Structure

The arrangement has been developed to provide a structurally efficient design, suitable for the supports available and maximising element repetition where possible. The arrangement is also influenced by the operational modes required.

6.11 Roof Technical Grid

The technical grid and access arrangement within the roof structure have been developed for the support of event lighting/audio equipment/visual equipment, etc. from the roof. This arrangement has been developed by Buro Happold following consultation with OVG and rigging specialists. The aim has been to make installing the rigging safer and faster than most comparable Arenas, whilst allowing a large degree of flexibility. Furthermore, a high maximum rigging height is achievable because of the form of the roof and the spacing and elevation of the rigging elements.

6.12 Dynamic Testing

An allowance should be made for dynamic testing towards the end of construction. This testing, usually undertaken with accelerometers and shaker devices, allows the client and operator to understand the dynamic performance compared to the IStructE publication 'Dynamic performance requirements for permanent grandstands subject to crowd action', 2008. A performance specification for this will be produced in due course.

6.13 Contractor Design Responsibility

Items requiring specialist design input by the Contractor, commonly referred to as Performance Specified Work (PSW), are described in each of the Structural Description Documents. An example of this is in the description documents for the steelwork packages, where the Contractor is assigned design responsibility for completing the connections / joint designs within the parameters / design intent provided by the Engineer.

The Structural Description Documents also state where work is appropriate to be performance specified for a specialist to complete. For example, for the pre-cast concrete elements the manufacturer will produce a design and layout in accordance with the Engineer and Architect's requirements.

6.14 Alternative Design Proposals

Conditions may arise where the Contractor wishes to propose alternative designs. For example:

- To suit the Contractor's preferred construction methodology.
- To suit the Contractor's preferred suppliers of components or systems.
- To suit the Contractor's preferred (and accepted) alternative material quality.

Such proposals shall be considered on a case by case basis.

The Engineer will not accept design responsibility for Contractor's alternative proposals unless they specifically agree to do so by Contract appointment. Otherwise the Contractor will accept full design liability for alternative design proposals.

7 Other Technical Requirements

This section should be read in conjunction with the other Contract documentation.

Contractors will be required to demonstrate or provide:

7.1 Quality Control Systems

Full and comprehensive QC systems shall be implemented for all aspects of the work in accordance with the specifications.

7.2 Quality Assurance Systems

The Contractor must show evidence that they audit their own on-site QC activities and that they also audit the QC systems of their suppliers to ensure overall compliance with specifications and material standards.

The Contractor shall comply with the Contract for Quality Assurance / Quality Control measures.

7.3 Material Certification

The Contractor shall provide documentation to authenticate the provenance of all base materials used in the works. This will include such items as materials test certification from their suppliers.

7.4 Material Testing expertise on site

The Contractor shall provide adequate material testing capability to carry out in-situ sampling and testing of all materials and workmanship to demonstrate compliance with the corresponding Material Detailed Specification (or Structural Description Document). Specialist testing and inspection capability will be required in certain instances.

7.5 Temporary works designs

Designs shall be provided to the Engineer well in advance of start on site for information and comment as appropriate (not checking). In particular, the Engineer shall review whether the permanent works may be detrimentally affected in the long term by the Temporary Works designs. The Contractor is to be fully responsible for the integrity of such structural design and the adequate provision of temporary stability – with all significant designs independently checked and certified.

7.6 Works Method Statements

The Contractor shall consider and develop buildability logistics and construction sequences; and shall provide summary Method Statements to the Engineer for comment well in advance of start on site of relevant packages. In particular, if Method Statements impact upon the permanent structural design (i.e. if more critical design cases result from the method of erection, or if alternatives to the structural arrangements result from the method of construction), the costs associated with the redesign shall be factored into the Contractor's cost for the works.

7.7 Health and Safety Compliance

Refer to:

- The Project Health & Safety Risk Register.
- BRA-BHE-ZZ-XX-RP-S-0301 – Record of Significant H & S Information.
- Health & Safety information provided on the structural drawings.
- Health & Safety information provided within other contract documentation.

8 Construction Sequence

8.1 Responsibilities and key considerations

The Contractor must develop and deliver a pragmatic sequence to satisfy the overall project requirements. In compiling the construction methodology, the Contractor and Sub-contractors must take the following influences into consideration:

- Site Layout and Constraints: refer to all relevant documentation prepared by the Client detailing layout space, access to site for delivery, craneage space, oversailing rights, work close to road, metro and canal, site work hours, and the like.
- Programme: the erection sequence from each sub-contractor should meet the Client schedule, and at the same time in no way adversely impact on the delivery of other works on the site. In order to achieve this, the sub-contractors should coordinate and programme their works with all other contractors on site. There will be an optimum erection method in terms of cost, programme and design for the steel, insitu concrete or pre-cast concrete elements considered in isolation; however, each specific erection sequence must be considered together with the overall project construction method.
- Any requirements for temporary works must also take into account the limitations (such as load limitations on the floor structures) defined in the Structural Basis of Design. All sub-contractors should allow sufficient time for this in their implementation programmes. Design of any temporary propping, including its support down to ground via permanent works piling, is the responsibility of the Contractor. This propping will include any back-propping required beneath floor structures.
- Health and Safety: Construction of the Arena will necessitate heavy lifts, constrained lifts, working at height, and the like. The Contractor is obliged to compile a detailed method statement for the erection of all structural elements. Where possible identified risks are to be eliminated by changes to the construction methodology; if this is not possible then the risk is to be managed so as to reduce its likelihood of occurrence and to minimise the impact of its occurrence.

8.2 Outline Erection Sequence

Buro Happold have outlined potential construction methodologies for both the retaining wall and associated concrete works, and the structural steel roof packages. Refer to the Description Reports.

9 Health and Safety Information

Refer to BRA-BHE-ZZ-XX-RP-S-0301 – Record of Significant H & S Info.

10 Codes of Practice, Design Guides and Software

10.1 Codes of practice and design guides

The structural design has been carried out in accordance with the appropriate Eurocodes and their relevant UK National Annex documents.

In addition to the Eurocodes, design guides specific to the design of Arenas have been used:

- IStructE: Dynamic performance requirements for permanent grandstands subject to crowd action – Recommendations for management, design and assessment
- Department for Culture Media and Sport: Guide to Safety at Sports Grounds, 6th Edition

In addition to these main codes and guides, where additional technical guidance has been used, these are listed in the references of the structural description reports and the material specifications and will be referenced in the structural calculations.

10.2 Software

The analysis of the superstructure and roof is carried out using ROBOT with the reinforced concrete structure modelled as finite element plates and steel beams as bar elements.

Loadings applied from the roof model to the superstructure model are transferred using spreadsheet data.

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