

# **OVG Manchester**

**Structural Description - Structural Precast Concrete - Bowl and Stairs**

**BRA-BHE-ZZ-XX-RP-S-0220**

**0042841**

3 July 2020

Revision P02



| Revision | Description             | Issued by | Date       | Checked |
|----------|-------------------------|-----------|------------|---------|
| P01      | Draft Stage 4a          | PE        | 09.04.2020 | TH      |
| P02      | Stage 4a Issue – Tender | PE        | 03.07.2020 | TH      |

This report has been prepared for the sole benefit, use and information of OVG Europe Ltd for the purposes set out in the report or instructions commissioning it. The liability of Buro Happold Limited in respect of the information contained in the report will not extend to any third party.

author **Paul Eddleston**

date **03.07.2020**

approved **Tom Headley**

signature



date **03.07.2020**



# Contents

|          |                                    |           |
|----------|------------------------------------|-----------|
| <b>1</b> | <b>Executive Summary</b>           | <b>11</b> |
| <b>2</b> | <b>Introduction</b>                | <b>12</b> |
| 2.1      | Purpose                            | 12        |
| 2.2      | Scope of works                     | 12        |
| 2.3      | Responsibilities                   | 12        |
| 2.4      | Design status                      | 13        |
| 2.4.1    | Current status                     | 13        |
| 2.4.2    | Further and final design           | 14        |
| 2.5      | Document status                    | 14        |
| 2.6      | Document list                      | 14        |
| 2.7      | Drawing list                       | 14        |
| 2.8      | References                         | 14        |
| <b>3</b> | <b>Health and Safety</b>           | <b>16</b> |
| 3.1      | Introduction                       | 16        |
| 3.2      | Key items                          | 16        |
| <b>4</b> | <b>Design Criteria</b>             | <b>17</b> |
| 4.1      | Introduction                       | 17        |
| 4.2      | Materials criteria                 | 17        |
| 4.2.1    | Preliminary concrete strength      | 17        |
| 4.3      | Loading criteria                   | 17        |
| 4.3.1    | Dead loading                       | 18        |
| 4.3.2    | General super imposed dead loading | 18        |
| 4.3.3    | Imposed loading                    | 18        |
| 4.3.4    | Horizontal loading on barriers     | 19        |
| 4.3.5    | Construction loads                 | 19        |
| 4.4      | Deflection criteria                | 19        |
| 4.5      | Vibration criteria                 | 20        |

|          |                                                                                 |           |
|----------|---------------------------------------------------------------------------------|-----------|
| 4.6      | Minimum reinforcement                                                           | 20        |
| 4.7      | Tolerance criteria: general                                                     | 20        |
| 4.7.1    | Manufacturing tolerances                                                        | 20        |
| 4.7.2    | Installation tolerance                                                          | 23        |
| 4.8      | Concrete finish criteria                                                        | 23        |
| 4.9      | Waterproofing criteria                                                          | 23        |
| 4.10     | Fire resistance criteria                                                        | 23        |
| 4.11     | Movement joint criteria                                                         | 23        |
| <b>5</b> | <b>Bowl Overview</b>                                                            | <b>25</b> |
| 5.1      | Introduction                                                                    | 25        |
| 5.2      | General bowl arrangement                                                        | 25        |
| 5.3      | Special Units                                                                   | 26        |
| 5.3.1    | Back of bowl                                                                    | 26        |
| 5.3.2    | Vomitory Units                                                                  | 26        |
| 5.3.3    | Treatment of Movement Joints                                                    | 27        |
| 5.3.4    | Accessible viewing platforms                                                    | 27        |
| 5.3.5    | Step blocks                                                                     | 27        |
| 5.3.6    | End panels                                                                      | 27        |
| 5.3.7    | Parapet units                                                                   | 27        |
| 5.3.8    | Chamfer units                                                                   | 28        |
| <b>6</b> | <b>General Details</b>                                                          | <b>29</b> |
| 6.1      | Connections between primary structure steel rakers and pre-cast terracing units | 29        |
| 6.2      | Joints and movement joints                                                      | 29        |
| 6.2.1    | Masticking                                                                      | 29        |
| 6.2.2    | Primary building radial movement joints                                         | 30        |
| 6.2.3    | Jointing at every raker position                                                | 30        |
| 6.2.4    | Jointing at front edge units                                                    | 30        |
| 6.3      | Packs and bearing                                                               | 30        |

|          |                                                            |           |
|----------|------------------------------------------------------------|-----------|
| 6.4      | Handrails and other barriers and fixings to pre-cast units | 30        |
| 6.5      | Architectural features                                     | 30        |
| 6.6      | Cast in lifting points                                     | 31        |
| <b>7</b> | <b>Bowl Description</b>                                    | <b>32</b> |
| 7.1      | East stand                                                 | 32        |
| 7.2      | North Stand (South similar)                                | 36        |
| 7.2.1    | Upper Tier                                                 | 36        |
| 7.2.2    | Mid-Tier                                                   | 39        |
| 7.2.3    | Lower Tier                                                 | 40        |
| 7.3      | West stand                                                 | 42        |
| 7.3.1    | Upper Tier                                                 | 43        |
| 7.3.2    | Lower tier                                                 | 45        |
| 7.4      | West Corners                                               | 46        |
| 7.4.1    | Upper tier                                                 | 47        |
| 7.4.2    | Lower tier                                                 | 52        |
| <b>8</b> | <b>Construction Sequence</b>                               | <b>54</b> |
| 8.1      | Introduction                                               | 54        |
| 8.2      | General Sequence                                           | 54        |
| 8.3      | Specific Issues                                            | 55        |
| 8.3.1    | Storage                                                    | 55        |
| 8.3.2    | Handling and Erection                                      | 55        |
| <b>9</b> | <b>Precast Stairs</b>                                      | <b>56</b> |
| 9.1      | Introduction                                               | 56        |
| 9.2      | Precast stair scope                                        | 56        |
| 9.3      | Responsibilities                                           | 56        |
| 9.4      | Design status                                              | 57        |
| 9.4.1    | Current status                                             | 57        |
| 9.4.2    | Further and final design                                   | 57        |

|        |                                                            |    |
|--------|------------------------------------------------------------|----|
| 9.5    | Design Criteria                                            | 57 |
| 9.5.1  | Materials criteria                                         | 57 |
| 9.5.2  | Preliminary concrete strength                              | 58 |
| 9.5.3  | Loading criteria                                           | 58 |
| 9.5.4  | Deflection criteria                                        | 58 |
| 9.5.5  | Vibration criteria                                         | 58 |
| 9.5.6  | Tolerance criteria: general                                | 58 |
| 9.5.7  | Installation tolerance                                     | 58 |
| 9.5.8  | Concrete finish criteria                                   | 59 |
| 9.5.9  | Waterproofing criteria                                     | 59 |
| 9.5.10 | Fire resistance criteria                                   | 59 |
| 9.6    | Core Stairs                                                | 59 |
| 9.7    | Preliminary details                                        | 59 |
| 9.7.1  | Pre-cast stair to landing                                  | 59 |
| 9.7.2  | Pre-cast landing to core wall                              | 59 |
| 9.7.3  | Pre-cast infill piece to pre-cast stair                    | 60 |
| 9.8    | Feature stairs                                             | 61 |
| 9.9    | General Stair Details                                      | 61 |
| 9.9.1  | Joints and movement joints                                 | 61 |
| 9.9.2  | Packs and bearing                                          | 61 |
| 9.9.3  | Handrails and other barriers and fixings to pre-cast units | 61 |
| 9.9.4  | Architectural features                                     | 62 |
| 9.9.5  | Cast in lifting points                                     | 62 |

## Appendix A

### Table of Tables

|                                                                 |           |
|-----------------------------------------------------------------|-----------|
| <b>Table 2-1 Design responsibility</b>                          | <b>13</b> |
| <b>Table 2-2 Drawing list for Bowl Pre-cast</b>                 | <b>14</b> |
| <b>Table 2-3 Documents referenced within this specification</b> | <b>15</b> |

|                                                        |           |
|--------------------------------------------------------|-----------|
| <b>Table 4-1 Design data</b>                           | <b>17</b> |
| <b>Table 4-2 Super imposed dead loading</b>            | <b>18</b> |
| <b>Table 4-3 Imposed loading</b>                       | <b>18</b> |
| <b>Table 4-4 Horizontal loading on barriers</b>        | <b>19</b> |
| <b>Table 4-5 Permitted dimensional deviations</b>      | <b>22</b> |
| <b>Table 9-1 - Precast stair design responsibility</b> | <b>57</b> |
| <b>Table 9-2 - Design Data</b>                         | <b>57</b> |

## **Table of Figures**

|                                                                                    |           |
|------------------------------------------------------------------------------------|-----------|
| <b>Figure 4-1 Key to Table 4-5</b>                                                 | <b>21</b> |
| <b>Figure 5-1 General Terrace Elements</b>                                         | <b>26</b> |
| <b>Figure 5-2 Sections through front edge parapet unit</b>                         | <b>28</b> |
| <b>Figure 6-1 Typical steel raker to pre-cast unit connection</b>                  | <b>29</b> |
| <b>Figure 7-1 - East stand bowl and superstructure model</b>                       | <b>32</b> |
| <b>Figure 7-2 - Typical terrace unit within bowl</b>                               | <b>33</b> |
| <b>Figure 7-3 - Terrace unit with recess for aisle stairs</b>                      | <b>33</b> |
| <b>Figure 7-4 - East stand front parapet double unit</b>                           | <b>34</b> |
| <b>Figure 7-5 - Back of bowl interface with level 3 East stand</b>                 | <b>34</b> |
| <b>Figure 7-6 - East stand global frame MJ</b>                                     | <b>35</b> |
| <b>Figure 7-7 - Northern end of East bowl</b>                                      | <b>35</b> |
| <b>Figure 7-8 - North stand bowl and superstructure model</b>                      | <b>36</b> |
| <b>Figure 7-9 - North stand upper tier front parapet</b>                           | <b>37</b> |
| <b>Figure 7-10 - North upper tier back of bowl interface</b>                       | <b>37</b> |
| <b>Figure 7-11 - North stand upper tier vomitory</b>                               | <b>38</b> |
| <b>Figure 7-12 - North upper tier Eastern end</b>                                  | <b>38</b> |
| <b>Figure 7-13 - North stand mid-tier bowl</b>                                     | <b>39</b> |
| <b>Figure 7-14 - North mid-tier slab interface</b>                                 | <b>39</b> |
| <b>Figure 7-15 - North lower tier</b>                                              | <b>40</b> |
| <b>Figure 7-16 - Lower tier North back of bowl interface</b>                       | <b>40</b> |
| <b>Figure 7-17 - Proposed Lower tier North pre-cast/slab interface</b>             | <b>41</b> |
| <b>Figure 7-18 - Lower tier North interface with retractable seats</b>             | <b>41</b> |
| <b>Figure 7-19 - Lower tier North pre-cast to retractable interface no parapet</b> | <b>42</b> |

|                                                                                         |           |
|-----------------------------------------------------------------------------------------|-----------|
| <b>Figure 7-20 - West stand 3D model</b>                                                | <b>43</b> |
| <b>Figure 7-21 - West upper front parapet</b>                                           | <b>43</b> |
| <b>Figure 7-22 - West stand upper tier back of bowl</b>                                 | <b>44</b> |
| <b>Figure 7-23 - West upper tier vomitory stair</b>                                     | <b>44</b> |
| <b>Figure 7-24 - West stand upper tier parapet</b>                                      | <b>45</b> |
| <b>Figure 7-25 - West stand lower tier</b>                                              | <b>46</b> |
| <b>Figure 7-26 - West corners 3D model</b>                                              | <b>47</b> |
| <b>Figure 7-27 - West corner upper tier</b>                                             | <b>47</b> |
| <b>Figure 7-28 - North corner back of bowl sketch 1</b>                                 | <b>48</b> |
| <b>Figure 7-29 - West corner back of bowl interface</b>                                 | <b>49</b> |
| <b>Figure 7-30 - North corner back of bowl sketch 2</b>                                 | <b>49</b> |
| <b>Figure 7-31 - North corner back of bowl sketch 3</b>                                 | <b>50</b> |
| <b>Figure 7-32 - North corner back of bowl sketch 4</b>                                 | <b>50</b> |
| <b>Figure 7-33 - West corner upper tier sloped parapet wall</b>                         | <b>51</b> |
| <b>Figure 7-34 - NW2 joint geometry</b>                                                 | <b>51</b> |
| <b>Figure 7-35 - West corner mid-tier bowl geometry</b>                                 | <b>52</b> |
| <b>Figure 7-36 - West corner lower tier</b>                                             | <b>53</b> |
| <b>Figure 8-1 - Possible pre-cast vomitory wall to floor plate interface</b>            | <b>54</b> |
| <b>Figure 8-2 - Indicative vomitory wall stool detail</b>                               | <b>55</b> |
| <b>Figure 9-1 - Typical detail for pre-cast stair supported on cast in-situ landing</b> | <b>59</b> |
| <b>Figure 9-2 Typical detail for pre-cast stair supported on cast in-situ wall</b>      | <b>60</b> |
| <b>Figure 9-3 Typical detail for pre-cast in-fill unit supported on pre-cast stair</b>  | <b>61</b> |

# 1 Executive Summary

This document provides a structural description and specification of the bowl and stair pre-cast elements for the OVG Manchester Arena and their interface with the primary structure.

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.

To enable the development of the primary structure to the end of RIBA Stage 4A and then on to construction information Buro Happold have developed a structural design intent for the bowl pre-cast structure. A description of this structural intent including the arrangement of the pre-cast elements, their support conditions and preliminary sizes is included within this document. The document status describes the level of information which is anticipated to increase through the detailed design stage.

To ensure the validity of the design of the primary structure attention is drawn to some of the key design criteria held within this document:

- Pre-cast unit element weight criteria - Section 4.
- Vibration criteria – Section 4.5.
- Minimum reinforcement – Section 4.6.

In addition this document outlines:

- Scope of works, responsibilities, design status and additional information.
- Key health and safety items relating to the bowl pre-cast.
- Additional design criteria.
- General details for the pre-cast elements.
- Construction sequence information.

## 2 Introduction

### 2.1 Purpose

This document has been produced as a performance specification for the bowl pre-cast structure and associated elements. It should be read in conjunction with the Buro Happold drawings, structural design reports and material specifications and alongside the Architectural information including 3-D bowl model, drawings and specification.

### 2.2 Scope of works

The scope of works for which the specification applies is the Bowl Precast defined as:

- 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.

The scope of works for the Stairs and Landings can be found within the Precast Stair chapter in this document.

The scope of the works for the Bowl Pre-cast is shown on architectural and structural drawings. Certain information will be shown on only one set of drawings.

The project also includes the following additional secondary structure and architectural pre-cast elements not covered by this specification:

- External and bowl side cladding units;

### 2.3 Responsibilities

The main design of the arena will be completed by the time the Client's designer is novated to the Main Contractor. Completion of the final design, detailing, and submission of Building Control approvals, will be the responsibility of the Main Contractor, based on the requirements of the Structural Specifications and Drawings. The Main Contractor is also to take responsibility for all the design work to date and be satisfied that the specification requirements are achievable.

Detailed design, detailing and manufacture of the Bowl Pre-cast is to be completed by the Bowl Pre-cast Package Sub-Contractor's Designer based on the performance specification. This includes the reinforcement design and detailing with due consideration for installation and handling. The final design of the Bowl 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. An outline of design responsibilities is defined in Table 2-1.

| Design Responsibility                               |                                                |                                                                                                                                                                                                                                                                                                                                                                       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
|-----------------------------------------------------|------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Designer                                            | Package                                        | Element Design                                                                                                                                                                                                                                                                                                                                                        | Connection Design                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| Bowl Pre-cast Package Sub-Contractor Designer       | Secondary structure: Pre-cast Bowl Package     | Terracing units, step blocks, parapet units, end 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, pre-cast composite floor panels acting as interfacing between back of bowl and RC concourse structure, all other elements of Bowl Pre-cast. | <ul style="list-style-type: none"> <li>Connections between bowl pre-cast including steel angles between vomitory walls and units;</li> <li>Connections in/of pre-cast where connected to primary structure (requires coordination with Main Contractor's Engineer);</li> <li>Connections in/of pre-cast where connections to bowl metalwork (requires coordination with Main Contractor's Bowl Metalwork Engineer);</li> <li>Connections in/of bowl pre-cast structure where connected to miscellaneous metalwork (requires coordination with Main Contractor's Miscellaneous Metalwork Engineer);</li> <li>Additional bowl steelwork supports not shown on the drawings;</li> </ul> |
| Main Contractor's Engineer (BuroHappold)            | Primary Structure for permanent condition only | Primary structural support to Bowl Pre-cast: Steel rakers, back-of-bowl steel beams, vomitory support beams, slabs, RC walls, steel trimmers where shown on the drawings.                                                                                                                                                                                             | <ul style="list-style-type: none"> <li>Connections in/of primary structure where connected to bowl pre-cast (requires coordination with Bowl Pre-cast Package Contractor Designer) – connections to cast in-situ elements such as core walls, shear walls and slab edges.</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                 |
| Steel Fabricator                                    | Steel Frame                                    | <ul style="list-style-type: none"> <li>Shims for all rakers;</li> <li>Stools on steel rakers;</li> </ul>                                                                                                                                                                                                                                                              | <ul style="list-style-type: none"> <li>Connections in/of stools where connected to bowl pre-cast (requires coordination with Bowl Pre-cast Package Contractor Designer);</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| Miscellaneous Metalwork Package Contractor Designer | Secondary structure: Miscellaneous Metalwork   | <ul style="list-style-type: none"> <li>Metal platforms on pre-cast units (accessible platform in lower tier, follow spot platforms in upper and lower tiers).</li> </ul>                                                                                                                                                                                              | <ul style="list-style-type: none"> <li>Connections in/of metal platforms structure where connected to bowl pre-cast (requires coordination with Bowl Pre-cast Package Contractor Designer);</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| Bowl Metalwork Package Contractor Designer          | Secondary structure: Bowl Metalwork            | <ul style="list-style-type: none"> <li>Handrails;</li> <li>Barriers;</li> </ul>                                                                                                                                                                                                                                                                                       | <ul style="list-style-type: none"> <li>Connections in/of bowl metalwork structure where connected to bowl pre-cast (requires coordination with Bowl Pre-cast Package Contractor Designer);</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |

Table 2-1 Design responsibility

## 2.4 Design status

### 2.4.1 Current status

Preliminary section sizes and reinforcement content of typical units have been estimated to allow the design of the primary bowl structure to progress to the end of RIBA Stage 4 and construction documentation. The dynamic performance of the individual units has been empirically checked based on sector expertise and precedents.

Outline design calculations have been produced for typical pre-cast terracing units to deliver section sizes and general reinforcement requirements.

### 2.4.2 Further and final design

Further and final design is required by the Bowl Pre-cast Package Contractor Designer to incorporate the Main Contractors preferred installation methodology and finalise the sizes of the units and construction detailing. This is to be carried out in accordance with the performance specifications within this document and the final design must be verified to ensure that the natural frequency of the overall stand structure meets the project dynamic requirements.

## 2.5 Document status

Revision P02 of this document acts as the RIBA Stage 4a issue and adds detail to the previous issues which have been considered during detailed design. Additional information on areas within the package which are atypical have been included to allow the Package Contractor to have better understanding of the design and assist their costing exercise.

Updated information from the previous revision have been written blue for clarity.

## 2.6 Document list

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

Refer to BRA-BHE-ZZ-XX-RP-S-0100 – Structural Design Report for the structural document list.

## 2.7 Drawing list

The drawing list in Table 2-2 identifies the structural drawings specific to the bowl pre-cast elements. These should be read in conjunction with the architectural drawings and other structural drawings as necessary.

| Number                                  | Title                               | Comments |
|-----------------------------------------|-------------------------------------|----------|
| <b>Bowl pre-cast structure drawings</b> |                                     |          |
| BRA-BHE-XX-XX-DR-S-5151                 | SUPERSTRUCTURE BOWL DETAILS SHEET 1 |          |
| BRA-BHE-XX-XX-DR-S-5152                 | SUPERSTRUCTURE BOWL DETAILS SHEET 2 |          |

**Table 2-2 Drawing list for Bowl Pre-cast**

## 2.8 References

The documents referenced within this report are listed in Table 2-3.

| <b>Design Standards</b> |                                                                                                                                            |
|-------------------------|--------------------------------------------------------------------------------------------------------------------------------------------|
| <b>BS EN 1990</b>       | Basis of Structural Design                                                                                                                 |
| <b>BS EN 1991</b>       | Eurocode 1: Actions on Structures                                                                                                          |
| <b>BS EN 1992</b>       | Eurocode 2: Design of Concrete Structures                                                                                                  |
| <b>IStructE</b>         | Dynamic performance requirements for permanent grandstands subject to crowd action – Recommendations for management, design and assessment |
| <b>BS 5400: Part 2</b>  | Steel, concrete and composite bridges. Specification for loads (withdrawn)                                                                 |

|                  |                                            |
|------------------|--------------------------------------------|
| BS EN 13369:2014 | Common rules for precast concrete products |
|------------------|--------------------------------------------|

Note: where not listed the latest version of the document should be referenced.

Table 2-3 Documents referenced within this specification

## 3 Health and Safety

### 3.1 Introduction

Reference should be made to the Principal Designer risk register for key health and safety information and BRA-BHE-ZZ-XX-RP-S-0301 – Record of Significant H&S Information. Below follows a summary of some of the unique aspects of health and safety to be considered for this package.

### 3.2 Key items

The following items are key issues considered during the design that have residual risk i.e. could not be completely mitigated/eliminated during the design process.

- **Installation in limited work space** – the seating bowl is formed from pre-cast concrete elements on a primary structural steel frame. There are upper and mid level tiers with precast terrace components and a roof over. The tiers incorporate bowl-side cantilevers which are ‘stacked’ for the North and South stands and upper levels project over the pre-cast terracing units in some areas. There will be physical constraints of primary frame structure surrounding the bowl. Planning for the phasing and installation of precast bowl components will need to account for the surrounding structures and be safely carried out in a constrained environment.
- **Temporary stability of pre-cast elements** – temporary stability of the terracing units needs to be considered in the design of the temporary works and falsework.
- **Temporary stability of steel rakers** – the pre-cast unit installation sequence may need to be carried out by installing units row by row as opposed to bay by bay, if necessary, to prevent instability to the steel rakers.
- **Transport and erection of larger units** – units to span typically 8.5m to 10.1m between rakers will be required for much of the bowl, but longer, more complex and larger units will be required for specific cases at corners or for specific bowl details. Transport and erection of these larger units will need to be specifically planned;
- **Instability of pre-cast vomitory walls and bowl parapets** – a strategy will be needed for the provision of temporary stability for the pre-cast vomitory walls and bowl parapets where this is to be provided in the permanent case by subsequently installed pre-cast units.
- **Lifting of pre-cast elements** – allowance should be made by the contractor for cast-in lifting points for safe lifting of pre-cast elements.

## 4 Design Criteria

### 4.1 Introduction

The general design criteria including loading and performance requirements are recorded in BRA-BHE-ZZ-XX-RP-S-0200 Structural Basis of Design Report. The section below provides additional criteria for this package. Reference must also be made to the project material specifications including BRA-BHE-ZZ-ZZ-SP-S-0100 Structural Concrete Specification.

### 4.2 Materials criteria

Detailed design of the pre-cast terracing elements is the responsibility of the specialist sub-contractor.

| Criteria                             | Requirement                                                                                                                        |
|--------------------------------------|------------------------------------------------------------------------------------------------------------------------------------|
| Durability <sup>1</sup>              | To be designed for exposure class XC3/4                                                                                            |
| Design life                          | 50 Years                                                                                                                           |
| Maintenance/ replacement assumptions | The seating units will be dry cleaned after every event and local staining removed.<br>Jet washing and gritting is not to be used. |

**Notes:**

- Concrete exposure is based on conditions in use being moderate humidity or cyclic wet and dry, due to the surface being directly exposed to pedestrians, spillage and wet cleaning. If the conditions in storage or transportation of the pre-cast elements are likely to be more onerous, such as being stored outside or on the ground, the contractor should reassess the durability requirements based on the temporary condition, with the possibility of needing to specify XD, XF or CD classes and designing the concrete appropriately to prevent damage due to temporary conditions such as freeze/thaw damage.
- All shims to be stainless steel or non-corrosive to avoid rust staining at a later date.

**Table 4-1 Design data**

#### 4.2.1 Preliminary concrete strength

The preliminary design carried out by Buro Happold is based on C40/50 concrete strength.

### 4.3 Loading criteria

Complete loading information for the final state can be found on the loading drawings with some description in the Structural Basis of Design Report.

The primary structure supporting the pre-cast elements has been designed for a maximum self-weight of the pre-cast units. The final dimensions of the pre-cast units are subject to confirmation by the Bowl Pre-cast Package Sub-Contractor and their chosen design and method of manufacture. However, the Bowl Pre-cast Package Sub-Contractor Designer shall ensure that the weight of their final element design does not exceed that of the Buro Happold preliminary self-weight to ensure there is no negative impact on the primary structure.

The self-weight of the pre-cast units is described on the Superimposed Dead Load loading drawings.

### 4.3.1 Dead loading

The dead loading for the bowl pre-cast units from the Buro Happold preliminary design are included in the SDL loading applied to the primary structural frame and are therefore shown on the SDL loading drawings.

The final design of the pre-cast units by the Bowl Pre-cast Package Sub-Contractor shall not exceed these figures to ensure that the pre-cast units work in conjunction with the current design of the primary structure of the arena to meet overall performance requirements.

### 4.3.2 General super imposed dead loading

The super imposed dead loading (SDL) applied to the bowl terracing units are included in the SDL loading applied to the primary structural frame as shown on the SDL loading drawings.

The table below identifies the general superimposed dead loading that the Bowl Pre-cast is to be designed for. Certain pre-cast elements will need to be designed to support additional specific items of superimposed dead load such as temporary handrails, etc.

| Load type | Title                     | Location                                                                     | Description/comment                                                                          | Load / Area<br>kN/m <sup>2</sup> |
|-----------|---------------------------|------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------|----------------------------------|
| SDL       | Suspended plenum ceiling. | All units apart from those at the very front of the tiers with flat soffits. | Plenum to be hung from the pre-cast units to minimise the requirement for secondary framing. | Refer to Loading Drawing         |
| SDL       | Seating                   | All seating areas – refer to architects drawings.                            | Allowance for seats and seating rails.                                                       | Refer to Loading Drawing         |
| SDL       | Wheelchair platforms.     | TBC                                                                          |                                                                                              | TBC                              |
| SDL       | Electronic Display Boards | Line load to be applied on front of parapet.                                 | At front of upper and mid tiers.                                                             | Refer to Loading Drawing         |

Table 4-2 Super imposed dead loading

### 4.3.3 Imposed loading

The code defined imposed loading for the bowl pre-cast units is shown in Table 4-3. In noting the comments made in section 4.3.5 “Construction loads” it is recommended that the design of the pre-cast units be carried out using an imposed load of 5.0kN/m<sup>2</sup> throughout.

| Load type | Title   | Location                        | Description/comment | Load / Area<br>kN/m <sup>2</sup> |
|-----------|---------|---------------------------------|---------------------|----------------------------------|
| LL        | Aisle   | Shown on architectural drawings | -                   | 5.0                              |
| LL        | Seating | Shown on architectural drawings | -                   | 4.0                              |

Table 4-3 Imposed loading

#### 4.3.4 Horizontal loading on barriers

Refer to horizontal loading drawings BRA-BHE-ZZ-ZZ-DR-S-0310, 0330, 0350 for horizontal crowd loading on bowl elements in accordance with the 'Guide to Safety at Sports Grounds' document published by the Department for Culture, Media and Sport, referred to as the Green Guide.

For loads on barriers not covered by the Green Guide, reference should be made to EN 1991-1-1 cl. 6.4.

Below is a summary of some of the key loading requirements.

| Types of Barrier                                                                                                  | Horizontal Imposed Load         |
|-------------------------------------------------------------------------------------------------------------------|---------------------------------|
| 1. Crush barriers for standing accommodation                                                                      | See Table 11.2 (Green Guide)    |
| 2. Barriers for spectator galleries                                                                               | See Table 11.3 (Green Guide)    |
| 3. Barrier for gangways of seating decks, aligned at right angles to the direction of spectator movement          | 3.0 kN/m length                 |
| 4. Barriers for gangways of seating decks, parallel to the direction of spectator movement                        | 2.0 kN/m length                 |
| 5. Barriers for seating decks, adjacent to the end row of seats and protecting spectators from falling sideways   | 1.0 kN/m length                 |
| 6. Barriers for seating decks, behind a rear row of seats and protecting spectators from falling backwards        | 1.0 kN/m length                 |
| 7. Barriers positioned within 530mm in front of seats                                                             | 1.5 kN/m length                 |
| 8. Barriers for stairways, landings and ramps, aligned at right angles to the direction of movement of spectators | 3.0 kN/m length                 |
| 9. Barriers for stairways, landings and ramps, aligned with the direction of movement of spectators               | 2.0 kN/m length                 |
| 10. Barriers for gangways in standing areas, aligned at right angles to the direction of spectator movement       | 5.0 kN/m length                 |
| 11. Other barriers, including walls, boundary walls, fences and gates that may be subject to crowd loading        | See Section 11.17 (Green Guide) |

**Table 4-4 Horizontal loading on barriers**

#### 4.3.5 Construction loads

The Main Contractor shall be responsible for determining and specifying loads applied to any pre-cast units during construction. This will include any loads to the upper tier units arising from propping of roof steelwork.

The units to all tiers will need to be designed to carry a construction uniformly distributed live load of 5kN/m<sup>2</sup> and/or localised point loads of 5kN at 1.2m centres along the length of each unit, whichever produces the worst-case stresses/deflections for the area under consideration. This should be allowed for by the Bowl Pre-cast Package Sub-contractor in their design who should recognise that the Main Contractor will be required to confirm this.

#### 4.4 Deflection criteria

A maximum deflection for each unit is to be calculated by the Bowl Pre-cast Package Sub-contractor designer based on the final geometrical and structural design of the terracing units to suit the proposed construction sequence. This is then to be checked and agreed against overall project requirements and specifications.

Refer to Movement and Tolerances report for deflection criteria.

## 4.5 Vibration criteria

The assessment of the raker and terracing unit dynamics are to be carried out with reference to the IStructE guide entitled "*Dynamic performance requirements for permanent grandstands subject to crowd action*" – see the Structural Design Report for more details and for design assessments carried out to date.

Dynamic studies indicate that to achieve the required performance the individual terracing units should be sized initially to achieve a minimum vertical fundamental natural frequency of 10.0Hz. Frequencies may be calculated using BD37/01 Composite Version of BS 5400 part 2 Appendix B2.3 based on the gross (uncracked) section properties for the beam and using a Dynamic Young's Modulus for concrete to BS EN 1992 (typically 38N/mm<sup>2</sup> for grade C40). Loads should include the unit self-weight, applied dead load and super-imposed dead load carried by that unit and must include for details at steps and areas of infill blocks where total mass of concrete may be higher.

## 4.6 Minimum reinforcement

In typical 8.5m long 'beam' or parapet elements there should be a minimum of 2 No. H20's in the bottom and 2 No. H16's in the top.

Although the vibration criteria set out above is to be based on gross section properties of the bowl pre-cast units, as part of the global dynamic analysis of the arena, Buro Happold has carried out a more detailed assessment of the pre-cast units which includes an approximation of the amount of cracking in the tension face of the pre-cast. This level of cracking is dependent on the amount of reinforcement present in the units and therefore a minimum amount of reinforcement in each unit is to be specified.

## 4.7 Tolerance criteria: general

The Bowl Pre-cast Package Sub-contractor is responsible for coordinating tolerances in order to ensure that all elements of the structure fit together and comply with the dimensional requirements shown in the Contract Documents.

Before manufacture the Bowl Pre-cast Package Sub-contractor shall ensure that adequate allowance has been made for all construction tolerances to ensure proper fit up of the structure.

### 4.7.1 Manufacturing tolerances

Permitted dimensional deviations shall be less than that given in BS EN 13369:2014 clause 4.3.1.1 as summarised in Table 4-5 below.

The position of cast-in fixings, cast-in sleeves, service openings etc. shall be within 6mm of the datum line. Groups and lines of such items should be located similarly, but with the centre of the group or best line within 6mm of the datum. Within a group, each individual item should be within 3mm of the specified dimension in relation to the other items in the group or line.

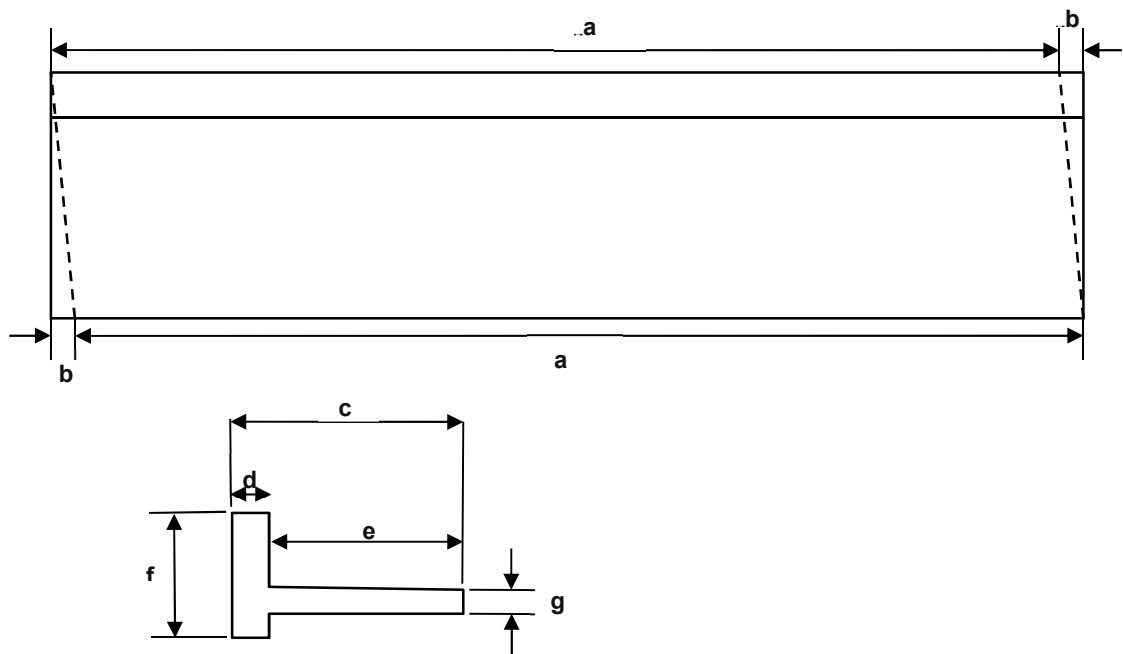


Figure 4-1 Key to Table 4-5

| Dimension                                                                                                           | Where dimension | Tolerance                                                       |
|---------------------------------------------------------------------------------------------------------------------|-----------------|-----------------------------------------------------------------|
| <b>LENGTH</b>                                                                                                       |                 |                                                                 |
| <b>a</b>                                                                                                            | Up to 3m        | ± 3mm                                                           |
| <b>a</b>                                                                                                            | 3-4.5m          | ± 4.5mm                                                         |
| <b>a</b>                                                                                                            | 4.5-6m          | ± 6mm                                                           |
| <b>a</b>                                                                                                            | 6-12m           | ± (6mm plus 0.5mm for every additional metre in length over 6m) |
| <b>STRAIGHTNESS OR BOW (deviation from intended line)</b>                                                           |                 |                                                                 |
| <b>a</b>                                                                                                            | 3m              | 3mm                                                             |
| <b>a</b>                                                                                                            | 3-6m            | 4.5mm                                                           |
| <b>a</b>                                                                                                            | 6-12m           | 6mm                                                             |
| <b>SQUARENESS</b>                                                                                                   |                 |                                                                 |
| <b>b</b>                                                                                                            | -               | ± 3mm                                                           |
| <b>CROSS SECTION</b>                                                                                                |                 |                                                                 |
| <b>c</b>                                                                                                            | 950-1050mm      | ± 6mm                                                           |
| <b>d</b>                                                                                                            | 150mm           | ± 3mm                                                           |
| <b>e</b>                                                                                                            | 800-900mm       | ± 5mm                                                           |
| <b>f</b>                                                                                                            | Up to 500mm     | ± 3mm                                                           |
| <b>f</b>                                                                                                            | 500-750mm       | ± 4.5mm                                                         |
| <b>g</b>                                                                                                            |                 | ± 3mm                                                           |
| <b>TWIST (any corner should be no more than the stated deviation from the plane containing the other 3 corners)</b> |                 |                                                                 |
| <b>a</b>                                                                                                            | Up to 6m        | 3mm                                                             |
| <b>a</b>                                                                                                            | Over 6m         | 6mm                                                             |
| <b>FLATNESS</b>                                                                                                     |                 |                                                                 |
| <b>Unformed surface</b>                                                                                             | -               | 3mm over 1.5m                                                   |
| <b>Formed surface</b>                                                                                               | -               | 2mm over 1.5m                                                   |

Table 4-5 Permitted dimensional deviations

#### 4.7.2 Installation tolerance

Terrace units shall be designed and installed so that the maximum difference in level between adjacent units is no more than 3mm to prevent trip hazards. This is particularly important for longitudinal joints; when units of different stiffness are installed side by side.

To achieve the required sightlines, the pre-cast terracing units shall be positioned in the main frame to the final tolerances outlined by the architect with verification of level measured above the support point at the rear of the slab as shown on the drawings.

All other associated pre-cast elements (such as vomitory walls) which provide support to the pre-cast terrace elements to be installed so that the support locations to the terrace units are never more than +/- 15mm horizontally or vertically from the position shown on the drawings measured at the height of the support.

The specialist pre-cast concrete sub-contractor is responsible for coordinating tolerances in order to ensure that all elements of the structure fit together and comply with the dimensional requirements shown in the Contract Documents.

#### 4.8 Concrete finish criteria

Refer to the architectural specification.

#### 4.9 Waterproofing criteria

Refer to the architectural specification.

#### 4.10 Fire resistance criteria

All pre-cast concrete elements and their support structure [including fixings](#) (both within this package of works and outside) e.g. rakers, walls, shelf angles etc., are to have a minimum of [90 minute](#) fire resistance (refer to Fire Report for further information). This includes the joints between the terracing units. [In some locations this can be reduced based on the Structural Fire Engineering analysis, refer to BRA-BHE-ZZ-ZZ-RP-YD-0002.](#)

#### 4.11 Movement joint criteria

##### Circumferential movement:

Circumferential movement of the bowl corresponds to movement in the direction of the span of the terrace units (orthogonal to the rakers). Positive movements refer to an opening of the joint.

- At primary building movement joints: refer to Movement and Tolerance Report;
- [At terrace unit movement joints locally within the bowl \(refer to Bowl GA plans for locations\): +/-10mm circumferential movement due to temperature;](#)

**Radial movement:**

At movement joints in the bowl a small amount of radial 'shear' is expected. This is not required to have a specific slotted hole and the terrace units acting as a plate in shear will resist racking. This is to be confirmed by the specialist Bowl Pre-cast concrete sub-contractor.

## 5 Bowl Overview

### 5.1 Introduction

The following sections describe the structural elements and give the design principals and assumptions for this package.

The design and arrangement of the precast elements and their supports has been developed to ensure a coherent, co-ordinated design of the architectural requirements and structure. The Bowl Pre-cast Package Sub-Contractor should develop their design of the pre-cast elements within the constraints provided.

### 5.2 General bowl arrangement

The pre-cast terracing is considered in 3 main areas:

East stand; typically with spans of 10.125m

North, South & West Middle Tier; typically with spans of 8.5m, although in the corners significantly longer spans exist

North, South & West Upper Tier; typically with spans of 8.5m, although in the corners significantly longer spans exist

In order to achieve the desired sightlines the seating unit top profiles are to be set out as shown on the architectural drawings.

All sizes given in this document are subject to confirmation following appointment of the chosen specialist pre-cast concrete seating unit supplier and their chosen design and method of manufacture of the units.

The pre-cast seating units are typically designed to work structurally as beams at the rear of the unit with a projecting slab. The slabs are supported on their front edge by the beam of the unit below. The going of the slabs is typically 800mm. The top surface of the slab has a nominal slope from back to front. It is anticipated that the beam portion of the units will be typically 175mm thick with the slab portion 100 to 110mm thick. [Outline dimensions for typical unit types are indicated on the superstructure bowl detail drawings. Minimum requirements for 90 minute fire resistance is 100mm thick with 30mm cover to reinforcement.](#)

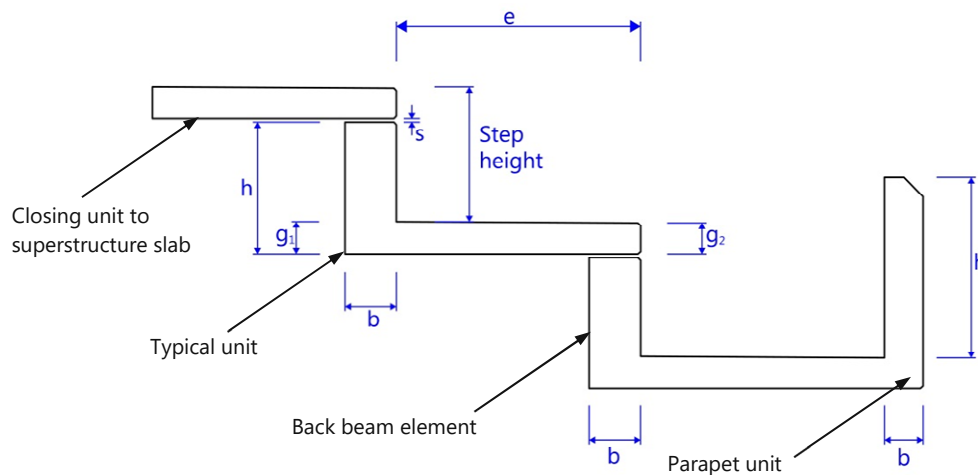


Figure 5-1 General Terrace Elements

Further typical details can be found on drawing BRA-BHE-XX-XX-DR-S-5151 and BRA-BHE-XX-XX-DR-S-5152.

### 5.3 Special Units

#### 5.3.1 Back of bowl

There are a number of different conditions at the back of the mid and upper tier bowl pre-cast. Typically flat pre-cast trimming panels are supported on frequently spaced shelf angles, either fixed into the cast concrete slab edge or to back of bowl steel beams running in the back of bowl. This detail is to be developed in conjunction with the Structural Engineer and the Pre-Cast designer.

In the West, the rake of the terracing and slope of the back-of-bowl creates a zone where a series of special units will be required to close off the bowl. [This detail is still under development, refer to 7.4 for further information. Above this closing piece, an acoustic wall \(secondary steel and insulation\) is required between the terracing and roof soffit level which will interface with the pre-cast elements.](#)

#### 5.3.2 Vomitory Units

To provide access to the seating terraces as series of vomitory units will be required. These are assumed to span between the steel raker and the pre-cast vomitory walls (designed by Pre-Cast designer).

### 5.3.3 Treatment of Movement Joints

The building has 4 main structural movement joints, approximately in the mid-point of each stand. A cover plate flush with the surface of the slab is required at the join between units at main bowl movement joint locations, which at the front of the mid and upper tiers will need to be detailed to account for the wide upstand of the inverted steel T and the depth of the pre-cast slab. Refer to the architectural specification for further requirements of the cover plates.

### 5.3.4 Accessible viewing platforms

Wheelchair platforms with companion seating are located primary in the corners of the west stand. These are large flat units which require special consideration due to the facet geometry in the corners.

### 5.3.5 Step blocks

Steps are typically assumed to be recessed type, requiring appropriated moulding to achieve. It should be recognised the steps fall in differing locations within the unit length and are not always mid-span. Additional blocks on top of the units will be necessary in conjunction with the recesses to form the required riser height.

### 5.3.6 End panels

At each end of the mid-tier a pre-cast end panel will be required to form a barrier and handrail. This will be formed from a single panel separate from the terrace units, supported from the side of the end rakers and propped from the end of the terrace units. The panel will have to extend down to hide the side of the raker. The pre-cast terrace units in this location will need to extend to the far side of the raker to meet the end wall and the raker will be designed specially to accommodate this.

### 5.3.7 Parapet units

The front edge parapet units will be special U-shaped pre-cast units which will incorporate a parapet on the front edge. The parapet shall be designed to support an electronic display boards which should include allowance for their weight, detailing for their attachment and ensuring any deflection limit requirements are met.

These units will require a thicker than normal slab element to resist applied moment from the eccentric horizontal barrier loading and also to enable the underside to be notched locally to the support to allow for the bottom plate of the inverted steel T (and shim depth) to be flush with the underside.

The thickness of the parapet element of the unit may be dictated by the need to accommodate cast in handrails above the unit especially in front of steps.

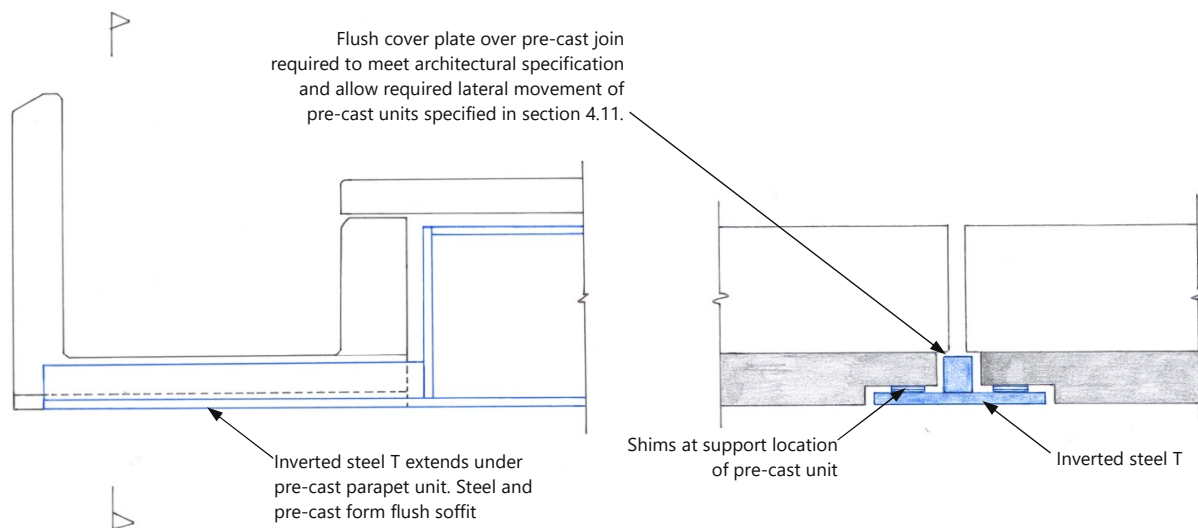


**Figure 5-2 Sections through front edge parapet unit**

### 5.3.8 Chamfer units

These units form the plan chamfer of the upper seating tier as it steps back between radial grids. These pre-cast units will require a parapet end wall along the line of the chamfer.

The units may need to be designed specially to accommodate a different support condition than standard and they may need to cantilever beyond the support depending on the final geometry of the steel structure. This may require thicker than standard elements. The very front unit may need to be a double unit as it does not have any front edge support.

## 6 General Details

### 6.1 Connections between primary structure steel rakers and pre-cast terracing units

The pre-cast units are to be supported on steel stools welded to the top of the rakers with the terrace units held in place by means of shear studs and steel dowels bolted to the stools and grouted into the units, see Figure 6-1 for details.

Pre-cast seating units shall be “fixed” connected at one end to the primary structure and be free to move at the other end in localised bays. This shall generally be achieved by seating tier unit end connections being grouted at one end and having flexible mastic sealant around the fixing at the other end. Neoprene bearing strips are indicated on our typical sections in this document. Larger movements will need to be accommodated at the ends of the units which correspond with the 4 radial building movement joints.

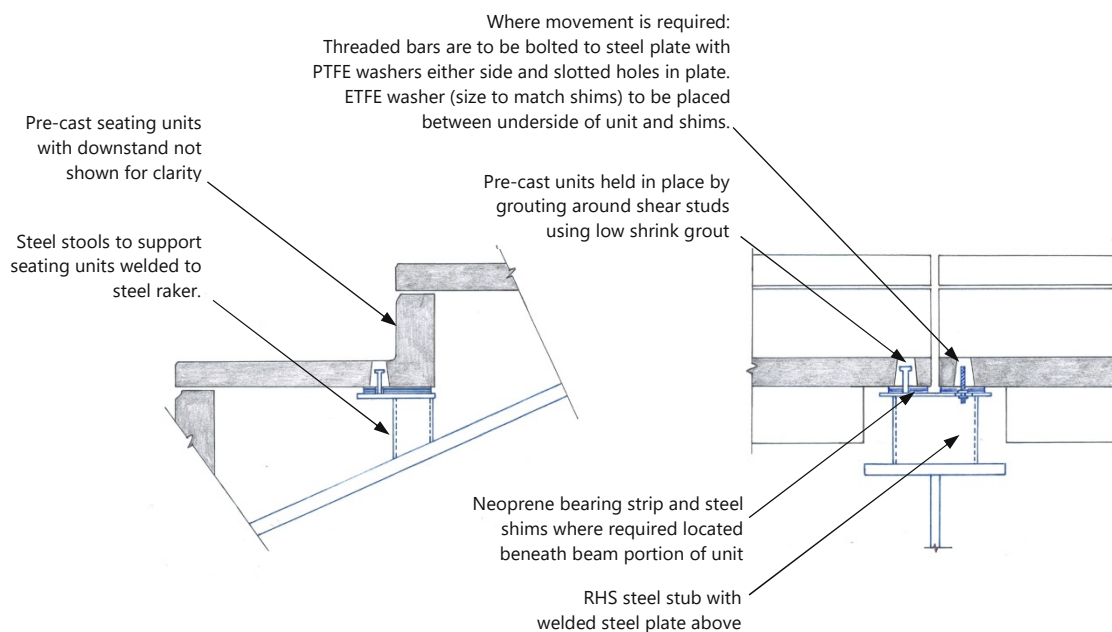


Figure 6-1 Typical steel raker to pre-cast unit connection

### 6.2 Joints and movement joints

#### 6.2.1 Masticking

All joints between pre-cast units both horizontal and vertical are to be masticked (unless a movement joint location requires a different detail to be developed by the Contractor that is capable of accommodating movement, but meeting all other criteria such as waterproofing).

All junctions between in-situ slabs/terraces and pre-cast terracing are also to be masticked (unless a movement joint location requires a different detail to be developed by the Contractor that is capable of accommodating movement, but meeting all other criteria such as waterproofing and fire).

In areas the mastic is required to be intumescent as part of the fire strategy, the extent of this is covered by information produced by the Architect.

### 6.2.2 Primary building radial movement joints

There are 4 principal building radial movement joint locations, corresponding to the movement joints in the main frame, which extend through the pre-cast units. The fixings of the pre-cast seating units at these principal movement joints needs to accommodate the same movements experienced by the main frame and require recessed steel cover plates set into the slabs of the pre-cast seating units. Design is to satisfy all other criteria.

### 6.2.3 Jointing at every raker position

At every raker position a mastic filled joint is to be formed between the units which, [in local positions noted on Bowl GA's](#) allows for thermal movements and shrinkage.

### 6.2.4 Jointing at front edge units

In all tiers the front edge units are supported on inverted steel T raker nibs. The slab element of these pre-cast units will be notched on the underside to be supported on the flange of the inverted T and provide a flush soffit. However the units on both sides will stop short of the upstand web of the steel T. The units will require recessed steel cover plates over this gap in the slab and the faces of the beam and parapet elements. Refer to architectural information for further details of the cover plate requirements and the requirements for their development.

## 6.3 Packs and bearing

Packs are required where pre-cast units are supported. This includes pre-cast to steel, pre-cast to in-situ concrete, pre-cast to pre-cast. In all cases the Bowl Pre-cast Package Sub-contractor is to determine the pack/shim size required in order to transfer the forces from the pre-cast unit to the bearing and also the maximum force to be taken by each pack type and to be capable of freely accommodating required movements where these will occur between components due to temperature. Shims to be stainless steel or non-corrosive.

## 6.4 Handrails and other barriers and fixings to pre-cast units

See Architect's drawings for details.

The design intent is that all handrails, barriers and fixings to the pre-cast terracing units are to be grouted into pockets cast-into the pre-cast elements or fixed in place using sockets and channels cast-into the pre-cast parapet units.

Most of the fixings for barriers are expected to use cast-in sockets into slabs and post-grouted pockets through slabs into beams due to the architectural layout and limited structural depth for post-drilled fittings; this includes fixings for the various configurations of crowd segregation barriers. As shown in the lower tier section the removable barriers over the retractable seating are intended to be fixed into the front edge of the pre-cast unit by a cast-in channel.

## 6.5 Architectural features

Allowance should be made for recessed architectural features, such as seat row numbering and step contrast strips on rise and tread of units and step blocks as shown on the Architectural drawings and in the Architectural specifications.

## 6.6 Cast in lifting points

Allowance should be made by the contractor for cast-in lifting points (in non-visible locations) for safe lifting of pre-cast elements.

## 7 Bowl Description

This chapter describes the pre-cast bowl elements and highlights some of the areas which the Package Contractor will require atypical elements. Some of the areas indicated require input and co-ordination between Package Contractors to finalise geometry or elements and supporting structure.

### 7.1 East stand

The East stand is a single tier terrace element which is situated behind the main performance stage. The geometry of the bowl is simple in that the terrace units run in a continuous straight line North to South between the cores in the North East and South East corners and in section the bowl is a single angle rake. The primary steelwork which supports the bowl pre-cast in this area is steel rakers at ~10m gridline centres. A global building movement joint is situated on GLE05 which allows building movements to be accommodated as noted in the Movement and Tolerance Report. At this joint there is a line of double structure including rakers to provide lateral stability to the overall frames.

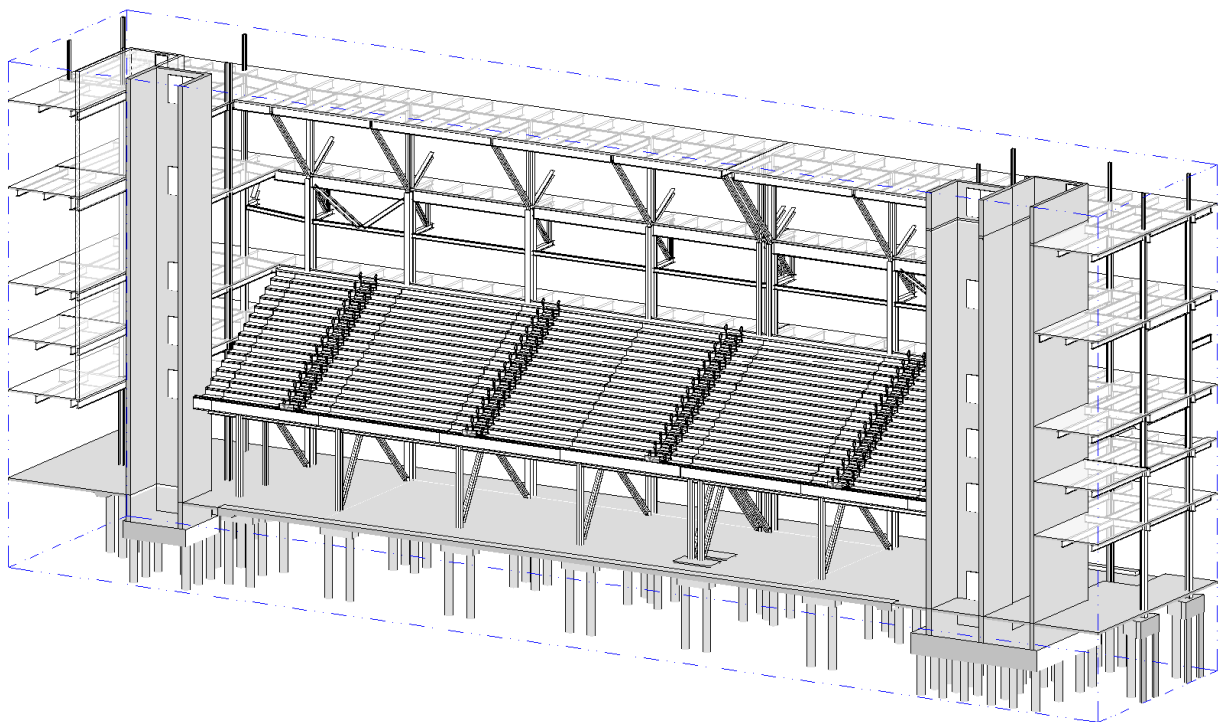


Figure 7-1 - East stand bowl and superstructure model

The standard terrace unit spans between the steel rakers and shall be supported on a steel stool fabricated with the primary steelwork as noted in 6.1. Refer to BH superstructure details for proposed detail. The Package Contractors should satisfy the BH performance criteria and Architectural requirements at this interface and they may propose alternative support if there is potential cost benefit.

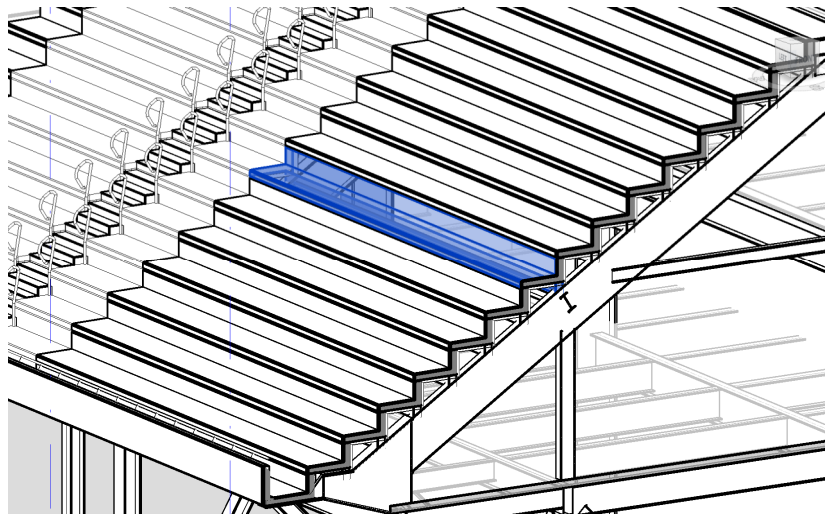


**Figure 7-2 - Typical terrace unit within bowl**

Where the spectator aisles are situated steps are formed from both a recess in the unit and a step block as described in 5.3.5. The position of the recess varies on units and will require bespoke moulds.

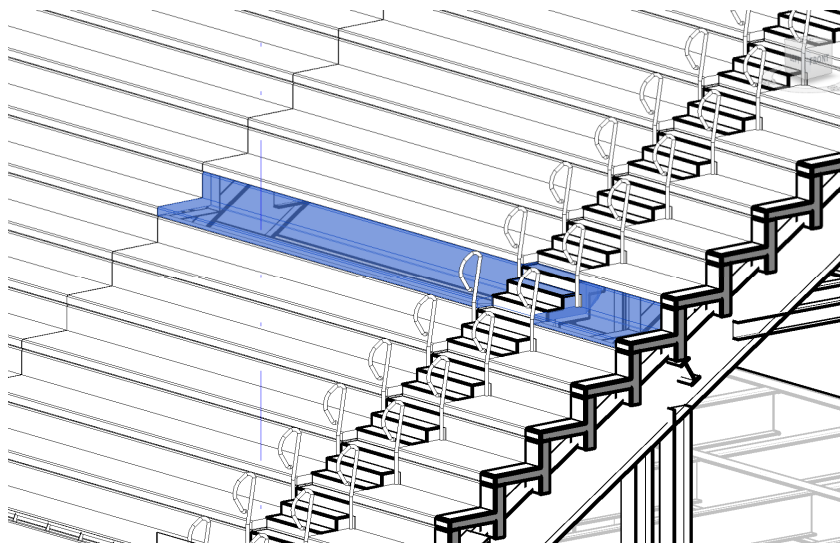


**Figure 7-3 - Terrace unit with recess for aisle stairs**

The front of the East stand terrace is a double unit U shaped parapet. This is required to achieve a flush soffit to the bowl and requires a thicker 'beam' as a result. These units are supported on inverted T steel tips. A cover plate will be required at each of these locations as the steel T requires an opening which cannot be achieved by the usual mastic joint system. Refer to Architectural details for the cover plate requirements.

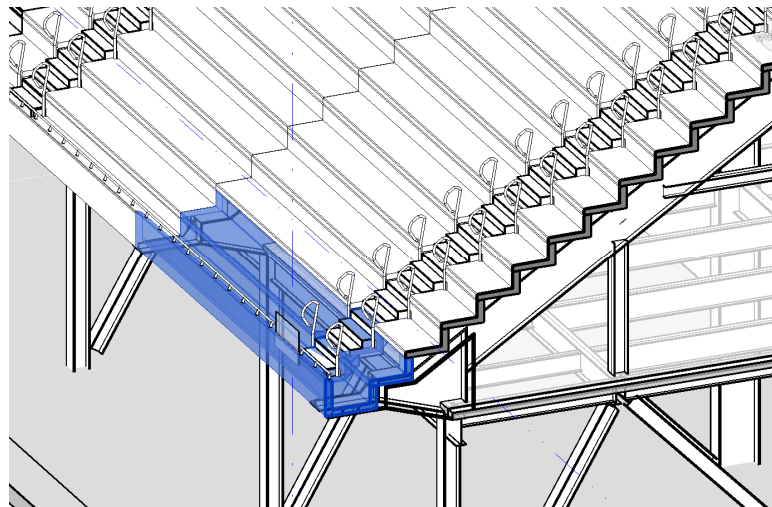


Figure 7-4 - East stand front parapet double unit

The East stand bowl has no vomitories with all access into the stand from the rear at level 3.

At the rear of the bowl the terrace units interface with the Level 3 floor plate. The rear pre-cast unit requires a flat unit which is supported on the terrace unit below and the steel beam which trims the composite deck. This beam may require a wider top flange to accommodate the bearing of both elements. This shall be developed with the Steelwork Contractor and Pre-cast contractor to ensure the required bearing for both elements is achieved. Construction programming should be considered with specific consideration to the composite decking, when this will be poured, and the joint between the rear pre-cast unit. The pre-cast unit should form a shutter from which a sacrificial piece and sealant can be used to form the joint.

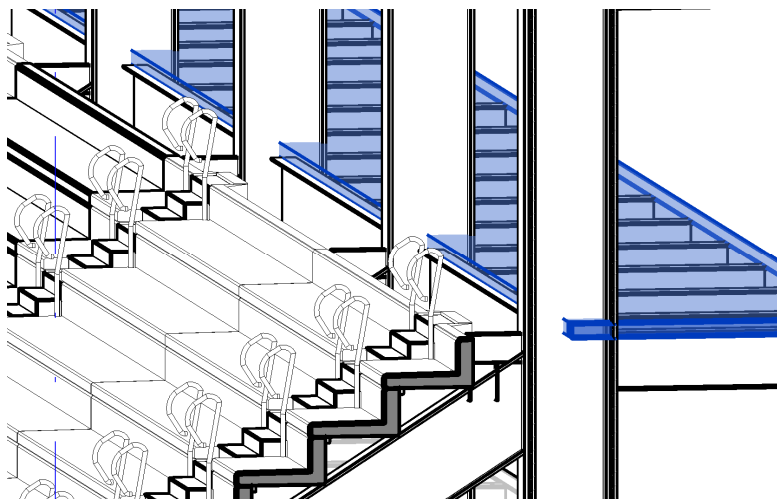


Figure 7-5 - Back of bowl interface with level 3 East stand

The global building movement joint in the East stand requires double structure and therefore has a slightly different support condition and may require special length units. The pre-cast units will be 'fixed' on both rakers at this position with the building movements accommodated by a physical joint in the bowl pre-cast.

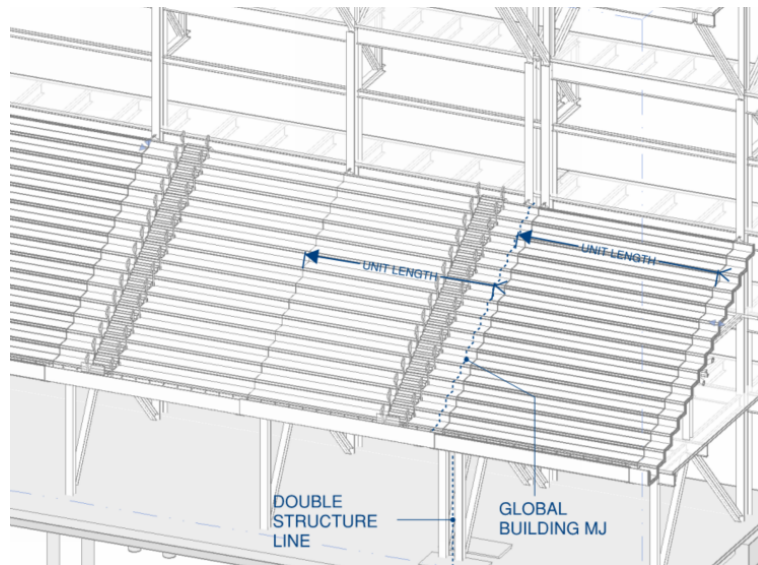


Figure 7-6 - East stand global frame MJ

In the Northern end of the East terrace the bowl extends ~1.6m beyond the gridline and primary structure line below. A duplicate of the primary gridline raker has been included to trim the pre-cast at this position. This raker is supported by transfer beams at Level 1, 2, and 3. At this stage this is in development and may benefit from Package Contractor input to offer a more cost effective solution.

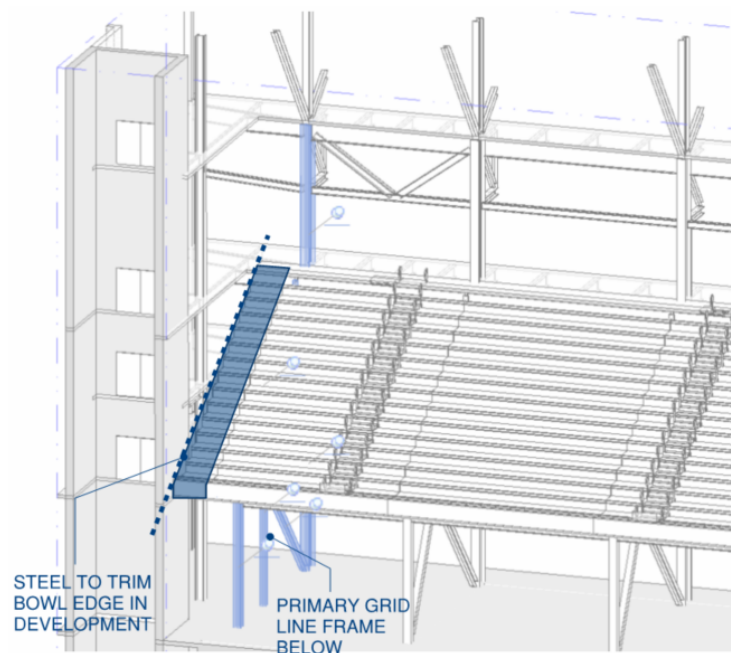


Figure 7-7 - Northern end of East bowl

## 7.2 North Stand (South similar)

The North stand (N05 to N12-1) has three tiers. The upper tier is between Level 3 and 4 with a couple of rows below level 3 supported on a cantilevered raker element. The mid-tier is a three-row tier at level 2. The lower tier is from level one and is a recent change where fully retractable seating has been changed to have a hybrid of steel frame and pre-cast bowl elements, and retractable units at the very front. The pre-cast terracing is oriented in a straight line from the Eastern end up to the West corner where the bowl geometry folds. The primary structure is on 8.5m centre gridlines and has one global building movement joint at N09 (S10 in South).

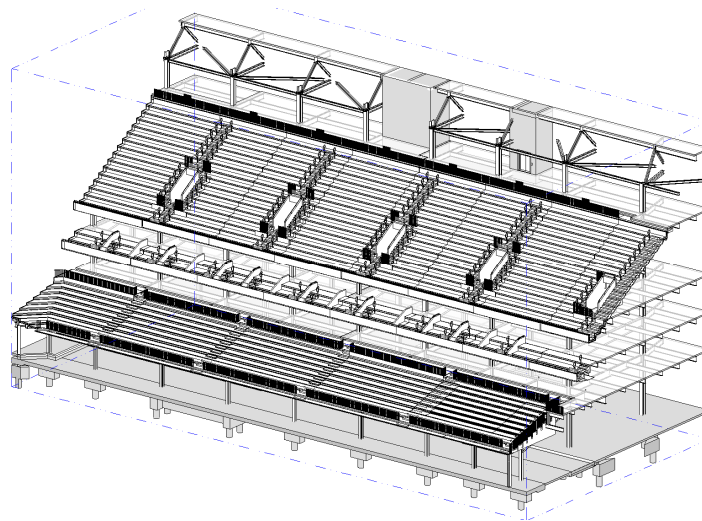


Figure 7-8 - North stand bowl and superstructure model

The typical conditions for the units are like those described in the East stand with stool support on rakers, and recessed units required at stair positions.

### 7.2.1 Upper Tier

At the front of the upper tier is a U-shaped parapet. Unlike in the East stand where a double unit is required due to large spans, a single U-shaped unit is required to form the lower unit and parapet to the tier as described in 5.3.7. These units are supported on inverted T steel tips. A cover plate will be required at each of these locations as the steel T requires an opening which cannot be achieved by the usual mastic joint system. Refer to Architectural details for the cover plate requirements.

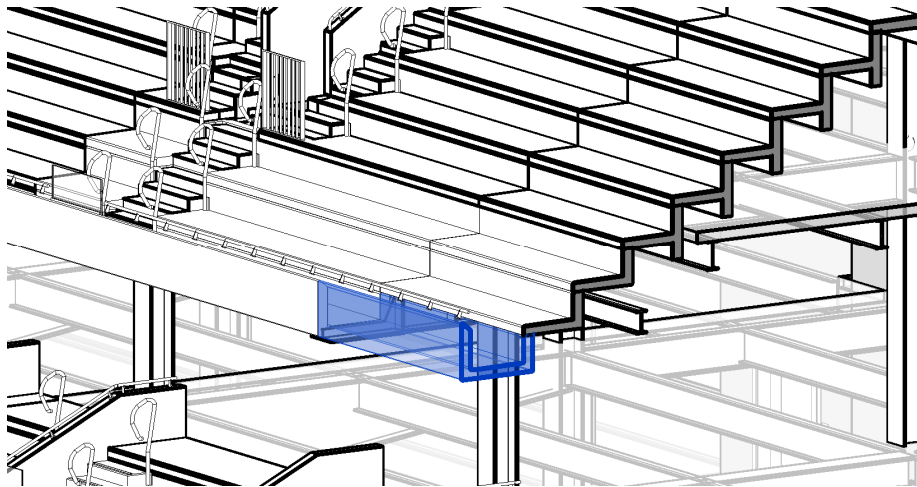


**Figure 7-9 - North stand upper tier front parapet**

At the rear of the bowl the terrace units interface with the Level 4 floor plate. The rear unit is parallel to the edge beam trimming the level 4 composite deck and spans between rakers. In local areas the FFL of the back unit differs which is expected to be formed through finishes. Refer to Architects documents for more information. Construction programming should be considered with specific consideration to the composite decking, when this will be poured, and the joint between the rear pre-cast unit. The pre-cast unit should form a shutter from which a sacrificial piece and sealant can be used to form the joint.

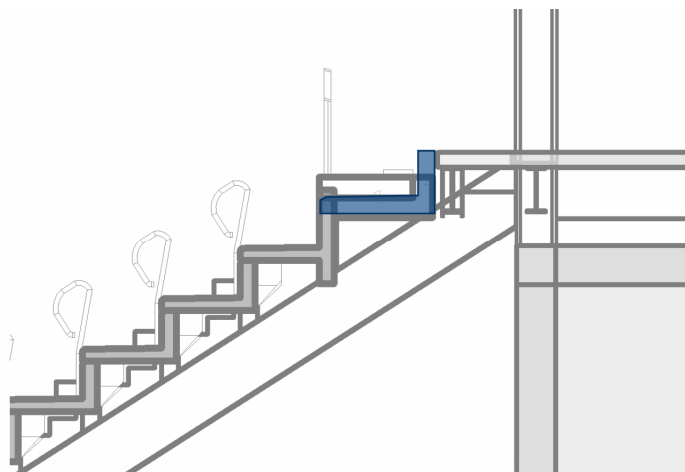


**Figure 7-10 - North upper tier back of bowl interface**

The upper tier has several vomitories providing access into the bowl from level 3. The vomitory pre-cast walls have primary steelwork aligned beneath to provide support. It is proposed that the wall elements are supported off stools at slab level which will require the wall to be designed accordingly as described in 8.2. The floor beams supporting pre-cast vomitory walls are designed compositely and therefore require the insitu concrete beneath the wall. The construction programme should take this into account.

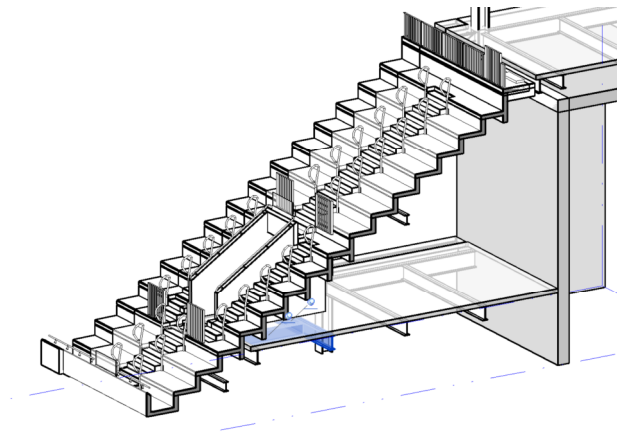


Figure 7-11 - North stand upper tier vomitory

At the Eastern end of the North upper tier the pre-cast bowl requires extending by approximately 500mm to the primary structure column line to be supported by the steel rakers.

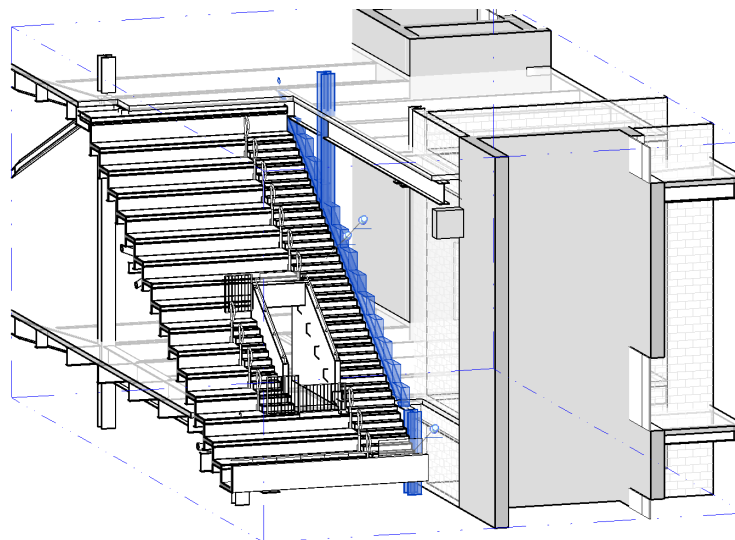


Figure 7-12 - North upper tier Eastern end

The pre-cast bowl also interfaces with a liner wall at this position which will require co-ordination between packages. The detail of the steelwork and pre-cast interface should be developed in conjunction with the liner wall in order to provide the most appropriate solution.

### 7.2.2 Mid-Tier

The mid-tier is where the hospitality boxes are situated and therefore bowl pre-cast elements include radial parapet walls to form these spaces. These parapet walls require stability to be taken within the pre-cast terrace units and to be considered in the design by the Package Contractor.

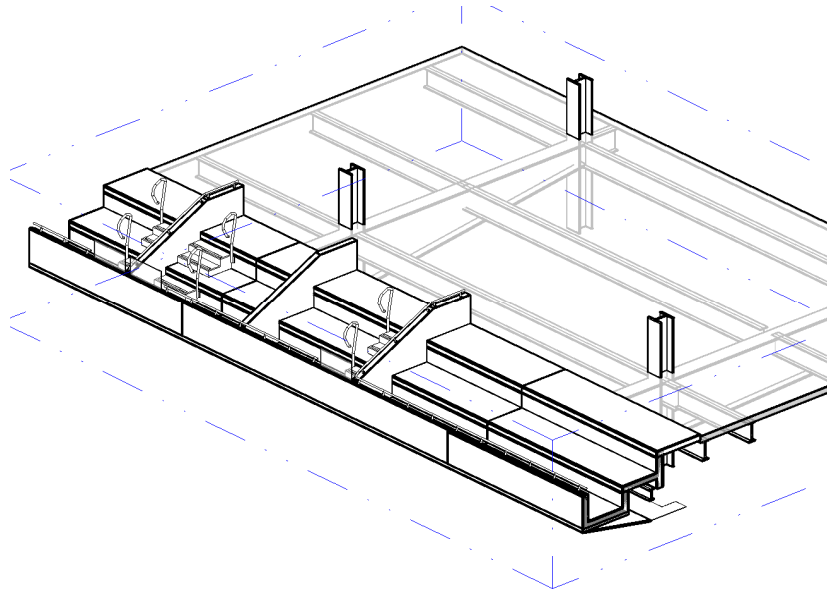


Figure 7-13 - North stand mid-tier bowl

The front unit is similar to that described in the upper tier as a U-shaped parapet single unit.

The rear unit of the mid-tier interfaces with level 2. It is proposed the rear unit has a downstand parallel to the edge beam trimming the level 2 slab. As an alternative and similar to the East stand back of bowl, a flat unit between the terrace unit below and the steel which trims the composite slab edge could be adopted. This should be developed with the Package Contractors to co-ordinate the most cost effective detail.

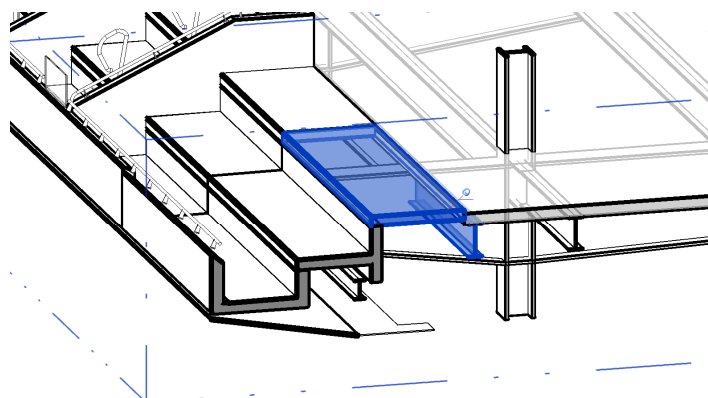


Figure 7-14 - North mid-tier slab interface

### 7.2.3 Lower Tier

The lower tier has both permanent and retractable elements. The permanent elements are situated from the back of the tier at level 1 towards the retractable seats at the front. The image below indicates the permanent bowl area in blue. This piece of the design was a Client formally instructed change and at RIBA Stage 4a BH have prioritised co-ordination with the Architect but requires detailed design before fully complete. The elements in the lower tier should therefore be considered as placeholders. Refer to the Primary Steelwork Description Report for further detail.

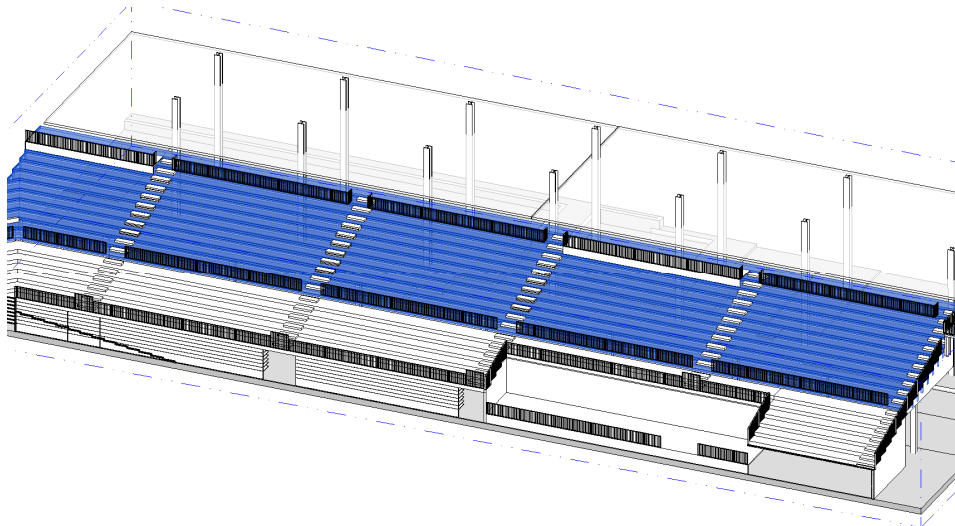


Figure 7-15 - North lower tier

At the interface of the permanent lower tier and the level 1 slab a flat terrace unit is required which needs to be extended to the slab edge. The composite slab has been aligned to the partitioning line and trimmed with steelwork accordingly. The flat terrace unit requires either a pre-cast downstand at the rear of the unit (proposed sketch below), or additional steel angle to the beam supporting slab edge. Similarly to elsewhere this could also be a fabricated section which provides bearing width for both the composite slab and the terrace unit. This should be confirmed with the Package Contractors and Architect to suit requirements.

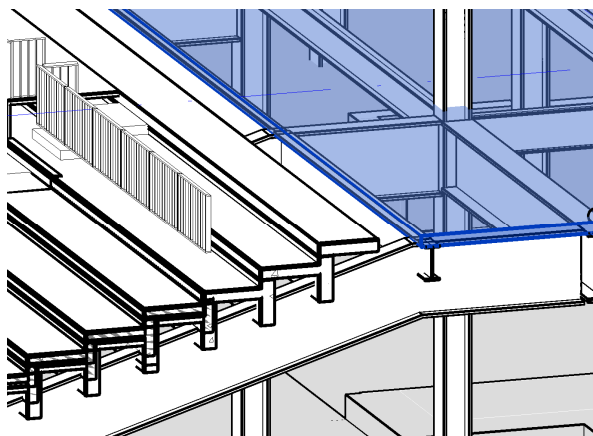


Figure 7-16 - Lower tier North back of bowl interface

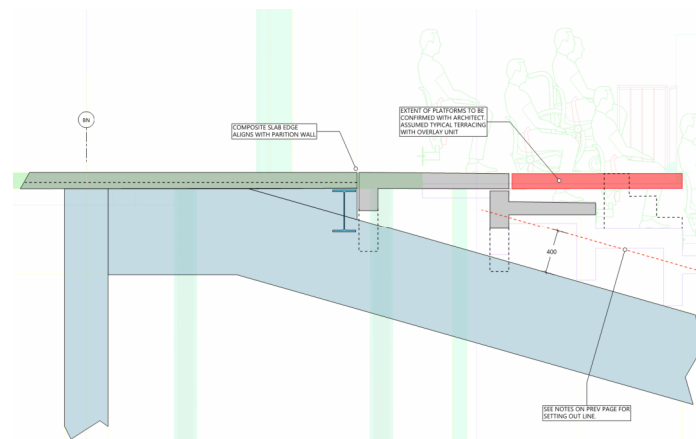


**Figure 7-17 - Proposed Lower tier North pre-cast/slab interface**

At the front of the permanent seating there is an interface with retractable seating units (shown blue in image below).

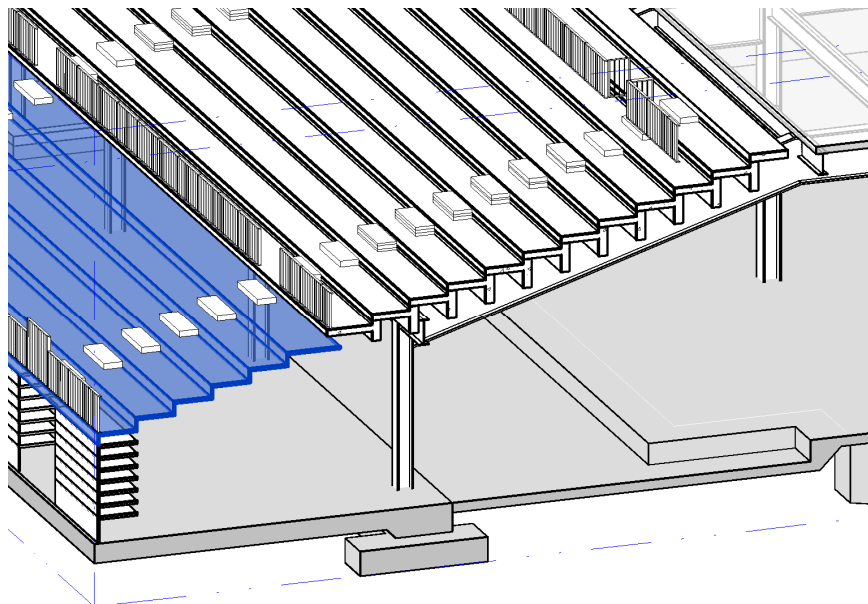


**Figure 7-18 - Lower tier North interface with retractable seats**

There are two conditions, one where a parapet unit can be used to help span the unit between rakers, and one where a parapet cannot be used and a thicker double unit required. Where the unit is unable to use the depth of a parapet the 'beam' in the middle of the double unit will be required to resist torsion from the cantilevering element.

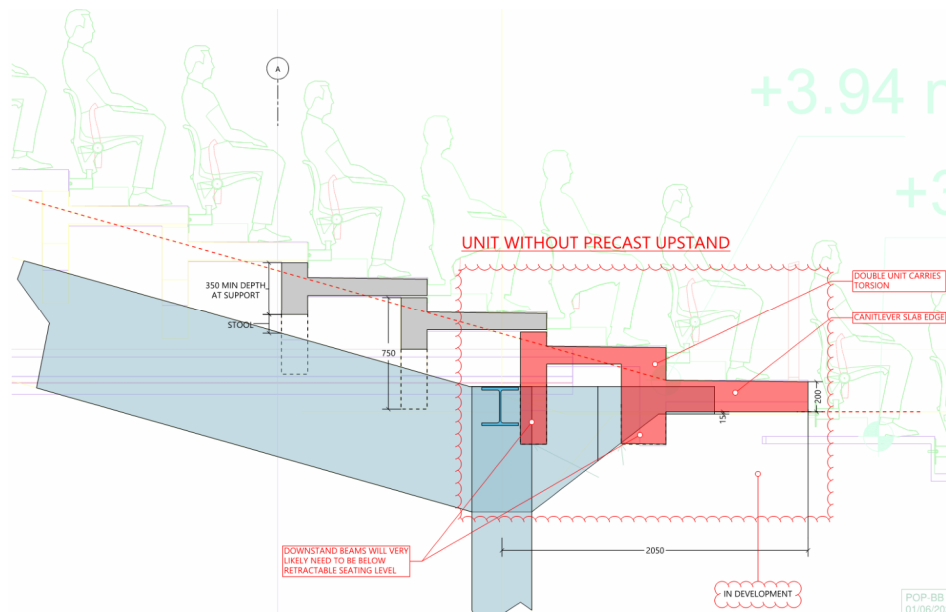


Figure 7-19 - Lower tier North pre-cast to retractable interface no parapet

### 7.3 West stand

The West stand (W02 to W07) has two tiers. The upper tier is between level 2 and back of bowl below level 5. The lower tier is from level one and is a recent change where fully retractable seating has been changed to have a hybrid of steel frame and pre-cast bowl elements, and retractable units at the very front. In this central portion not considering the corners (refer to 7.4) the pre-cast is oriented in a straight line from North to South where the bowl geometry folds in the corner. The primary structure is on 8.5m centre gridlines and has one global building movement joint at W04.

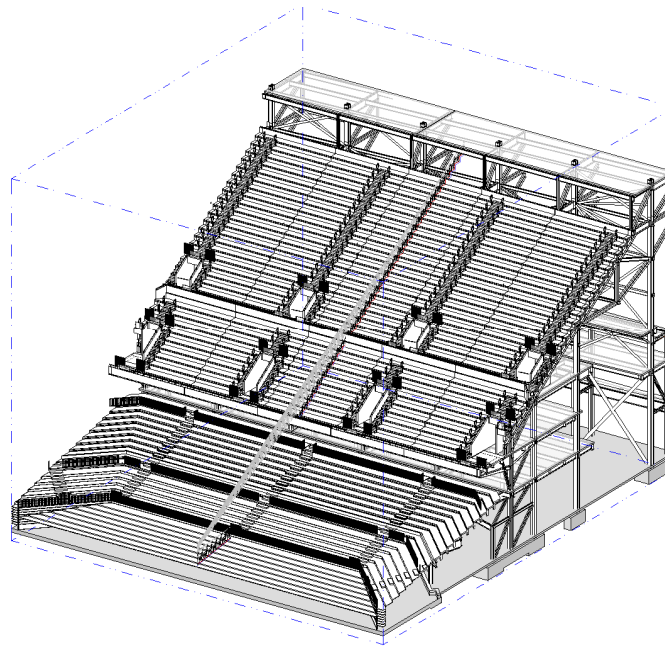


Figure 7-20 - West stand 3D model

The typical conditions for the units are like those described in the East stand with stool support on rakers, and recessed units required at stair positions.

### 7.3.1 Upper Tier

At the front of the upper tier is a U-shaped parapet. Similar to the North and South stands, a single U-shaped unit is required to form the lower unit and parapet to the tier as described in 5.3.7.

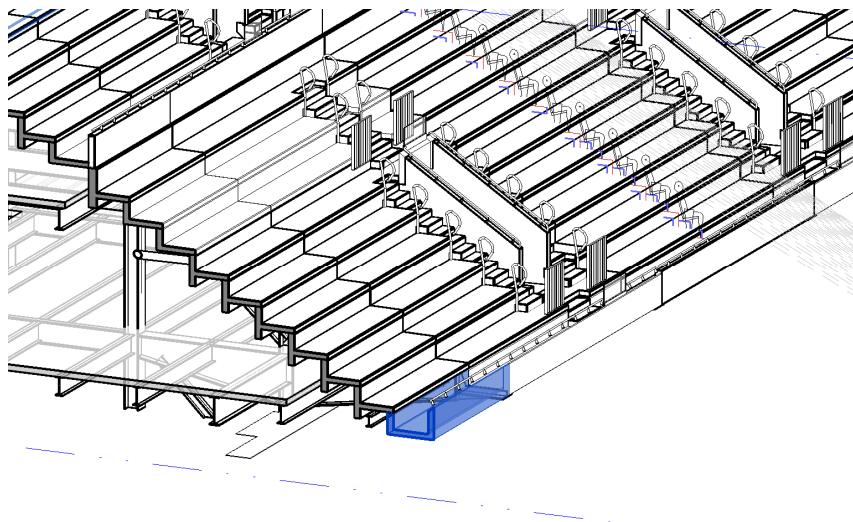


Figure 7-21 - West upper front parapet

The upper tier back of bowl is relatively simple in that the back typical unit spans between rakers and the pre-cast downstand mitigates any requirement for trimming the back of the unit. The back of bowl has an acoustic liner wall which will have some interface and will require co-ordination between Package Contractors.

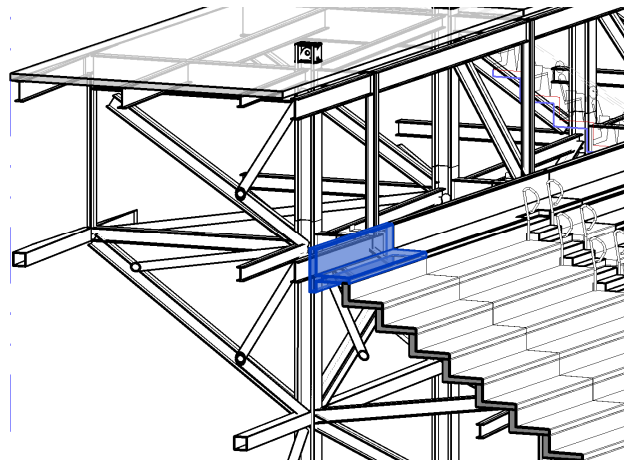


Figure 7-22 - West stand upper tier back of bowl

The upper tier has vomitories at two levels providing access into the bowl at level 2 and level 3. Similarly to the North stand the wall elements of the vomitories are supported off stools at slab level and should be designed with point supports accordingly. The floor beams supporting composite deck are designed compositely and therefore require the insitu concrete beneath the wall. The construction programme should take this into account.

The vomitories at level 3 require pre-cast stairs to link level 3 to the bowl. It is understood at this stage that Contractor preference would be to span the stairs top to bottom. Additional trimming beams should be allowed for to provide support and should be considered similar to the main wall elements that they will require stools to support at slab level. The Pre-cast Contractor shall provide support to the top of the stair most likely by addition of a pre-cast beam at the landing.

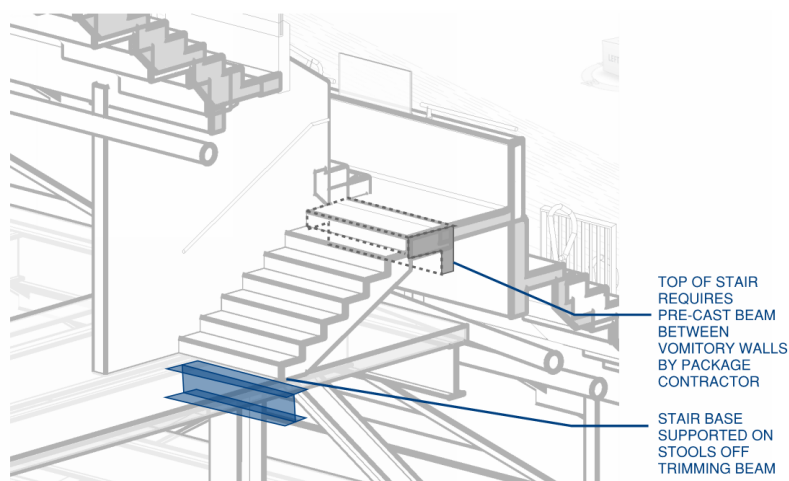


Figure 7-23 - West upper tier vomitory stair

The vomitories at level 2 do not require pre-cast stairs and follow the typical arrangement as described in the North Stand upper tier noted in 7.2.1.

Within the upper tier bowl there is an additional pre-cast parapet which segregates spectators. This should be a U-shaped parapet unit supported off steel stools at the back of the unit and at the front off the typical terrace unit upstand below.

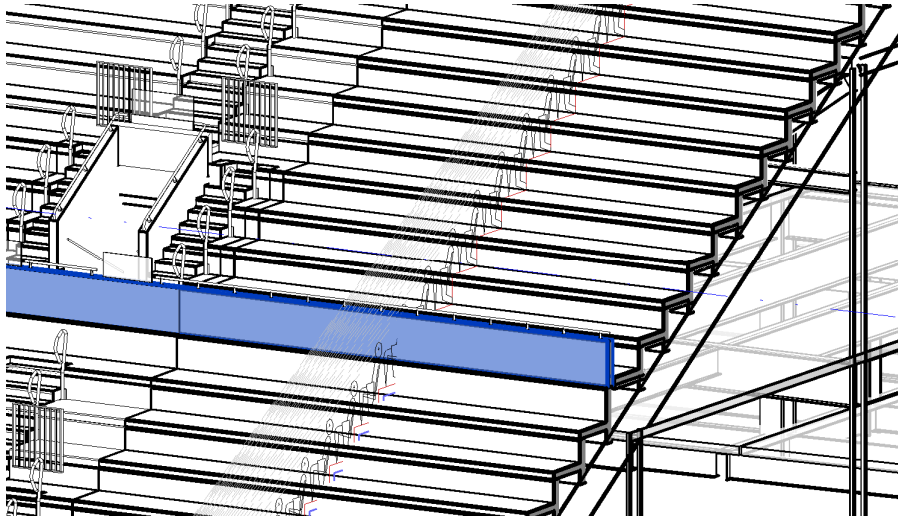


Figure 7-24 - West stand upper tier parapet

### 7.3.2 Lower tier

The lower tier has both permanent and retractable elements. The permanent elements are situated from the back of the tier at level 1 towards the retractable seats at the front. The image below indicates the permanent bowl area in blue. This piece of the design was a Client formally instructed change and at RIBA Stage 4a BH have prioritised co-ordination with the Architect but requires detailed design before fully complete. The elements in the lower tier should therefore be considered as placeholders. Refer to the Primary Steelwork Description Report for further detail.

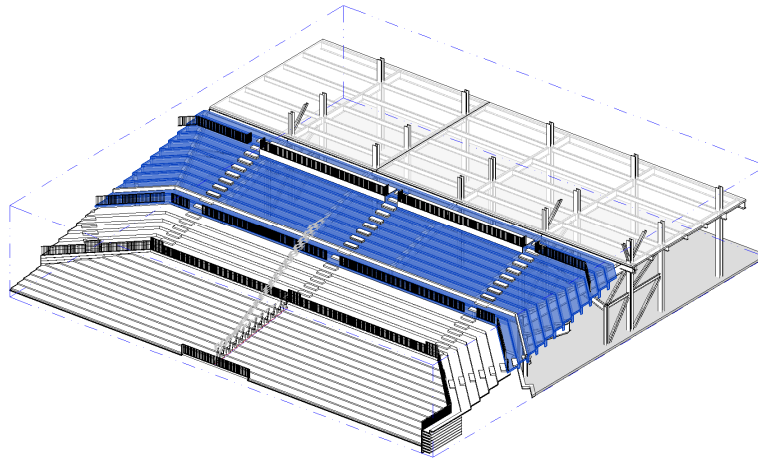


Figure 7-25 - West stand lower tier

At the back of the lower tier the pre-cast terracing interfaces with level 1 slab similarly to as described in 7.2.3. Similarly the front interface of the permanent pre-cast elements with the retractable seating should be considered as described in the same section.

#### 7.4 West Corners

The corners of the bowl in the West are similar North and South. The North West corner for this purpose is described as W07 to N05 as illustrated in the 3D model image below. The corners merge the West bowl geometry with the North and South bowl geometry. This requires some bespoke pre-cast elements to interface between the orthogonal stands which are highlighted in the text below. The corner comprises an upper tier with varying level back of bowl, a mid-tier from the North and South stands ends in the corner, and the lower tier is a hybrid of permanent pre-cast terrace and retractable units described below.

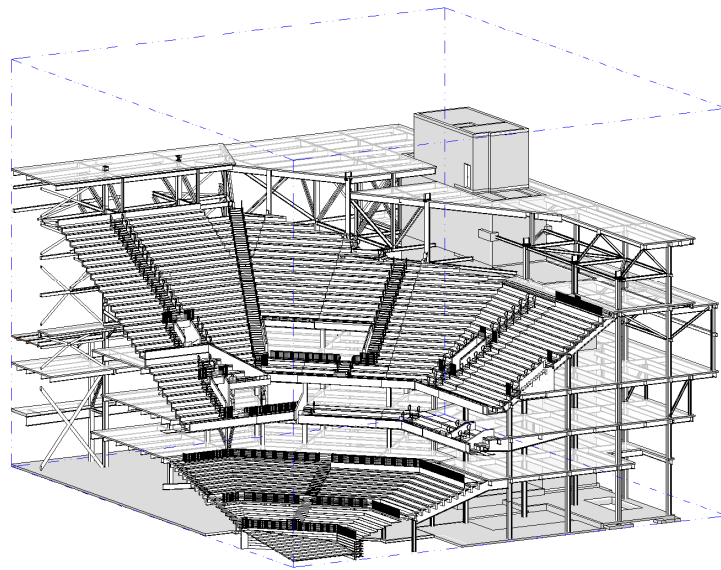


Figure 7-26 - West corners 3D model

#### 7.4.1 Upper tier

The upper tier of the West corner has multiple terrace unit types. Refer to the Architects bowl information for unit typologies. Descriptions of some of the main elements are described below.

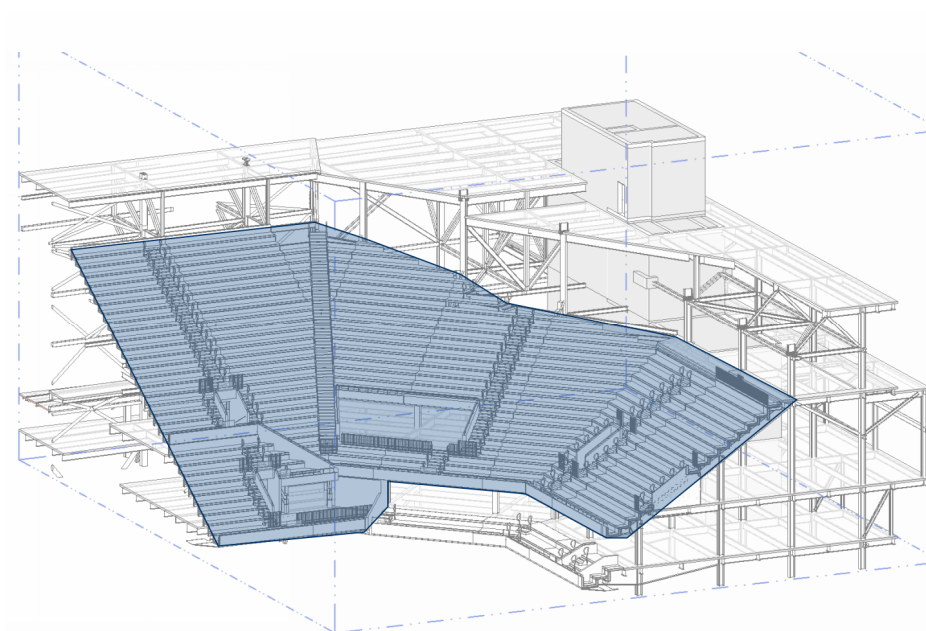


Figure 7-27 - West corner upper tier

At the front of the upper tier a U-shaped parapet unit is required as described in the North and West upper tier headings. At the rear of the upper tier between W07-NW2 the rear unit is as described in 7.3.1. Between NW6 and N05 the rear unit is as described in 7.2.1.

Between NW2 and NW6 the terrace at the back of bowl geometry doesn't offer a simple steelwork arrangement to provide support. This area would benefit from Steel and Pre-cast Contractor input to achieve the most suitable solution and co-ordinate the packages. The sketches below have been developed to consider an approach at RIBA Stage 4a to prompt discussion between the team for the next stage. The back of bowl beam would likely benefit from being a closed section to deal with eccentricities from the various interfaces in this location.

Between NW2 and NW3 the beam at the back of bowl could be inclined to reduce the amount of framing and additional steelwork to support pre-cast. There will be requirement for significant stool arrangements or additional beam and stub framing to support the flat pre-cast infill elements which should be considered by the Package Contractors and associated cost allowance made.

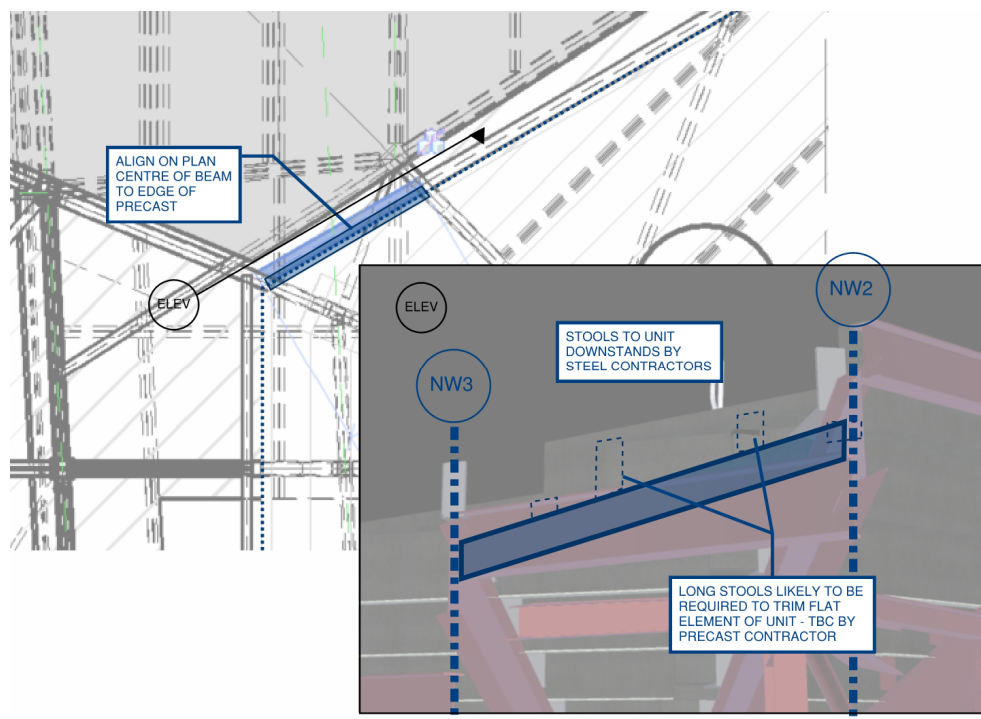


Figure 7-28 - North corner back of bowl sketch 1

The bowl also has a significant height acoustic liner from this level up to the soffit of the roof above as part of a secondary steelwork package. There is likely to be a support to the liner wall which will require co-ordination with this back of bowl beam. An indicative sketch of a possible arrangement is shown below. With the height of stools and likely connection of liner wall it is likely the beam suits a closed section like an RHS member to deal with some eccentricities of supports and resulting torsion.

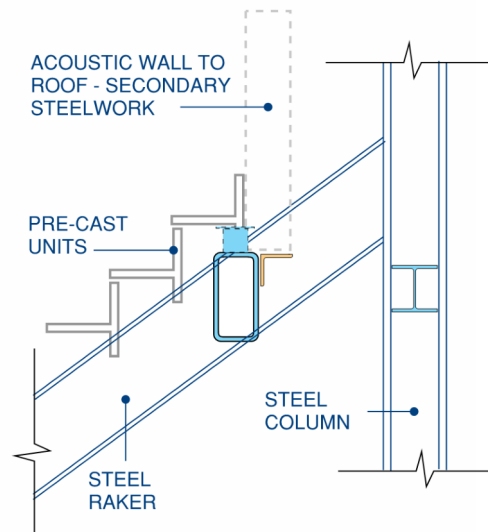


Figure 7-29 - West corner back of bowl interface

Between NW3 and N4 a similar arrangement of inclined back of bowl beam is suggested as shown.

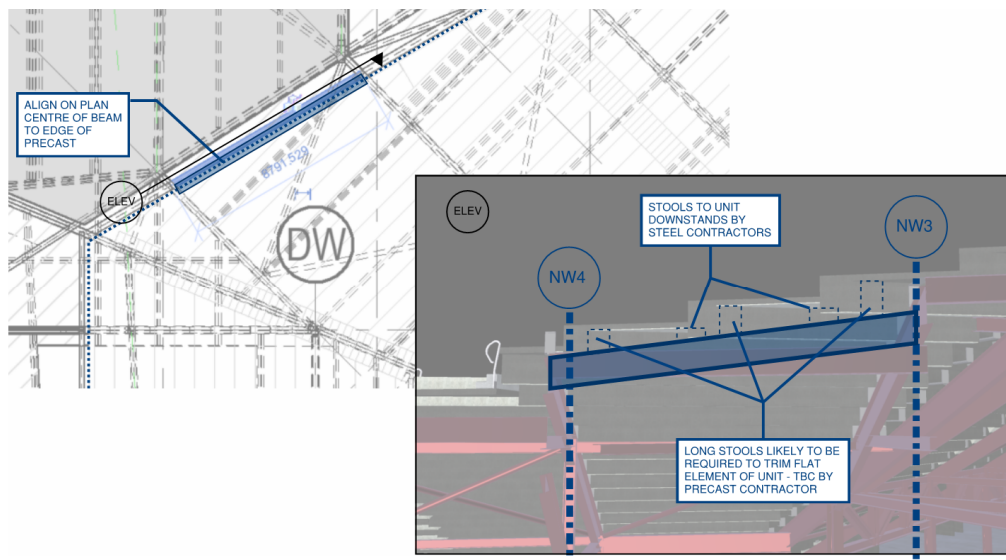


Figure 7-30 - North corner back of bowl sketch 2

NW4 to NW5 may require additional steelwork to the raker elements to provide connections to an inclined beam as shown.

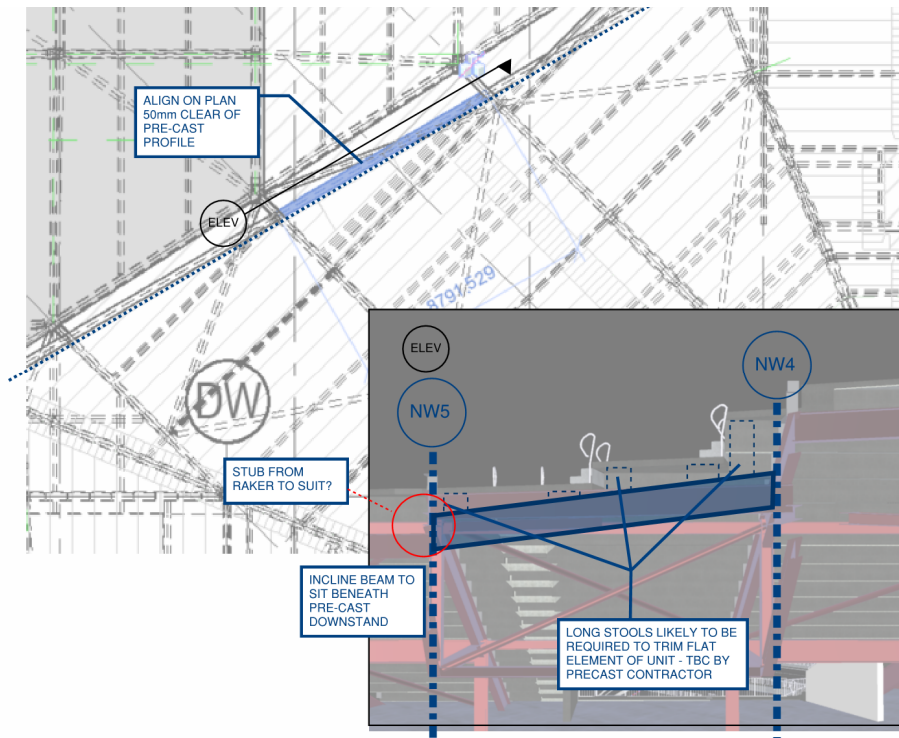


Figure 7-31 - North corner back of bowl sketch 3

NW5 to NW6 is similar.

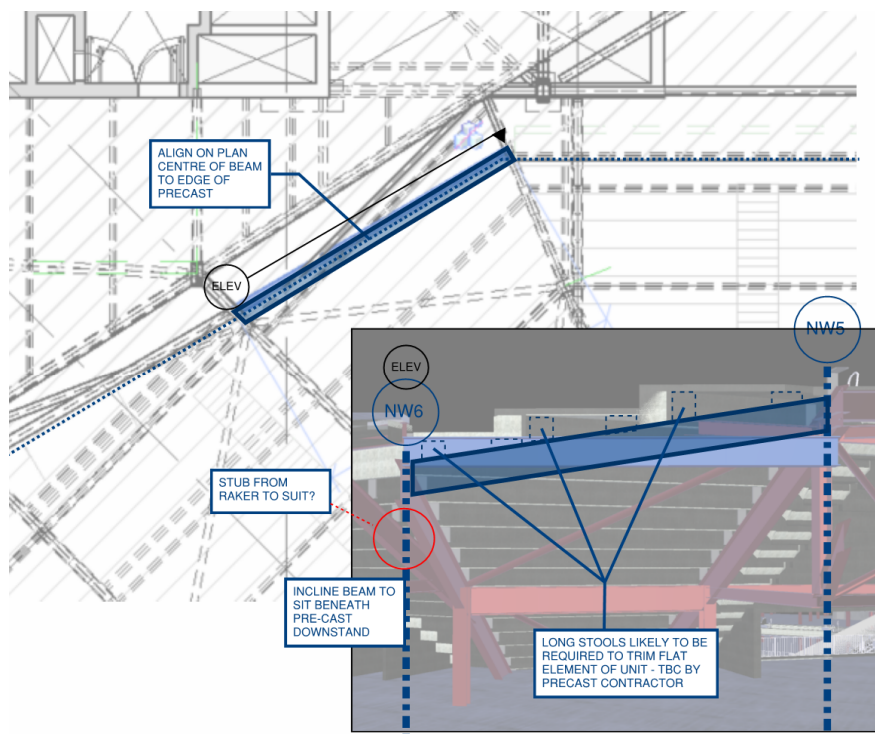


Figure 7-32 - North corner back of bowl sketch 4

Between W07 and NW2 a parapet wall in the bowl provides the interface between two terrace geometries. An inclined 'pseudo raker' is required to support this wall. The parapet wall will provide support to terrace units which interface and will require numerous support angles which should be considered by the Package Contractor. The stability of the wall shall be provided by the pre-cast terrace units and other parapets that connect at the ends.

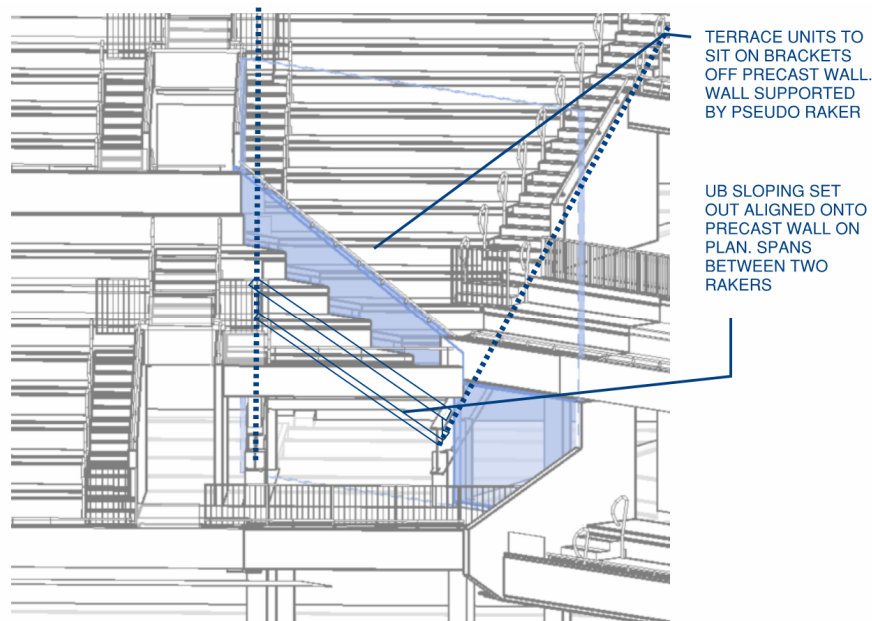


Figure 7-33 - West corner upper tier sloped parapet wall

On Gridline NW2 the bowl pre-cast elements fold to form the corner. The Architect proposes a gangway stair in this location and is developing the detail. The joint position will result in a mastic line positioned centrally on the stair. The geometry of the stair and recesses do not align with the terrace units either side and will require bespoke units.

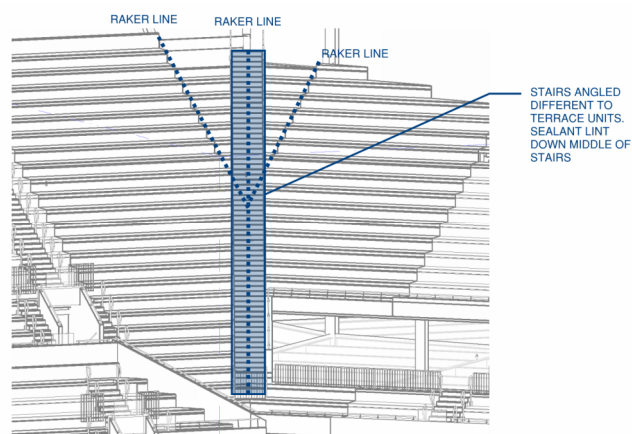


Figure 7-34 - NW2 joint geometry

At the interface of the North mid-tier and the West upper tier the bowl pre-cast has numerous bespoke elements. Interfaces between pre-cast, primary steelwork, and composite deck require co-ordination based on input from Package Contractors.

In this location the level of the North stand front U-shaped parapet element is lower than the West upper tier parapet. The flat pre-cast element for the wheelchair positions should span radially between trimming steel elements. The raker tip on the NW4 at level 2 and elements connecting to it will require co-ordination of interfaces between packages before finalising the steel geometry.

The vertical panels that partition the bowl to concourse behind the wheelchair platform are to be non-loadbearing elements.

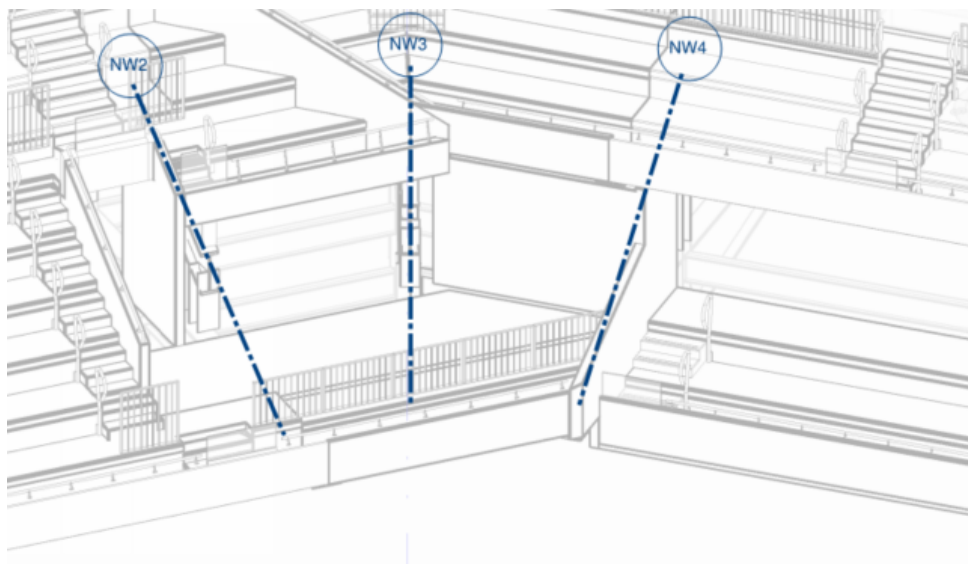


**Figure 7-35 - West corner mid-tier bowl geometry**

The mid-tier and upper tier beyond NW4 follow the same arrangement of unit typology described in 7.2.1 and 7.2.2.

#### **7.4.2 Lower tier**

The lower tier has both permanent and retractable elements. The permanent elements are situated from the back of the tier at level 1 towards the retractable seats at the front. The image below indicates the permanent bowl area in blue.

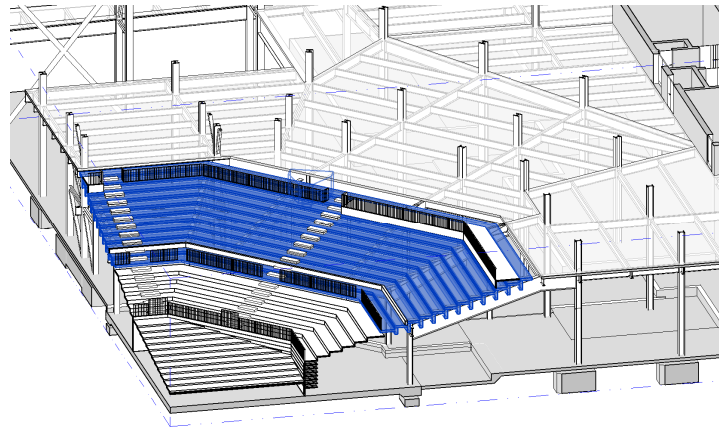


Figure 7-36 - West corner lower tier

At the back of the lower tier the pre-cast terracing interfaces with level 1 slab similarly to as described in 7.2.3. Similarly the front interface of the permanent pre-cast elements with the retractable seating should be considered as described in the same section.

## 8 Construction Sequence

### 8.1 Introduction

The Main Contractor shall develop their own final sequence. This section describes specific details relating to the construction of the pre-cast package.

### 8.2 General Sequence

In general, the design of the bowl structure and arrangement of elements has been developed to enable a consecutive construction sequence such that the cast in-situ concrete can be constructed first, then the steel elements of the structure can be fully completed prior to the installation of the pre-cast.

The overall sequencing of each tier will depend on the phasing requirements and the Main Contractors preferred methodology.

It is assumed that the units will be installed, working from the parapet to the rear, and initially it is expected that this will be on one side of the raker before any units are installed on the other side. However, the final design of the steel rakers may require a more balanced approach to loading on either side to reduce the levels of torsion applied to the rakers. This should be co-ordinated as the final construction sequence is being developed.

Installation tolerances are to include an allowance for deflection. Once the installation sequence is confirmed, deflection allowances will need to be produced by the Bowl Pre-cast Package Contractor Designer to suit the proposed method of working. See Section 4.4 and Section 4.7 for further details on deflections and tolerances.

Pre-cast vomitory walls situated on floor plates should be considered by the Main Contractor construction methodology. The support of pre-cast walls may require steelwork stools to primary structure should the composite deck concrete not be in place prior to erection.

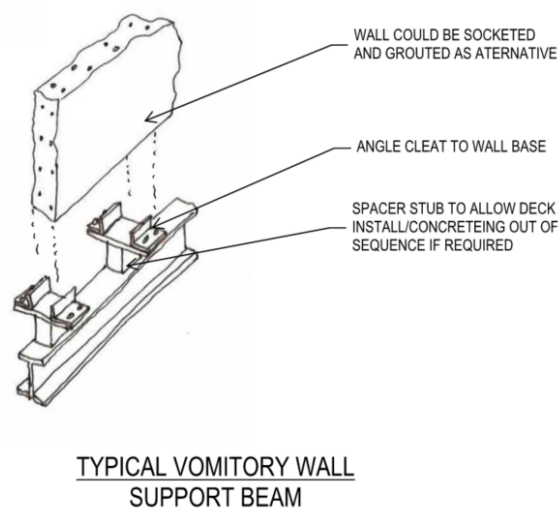


Figure 8-1 - Possible pre-cast vomitory wall to floor plate interface

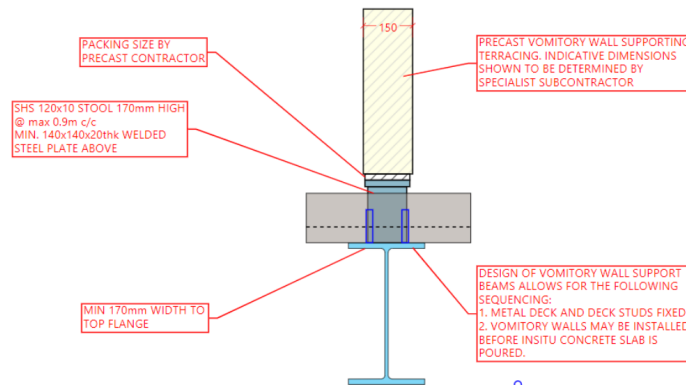


Figure 8-2 - Indicative vomitory wall stool detail

### 8.3 Specific Issues

#### 8.3.1 Storage

All bearers/packers and storage methods shall be such that they do not leave permanent marks on the pre-cast units.

#### 8.3.2 Handling and Erection

- Units to be lifted using designed lifting points only, using special lifting devices and cradles as necessary.
- Packs are required where pre-cast units are supported. This includes pre-cast to steel, pre-cast to in-situ concrete, pre-cast to pre-cast. In all cases the specialist pre-cast concrete sub-contractor is to determine the pack/shim size required in order to transfer the forces from the pre-cast unit to the bearing and also the maximum force to be taken by each pack type. Shims to be stainless steel or non-corrosive.
- Units to be installed to ensure that the minimum required bearing is provided. Minimum bearing to be determined by the specialist pre-cast concrete sub-contractor, see above.
- Do not drill or cut units, once they have been cast, unless otherwise agreed with the Employer.

## 9 Precast Stairs

### 9.1 Introduction

This chapter has been produced as a performance specification for the pre-cast stair elements and associated details. It should be read in conjunction with the Buro Happold drawings, structural design reports and material specifications and alongside the Architectural information including 3-D bowl model, drawings and specification.

### 9.2 Precast stair scope

The precast stair elements are to be designed by the pre-cast subcontractor, this document explains the arrangement of the stairs and indicative structural arrangement of the pre-cast units.

Reference should be made to the Architectural drawings for locations of pre-cast stairs. The following list will be updated through the detailed design but assumptions of locations at present are;

- Core internal stairs
- Feature stairs (TBC)
- Access stairs (TBC)

Buro Happold are to undertake the design of the following items:

- Supporting steel angles and cast-in connections to in-situ walls.
- In-situ corbels in walls and columns.

Buro Happold are not undertaking the design of the following items:

- The pre-cast elements (only initial sizing has been undertaken for coordination).
- Fixings cast into the pre-cast elements, either to support handrails and balustrades or other precast elements.
- Grout layers and shims at interfaces between elements.
- Screed toppings.

### 9.3 Responsibilities

Completion of the final design, detailing, and submission of Building Control approvals, will be the responsibility of the Main Contractor, based on the requirements of the Structural Specifications and Drawings. The Main Contractor is also to take responsibility for all the design work to date and be satisfied that the specification requirements are achievable.

Detailed design, detailing and manufacture of the Pre-cast is to be completed by the Stair Pre-cast Package Sub-Contractor's Designer based on the performance specification. This includes the reinforcement design and detailing with due consideration for installation and handling. The final design of the Stair 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. An outline of design responsibilities is defined in Table 9-1.

**Table 9-1 - Precast stair design responsibility**

| Item                                                                                                                     | Designer                                     |
|--------------------------------------------------------------------------------------------------------------------------|----------------------------------------------|
| Setting out and modelling of stair pre-cast flights and landings, stair treads and associated metalwork and balustrades. | Architect                                    |
| Design of precast elements and associated cast-in fixings to pre-cast elements                                           | Pre-Cast Sub-contractor                      |
| Design of fixings for metalwork and balustrades                                                                          | Appropriate package sub-contractor           |
| Steel support angles and fixings into in-situ concrete                                                                   | Buro Happold                                 |
| In-situ concrete corbels supporting pre-cast elements                                                                    | Buro Happold                                 |
| Grouting and shims at interfaces between pre-cast elements and pre-cast/in-situ or steel elements                        | Pre-Cast Sub-contractor and Main Contractor. |

## 9.4 Design status

### 9.4.1 Current status

Preliminary information regarding the stair flights have been provided at this stage to assist the procurement of packages. This document will be developed with further detail through RIBA Stage 4b and construction documentation.

### 9.4.2 Further and final design

Further and final design will be required by the Pre-cast Package Contractor Designer to incorporate the Main Contractors preferred installation methodology and finalise the sizes of the elements and construction detailing. This is to be carried out in accordance with the performance specifications within this document.

## 9.5 Design Criteria

The general design criteria including loading and performance requirements are recorded in BRA-BHE-ZZ-XX-RP-S-0200 Structural Basis of Design Specification. The section below provides additional criteria for this package. Also refer BRA-BHE-ZZ-ZZ-SP-S-0100 Structural Concrete Specification.

### 9.5.1 Materials criteria

Detailed design of the pre-cast stair elements is the responsibility of the specialist sub-contractor.

**Table 9-2 - Design Data**

| Criteria                             | Requirement                                                                                                           |
|--------------------------------------|-----------------------------------------------------------------------------------------------------------------------|
| Durability <sup>1</sup>              | To be designed for exposure class XC3/4                                                                               |
| Design life                          | 50 Years                                                                                                              |
| Maintenance/ replacement assumptions | The stairs may be dry cleaned after events and local staining removed.<br>Jet washing and gritting is not to be used. |

**Notes:**

1. Concrete exposure is based on conditions in use being moderate humidity or cyclic wet and dry, due to the surface being directly exposed to pedestrians, spillage and wet cleaning. If the conditions in storage or transportation of the pre-cast elements are likely to be more onerous, such as being stored outside or on the ground, the contractor should reassess the durability requirements based on the temporary condition, with the possibility of needing to specify XD, XF or CD classes and designing the concrete appropriately to prevent damage due to temporary conditions such as freeze/thaw damage.
2. All shims to be stainless steel or non-corrosive to avoid rust staining at a later date.

### 9.5.2 Preliminary concrete strength

The preliminary design carried out by Buro Happold is based on C40/50 concrete strength.

### 9.5.3 Loading criteria

Complete loading information for the final state can be found in the Basis of Design specification, a summary which is provided below:

|     |                                                            |
|-----|------------------------------------------------------------|
| DL  | = Unit Self-weight                                         |
| SDL | = 1.0kN/m <sup>2</sup> (on plan) for services and finishes |
| LL  | = 5.0kN/m <sup>2</sup> (on plan)                           |

### 9.5.4 Deflection criteria

A deflection allowance is to be calculated by the Stair Pre-cast Package Sub-contractor designer based on the final geometrical and structural design of the stair units. This is then to be checked and agreed against overall project requirements and specifications.

### 9.5.5 Vibration criteria

Stairs can be sensitive to human induced vibrations, as such pre-cast elements and stair assemblies as a whole should be designed to have a minimum natural frequency of 15 Hz.

### 9.5.6 Tolerance criteria: general

The Stair Pre-cast Package Sub-contractor is responsible for coordinating tolerances in order to ensure that all elements of the structure fit together and comply with the dimensional requirements shown in the Contract Documents.

Before manufacture the Stair Pre-cast Package Sub-contractor shall ensure that adequate allowance has been made for all construction tolerances to ensure proper fit up of the structure.

Permitted dimensional deviations shall be less than that given in BS EN 13369:2014 clause 4.3.1.1 and those given in the concrete specification

### 9.5.7 Installation tolerance

Units shall be designed and installed so that the maximum difference in level between adjacent units is no more than 5mm to prevent trip hazards. This is particularly important across stair landings; when units of different stiffness are installed side by side.

The specialist pre-cast concrete sub-contractor is responsible for coordinating tolerances in order to ensure that all elements of the structure fit together and comply with the dimensional requirements shown in the Contract Documents.

### 9.5.8 Concrete finish criteria

Refer to the architectural specification.

### 9.5.9 Waterproofing criteria

Refer to the architectural specification.

### 9.5.10 Fire resistance criteria

All pre-cast concrete elements and their support structure [including fixings](#) (both within this package of works and outside) e.g. walls, shelf angles etc., are to have a minimum of **90 minute** fire resistance unless noted otherwise. Staircases within cores may be fire-fighting access routes and have increased fire resistance periods. Refer to fire engineering information for more detail.

## 9.6 Core Stairs

At this stage in the design all stairs within the cores are pre-cast elements. [For the principles of the pre-cast components forming the core stairs refer to Appendix A.](#)

Refer to the Architects information for further information.

## 9.7 Preliminary details

### 9.7.1 Pre-cast stair to landing

The detail in Figure 9-1 shows a typical precast sub-contractor detail for the connection of the pre-cast stairs to the pre-cast in-situ landing.

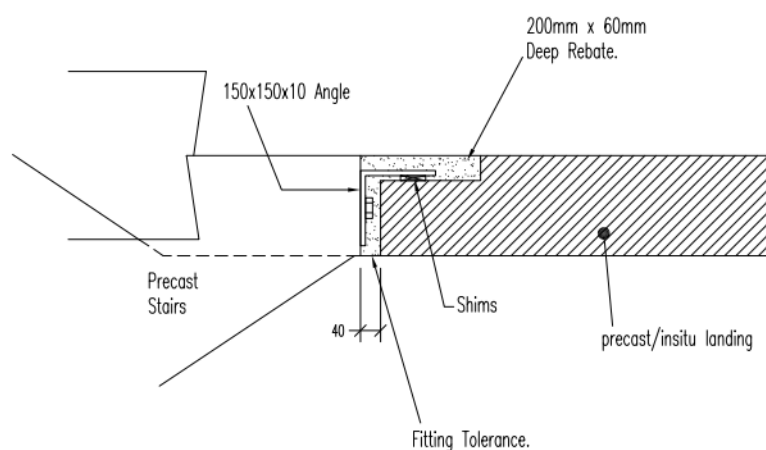


Figure 9-1 - Typical detail for pre-cast stair supported on cast in-situ landing

### 9.7.2 Pre-cast landing to core wall

The preliminary detail in Figure 9-2 shows a proposed detail for the connection of the pre-cast stair landing to a cast in-situ core wall. This includes a 20mm shadow gap and a recess on the underside.

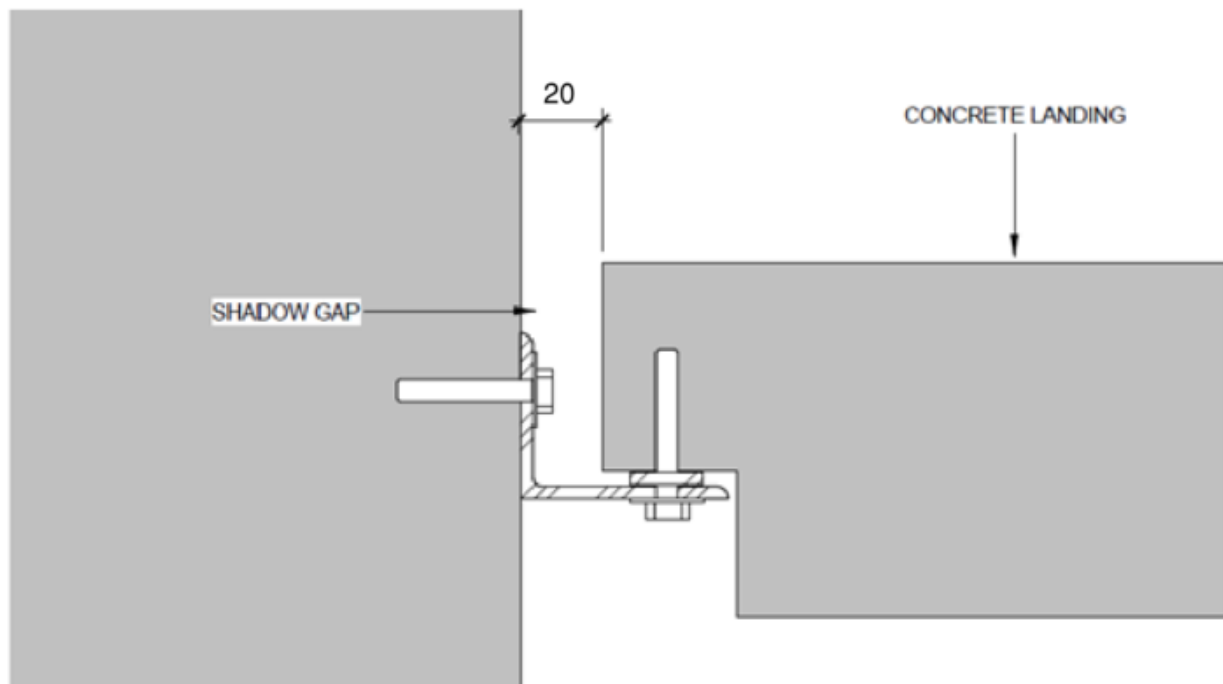


**Figure 9-2 Typical detail for pre-cast stair supported on cast in-situ wall**

The support angle is to be a 200x200x16EA connected to the core wall with cast-in Halfen HUC universal connectors HSC-B 16 and M16 8.8 bolts at 450mm centres, or similar. The final connection detail is to be developed with input from contractor and pre-cast stair sub-contractor.

[An invisible connection could be adopted as an alternative which should be developed alongside the Package Contractor to suit the Architect's requirements.](#)

### **9.7.3 Pre-cast infill piece to pre-cast stair**

Where the pre-cast infill panel is supported on the side of the pre-cast stair landing a similar connection detail to the pre-cast stair to in-situ landing could be used as shown in Figure 9-3.

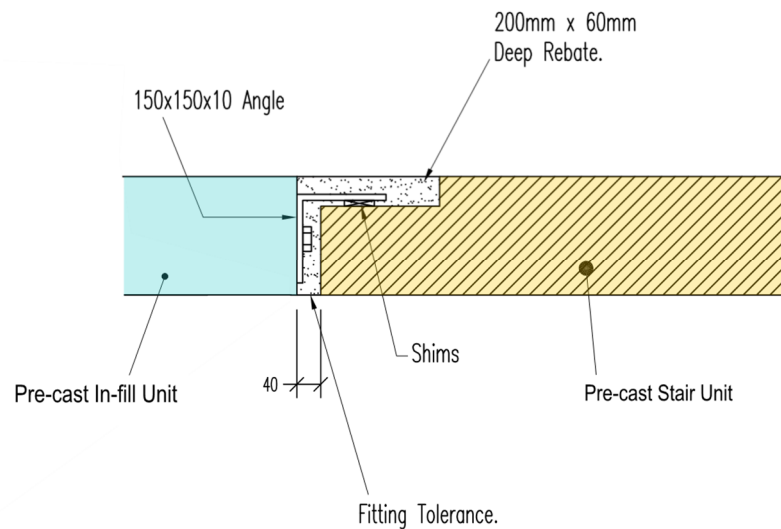


Figure 9-3 Typical detail for pre-cast in-fill unit supported on pre-cast stair

## 9.8 Feature stairs

At RIBA Stage 4a it is assumed all large feature stairs are steel tread and resin infill.

Refer to the Architects information for further information.

## 9.9 General Stair Details

### 9.9.1 Joints and movement joints

#### 9.9.1.1 Masticking

Joints between pre-cast units both horizontal and vertical are to be masticked, unless grout is required for specific details.

All junctions between cast in-situ elements (slabs and walls) and pre-cast elements are also to be masticked, unless grout is required for specific details. This is typically in joints running parallel to the spans of the pre-cast elements.

#### 9.9.2 Packs and bearing

Packs are required where pre-cast units are supported. This includes pre-cast to steel, pre-cast to in-situ concrete, pre-cast to pre-cast. In all cases the Stair Pre-cast Package Sub-contractor is to determine the pack/shim size required in order to transfer the forces from the pre-cast unit to the bearing and also the maximum force to be taken by each pack type and to be capable of freely accommodating required movements where these will occur between components due to temperature. Shims to be stainless steel or non-corrosive.

#### 9.9.3 Handrails and other barriers and fixings to pre-cast units

See Architect's drawings for details.

The design intent is that all handrails, barriers and fixings to the pre-cast units are to be grouted into pockets cast-into the pre-cast elements or fixed in place using sockets and channels cast-into the pre-cast units.

#### **9.9.4 Architectural features**

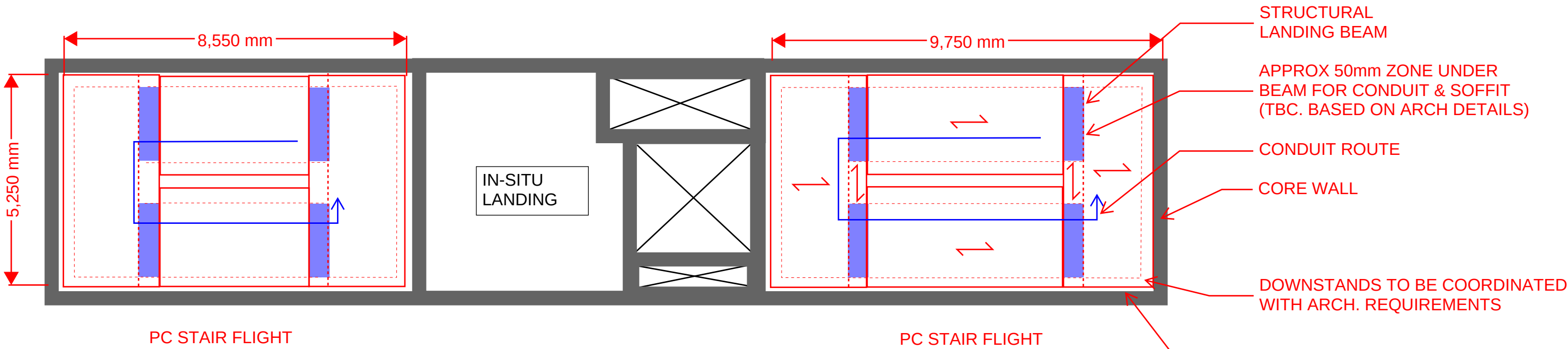
Allowance should be made for recessed architectural features, such as step contrast strips and lighting recesses. See Architect's drawings for details.

#### **9.9.5 Cast in lifting points**

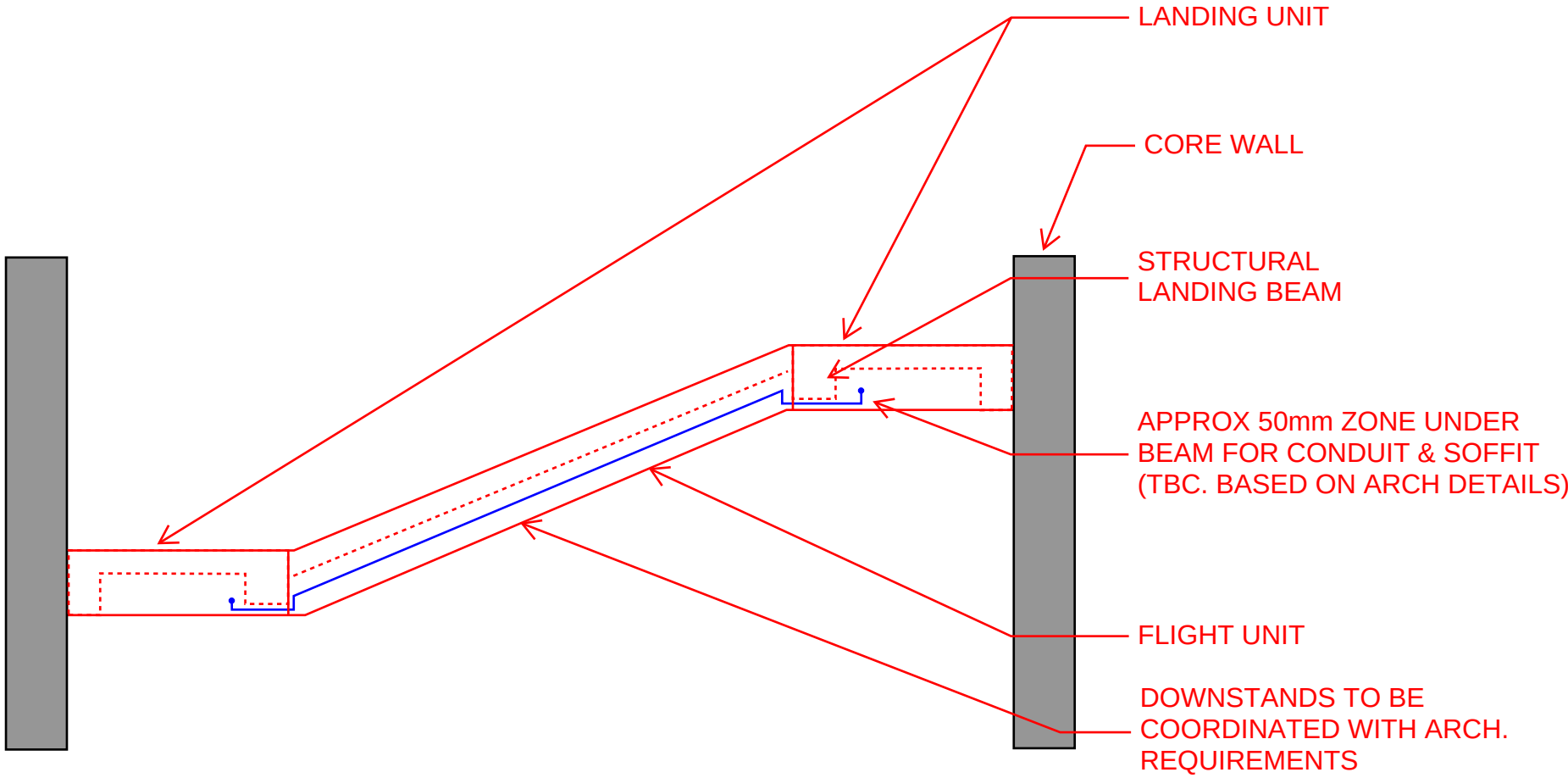
Allowance should be made by the contractor for cast-in lifting points (in non-visible locations) for safe lifting of pre-cast elements.

# Appendix A

## A.1 Core Stair pre-cast element principles



**TYPICAL CORE PLAN**  
(DIMENSIONS APPROXIMATE, CORES VARY)



**TYPICAL SECTION THROUGH STAIR**

| BURO HAPPOLD<br>ENGINEERING                                     |                 |                  |
|-----------------------------------------------------------------|-----------------|------------------|
| Project:<br>OVG MANCHESTER                                      |                 |                  |
| Project Number: 0042841                                         |                 |                  |
| Sketch Title:<br>CORE PC STAIR ASSUMED<br>STRUCTURAL PRINCIPLES |                 |                  |
| Sketch Number:<br>....                                          |                 |                  |
| Status: FOR INFORMATION                                         |                 |                  |
| Date:<br>29/06/20                                               | Initials:<br>TH | Revision:<br>P00 |

Paul Eddleston  
Buro Happold Limited  
Camden Mill  
Lower Bristol Road  
Bath  
BA2 3DQ  
UK

T: +44 (0)1225 320 600

F: +44 (0)870 787 4148

Email: [Paul.Eddleston@BuroHappold.com](mailto:Paul.Eddleston@BuroHappold.com)