THE QUEENSLAND STATE VELODROME:

FORM AND STRUCTURE THROUGH PARAMETRIC DESIGN

BrisBIMx

Technology Innovation in the Built Environment

COX RAYNER ARCHITECTS

01

INTRODUCTION

PROJECT OVERVIEW

- New indoor 250m timber track velodrome to act as the Queensland state centre and have capability for international UCI events
- Large clear spanning indoor stadium
- Basic form a response to requirements of natural ventilation, seating strategies and dynamic form inspired by the track geometries

USE OF PARAMETRICS THROUGHOUT THE DESIGN STAGES

- Conceptual form finding
- Conceptual structural modelling
- Quantity analysis and design calibration
- Analytical definitions for design proof
- Detail design development
- Construction modelling and shop drawing coordination
- Integration of structural detailing with shop models

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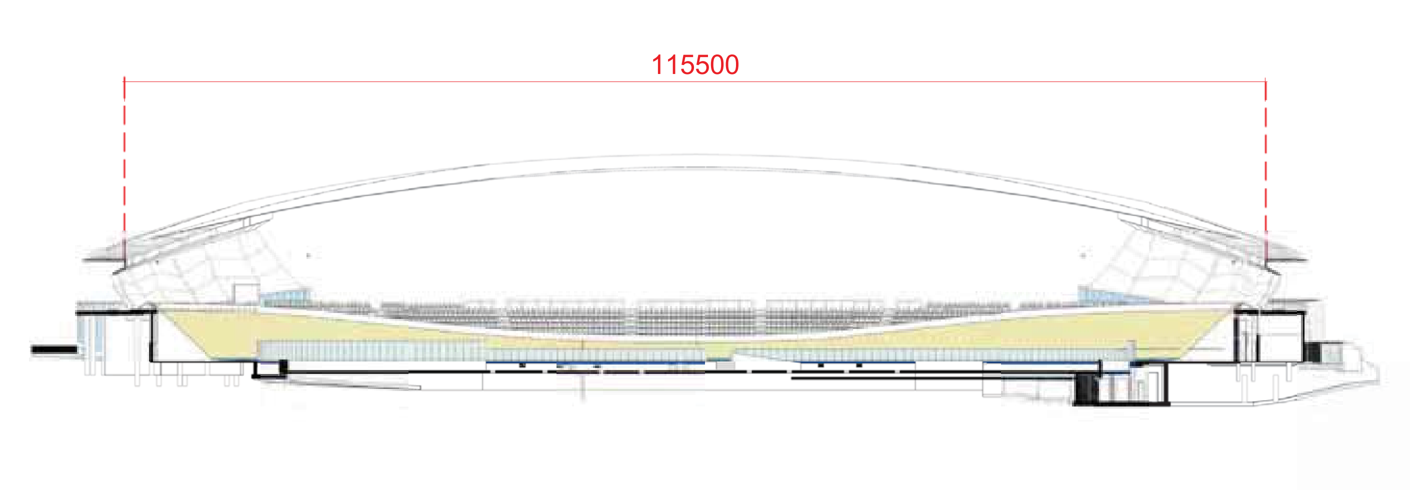
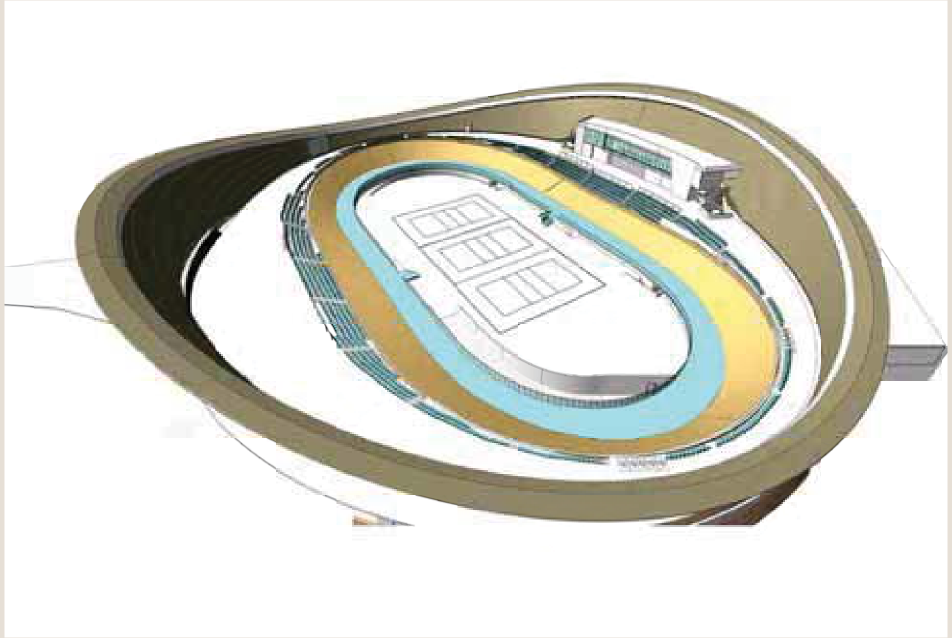
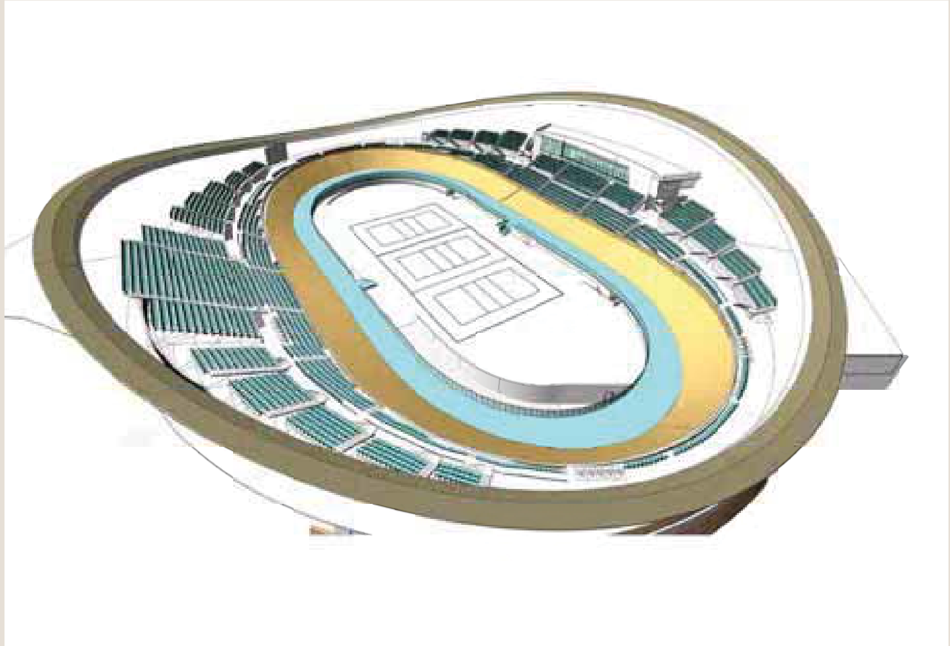




LEGACY SEATING VIEW



OVERLAY SEATING VIEW

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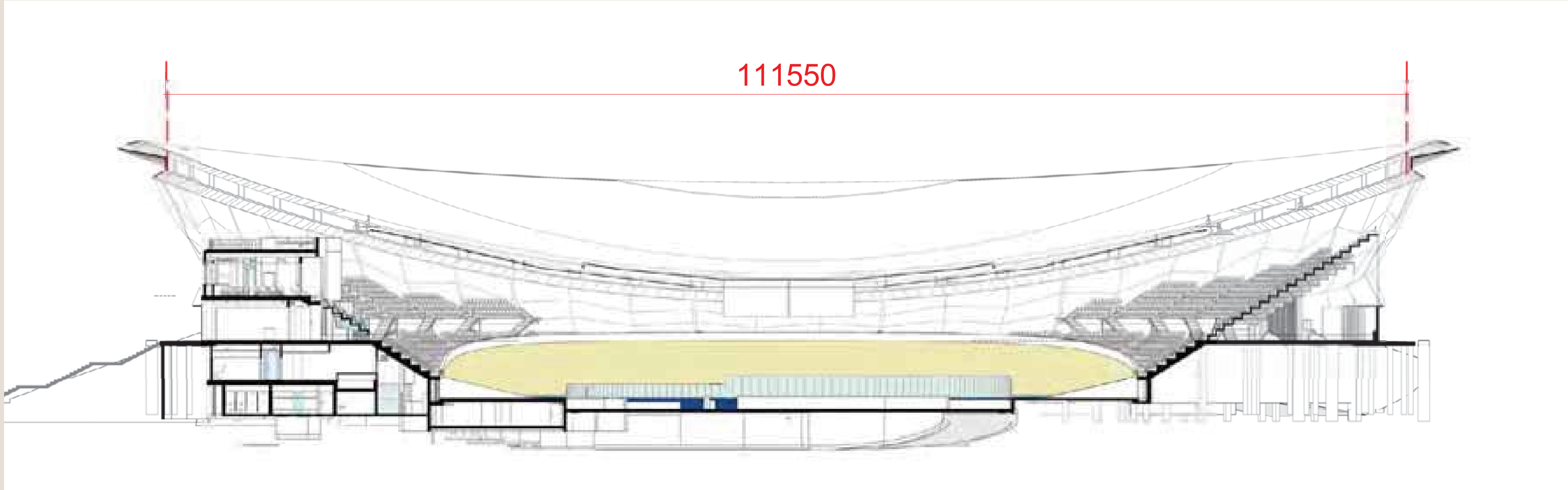
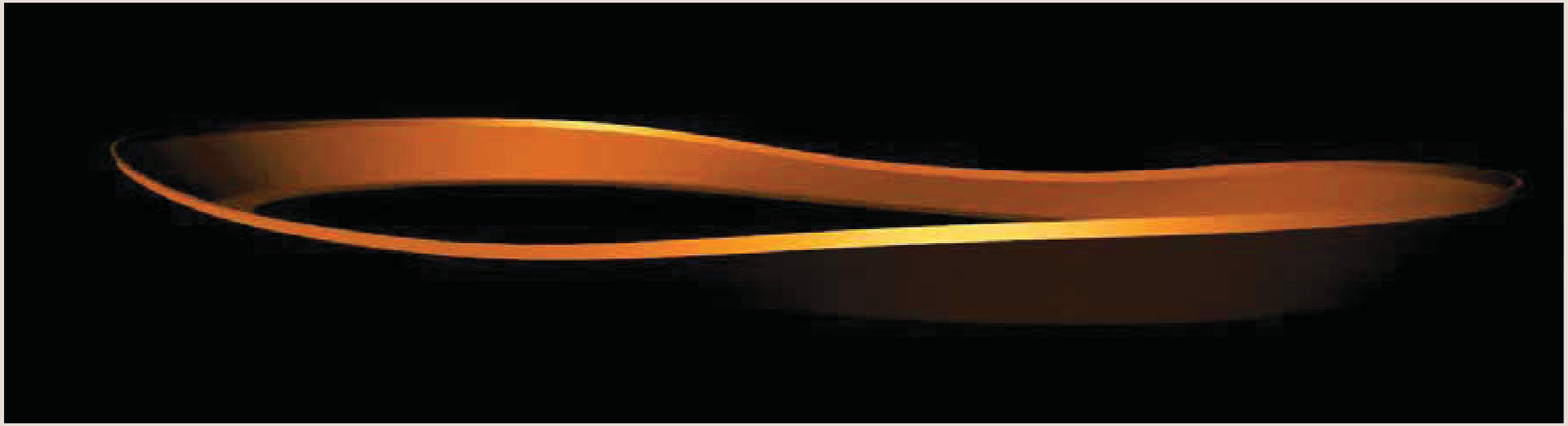




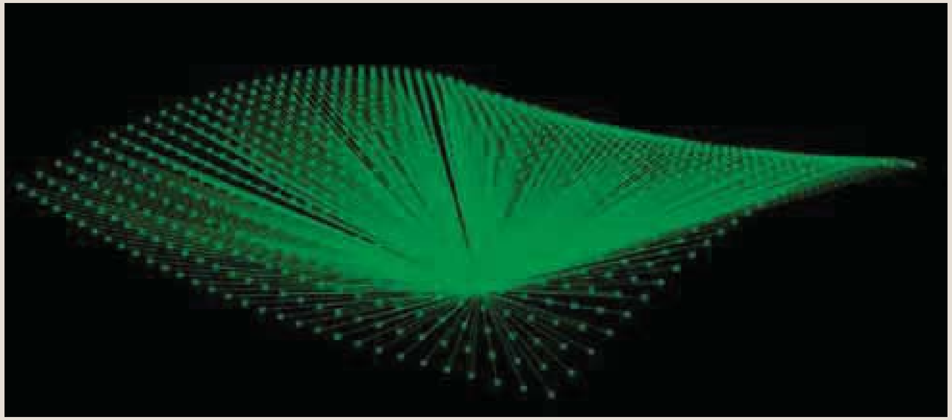
COX RAYNER ARCHITECTS

02

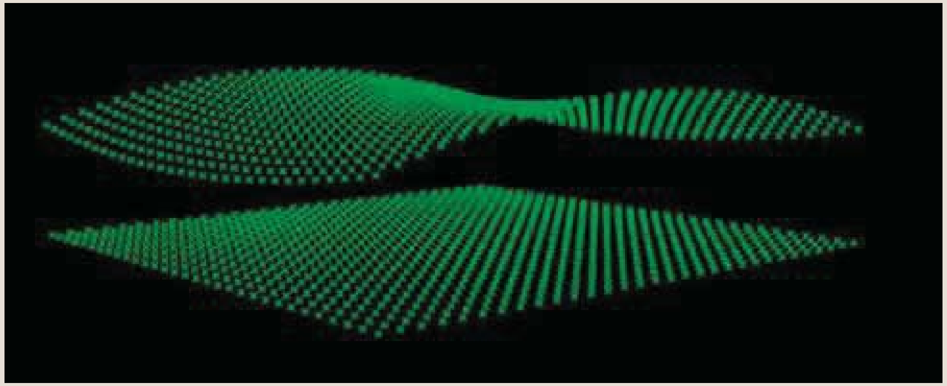
CONCEPTUAL FORM FINDING

ROOF FORM

- Hyperbolic Parabola roof (pringle chip) form is generated mathematically from a single centre point. Being a mathematical representation the form remains pure and accurate.



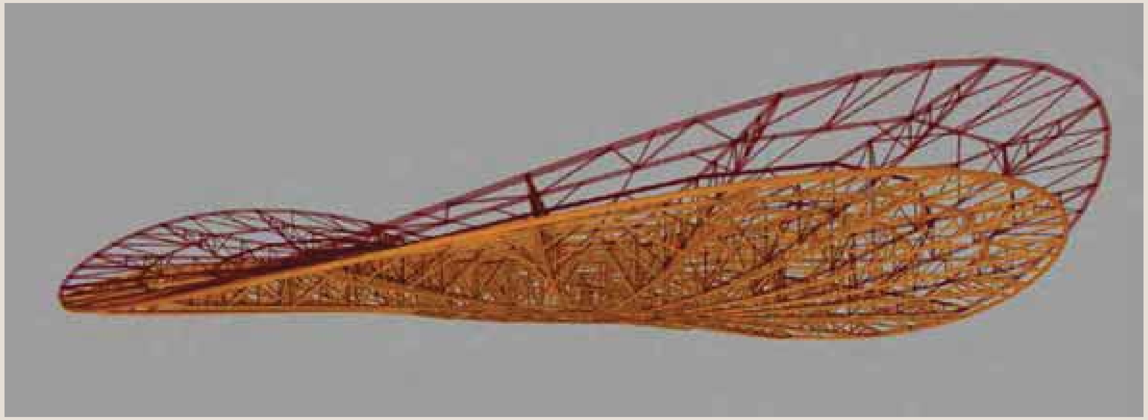
$$[z=ax^2-by^2]$$

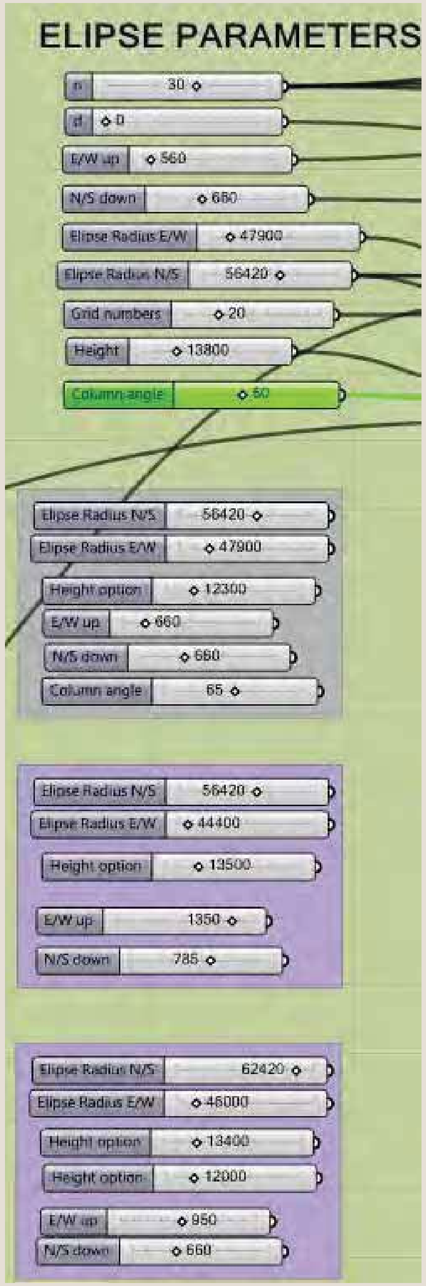


ROOF FORM

» Control ratios added to adjust the flex of the form in both directions that allowed studies of form generated by the constraints of different cladding materials

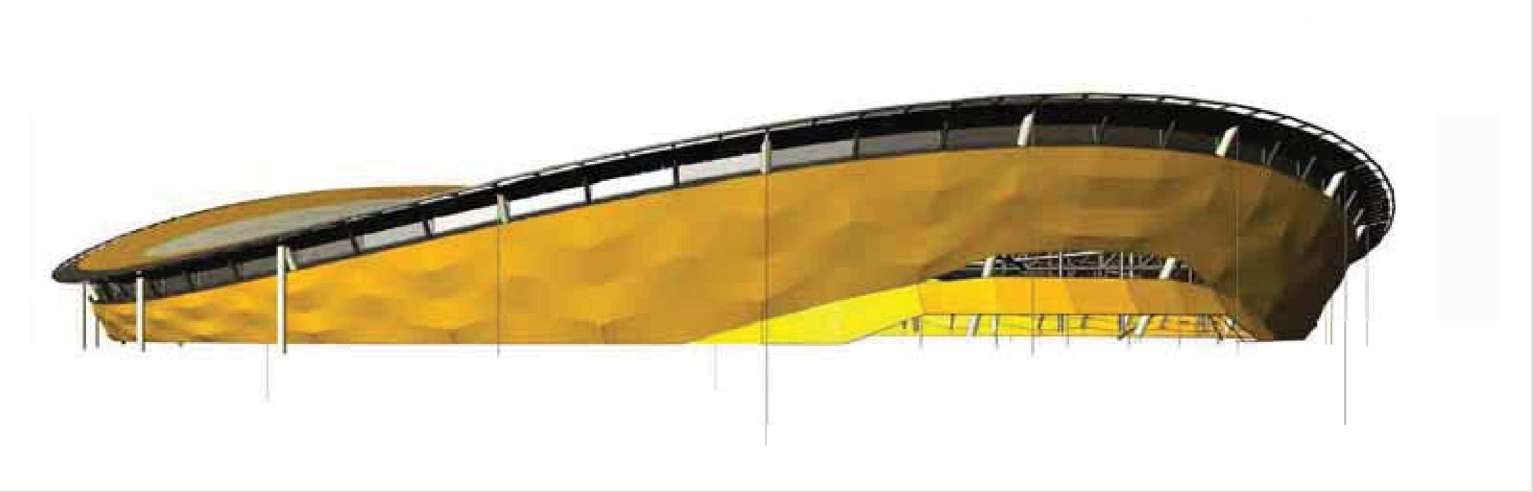
» These controls also allowed adjustments in the structural solution to raise or lower the extent of catenary arching actions across the span





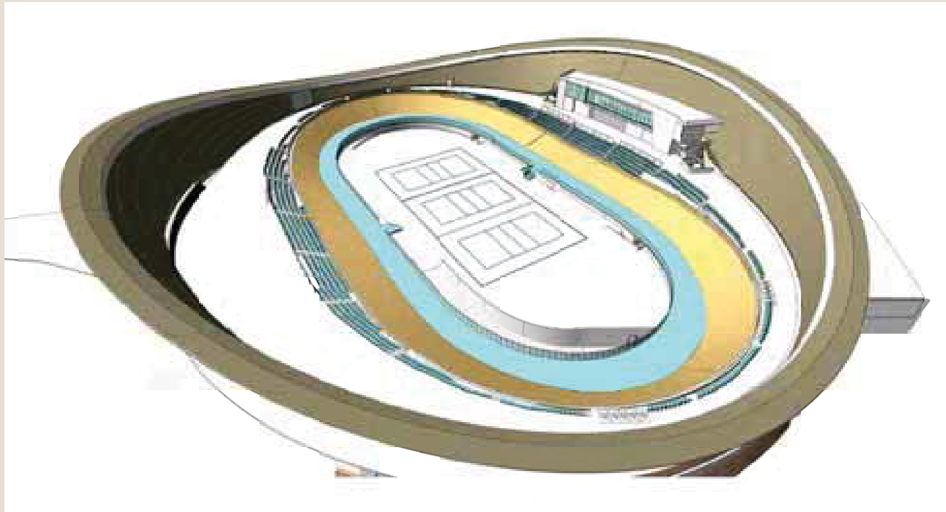
WALL FORM

- The extent of the wall structure is governed by the shape of the track, which can vary significantly within the UCI standards, and the extent of seating required
- Traditional modelling techniques become very inefficient when dealing with a high degree of flex in a complex form

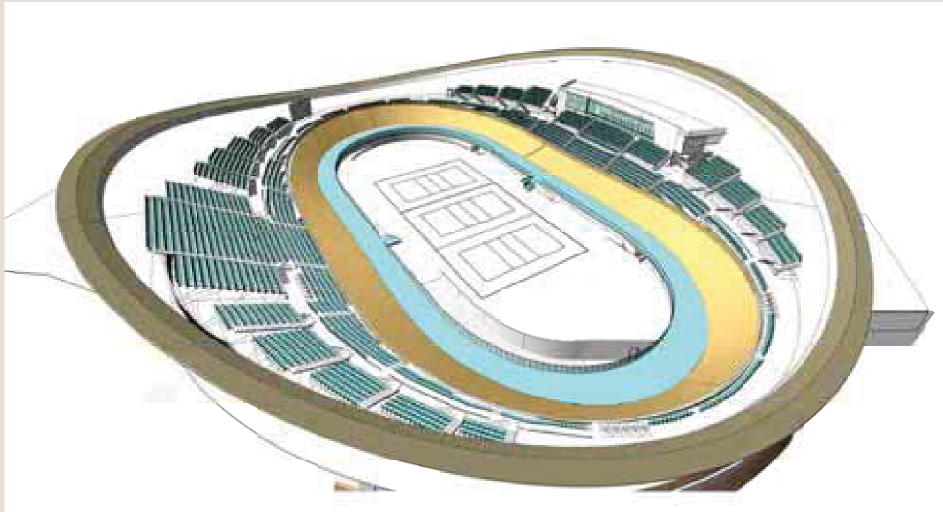


WALL FORM

» Early forms needed to allow for this flexibility so were controlled by an elliptical plan generation to allow for independent stretching in both axes



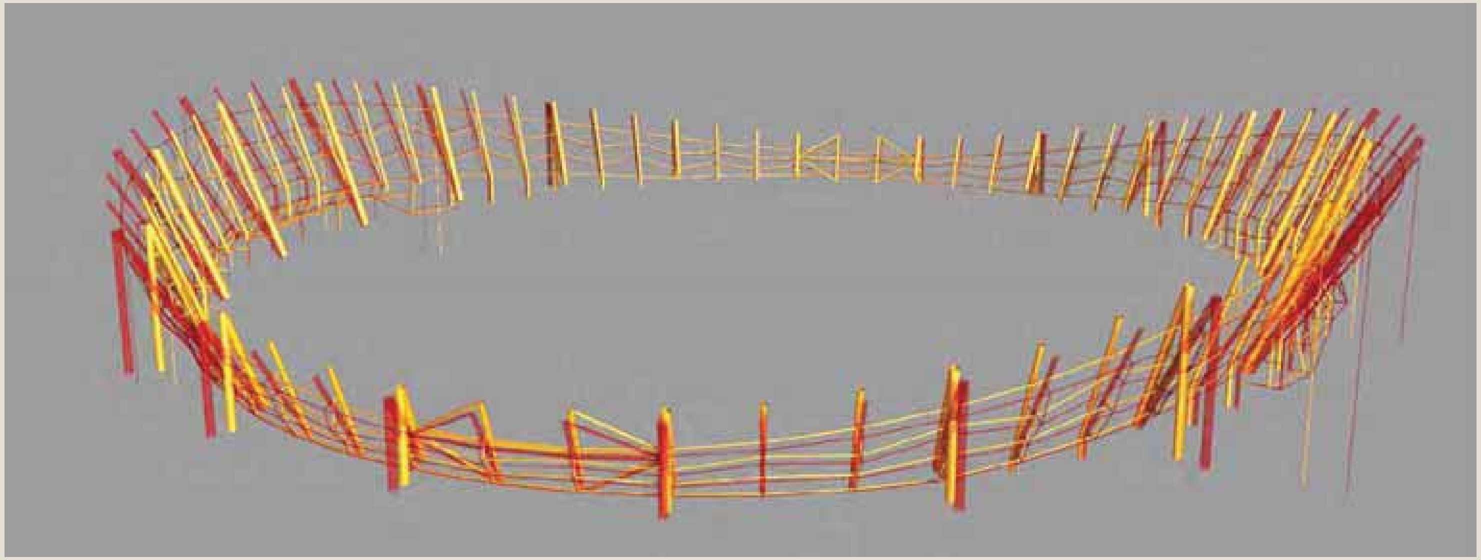
LEGACY SEATING VIEW



OVERLAY SEATING VIEW

WALL FORM

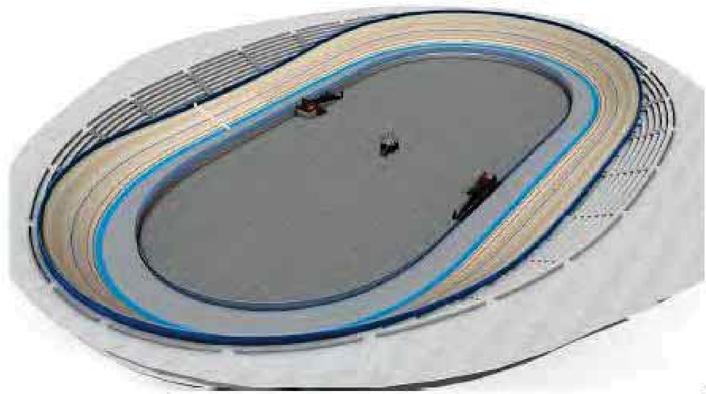
» Wall pitch needed to be adjustable so the structural span could be fine-tuned over the top of the general building size adjustments.



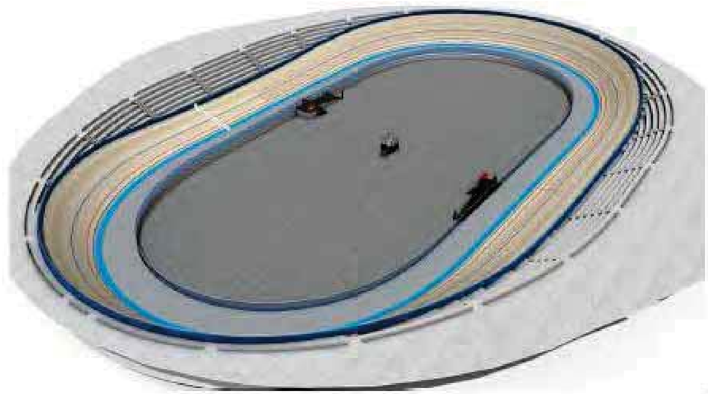
SEATING BOWL

- The seating bowl is generated directly from the form of the track to allow sightlines and coordination with the top of the track
- The elliptical base form allows easy adjustment to deal with studies affecting the seating form

400/850



450/850



540/850

03

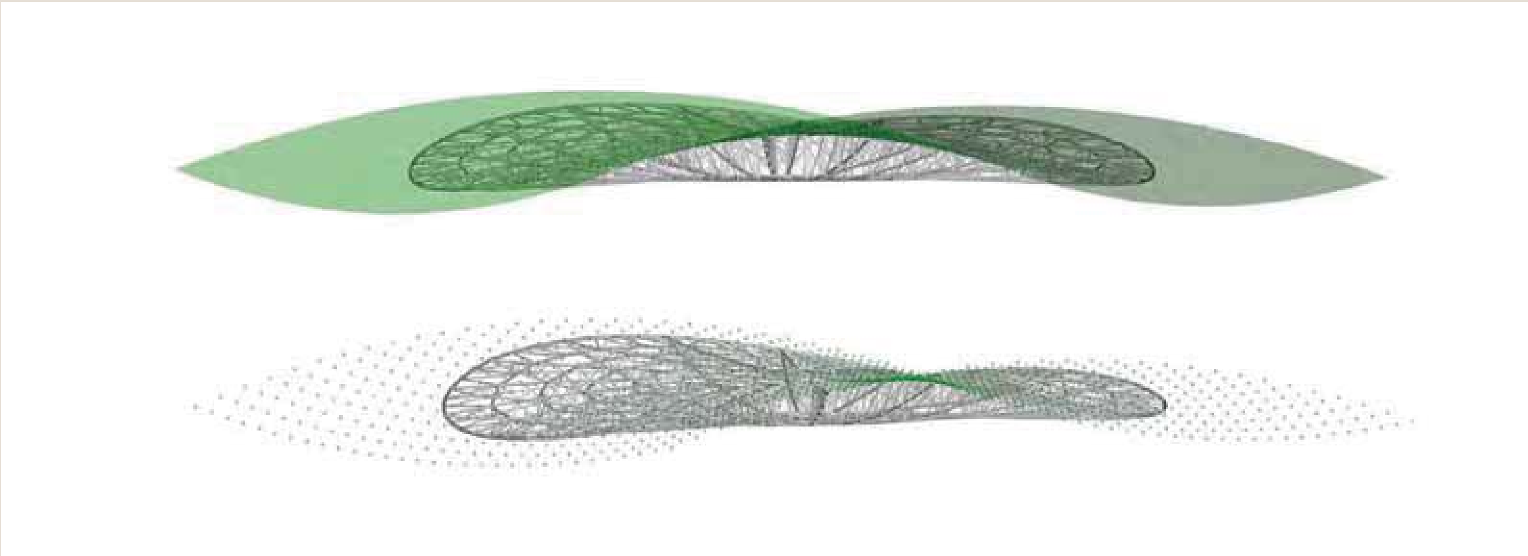
CONCEPTUAL STRUCTURAL MODELLING

ROOF FORMS

- A major design issue for large span roofs is the structural concept and generation of a structural diagram that is both efficient and in keeping with the architectural concept.

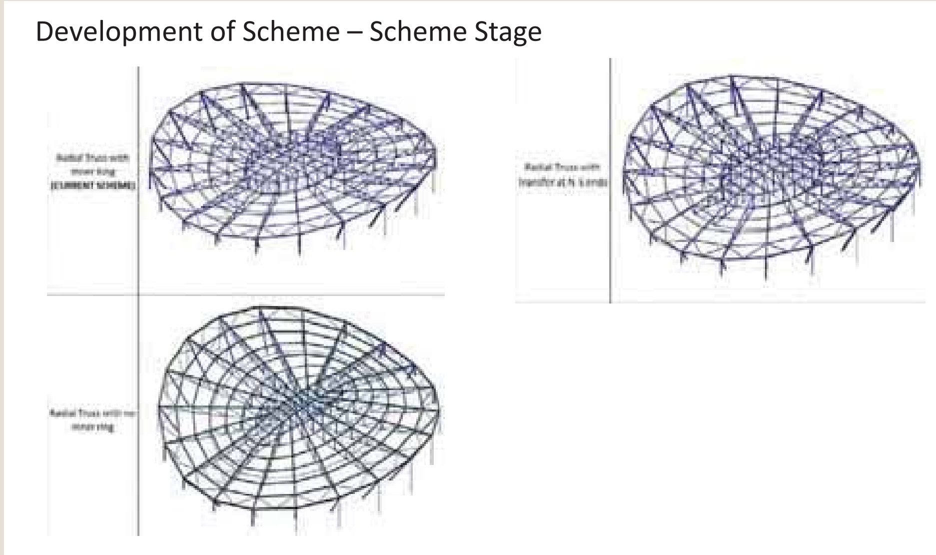
ROOF FORMS

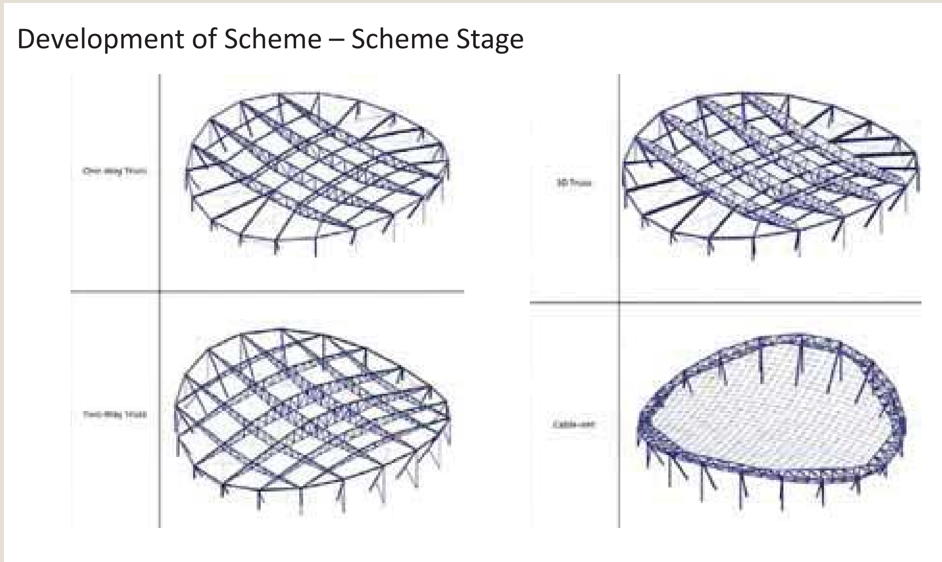
» Using the base architectural form definition to generate the structural diagram parametrically provided flexibility in conceptual stages



ROOF FORMS

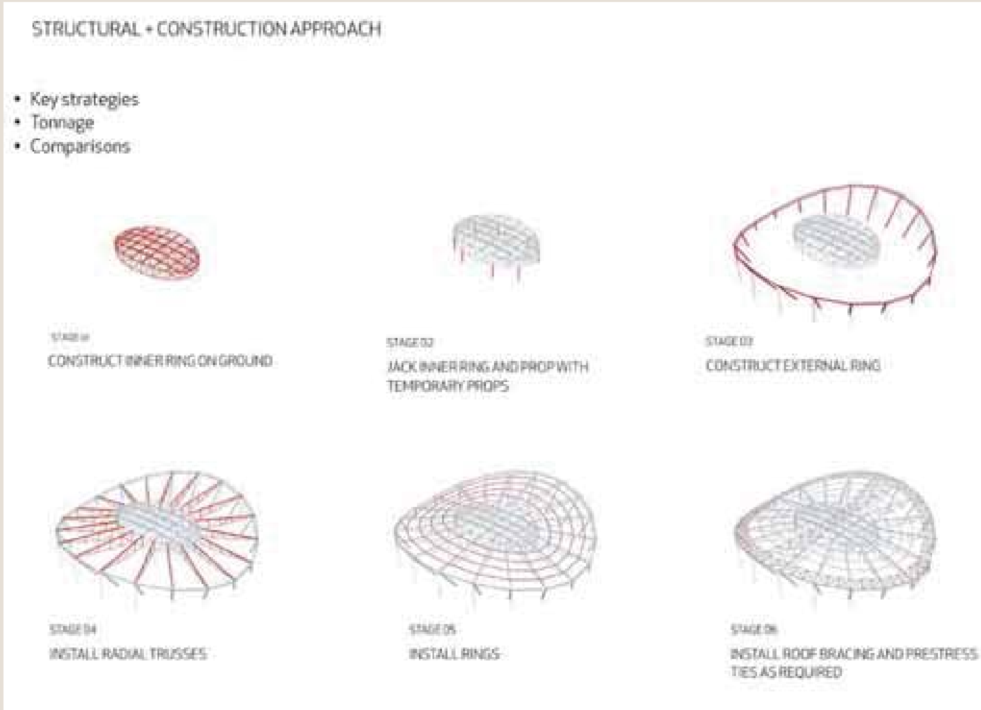
- Ability to assess a range of options quickly both structurally and against architectural design intent.
- Use of geometry gym to convert centre line to a GSA compatible format to allow for quick analysis





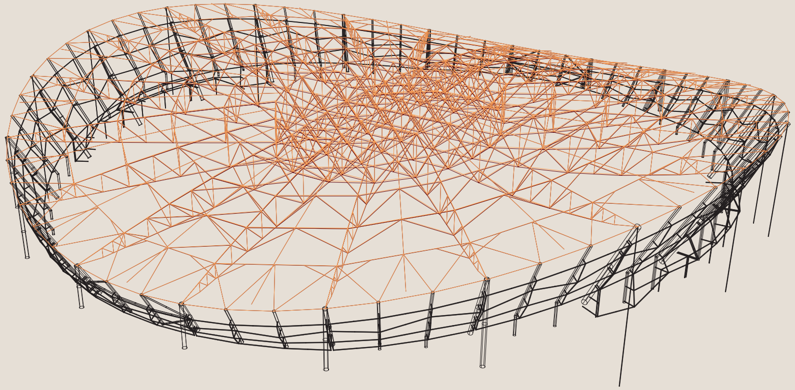
ROOF FORMS

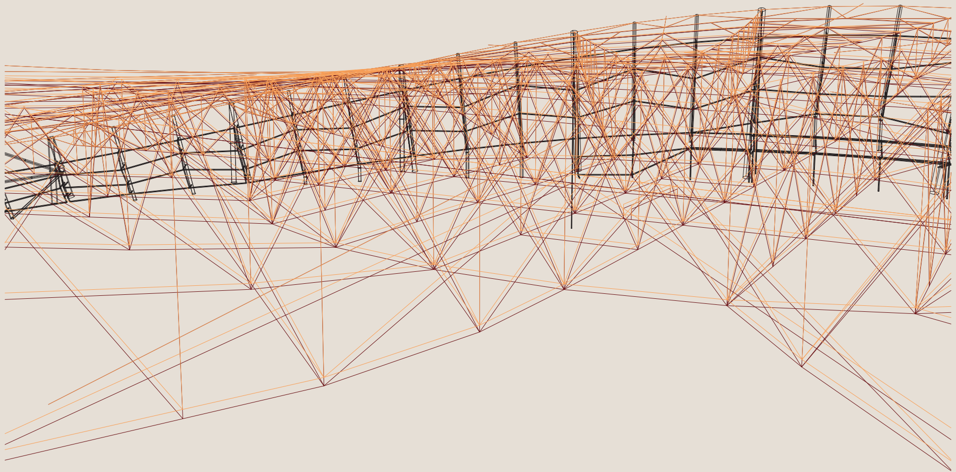
- » A radial truss solution was developed as it kept all angled columns and trusses in plane whilst allowing a perpendicular interface to the cladding form at column lines. Architecturally this structural form could begin to express the form of the building well rather than competing with it.
- » Structural Engineers were able to set parameters in the definition so that the form could evolve whilst adhering to the basic structural solution.



ROOF FORMS

» The expected deflection is in the order of 200mm so a pre-cambered steel set out was required to be developed. This required two models to be run simultaneously; this final state for analysis and building coordination, and a pre-cambered state for steel shop drawings. Writing this parametrically allowed a very quick and accurate way to run both and pick up any design development accurately.





04

QUANTITY ANALYSIS FOR COST PLANNING

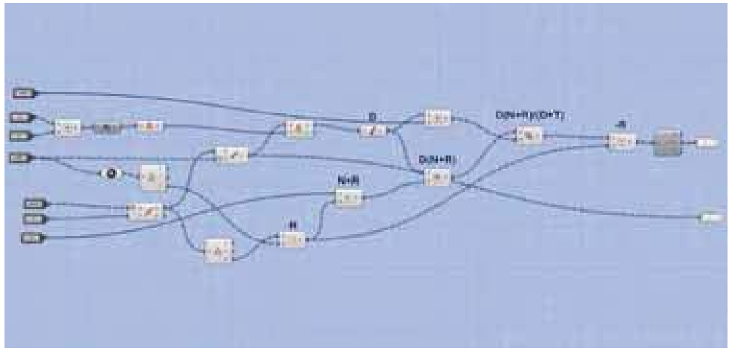
DESIGN CALIBRATION

- Through the cost analysis stages a balance has to be struck to deliver the building on cost.
- For more complex forms, parametric quantity analysis allows a very quick and flexible method to test many options for impact on building material quantity as well as design intent and effects on building function.
- The effects of increasing curvature, wall angle or raising the structure can be hard to predict, but become quickly manageable

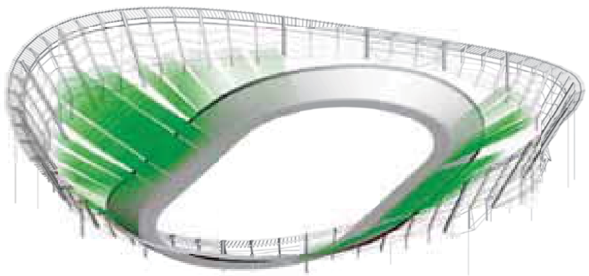
05

ANALYTICAL DEFINITIONS FOR DESIGN PROOF

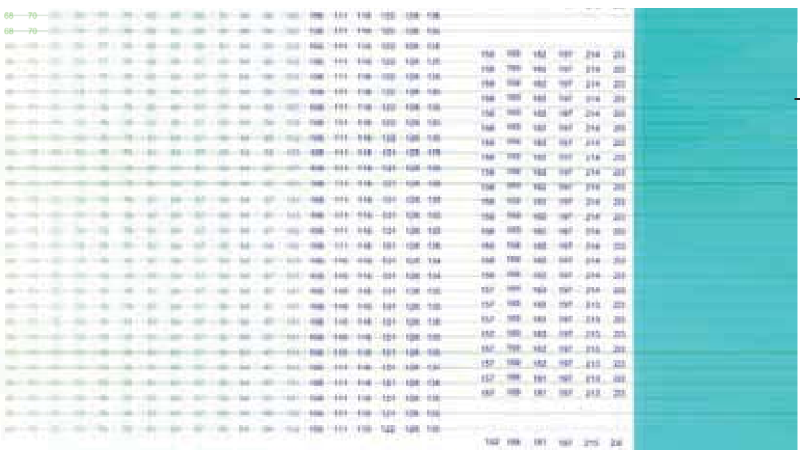
» Sight line studies



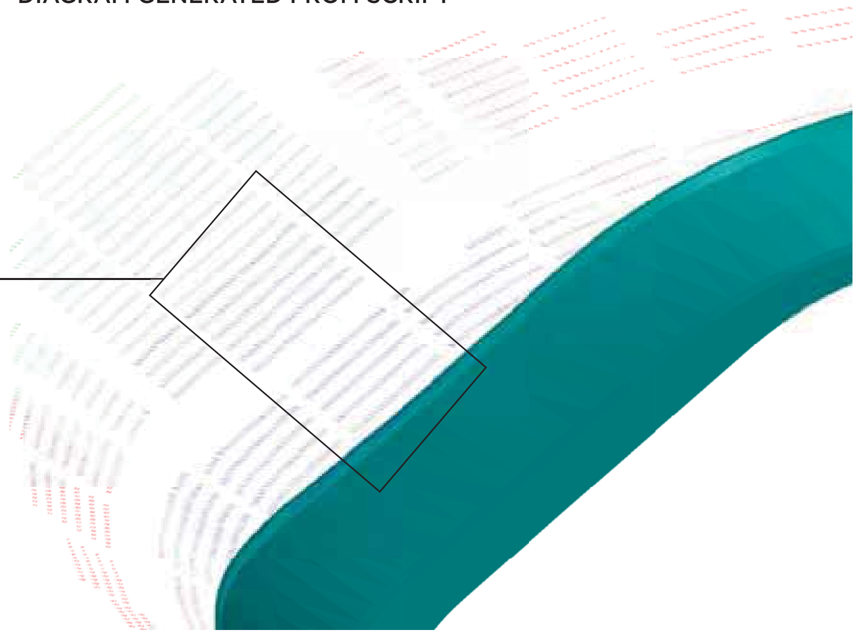
C VALUE CALCULATION SCRIPT



FULL STADIUM SIGHT LINE
DIAGRAM GENERATED FROM SCRIPT

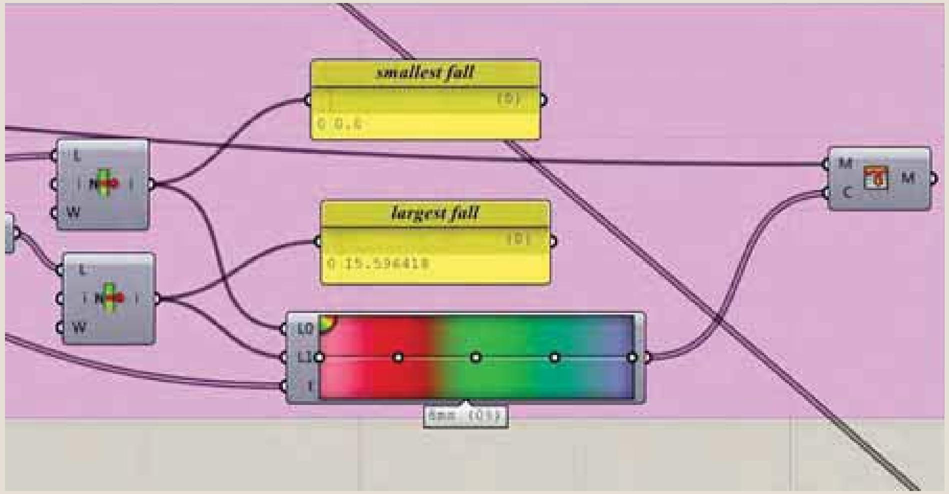


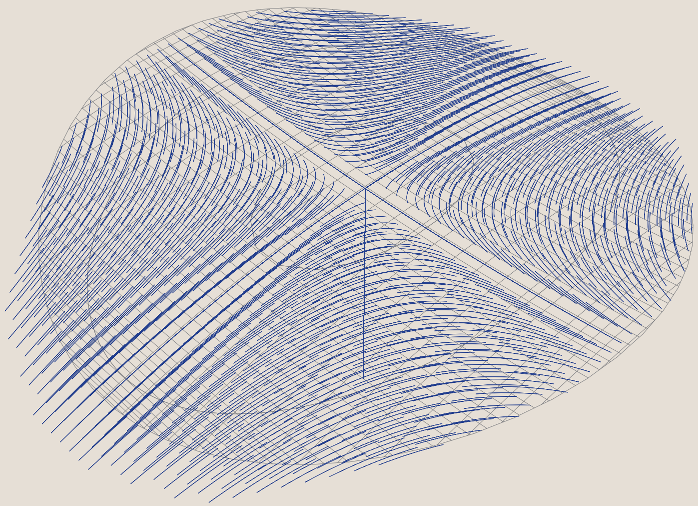
C VALUE DETAIL WEST GRANDSTAND



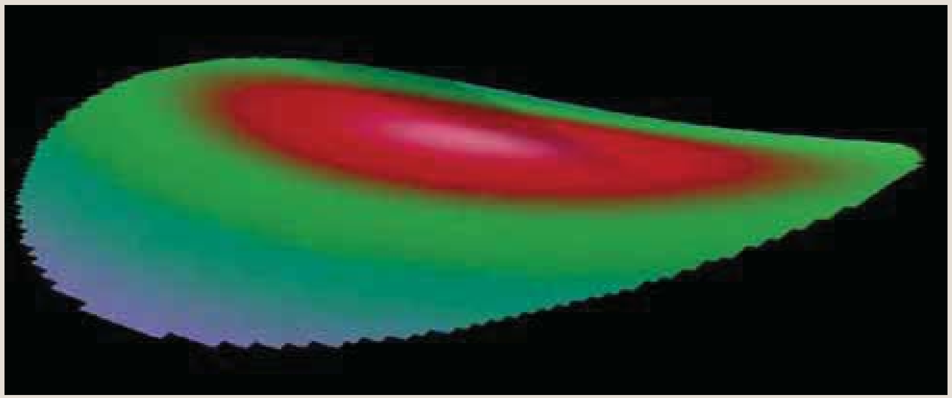
C VALUE RANGES GRADED BY COLOUR

- Rainwater flow paths
- Roof Curvature ananlysis



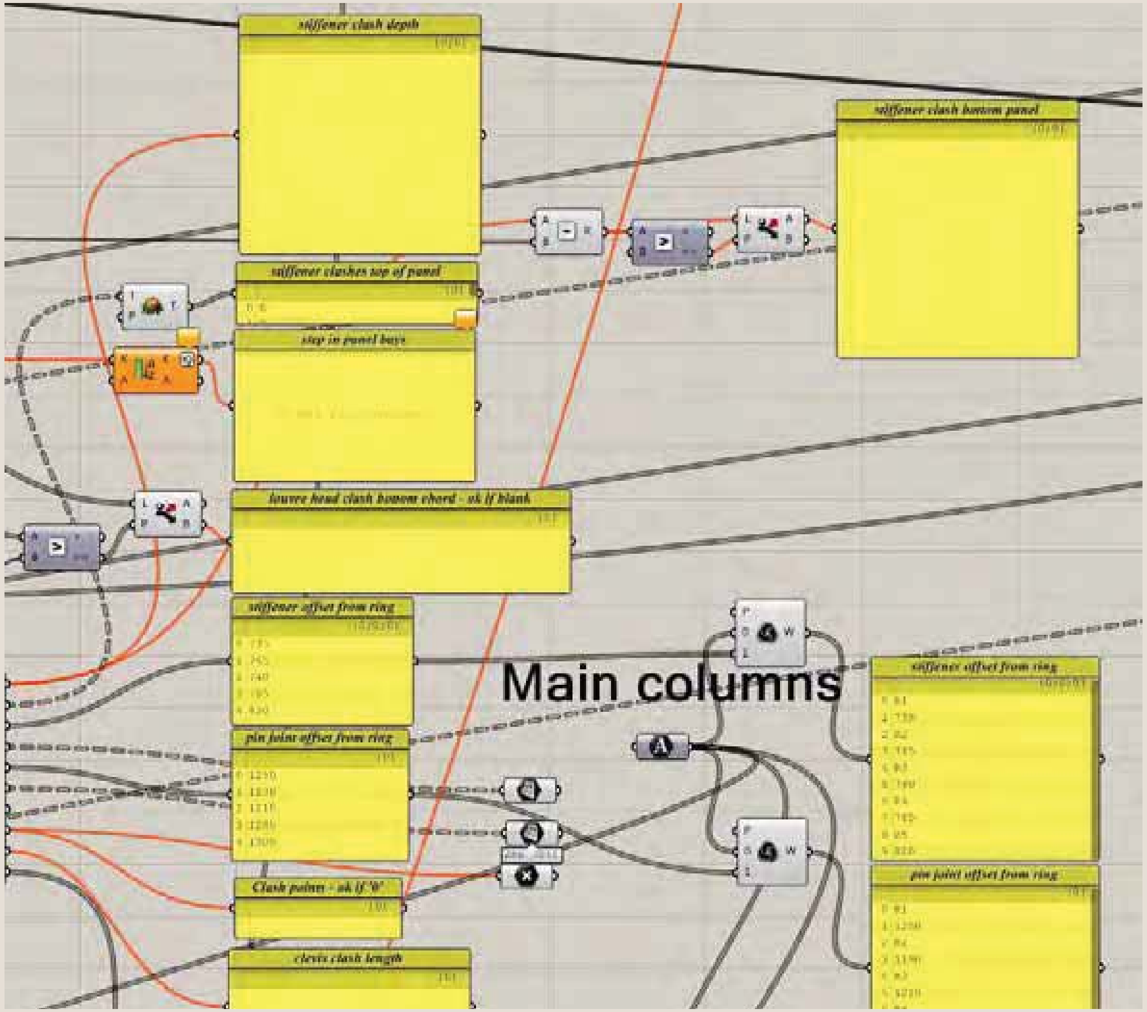


RAIN WATER PATH ANALYSIS



GRAPHIC REPRESENTATION OF CURVATURE

» Eaves clash analysis



06

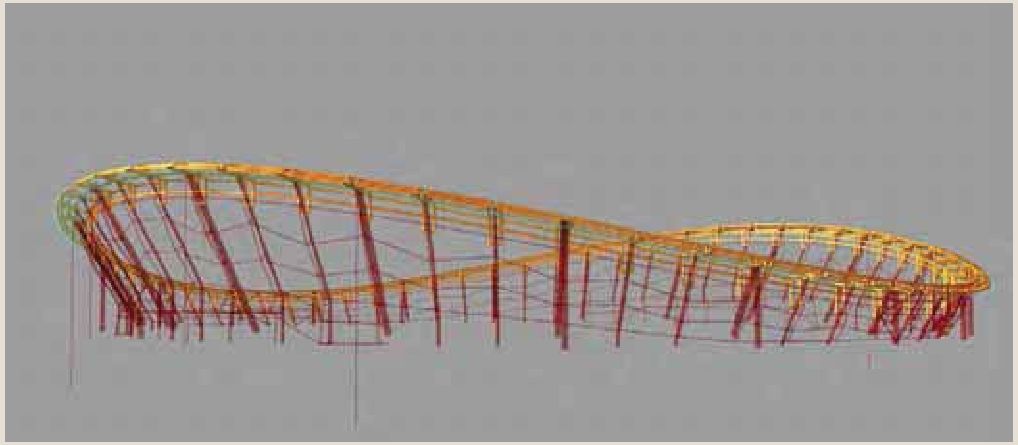
DETAILED DESIGN DEVELOPMENT

DEVELOPMENT OF THE WALL STRUCTURES

- » The use of fabric as a cladding material allowed to façade to be developed as a twisted geometry
- » The wall framing definition used a weave effect projecting alternate nodes to create straight steel lines that induced a warp into the fabric plane
- » The size of the structural bay is an equal division of the wall creating a compression of the warp as the building curves around the low ends.

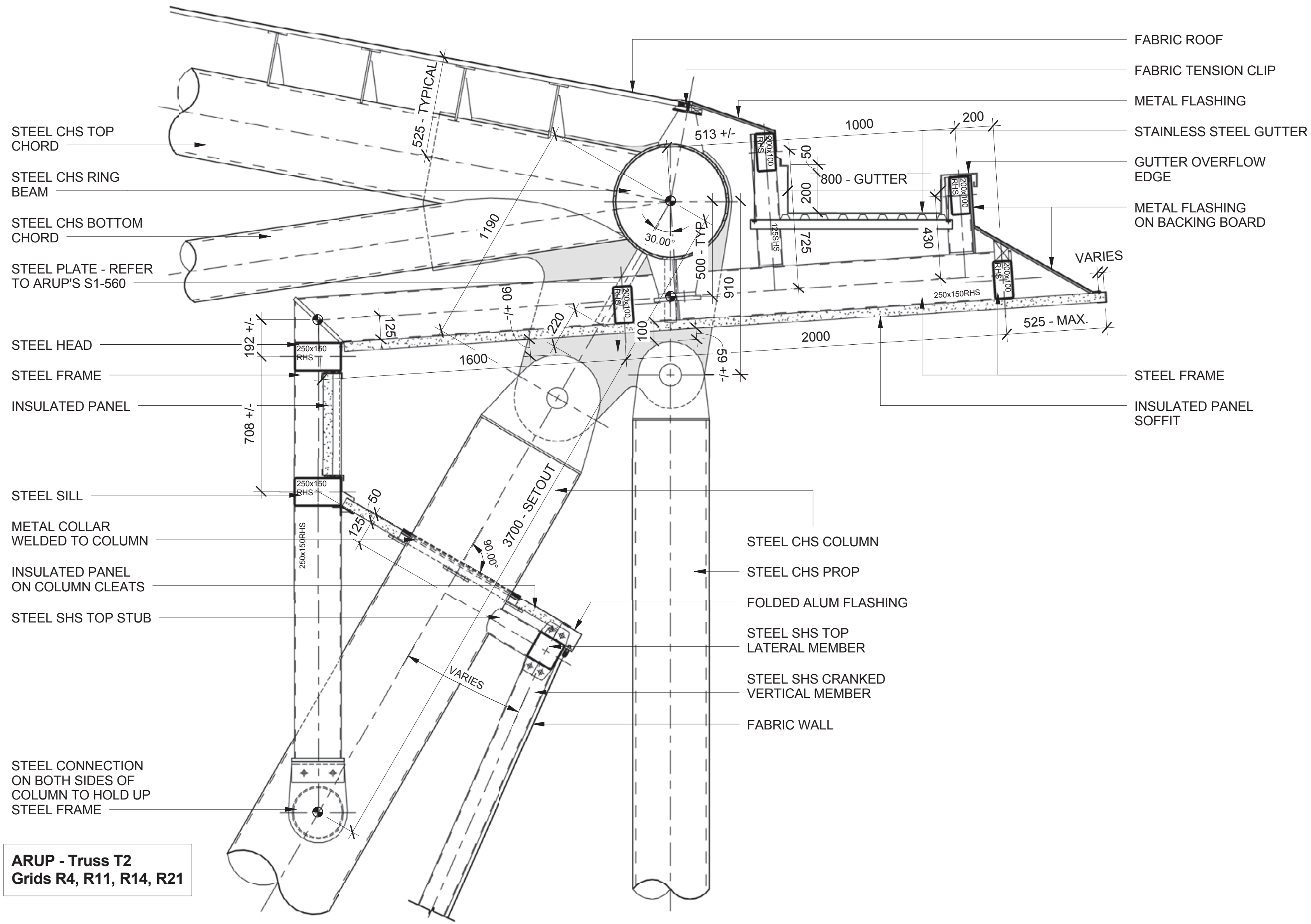
DEVELOPMENT OF EAVES STRUCTURES

- The development of the eaves form was a complicated process with a number of constraints that needed satisfying
- Parametric techniques allowed the design constraints to be built into the definition
- The low points required a horizontal plane for coordination of syphonic drains, and the high points were defined by the junction of the louvre head and steel truss lines



THREADING THE NEEDLE

- A plane for each structural bay needed to be set which combined to maintain the fluid eaves form
- The structural constraints only allowed a zone of approx. 200mm through which these planes had to pass in all cases regardless of the pitch in each bay
- The planes then needed to be averaged out in a manner that resolved the misalignment in the least visual area
- The steel can then be detailed as a flat planar frame making fabrication much easier



ARUP - Truss T2
Grids R4, R11, R14, R21

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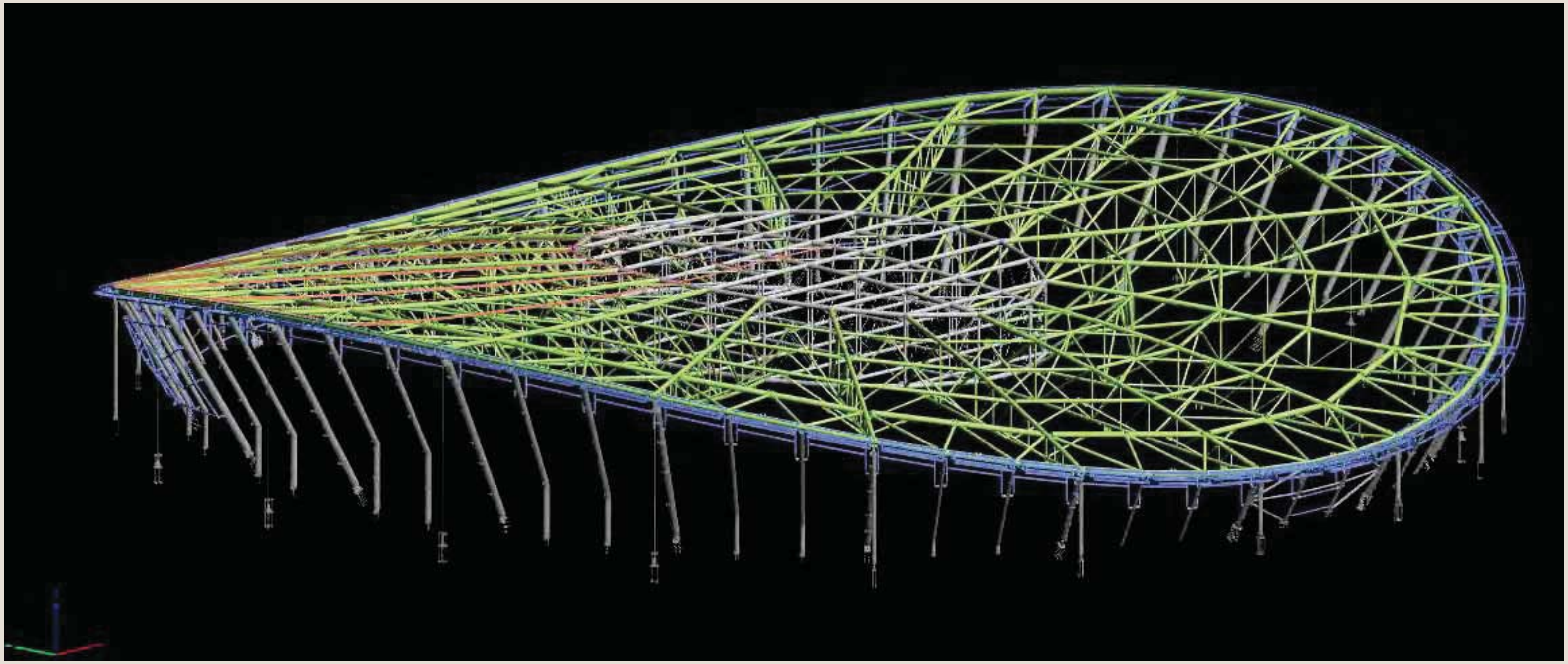
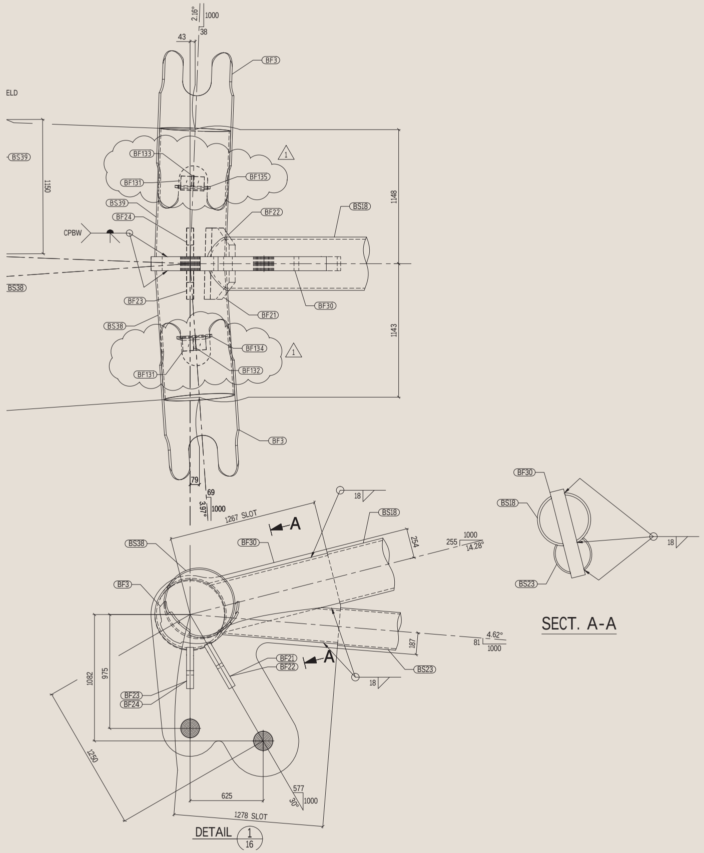
07

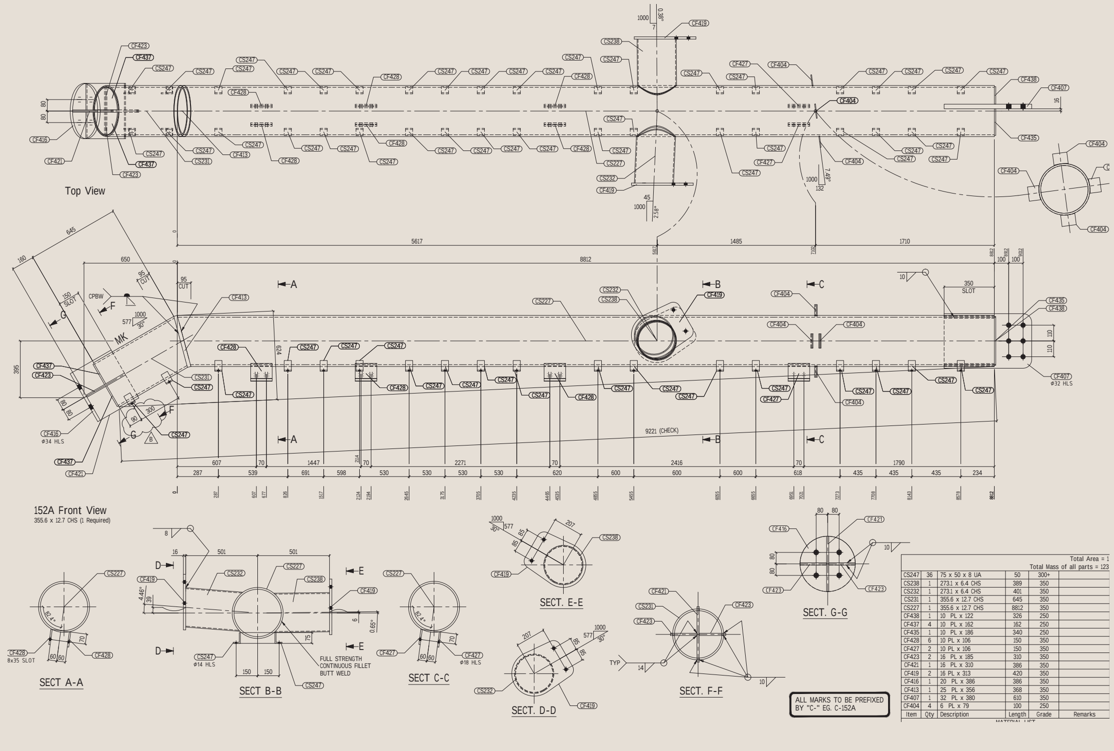
CONSTRUCTION MODELLING AND SHOP DRAWING COORDINATION

- A structure such as this takes thousands of steel shop drawings and with a complex geometry traditional set out checks in 2D would be extremely laborious.
- Traditionally a BIM, when it gets to shop drawing stage has not been of high quality for that purpose and often contains large amounts of superfluous information



- » Using raw centre line geometry allows all parties to generate information for base information which has pinpoint accuracy
- » Minor adjustments can be made to suit steel detailing from this base source

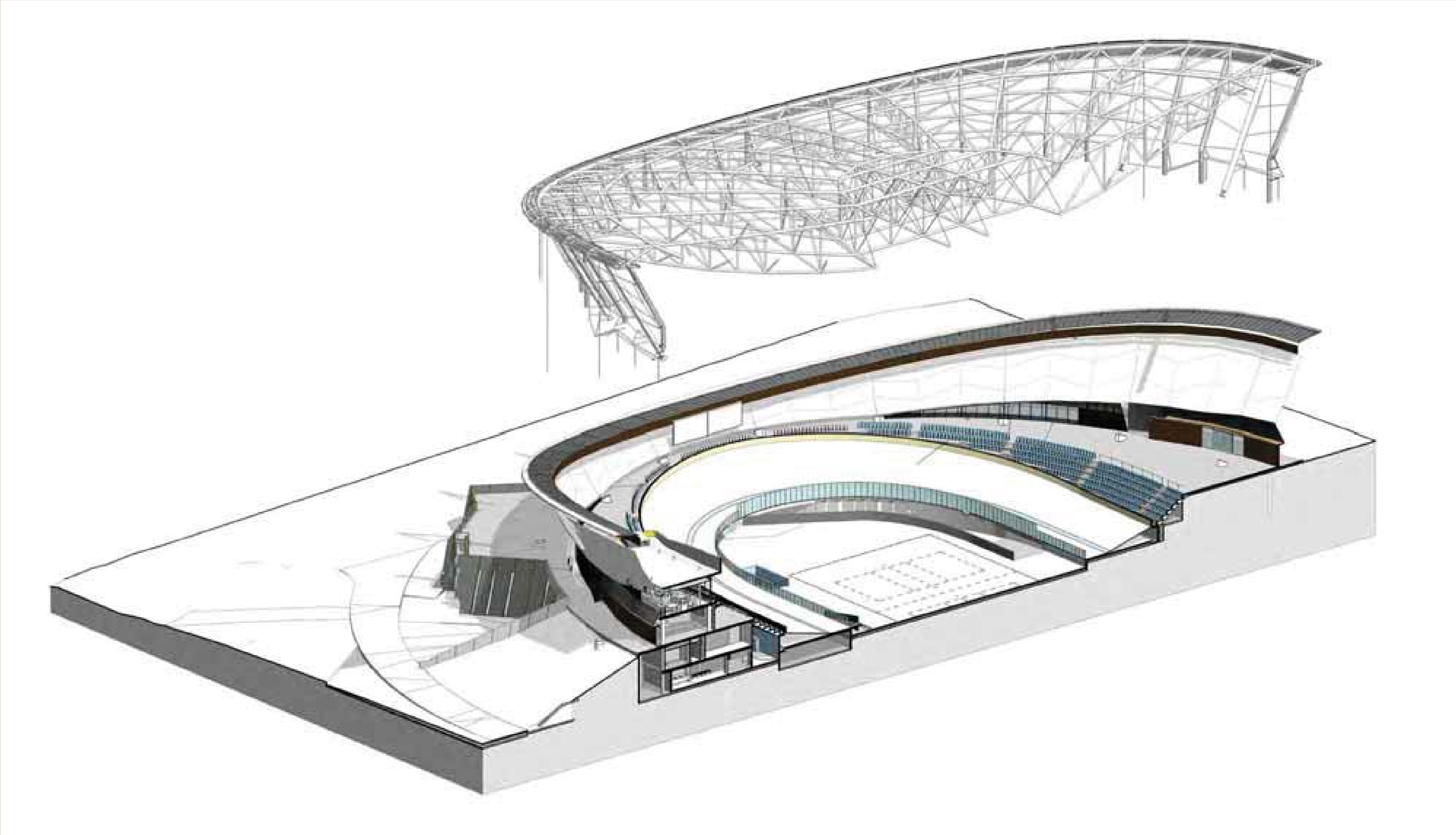




- Structural model Bentley Prostructures
- Full shop model reviews centred around detailing only as base geometry was controlled from base source saving considerable time and maintaining accuracy.

REVIT INTERGRATION

Combining Steel models for coordination into Revit using the Grasshopper – Dynamo work flow allows for quick updates to be represented in the base drawings



08

FINAL IMAGES

INTERIOR RENDER

FINAL IMAGES

FINAL IMAGES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