Sydney Football Stadium Temporary Works

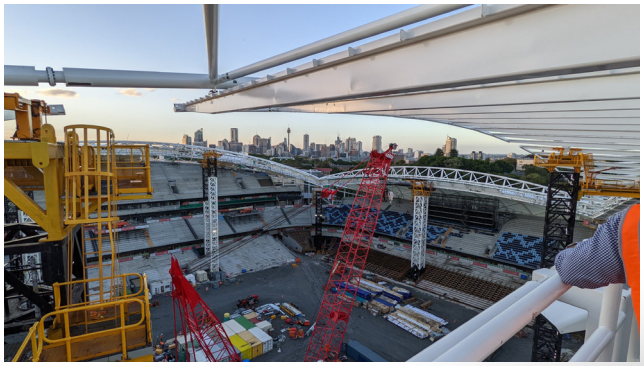
ACSE 2022 Awards
Large Projects Category

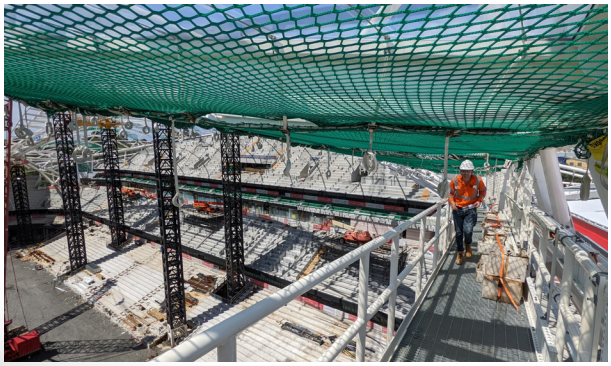
1. Introduction

Robert Bird Group (RBG) worked collaboratively with John Holland to facilitate all temporary works for the stadium construction. The original Sydney Football Stadium was opened in 1988 and was demolished in 2019 to make way for the new Sydney Football Stadium.

As with all large span steel stadia structures, the permanent works design must be informed by well-coordinated Construction Methodology & Erection Sequence (CMES) and associated temporary works. Our approach achieved a unique feat of rising to both the structural engineering and construction challenges that apply to large span steel structures. We aligned the construction methodology and temporary works to go hand in hand to deliver a safe and efficient build for all stakeholders.

On-time and on-budget delivery of Sydney Football Stadium (a rare feat for a stadium of this grandeur) puts this project on track from day one to integrate into the Sydney community it serves, taking on the role of both entertainment destination and iconic city landmark.





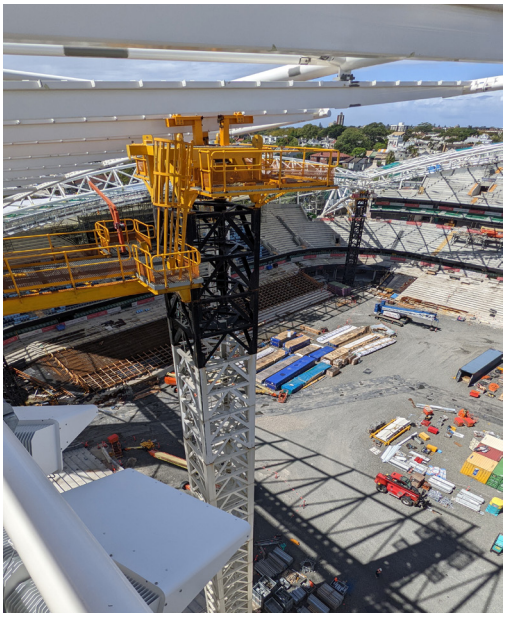
2. Project Brief

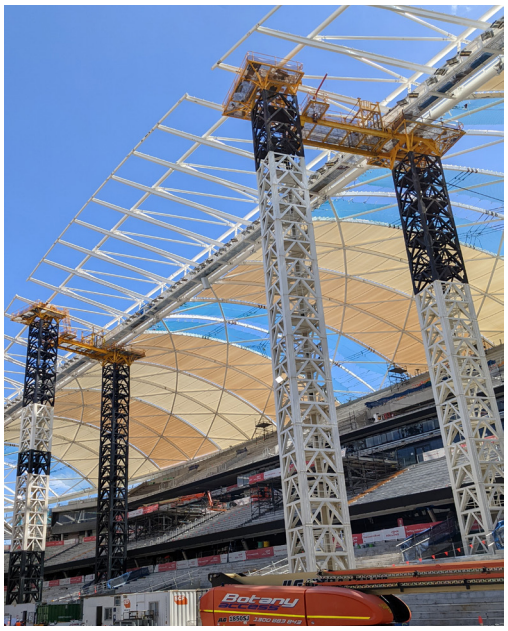
RBG's design brief was to develop the temporary works in conjunction with the construction methodology in collaboration with John Holland for both the stadium roof and stadium bowl. The construction sequence enabled large savings in roof weight through pre-set geometry of the following:

- The pre-set workshop geometry of the leading edge roof trusses involved fabricating the trusses longer than the gap between their supports at the stadium corners. The trusses were then jacked during the splicing process so that they fit between derricks (fabricated 90mm longer than the final installation geometry)
- Pre-set roof rafters through the diagrid held in position using underslung cables to elastically deform rafters to fit within truss and tension ring workshop geometry
- Tension ring erected inwards with a smaller diameter than the final geometry (fabricated 150mm inwards of final geometry)

It is important to differentiate that the above pre-set geometries are not pre-cambers, but fabricated geometries which required constructed sequence and jacking to enable them to fit together and deflect into the final arrangement.

The bowl constructions sequence required a series of temporary movements joints which isolated large sections of the stadium from the permanent lateral load path during construction. The temporary movement joints were required due to a combination of the continuity of the bowl/concourse structure in the permanent structural configuration (a continuous ring around the pitch) and the inward overturning moments at each corner due to the 4 derrick elements supporting the 4 inner corners of the roof.





3. The Method and Construction Process

RBG took into consideration the project brief and constraints to develop innovative structural solutions that would ensure successful delivery of the program. The major temporary works packages included:

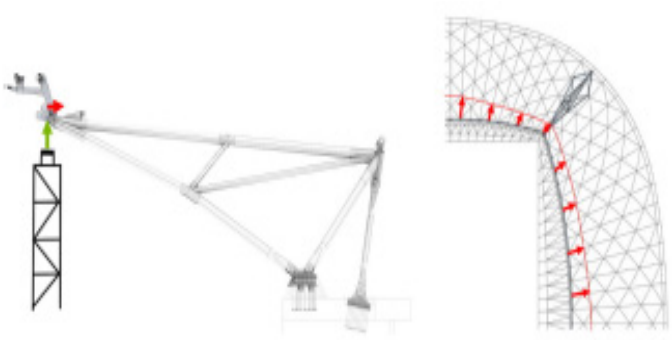
- Temporary propping towers for roof truss installation and support of the roof until installation 100% complete
- Jacking supports for locations that required full lateral restraint and those required to provide movement to accommodate roof installation sequence
- Underslung cable details including jacking and de-jacking details. Akin to tunning the bicycle spokes on a bike wheel.
- Lifting analysis for all roof element installation
- Jacking frame to installation of diagrid struts to return structure to fore-free condition prior to installing diagrid elements

- Tension ring propping
- Safe access solutions for all splice locations to eliminate working from harness

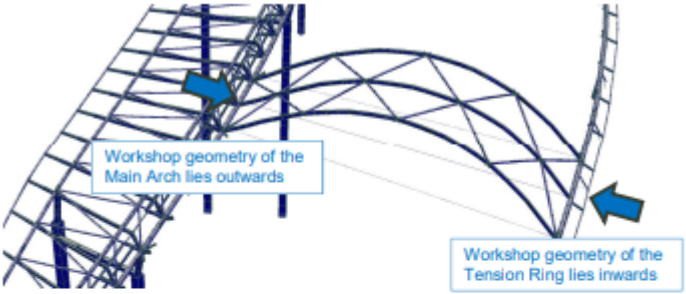
Peer review of the permanent roof design which identified key improvements to the structural geometry models which ultimately de-risked the methodology and fabrication. RBG took into consideration the project brief and constraints to develop innovative structural solutions that would ensure successful delivery of the program.

Bowl Construction

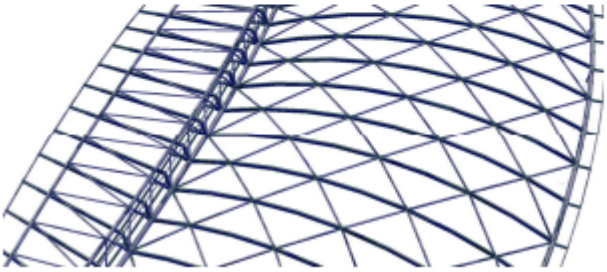
The TMJs throughout the bowl, at face value, appear to be a relatively simple detail to mitigate shrinkage cracking and remove the impact of roof movements during de-jacking on the bowl lateral stability elements, however the TMJs isolated large sections of the bowl from lateral stability elements (ie lift and stair cores). RBG were then required to perform a staged lateral stability analysis for each of the bowl sections. Consideration of the construction sequence and framing action enabled RBG to limit the size and quantity of temporary propping to provide lateral stability until the TMJs could be closed.



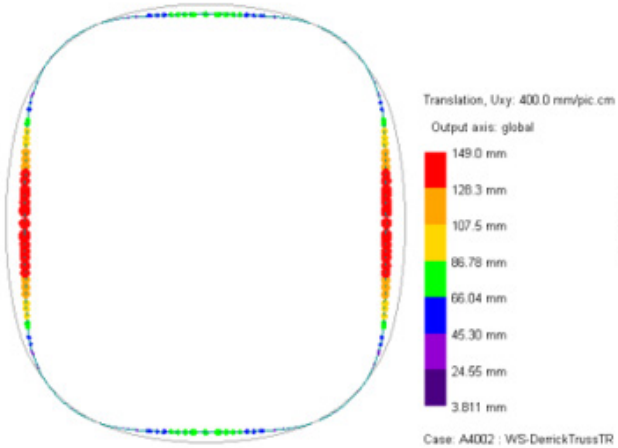
Linked movements at Derrick tips



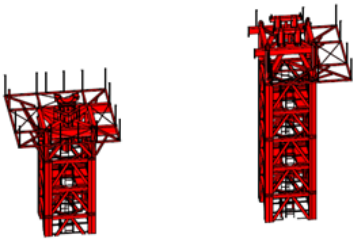
Installation geometry of diagrid bays (deformation magnified 10x, only one module shown for clarity)

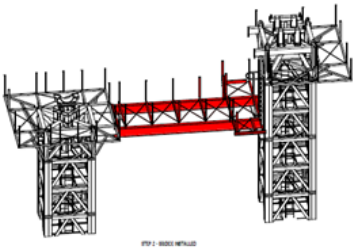


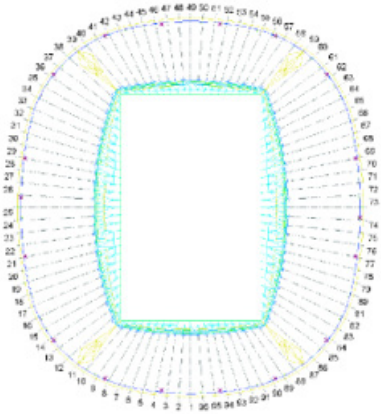
Final geometry



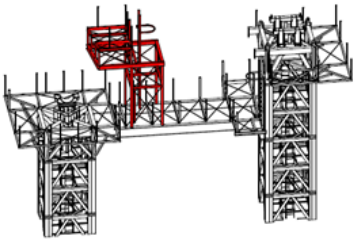
Theoretical installation position of the Tension Ring

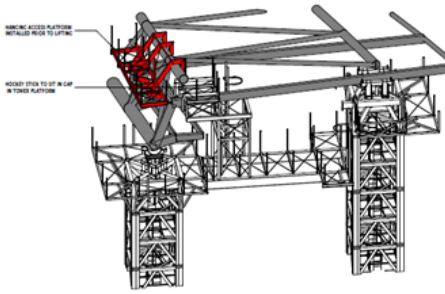






Positions of temporary column struts





4. Sustainability, Built Environment and Heritage

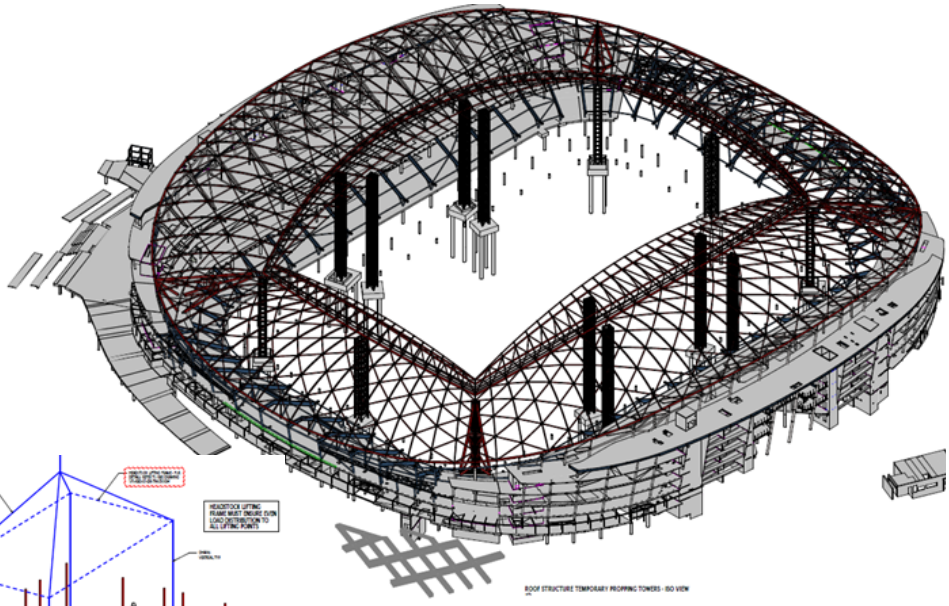
The temporary propping towers were primarily constructed of tower crane tower sections which were hired for the project and thus eliminated approximately 585 tonnes of temporary steelwork from the project.
The lifting attachments throughout the project made use of bolt on lifting brackets which were re-used throughout all roof truss and roof rafter installations. The bolts were sized to keep the lifting stresses low and enable re-use for each new lift.

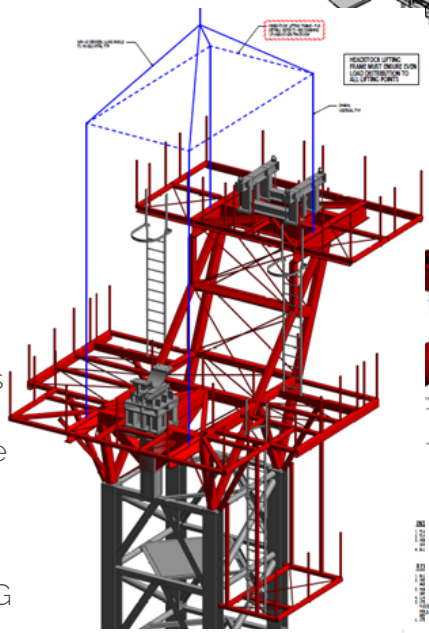
The project is an excellent example of construction methodology which enables a more efficient roof structure and thus enabling a more sustainable design through lower embedded carbon.

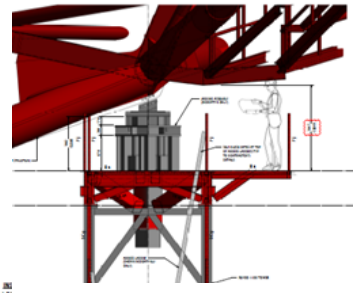
Temporary platforms for EWP positioning on the plats were designed using proprietary Coates hire falsework components which were specified to form the bespoke platform. These components were hired, used for the project and returned to the supplier for re-use on other projects. This demonstrated an improvement when compared to similar projects which have made use of bespoke structural steel platforms which are discarded at the end of the project.

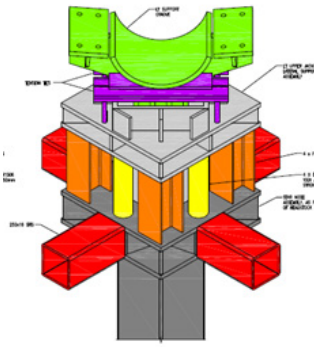
5. Innovation

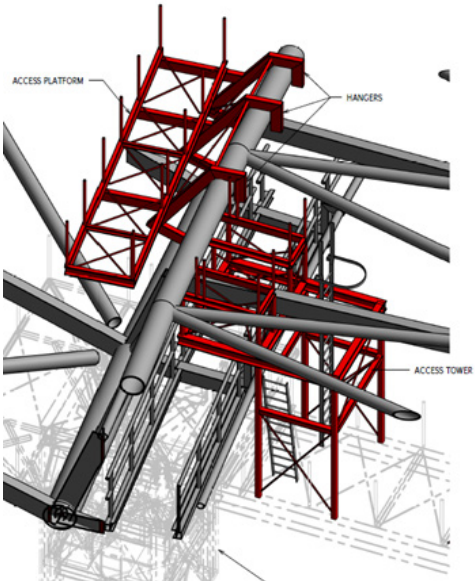
The roof of the stadium is structurally efficient and represents an evolution of AAMI Park in Melbourne and Adelaide Oval with a dash of Suncorp Stadium from Brisbane. The height constraints for the new SFS required a single layer shell roof structure while keeping the eaves low to fit within an overall project height limit. This led to a roof structure which consists of a form found cable net shape with imposed loads, including front eyebrow and front edge stiffening trusses, supported from the perimeter and the corners of the lower stand and a geometrically pre-set tension ring supporting the diagrid. The diagrid roof uses deeper members in the arching radial direction to facilitate bay by bay erection. None of these structural innovations would be possible without the temporary works and construction methodology delivered by the RBG Construction Engineering team.

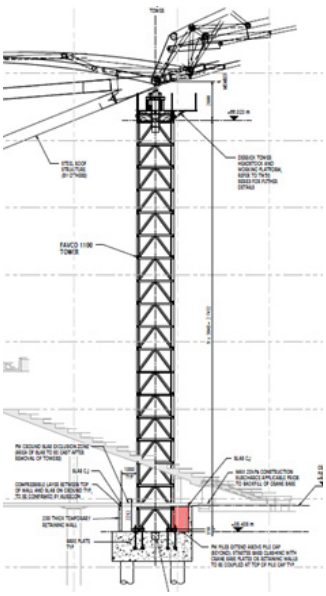


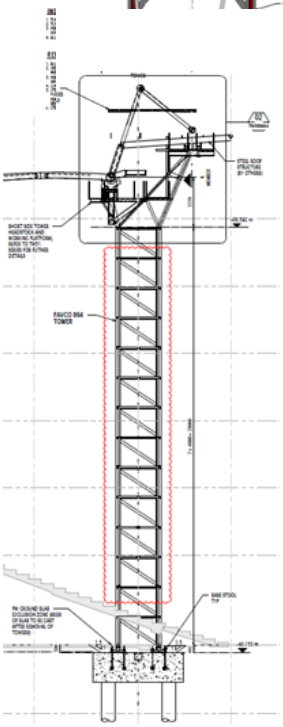


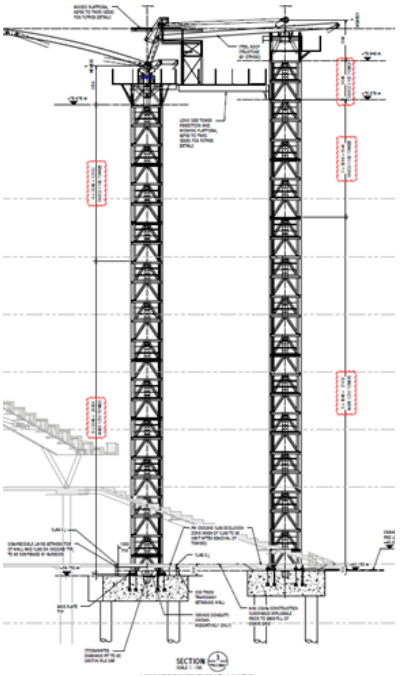












6. The Challenges and Resolutions

The structural form of the roof, while efficient and slender, led to the unique engineering and construction challenges that had to be address included but not limited to:

Temporary propping of the roof as it is not stable until the last roof element is installed

Propping incorporated a complex jacking procedure to adjust the geometry during installation to preload the leading-edge truss

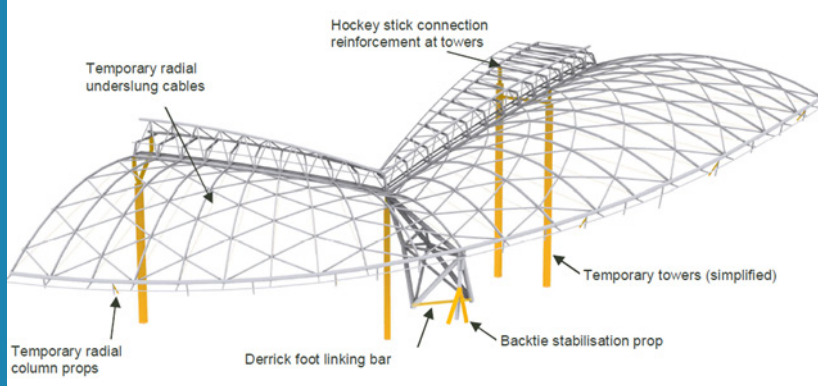
Bowstring tension ties for diagrid rafter installation. Akin to tuning a set of bicycle spokes, these enable safe installation of the rafters without propping as well as enabled the perimeter tension ring to be preloaded as the bowstrings were destressed

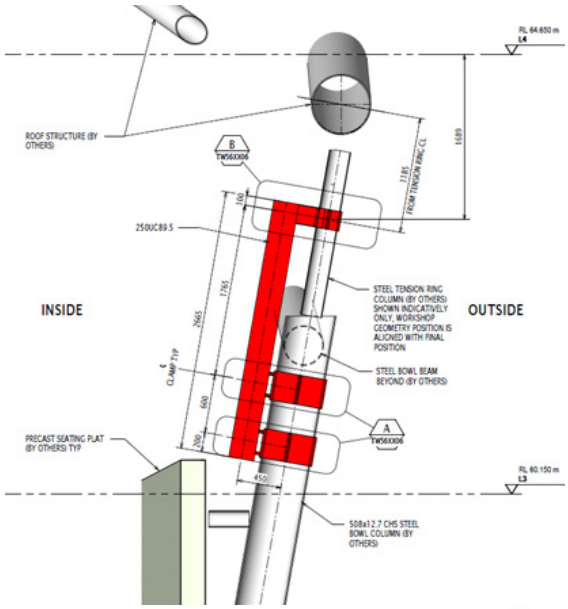
Propping and preloading of the tension ring. The tension ring was not stable until all diagrids were installed. Stiffness of the propping was very sensitive to the structural capacity of the tension ring columns and required many bespoke tuned beam props rather than simple raking props.

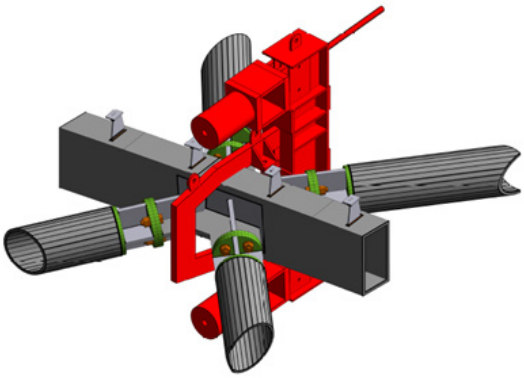
Safe access in and around all temporary works given constraints of working at heights and geometry of access being required over construction of the concrete bowl.

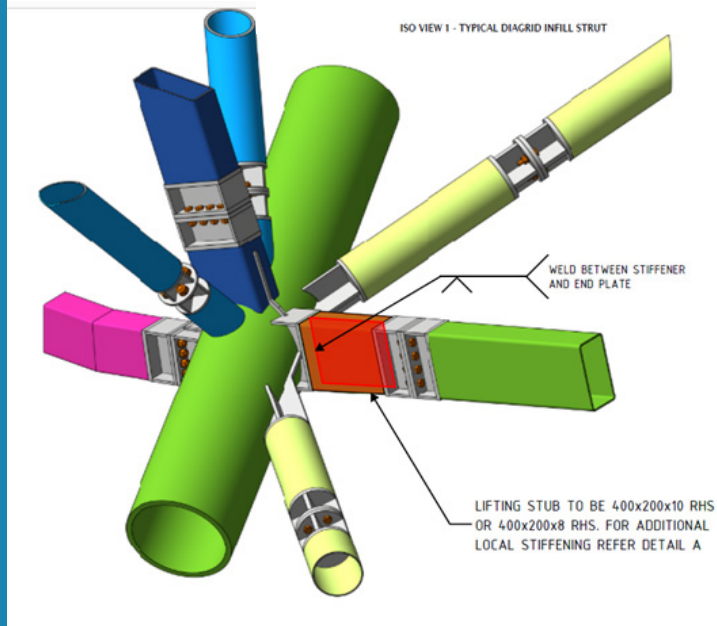
Temporary movement joints through the bowl. Temporary movement joints were required throughout the bowl to allow for concrete creep and shrinkage throughout construction. Further the roof derrick structures placed large inwards movements into the pitch which required movements joints to be closed after roof de-propping. This resulted in large sections of the concrete bowl left in the temporary situation with no lateral load paths. RBG Performed detailed CMES and temporary works designs address these issues and stabilise the bowl during construction.

RBG worked collaboratively with John Holland, Aurecon and Schlaich Bergermann Partner to design the temporary works for the erection of the stadium roof and the construction of the bowl and concourse stadium structures. On time and on budget construction is a remarkable achievement for any stadium and we consider this to be an amazing accomplishment considering the impact the Covid-19 pandemic placed on our design teams working from home.









3D VIEW - ROOF DETAIL 4