The Collaborative Design of the Adelaide Oval Diagrid Roof

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Abstract

The Adelaide Oval Western Grandstand Redevelopment comprises the partial demolition and reconstruction of the existing heritage listed western members grandstand into a new A$116m 14,000 seat grandstand. The iconic grandstand was opened for the 2010 Ashes Second Test Match to rave reviews. The diagrid roof forms the centrepiece of the new grandstand achieving structural spans up to 55m with arched 219CHS sections leading to an elegant and exceptionally light (55kg/m2) roof solution to provide the required cover to the grandstand patrons with unobstructed views and designed to withstand 180kph design wind speeds.

Early in the design the impact of the steel fabrication, erection and site tolerances were identified as of critical importance to the successful implementation of the diagrid roof design. To accommodate this the Steel Subcontractor was invited into the design team early at 50% completion to workshop with Aurecon, the Architects, Managing Contractor and Client to provide the best for project solution and ensure that the final design was constructible within the required design brief, programme and cost plan. This early involvement allowed the design team to consider these parameters early in the process and has resulted in a very successful erection process and outstanding result for the Client.

1. Introduction

Following progressive upgrades over the years the Western Grandstand has been present at Adelaide Oval in some form serving SACA members for in excess of 100 years. The heritage listed structure was renown throughout South Australia and the world however it had fallen below the standards expected by modern stadia. SACA's aims were to bring the members stand into the modern age whilst still acknowledging and celebrating its place in the ground and states history.

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This paper, for the Lightweight Structures Association of Australia, deals specifically with the lightweight diagrid roof solution and the processes and collaboration within the design and construction teams that delivered this iconic component of the project.

2. Client Requirements and Roof Brief

The following key client requirements were successfully implemented within the roof design:

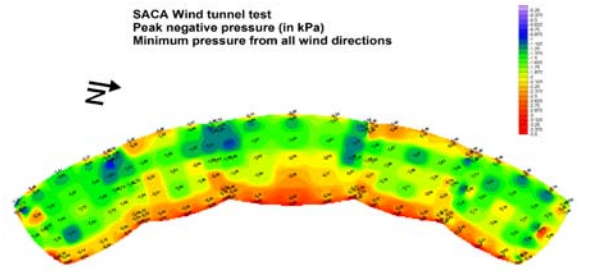
- Iconic world class roof design.
- Improving patron amenity by improving the roof coverage for both rain events and for shading patrons from the sun (100% shade by lunchtime and drip line coverage to the concourse).
- Column free unobstructed views.
- Minimum material usage
- Maintaining lighting levels to the ground and improvement of general lighting
- Ground remained operational throughout the construction phase to hold cricket and concert events
- Value for Money
- The new facilities are to be safe, with easy public access, utilising a cost effective design and well managed ongoing operations
- Construction complete ready for a capacity crowd for the 2010-11 Ashes test match between Australia and England

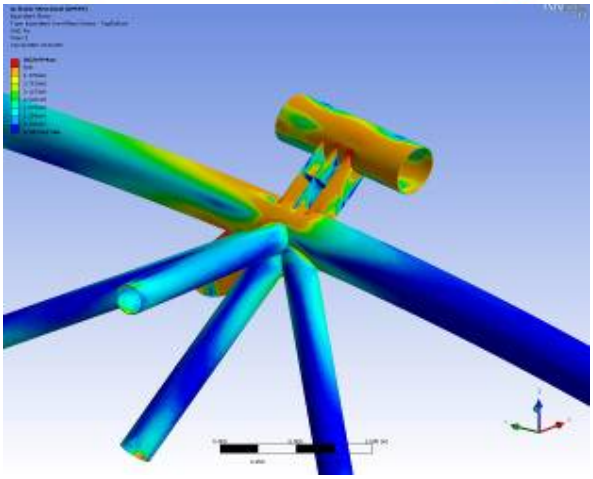
3. Stadiums and Large Span Roofs

Key to the success of the Western Grandstand was that the final product must be iconic, it must be quintessentially Adelaide and it must work in harmony with the existing fabric of the ground. The diagrid roof forms the centrepiece of the new grandstand and is divided into 5 main sections with the central dome drawing the eye to the historic Giffen Stand – the oldest party of the existing fabric. The use of a diagrid for a stadia roof has seldom been undertaken as in the Western Grandstand solution anywhere in the world and never in Australia. This innovative roof is formed using curved 219CHS sections to achieve spans up to 55m, leading to an elegant and exceptionally light (55kg/m^2) roof solution, making it one of the lightest roofs in Australia and globally. This support system provides patrons unobstructed views of the ground.

The roof design was optimised through sophisticated analysis and design including:

- Working with the design team Aurecon championed the early involvement of the steel subcontractor who was brought into the team at the completion of the schematic design. This allowed Aurecon to work directly with Built Environs and Samaras to ensure the roof solution could be built within appropriate tolerances and temporary staging
- Aurecon undertook wind tunnel modelling allowing both a reduction in design wind pressures and design certainty for the roof to be pushed to the limit. The resulting roof is one of the lightest roofs ever constructed in Australia achieving the 7,000m^2 coverage with sophistication and elegance
- The roof 3D model was used for shop detailing, imported into engineering software and for architectural design
- Non-linear buckling analysis to determine the overall stability, erection sequencing and temporary works
- Finite element analysis of the critical nodal connections that minimized the additional strengthening requirements of the thin walled lightweight members. Connection designs included design of the primary roof column node incorporating a 2 tonne solid steel billet
- Temporary and erection cases necessitated the roof modelled dozens of times to allow not only for the final case but the temporary cases as the roof was delivered to site in approximately 100 pieces and required to be erected cognisant of other site construction to meet program
- Integration of lighting cables and support framing to maintain elegance of the design solution





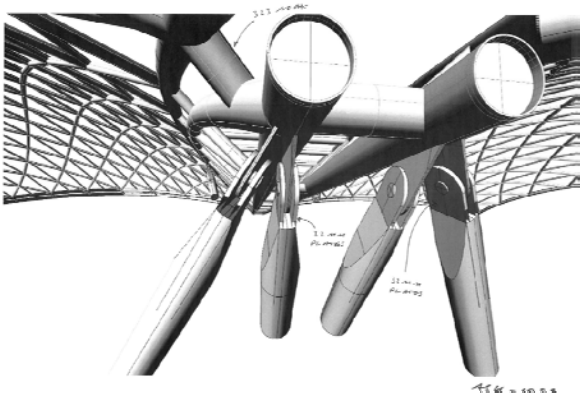
4. Collaborative Design Development

Collaboration was at the forefront of the delivery of the Western Grandstand. Intensive workshops were held throughout the project duration and resulted in an optimised design while maintaining the client requirements. While this approach was utilised through the entire project the key example was the lightweight roof design where the architecture, engineering and construction are intrinsically linked. This involved Aurecon understanding the key architectural and constructability drivers and in return communicating the structural behaviour. This process of collaboration and communication is the way of the future in achieving lightweight large span structures of high aesthetic appeal.

The design development of the structure as a whole and the diagrid roof in particular utilised a highly collaborative approach throughout all stages as described following:

Concept Design and Project Brief:

Recognising the required synergies between the engineering and the architecture Aurecon integrated the architectural vision with the engineering design from the outset and throughout the design. The process started with intensive briefings with SACA as the client to ensure that the Client's brief and vision for the roof were communicated and well understood by all. The critical client requirement was improving patron amenity by improving the roof coverage for both rain events and for shading patrons from the sun. Coupled with this was an essential requirement for unobstructed views necessitating a cantilevered roof solution.



Schematic Design

For the Western Grandstand the design team was supplemented by the early involvement of the Managing Contractor, Built Environs, who was appointed to provide specialist advice during the design following the concept phase. This advice was particularly of benefit for constructability interfaces with discussions frequently based around transportation, erection, craneage, programme and the like which enabled the design team to focus on design solutions that maximised the construction due to the short construction period available before the international showcase that accompanies the Ashes cricket test series.

During this stage Aurecon and the design team undertook a multitude of design options to achieve the client objectives through extensive workshopping with SACA as the client, the architects, managing contractor and cost manager where a variety of roof solutions were considered. Consideration included the following aspects of the design solution:

- Cost
- Programme
- Aesthetic appeal
- Material use
- Iconic status
- Constructability
- Fabrication and transportation

The preferred roof solution comprised 6 roof trusses arranged on a radial grid centred on the existing Giffen Stand. The roof is supported on feature precast columns that weave through the retained heritage wall beneath with the elegant diagrid shells between. The resultant roof cantilevers 30m from the rear seats proving drip line coverage for patrons in the mid and upper tiers. Detailed sun shade modelling also proved all patrons in the grandstand including those in the lower tier were in shade after the lunch break of the cricket test match. These improvements dramatically improve the viewing experience of the new grandstand which is the primary driver for patron attendances.

Concurrent with the design process the team also worked on the procurement strategy for the roof contract which represented the most challenging aspect of the construction and as such a significant risk to the project cost, programme and brief. With these factors in mind the Client and Design Team approved an early subcontractor involvement approach based on the 50% schematic documents whereby the specialist steelwork subcontractor would be invited into the design team and work with the consultants and client to optimise the design, minimise the construction risks of the solution and accelerate the programme with the shop detailing and construction planning undertaken concurrent with the completion of the design.

The process for the early steelwork subcontractor involvement was:

- The Managing Contractor working with the design team established a list of suitable steelwork subcontractors capable of undertaking the diagrid scope of work
- Expressions of interest sought from this shortlist outlining the collaborative process and design solutions envisaged
- Steel subcontractors submitted their expressions of interest and presented to the project team and how they could embrace the collaboration proposed
- Subcontractors shortlisted for tender submission based on the 50% design documents
- Samaras selected as preferred subcontractor and appointed on the basis of the 50% schematic drawings and contracted with a bill of schedules allowing for fair and equitable adjustment in the contract price as the design is completed

<u>Design Development</u>

Following the appointment of the steelwork subcontractor a series of design workshops were held where the preferred design was interrogated. At these sessions the issues of erection, transportation, fabrication, tolerance, temporary staging were entwined with the design aesthetics, structural performance, wind load resistance, servicing, etc to create a coordinated design solution. In order to fast track the roof design and construction process and to guarantee the high degree of accuracy and quality required, the 3D modelling by the steel contractor occurred concurrent with the completion of the architectural and structural designs. This initiative allowed the complexities of the 3D design to be worked through in an expedient manner, satisfying the design, fabrication, transportation and erection requirements. It also facilitated the integration of the service provisions for the lighting cabling and guttering amongst the structure.

5. Project Fabrication

Fabrication, Erection and Transportation

Connections in the diagrid were developed in careful consultation between Aurecon and the Architects and Steel Subcontractor. The connections were developed to achieve the required load transfer necessitated by the structural design for both the permanent and various temporary conditions requiring close liaison with the Managing Contractor and Steel Subcontractor to optimize the connections for position, tolerance and fabrication aims while ultimately creating a connection of high visual appeal given the exposed nature of the feature roof.

To ensure the appropriate fit on site trial assembly was undertaken on each area of the roof in the Steel Contractors yard where matching of connections was undertaken in a controlled environment facilitating subtle adjustments before completion of the fabrication and shop painting. This enabled the design solutions to cater for various load scenarios from the permanent condition with ultimate wind loads to the various temporary conditions as the 100 pieces of the roof were delivered, erected and clad insitu sequentially from south to north.

6. Project Construction

Construction

The project construction period was a very tight 18 months coupled with a requirement for Adelaide Oval to remain operational for events. This necessitated Aurecon working with Built Environs and the design team to determine design solutions that allowed for rapid construction and for erection primarily from the western side with the Oval to the east causing a natural boundary. Around 1,450 t of steel was used in the main frame, with around 480 t used in the diagrid roof.

As the steelwork was delivered to site Aurecon and the design team were on hand to witness primary lifts and assist with the erection engineering as the roof was sequentially surveyed and checked against the anticipated behaviour. This iterative process was required to be worked closely with the Built Environs process to incorporate the roof construction

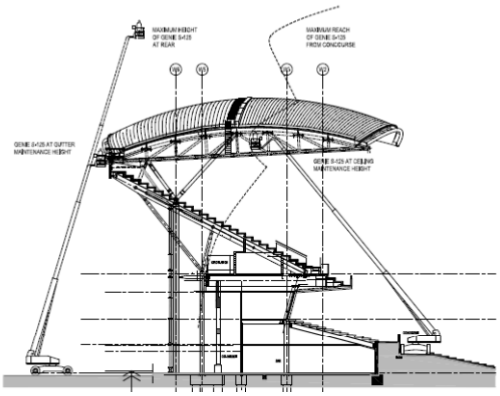
into the overall project works which were hectic and the Ashes deadline approached.

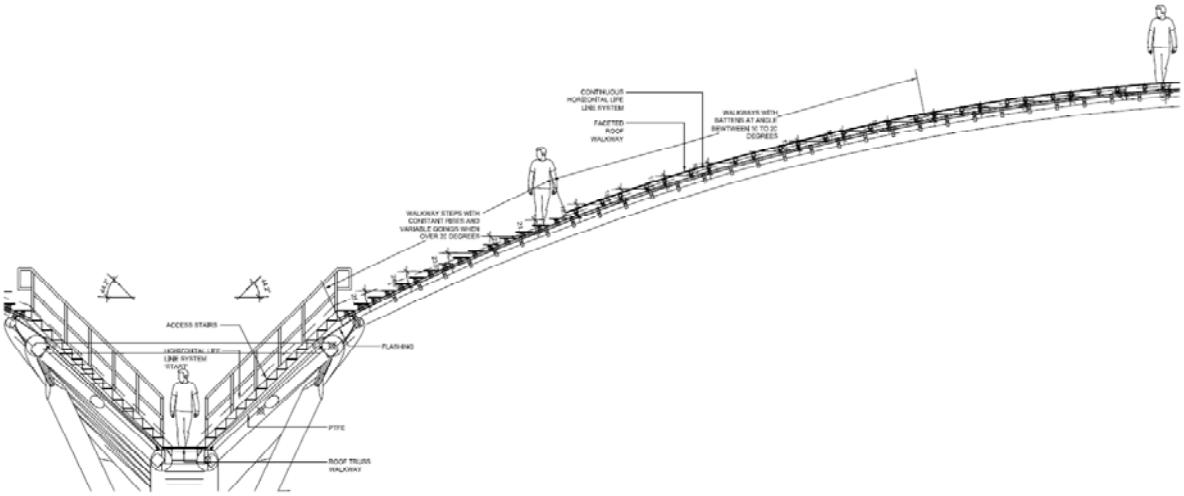
Ultimately the roof erection was highly successful with the construction exceeding the programmed timelines proving instrumental in the delivery of the project on time. The collaborative process undertaken through all stages of the design and construction was pivotal in achieving this goal.

Therefore despite the challenging 18 month construction program coincident with one summer of international cricket plus major concerts for AC/DC and Pearl Jam amongst other events, the grandstand was opened on time for the Ashes test between Australia and England with the highest single day test crowd for over 50 years.

7. Project Operations and Maintenance

Safety in Design (SID) for a grandstand structure is paramount and Aurecon championed and led the Client and Project Team through this process. The SID process incorporated a series of half day workshops where safety risks were identified for all stages of the project – construction, maintenance, operation and even demolition. Through this early assessment proactive design solutions were incorporated to the roof including the strategic locating of servicing to the roof to only areas easily accessible via boom access off the concourse below and the provision of walk boards and ladder access to the roof and material selections to reduce maintenance demands.





8. Summary

Aurecon played a crucial part in the delivery of what is truly a world class grandstand. Through our innovative, cutting edge design solutions and methods and our proactive role with the Design and Construction teams, the Western Grandstand Redevelopment establishes Adelaide Oval as South Australia's premier sports venue. The new grandstand provides unrivalled amenity, roof coverage, sight lines and appeal for sports fans and has brought the heritage grandstand fabric along by creatively incorporating the existing into the new facility. The Western Grandstand therefore looks to the future while acknowledging the past and has been very well received by the South Australian public, national and international fans, members and media alike.

Aurecon provided a coordinated broad range of engineering services including structural, civil, electrical, mechanical, hydraulics, fire protection services, egress, wind, sports lighting, security, acoustics and audiovisual to produce an excellent result.

The positive and proactive collaboration between Aurecon, the client, the architects and the managing contractor, coupled with the advanced use of technology was the secret to the outstanding success of the project.

Adelaide Oval has been enhanced as a safe, accessible, vibrant destination that will attract the best national and international sporting events, international concerts and other events to Adelaide to the benefit of all South Australians.

9. Credits

Project Name	**Adelaide Oval Western Grandstand Redevelopment**
Address	Adelaide Oval,North Adelaide, South Australia, 5000
Completion Date	December 2010
Paper Title	**The Collaborative Design of the Adelaide Oval Diagrid Roof**
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Project Client	South Australian Cricket Association (SACA)
Project Manager	Mortimer Project Management (now Mott MacDonald MPM)
Project Architect	HASSELL + Cox
Structural Engineer	Aurecon
Other Consultants	Aurecon (Structural, Civil, Electrical, Mechanical, Hydraulics, Fire Protection, Egress, Wind, Sports Lighting, Security, Acoustics and Audiovisual) -
Building Contractor	Built Environs
Fabricator(s)	Samaras