THE SHOWRING ROOF FOR THE NEW SYDNEY SHOWGROUND AT HOMEBUSH

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ABSTRACT

This paper describes the design of the roof for the Showring grandstand for the New Sydney Showground at Homebush Bay. This lightweight cable truss structure features the use of high strength strand cables and structural steel sections.
The new Showring is a key component of the New Sydney Showground and will also be Sydney's main Baseball Stadium and be used for Baseball during the 2000 Olympics.
The Showring roof covers a 10,000 seat grandstand. The grandstand is a horseshoe shape typical of baseball venues. The roof is divided into 5 bays and is supported by six main lighting masts. The structure consists of cable trusses spanning in two directions. The main trusses span approximately 60 metres between the lighting masts. The secondary trusses cantilever 26 metres and are supported by the primary trusses and by triangulated tubular steel frames at the rear of the grandstand.
The light masts are 50 metres high triangular in shape and taper from 486mm width at the base to 8.5 metres at the top. The lateral stability of the masts is provided by tie down cables at both ends of the roof and by cables attached to the rear of the grandstand.

INTRODUCTION

In March 1996 architects Cox Richardson, Peddle Thorp and Conybeare Morrison with Hyder Consulting, then known as Acer Wargon Chapman as structural engineers were awarded the contract for the design of Zone 1 at the New Sydney Showground. Zone 1 included the main Showring as well as an outdoor theatre, horse arena, woodchop arena and cat, dog and horticulture pavilions.

The Client was the Olympic Co-ordination Authority and the stakeholders were the Royal Agricultural Society of New South Wales and the Sydney Organising Committee of the Olympic Games.

The project was required to be completed in time to be used for the 1998 Easter Show.

The Showring brief called for a 10,000 seat grandstand with 5,000 seats under cover and an additional 10,000 seats on grassed embankments. There was a requirement for corporate boxes for both R.A.S. and baseball patrons. Vehicle access was required into the arena at two locations.

The criterion for the covered seating was that they be protected from rain driving at an angle of 35^0. The roof was therefore required to cantilever 26 metres to protect the upper tier of seating.

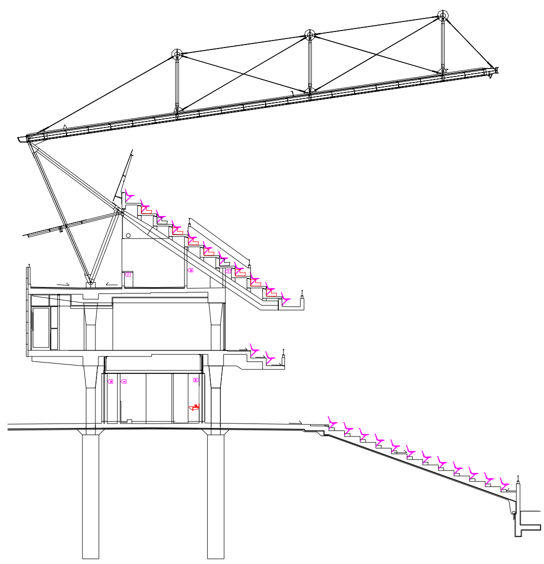
The brief required that the Showring design took account of environmentally sustainable development considerations. It became apparent that minimising the use of materials and optimising the design would have considerable ESD benefits.

The Showring was required to be lit to a standard suitable for colour television broadcasts. Baseball playing required the lights to be high such as not to distract players. The lighting masts therefore were required to be significant structures and the design team was keen for them to be used to support the roof.

The design developed as an elegant lightweight structure comprising of radial cable trusses connected to the back of the grandstand by triangular shaped tubular steel frames. These secondary trusses were supported by three main cable trusses spanning approximately 60 metres between the lighting masts.

DESCRIPTION

Figure 1 shows a cross section through the Showring. The concourse level, upper concourse level and corporate level consist of conventional in-situ reinforced concrete beam and slab construction. The columns are circular with tapering heads that are used both for aesthetics and to increase punching shear capacity.

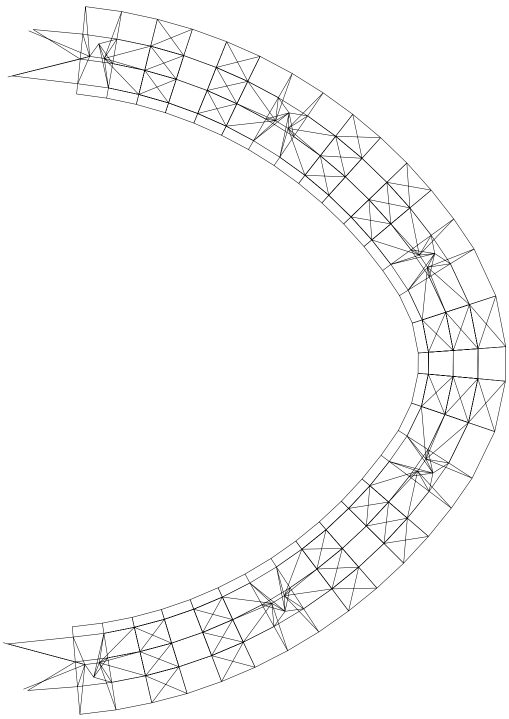


TYPICAL SECTION
FIGURE 1

The seating is made up of pre-cast pre-stressed concrete units supported on box section raking beams in grade 400 steel. The front support of the raking beams is to the concrete superstructure and the rear support is to a triangular tubular steel frame. As is normal with grandstands the length of seating units sets the structural grid.

The average span of the seating units is approximately 10 metres resulting in an economical structure. The tighter radius of the grandstand around home base resulted in a larger number of pre-cast variants. The seating units are designed without a downturn at the rear of the seat in order to give a clean appearance to the underside of the seating.

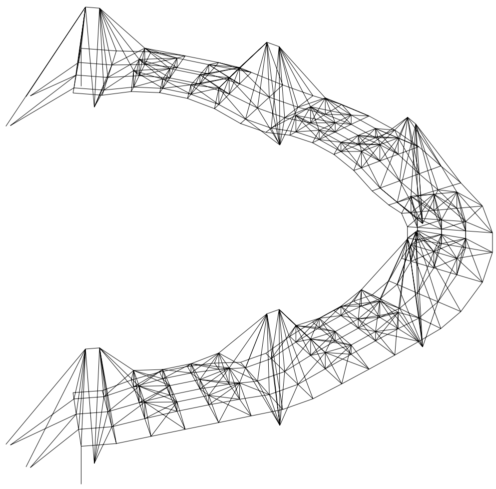
The Showring roof structure consists of cable trusses spanning in two directions (figures 2 & 3). It is unusual in that the main trusses are curved on plan to follow the line of the grandstand. The trusses span approximately 60 metres between the lighting masts.



PLAN
FIGURE 2

The secondary trusses coincide with the seating bays and are supported by the primary trusses and by triangulated tubular steel frames at the rear of the grandstand.

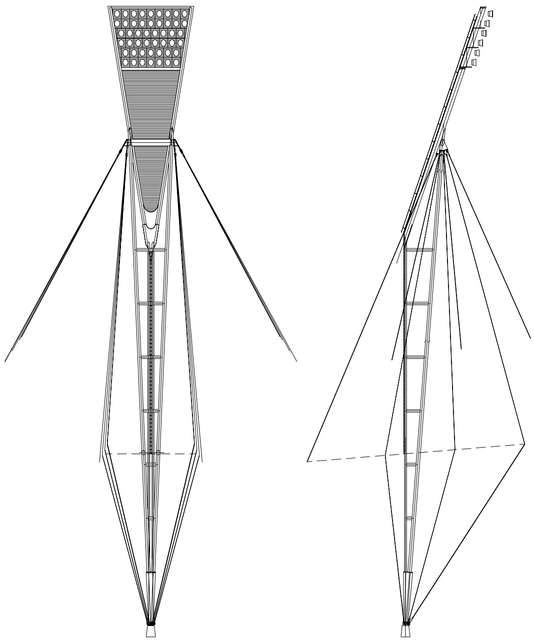
The top chords of the trusses are generally cables except in the secondary trusses adjacent to the masts where the 'hammock' like geometry of the catenary cables introduces compressive forces. In these locations the top chord is a 219mm diameter circular hollow section. The top and bottom chords of the trusses are separated by vertical steel circular hollow section struts and cross bracing where required is provided by cables.



ISOMETRIC VIEW
FIGURE 3

The light masts provide the main support for the roof structure (figure 4). They are 50 metres high triangular in shape and taper from 486mm width at the base to 8.5 metres at the top.

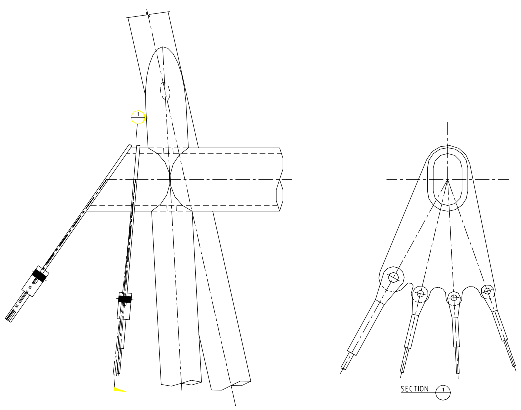
The masts are a fully welded frame of 356mm & 219mm diameter circular hollow sections. They are trapezoidal on plan and taper from a fabricated inverted cone at the base up to the lighting frame and cable support.



MAST
FIGURE 4

The lighting frames are clad in expanded metal mesh

The cable connection point (figure 5) is at 40 metres height and the lighting frame cantilevers from this point. The perimeter of the lighting frame consists of a fabricated rectangular hollow section 530mm deep by 380mm wide.



MAST - CABLE CONNECTION
FIGURE 5

The tie down and roof support cables are connected to foot shaped plates welded to the end of a fabricated oval shaped cross member. The shear forces are very high and therefore the member has a 50 mm wall thickness.

The cables are Grade 1570 strand to AS2841. Sizes vary from 54mm diameter for the main end tie down cables with a minimum breaking force of 2610kN down to 14mm diameter for secondary bracing. The strands are heavy galvanised with a minimum coating thickness of 400g/m^2. The galvanising is more than twice the thickness used for the cables on Centrepoint Tower that are still in good condition after over 20 years.

For durability and to reduce maintenance heavy galvanising was used on concealed steelwork and the exposed steelwork was coated with a high performance protection system.

To minimise any elongation all cables have been pre-stretched. The maximum cable loads have been limited to 40% of the minimum breaking force. Permanent elongation of the cables takes place at approximately 70% of the minimum breaking force.

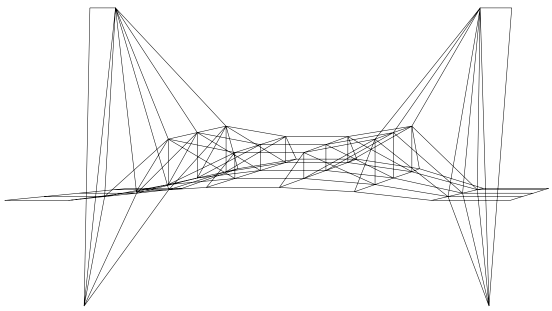
The typical roof panel tapers from 8.5 metres width at the front to 10.5 metres at the rear. It is clad in metal decking with a perforated sheet to the soffit. The purlins are Z300 and span between 380mm deep channels at the edge of the panel. The roof panel in the mast location is clad in polycarbonate. There is a slot at the leading edge of the roof that assists the roof's performance under wind load and is also used for the mounting of lights and speakers.

ANALYSIS & DESIGN

The design team considered various options for the roof including tensioned fabric and simple structural steel cantilever options. Three preliminary schemes were costed and presented to the design review panel.

In June 1996 the review panel selected the cable truss option clad in profiled steel sheeting. As the programme was extremely tight the design was required to be developed very quickly in order to have tender documents ready in less than 9 weeks. At this stage construction work on the substructure was well under way and support reactions had to be estimated.

The cable roof structure has two distinct load paths (figure 6). For uplift the loads are primarily resisted by an inverted catenary. Cables are connected from the mast base to the underside of the roof frame. For gravity loads the load path is provided by a catenary suspended from the lighting mast and connected to the top of the roof.



TYPICAL ROOF BAY
FIGURE 6

The lateral stability of the masts is provided by tie down cables at both ends of the roof and by cables attached to the rear of the grandstand.
Initially the roof was analysed using a 2-dimensional frame analysis. When the geometry was resolved a 3 dimensional frame analysis was carried out. The roof was modelled non-linearly to check the effects of deformation under load. A design check was carried out with one of the major tie down cables removed. In this condition the roof would undergo large displacements but remain stable.

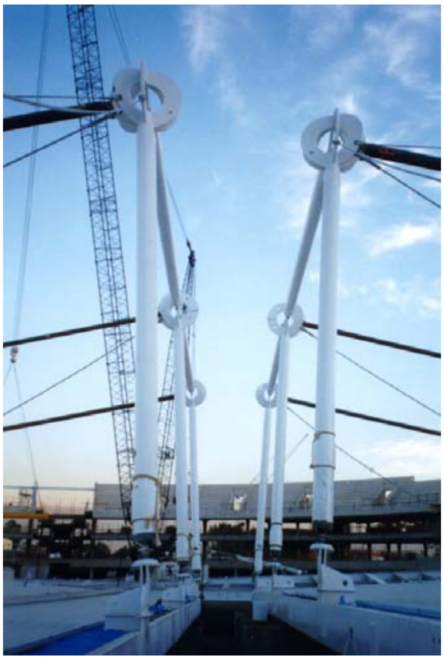
For the design that went out to tender the level of pre-stress in all cables was set such that no cable would go slack under service loading. This level of pre-stress was required to control deflections particularly under out of balance loading.

Wind loads were estimated using Australian Standard 1170.2 wind loading code. When the design was developed wind tunnel testing of the Showring and and the adjacent Outdoor Theatre was carried out by Professor Bill Melbourne of Monash University. The highest peak pressures were found to be similar but not greater than those determined using the AS1170.2. Many areas have design pressures significantly lower than those determined by the code.

CONSTRUCTION

The short construction programme meant that constructability was a major consideration in the design. Hyder worked closely with the design team and with the Managing Contractor John Holland Construction and Engineering and Project Manager Australia Pacific Projects to ensure the structure could be built on time. The use of structural steel for the raking beams (seating supports) and for the roof and pre-cast concrete for the seating allowed off-site fabrication whilst the in-situ reinforced concrete superstructure was being constructed.

To facilitate fast erection the roof steelwork was panellised. Back to back channels were substituted for the bottom chords of the radial trusses allowing individual panels to be assembled on the ground and be sheeted prior to lifting into place. The top node connectors of the trusses allowed temporary struts to be installed making the roof panels stable for lifting.



Roof panels being assembled on the ground.

Each panel was fixed to the triangular support frames at the rear of the roof and temporarily supported on props.

Erection of first roof panel

The props were to remain in place until all the panels of a bay were erected. The masts were then to be installed and temporarily braced before the props were removed.

Mast Erection

The contract for fabrication and erection of the roof steelwork and erection of the pre-cast concrete seating was awarded to Transfield Constructions. They proposed a design modification which added additional cable cross bracing to control deflections and allowed the level of pre-stress to be reduced. The reduction in pre-stress simplified construction but required additional turnbuckles to be introduced to ensure cables were not slack after erection.
The erection sequence introduced pre-stress by two methods.
(i) After erection of the roof onto temporary props pre-stress is introduced to the 'suspension' cables by de-propping and taking up the self weight of the structure.
(ii) The main 54mm diameter end tie down cables are tensioned to a load of 517 kN providing additional lateral stability to the masts.
During these two procedures the cables under zero load, particularly the tie down cables are progressively tightened using turnbuckles to take out any slackness.

Tensioning Tie Down Cable

The facility brief called for design excellence, in keeping with the development plans and profile of Homebush Bay. It also called for the design to present a distinctive image in keeping with its status as the primary venue for the Royal Agricultural Society in Sydney, as an Olympic venue and as a major sporting venue.
These requirements proved very challenging and the architectural and structural engineering team have co-operated to integrate aesthetics and structural efficiency to provide an elegant innovative lightweight structure that complements the other structures at Homebush Bay.

CONCLUSION

Although at times it appeared to be an almost impossible task the Showring was completed on time and on budget. All involved should take credit.