Mildura Performance Venue – Concept to Grand Opening

J.R. Marr
Tensys

This article tracks the design and construction of the riverside Mildura Performance Venue (MPV) from concept to grand opening. The focus is the 650m^2 PVC coated polyester fabric tensile membrane free from conical canopy with a central high translucency (polyester/PVC) fabric skylight. The skylight caps the central steel tree column with the perimeter being supported by efficient mast and cable tieback arrangements. The tensile fabric structure forms the canopy to a 12 x 10m stage which has 3 separate grassed audience areas with audience capacity up to 15,000. Back of house facilities are provided in converted shipping containers concealed by a feature "corten" steel clad wall.

Image 1 – View from front of stage right

Items to be discussed include, conceptual form finding, designing on a floodplain, cost plan budgeting, fabric selection, cable and fitting specification, erection methodology/steelwork detailing, tender/construction.

Conceptual form finding

As with most designs involving free form tension structures, the starting point is literally a blank canvas or sheet of paper. The general plan layout was determined quite early and essentially remained consistent throughout the design development however there were a number of iterations to achieve a functional and aesthetic form involving both the architect and engineer. Sketches and 3D cad forms where used to develop the desired shape.

The initial concept was a free form 'hypar' shape achieved with varying height perimeter supports (Image 2). These hand sketches were form found using Tensys' INTENS software (which uses dynamic relaxation for analysis of large displacement structures) Image 3 shows the side elevation of an early model. The review of these computer generated 3D forms resulted in a number of iterations and parametric studies to try and achieve the required aesthetic and maintain an efficient structural form. Items investigated involved changing the heights of the perimeter support points and the introduction of a varying number of central columns. Image 4 provides an elevation sketch including central mast.

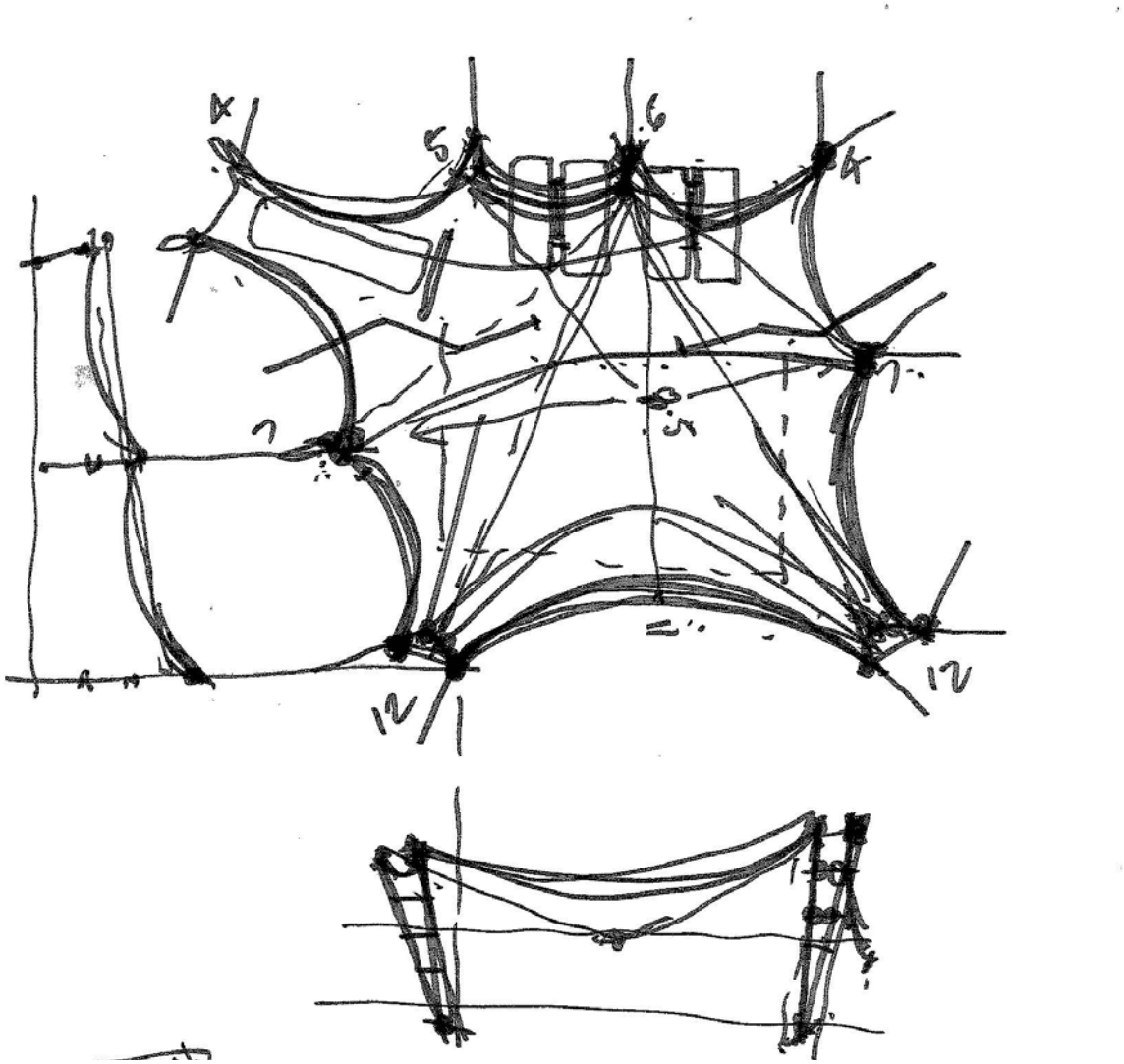

Image 2 - Daryl Jackson Plan and Elevation Sketch 04/12/07

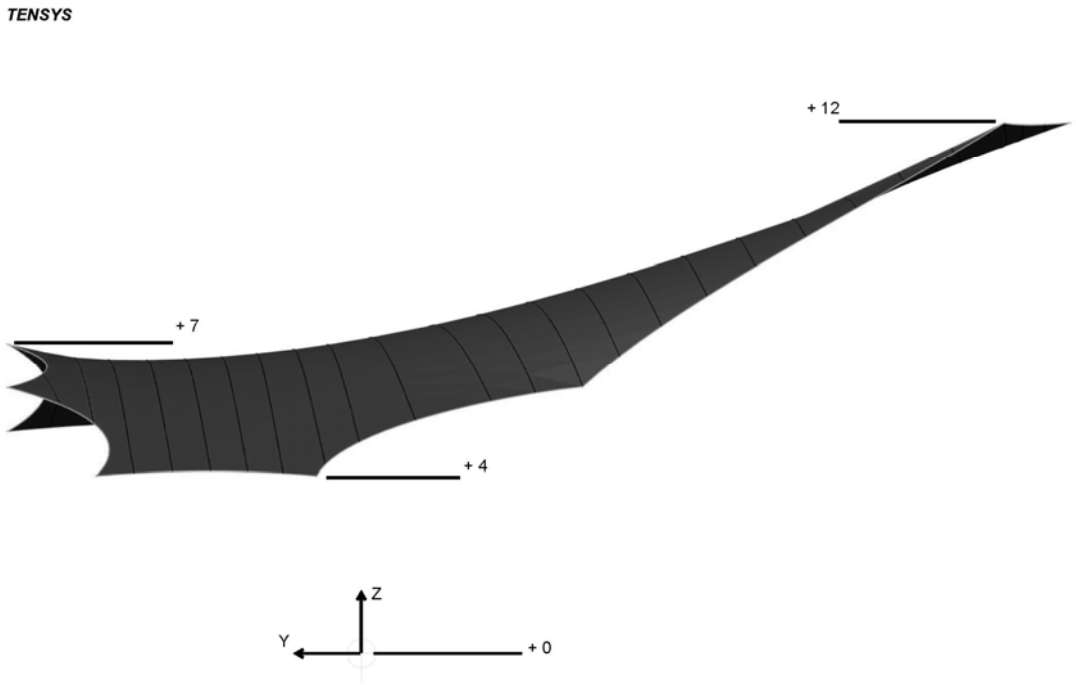

Image 3 - Tensys Preliminary form Side Elevation 5/12/07

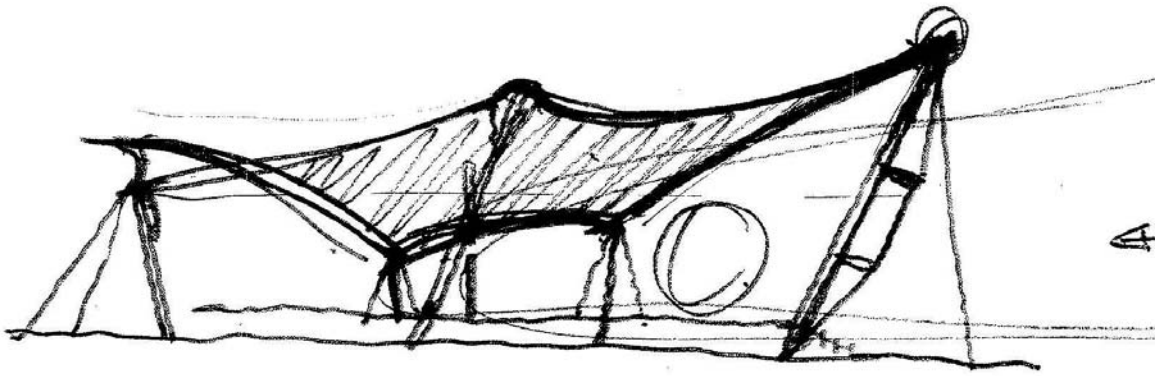

Image 4 – Architectural elevational investigation of additional central mast

The introduction of the central column support changes the overall shape to a more conic form however by utilizing a relative large elliptical head ring, the overall height of the form could be kept rather streamlined while retaining a suitable amount of curvature for fabric spanning efficiency. By varying the radial warp prestress (refer to image 5), the fabric form was refined to give a smooth flowing shape to the ring and balance the net force with the orientation of the supporting mast. Biaxial testing of the fabric stretch characteristics considered this varying prestress along with the expected stresses under load. This allowed the fabric patterns to be compensated (shrunk) appropriately to simulate this theoretical shape quite closely as images 5 and 6 illustrate. The central mast also provided opportunity to natural vent rising hot air from beneath

the structure by raising the crossed arch fabric cap approximately one metre above the main head ring.

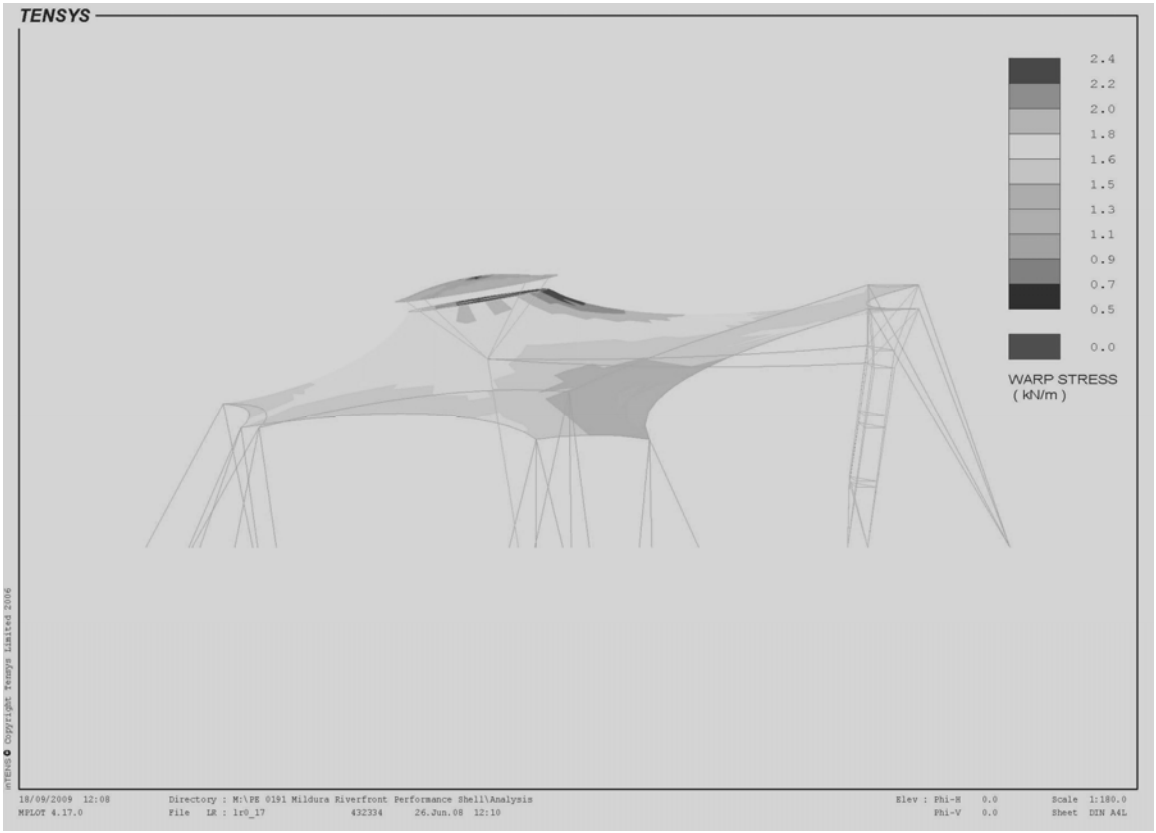

Image 5 - Varying radial warp prestress to smooth form at central mast head ring and align resultant force with column

Image 6 – MPV Side elevation

Designing on a floodplain

This structure is located within one hundred metres of the Murray River. Under the one in hundred year flood the water level would be around that of the lower edge catenaries. A number of options were considered for allowing for this design constraint. One would normally consider designing the structure to withstand the flood. In this instance, there is reasonable advanced warnings available (for floods in this area), this structure has be detailed to allow it to be removed and then re-erected. The canopy part of this structure can be dismantled within a few days. Given the canopy's semi secluded location, vandalism was a consideration the design process. The main truss columns have minimal horizontal members and the single masts with tiebacks poses difficulty to any potential climbers. Image 6 highlights the cutouts in the feature wall which also helps to reduce the likelihood of access to the canopy from the wall.

Cost plan budgeting

Historical data on similar sized project costs where used to establish a preliminary budget. As the design developed these were replaced by construction estimates by the designer.

As part of the iterative process, material selection (galvanized cables were specified rather than stainless) along with the structural form as the fabric efficiency is proportionally to the support steelwork which would be required were put back into the budget calculations. Maximising fabric curvature helped reduce steelwork design loads while using cable tiebacks around the perimeter is a very effective method to transfer the horizontal design loads to ground. A pinned based central column aligned with the resultant force from the roof results in minimal bending and so a slender column.

With design reasonably well defined (preliminary sizes and specification for all components) a specialist tensile membrane contractor was approached to give feedback on the constructability as well as budgeting and programming for the canopy.

Fabric selection

Budget and removability both pointed to selecting a PVC/polyester fabric for the tension membrane due to its cost and reduced likelihood of damage during handling compared PTFE/glass fabric.

It was a conscience decision to highlight and contrast the cover central column cap from the rest of the tensile form. Given the smaller spans of the central column cap a lower structural capacity fabric could be utilized in this area.

This presented the opportunity to use a high translucency fabric to achieve the contrast. Sundream Cool (by Hiraoka) was selected with its translucency around 54% providing a significant contrast to the main fabric body of 212T with around 12% light transmission as shown in image 7.

Image 7 – Contrast of High Translucency Cap Fabric with Main Fabric body

Cable and fitting specification

Use of galvanized cables and fittings provide a cost effective solution for non severe corrosion environments. The fittings have a more industrial look stemming from their predominate use in the lifting applications. Turnbuckles are utilized to allow for adjustability in cable lengths and are utilized during demounting and reinstallation. Refer to image 8 for typical top of perimeter column detail and fabric termination membrane plate.

The geometry of the membrane plates were studied in great detail. Due to the geometrical shape of the structure, there were some very large membrane plates and a decision was taken to try and minimise the overall form of these plates. These plates are subjected mainly the tension forces and it was possible to create the openings and reduce overall mass of the membrane plates (as shown on Image 8)

Image 8 – Typical Membrane Plate detail with galvanized fittings

Erection methodology/Steelwork Detailing

During discussions with potential contractor with regards to cost budget, the erection methodology was reviewed and developed in great detail. This development work enabled the steelwork to be detailed to suit.

Perimeter masts with double tiebacks can be erected in a forward sloping position ready for connection of the fabric.

Detailing a bolted splice at the where the central column braches out (refer to image 7) the main body of fabric could be clamped to the ring at ground level. Positioning the lower part of the column below the ring and using two hooks on the crane the fabric clad head ring and the lower column could be lifted in one operation. The splice bolted the fabric enabled it to be easily connected to the perimeter support points. The central mast was detailed with a jack-able base. After tensioning of the main fabric the cap to the central mast was clamped on at ground level and then lifted into position as shown in image 9. In addition to detailing the steelwork for the structural adequacy and erection ease, architectural considerations were also incorporated. The trussed front masts went through a number of iterations to achieve the balance between structural efficiency, appearance and vandal proof (climbing deterrent). Access points were provided so that wiring could be concealed. The steelwork is painted a dark grey/blue colour. This colour scheme helps draw the audiences attention to the performers rather than the steelwork.

Image 9 – Cap installation

Tender/Construction

The conclusion of the design work outlined above culminated in a fully designed set of documents suitable for tender by specialist fabric contractors. With Oasis' involvement during the design development period, they had a very good understanding of the structure and ended up negotiating their contract to complete the construction for a fixed price. The fully design and detailed tender drawings ensured that this elegant design was reflected in the constructed canopy very well.

The official grand opening is planned for 14th November 2009.

Client: Mildura Rural City Council
Architect: Jackson Architecture
Canopy Design: Tensys
Canopy Sub-Contractor: Oasis Tension Structures