AURORA PLACE, SYDNEY. DESIGN AND CONTRUCTION OF THE GLAZED CANOPY
Stephen Wrightson
Engineering Manager, Austress Freyssinet

Abstract
In September 1999 Austress Freyssinet were awarded a contract for the design, fabrication and installation of the glazed canopy for the Aurora Place development based upon an alternative design which utilised stainless steel rods in lieu of the stainless cable.

This paper discusses the design, fabrication and installation aspects of this project focusing on the design development of the structural components for the cable net and the proposed method of erection for the cable net and the suspended glazing.

Introduction
The concept for the glazed canopy as envisaged by Renzo Piano, one of the worlds leading architects, was for a canopy of glass supported by a "spiders web". The canopy would provide protection from the elements in the Piazza area whilst allowing maximum transparency through the glass and its structural elements.

The canopy has a plan area of approximately 650m^2 and is suspended between a 20 storey residential tower and a 45 storey office tower in Macquarie Street, Sydney giving a maximum span of about 30 metres. Support for the frameless glass is provided by a cable net, formed into an anticlastic surface to ensure structural resistance to both downwards and upwards loading.

The glass surface is suspended from the cable net via droppers located at each of the approximately 300 intersection points of the cable net. Another unique feature is that the glass is also warped into a shape that will provide positive falls to a single drainage point at the northern edge of the canopy.

The concept of the typical cable net, as proposed and developed by Austress Freyssinet is 18mm diameter, high tensile, stainless steel rods connected at each intersection via stainless steel cast nodes. The glass is typically 16mm thick heat strengthened laminated and patch supported at each corner via stainless steel cast spiders. The glass around the edges of the canopy is 20mm thick due to the requirement for a 500mm cantilever. The link between the glass plane and the cable net is via droppers of varying diameter and length and made from stainless steel circular hollow sections.

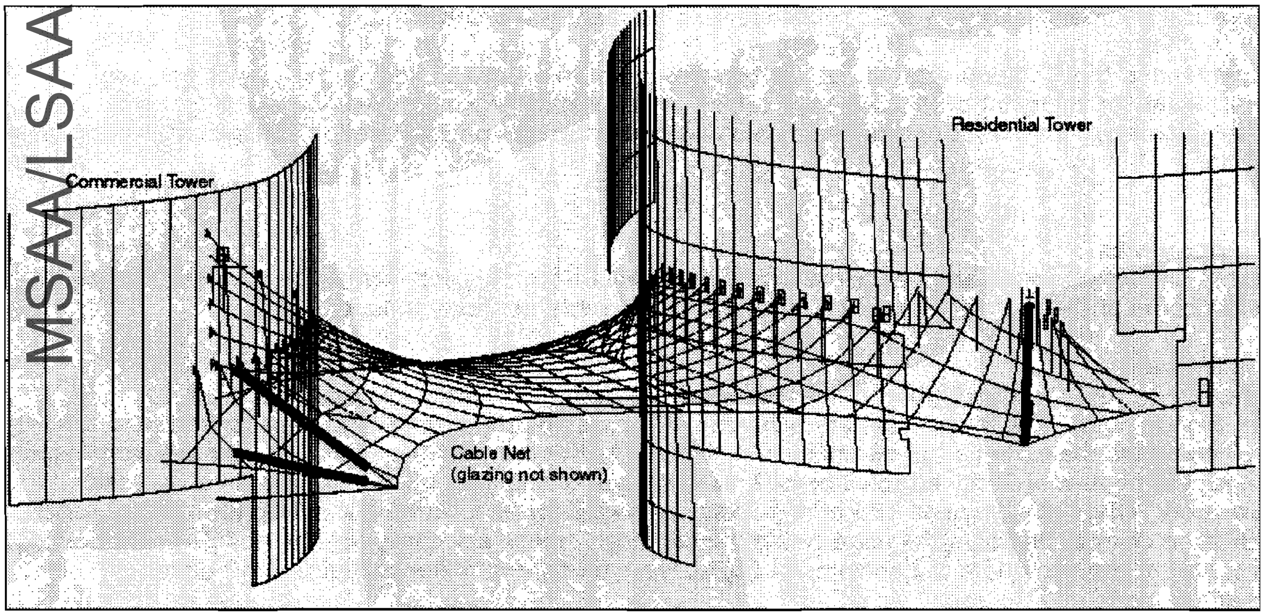

Figure 1 Glazed Canopy General Arrangement

In early 1999 Austress Freyssinet were one of five companies selected to tender for this prestigious and technically complex project. During the tender stage the conforming design was closely studied and although feasible it presented many potential problems mainly relating to the fabrication and erection of the cable net.

The Cable Net
One of the main problems was the limited number of local suppliers (in fact only one) of the stainless wire cable who could also carry out the difficult swaging operations. Overseas suppliers would not quote, as the quantity of cable was not sufficiently large enough.

Other perceived potential problems were the risk in the accuracy of the internal swages, which fixed the location of the nodes. Also the flexibility of the wire based cable net during glazing erection which might result in high deflections when only one section of glass was erected.

To reduce both cost and to make the cable net a more rigid structure during erection an alternative was developed by Austress Freyssinet. The most notable feature of this was the substitution of the stainless wire rope with Grade 316 Cold Drawn stainless rod. Other features of this alternative was that many of the components such as special investment castings, machined items, screws etc. required for the wire rope solution were either eliminated completely or greatly simplified. Another advantage of the rod solution was that it was a readily available item and could be cut and threaded by virtually any machining shop. Both lead-time and cost were hence substantially reduced as a result.

As all tender prices were initially substantially over the client's budget further work was done during the post-tender discussions in order to find further savings. This was achieved by modifications to the droppers, spiders, patch fittings and the steel brackets known as the 'puntones'. Austress Freyssinet was also able to utilise on the rods its standard range of Macalloy 460 fittings further reducing the requirement for specially made fittings.

The Glass
The conforming design called for a fully toughened and heat soaked, low iron glass of either 16mm or 20mm nominal thickness. The low iron type glass is probably one of the more expensive types of glasses and was already in use on the facades for the two towers.

In order to further reduce cost an alternative proposed at tender time was for one layer of heat strengthened glass and one layer of toughened glass and this has been accepted subject to satisfactory testing.

Proposed Construction Sequence
The change to a rod-based cable net meant a totally different approach to the erection of the cable net. As the edge cables were both of large diameter (44mm) and considerably curved in plan it was necessary to erect these first on falsework. The east-west cables would then be erected as a single unit on the ground and then lifted into place. The north-south cables would then be erected one panel at a time by inserting them between two east-west cables. These cables will be placed by the use of mobile scissor lifts.

As the rods are relatively stiff there will be only minimal extension during the stressing process. Therefore all the rods will be screwed in to a predetermined length ensuring the geometry of the cable net is very close to the required theoretical geometry and very little subsequent adjustment will be required.

It is currently intended that the entire cable net will be stressed to the required load by jacking at only two locations, typically at the midpoint of the two edge cables. A proprietary jacking device known as a Tecno-tensioner as used by Austress Freyssinet for the tensioning of turnbuckles on its Macalloy 460 system will be used for this operation.

The Main Components
As the canopy is not yet complete and hence the actual final construction aspects cannot be discussed I have described below some of the main components, which make the cable net fairly unique.

The Internal Nodes
To achieve the same profile with straight rods as that which was achieved with cable each rod must be terminated at a node point. This means that at each node four rods and the dropper intersect. In order to ensure the loads are concentric the node had to be uniquely designed. As the drape of the cable net changes significantly across its length the node was designed to cater for large changes of angle for each rod in both vertical and horizontal directions. Originally only one size of node was envisaged for all location but due to the requirement to cater for such large changes in angle the node became quite large. Hence a second, smaller node was introduced for the central part of the net where the changes in angles were much less. Refer to Figure 2 for general arrangement of the node and the rods.

The Edge Nodes

The edge nodes work in a similar manner to the internal nodes but with two main differences. The edge cables are 44 diam. instead of 18mm resulting in a much larger node and because some of the internal cables intersect the node at extremely acute angles a cleat plate and clevis must be used. This also means that the loads are not all concentric. However, this was not necessarily a problem as the loads for the internal cables are much less than the edge nodes. The general arrangement of the node and the rods is given in Figure 3.

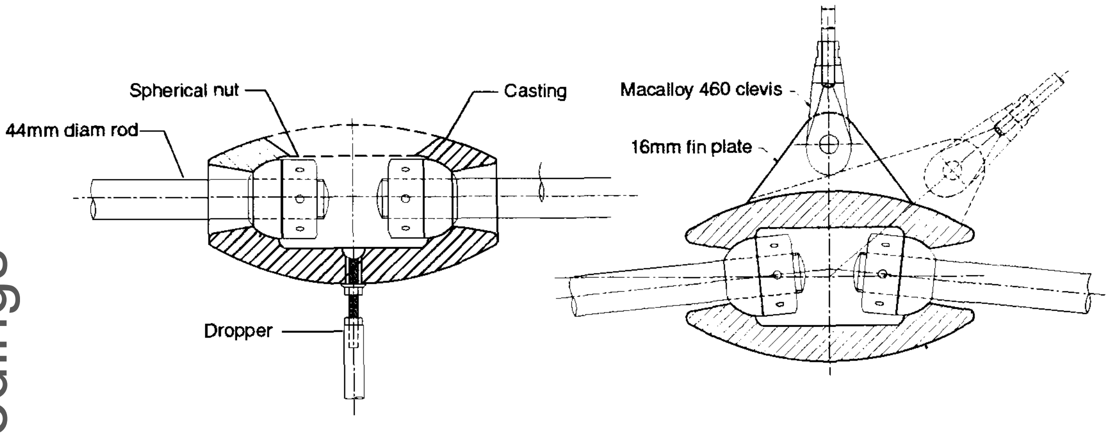

Figure 3. Typical Edge Node ELEVATION PLAN VIEW

The Spiders

The spiders are essentially standard but have a spherical seating and lock nut to allow the spider to rotate on the dropper to follow the angle of the glass and then be locked into position to transfer any live or wind load bending moments.

The majority of spiders are four leg spiders but three, two and even one leg spiders have now been introduced. The general arrangement of the node and the rods is given in Figure 4.

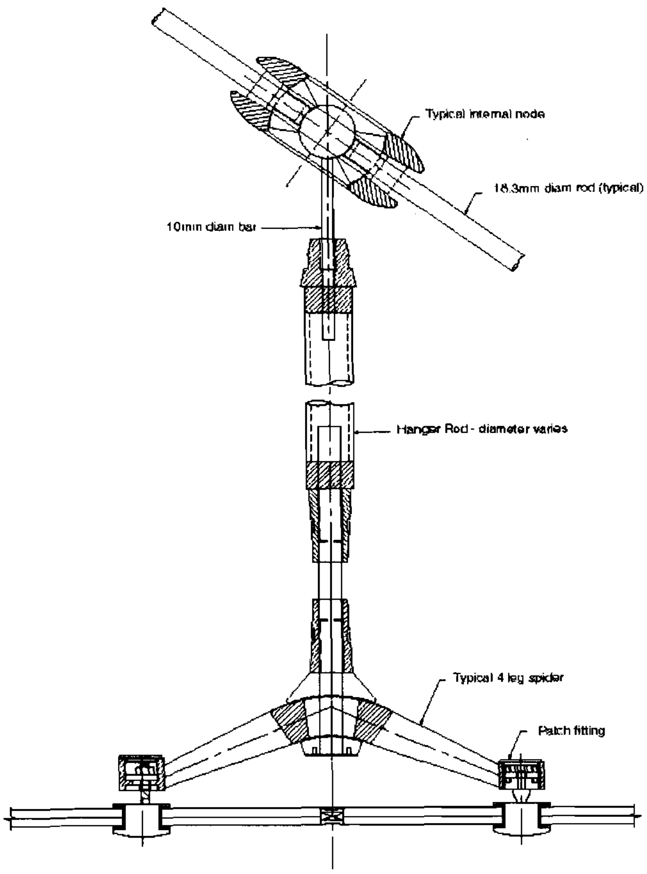

Figure 4 Node / Hanger / Spider Assembly

Work to Date
As the cable net is to be connected to the two towers, plates were cast into the edge beams during construction of the concrete frames. The as built position of these plates has been surveyed and plotted on a 3D drawing so that the final geometry of the cable net can be determined prior to final analysis.

At the time of writing, most of the detailed analysis and design work for the structure, including the glass, has been completed and work on the construction sequence, including the stressing procedure, is underway.

After considerable development of the basic idea presented at tender time the final details for all the major components are complete and approved. The shop drawings are mainly complete and some of the prototype castings for the nodes and spiders are underway.

The special low iron glass has been ordered with the samples for testing due to arrive in March 2000. The site work for the erection of the cable net is programmed for around May 2000.