SYDNEY SUPERDOME

Cable Supply and Stressing of the Roof Stay Cables

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Introduction

In December 1997 Austress Freyssinet were awarded the contract for the design, supply and stressing of the roof stay cables plus the lowering of the roof off the temporary supports during the cable stressing operation. These components of the project were completed in May 1999.

The stay cables used were developed from Freyssinet's proven bridge stay cable system and utilised the high performance strand used in bridges which provided a level of fatigue resistance and corrosion protection not achieved before in Australia on similar structures.

This paper discusses the design; fabrication, installation and stressing of the strand stay cables and Macalloy bar cables as well as the lowering of the roof off the temporary falsework supports by means of 16 hydraulic jacks.

Description of Roof Structure

The main roof dimensions are 140 metres x 100 metres giving a total area of 12,500m^2. It is principally an arch structure which is assisted by a system of stay cables. There are 18 perimeter columns at typically 20 metre centres but up to 32 metre centres around the corners. The centre of the roof over the event floor covers an area of 40 metres by 70 metres and consists of a trussed space frame 5 metres deep.

Radiating from the centre space frame are 36 trusses at 20 metre centres, which span the 30 metres to the perimeter of the building. Between these trusses is a conventional beam and purlin system. There is a horizontal truss around the perimeter of the roof, which distributes the thrust from the radial trusses and radial into the base of the columns. The thrusts from the dome are resisted by ring action in the plant room slab.

At each of the 18 masts are a total of six strand stay cables (denoted as ca1, ca2, ca3 and ca4) and two Macalloy bar cables (denoted as ca5). This gave a total of 108 no. strand cables and 36 no. bar cables.

The Stay Cables

Over the past decade or so there has been a growing interest in lightweight roof structures for major buildings and structures such as sport stadiums, public buildings and theatres. Until now the primary tension element for such types of roofs has been with locked coil wire ropes or parallel wire rope systems, which require substantial operations for the fixing of end and intermediate connections.

Through intensive testing and site experience, Freyssinet developed a modular stay cable system which satisfied all needs for traditional and "State of the Art" civil engineering structures, cable roof structures, suspension bridge hangers etc. The Freyssinet stay cable system has been developed primarily for bridges and has been used on over 80 bridges worldwide since the early 1970's.

The stay cables for the superdome are made up of a bundle of individually corrosion protected strands the total number of which was determined by the required load in the cable. Each strand is individually anchored in a multistrand anchorage block, in a conical shaped hole, by means of a three-piece jaw, specifically designed for high fatigue and static strength. There is no contact steel to steel, detrimental to fatigue resistance, other than the strand-jaw contact.

End terminations are by means of a combined anchorage and clevis. The fabricated anchorage provides the termination point for the strands and the clevis allows for easy connection to the roof structure. The end clevis connections were provided with suitable corrosion protection.

The combined clevis / anchorage includes several other components described below. A particular Freyssinet feature is the "guide/stuffing box" assembly which acts as a waterproof barrier in the transition zone in which the strands are protected by a flexible compound (wax), and the zone where the Freyssinet strands are protected by the factory-applied permanent protection.

Each strand is individually protected and is encapsulated in an outer HDPE sheathing. This sheath provides an additional layer of corrosion protection and gives the tendon a uniform appearance. It is welded together to form a continuous sheath over the length of the tendon. As a standard and for this project this sheath is black but can be optionally supplied in a range of colours including white, grey, light blue and yellow.

For this project two sizes of cables used, denoted as 5HD15 and 13HD15, using up to 5 and 13 strands respectively.

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Benefits of The System
The main reasons for choosing the Freyssinet stay cable system were as follows:

The combination of the factory corrosion protection of the strands plus the outer sheathing give the Freyssinet cable stay a total of four layers of corrosion protection which far exceeds any other product on the market. This level of protection ensures minimal maintenance over the life of the structure.

The Freyssinet cable stay concept is based on the independence of the strands and allows an almost limitless range of cable sizes ranging from as few as four to over two hundred. This provides a cable with an ultimate capacity ranging from approximately 100 tonnes to over 5300 tonnes.

The cable system has been designed for easy assembly on site without the need for heavy equipment such as swaging machines. The tendons can be made to almost any length and are sufficiently flexible to be lifted by crane without risk of damage provided the correct procedures are followed.

With the main element of the cable being fatigue resistant, seven wire strand there is no prestretching necessary which can be necessary with wire rope systems. This can be an important feature when the stays are required to be tensioned to precise loads and/or lengths as load/elongation relationships are important.

Strand Specification
The resisting element of the Freyssinet stay cables is a bundle of parallel individually protected, 15mm nominal diameter, seven wire, high tensile strands. The strand is hot dipped galvanised before the last drawing operation and then factory sheathed with a tight high density polyethylene coating. A petroleum wax fills all the interwire voids at the strand/sheath interface.

Installation if the Roof and Stays
The roof was constructed in 9 main segments with each segment lifted into place complete with the ca3 and ca4 cables fixed at their lower end and resting on the roof sheeting. The heaviest segment to be lifted was approximately 350 tonnes. The perimeter segments were erected first and supported on temporary towers. The joint between the perimeter segments and the centre segment is one bay into the centre space frame and the roof segments had all cladding in place prior to lifting into position. The infill sections between each perimeter segment were erected insitu.

The centre segments were lifted into place and held by the crane until the connections of the top and bottom chords are made good. The next step in the erection were the masts and cables which were positioned and the drape taken out of the cables. The masts were erected with cables ca1 and ca2 connected to the top and hanging loose until joined with those cables already on the roof.

The Macalloy bar stays (ca5) were erected and stressed independently of the strand stays as they connected the base of the mast to the roof.

Stressing of the Cables
After the award of the steelwork contract Austress Freyssinet were involved to assist the designers in determining the stressing sequence as this had not been specified prior to award of the contract. In fact the stressing sequence was somewhat simplified during detail analysis as the structure was found to be less sensitive to the stressing of one set of cables than had been originally expected. The stressing of a set of two CA1 cables at any mast did not have a significant effect on the forces of the adjoining set of cables. This meant there was no need to restrict the number of sets of cables that need to be stressed together nor the stressing sequence. This allowed the cables to be stressed one mast at a time and then moving to the next adjacent mast.

A two stage stressing sequence was developed. The majority of the load, 75 percent, would be applied during the first stage. When this was complete the roof would be lowered off its temporary supports and become self supporting, The self weight of the roof would then add most of the remaining load to the cables. The second stressing stage would be primarily a load check and final adjustment where required.

The cables were designed to be tensioned using Macalloy prestressing bars located at the lower end of each cable. The bars connect two halves of a fin plate which were preset with a gap of 100mm prior to commencement of any stressing. The 100mm was calculated as the maximum adjustment required on any one cable.

At each of the 18 masts there are a total of six cables, 2 x ca1, 1 x ca2, 1 x ca3 and 2 x ca4. Where cable ca1 connected to the rear column 4 jacks were required per cable and where ca3 and ca4 connect to the roof two jacks were required giving a total of 14 jacks per mast.

It was anticipated prior to stressing that most of the adjustment would come from the ca1 cables and this was verified during stressing. Although jacks were located on the ca3 and ca4 cables they were primarily used for minor adjustment of the loads after ca1 had been stressed.

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After the first round of stressing it was found that some of the masts were not vertical in the transverse so some adjustment was carried out on these locations.

Once the roof was lowered off its temporary support (see next section) the second stage of stressing was completed. It was found that the cable has performed fairly much to predictions and that only load checks and minor adjustments were required to achieve the required theoretical loads and complete the stressing operation.

Lowering of the Roof
As described in Section 4 the roof was erected in 9 main sections with the perimeter section being supported on falsework towers made up of RMD Megashore sections. On these towers were 16 main support points. Once the roof was complete and the stay cables were in place it was necessary to lower the entire centre section of the roof approximately 250mm. Once the load was removed from the falsework towers they could be removed returning much needed access to the arena area.

The lowering operation was carried out using 16 no. 100 tonne rams fixed at each of the support locations. Two power packs, each controlling six jacks were used to lower the roof uniformly. To ensure a failsafe system, ie no sudden drop of the roof due to a hydraulic failure a series of packers were used adjacent to the jacks to ensure the roof could not drop by any more than 20mm in such a scenario.

The roof was lowered by taking the load on the extended rams and gradually retracting the double acting rams. As the stroke of the rams was only 150mm the jacks were reset midway the operation during which the roof was supported on temporary shims.

The entire lowering operation was carried out without incident in one day.

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