MEMBRANE STRUCTURES ASSOCIATION OF AUSTRALIA CONFERENCE 93, AUCKLAND, NEW ZEALAND INNOVATIVE LIGHTWEIGHT ROOF STRUCTURES

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1.0 INTRODUCTION

There is an ever increasing demand for long span, lightweight roof structures in a wide variety of applications including sports facilities, entertainment venues and shopping centre atria, to list a few.

The need for a long span enclosure may be functional; for example, a long span aircraft hanger to house a Boeing 747 plane, or a column-free grandstand roof to provide unobstructed sight lines for spectators. On the other hand a long span facility may be desired to maximise the planning flexibility and to more easily accommodate future changes.

By way of case-study examples, this paper describes a number of interesting lightweight roof structures engineered by Connell Wagner starting with 1988 Australian Bicentennial projects and culminating in the highly exciting Sydney Olympic facilities at the Homebush site.

2.0 AUSTRALIAN BICENTENNIAL TRAVELLING EXHIBITION

This project was an excellent example of fabric roofs for exhibition enclosures. A total of 11 structures were involved comprising a variety of membrane forms and cleverly making use of pantechnicons to house the displays as well as providing support and anchorage to the fabrics. Even the prime movers were used as ballast anchorage.

The centrepiece was a 25 metre high, 40 metre diameter conically shaped membrane enclosing an audio visual show for 600 people. Referring to figure 1, the structure base was formed by five pantechnicons and the fabric roofs were supported from a central mast which folded into 3 sections for transportation.

PVC coated polyester fabrics were used for their 'foldability' during transport and the fact that the structures looked virtually new after 40 erection/dismantling operations attests to their performance.

The architects for the project were Daryl Jackson Pty Ltd and the design received engineering excellence awards from the IEAust and ACEA.

3.0 BICENTENNIAL CONSERVATORY, ADELAIDE, AUSTRALIA

As part of their Bicentennial celebrations, Adelaide commissioned architects Raffen Maron Pty Ltd to design a new tropical conservatory. This is the largest single-span conservatory in the Southern Hemisphere. In conjunction with Connell Wagner they conceived a state-of-the-art glazed shell structure with a clear span of almost 100 metres - see figure 2. The interior simulates a rainforest environment complete with a sprayed mist from the roof steelwork.

The major challenge was to devise a structure which could be glazed at ground level thereby avoiding the need for expensive scaffolding. An innovative design was developed comprising a tubular spline truss running the whole length of the enclosure which acts as the support for pre-glazed radial trusses.

Extensive computer analyses were carried out to check the structure for wind loads, earthquakes and temperature effects.

4.0 SHELL WESTGATE FABRIC CANOPIES, MELBOURNE, AUSTRALIA

This is another fascinating project which serves to demonstrate the diversity of membrane structure applications. The Shell Company of Australia was invited to tender for the provision of a service station on the approach roads to the Westgate Bridge in Melbourne. Graeme Law Architects (Pty Ltd) were engaged by Shell and proposed a fabric roof solution to act as a landmark structure and mirror the nearby Westgate cable-stayed bridge.

The architect, fabric designers Spacetech and structural engineers Connell Wagner developed the design concept making extensive use of stocking models and computer modelling to optimise the fabric forms. The largest canopies cover the bowser forecourt area and involve a 30 metre clear span. Wind tunnel testing indicated significantly lower pressures then those obtained from the wind code and as a result offered substantial savings in the cost of the piled foundations.

5.0 MCG SOUTHERN STAND, MELBOURNE, AUSTRALIA

The new $140M seven storey, 350 m long southern grandstand encompasses 45% of the MCG stadium and provides seating for 48,000 spectators. It also provides 73 sponsor boxes, restaurants, bars and basement car parking. Architects for the project were Tompkins Shaw & Evans/Daryl Jackson Pty Ltd and the builder was Holland Constructions Pty Ltd.

Figure 3 shows a section through the stand with its dramatic 27 m cantilever roof. The lightweight tubular truss roof design was strongly architecturally dictated and cantilevers from the topmost raking steel beams of the stand.

Wind tunnel testing was performed at Monash University and as a result slots through the roof were introduced which reduced the uplift wind pressures by 20%.

A critical aspect of the project was its speed of construction so that it could be built in one football season. As a result the project involved a high degree of pre-fabrication using a combination of precast concrete and steelwork. Metal sheeting was used as the roof cladding, and this was assembled at ground level in modules and then craned into position. The success of this innovative design was proved by its construction which was completed within a 12 month period.

6.0 STATE ATHLETIC AND AQUATIC CENTRE STRUCTURE, HOMEBUSH, SYDNEY, AUSTRALIA

The last case study describes the state-of-the-art roof structures for the Sydney International Athletic and Aquatic centres at Homebush, 20 km west of Sydney. These centres, developed by the New South Wales Public Works Department, are currently under construction to coincide with Sydney's bid for the Olympic Games in the year 2000. In the event of a successful bid these two facilities will be modified as described below and further venues will be built at the site.

The project manager is Civil & Civic, the architects are Philip Cox Richardson Taylor/Peddle Thorp and the structural design was performed by Connell Wagner's Sydney office under the direction of Owen Martin.

Athletic Centre

The Athletic Centre grandstand seats 5,000 people with 2,500 people under cover. Figure 4 shows a section through the stand comprising prestressed precast concrete seating plats spanning 12 metres onto raking steel box beams. An innovative 150 m spanning cable structure was developed to support the front of the roof providing a column free enclosure with the rear edge of the roof supported by columns at the top of the stand.

Downward loads acting on the roof are supported by a series of inclined stays radiating from two 45 m high cable stayed masts which also support the flood lighting. Upward wind loadings are resisted by a catenary cable tensioned to rock anchors.

Aquatic Centre

This innovative structure involves a 70 metre spanning barrel vault roof over an Olympic-sized pool. The vault comprises a steel diagrid using 300 mm diameter tubes and cast steel connections. Along the east wall of the roof is a 140 m spanning arch structure, which allows the edge columns to be removed in the Olympic Mode and an extension of the enclosure to expand the seating capacity from 4,400 to 12,500 people.

7.0 REFERENCES

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(e) 'The Structure of the Sydney International Athletic Centre'
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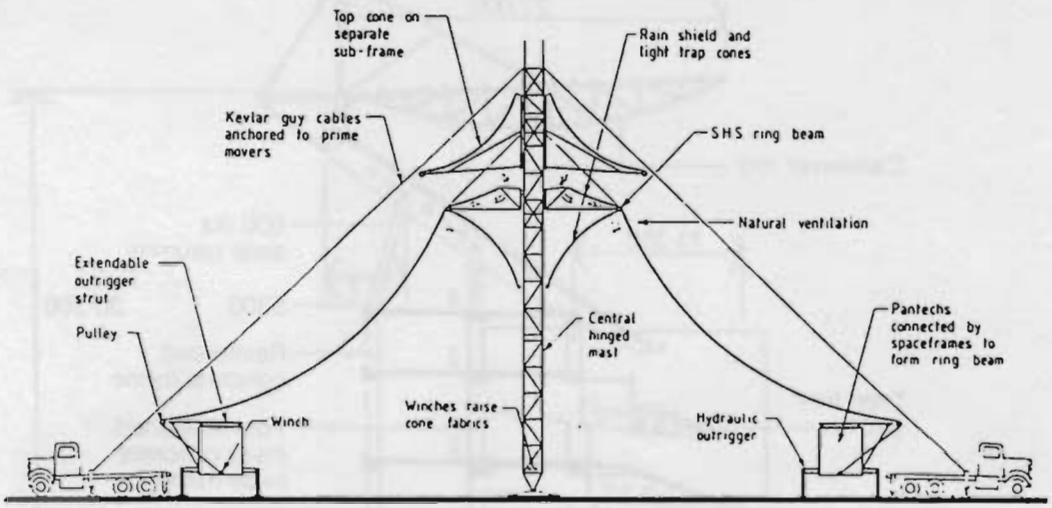
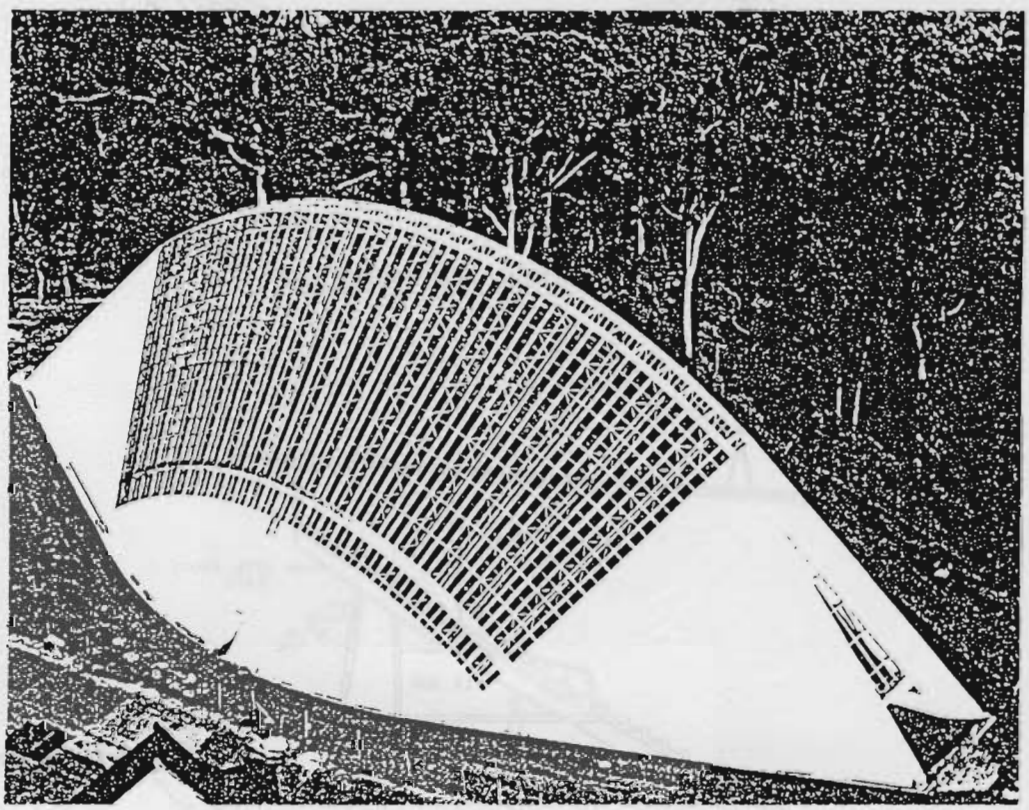


AUSTRALIAN BICENTENNIAL EXHIBITION

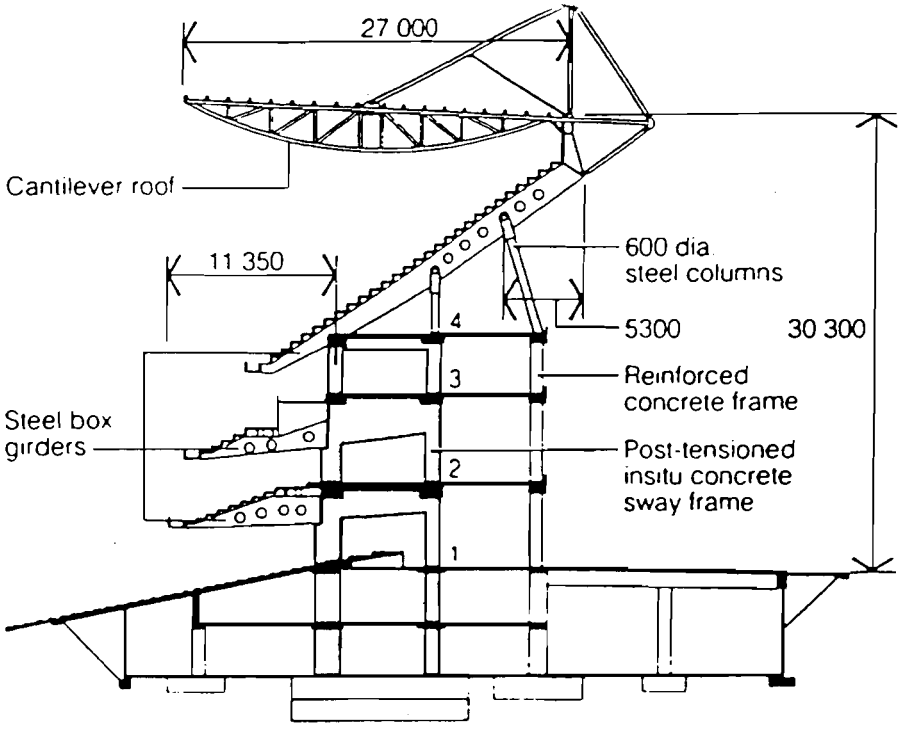
SECTION THROUGH AUDIO VISUAL THREATRE STRUCTURE

FIG. 1



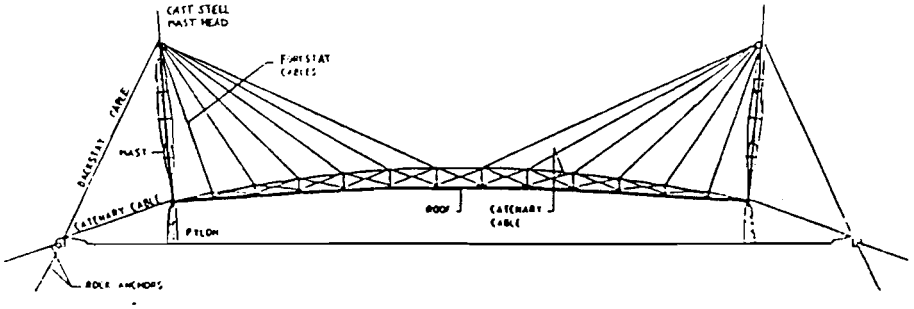
BICENTENNIAL CONSERVATORY ADELAIDE

FIG. 2

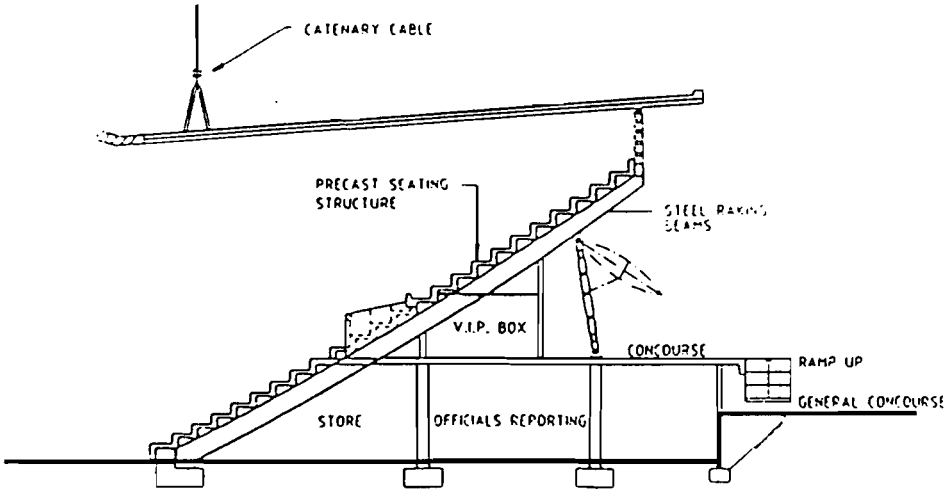


M.C.G. SOUTHERN STAND

FIG. 3



ELEVATION ROOF STRUCTURE



SECTION THROUGH GRANDSTAND

STATE ATHLETIC CENTRE

HOMEBUSH N.S.W.

FIG. 4