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## 6. Mobile Stage for Open-Air Performances, Sydney (Australia)

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| *Owner:* | *New South Wales Department for Cultural Affairs* |
| *Architect/Designer:* | *Surface & Spatial Structures, Vinzenz Sedlak* |
| *Engineer:* | *George Clark & Associates and Peter Kneen P/L (CAD)* |
| *Fabricator, Contractor:* | *B. W. Bilsborough & Sons P/L* |
| *Total Floor Area:* | *830 m²* |
| *Maximum Height:* | *14 m (20 m at masttop)* |
| *Length:* | *36 m* |
| *Width:* | *26 m* |
| *Span:* | *42 m (main edgecable)* |
| *Design/Construction:* | *4 Months* |
| *Completion of Work:* | *January 1984* |

Constructed for the Festival of Sydney in January 1984, the «Mobile Stage» is erected each year in December for a period of two months in the historic Domain Park, close to Sydney City Centre. Four to five major performances take place under the prestressed membrane roof including the popular «Opera in the Park» each attracting up to 120,000 spectators (Figure 1). The attractive and elegant structure, also termed the «Temporary Sydney Opera House», has become a successful major feature to Sydney being the only facility of its kind.

The structure is designed for high windloads to a specified 156 km/h design windspeed with a 50 year return period, while being readily demountable. The overall scheme is composed of 3 separate components: a demountable stage platform (18.5 m × 12 m with 2.5 m side-extensions), and independent frame structure for overhead lighting (18.7 m × 12.7 m and 11 m high) above the stage, and a prestressed membrane roof covering both.

### Structural and Architectural Design and Behaviour

The roof is an anticlastically shaped prestressed membrane surface, supported by an internal, diagonal cable system: two intersecting maincables – which, in turn, are supported by four internal masts and a central «flying strut» at their intersection – connect the four masttops and four maststying cables to their ground anchorages. The membrane is bordered by steel edge cables and is tensioned upwards to the four masttops utilising rosettes and downwards from the cornerfittings of intersecting edgecables to altogether nine anchorages.

An internal cable support system was chosen against an external one because it enabled tighter control of deflections within the surface and flatter entrance curvatures at the high points. It was therefore possible to economise on the overall surface area required for coverage of

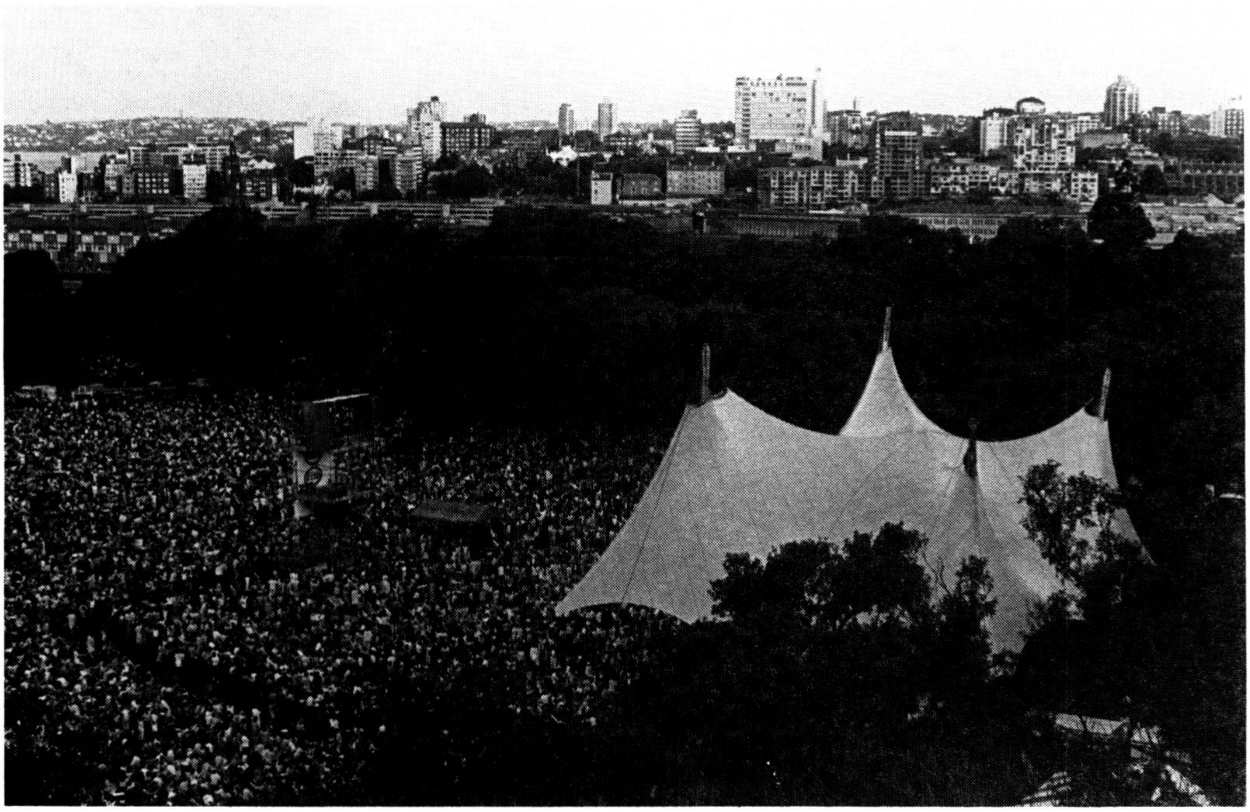

*Fig. 1 The mobile stage during a performance*

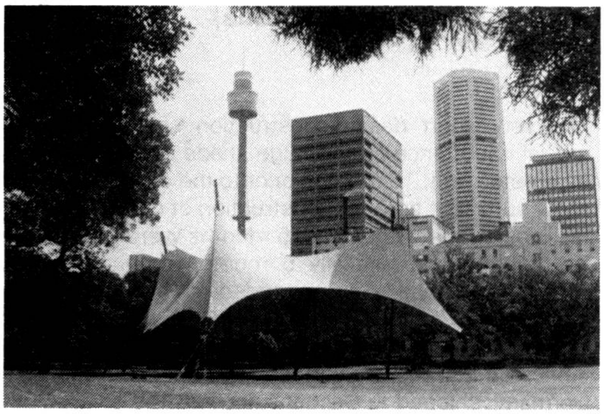

*Fig. 2 The structure in its setting in the Domain*

the opera-size stage by keeping the membrane surface close to the overhead lighting frame and by reducing overall mast heights as well as ground coverage. The maststays are integrated with the cable support system required for the membrane and thus the smallest number of perimeter anchorages and full lateral stability was achieved.

Shape design for the structure was conducted by utilising several scale models and computer analysis interactively. Windloads were determined in windtunnel tests on a rigid 1 : 100 scale model and windpressures were established for both, internal and external surfaces. The shape of the membrane surface was optimised on a 1 : 100 design model and the geometry of the surface, initially obtained by co-ordinate measurement of salient points from the model, was checked against a minimum energy soap-film shape by computer and verified in a 1 : 25 scale construction model (Figure 3).

The structure is designed to redistribute windforces by moving into a position of equilibrium between edge cable tensions, the main diagonal cable tensions and mast compressions. Essentially, any high membrane stresses tend to be shared throughout the structure by large deformations resulting in load redistribution. Any increase in edge cable forces and hence anchorage loads is balanced by a combination of wind uplift and mast compression.

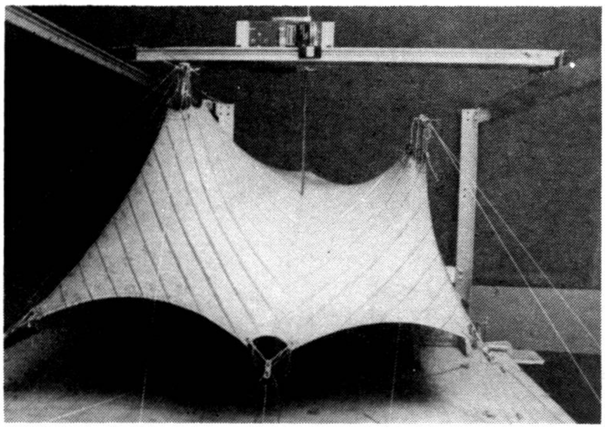

*Fig. 3 Cutting pattern construction model*

*Fig. 4 Underside view showing mast, membrane corner and fabric pattern*

**Construction Details**

The membrane material is a PVC-coated polyester fabric, 2/2 (panama) weave construction, 900 g/$m^2$ overall weight, flameretardent to AS1530 and stabilised for high UV exposure. In order to facilitate handling during fabrication and erection and dismantling the membrane surface having a total surface area 1340 $m^2$ is subdivised into four individual panels which are joined by site joints located alongside the main ridges. Circular corner cutouts teminate the membrane at cable intersections. Tangential stressing cables connect webbing reinforcement along the membrane edge to steel plate corner fittings. All supportcables within the membrane surface are galvanised steel of a diameter 26 mm, with the exception of the front edgecable which is 36 mm in diameter. All anchorage cables are 36 mm in diameter. These sizes allow for a safety factor of 2.25 based on a UTS of 1770 MPa at maximum wind loading.

The masts are galvanised mild steel built up struts from three circular hollow tube sections battened apart and spliced for transport and storage. Mastfootings are bored piers and the base plate has universal joint action to allow unrestricted mast movement during windloading. Grouted high yield reinforcing bars into bedrock are used for all ground anchors. The anchorages were drilled up to 10 m long into the ground at specified entrance angles and are covered by grass sods during the periods when the structure is not erected.

Overall erection time is three days, dismantling time is one and a half days including site-preparation, transport and storage. Total costs were A$ 400,000 with annual erection and dismantling costs of A$ 30.000.

*(Vinzenz Sedlak)*