MEMBRANE STRUCTURES

AN ARCHITECTURAL OVERVIEW

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Membrane Structures, an Architectural Overview.

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There will be many different interests represented at this first membrane structure seminar in Queensland. There will be many who know much more than I do about them and doubtless some for whom this is almost the first exposure to this form of construction.

The view point that I would like to take in this talk is from the designers and user's point of view, and in this case the designer is one whose task is to fit the structure into its environment, be that landscape, building, recreation space, exhibition shelter, agricultural or industrial context.

It is a great honour to be asked to give this talk in Brisbane at this time, for the proposed membrane structure to cover portion of the Expo 88 Exhibition will surely be one of the most notable membrane structures in the world to date and should really put this type of structure, which has been sitting in the wings here for some years, right on the forefront of the Australian construction stage.

The effect of this structure on the psyche of those visiting Expo I am sure will prove dynamic, and all parties to the conception and implementation are to be congratulated in their foresight in bringing this great project towards reality.

My own involvement in Membrane Structures to date has been at a smaller scale, and in this brief talk I would like to dwell a little on the detailed experience I have had with this type of structure in Australia and following that, to set some sights for the future development of membrane structures especially in a tropical setting.

As this talk is intended to be an overview, I also feel responsible to give a brief potted history of membrane structures if those who are familiar with the medium will allow this indulgence.

The other broad comment I would like to make is that although construction technology tends to move fairly quickly, it is very exciting to be involved in what are the early stages in Australia of a totally new way of looking at structures.

I really feel we are still in the kindergarten of possibilities of the medium and don't believe I am overstating its importance if I compare the introduction tension structures with the introduction of reinforced concrete. Perhaps it is not as widespread yet throughout the industry, but the potential for providing speedy, economic and durable shelter has not yet been generally recognised by the construction community, let alone the client community at large.

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HISTORY

First, the potted history, and I am indebted to my colleague Erich Dollansky for the material of this section of the talk, as well as the excellent publications prepared by the Membrane Structures Research Institute at the University of N.S.W.

The forerunner of today's widespread roofing structures sprang forth in the dawning chapter of history.

Tents (or tent-like constructions) rank among man's oldest dwelling places; the first vestiges date back to the early Stone Age. Indeed, the tent must be considered a integral part of dawning civilisation. Nomadic peoples designed light, collapsible tents for the sake of transportability, whereas the non-Nomadics constructed tents of a more stationary nature, chiefly for military purposes.

More than 3000 years ago the Israilites built their famous tabernacle that was carried through the desert after the exodus from Egypt. The Assyrians made use of tents in their military camps. The Bedouins of today house in a variation of this Assyrian predecessor. Military tents of similar design were used by Egyptians, the Romans; in general, by most armies from the Middle Ages down to the present day. Tents, however, were not solely temporary accomodation in military campaigns, for widespanned roofing structures are frequently erected for providing a sheltering roof over festivities, representative functions and state ceremonies.

A culminating point in this respect was the Golden Drape Meeting (Camp des drap d'or) near Calais, France, in 1520, at which King Henry VIII and his retinue took part in more than 400 tents

Mass production of the tent began in the 19th Century, after the Industrial Revolution. England was a pioneer in outdoor housing and equipment, as is witnessed by the many catalogues from that country offering tents and marquees to the military, and as temporary exhibition, agricultural and factory sites.

Wandering circuses, which came into vogue around 1840, were likewise important cutomers for tent makers.

Nets, it is believed, orginated in or before the 3rd Century B.C. They were not employed in the building trades, though; more for catching anomals and fish. Still, nets for protection, packaging, and as an article of clothing, etc., have been in existence for a long time.

A relief of Trajan's column in Rome (113 A.D.) depicts Roman military tents reinforced with netting. Moreover, the thatching of the dome-shaped huts of the Zulus in South Africa is held in place with rope netting made of grass.

The roots of pneumatic devices reach back to the sails of sailing ships and of land-borne vehicles. Kites are also included in this category: they stem from remote antiquity, when numerous peoples, the Persians, for example, flew them. Since the times of Constantine, the Romans used kites as banners.

And finally, parachutes as well as free and anchored balloons (Leonardo Da Vinci produced a drawing of a dense linen canopy as early as 1500) must be counted among the pneumatic firsts.

Even though the invention of the latter is not positively documented, the hot air balloons of the brothers Joseph M. and Jacques E. Montgolfier were definitely their own invention (1783).

The idea of applying the pneumatic principle to the construction of buildings was the brainchild of F.W. Lanchester, a British Engineer; he was awarded a patent in 1918.

In the years that followed, pneumatic reinforcement was utilized over a wide spectrum from dwelling blocks to the roofing of stadiums.

Retractable roofs were originally in the form of an umbrella; the Greeks using parasols since the 5th Century B.C. They were the earliest collapsible roofs authentically recorded. The Romans covered their open-air arenas with lightweight fabric roofing; even the Colosseum was shaded against the burning sun by a circumambient roof.

Nowadays, lightweight roofing is a permanent part of architecture. The development of new materials affording high tensile strength and resistence to atmospheric corrosion makes for the roofing of larger and larger areas.

There has also been a growing desire within the ranks of architects and engineers to strive for lighter and airier structures. I well remember attending a talk by the late Buckminster Fuller at a Habitat Convention in Vancouver, comparing the weight of a structure in masonry to that of a geodesic dome. Air supported structures have gone even further in transferring a negative weight to their anchoring points.

The architectural design works of Frei Otto and Kenzo Tange also deserve special mention as they have proven seminal developments in the design of membrane structures over the last two or three decades.

The recent colossal advances in membrane technology have now freed the structural basis even from cable net systems, so that the latest membranes can span distances of 50 metres or more without relying on interstitial cable support.

The greatest benefit this gives is its translucency or even transparency, giving a lightness and uplifting quality unmatched in any other structure. The further development of mesh fabrics has proven a real boom in agricultural and sun-control technology, and the recent development of solar absorptive membranes gives hint of a most exciting future for membrane structures in energy gathering and conservation.

The structural support systems now available consist of masts and cables, portal frames and trusses both internal and external, cable nets, between buildings, between ground supports, retractable, air inflated, air supported and various forms of storage.

To my mind, the aims for utilisation of membrane structures is to give light, translucent poetic structures, that give lightness in weight, great strength, durability and at least comparative economy with other forms of structure.

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Australian Experience

The last time I spoke on Membrane Structures was at the Seminar in Sydney three years ago when we had just completed a tent structure over the Atrium of the Canberra International Motor Inn. This roof has proved enormously successful in both environmental and commercial terms, and there are now a number of other buildings that our office has designed utilising a membrane structure component.

I would like to give you some illustrations of these projects to show how membrane structures are suitable for a variety of building types.

The original Canberra International Motor Inn roof is approximately 25 metres square and is supported on a central mast 16 metres. The material is woven polyester fabric coated with PVC and white in colour.

Our next project was Corinna Chambers at Woden in the A.C.T., a medical building for a group of specialists. The central landscaped atrium is covered with a 12 metre square teflon coated fibreglass roof with the centre mast supported from the steel perimeter ring beam by four diagonal cables. This roof has also proved very successful, in that the central atrium provides a very restful waiting area for patients and suffuses the whole centre of the building with a gentle natural light.

We have also designed membrane structures for three additional motel buildings, including the luxurious Guest Quarters at the Canberra International, where the centre mast is supported on cable spokes from a circular ring beam 22 metres in diameter, the Airport Motel in Queanbeyan, where all of the rooms look onto a central atrium space covered by six linked roofs, and the very latest roof, a 30 metre high structure for the Pavilion Motor Inn at Wagga Wagga which was only completed last weekend. For this most interesting construction which consists of a tall cone intersecting hyperbolic paraboloids attached to the perimeter building and covering a central courtyard, I would like to show a series of slides demonstrating the construction method.

We have also recently completed a teflon coated fibreglass roof at Tintern Girls Grammar School in Melbourne covering a 15 metre square forum area associated with a new classroom block and we are currently working on a number of roofs associated with schools, recreation areas, a church, further office buildings and an exhibition area.

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Some Recent European Projects

Erich Dollansky has provided some illustrations of recent projects carried out in Germany by the firm of Naumann Dollansky. Notable among these is a new community pool and recreation complex enclosed by a double membrane inflated roof and surrounded with a new solar collecting membrane that has recently been developed.

By use of heat exchange equipment and an adjoining lake as a heat sink, the building has proved self sufficient year round for energy, and even during the depth of winter there is enough reserve energy available to heat a nearby elderly persons village.

Design Considerations

It is something of a step from the depth of a European winter to the tropical climes of Queensland. However, it is my firm belief that the potential for use of membrane structures in tropical conditions has hardly been tapped. In temperate and cold climates, it is essential that if membrane structures are to be used year round, they be fully enclosed and heated. In tropical areas, the shading and rain shelter characteristics will suffice to provide major usable covered areas year round, and the possibilities for use of mesh fabrics in agricultural and sunshading functions seems limitless.

The solar collecting capabilities of membrane structures have also been utilised in an experimental power station in Spain with the use of reflective fabric and further research into the use of the new solar collecting fabric in tropical areas should prove most fruitful.

There are also additional benefits to be gained from the use of membranes. We have found that the 8% - 11% translucency of the fabrics, together with the ultra violet block that can be included in the coating, gives a light environment very similar to the low storey of a rain forest, and plant growth for selected species is excellent.

The stress induced in the fabric also provides excellent acoustic characteristics. The roof provided at Tintern Girls Grammar School in Melbourne has proved to be an excellent environment for choral and instrumental performances.

In the space of this talk, there are many other aspects of design that are worth mentioning, but time demands that they may be only summarised as follows.

- Structural engineering - simplicity in shapes, profiles and connections.
- Mechanical engineering - utilising the natural "Venturi" characteristics of the fabric shapes, with adjustable inlet and outlet venting areas for different seasons and conditions.
- Choice of membrane, P.V.C., teflon coated fibreglass, mesh, coated cottons.
- Patterns of joints and methods of jointing.
- Systems for tensioning.
- Imaginative use of shapes for ensuring double tension in all areas and convenient arrangements for water shedding.
- Use of retractable roofs for recreational activities.
- Landmark design for subtle advertising associated with commercial projects.

A Personal view of the future

As this talk is specifically directed to membrane structures in tropical areas. I foresee a number of ways in which the introduction of fabric structures should make a major difference to the construction and the quality of life.

In areas of high rainfall, membrane structures can provide shelter over busy pedestrian areas, and this could transform the central commercial areas of cities and major towns.

In areas of intense heat and sunlight but low rainfall, mesh fabric could be used in similar fashion.

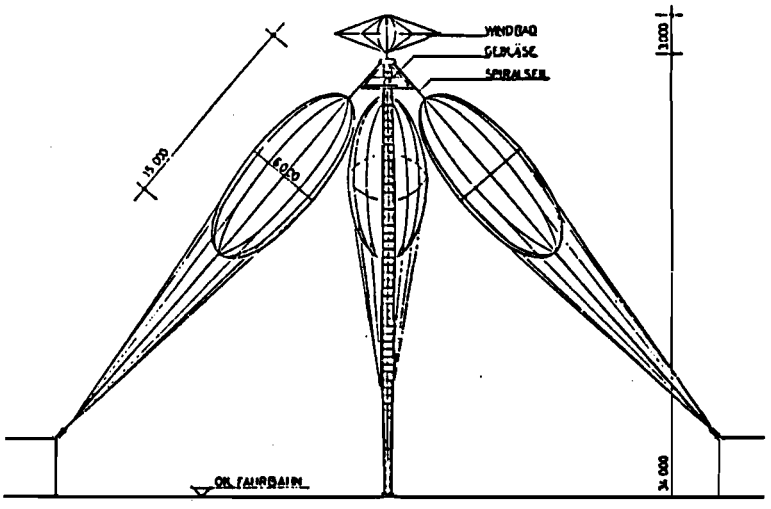
There are endless possibilities for use of membrane structures in connection with all types of buildings. The Sheraton at Ayers Rock is one of the first Australian examples of use of fabric in desert conditions, something pioneered years ago by Frank Lloyd Wright at Taliesin West in Arizona.

Membrane structures would be suitable in tropical areas for hotels, restaurants, shopping centres, entertainment areas, sporting venues, offices, schools, houses and many other building types.

Agricultural uses have also been mentioned and a number of examples of creating a new shaded microclimate with fabric mesh, have already been developed in Arabian countries.

Areas of high continuous sunlight could also use fabric solar collectors for energy generation.

In summary, I believe the potential for using membrane structures in tropical areas is limitless and as far as realising the design potential and ways of utilising this structural form the whole field is still in its infancy.



Bundesgartenschau Berlin 1985

Ballon-Eingangs-Signal

Masthöhe (einschl. Windrad)	36 m
max. Druckkraft des Mastes	100 t
Windrad Durchmesser	8 m
Ballons Länge	15 m
Durchmesser	6 m
Rauminhalt	283 m^3
innerer Überdruck	100 kg/m^2
Stahlseile Durchmesser	40 mm
max. Belastung	47 t
Verankerung der Seile durch Einstabinjektionsanker Länge	12 m

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