TENTS, TECHNOLOGY AND TECTONICS

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Tents - portable shelter of skins,.....supported by one or more poles,...... and usually extended by ropes fastened to pegs in the ground.

Technology - the branch of knowledge that deals with science and engineering, or its practice, as applied to practice.

Tectonics - the science or art of assembling, shaping, or ornamenting materials in construction.

* Explanations of meanings from The Macquarie Dictionary.

In this paper I will outline the development of our thought processes, and trace the evolution of the design solution for the Keysborough Golf City project.

The Keysborough Golf City project was our firm's first experience in designing with membrane structures.

Completed in March this year, the project encompassed the design of a golf driving range located in an outer southeastern suburb of Melbourne.

A large dual *cone* membrane roof is utilised over much of the operational area of the facility, and provides for the user, both a stimulating internal space, and a strong external identity.

Our firm, Millar Sainsbery Mulcair were the Architects for this project, which was project managed by WBCM Consultants. WBCM consultants also provided general structural design expertise, whilst Connell Barrow McCready provided the specialist engineering design skills required for fabric structures. Spacetech were responsible for the fabrication and installation of the fabric roof.

The principles of lightweight membrane structures have been with us for many hundreds of *years.* Simple tent s t r u m , using relatively primitive materials, have provided an age old system of cover and protection from the elements. These structures have generally been temporary ones, capable of being packed up, moved, and reconstructed with relative ease, creating in our psyche a perception of such structures as temporal or transitory.

The developments in science and technology in the last century have been staggering by any measure. This is very much in evidence in relation to membrane structures.

Today's membrane structures are more than a sophisticated form of tent structure. They utilise advanced fabric materials that have embraced superior technologies in their production to provide levels of tensile strength, and long term durability, previously unachievable.

The problem facing designers, be they architects or engineers, in designing with membrane structures is then essentially a tectonic one. That is, the shaping and making of forms which whilst stretching the inherent properties of the material to its limits, provide appropriate and effective solutions to the problem of enclosing space and creating visually and physically stimulating environments for humans to inhabit.

The adoption of membrane structures by a designer, carries with it the need to understand the rules as it were, in utilising such structures, as well as a discipline involving the understanding of minimalist engineering detailing and fabrication principles.

The design of membrane roof structures involves a multi-disciplinary group of professionals and requires the blurring, or even abolition of traditional boundaries of professional expertise. For example, the architect is required to know and understand the complexities of detailing engineering edge support conditions as much as the engineer is required to comprehend the subtleties inherent in the form making aspirations of the project. In the *end* the design solution comes from the fusion of ideas generated by the removal of barriers, and the allowance of inquiry as a formal design tool.

In designing the Keysborough Golf City project we did not automatically decide to use a fabric m f . Rather the decision evolved as we explored the physical planning requirements, budgetary parameters, and imagery for the project.

The client, Keysborough Golf Club came to us after they had undertaken *sane* preliminary research into other facilities of this type. This research had led them to Japan, the home of the world's most sophisticated driving ranges, as well as various facilities already operating throughout Australia.

Their brief was quite clear. They wanted to develop the best golf driving range in Australia, utilising within it, the most up to date golf range technology and systems available in Australia. The project was to comprise a range of practice facilities designed to cater for the specific practice requirements of golfers of various standards. When completed, it was to provide a level of amenity unparalleled in Australia.

The chosen site was located in the south western corner of their Golf Course on the corner of Springvale Road and Hutton Road, Keysborough. In terms of marketing potential, this site had obvious advantages, as Springvale Road, carrying up to 30,000 vehicles per day, is one of Melbourne's busiest roads.

The 5 Hectare site, however, possessed a number of inherent problems. It was a partially filled, low lying former *swamp* with extremely poor soil conditions. This was to create a number of problems in the design of the slab and below ground *structure,* as well as ongoing logistical problems during construction.

The detailed design brief called for a 2 storey 60 bay golf driving range, chipping, sand trap and practice putting areas as well as a pro-shop, creche, restaurant and bar facilities. Additionally a series of mini-golf, or putt-putt courses were planned to attract the less serious golfer and family groups.

It is an essential part of our firm's design philosophy to approach projects with a minimum of pre-conceived ideas, preferring rather to let the project brief, site, client interaction, and our detailed analysis of the project act as the generator of the design solution.

As the design process for this project evolved, we determined a series of design tactics aimed at addressing the inherent restrictions of the site, whilst exploring the architectural form of the building, and its relevance to the functions contained therein.

These tactics were to:

i) develop a strong verticality in the primary building form to ensure the building was clearly visible frun Springvale Road.

ii) develop a dynamic building form reflective of the nature of the game of golf itself.

iii) ensure that the building form was visually dominant, with a strong architectural presence separating it frun *other* buildings in the vicinity, and other related uses.

iv) ensure the building possessed an identifiable and marketable imagery.

v) develop an efficient and repetitive structural ***system*** that could be utilised in all circumstances.

Whilst these ***tactics*** were somewhat illusory, they provided us with a framework within which to develop and test the evolving design for the building.

The Driving Range is a new type of building in Australia. As a result our design did not have to be constrained by an established language of elements or forms, such as when designing an office, or a shopping centre, whereby enough elements must read as being descriptive of the buildings function for it to be rewgnisable.

Our design problem, in effect was to create an image that would become synonomous with the building and its function. We were also aware that in doing so, we may also be creating the image for an emerging building type.

As we embarked upon the detailed site planning, a number of constraints were identified. These included the locations of a series of existing and filled dams, the height of the tree line along the Springvale Road frontage and the restricted public access available to the site.

With no real established design standards far Golf Driving Ranges available to us, prior to commencing the functional planning of the facility, we developed a series of spatial and functional models that were tested, refined and ultimately adopted in the planning of the facility. These included areas ***such*** as driving bay sizes, and ball delivery and return systems, as we11 as the spatial relationships between the individual areas called up in the brief.

Our early building form studies investigated roof forms that were simple, constructed in conventional materials and supported on a *regular* grided steel structure.

This early work, whilst confirming the appropriateness of our approach to the siting and internal planning of the facility, failed to resolve satisfactorily, the architectural place making, or formal expression of the building in a manner that was appropriate.

While the solutions that were developing reflected many of our aims, we felt this was in a static way only, and that they failed to provide the strong dynamic farm we were seeking.

We then quite consciously sought to explore in the design, a farm that referred more directly to the fluid nature of golf.

It was at this point that we first began investigating membrane structures.

Our initial proposals incorporating a membrane roof explored the roof as a series of tent like forms, or skins, held fran above in tension by a series of cables connected to rigid steel frames or poles. They were then pegged at their bases to a rigid steel frame.

Although comparatively raw and tent-like, this idea had considerable merit we believed, and it was decided to undertake a period of research and consultation with various people experienced in the design and erection of membrane structures.

We were aware of the many applications of membrane structures throughout the east coast and central desert parts of Australia. We observed however, that many of these structures were designed to cover, screen, or protect external spaces. Few grappled with the problem of enclosing internal spaces below a membrane roof enclosed on its sides with rigid external walls. Those that did, often resolved the problem of differential movement between the flexible roof membrane and the static walls by the placement of a flexible diaphragm at the junction point to control all movement.

In deciding to utilise a membrane roof, we wanted to create below it a stimulating interior space, full of light and movement, that was integrated with the overall building form, not separate from it.

At this time we met with Bob Barrow of Cornell Barrow McCready and Spacetech. Our early discussions with him and subsequent visits to look at existing membrane structures confirmed some of the complications that were inherent in our current design solution.

This then led to a period of reassessment of our design approach to date. Rather than roof the entire building with a membrane roof, we determined to enclose the pro-shop, restaurant and bar facilities below a membrane roof structure which would abut and join the more conventially constructed steel and glass structure of the driving range itself.

Given the relative complications of joining a membrane roof to an articulated building form, our initial analysis with Bob Barrow focused on shaping and tensioning the membrane to ensure it would maintain its shape free fran flat areas, wrinkles, and the possibility of long term sagging.

The solution developed was to create a major roof with dual peaks enclosing the internal space, and a somewhat smaller roof with a single peak over the external point of entry.

The major roof would be strung between two steel columns and a rigid steel ring beam, which would be incorporated into, or attached to the external walling.

A smaller roof over the main entry, whilst similiarly attached to a ring beam around its perimeter was to be supported at its peak by a flying stub column supported on steel cables tied back to the ring beam.

Our presentation of concept drawings of the membrane roof to our client at this stage met with strong approval, not withstanding that it would add significantly to their budget. They felt strongly however, that the image such a roof would create, would, over time offset any additional costs.

It is worth noting that the form of the roof has subsequently been adopted as the corporate and marketing image for the facility.

Now having confirmed the inclusion of a membrane roof, the detailed design analysis commenced, and the fax machine between our office and Spacetech was, to say the least, kept busy.

As already noted, we were aware that in dealing with relatively minimalist structures such as these, a close working relationship between architect and engineer was essential. All details, be they fabric joints, or steel plate fixings to edge beams, would ultimately be exposed. Thus their careful detailing, to suit both the architectural and structural agendas, would need to be undertaken in close association with the engineers.

Our design however, still had a number of complexities which required analysis and careful resolution. The two long sides of the roofed area for example were not parallel, in fact as well as curving in plan form against each other - like back to back boomerangs - they were located at different heights vertically.

This created a series of difficulties in shaping and cutting the roof, as well as making it difficult to maintain all sections of the roof in tension.

The initial shaping of the roof was also somewhat flat, raising the potential for water ponding, and still lacking the dynamic form we had been seeking.

In consultation with Bob Barrow and Peter Lim of Spacetech, it was decided to raise the height of the peaks to 14 metres, tilt the major support columns outwards and slightly forward, whilst bringing the two long sides of the building into parallel.

A series of wire mesh form finding shape perspectives were generated by Spacetech for further analysis, and following some minor adjustments, the final shape was confirmed and the design detailing completed.

The membrane utilised is a woven PVC mated polyester fabric with tedlar laminations on the top. It was selected for its durability with respect to its resistance to ultra violet degradation, and its inherent self cleaning properties.

The edge support for the membrane roof comprises a steel ring beam turned at 90° through its XY axis to provide stiffness in the horizontal plane, and is fixed to fabricated steel trussed columns designed to act as vertical cantilevers to resist the inward pull of the tensioned roof. These trusses are identical to but somewhat smaller than, the trussed columns supporting the roof and first floor level of the driving bay itself.

The fine tolerances in the fabrication and erection of the membrane required that, once the ring beam at the base of the membrane was securely fixed in position on site, a licensed surveyor be engaged to plot all as constructed steel locations prior to final fabric cutting patterns being created.

The steel ring beam, also acts as a gutter and provides the head support for both the external walling and glazing.

The design of both the mechanical and electrical services also required careful integration, as both would be largley visible, and had to contend with providing an effective level of amenity to an unusually shaped space.

The fabric roof material has a poor thermal resistance for transmission and also allows a proportion of solar radiation to penetrate directly into the space. This resulted in significantly larger heating/cooling capacities for the air conditioning apparatus.

A *system* of split reverse cycle air conditioning was provided to the main area with the fan coil section mounted above the amenities area and the condensing unit on a plinth outside.

Because of the large volume of space at high level, jet diffusers were provided to ensure mixing of the air conditioned air with the room air over the full width of the room at low height. Exhaust fans are also placed at high level to exhaust the build up of hot air under the roof in summer, caused by the penetration of solar radiation through the membrane roof.

The effective lighting of a shape and material such as this requires the creative and adaptive use of light fittings.

To achieve an even lighting distribution throughout the main space, a system of uplighting was utilised. Because of the limited support locations within the fabric roof, all discharge uplighting had to be located on the support masts, or ring beam.

This lighting is a combination of 150w metal halide uplighters and 150w metal halide spotlights.

The light coloured fabric provides good reflection for the internal lighting and the fact that the material is partially translucent, allows the structure to be extremely well illuminated at night. This characteristic was exploited to ensure that the building became highly visible at night across the relatively flat adjacent landscape.

The construction of the overall facility took 18 months, mainly due to the difficult site conditions, with the onsite installation of the membrane roof taking 6 days.

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The roof has already achieved popular appeal and ready identification amongst both users and the general public.

The client is satisfied it has realised a building that provides a clear sense of identity for itself, functioning both as a strong corporate image and a stimulating interior space. Its commercial success as golf driving range has been well founded.

Membrane structures provide the designer with enormous opportunity in form making and shaping, but their adoption requires that one develops an understanding of the basic nature of the material, its rules, and its restrictions.

The committment, interaction and mutual respect between all members of the consulting team is a vital part of achieving a successful project, certainly more so than in a conventially constructed building where the majority if not all the structure and connections are concealed.

A visionary client is also a must..