3.6 Design Development and Detailing

Tensioned membrane structures have been in progress for the last fifty years. Technology has reached maturity and masterpieces of lightweight membrane architecture have been built. The task now is to develop this technology for a broader spectrum of applications and to continue to improve the art of lightweight building. This could include:

a) the development of multi-layer membrane structures for low energy consumption buildings that permit many activities all year round. Guided by a deep architectural understanding coupled with physical and technical know-how, multi layer membrane technology can extend the scope of lightweight architecture. (See Chapter 5).

b) extensions to existing buildings to enrich the quality of the urban environment.

c) high standard flexible and mobile membrane building systems for short and medium term use.

d) convertible weather shelters over the public spaces of historic city centres as well as in modern developments.

3.6.1 Form Finding

Whilst evaluating the requirements and conditions of a client's brief the designer develops the form concepts. This involves a preliminary layout of the boundary conditions including the arrangements for the low and high points needed for the support/suspension of the membrane. This leads directly to finding the tension equilibrium form described in chapter 3.1.1 - 3.1.4.

Fig. 30 Digital Form finding process with PAM Lisa: from left top clockwise: boundaries, geometry with net, generated form and wind forces on the form; Architekturbüro Rasch + Bradatsch 2003.
3.6.2 CUTTING PATTERNS

Cutting patterns are two dimensional shapes which when assembled together and pre-stressed produce the intended three dimensional surface.

Many requirements must be fulfilled in the cutting pattern design. They are related to both physical and architectural aspects.

The first point to be considered is the orientation of the weave of the fabric in relation to the principal stresses within the membrane. The economic use of the material is also relevant.

Regarding formal architectural aspects, it is clear that the rhythm imposed by the seam lines plays an important role in the perception of a membrane's doubly curved shape and this quality can be exploited architecturally to good effect.

When membranes have simple shapes they lead to characteristic cutting patterns layouts, such as, a radial layout for conical shapes and a parallel one for saddle shapes. Such examples are presented here only to show the influence of the cutting pattern in the perception of the structure's shape. It should not influence further architectural investigation and experimentation since each structure should be studied individually. However in cases of continuous more freely shaped membrane structures, the criteria for laying out the seams are less obvious and require closer study.

Establishing compatibility between these seam lines and the main structure's curvature is important in improving the expressiveness of the tensioned membrane. This is especially relevant when the membrane curvatures are very subtle.
Whilst internal lux levels are high during the hours of daylight, membranes cause incident sunlight to become diffuse and with little contrast. This tends to diminish the perception of a membrane’s shape. When carefully considered, the welding pattern can create results as interesting as those, for example, provided by the ribs of Gothic rib vaulting in which rhythm and pattern were major tools for expression.

A stronger cloth may be necessary where there is a local concentration of stresses. This leads to a difference in appearance in the surface due to a lower translucency. However, a skilful design can integrate such effects successfully to enhance the main characteristics of the shape when a heavier grade of cloth is used at the points of load accumulation. Aspects such as this should ideally be developed in tandem with the structural requirements, as well as the % wastage of material. In some circumstances a balance may need to be made between cost and aesthetic consideration.

The “readability” of a doubly curved membrane is an important factor to be considered by the Architect, and the qualities of natural light should be used to obtain the best appearance. The daily as well as yearly movement of the sun must be taken into account when considering the layout of a membrane’s shape. The combination of direct and diffused daylight greatly enhances the light quality of the space, as well as the appearance of the structure.
One way of achieving a good effect is by articulating the position, form and detailing of openings in the membrane. There are many possibilities. This kind of approach is also useful in supporting the readability of the membrane’s shape, whilst the introduction of direct daylight will immediately make it readable. This lighting effect is known as ‘washing’, and is especially interesting in cases of subtly curved structures.

Reflecting daylight off a bright surface such as water is another way of introducing daylight onto the membrane’s inner surface, enhancing visual stimulation and spatial orientation. Artificial light sources are also good for washing over the membrane and so revealing their subtle undulations. The effect is however more related to nighttime illumination when exterior light levels are much reduced.

3.6.3 SKYLIGHTS, OPENINGS – NATURAL LIGHTING

Openings in membrane surfaces need to respect structural load paths. Whilst the openings are elements that may have been incorporated during the development of the whole design they must be an integral part of the membrane’s tension equilibrium shape. The perimeters of these openings have to be considered and reinforced as membrane edges in relation to their radii of curvature. Sharp cornered openings do not work well on membranes. Typical openings are eyelid shapes, teardrop shapes or rings.

Openings that are integrated with the membrane surface are important not only for the introduction of natural ventilation and direct light into the space, but also because they provide particular views to the outside.

A great number of possibilities have already been explored, but this is one area of membrane design where new solutions will continue to be found. The shape of an opening and the structure that encloses it have, of course, to be considered simultaneously.

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3.6.4 THE MEMBRANE EDGE – CONNECTION TO OTHER BUILDING SYSTEMS

Structural aspects of membrane boundaries are discussed in the previous chapter. Architecturally, the membrane edge is the boundary line of a unique tension equilibrium shape that touches its immediate surroundings environment at articulated corner anchorage points. Along its three-dimensional perimeter the membrane structure gets into relation with the environment as well as adjoining building elements.

The ‘force collecting corner points’ of the linear membrane edge are particularly important in the development of an architectural vocabulary for lightweight membranes. They can be compared with column capitals in classical architecture, expressing the transmission of concentrated forces from one element to the next and then into the ground. Many linear elements converge on the membrane corner points, coming from different directions whilst lying in different planes. It is important to develop the simplest and most minimal configuration for these points.

Juxtaposing fabric membrane structures with conventional building systems has great potential for development. Areas covered by membranes express a completely different kind of architectural space, contributing a “non-euclidean” and dynamic aspect to the existing built environment via both temporary and permanent solutions. When associating membrane structures with more traditional building systems there are several aspects to be considered. The first concerns the large deflection characteristic of membranes. At intersections with stiff walls, such as glass facades, an intermediate flexible element is required to absorb the deflections of the membrane roof under external loads. Such flexible interfaces can also be used to provide the natural ventilation associated with small retractable systems.

Where membrane panels are connected to a rigid component such as a wall, a great variety of solutions (watertight, airtight, translucent) are available to play on the architectural theme, “light touches mass”. For example:

a) The membrane is hovering beyond the wall, and the gap between the top of the wall and the membrane is used as a mediator, pretending that the membrane and the wall are visually independent.

b) The membrane is wrapping over the wall, resulting in a detail which for an interior observer disappears beyond the visual horizon of the wall.

c) The membrane is only slightly touching the wall, and again the scalloped edges admit direct light into the interior. If full...
enclosure is needed, a mediating element to cover the scallops is introduced, generally hinged between the wall element and the membrane’s edge cable. Gaps admit air and light. Life develops from such junctions in a dialogue of different colours and textures of materials, natural and artificial, heavy and light, smooth and rough, ‘high tech’ and hand crafted – a rich source of inspiration for new architectural details.

3.7 Applications and Classification

Textile constructions are already in use for a wide range of buildings serving a variety of purposes. A schematic classification is presented here to illustrate the range of applications for which tensile structures are currently being used.

Tensile membranes can be classified according to different aspects such as the function of the building, the functions of the tensile membrane (daylight transmission, rain protection, sun protection, space defining element...), the span, whether it is convertible or not, the degree of enclosure, or the duration of use.

The following examples illustrate the different qualities of coated textiles and foils – e.g. translucency, lightweight – and the variety of architecture that can be created – e.g. natural forms, regular shapes, open or enclosed. A range of examples can be found at www.tensinet.com. Projects with a contrasting appearance suggest an almost endless range of possibilities. The manipulation of structure, form, and multiple layers can be used to reinforce specific architectural objectives. ‘High-tech’ textiles can be used for new buildings, as well as in the refurbishment and extensions of existing buildings. In the following scheme the columns from left to right show ‘open constructions’, ‘enclosed’ and ‘convertible’ envelopes. The three rows show technical fabrics serving three different purposes – envelopes, internal applications or constructions attached to a building.

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Fig. 37 Classification of tensile membrane constructions

This particular classification of tensile membrane constructions is not intended to be restrictive, but rather to allow comparison and exploration of existing solutions prior to the design stage.

This classification considers the main function of the membrane construction. Normally a technical textile can fulfil more than one function.