

Chapter 6

Membrane Structures

Principles, Details and Projects

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Abstract The point of view of designers and suppliers. Ten membrane experts founded formTL in April 2004 with the aim to design light covers and beautiful structures. The company is constantly looking for the clarity of the plain detail and the logical structure of the project. The chapter contains a series of lightweight architectures realized with textiles and foils.

6.1 Introduction

Membrane structures are often used when large spans need to be realised in short time with a reasonable budget. In the majority of the cases, short realisation time means that the design process is parallel to the realisation, a high level of prefabrication and short installation time.

The limitation to a few suppliers and interfaces is an advantage for timing and costs. With reduced requirements on insulation values, cost optimised structures can be realised. These structures are extremely light, starting with approximately 2 kg/m² above foundation. High tension forces cause a higher foundation effort.

6.2 Theory

Membrane structures carry their load as tension in the plane of the membrane. Every applied load needs therefore a change in geometry to reach a new equilibrium state. Loads are carried biaxial in the membrane. To guarantee the biaxial load bearing behavior and to avoid slack areas, the membrane is pretensioned in both directions. We differentiate between mechanically tensioned structures with

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anticlastic curvature and pneumatic structures with synclastic curvature. With design parameters we can develop typical construction principles (Tables 6.1 and 6.2). Most tensile structures can be classified with the following categories or a combination of them:

Table 6.1 Design parameters for lightweight structures (Source Courtesy formTL)





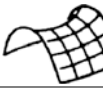

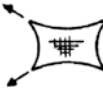

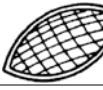
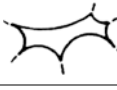








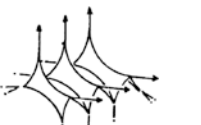
Surface, open or close	Net		Membrane	
Loads, wind and snow	Flat surface		Spatially curved surface	
Surface, form	Saddle = anticlastic curvature		Pneu, cushion = synclastic curvature	
Method of prestress	Pull borders outside Pull weft of membrane to prestress warp		Air pressure	
Border	Fixed boundary		Free boundary (e.g. cable)	
Additional supports	Point - highpoint - lowpoint		Line - cable - linear profile - arch	
Cutting pattern	Radial pattern		Parallel pattern	

Table 6.2 Types of tensile structures (Source Courtesy formTL)

Spacially curved and tensioned membrane		Pneumatic structure	
Spacially curved and tensioned cable-net with cladding		Shell	
Cable supported membrane structure			

- Hypar surface;
- Arch membrane;
- Cone structure;
- Ridge and valley cable membranes (folded plates);
- Cushion;
- Bubble;
- Cable girder.

6.3 Detailing

Characteristic is the concentration of membrane-stress in border-, ridge- or valley-cables. These cable forces are collected in individual nodes, redirected and anchored in the ground or in neighbour buildings.

6.3.1 Typical Details

An important for achieving strength is the joining technology.

Furthermore the seam layout plays an important role in the architectural appearance. Typical details are:

- Welded seam
- Clamping joint (Fig. 6.1);
- Cable cuff (Fig. 6.2);
- Clamped border line (typical for PTFE-glass);
- Fixed clamping;

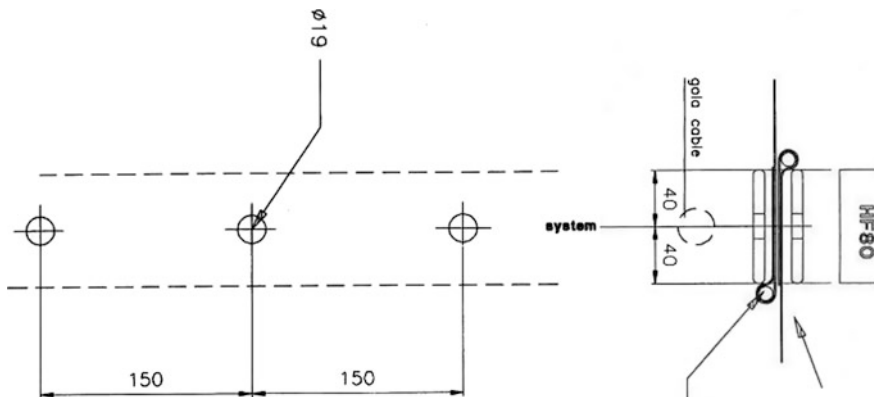


Fig. 6.1 Clamping joint (Source Courtesy formTL)

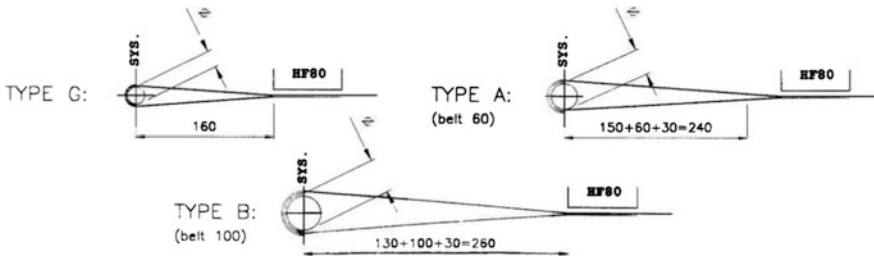


Fig. 6.2 Cable cuff (Source Courtesy formTL)

- Cone rings;
- Membrane tips;
- Cut outs.

6.3.2 Cutting Pattern

To generate the double curved shape the membrane needs to be cut along predefined cutting lines (typically geodesic lines). The pattern width is to be defined in accordance with the allowable distortion and the material width (Fig. 6.3).

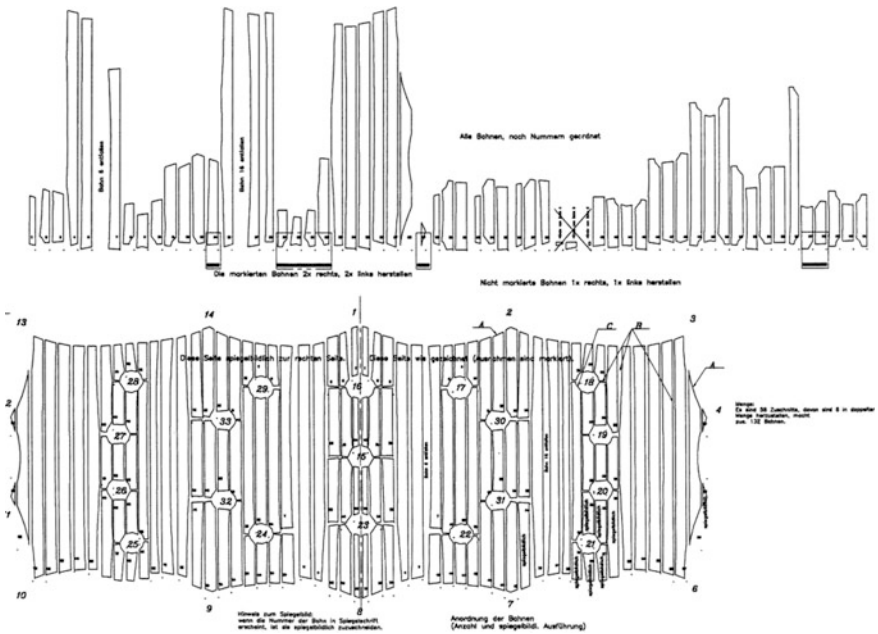


Fig. 6.3 Sample of a seam layout (Source Courtesy formTL)

Fig. 6.4 Forum Kirchberg
(Source Courtesy formTL)



Fig. 6.5 Velodrome Abuja
(Source Courtesy formTL)



Fig. 6.6 Nouvelle
DestiNation (Source Courtesy
formTL)



Fig. 6.7 GEK Travelling
Exhibition (Source Courtesy
Schienbein + Pier)



Fig. 6.8 Tropical Islands
(*Source* Courtesy Ceno Tec)



Fig. 6.9 Kongsberg
Jazz-festival (*Source*
Courtesy Canobbio)



Fig. 6.10 Weltjugendtag
Köln (*Source* Courtesy
formTL)





Fig. 6.11 Bancoposta, Italy (*Source* Courtesy formTL)

6.4 Projects

The following projects show the great variety within the field of textile architecture.

The atrium roof for the Shopping Mall Forum Kirchberg in Luxembourg has been developed to bring sufficient daylight into the high mall, with still a reasonable shading, so that the cooling energy can be reduced (Fig. 6.4).

After the failure due to a thunderstorm, the Velodrome in Abuja has been rebuilt as a redundant system with a primary cable net, that is still stable even if in the future one or more panels should be damaged (Fig. 6.5).

The project Nouvelle DestiNation was one of the federal pavilions on the Expo in Switzerland in 2002. The concept was a breathing air supported hall with noticeable deflections (Fig. 6.6).

For a road show through Germany the health insurance company GEK needed an adaptable exhibition space for indoor use that would fit for whatever location in different cities (Fig. 6.7).

The former Cargo Lifter Airship hangar was converted into a leisure area with a 20,000 m² transparent cushion roof on the south side (Fig. 6.8).



Fig. 6.12 NTC London (*Source* Morley von Sternberg)

Fig. 6.13 Zenith of
Strasbourg (*Source* Courtesy
Canobbio)



Fig. 6.14 Athens Heart
(*Source* Stelios Tzetzias)



Fig. 6.15 The Modern
Teahouse (*Source* Courtesy
Museum für Angewandte
Kunst, Frankfurt/Main)



The stage roof for the Kongsberg Jazz festival is an example for extreme variations in radius over the roof surface. The long cutting pattern varied from full width down to a few centimetres back to almost the full width (Fig. 6.9).

To celebrate the mass one night at the World Youth Day 2005, an altar was realised sitting on a hill and covered with an illuminated cushion, glowing like a bulb (Fig. 6.10).

The pneumatic sphere for Bancoposta was used for a road show through Italy. Inside is a stiff steel structure, so that no airlocks are required (Fig. 6.11).

For training purposes the LTA in London built a temporary roof over a clay court, so that the training is also possible from autumn to spring (Fig. 6.12).

The façade of the Zénith de Strasbourg is made of 12,000 m² highly translucent orange membrane (Fig. 6.13).

The atrium of the shopping mall Athens Heart is covered with the combination of a retractable roof and ETFE cushions towards the north (Fig. 6.14).

As a present from Japanese companies the city of Frankfurt/Main received the Modern Teahouse, a double layer inflatable roof, used for tea ceremonies (Fig. 6.15).