6. Tent Structures

6.1. INTRODUCTION

Tent structures are affined to cable structures. They can resist only tensile strength. They are made of fabric materials which are thin and flexible. They carry loads primarily through the development of tensile stresses. The membrane structure is prestressed by externally applied forces so that it is held completely taut under all anticipated load conditions.

6.2. Fabric material

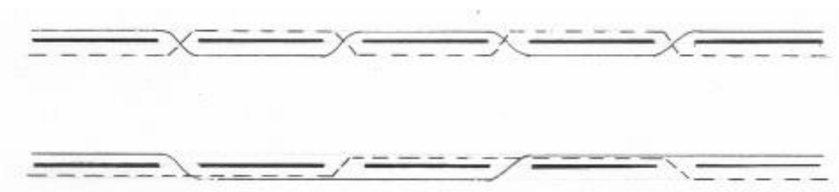
Natural textiles made of animal skins or plants, rather used in the old times

Technical textiles: a coated textile woven in two directions

Simple woven.

Panama woven: mostly used in structures. The weft directional fibers remain more straight, which is more favorable regarding elongation and strength. The fibers straighten less due to load, which means the material behaves more rigid.

Upper: simple woven; Lower panama woven

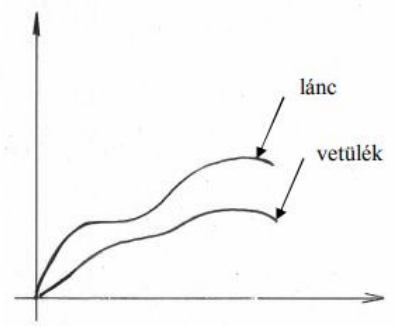


The fibers of the fabric can be made of polyethylene (nowadays not used), polyester, and glass fibers.

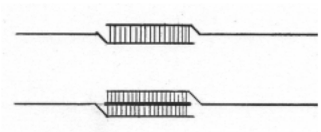
The fabric material is usually coated by the so called matrix, which makes the surface continuous, protects the fibers, gives a slight shear strength, and makes welding possible. This matrix can be made of PVC or Teflon (PTFE)

The textile materials are orthotropic (their behavior in the two perpendicular direction is different), nonlinear (the Hook law is not valid for this material), and has only tensile strength (its shear strength, coming mostly from the matrix properties, is only 1/50 – 1/100 of the tensile strength).

Nonlinear behavior of textiles (lánc=chain or warp direction, vetülék=weft direction):



The connecting of textiles was traditionally made by sewing, nowadays they are welded in 2-6 cm breadth. Welding of Teflon is more complicated then PVC. In case of Teflon welding the surface has to be burnished and connecting layer has to be added before the welding is done at more than 300°C.



Some typical technical textile combinations and their properties:

Polyester fabric coated by PVC: rather ductile, cheap, and the required auxiliary structures are cheaper, but PVC is sensitive to UV radiation so their lifespan is short (10-15 years). Can be found in different color, but gets dirty fast.

Teflon coating: resistant, not sensitive to UV radiation, remains clean, expected lifespan: 30-40 years. Rather slippery, which hardens the construction process. Only in white color. Expensive.

Polyester fabric coated by Teflon: relatively easy construction process

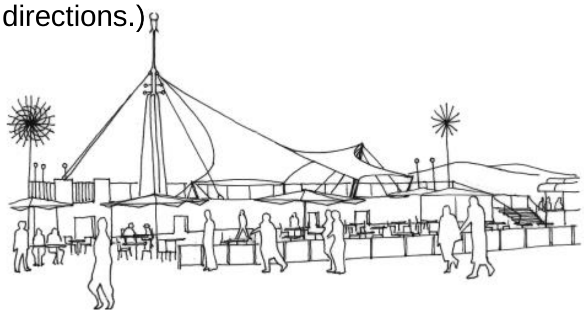
Glass fiber fabric coated by Teflon: hard to prestress the textile.

ETFE: transparent film without reinforcing fibers. Only for small spans. Typical for pneumatic tubes and cushion structures.

6.3. Typical tent structure

In case of tent structures, the most important is that the textile material should be tensed in every direction. Without this tension the soft material would not keep its form, it would hover in the wind. The principal load on the structure is the prestress to keep the geometry of the structure. The structures can be group based on the way the prestress is applied on the membrane:

Tensioned tents: prestress is applied on the edges, the geometry has to be hyperbolical (the principal curvatures have to curve in opposed directions.)

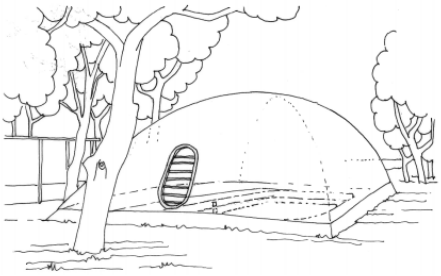


Pneumatic tents: a membrane structure that is placed in tension and stabilized by the pressure of compressed air. A pneumatic structure consisting of a single layer supported by an internal air pressure slightly higher than normal atmospheric pressure and securely anchored and sealed along the perimeter to avoid leaking can be called as one-layer air supported structure. Air locks are required at entrance to maintain the internal air pressure. The overpressure can be calculated from external effects, like wind load or snow load. The exceptional snow load (2 kN/m^2) is the biggest effect on the structure, so according to regulations this effect has to be equilibrated by the overpressure.

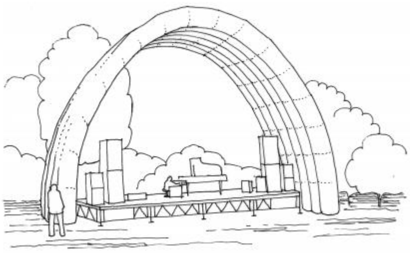
$1\ A \approx 10^5\ Pa = 10^5\ N/m^2 = 100\ kN/m^2$ so $2\ kN/m^2 = 0{,}02\ A$

The maximal overpressure the human body can tolerate without side effects is 0,03 A (for daily use).

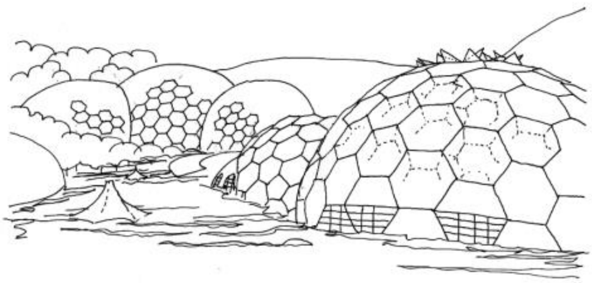
The overpressure, the air exchange, and heating can be obtained by relatively small mechanical equipment and energy input. The collapse of an air supported structure is relative slaw, so there is enough time to escape in case the mechanical equipment stopped working.



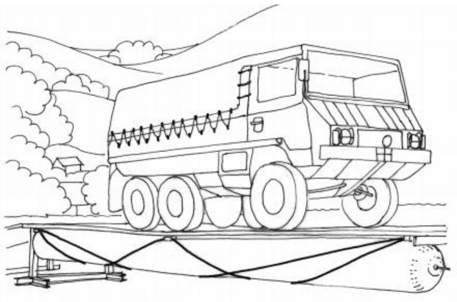
Pneumatic tubes: behaves similarly to the inner tire of a bicycle. Cylindrical or sphere like structures are typical. These pressurized inflated elements are shaped to carry load in a traditional manner. Mechanical equipment is also required to maintain overpressure in the structural elements, but as volume of the escaping air is smaller, so the required energy to obtain the overpressure is also smaller than in the case of one-layer air supported structures.



Cushion structures: a special type of pneumatic tubes. The air pressure stabilized cushions are in a frame. They are typically made of transparent ETFE so the maximal span of these cushions is 4-8 m.

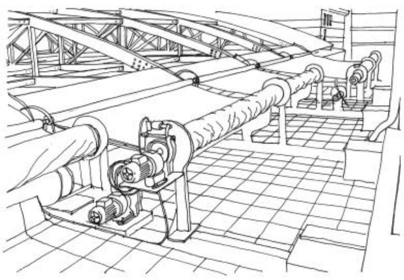
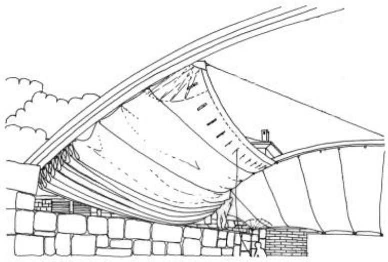
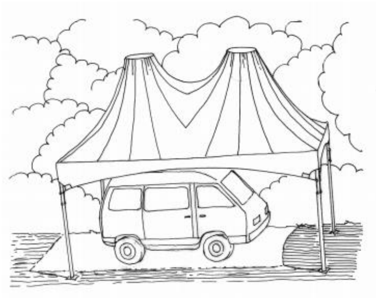


TensAirity: a pneumatic tube reinforced by rigid bars and cables. This cable reinforcement increases the load carrying capacity and the confidence. It behaves like a traditional beam, the compression is carried by the rigid bar or the air pressure, the tension is carried principally by the cables and secondarily by the textile material.



Mixed structures: where the tent is only secondary structure like cable roofs and rigid structures

Mobile structures: as the self-weight of textile materials is small it is often used in mobile structures. The textile material can be moved in small structures, like shading of balconies. At bigger structures it is recommended that the textile material is tensed on a frame, and the whole element is moved. Tent structures are used from temporary structures as well.

6.4. Construction process

The design process starts with the definition of the architectural concept and the form finding based on static and geometric calculations. The result of the design process is a pattern which can be manufactured afterwards. After cutting the pattern the parts have to be welded together. At site this already welded textile can be assembled with the supporting structure.

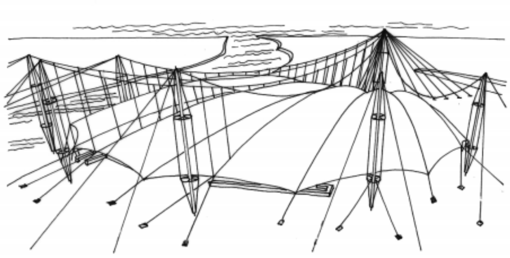
6.5. Edges, support of the tent structure

Cable edges: The ductile textile can be supported by ductile cable edges. The difference in the behavior of textile and of cable has to be considered to avoid ice ponds.

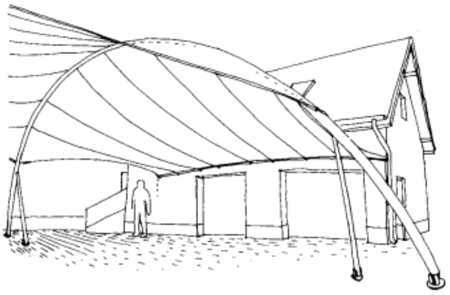
The shape of the cable edges has to be a catenary curve.

At the design process the shape of the cable edge can not be defined clearly as the shape and the prestress of the textile on it is not yet designed. The structure is overdeterminate. If a soap film like stress distribution is given than the force in the cables has to be given as well. The stress at the surface and the force in the cable defines together the shape of the cable edge. In case of Pelikán-membrane like stress distribution the horizontal components of the stresses are given, so the horizontal component of the force in the cable edge is known.

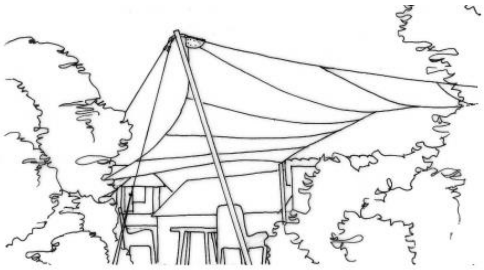
Inner cable supports can be used if the direction of the textile is modified or the resistance of the textile material is not enough.



Rigid edges: They do not fit to the textile material but due to architectural concepts they are often used. Their form can be straight or curved but sharp edges should be avoided. It is recommended to let the free movement of the internal supporting elements and hold them by the textile structure.



Mast: Recommended to connect to the foundation by a hinge. A mast gives a support at a point of the textile. To avoid damages from the concentrated force acting on the textile a load distribution ring or cable is recommended.



6.6. Recommended site:

https://www.tensinet.com/index.php/projects-database/projects