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Dalton Park (County Durham, UK)

ARTICLE ON TENSILE FABRIC STRUCTURE

OR TENSILE MEMBRANE STRUCTURE

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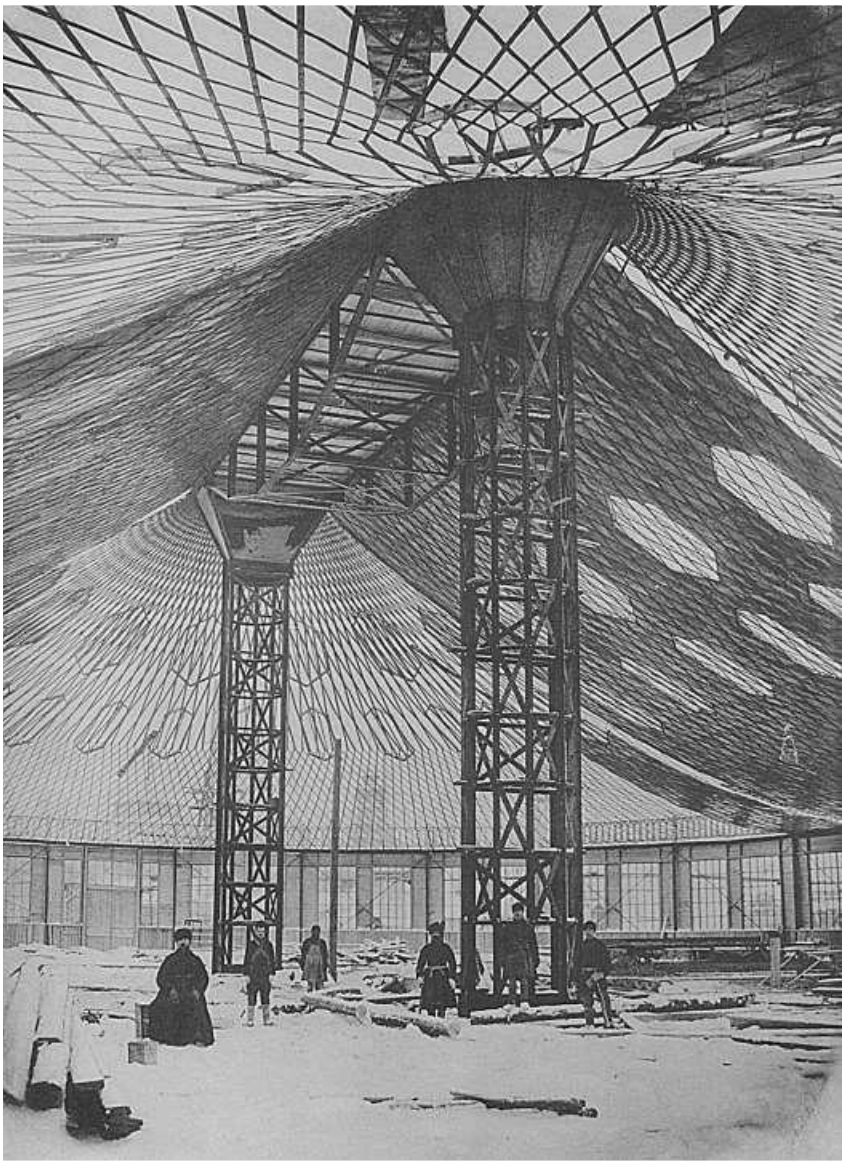
Tensioned Fabric Structure: A structure where the exterior shell is a fabric material spread over a framework. The fabric is maintained in tension in all directions to provide stability.

or

Tensile Structures

Tension roofs or canopies are those in which every part of the structure is loaded only in tension, with no requirement to resist compression or bending forces.



The world's first tensile steel Shell by ***Vladimir Shukhov*** (during construction), Nizhny Novgorod, 1895

Why tensiles are the shape they are?

•Large flat pieces of fabric are very poor at resisting loads.

•Imagine four of you each pulling on the strings laced through a tennis ball. Fig 1. A fifth person pushing down on the ball can deflect it easily.

•Fig 2. The ball is now locked in space. Apply this principle to fabric and you have created 'anticlastic' double curvature. Sounds grand but actually is simply derived from one of three fabric shapes; the hypar, the cone and the barrel.

Barrel Vault

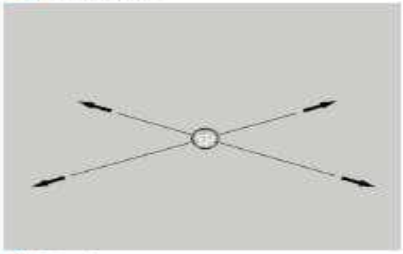


Fig. 1

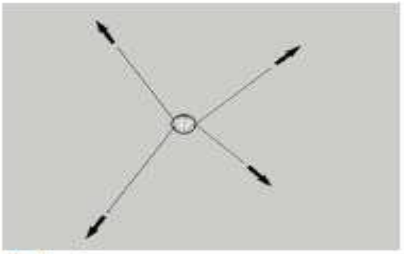


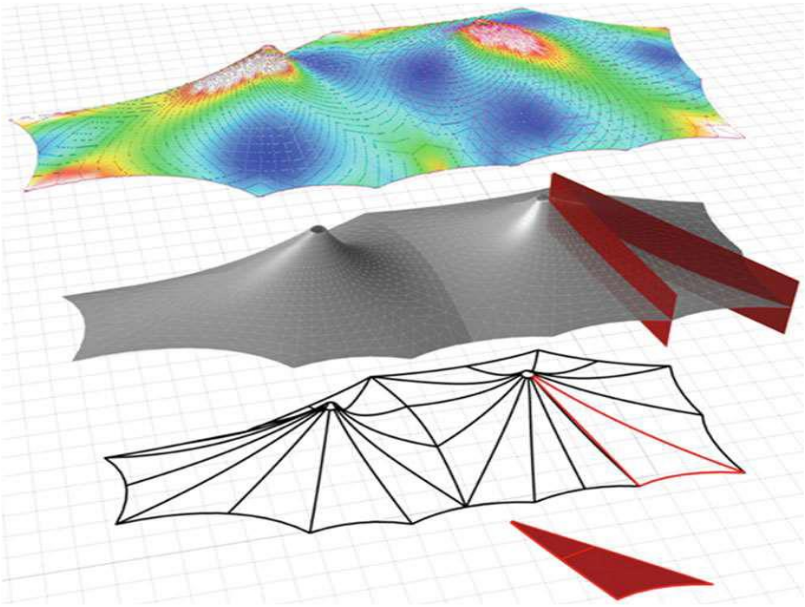
Fig. 2

Cone

Hypar

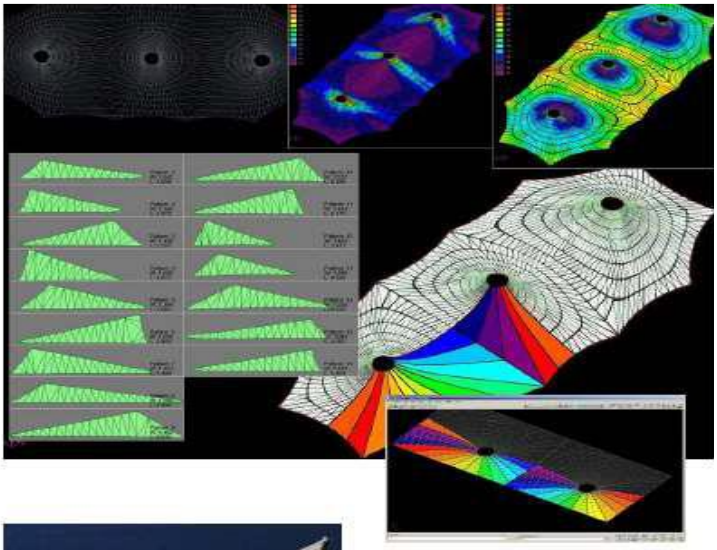
Design process for membrane structures:

01. Form finding
Establish the equilibrium where the architectural idea and structural idea should converge to a point which is both aesthetically pleasing and structurally efficient.
Consider the issue related to chosen material so manufacture is involved from first day of design.



02. Static analysis:

Predicting the stress and development which rise in the tensioned surface due to the presence of external load such as snow or wind.



03***. Patterning:***
The three-dimensional surface, found by the means of the form finding, is flattened obtaining a two dimensional cutting pattern for manufacturing of fabric.

04. ***Dynamic analysis:***
Evaluation of the interaction between a fluctuating external load and the structure.

Exceptional Advantage of Tensile Structure:

There are many great advantages and functional benefits of tensile membrane structures and here are few reasons why:

Flexible Design Aesthetics - Tensile membrane structures provide virtually unlimited designs of distinctive elegant forms that can be realized because of the unique flexible characteristics of membrane resulting in an iconic and unique
structure or feature for any building owner, city or even region.

Outstanding Translucency – In daylight, fabric membrane translucency offers soft diffused naturally lit spaces reducing the interior lighting costs while at night, artificial lighting creates an ambient exterior luminescence.

Excellent Durability – With several different membranes in the market place such as PTFE fiberglass, ETFE film, PVC, and ePTFE, the durability and longevity of tensile membrane structures have been proven.

Lightweight Nature - The lightweight nature of membrane is a cost-effective solution that requires less structural steel to support the roof compared to conventional building materials, enabling long spans of column-free space.

Low Maintenance – Tensile membrane systems are somewhat unique in that they require minimal maintenance when compared to an equivalent-sized conventional building.

Cost Benefits – Most tensile membrane structures have high sun reflectivity and low absorption of sunlight, thus resulting in less energy used within a building and ultimately reducing electrical energy costs

ADVANTAGES FABRIC TENSILE STRUCTURE

One of the main advantages of fabric structure is that you can install it rapidly and easily.
Tension fabric buildings provide abundant daytime lighting that is bright and natural,
the interior of a fabric structure is an inviting environment that people, plants and animals thrive in.
Fabric buildings are Acoustics exceptional; no sounds of pelting rain.
Fabric buildings have Low cost per square foot, Initial investment is low.
Fabric buildings are self-cleaning; never needs painting; dust, dirt, pollutants wash off with Water no rotting parts to replace.
Fabric structures are durable, corrosion resistance. salt, fertilizer and other corrosive materials
have virtually no effect on polyethylene fabric.
Flexibility, when a large clear span building with tall overhead clearances is needed,
a fabric structure is an economical solution.

COMMON MISCONCEPTIONS

• FABRIC STRUCTURES CANNOT TAKE HEAVY WEATHER CONDITIONS (i.e. FALSE)
• FABRIC IS ELASTIC AND STRETCHES Fabric has a strong tensile strength and will creep (stretch very slightly) only a few percent over 20 years of use.

Advantage

Unique designs
Lightweight and flexible
Environmentally sensitive
High strength weight ratio

Disadvantage
• Little to no rigidity
• Loss of tension is dangerous for stability
• Thermal values limit use

TYPES OF FABRIC STRUCTURES

• Saddle roof
• Mast supported
• Arch supported
• Point supported
• Combinations

MATERIAL FOR TENSILE MEMBRANE:

Structural Fabric

Structural fabric is the material that defines lightweight tensile structures.

Requirements

As a primary structural element, it must have the strength to span between supporting elements, carry snow and wind loads, and be safe to walk on.
As enclosure element, it needs to be airtight, waterproof, fire resistant and durable.
As daily use element, it requires to transmit daylight, reflect heat, control sound, and be easy to keep clean.

Sample Materials

Fiberglass, Polyester Cloth, PVC, Teflon.

TYPES OF FABRIC MEMBRANES

PVC

- Less expensive
- 15 to 20 year life span
- Easy to erect

•SILICON GLASS

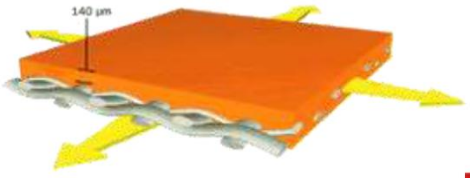
- Higher tensile strength
- Brittle, subject to damage from flexing
- 30+ year life span

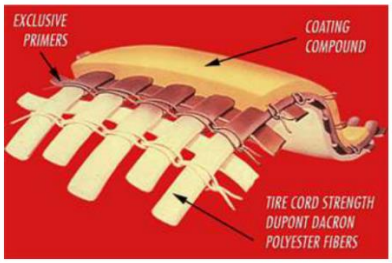
TEFLON GLASS

Similar to silicon glass, less brittle.

MEMBRANE

Forms the enclosure of the structure. Connections can be glued or heat welded





Cables

Cables serve a number of functions in tensile structure applications:
reinforcement of the fabric where the spans and stresses get too large; linear tension support elements along edges; tie-backs and stays to stabilize rigid support element.

Requirements
The cables need to be light, high-strength and flexible to some extent.

Sample Materials
High Strength Bridge Strand, Steel,
Glass Fiber.

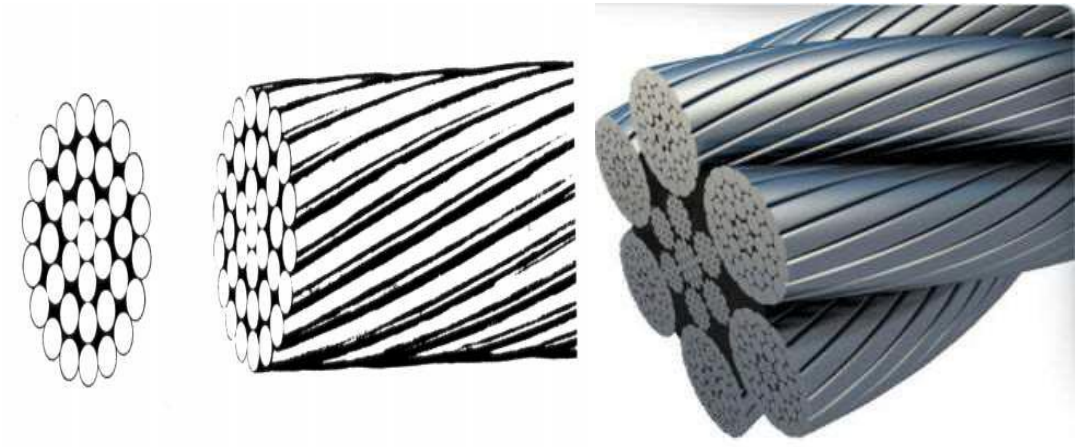


Figure 1: High Strength Steel Cable (HSS)

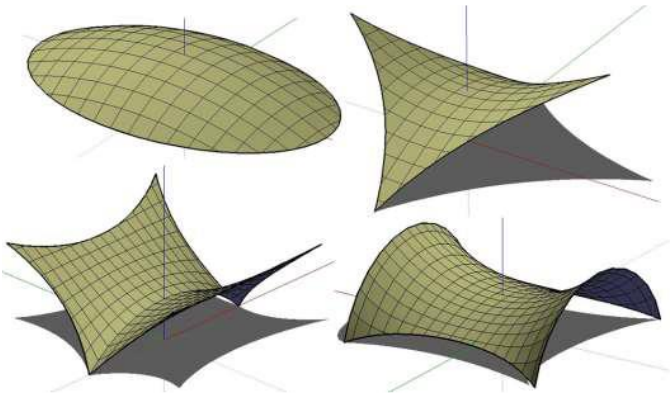
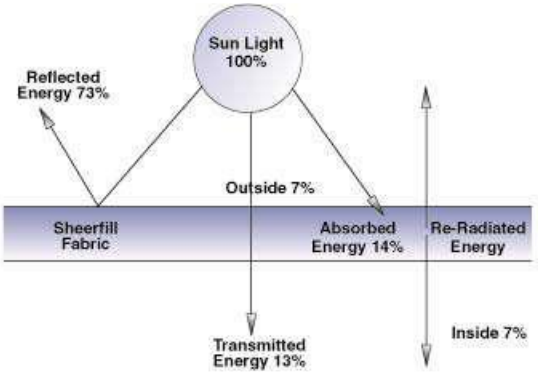


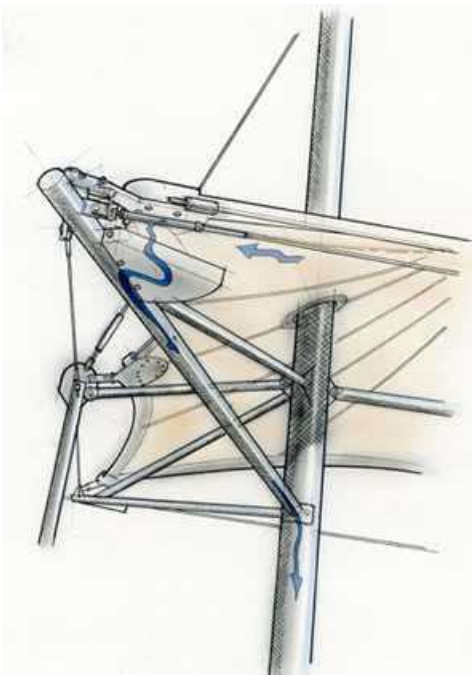
Figure 2: GRID SHOWS THE BASE OF CABLE IN STRUCTURES

SOLAR BEHAVIOR



WATER DRAINAGE VIA MEMBRANE PLATES

OPEN STRUCTURE



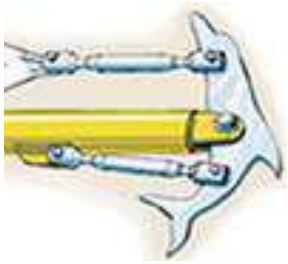
SPECIALIZED HARDWARE

BALE RING / MEMBRANE PLATE

• Provide a link between the membrane and structural elements.
– Bale rings are used at the top of conical shapes.
– Membrane plates accept centenary cables and pin connection hardware.

Tripod head with centenary cables

Centenary cables at a side connection



Tensioner

Extruded section with membrane plate and centenary cables

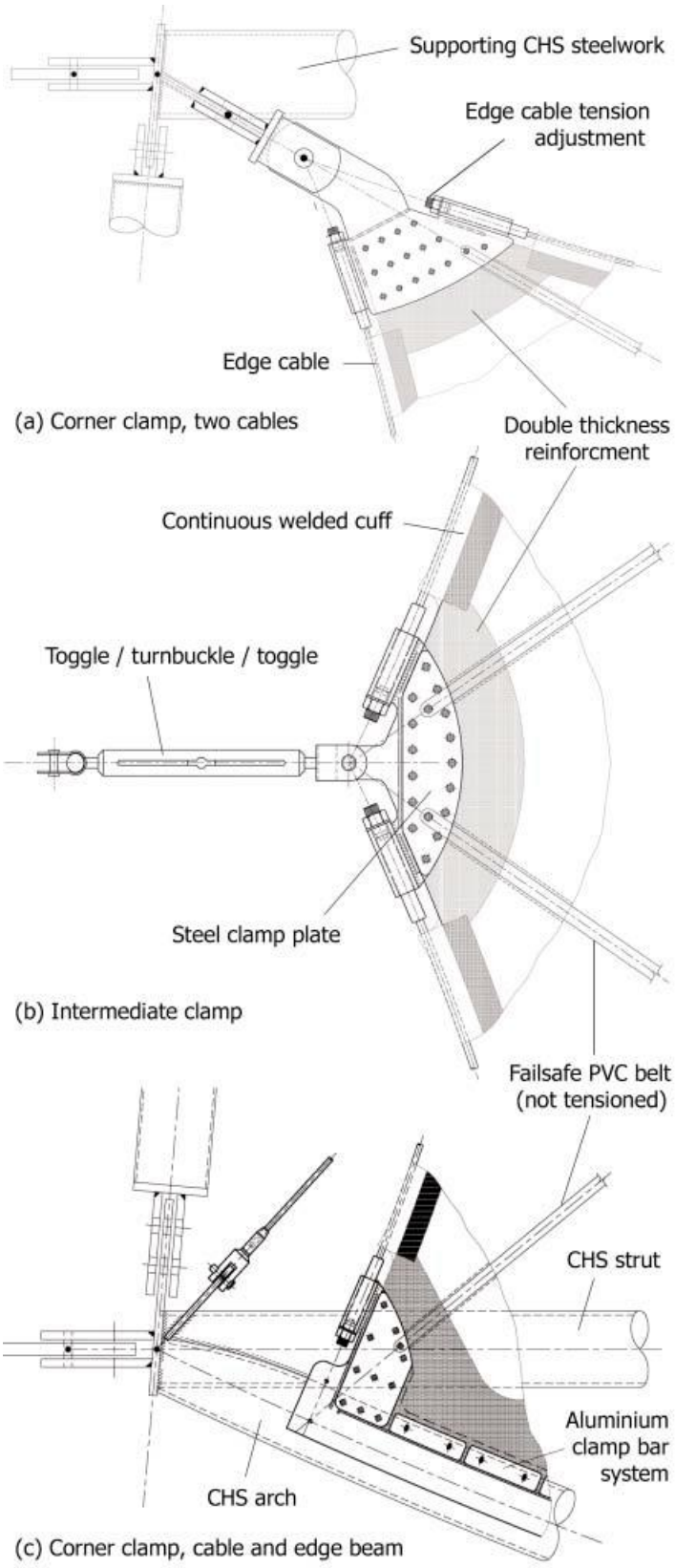


Figure Membrane connection details

Resources:

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