Tension forces in textile architecture
Introduction to form-finding, possible shapes, equilibrium of forces and structural behavior of tensioned surface structures

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Tensile Surface Structures

Technical textiles
- Coated woven materials
- Only resist to tension

Tensile Surface Structures
Form-active structures = Depends on the external load Large deformations can occur

Tensile Surface Structures
Hanging cables + tensioning cables opposite curvature = Stable construction

Tensile Surface Structures
Anticlastic surface =
- Double curvature
- Positive in 1st direction + negative in 2nd direction

Tensile Surface Structures
Synclastic surface =
- Double curvature
- Positive in 1st direction + positive in 2nd direction
Inflated systems
Pretension stabilises the system: can carry downward loads

Pretension stabilises the system: can carry upward loads

Pretension in the surface stabilises the shape

Typical anticlastic shapes
- Saddle
- Conical with high or low points in the surface

Formfinding
- Geometry of the equilibrium form
- Internal forces in this equilibrium form

Primary structure
- Transfers loads and pretension to the foundations
- Can consist of
  - Struts + tie cables
  - Beams
  - Arches...
Tensile Surface Structures

Consist of
- supporting structure
- curved tensioned surface
- connections
- anchorage

Disaster relief
Plastic tarp?
Structurally stable set-up?

Clever roof? Avoid ponding and wrinkling?

Clever roof concept
- New type of shelter!
- To be used during the first hours after disaster
- Material & components pre-positioned
- Shelter for rain, heat and cold
- To be used for different functions: first aid, meeting zone …

Clever roof concept
- Structurally stable
- Cheap

Clever roof concept
'Simplistic' design with natural materials to meet basic needs …
nothing fancy, nothing complicated, as architecture was just being born as a utility'

http://www.unrefugees.org.au
http://landarchs.com/tick-vs-.lock-architecture/
Clever roof concept

Existing shelters
Well ‘tensioned’ tent: Sahrawi tent Aousserd refugee camp 2002
http://www.flickr.com/photos/simon-james/2676927132/in/photostream/
http://www.ragdollfoundation.org.uk/wmmhdiaries/saharafilm.html

Clever roof concept
Designs by architect Frei Otto
- Based on ‘traditional’ tents

Clever roof concept
Designs by architect Frei Otto
- Flexible
- Modular
- Robust
Not made from flat sheets

Clever roof concept
Design by architect Shigeru Ban
PAPER in Architecture

Ban’s practice proposes a return to first principles – exploring the necessity of shelter and its crucial role in the formation and preservation of human society
www.shigerubanarchitects.com
Ban’s experiments in temporary shelter do not only serve craft, but is dedicated to an ease of use that invites the participation by anyone – skilled or unskilled – at any time.

For me, I believe a structure made with materials light enough to be constructed by just one person serves the purposes better.

Shigeru Ban

A group of students and graduates from the Architectural Association School in London produced a kit that can help turn unused spaces into public amenities.
Asif Khan, Omid Kamvari and Pavlos Sideris produced the Public Space Shading Canopy kit after their successful experience erecting a 15m-long lycra canopy in the slum of Favela do Pilar in Recife, Brazil.

The bright yellow awning was slung from telegraph poles and buildings using cables. It was erected in just four hours with the help of locals. It immediately turned the neglected thoroughfare into a vibrant public space.

The new kit, which provides shelter from sun and rain, contains all the materials and tools people need to create their own canopies.

It comes in S, M, L and XL sizes. Robustness?

Elementary shelter:
- Water tight
- Strong

How to obtain a safe Clever roof kit?

http://archithoughts.wordpress.com/

Clever roof concept

- A well tensioned membrane
- Compression elements
- Ropes or belts
- Anchorage
- Made from tarps

A kit solution: different forms with the same elements

A kit solution: Combined with other structural sub-systems

Cable strut model:
- 4 poles
- 8 ropes
- 2 high, 2 low points in the roof (4mx4m)

Clever roof prototypes

Cable strut model: Material strength?
Clever roof prototypes

Bending active model:
- using slender curved beams

250 TE Work Tent
€535

Woven material!

Clever roof prototypes

Bending active model:
- 2 bended beams
- 5 poles
Appropriate bending stiffness needed!

Align the weave directions with the directions of highest curvature // with the edges (6mx4m)

Hypar: fibers aligned with the edges
High stresses in the boundaries, low in the central part
Uniform upward wind loading 0.6kN/m²: Deflection > 0.5m

‘Light’ set-up for light weather conditions
Improve performance when needed:
- Increase the pre-stress
- Add/reinforce poles and tie down ropes

- Reinforce the membrane by additional belts or ropes:
  - Tensioning down for uplift
  - Increasing stiffness/strength in the hanging direction
- Assure anchorage
- Change the shape (fold down)

SLS: Self weight: 2.6 N/m²
Wind pressure: 180.3 N/m²
Deflection without reinforcement: 45cm

SLS: Self weight: 2.6 N/m²
Uplift wind: 360.6 N/m²
Deflection with reinforcement: 59cm
Provide stiffer ropes or belts
‘God is in the details’
Nic Goldschmidt

A structure is as strong as the weakest link …

An appropriate pretension is crucial

Connections
- Low-tech
- Cheap
- Light
- To be assembled by hand building
- Robust

Connections
- Polyethylene sheets
- PVC-coated polyester sheets
- Polyester ropes
- Polyester belts
- Wooden poles

Typical connections
- Rope-rope
- Rope-membrane
- Membrane-membrane
- Pole-pole
- Pole-membrane
- Pole-rope
- Rope-anchorage
- …
Clever roof connections
Several solutions
Membrane-rope
Robustness?

Clever roof connections
Several solutions
Membrane-rope
Robustness?

Clever roof connections
Several solutions
Membrane-membrane

Clever roof connections
Several solutions
Pole-membrane

Clever roof connections
Several solutions
Pole-rope

Clever roof connections
Several solutions
Rope-anchorage
Clever roof connections

How to introduce the pretension?
- Easy in use
- Strong
- Safe

Optimisation according the use in the kit:
- Connections
- Poles
- Ropes
- Materials
- Dimensions
- Transport …

Building with textiles

Example

Temporary pneumatic
Modern Tea House
Museum für angewandte Kunst (MAK), Frankfurt 2007

The inflatable Tea Pavilion is as a kind of a sculpture to be used as a temporary room for ceremonies
Already on his first drawings Kengo Kuma showed a smoothly shaped double-bowl structure. The design was modified and adjusted during monthly meetings of the team.

Membrane HF weldable Gore Tenara 630 gr/m² PTFE-fabric coated with fluor foil with 38% translucency.

The organic shaped structure with membrane cover became a self-carrying double-wall pneu with minimized assembly and dismantling times.

At the footprint the 2 covers are air-tightly welded + 3-4 times per m² point-wisely joined with thin synthetic ropes which leads to a golf ball shape when the air is blown in.

The Modern Tea House was very concisely designed: form, material and structural analysis were one. The details were tested and optimized.

From 10mbar internal pressure the ‘Peanut’ stands up and with 15mbar the flexible bowl is stable enough to face a storm.
The Modern Tea House is a thin-skinned simple room.

Clever roof: complex constraints!

Holistic approach!

Clever roof kit

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