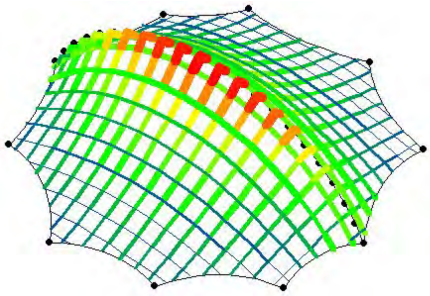

Textile Roofs 2014

May 26th - 28th 2014

Prof. Dr.-Ing. Rosemarie Wagner

Dr.-Ing. Bernd Stary

Deutsches Technikmuseum Berlin

Report

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3dtex, 2014: Sculpture Sail, Eckernförde

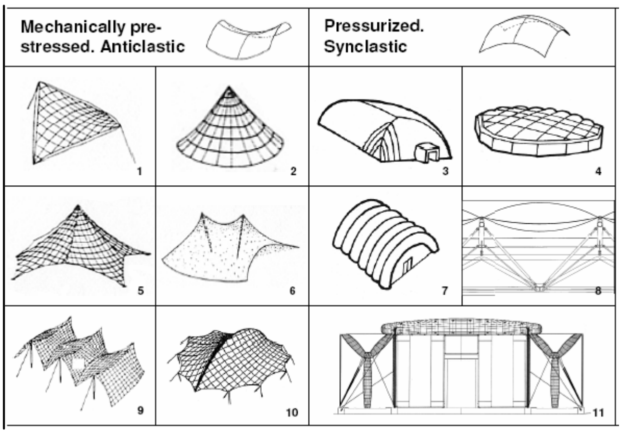
ARCHTEX, 2013: Textile façade

Introduction

Textile Roofs 2014, the Nineteenth International Workshop on the Design and Practical Realisation of Architectural Membranes, took place on 26–28 May at the Deutsches Technikmuseum Berlin, and was chaired by Prof. Dr.-Ing .Rosemarie Wagner (Karlsruhe Institute of Technology, KIT) and Dr.-Ing. Bernd Stary (Berlin Academy of Architectural Membrane Structures, AcaMem). It was attended by 90 participants from 27 countries from four continents. Once again, the attendance demonstrated the success of the event, which has become firmly established since it was first held in 1995.

Introduction to the topic and overview.

Prof.Dr.Arch. Josep Llorens from the School of Architecture of Barcelona introduced the topic of textile roofs and structural membranes pointing out their main characteristics. He started with tents and awnings for shading and mentioned the crucial contributions of Frei Otto and other pioneers who established the fundamentals. He formulated a typology based on the pretension mechanisms and shapes.



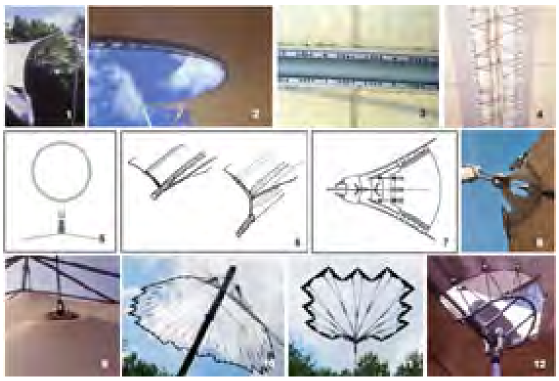
Left: **mechanically pre-stressed**, anticlastic.(1) Saddles and (2) conoids in units (1-2) or compositions (5-6). (9) Wave forms (ridges and valleys and (10) arch supported.

Right: **pressurized**, sinclastic. **Air supported**: (3) single or two layered and (4) reinforced. **Air inflated**: (7) arches, (8) cushions and (11) beams (FESTO Airtecture Pavilion, 1996).

At the moment, cushions (8) are particularly relevant due to recent ETFE applications.

Deployable, movable, adaptable, and transformable roofs were also included, as well as structural supports, cables, arches, masts, beams, and frames. Reference was made to the three basic principles of textile roofs and structural membranes (only tension, double curvature and prestress) and to the characteristic values of the most commonly-used materials (PVC- coated polyester, PTFE- coated fibre glass, and ETFE).

The main membrane requirements (other than structural) were listed, with special reference to light, thermal performance, acoustics, fire resistance, environmental impacts, site location, visual expression, geometry, installation considerations, and economy. The need to consider all of these requirements at an early stage of the design process was shown. The design process was also described, and it was stressed that this does not only include form-finding, structural analysis and patterning. It also comprises initial information, preliminary design, detailing, specifications, bills of quantities, cost estimation, and culminates with manufacturing, handling, transportation, installation, and maintenance.



Design process – Detailing

Edges: **1**,**2** flexible; **3** rigid; **4** semi-flexible **5** Ridges. **6** Valleys. **7**, **8** Corners. **9**,**10** High points. **11**,**12** Low points.

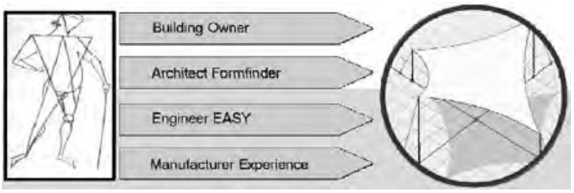
Details cannot be transplanted from a standard repertoire, since they have to be adapted to the requirements of each case. Solutions are successful when they meet the specific requirements of the entire structure.

Any time requirements are changed, the design must also be altered.

To conclude, future trends were identified such as the parametric design, multi-layering, façades as envelopes, energy harvesting, glass substitution, refurbishment, large span roofing of existing buildings and archaeological areas, translucent insulation, new materials, or the Tensairity system for optimizing inflated beams.

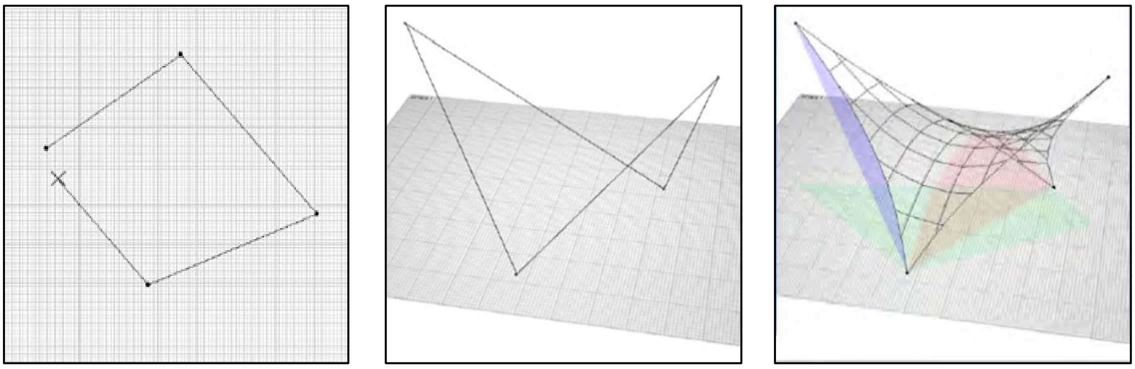
The design of tensile architecture.

DI. Dr. Techn. Robert Roithmayr from the Vienna University of Technology described the philosophy involved in "**Formfinder**", a software developed to assist architects in the design, planning, and cost-effective assessment for the implementation of tensile membrane structures: *http://www.formfinder.at*.



The design process is based on a dialog between clients, architects, structural engineers, manufacturers, and builders, and begins with a hand-sketched spatial model.

Forces, form finding, typology, proportion, components, appearance, and proper detailing are considered.



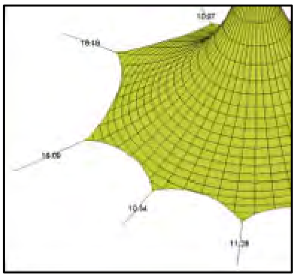
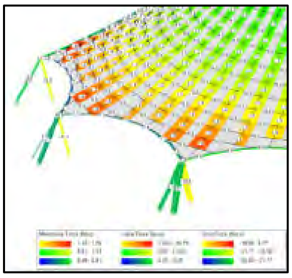
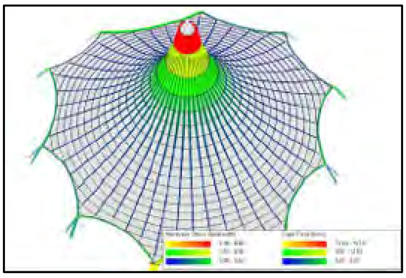
The design can be compared with the projects of the database provided in the software in order to know what has already been built. The result goes to the "**Technet**" related software, in order to proceed with the analysis and patterning.

He also called attention to the postgraduate MEng program "Membrane Lightweight Structures," launched for the first time in November 2010 at the Vienna University of Technology. This program prepares postgraduate students to work in the field of membrane construction, providing profound knowledge for qualified participation in architects' and engineers' offices, in implementing companies in the private sector, as well as in the public sector.

Computational modelling of lightweight structures.

After presenting the company "**Technet**", its partners and academic institutions, Dr.-Ing. Dieter Ströbel went over the main restrictions of physical models, (namely the lack of post-processing, time, and scale), to emphasize the need for computational modelling: *http://www.technet-gmbh.com*.

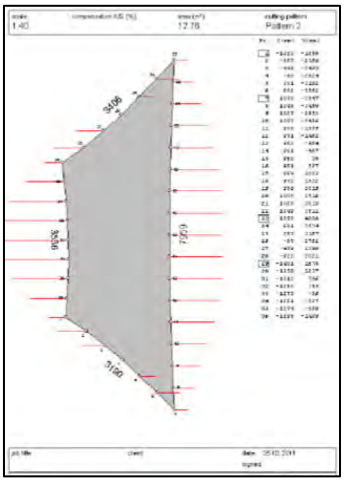
He defined the form finding process as a procedure for the determination of the geometry of a balanced structural system where "form follows force." The material is flexible, and only tensile forces can be borne, leading to anticlastic forms prestressed mechanically, or synclastic forms, where prestress is introduced pneumatically

Regarding the analytical procedure, Dr. Ströbel summarized the linear force density method that begins with the boundaries and mesh, and provides the shape, support forces, force and stress distribution, contour lines, slope arrows, and slope lines for drainage. Automatic generation of primary structure is also implemented, and different net types are made possible in combination with rigid members and enslaved points.

The subsequent static analysis includes shear stiffness, prestress, external loads, cables, bending elements, and struts. It connects to RStab for the stress analysis of the steel members and provides for cross section optimisation.

Tensotech inflated air hall			
	No external loads	Wind (p constant)	Wind ($p \cdot V$ = constant)
Inner pressure	0,55 kN/m^2	0,55 kN/m^2	0,18 kN/m^2
Volume	77.036 m^3		77.321 m^3
Max. stress	25 kN/m	60 kN/m	29 kN/m



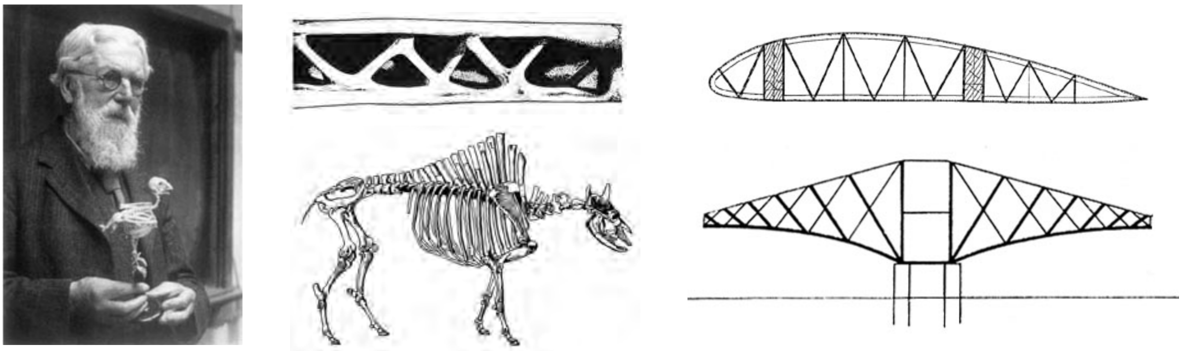
In pneumatic membranes, the gas law $\mathbf{p_1 \cdot V_1 = p_2 \cdot V_2}$ is satisfied so that the volume and interior pressure are inversely related, and hence the membrane stresses are relaxed. "Add- ons" to the system are the silo, car shades, and cushion automatic patterning creators.

In the description of the cutting pattern generation, Dr. Ströbel noted the convenience of following geodesic lines and shortening the dimensions, in order to obtain the prestressed surface that minimizes the distortion. He covered additional aspects, such as checking the lengths and marking the seams.

He concluded by stating that computer models use information from many different experts, and need to be accurate, fast, and usable for mass production.

On shapes, forms and structures.

As usual, Dipl.-Ing. Jürgen Hennicke recounted the principles of lightweight structures, starting with the generating processes of objects in nature and their ability to bear and transmit forces. Key aspects of his presentation were the similarities between form, structure, material, loading, bearing capacity, mass, and energy expense. These principles can be used for design and optimization processes in architecture, as well as a model of thinking, and as a way of proceeding in design, construction, and in life in general.



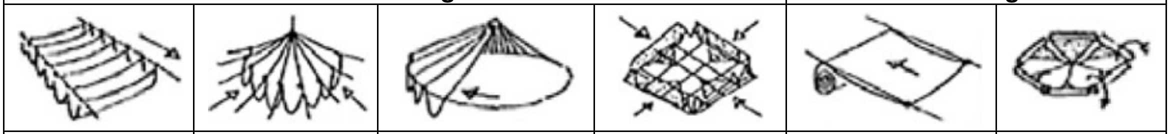
Sir D'Arcy Wentworth Thompson (1860-1948) developed these approaches from the viewpoint of bio-sciences, and introduced them into the general scientific discussion. Top: the metacarpal bone of the vulture's wing is stiffened after the manner of a Warren's truss, often used for the main ribs in aeroplanes. Bottom: the skeleton of an American bison represents the compression parts (bones) of a quadrupedal bridge. In the two- armed cantilever of the Firth of Forth Bridge, the thick lines represent compression members (as do bones), and the thin lines represent tension members (as do ligaments).

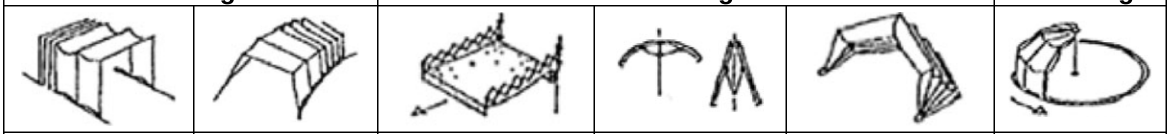
There are two ways of building: 1) with columns and beams (forces follow form) still commonly used nowadays (2014), or 2) funicular shapes (forms follow forces). Left: T-shaped hypostyle hall, temple of Chephren's pyramid complex (2520 bC). Right: A. Gaudi, 1878: "La obrera mataronense" textile cooperative shed, Mataró.

Mr. Hennicke stated that, by taking care of the influences of sun, air, water and earth, lightweight structures can provide everyday architectural solutions, and can fulfil common objectives and demands of people by upgrading the built environment, improving architectural quality by avoiding a conflict with nature, and ensuring our survival through sustainability.

Integrated analysis and experimental verification of kinematic form active structures.

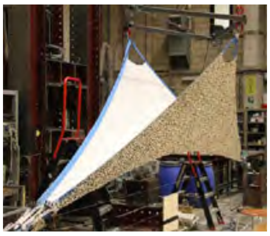
“Can fabrics be tensioned in different configurations for similar applications?” was the key issue formulated by Prof. Marijke Mollaert from the Vrije Universiteit, Brussels, responding to the growing interest in foldable protections.

Type of movement: membrane					
Bunching				Sliding	
					
Parallel	Central	Circular	Peripheral	Parallel	Peripheral

Type of movement: supporting structure					
Rolling		Folding			Rotating
					
Parallel	Circular	Parallel	Central	Circular	Circular

She presented a typology of adaptable membrane structures based on the movement of the membrane or supporting structure.






Three tests and numerical simulations have been conducted with a deployable dome (based on a rotating supporting structure), a full-scale single panel, and a full-scale single foldable unit.

As a conclusion, Prof. Mollaert indicated that the initial question remains unanswered, because the folding of a structure is not an unsurmountable problem. Nevertheless, the tension of the membrane requires adjustments and control in each configuration. The numerical values of stresses are similar, but reinforcements and wrinkling do not fit the experimental values. It seems to be a long way before experiments and simulations match up with each other. A supplementary question arose in this discussion: can a retractable membrane system be stable in intermediate configurations and thus bear snow and wind loads without wrinkling?

Finally, Prof. Mollaert showed the “Soft House” designed by Kennedy & Violich Architecture in Hamburg, an example of dynamic textile façade that moves and turns towards the sunlight, similarly to a sunflower, with photovoltaic cells incorporated into the membrane that make the best use of the sunlight for producing energy. Parts of the façade also cast shade in summer, while in winter they minimise energy loss and allow light to penetrate deeper into the interior. The view can also be adjusted by residents. For more information: *http://www.iba-hamburg.de/en/projects/the-building-exhibition-within-the-building-exhibition/smart-material-houses/soft-house/projekt/soft-house.html*

MORE WITH LESS. Multiperformative surfaces in architectural design.

The most astonishing contribution to Textile Roofs 2014 was presented by LAVA, the Laboratory for Visionary Architecture (T. Wallisser, Ch. Bosse, & A. Rieck). Incredible projects were paraded under the slogan "Man – Nature - Technology." These projects are based on complex surfaces developed by computer for different functions: *http://www.l-a-v-a.net*.

Four milestones by LAVA are: Watercube Stadium, Mercedes Benz Museum, Snowflake Tower and Green Void.

"Learning from nature and advanced computing enables us to conceive structures of incredible lightness, efficiency, and elegance."

World Cup Membrane Structures. Dipl.-Ing.Arch.Ms.L.Brögger and Mr.M.Glass.

Lena and Martin have continued to develop spectacular textile stadiums, recently for the Brasil World Cup: Belo Horizonte, Manaus, and Brasilia: *http://www.gmp-architekten.com/projects.html*.

Comparative life cycle assessment: Texlon ETFE and glass cladding

Dr. Carl Maywald from Vector Foiltec GmbH began his presentation mentioning relevant ETFE applications.

1983: Mangrovehall, Burger's Zoo, Arnheim. 2001: Eden Project, Cornwall. 2008: Water Cube, Beijing. 2010: Kahn Shatyr Entertainment Centre, Astana. 2013: Fisht Olympia Stadion, Sotschi. 2013: Pernambuco Arena, Recife. 2013: The Avenues, Kuwait. 2013: Grasjoch Cablecar, St.Gallenkirch.

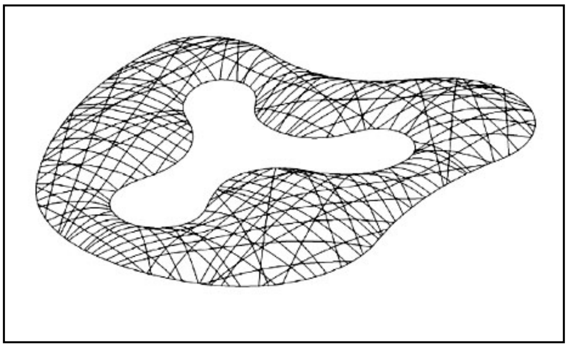
In addition to having transparency, Texlon®ETFE is resistant, aseptic, non-metabolizable, acid-resistant, alkali-resistant, UV stable, self-cleaning, flexible (elongation at break > 300%), and lightweight (1 kp/m^2 for 3 layers). To compare the characteristics of glass with ETFE, a life cycle assessment has been made of two existing roofs: DomAquarée Complex, Berlin and Kapuzinergraben, Aachen.

	Domaquaree Office Atrium: 1.600 m^2				**Kapuzinergraben**			
	Texlon roof		**Glass roof**		**Texlon roof**		**Glass roof**	
	14 three-layer (1 printed and 2 transparent foils) cushions 3 x 40 m. Same structure as glass. No secondary aluminium network		2,7 x 1,33 m panes of laminated glass with low emissivity coating. Steel structure + secondary aluminium network		10 three-layer cushions 2,5 x 16 m with transparent foils.. Light network of steel beams and cables.		2,02 x 1,5 m panes of laminated glass with low emissivity coating. Steel structure with several columns and beams.	
Weight	Kp	%	Kp	%	Kp	%	Kp	%
Steel	95.466	94,7	103.066	55,7	12.250	91,1	78.270	80,7
Aluminium	3.719	3,7	22.103	12	801	6	1.000	1
ETFE	1.323	1,3	-	-	352	2,6	-	-
Glass	-	-	59.113	32,1	-	-	17.601	18,2
EPDM	216	0,2	420	0,2	38	0,3	103	0,1
PP	33	0,03	-	-	9,2	0,1	-	-
Total	**100.756**	**100**	**184.900**	**100**	**13.456**	**100**	**96.974**	**100**

The Texlon cladding system is more environmentally friendly than glass for transparent roofs because the production of Teflon cushions is much more ecological, and the amount of steel and aluminium required is less. Improvements could be made by using renewable energies and less energy-demanding air supply and drying systems. *http://www.vector-foiltec.com*

Aarau Bus Station Canopy

Dipl.-Ing. Gerd Schmid from "form TL" showed in detail the development and construction of the bus terminal of Aarau, designed by Mateja Vehovar & Stefan Jauslin Architektur, which was given a 83,8% approval by the citizens of the city. http://www.archdaily.com/473610/aarau-bus-station-canopy-vehovar-and-jauslin-architektur/



Irregular network of cables

The reflective semi-transparent canopy, qualified as a "functional sculpture," or "blue amoeba cloud," provides protection from rain and snow. The organically-shaped opening in the middle of the inflated cushion intensifies the impression of lightness.

Steel shop design (81 kp/m^2)

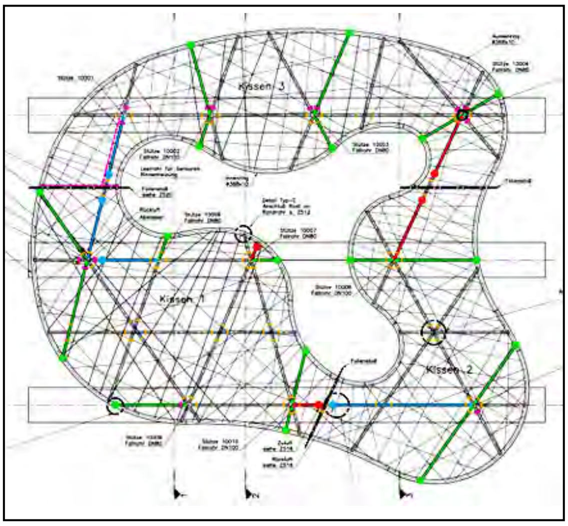


Table structure plan with cables

Beams. border tubes and plates

Installation process

Précontraint TX 30: a new generation of Précontraint flexible composite materials.

Mme. Françoise Fournier from Serge Ferrari S.A.S. presented the Précontraint TX 30 new range with a design life of 30+ years -for tensile structures. This durability is possible thanks to a new top coat technology (CROSSLINK), and a 30 YEAR PVC formulation. Specific accelerated weathering protocols have been designed for this polymer, in order to quantify the photo oxidation rate and the remaining tensile strength after 30 years. She also showed recent applications of the Serge Ferrari products in architecture.

The Arena das Dunas is a football stadium designed by Christopher Lee, Australian architect of Populous, and responsible for the master plan of the London Olympic Games, 2012. The stadium was built in 2014 in Natal, the capital of Rio Grande do Norte Brazilian state, to host football matches for the 2014 FIFA World Cup held in Brazil: *http://populous.com/project/arena-das-dunas/*

The Arena Corinthians in Sao Paulo, Brazil, is the stadium of Sport Club Corinthians Paulista, also built to host the 2014 FIFA World Cup. It was designed by Aníbal Coutinho, and engineered by Werner Sobek:
http://www.ice.org.uk/topics/structuresandbuildings/Case-Studies---Information/World-Cup-2014-Stadiums/Arena-Corinthians

ETFE in China. An overview.

Dipl.-Ing. Björn Beckert from "Seele Covertex Membranes Shanghai Co" presented a report on the development of ETFE for architectural applications in China over the last ten years, with attention to commercial and institutional achievements.

From 2007 until now, the main ETFE applications are distributed as follows: 58.3% sport, 18.6% commercial, 10.6% transport, 9.3% exhibition and 3.2% leisure, offices, greenhouses, industrial facilities, etc.

Guangzhou train station, 2010

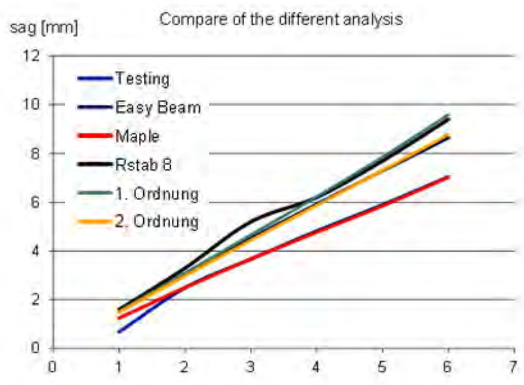
Sun Island membrane structure, Heliongjiang, 2012 (single layer)

Line 11 Longyang Station, Shanghai 2014 (single layer).

He finally concluded that after 10 years, the ETFE market in China can be seen as fully developed. Private investors are increasingly taking advantage of ETFE, while government funds still play a major role in infrastructure projects. The complexity of ETFE projects is increasing.

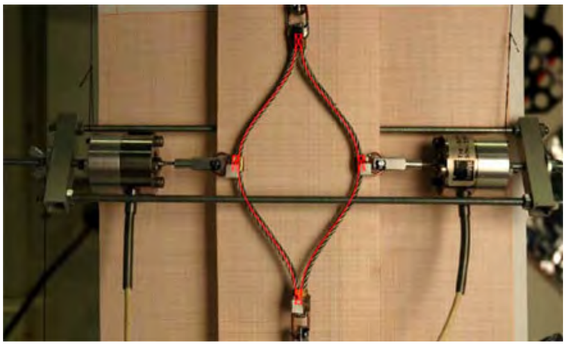
Theory and design of cable-net structures.

Dipl.-Ing. Kai Heinlein revealed the project MemNet, conducted with Prof. Dr.-Ing. R. Wagner from Karslruhe Institute of Technology, which was developed to simulate the behaviour of cable nets used for security, design, zoos, and façades.

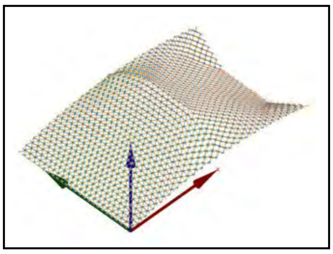


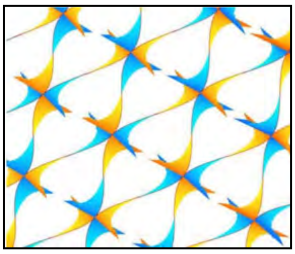
Individual cables were tested in tension to determine the E modulus, which was not constant. Bending tests were also performed, and the relationship between loads and sags were measured. From the comparison of these values based on various simulations, it followed that the moment of inertia under different bending moments is not constant.

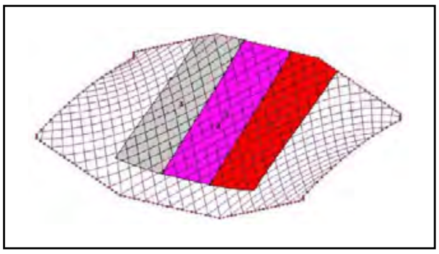
Biaxial testing was performed on a single element of mesh (spreading it out), as well as on the whole net. Due to -bending moments, a lower level of stress in the centre and a higher level in the border of the net were observed.



On the other hand, a mock-up simulation revealed the interdependency between the bending moments on the knot points and the spreading out of the cable net. Finally, the cutting pattern of the textile covering of the net was also explored.







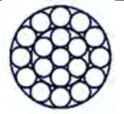
The conclusions were formulated as follows:

- For correct analysis and simulation of cable structures, it is necessary to use beam elements to represent correct results.
- Associated to beam analysis with large deformation, the correct curvature has to be integrated.
- It is possible to simulate with virtual moments of inertia.
- For structural load analysis of cable net structures, it is necessary to know the initial condition of the net or the inner energy.

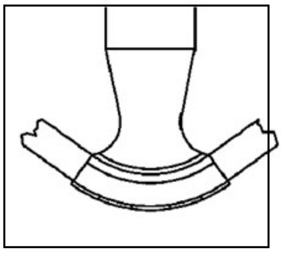
Fastening details. Ropes and fittings.

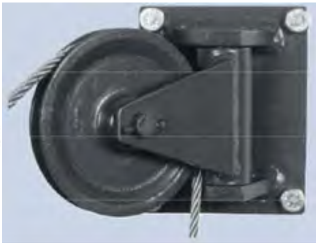
Dipl.-Ing. Thomas Krieger from Carl Stahl GmbH recounted the main features of cables and fittings, and gave some tips on their use in structural membranes.

Because there are more than 9,000 different types of ropes, a selective criteria is needed that can be based on function (running or standing), the required end fittings, tensile strength, breaking load, or environmental conditions.

Ø 6 mm rope		7 x 19		1 x 19
Metallic cross section		14,92 mm^2		21,49 mm^2
Breaking load		≥18.8 kN		≥ 29,7 kN

Typical tensile strength of wires is 1,370 to 2,400 N/mm^2, with higher values corresponding to smaller diameters. The breaking load of the rope and its metallic cross section depend on the diameter of the cable and its composition.





Rope	**Ø pulley**
1 x 19	unsuitable
7 x 7	42·Ø rope
7 x 19	25·Ø rope

In saddles (left), if the radius r_1 is not less than the greater of 30·d or 400·Ø, the breaking resistance of the strand and rope is reduced by not more than 3% (d is the diameter of the cable and Ø is the diameter of the wire, according to EN 1991-1-11: Eurocode 3. Design of steel structures. Part 1-11). For running cable pulleys (right), the diameter of the pulley is related to the diameter of the rope.

When assembling cable ends, care should be taken with the weakest point because it determines the load capacity. Weakest points tend to be at welded forks, bolt contacts or eccentric connections. With the special TENNECT Carl Stahl universal connecting element, most weak points can be avoided: www.tennect.com.

Regarding expansion:

- for temperature, the thermal coefficient is $16 \cdot 10^{-6}$, which has to be multiplied by the length and the difference in temperature
- for construction, no proper values can be calculated
- the increase of length due to tension is (rope length x force) / (metallic section x E modulus).

Handling, assembly, protection, and maintenance were the subject of practical advice that also apply to stainless steel.

Finally, Dipl.-Ing. Thomas Krieger referred to X-TEND, the stainless steel wire mesh for zoos, façades, railings and falling protections: http://www.carlstahl-architektur.com/en/products/x-tend.html

Installation of membrane structures. Requirements and accomplishments.

The installation was the subject of Architect/ Project Manager Claudius Dangel from 3dtex. He exposed some case studies that illustrated different particularities of the process: *http://3dtex.net/*.




The Venezuela Pavilion was first erected in Hanover 2000, and was re-built in Barquisimeto in 2007. An auxiliary temporary structure was used for pre-assembling the petals. The tensioning of the membrane in Hanover was difficult due to the size of the corners. For this reason, they designed a special tool for Barquisimeto.

The installation concept is influenced by:

- Choice of -materials (PTFE-coated glass fabric, or PVC-coated polyester)
- Local conditions on building site regarding the possibilities of delivering, material storage, points of anchoring, other craftsmen, and installation of barriers
- Installation model or simulation
- Installation team: skills, experience in membrane installations, industrial climbers, and number of workers
- Tools: development of special tensioning tools, tool list, cranes, and lifting ramps
- Consultation with the person who will be in charge of the installation
- Wind, rain, snow, and ice make the installation more complicated or even impossible. Weather forecasts have to be checked before and during the duration of the entire installation
- Safety concepts, as well as an emergency plan have to be worked out
- After the completion of the installation, there should be a debriefing between planners and workers to optimize future installations.



Other cases mentioned were the ponding on the Berlin Gasometer, 2011, the accumulation of snow on the PTFE-coated fibreglass "Schoolyard canopy" in Aarau 2012, and the compensation factor for the membrane "Sculpture Sail" in Eckernförde, 2014, not considered in the cable length.

Mr. Dangel concluded by highlighting the need to consider the installation process during the design and detailed planning work.

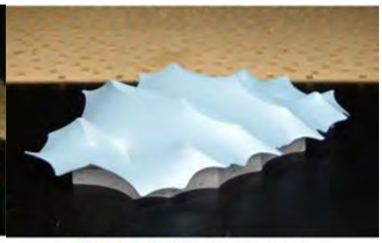
Wind loads on fabric roofs and corresponding dynamic response.

Dipl.-Ing. Michael Buselmeier introduced Wacker Ingenieure – Wind Engineering consultants. Since 1992, they offer services within the scope of applied building aerodynamics and indoor airflow. They provide expert opinions, analysis, prognoses, calculations, measurements, and worked-out solutions which are based on literature searches, simulations, and wind tunnel experiments: http://www.wacker-ingenieure.de/.

Wind tunnel experiments are useful in cases where simple approaches and numerical models cannot be applied. For numerical air flow, pressure and temperature simulations, they use different computer models, including finite element approaches, computational fluid dynamics (CFD), as well as zone/node models. They combine traditional with modern rapid prototyping manufacturing methods to investigate special structures not covered under the standards.

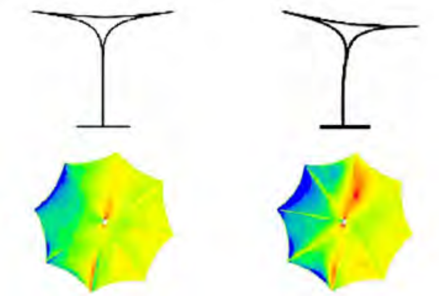

Four Umbrellas (Dublin, Ireland)


Han Chadiri Center (Astana, Kazakhstan)


Olympiahalle (Munich, Germany)

For the structural design of a fabric roof, realistic dynamic wind loads are required. These loads, together with the variability and complexity of shapes make it often necessary wind tunnel testing. Moreover, membrane structures are often attached to larger structures, which complicate wind factors, and enhance turbulences and dynamic excitation, which are situations not addressed by codes or past experience.

The main characteristics of wind tunnel testing are the modelling laws (geometric similarity, similarity of the approaching flow, the flow around the structure), and rigidity. Rigid models are usually used, assuming that deflections are small enough to not influence the pressure distribution. When deformations are significant, additional tests may determine the deflected shape, or theoretical estimations, and numerical calculations may be performed, because aerolastic modelling is extremely complex, inexact, and expensive.

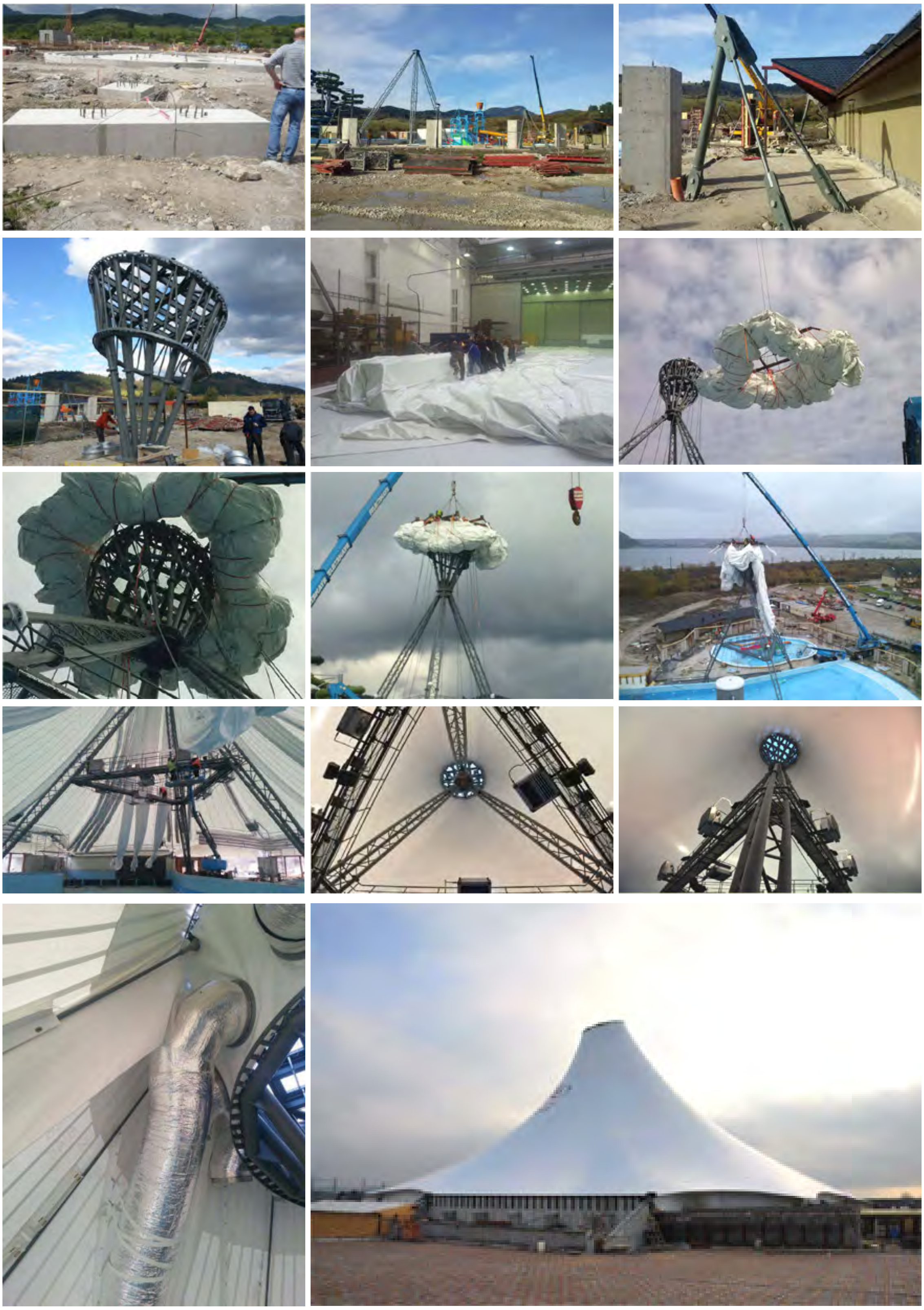


Two case studies were presented: large scale 53 x 53 m umbrellas and 180 x 90 m flat fabric roof exposed to strongly turbulent wind. In conclusion, Dipl.-Ing. Michael Buselmeier summarized his presentation concluding that:

- Wind may affect membrane roof design in various ways.
- Wind effects on membrane roofs can be investigated by means of appropriate wind tunnel tests in a boundary layer wind tunnel.
- The appropriateness of these tests is especially evident with regard to the assessment of structural and local design wind loads and the corresponding dynamic wind loading effects.
- The benefit of wind tunnel tests is demonstrable, especially if the wind engineer is involved in an early stage of planning.

Gino Park Besenová membrane.

Dipl. Ing. Arch. Ján Dolejsi showed in detail the installation of a double-layer membrane for a thermal swimming pool in Slovenia. Particularly outstanding features were, among others, the deep foundation made of piles, the central tripod supporting the high point, and all the ducts hanging from the upper membrane which ran into the cavity.



Textile façade for tower on Velaa private island, Maldives.

Ing. Arch. Zdenek Hirnsal presented Archtex/Kontis, a joint venture that offers complete turnkey projects from architecture design, manufacturing of textile membranes, ropes and supporting structures. Projects include the installation, and are executed around the world.

They designed the textile façade of a tower for a restaurant on Velaa island, the northern atoll of Maldives Islands. The façade was based on irregular elliptical rings with different inclinations. Total height: 25 m, and diameter: 11 m.

A special feature of the form finding and cutting patterns of the membrane (assisted by D. Ströbel), was the cable net inside the windows to transfer the loads through the surface.

All the parts were manufactured in the Czech Republic and in Germany, and were transported by ship to the worksite. Materials for the textile façade included 800 m^2 of Serge Ferrari Stamisol FT381, 380 m^2 of Carl Stahl cable mesh and ropes, 5 T of stainless steel for the façade and 4,5 T of stainless steel for the handrails. Installation was done floor by floor with scaffolding, and was completed in 24 days by 9 workers: *http://www.archtex.cz/en/projekty.html*.

Student's Project Week: **"Cloud of shading"**

The students' project week ran parallel to Textile Roofs 2014.

The subject was "cloud of shading", a flying roof that defies gravity, disregards supports, and hangs from the sky on the Earth instead of standing on the ground, and is easy to install.

The final presentation and discussion took place at the closing of the Workshop.

The following six proposals were presented and discussed by the students, the audience, and the teaching team composed by R. Wagner, L. Brügger, M. Glass and S. Bringmann:

1 Redesigning the logo as a chain of holes.

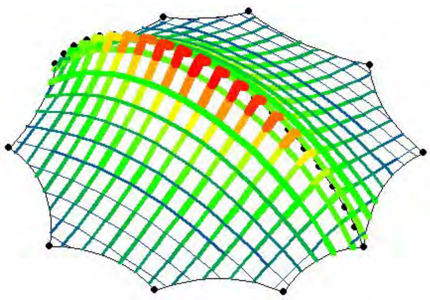
2 Not only a roof for the entrance of the hall.

3 Red flag: an hyperbolic paraboloid for the entrance of the museum.

4 Weather balloons.

5 Drops connected by a net or by Velcro.

6 An inflated torus used as a canopy.



Textile Roofs 2015

May 11th - 13th 2015

Prof. Dr.-Ing. Rosemarie Wagner

Dr.-Ing. Bernd Stary

Deutsches Technikmuseum Berlin

The Twentieth International Workshop on the Design and Practical Realisation of Architectural Membrane Structures will be held on 11-13 May 2015. In celebration of its 20th anniversary, TR 2015 will invite lecturers of the past 20 years. The format will be similar to that of TR 2014, with seminar-style lectures and hands-on activities. It will be preceded by the student seminar and sponsored by AcaMem, gmp, Serge Ferrari, KIT, Carl Stahl, Technet and TensiNet: *http://www.textile-roofs.de*.