TEXTILE ROOFS 2015

Textile Roofs 2015, the twentieth International Workshop on the Design and Practical Realisation of Architectural Membranes, took place on 11–13 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 92 participants from 22 countries covering three continents. Once again, the attendance demonstrated the success of the event, which has become firmly established since it was first held in 1995.

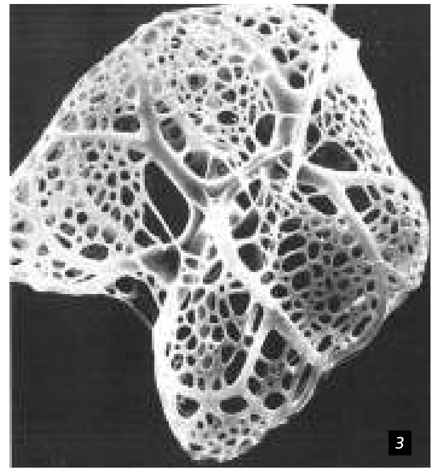

Figure 3. Skeleton of Lyriospyris (IL 33).
Figure 4. Bedouin tent.
Figure 5. Pompeii amphitheatre, 1rst C.
Figure 6. Chartres cathedral 1194-1250.

20 Years of Textile Roofs. A summary.

Prof. Dr. Arch. Josep Llorens from the School of Architecture of Barcelona summarized in 30 minutes what has happened over 20 years, stating briefly: "Textile Roofs has delivered what it has promised." In 1995, the primary objectives were established as "providing fundamental practical information as well as presenting the state-of-the-art in textile roof engineering to facilitate technology transfer and to increase confidence." From 1995 to 2015, 1,479 participants from 69 countries covering 5 continents, certify that these objectives have been fully satisfied (Fig. 1).
The balance of activity also includes 239 lectures by 93 speakers, 3 fabrication workshops, 7 student seminars and the Asia 2003 edition given in the Tongji University, Shanghai. These lectures and workshops covered the aspects that characterize tensile surface, together with the properties of the materials used and their environmental conditions, including some pragmatic concerns such as installation, cost, and durability.
Increasing from 48 participants in 1997 to 100 in 2000, a grand total of 1,479 have attended "Textile Roofs" between 1995 and 2015 (Fig. 2).
It is noteworthy that proportions between attendees from Germany, the rest of Europe, and the rest of the world have remained steady.
Textile Roofs has also facilitated the creation of -TensiNet, the multi-disciplinary association for all parties interested in tensioned membrane construction (http://www.tensinet.com/), master courses in Dessau (http://www.ims-institute.org/membrane-structure-programs.html) and Vienna (http://mls.tuwien.ac.at/) and the Berlin Academy of Architectural Membrane Structures, AcaMem (http://www.acamem.de/).
Nevertheless, the best indicator of the success of these workshops is the announcement of the upcoming 2016 edition: http://www.textile-roofs.com/.

Homage to Frei Otto

Jürgen Hennicke, IL - University of Stuttgart & Vienna University of Technology.

Jürgen Hennicke summarised the ideas of Frei Otto (1925-2015) who passed away last March, after receiving the 2015 Pritzker Architecture Prize.
Interests of Frei Otto may be represented by the-following figures: skeleton of Lyriospyris (Fig. 3); Bedouin tent (Fig. 4); Roman convertible roof (Fig. 5), and Chartres Cathedral 1194-1250, that strongly impressed him (Fig. 6). These works were captioned: "Most of the things we are doing today are not new" because they summarize most of the principles of nature and experimentation developed at the Institute for Lightweight Structures (IL) at the University of Stuttgart.

The Institute for Lightweight Structures was founded in 1964, and over the years, 150 people have worked there. They did not concentrate on a single thing, but - wanted to cover the entire field, searching the laws of Nature to create that which is new. The methodology was experimental, starting from

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Figure 1. World of Textile Roofs 1995-2015: 69 countries from Africa (3), America (11), Asia (22), Europe (31) and Oceania (2).

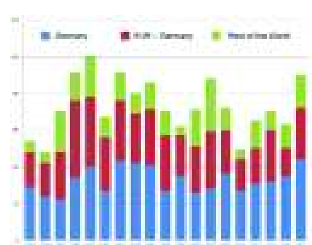

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Figure 2. From 48 participants in 1997 to 100 in 2000, a total of 1.479 attended "Textile Roofs" between 1995 and 2015.

the process of form shaping based on physical modelling. Sources of inspiration were fisherman nets and spider webs, catenaries, suspended bridges, yurts, cantilevered systems, grid shells, air-inflated systems, and trees, among many others.
The research delved into construction methods that could be highly effective with very little material used to fulfil common objectives and demands of people, upgrading the built environment by avoiding conflicts with nature and ensuring our survival through sustainability, a fourth principle to be added to Marcus Vitruvius' (80/70 BC to 13 BC) philosophy: firmitas, utilitas, venustas – that is, solid, useful and beautiful.
A complete biography of Frei Otto is available at: www.pritzkerprize.com/2015/biography

Computational modelling of lightweight structures

Dr. Dieter Ströbel, Technet GmbH:
http://technet-gmbh.de/index.php?id=63&L=1

Dieter Ströbel outlined fundamental aspects of the design concerning analytical form finding, static analysis, add-ons, and cutting patterns. Starting from the restrictions of physical modelling, he raised the problem of finding the form of a mechanically or pneumatically-stressed, double-curved surface made of a flexible material which can only bear tensile forces. He chose the force density method and expounded it step-by-step, showing possibilities and results.
The static analysis is based on a non-linear system that requires approximate values, material properties (simplified or extended with shear stiffness), and external loads provided by codes or tests. Relevant considerations include material directions, cables, struts, bending elements, and gas law (in case of pneumatic structures).
Automatic form-finding, patterning and optimization have been developed for balloons, car-shades, the Astana cable tower, silos, and textile halls.
And finally, patterning is needed because doubly-curved surfaces cannot be represented on a plane without distortion. In addition, planar strips have to be as straight as possible, the width of 2D strips should be as wide as possible, geometrically-developed surfaces have to be corrected, corresponding seam lines must have the same lengths, and cutting drawings have to be transferred onto the fabric. Dr. Ströbel concluded by stating that computer models must be correct, precise, complete, and generated in a fast manner for mass production, making use of information from diverse experts.

The design of tensile architecture

Dl Dr. Techn. Robert Roithmayr

Robert Roithmayr presented the design process of tensile architecture based on the software "Formfinder Architectural Design System" (http://www.formfinder.at). He began by mentioning the players of the design, namely the building owner, the architect, the engineer, and the manufacturer.
He showed the potential of "formfinder" to sketch easily a design from scratch and recommended checking "formfinder" databases for types, built examples, details, and materials.
Useful advice was given regarding the influence of sags in the quantity of forces, deformations, and waterponding situations. Double curvature, the number of corner points, proportions, and directions of the mesh were also reviewed as project variables that influence the outcome.

Referring to details, three interesting options were mentioned:
- Tennect aluminium profiles for linear fixation of membrane borders (Fig. 7) (http://www.tennect.com/fileadmin/files/tennect/specification_sheet_welt-section.pdf)
- The Tennect clamping and fastening system for point or linear fastenings that connects elements and the forces acting on them are adjusted in the direction of pull (Fig. 8). (http://www.carlstahl-architektur.com/fileadmin//downloads/pdf/broschueren/produkt/Carl_Stahl-TENNECT.pdf)
- Carl Stahl X-LED light module system for architectural illuminations (Fig. 9). (http://www.carlstahl-architektur.com/fileadmin//downloads/pdf/broschueren/produkt/Carl_Stahl-X-LED.pdf)

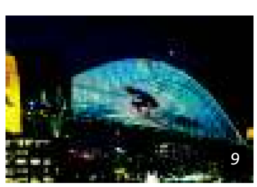

Figure 7. Tennect aluminium profiles.
Figure 8. Tennect clamping and fastening system.
Figure 9. X-LED light module system.

Multifunctionality of membrane material

Dr. Ing. Thomas Stegmaier,
ITV Denkendorf
www.itv-denkendorf.de

A wealth of applications of textiles and fibres have been developed by the German Institutes for Textile and Fibre Research -Denkendorf (DITF). Textiles are soft, cosy, warming, resistant, and they act as barriers against impacts, weather, liquids, and chemicals. Dr. Ing. Thomas Stegmaier showed that they can also be hygienic, air cleaning, protective, form-changing, thermal insulating, fire retardant-, sound-absorbing, and they act as actuators and/or sensors.
The shielding effect against electromagnetic waves was highlighted. Humans are permanently exposed to artificially-generated electric and magnetic waves that may produce an increased rate of cell division, an impairment of the immune system, an increased risk of cancer, the malformation of embryos, the shifting of biological processes, interference with cardiac pacemakers, the sensation of flickering before the eyes (artificial snow), fatigue, nausea, insomnia, and the impairment of learning ability, among other effects. Conductive filaments with soot parts provide protection against high-frequency, electromagnetic waves that may be measured in terms of the quantitative shielding effect and the quality of sleep.
Another property of textiles for architecture is the capability of form change. Some of them admit bending, and therefore, they can be folded and rolled. This property facilitates the transport and installation process and allows for the use of retractable and pneumatic roofs and actuators for a wide range of applications. (Fig. 10).
Other interesting possibilities were mentioned, such as the incorporation of lighting, acoustically-effective textile walls, multilayer textile heating, and sensor technology used in floors to detect, for example, the presence, position and, movement of people.

Figure 10. Buildair large scale portable hangar built with low pressure inflatable tubes.

Msheireb - Heart of Doha, Qatar, retractable shade canopy

Thomas Hermeking, PFEIFER
http://www.pfeifer.de/en

Based on the old tradition of the "Seville awning" (Condesa de Lebrija House, Seville, Fig. 11), a 90x34=3.060m^2 retractable shade canopy has been engineered by Burns McDonald with sbp New York and Pfeifer in Doha (Fig. 12).

Some data:
- 30 Foldable strips composed of 30x36 =1.080 framed panels (2.80x1.40m) sliding through 60 main strands (2 main strands per strip).
- 80 to 400kN load per strand, depending on the load case (up to 29.6m/s wind).
- Serge Ferrari Précontraint 1002 membrane, gold colour on the top and white underneath.

Due to the dimensions of the roof, the traditional lightweight flexible solution based on strips of fabric sliding by hand between ropes was converted into a series of stiff, aluminium-framed panels hung from steel strands, and operated by powered engines. Aluminium was chosen to frame the panels due to the ease of manufacture and maintenance, a good stiffness/weight ratio, and resistance to corrosion. In addition, the connection of the membrane is clear and adjustable with no need for in-situ welding of the membrane. Prior to the installation, a 1:1 scale mock-up was tested.
A comparison of the final solution with the traditional "Seville awning" calls to mind the statement made in a previous edition of Textile Roofs: "Changing the scale means much more than changing the size."

Figure 11. "Toldo sevillano". Condesa de Lebrija House, Sevilla.
Figure 12. Retractable shade canopy, Doha.

Flat tensioned building skins. A work show.

Dirk P. Emmer, Temme/Obermeier
http://www.to-experts.com

Dirk Emmer submitted several applications of flat-tensioned building skins used for climate protection and aesthetics. The building skin protects the inner structure and the occupants, regulates energy impact or loss, and reveals the architect's design intentions. Membranes for building skins provide lightness in weight, light-transmission control, large-span cladding, and a very long lifespan of the facility with low maintenance.

Recent developments in composites

Farid Sahnoune, Serge Ferrari
http://www.sergeferrari.com

Serge Ferrari has recently come up with innovations in the composite-coated textile industry: the PRÉCONTRAINT TX30 with a design life of 30 years, featuring the Texyloop process of recycling and the Batyline Aw series of micro-perforated, acoustic absorbents.
The new fabric PRÉCONTRAINT TX30 is an application of the Crosslink technology that strongly bonds the PVDF top coat, thus providing:
- Higher resistance to photo-oxidation and micro-cracks,
- A more stable and smoother surface that prevents dirt in-grain,
- Easier and more efficient cleaning of the even surface.

To test longevity, accelerated weathering is needed, provided that the main ageing factors are considered. In this case, an accelerated weathering protocol has been established based on the photo-oxidation of the surface. In this way, it is possible to predict 30 years' behaviour in 7.500 hours (312,5 days).
Surface evolution after ageing 30 years: the standard PVC/PVDF shows lots of cracks and exposed yarns. Minor traces of oxidation affect the surface of the PRÉCONTRAINT TX30 Crosslink PVDF. It was concluded that TX30 is an alternative to glass/PTFE because it is less sensitive to folding, is resistant to dirt, is competitive in price, and is recyclable with a warranty of up to 25 years.

Two case studies

Dipl.- Ing. Martin Glass, gmp Architekten
http://www.gmp-architekten.com/start.html

In recent years, participants in Textile Roofs have become accustomed to expect the impressive presentations of Lena Brögger and Martin Glass. At the 20th anniversary of Textile Roofs, not to be outdone, Martin Glass presented the FC Krasnodar (Krasnodar, Russia) and Santiago Bernabeu (Madrid) stadiums.

Figure 13. FC Krasnodar Stadium.
Figure 14. Santiago Bernabeu Stadium, Madrid

The FC Krasnodar stadium is a double-layered, radial-tensile roof that contains, not only the usual sound equipment, but also gas heaters that made the design, installation, and operation considerably more difficult (Fig. 13). The Santiago Bernabeu Stadium in Madrid was built in 1947, and was successively enlarged - in 1954, 1982, 1988, and 2002. The new design includes a retractable roof and a sheet metal wrapping that transforms the stadium into an autistic object with respect to the city (Fig. 14). It is another collaboration between gmp Architekten and Schlaich Bergermann und Partner.

Gyor Sport Arena

Ms. Ildikó Györ, Graboplan Kft
http://www.graboplan.hu/eng

Graboplan Tent Manufacturer and Technical Confection Ltd is an Hungarian company especially interested in the design, manufacture, and installation of lightweight roofs above stadium tribunes, as well as tensioned membranes suitable for temporary and permanent use, such as sports and entertainment facilities, culture, shopping, industry, warehousing, military purposes, aircraft hangars, etc.
Ms. Ildikó Györ presented the recent realizations of the new Audi Arena in Györ and the refurbishment of the old one. The multi-purpose Audi Arena Györ is the newest and most modern hall in Hungary. (Fig. 15). Its construction was completed in November 2014, right before the Women's EHF European Handball Championships. The hall seats 5.500 spectators and its main structure is made of reinforced concrete and steel-trussed arches. The textile envelope is installed on a steel framework fixed to the concrete structure with adjustable, sliding brackets (to accept tolerances) and special sections to receive Keder sections and LED's. A special feature of

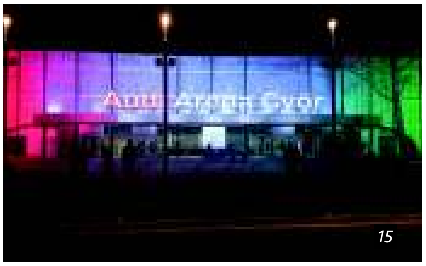

Figure 15. Audi Arena, Györ.
Figure 16. Training centre of the mountain rescue Bavaria in Bad Tölz.
Figure 17. "Miroiterie Flon" building in Lausanne.
Figure 18. Alnwick garden visitor centre and pavilion in Northumberland.

this envelope is the printing of the fabric that needs to be related to the cutting patterning in order to maintain the design.
The renovation of the old Arena was also based on wrapping the building with decorative panels, thus demonstrating, together with the new one, that textile façades are a new growing market for fabric architecture.

World-leading at the HF welding arena

Mikael Wallin, Forsstrom High Frequency AB
http://www.forsstrom.com

The lecture of Mikael Wallin was quite academic, as he defined and explained the basics of high frequency welding. High frequency welding is the joining of materials by supplying HF energy in the form of an electromagnetic wave (27.12 MHz) and pressure to material surfaces. PVC and PU are the materials most commonly used with HF welding. There is a wide range of HF welding machines. Each machine has been developed to suit different types of manufacturing. Knowledge and experience for every need is available. Machines can be stationary or travelling. As an application of the HF welding machines, Mikael Wallin also presented Forflexx and Tubeflexx. Forflexx makes it possible to join flexible, PVC and PU-coated fabrics with metal attachments for the production of truck and boat covers, tarpaulins, tents, structures, oil booms, and the universal corner plate developed with Formfinder and Horst Dürr. On the other hand, TubeFlexx is a production technology for faster and easier production of arched tubes.
Mikael finally invited the audience to visit Forsstrom's HF welding centre in Lysekil, Sweden where a complete machine line of HF welding machines, an eyelet press, cutting machines and a tensile tester are available. (see also page 24)

The future in membrane design Modular systems

Frank Molter, Hightex
http://www.hightexworld.com

After summarizing the characteristics of the most widely-used materials for structural membranes, Frank Molter opted decisively for modular systems because the current challenges of membrane architecture are:
- To establish membranes as a standardised building material.
- To increase the utilisation of membrane architecture by increasing the awareness of its advantages to a wider number of architects, namely: lightness in weight, self-cleaning properties (ETFE and PTFE), installation time, ease of replacement or repair, and energy efficiency of the product itself, among others.
- To develop a module-based construction system, which permits numerous options.

In order to reach these objectives, membranes have to be developed as a standardised product by developing a modular system, especially for façades. The energy efficiency that can be reached also needs to be demonstrated, and the disseminating of lectures on membrane materials in traditional education and research forums should be sought after. Three examples illustrated success in the aforementioned objectives: the Training centre of the Mountain Rescue Bavaria in Bad Tölz (Fig. 16), the "Miroiterie Flon" building in Lausanne (Fig. 17) and the Alnwick garden visitor centre and pavilion in Northumberland (Fig. 18).

Sustainability of buildings with membrane façades

Thomas Reber, HP Gasser AG Membranbau
http://www.hpgasser.ch/en

Thomas Reber dissertation was centred on façades, energy, low cost (Fig. 19), aesthetics, non-flammable materials, roofing (Fig. 20), sails, air-supported and industrial halls.

Figure 19. City Cube detail, Messe Berlin.

Figure 20. Amphitheatre Wiltz LU.

Mechanical testing of membranes

Dipl. -Ing. Kai Heinlein, Karlsruhe Institute of Technology (KIT)
http://www.kit.edu/english

Kai Heinlein reported on two research projects: TransMem and WindTent, which were based on testing membranes.
The TransMem project started from a new kind of textile fabric made of warp and weft mono filaments in unidirectional layers connected with an additional filament with 8 (warp) x 56 filaments per cm^2 that revealed, as was expected, different behaviour.
A biaxial test setup has been developed with an optical deformation sensor, spindle lifting, and climate heating equipment for a specimen size of 1x1m, tensile area 0.6mx0.6m, maximum load of 83kN/m, and optical strain measurement area 0.12x0.12m (Fig. 21). The results will be presented next year.
The WindTent project explores the behaviour of temporary and permanent tent halls enveloped by low pretensioned flat membrane surfaces submitted to wind gusts. The KIT tasks are the analysis of the material properties and behaviour (PVC-coated PET fabric type 0 of Sattler AG) and the modelling and measurement of the wind impact.
Regarding the viscoelastic material behaviour, it has only been measured at the PVC coating due to the shear. On the other hand, the damping of PVC coated PET fabric resulted fast (ratio ≈ 0,078) and the steady-load tests did not reveal any effect on the material properties. Other conclusions of the research concern the need for the development of new experimental setups and programs.

Figure 21. Biaxial test set up developed at KIT.




Figure 22. Cardo-Decumano-Secondario-Tornellerie: 70.000m² under construction.
Figure 23. Cardo-Decumano-Secondario-Tornellerie: 70.000m² at work.
Figure 24. German Pavilion: 2.050m²
Figure 25. Kuwait Pavilion: 2.000m²

Special guest lecture **EXPO Milano and its membrane structures.**

Dipl.- Ing.(FH) Frank Höreth,
TAIYO EUROPE GmbH
www.taiyo-europe.com

Catalogue of Taiyo Europe pavilions for the EXPO 2015: "Feeding the planet. Energy for life". (Figures 22 to 25). (see also page 18)

Student Project Week

"Roof for the main entrance of the Berlin Museum of Technology"

The subject was a roof for the main entrance of the museum to make it more visible. The final presentation took place at the closing of the Workshop. There were three proposals:

1 Alessandra Bruè & Pauline Chavassieux were inspired by the Leonardo da Vinci design shown in the museum (Fig. 26). Two triangular wings made of slender ribs and pretensioned membrane mark and protect the entrance, flying and contrast with the brick masonry of the façade.
2 Ana Duque, Santiago Garcés & Carlos Novella resorted to three saddles for signalling the approach to the museum from Trebbiner Strasse (Fig. 27).
3 Sebastián Gallardo & Antoine Taloid were inspired (in their plan) by the three circles of the logo of the museum (Fig. 28). Their design was the largest and most structurally-demanding of the three.

Prof. Dr.-Architect Josep Llorens
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Figure 26. Alessandra Bruè & Pauline Chavassieux.
Figure 27. Ana Duque, Santiago Garcés & Carlos Novella.
Figure 28. Sebastián Gallardo & Antoine Taloid.

The Twenty-first International Workshop on the Design and Practical Realisation of Architectural Membrane Structures will be held on 2-4 May 2016.
Its format will be similar to that of TR 2015, 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.

TENSINET COST Action TU1303 SYMPOSIUM 2016

NOVEL STRUCTURAL SKINS IMPROVING SUSTAINABILITY AND EFFICIENCY THROUGH NEW STRUCTURAL TEXTILE MATERIALS AND DESIGNS

WEDNESDAY 26, THURSDAY 27 AND FRIDAY 28 OCTOBER 2016 NEWCASTLE UNIVERSITY, UNITED KINGDOM

The TensiNet - COST Action TU1303 Symposium 2016 will be organised by the TensiNet Association, COST Action TU1303 *Novel Structural Skins* and Newcastle University as hosting university. The symposium will be the fifth of a series that began in Brussels in 2003: *Designing Tensile Architecture*, and continued in Milano in 2007: *Ephemeral Architecture: Time and Textiles*, Sofia in 2010: *Tensile Architecture: Connecting Past and Future*, and in Istanbul in 2013: *[RE]THINKING Lightweight Structures*.

The theme of the COST Action TU1303 (2014-17) is *Novel structural skins - Improving sustainability and efficiency through new structural textile materials and designs* and will also be the leading theme of the upcoming Symposium.

The 3-day event will start with an 'open session' (Wednesday afternoon and evening) to attract an audience of architects, engineers, academics and professionals involved in the design of *Novel Structural Skins*. Prominent experts in the architectural and engineering world will present inspiring projects to demonstrate to the audience the multitude of possibilities that lightweight structures have.

Since the COST Action TU1303 will be in its last year of funding, members of the Working Groups will present state of the art papers on recent research and interdisciplinary work performed in the frame of the COST Action. The priorities of the Working Groups are described below.

WG1 '*New applications of structural skins and new concepts*' has 3 subgroups (a) Adaptable skins and structures, (b) bending-active structures and (c) fabric formwork. Various topics are considered, such as methods for adaptable tensioned structures, advanced systems capable of changing properties, such as light transmission, light reflection and/or shape, shell structures made with membrane scaffolding, hardening tensioned membranes for composite or shell structures with textile reinforcement and self-tensioned membrane structures with an advanced interaction between bending and tension elements.

WG2 *'Sustainability and Life Cycle Analysis of structural skins'* is focusing on novel structural skins in which structural membranes and advanced tex-