TENSINET - COST ACTION TU1303 SYMPOSIUM 2016

NOVEL STRUCTURAL SKINS

NEWCASTLE 26TH-28TH OCTOBER 2016

The TensiNet – COST Action TU1303 Symposium "Novel Structural Skins" was held in Newcastle in October 2016. It was organized by the TensiNet Association, COST Action TU 1303 Novel Structural Skins and the Newcastle University. It was the fifth of a series of symposiums that began in Brussels in 2003: "Designing Tensile Architecture," which was continued in Milan in 2007: "Ephemeral Architecture: Time and Textiles," in Sofia in 2010: "Tensile Architecture: Connecting Past and Future," and in Istanbul in 2013: "[RE]Thinking Lightweight Structures."

At the three-day conference, 65 presentations were given in 15 sessions, including 9 keynote speakers to 131 participants from 16 countries. The main topics were standardisation; materials and testing; form and design; thermal, acoustic, and lighting conditions; projects and realizations; durability; environmental issues; and life-cycle assessment.

STANDARDISATION

The process of creating a new standard for tensile membrane structures was introduced by Natalie Stranghöner. Comments on the "Prospect for European guidance for the structural design of tensile membrane structures" are available at https://ec.europa.eu/jrc/en/publication/eur-scientific-and-technical-research-reports/prospect-european-guidance-structural-design-tensile-membrane-structures-support. Two more presentations from the Vrije Universiteit Brussel were concerned with standardisation. One was regarding the partial factors for prestressing in accordance with existing Eurocodes, and the other addressed the wind pressure coefficient distributions for basic membrane shapes (J. Colliers).

MATERIALS AND TESTING

R. Fangueiro from the University of Minho presented "Fibrenamics. Fibre the future", an international multidisciplinary platform for the development of innovative products based on fibres, which is available at: http://www.web.fibrenamics.com/pt/. Dr. Fanqueiro also reviewed the physical, chemical, and biological treatments of natural fibres in order to fully utilize their advantages in composite materials and to successfully utilize them in various industrial applications. Additionally, he presented LFS (Life Form Structure), a new composite material with the ability to change its shape according to the environmental conditions. It is a multilayer structure with a total thickness of around 6 mm, consisting of rigid PVC plates in the interior, bonded to a PVC-coated, high-tenacity, polyester membrane. In this configuration, the outer layer of the system is continuous while the interior remains discontinuous, enabling them to create a geometric matrix, which provides features of structural shape shifting.

ETFE film as a material was addressed by T. Yoshino, who dealt with the analysis of deformation under biaxial stress, taking into account biaxial creep characteristics. H. Bögner-Balz, presented her investigation of the yield point, yield conditions, hardening, behaviour under cyclic loading, and failure. Available Fluor polymeric products were also represented by the 3M Dyneon product range and the Solvay "Halar High Clarity" ECTFE film, a new fluorinated polymer with outstanding transparency, high thickness, excellent weather ability, and outdoor stability.

Knitted fabric was expounded by M. Schmeck, who proposed a method for making informed design decisions to support an intuitive way of understanding the structural system. The method consists of simulating the knitted fabric as a two-dimensional grid, which is calibrated by adjusting its geometry and the stiffness of its members to match the properties of a tested knitted membrane specimen.

Other contributions regarding innovative materials were the recent advances in sensor-embedded textiles (P. Heyse, TensiNews 30, pp. 10-11), the exploration of the possibilities of surface composite structures from inflatable moulds (D. Costanza), and the development of an ETFE-Phase Change Material to better manage the interior temperature of a greenhouse (P. Beccarelli).

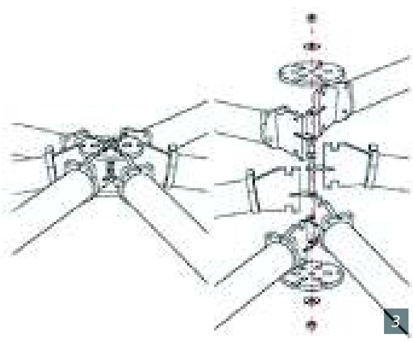
Testing and modelling were also considered with the appropriate determination of the stiffness and compensation values (B. Stimpfle) and the application of artificial neural networks to reproduce the mechanical behaviour of coated fabrics, including shear (P. Gosling). The importance of the post processing of the stress-strain data from biaxial tests and the principles for refined biaxial test procedures that meet the requirements of structural fabrics were approached by M. Van Craenenbroeck and J. Uhlemann, respectively.

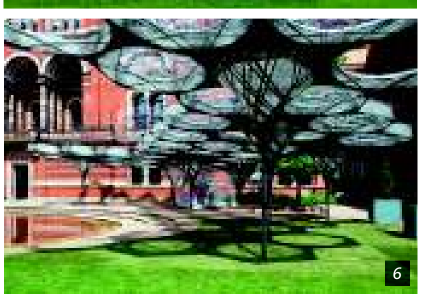
FORM

Three presentations addressed different approaches to form. S. Bhooshan turned to social sciences to justify the spectacular formalism of the so-called "logical" forms of some projects, highlighting the new Mathematics Gallery at the London Science Museum, designed by Z. Hadid (Fig. 1). J. Lienhard explained what he meant by "pushing the boundaries of textiles in architecture," by asserting that it is possible to design starting with the form. He illustrated the hypothesis with the Mitoseum at the Saurierpark Bautzen, a large grid shell with inflated cushions based on the digital design of the steel nodes (Figs. 2 and 3).

H. Ibrahim expressed his concern with the great variety of membrane forms to develop novel tensile membrane structures and adaptable textile-covered building facades, integrating tensile photovoltaic membranes for energy harvesting and environmental control. That is why he introduced the development of the Grasshopper parametric tool to analyse the layout orientation, the effect of shadowing, and the maximum allowable deflection for the membrane surface under different loading conditions.

S. Brancart demonstrated a principle for deployable bending-active structures based on the interaction between a deployable grid and a restraining membrane, illustrated by a case study where the large interdependency of form and material behaviour requires a specific modelling approach (Fig. 4). He was followed by R. van Knippenberg, who discussed a typology of foldable structures, illustrated with the design of a pavilion which is able to be transformed into multiple configurations only by moving the support points (Fig. 5).





Bionic shapes were shown by J. Knippers in his presentation of a series of research pavilions which showcase the potential of novel design, simulation, and fabrication processes in architecture based on principles of nature: heterogeneity, adaptability, redundancy, hierarchy, and multi-functionality (TensiNews 30, pp. 18-19). The projects were planned and constructed by students and researchers within a multi-disciplinary team of biologists, palaeontologists, architects, and engineers (Fig. 6).

Regarding adaptive structures, A. Habraken demonstrated a practical implementation of a control system with actuators used to minimize the maximum stress in an arch of Plexiglas when externally loaded with varying static loads by active rotation of the supports.

The presentations of A. Holden and A. Campesato were more speculative. A. Holden introduced a flexible and real-time computational design modelling for the exploration of novel, form-active, hybrid structures that would enable designers and engineers to iteratively construct and manipulate form-active hybrid assembly topology on the fly. A. Campesato dared to achieve arbitrary designs by mixing biomimetics, tensegrities, injection moulding techniques, and 3D printing.

DESIGN

Form finding, structural analysis, cutting patterning, and detailing, together with form, which has been treated in prior presentations, were also of interest.

B. Philipp contributed with the application of a newly-developed isogeometric B-Rep analysis to the form-finding and structural analysis of structural membranes. The result of this approach is the possibility of performing mechanically-accurate form-finding (and follow-up analyses) directly within a CAD environment on a full NURBS-based CAD model.

Referring to the structural analysis, J.C. Thomas considered inflatable beams. He showed his studies of the non-linear portion of the load-displacement curve, giving the analytical formulation that allows for obtaining the displacement between the wrinkling load and collapse. The case of an inflatable arch was also presented as an example.

Two presentations from the Technische Universität München were concerned with the generation of optimized cutting patterns. The first one went over a novel approach towards cutting pattern generation, minimizing the total potential energy arising from the motion of a planar cutting pattern to its corresponding three-dimensional shape. The second was an inverse approach, defining the nodal positions in the material configuration as design variables holding the fixed spatial configuration. In this way, the stress-free state of the cutting pattern, which is an important characteristic of the manufacturing process, is preserved.

Three expanded capabilities of analysis were explored by A. Bown. The first was hydraulic flow modelling, used to simulate unsteady fluid flow across an arbitrary mesh surface. The second was the time-stepped ponding that allows for cases where the pond load varies (Fig. 7). Finally, the third was the failure propagation collapse analysis to assess the potential for a failure propagation of a combined membrane and cable structure.

THERMAL, ACOUSTIC, AND LIGHTING CONDITIONS

D. Buck showed the simulation and test of a sport centre roof, consisting of a translucent multilayer and insulated membrane. Experimental and numerical simulations were performed concerning the air flow conditions within the cavity between the top membrane and the inner part of the roof. In addition, the air and moisture conditions within the venti

Figure 1. Zaha Hadid, 2016: London Science Museum Mathematics Gallery.
Figure 2. Rimpf Architekten, 2016: Mitoseum Saurierpark, Bautzen.
Figure 3. Digital design of the steel node by structure (http://www.str-ucture.com).
Figure 4. Physical models allow experimental insight in the behaviour of deployable & bending-active structures (S. Brancart et al.).
Figure 5. Adaptable pavilion for promotional purposes at festivals (R. van Knippenberg).
Figure 6. A. Menges, 2016: Elytra Filament Pavilion, London Victoria and Albert Museum. A modular, adaptive, fibrous canopy inspired by beetles and fabricated by a robot.
Figure 7. Seed event and subsequent rainfall causing hydrostatic loading onto the surface of a typical pneumatic structure (A. Bown et al).

lated air layer were investigated. The result is a methodical analysis and development of energy-efficient structural measures for buildings with membranes.

Two presentations dealt with the reduction of solar gains under ETFE roofs by adding a new material (H. Marx) or cooling the envelope by introducing a water spray system (A. G. Mainini). M. de Vita also addressed solar gains. Her case of study was an adaptive umbrella. She analysed its inner thermal comfort by means of the software package Energy Plus, which allowed the simulation of the performance in several climatic conditions.

Regarding the luminous environment, B. Lau showed through field studies that the selective use of transparent and translucent components in the ETFE envelope can offer architectural designers opportunities to create well-balanced, yet dynamic, illuminated scenes. On the other hand, A. Vargová referred to the night image of textile façades in contemporary architecture because the potential of membrane façades lies not only in their shape, but also in the ability to utilise light as a means of expression.

Acoustics were also present with V. Chmelik, who analysed the atrium of the Slovak Philharmonic, and D. Urban, who compared three large gathering places with multipurpose functions in Bratislava, together with several solutions for improvement of their acoustic situations based on transparent or removable products, such as polycarbonate, micro-perforate foils, or textiles.

PROJECTS AND REALIZATIONS

To provide shade and ventilation, a dramatic sculptural mixture of fabric and steel was designed by Z. Hadid for the KAPSARC, King Abdullah Petroleum Research Centre (Fig. 8). B. Whybrow described this astonishing, oversized structure, showing once again that structural membranes, if not designed as such, require an imposing steel structure, as happened at the Beijing Olympic Stadium. Insisting on the application of membranes and foils as a complement to steel structures, B. Stimpfle showed the use of PTFE-covered continuous stripes for sun shading over the Brickell City Centre in Miami (Fig. 9) and P. Romain showed a striking tram stop canopy in Lodz (Fig. 10).
A. Fisher contributed with the London Olympic Stadium transformation to retain its original running track whilst functioning as an economically-sustainable, multi-use venue. The fabric roof used during the games has been removed and replaced by a larger, solid roof. The stadium roof structure is the largest single-span and cable net in the world, 45.000m² in size, and 84m in height at its highest point (Figs. 11 and 12).

A wide variety of textile membranes and foils are used in façade applications. Ch. Paech discussed several options. The stadiums of Al Ain, Vancouver, and Cape Town illustrate different solutions for different purposes and locations such as those adopted for the 16 textile pavilions of the Indo-German Urban Festival, which are wrapped with different types of textile membranes in order to achieve different appearances. Other special applications are the replacement of the Munich Olympic swimming pool roof and the inner ETFE skin of the Madrid Memorial (Fig. 14).

A complete description of the two Ontario Celebration Zone temporary pavilions was presented by H. Jungjohann (Figs. 15 and 16). He highlighted the form-finding process, the wind loading simulation (wind tunnel tests were not



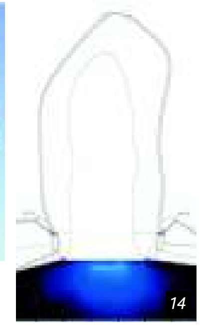
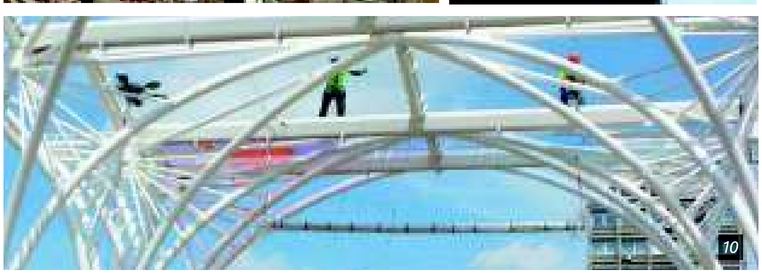





Figure 8. Installation of the canopies. KAPSARC (B. Whybrow).
Figure 9. 3D-shaped blades of PTFE-covered continuous stripes for shading. Brickell City Centre, Miami (B. Stimpfle).
Figure 10. Piotrkowska Street tram stop canopy, Lodz (P. Romain).
Figure 11. London Olympic Stadium during the Games (Al Fisher).
Figure 12. London Olympic Stadium after the Games (Al Fisher).

Figure 13. Semi-permanent, wide-span, inflated structure (B. Barton).
Figure 14. ETFE Memorial, Madrid (Ch. Paech).
Figure 15. The largest Ontario Celebration Zone Pavilion (H. Jungjohann).
Figure 16. Cutaway view showing primary airflow through span-wise arch tubes and secondary airflow through pillows with internal formers (H. Jungjohann).

available due to budgetary and time constraints), the structural design (assisted by Easy and SOFISTIK), the light foundations (Krinner Ground Screws), the fabrication (10 weeks), and the installation (1 week). It turned out to be a holistic approach due to the combination of architecture, structure, foundations, fabrication, and installation, compared to other cases presented, in which the form prevails.

A temporary pavilion divided into two canopies attached along the sides of a lorry was designed by Maco Technology and the University of Nottingham for events organized in conjunction with motorsport races (Fig. 17). The solution is based on bent aluminium profiles, designed to minimize the weight of the structures, and a double-membrane skin for waterproofing and solar radiation control. The design and manufacturing aspects were described by P. Beccarelli, who pointed out the challenging requirements of the client in terms of overall price, installation procedure, transportation volume, weight, and architectural appeal.

A novel, winterized textile partition to accommodate refugees during humanitarian crises was the topic of S. Viscuso. After the analysis of current literature, a set of requirements coming from users' needs was identified, and the current technologies in sheltering production were included. Finally, the most effective solution was prototyped and tested in the field (Fig.18).

An interesting description of the cable erection of the Krasnodar stadium suspended roof was carried out by D. Lombardini. The cable-supported membrane structure of the roof is based on the wheel spoke principle, with two steel box compression rings, one cable tension ring, and radial cables spanning between them, forming radial, cable trusses (Fig. 19). She completed the description with a video of virtual images which gave the appearance that all operations of assembly were very easy.

J. Llorens closed the series of presentations related to projects and realizations with the review of 80 interventions on historic buildings (Fig. 20). He revealed the characteristics that make structural membranes suitable for refurbishment. Because they are light, translucent, non-invasive, differentiated, reversible, and compatible, they can be integrated into the building layout, preserving its historic character and architectural configuration. Three design strategies have been identified and contrasted with the principles set by the International Council on Monuments and Sites. The complete list of interventions and links is available at: http://sites.upc.es/~www-ca1/cat/recerca/tensilestruc/REFURBISHMENT_web.pdf

ENVIRONMENTAL ISSUES AND LIFE CYCLE ASSESSMENT

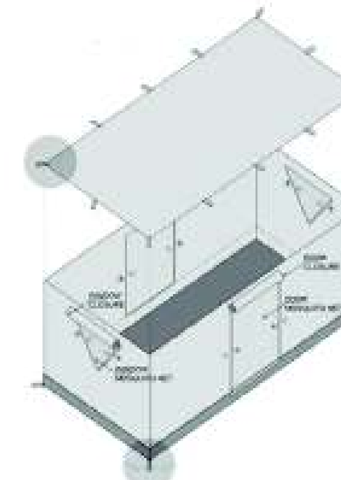
C. Maywald headed an apology of ETFE, based on a comparative study between glass and ETFE (TensiNews 27, p. 21). C. Monticelli reported on the research results regarding the eco-efficiency principles in the field of membrane architecture, based on the application of the Life Cycle Assessment methodology. R. Fangueiro, the most conspicuous presenter of the Symposium, approached the durability of two architectural membranes: one produced with polyester fibre, coated with polyvinylchloride (PVC), and other produced with glass fibre, coated with polytetrafluorothylene (PTFE) at the initial stages of environmental exposure. M. Barozzi presented several examples of searching for effectiveness of dynamics applied to architecture. She found an increase in performance obtained by reducing energy consumption through the optimization of the building envelope, together with the minimization of energy use and the employment of raw materials (considering the embodied energy of building components).

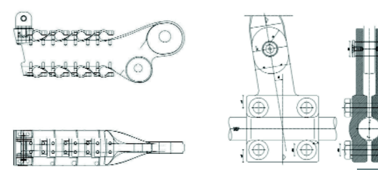
OTHER ACTIVITIES

Apart form the presentations, other activities offered during the Symposium included a guided tour to the Key, the University's new fabric structure working space reported on TensiNews 31, p. 6, the regular TensiNet Annual General Meeting, and, of course, the conference dinner served at the Great Hall (Fig. 21). The next day an excursion to the Alnwick Castle, Grounds and Gardens was foreseen.

Other presentations are reported in TensiNews: J. Wacker (nº 31, p. 13); F. Sahnoune, (nº 31, p. 12); S. Chiu (nº 30, p. 8); K. Bernert (nº 29, pp. 10-11) and G. Grunwald (nº 29, p. 14).

Josep I. de Llorens
ignasi.llorens@upc.edu
ETSAB/UPC





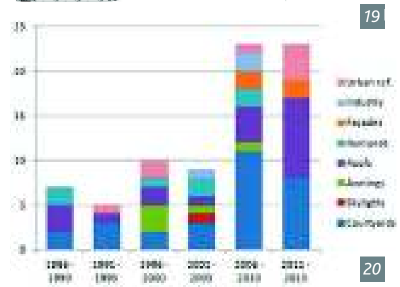


Figure 17. Linko demountable fabric pavilion for the motorsport sector (P. Beccarelli).
Figure 18. Isometric view of the final design of the emergency shelter (S. Viscuso).
Figure 19. Ring cable connectors (left). Hanger clap (right) (D. Lombardini).
Figure 20. 80 Interventions with structural membranes on existing buildings 1986-2015. An increase in the use of membranes over the last 30 years is clearly observed, led by applications in courtyards and roofs. (J. Llorens & A. Zanelli).
Figure 21. The magnificent wood-panelled and tiled Great Hall where the conference dinner was served. (Former Co-operative Wholesale Society warehouse, now Discovery Museum, by Oliver, Leeson, & Wood, 1897-1899).