ISTANBUL2013

TENSINET SYMPOSIUM 2013 [RE]THINKING LIGHTWEIGHT

The TensiNet Symposium "[RE]THINKING Lightweight Structures" was held in Istanbul in May 2013. It was organized by the TensiNet Association and the Mimar Sinan Fine Arts University in collaboration with the International Association for Shell and Spatial Structures, in memory of Prof. Dr. M. Ihsan Mungan. It was the fourth of a series of symposia that began in Brussels in 2003: "Designing Tensile Architecture" and continued in Milano in 2007: "Ephemeral Architecture: Time and Textiles" and in Sofia in 2010: "Tensile Architecture: Connecting Past and Future".
At the three-day conference, 49 presentations were given in eight sessions including 10 keynote speakers to 178 participants from 22 countries and 5 continents. The main topics were materials and testing (including a dedicated session to ETFE), form and design, projects and realizations (with special attention to pneumatic and non-conventional structures), environmental issues and life cycle assessment.

MATERIALS AND TESTING

The Symposium started with a dedicated session to ETFE. R. Houtman presented the comprehensive "Design recommendations for ETFE foil structures" established by the TensiNet ETFE Working Group. It includes the description of the material itself and the design, calculation, manufacture, installation, maintenance, operation, examination and testing. See also bookrevue page 16.
His colleague, F. Reitsma from IASO, discussed several cases highlighting the need for balancing architectural value and engineering restrictions that leads to changes from the initial design. An outstanding example is the new lobby of the Luxembourg Railway Station, where a single printed cable- reinforced layer of ETFE provides a respectful solution for the extension of an historical building (Fig. 1).

A. Escoffier showed the use of a flat single layer of ETFE for the stadium of Nice, subjected to experimental tests in order to be approved. The panels of ETFE were connected to 10mm diameter cables and pre-stressed to 0.6kN/m, that required a fixation detail for initial installation and re-stress (Fig. 2).

Instead of one single layer, cushions were adopted for the renovation of the Salzburg Central Station, as presented by K. Gipperich. The structural design was based on maximum stresses of 6,7N/mm2 (for dead load + pressure), 12N/mm2 (for snow) and 16,3N/mm2 (for gusts of wind) in order to withstand the required 1,40kN/m2 under peak snow load (Fig. 3).

Other materials considered were warp-knitted fabrics (T. Gereke), PTFE-coated fibreglass yarns (M. Dery) and waterborne fluoropolymer PVDF resins (K. Kech).
With regard to testing, A. Colman described a methodology that enables the application of a homogenous state of shear strain to architectural fabric specimens with a known state of biaxial stress, which allows a simple determination of the shear stress-strain relationship. P. Beccarelli reported on strain-controlled biaxial tests on cruciform specimens of coated fabrics, which are particularly meaningful for membrane installation processes and are complementary to stress-controlled experiments.

FORM AND DESIGN

Three presentations addressed explicitly the problem of form. N. Jakica focussed on the possibility of optimizing form by presenting the parametric design process of the Sport Stadium in Lamezia Terme (Fig. 4). He summarised the creation of the structural solution and building shape, as well as the panelling strategies for the ETFE cushions. He noted that, despite parametric modelling, a lot of manual work was required.
Conversely, S. Bhooshan presented an intuitive, collaborative, physically-based form finding procedure to explore formal expressions for architectural modelling (Fig. 5).
An outstanding contribution of the symposium

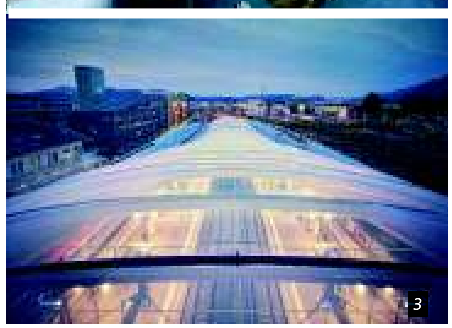


Figure 1. Luxembourg Station, IASO

Figure 2. Fixation detail. Nice Stadium
Figure 3. Salzburg Central Station

Figure 4. Pallazetto dello Sport, Lamezia
Figure 5. Short-term research prototype, Z. Hadid Architects

was the creative sculpture "cut.enoid.tower," made by G. Filz of the KoGe Institute of Structure and Design, Innsbruck. The experimental "cut.enoid.tower" was erected making into consideration architectural, structural and functional issues. It is an active bending system, made of irregularly-arranged, hinged columns and pre-stressed, tension-only, minimal surface catenoids (Fig. 6).

Regarding design methods, P. Gosling conducted round-robin exercises to quantify the analysis of simple conic and hypar membrane structures, and to provide a link between material characterisation and structural analysis. F. Dieringer discussed a computational method for cutting pattern generation. The process starts from three dimensional coordinates and the final prestress state, and determines a two-dimensional surface, minimizing the difference between the elastic stresses arising form the manufacturing process and the final prestress. In this way, the influence of the seam lines to the stress distribution is investigated and the equal length for adjacent patterns is controlled. P. Teuffel defined the "generative modelling" of membrane structures, consisting of parameters and algorithms that convert the manual design into a more efficient automated process. A four point hypar shell submitted to this "generative modelling" revealed an improvement in the time duration of the design process and achieved much more controllable precision. The geometry was found much faster and standard details were parameterized (Fig. 7).

R. Wehdorn went into cost control, analysing a four-point 10x10m sail. He found that costs increase when the curvature of the membrane and the inclination of the guy cables are decreased. Regarding the edge cables, total costs also increase when their curvature decreases but the unit cost results in a U-shaped graph (Fig. 8). When curvatures range from 3% to 12%, the unit cost follows the total cost, but when it exceeds 12%, the unit cost increases further because the surface of the membrane decreases. These conclusions are limited in scope, but are indicative of the interest of investigating the influence of the design parameters on costs, and implementing them in software tools such as "Formfinder". Other presentations related to design methods addressed the Poisson's ratio (J. Uhlemann), neural networks to capture the relationship between experimental input and output data (N. Bartle), the force density method (F. Dansik) and the application of three dimension, minimal path computations to space frames (M. Fleischmann).

PROJECTS AND REALIZATIONS

Most of the Symposium was devoted to projects and realizations. Noteworthy examples were the Marseille and Nice Stadia (A. Escoffier), the Titan Plaza Shopping Centre in Bogotá (B. Stimpfle), the Camper Pavilion for the Volvo Ocean Race (R. Houtman), the Façade of the Ministry of Justice in Georgia (M.Yilmaz) and the London 2012 Olympic Stadium Wrap (P. Romain).

Pneumatic structures

M. Birchall chaired the special session dedicated to pneumatic structures. He emphasized their great potential to fulfil the needs of the constructed environment, and provided recommendations and potential opportunities to designers and contractors. Additionally he gave an overview of the main issues and recent developments such as control systems and insulation capabilities (Fig. 9). He reminded the audience of the TensiNet Working Group on Pneumatic Structures.

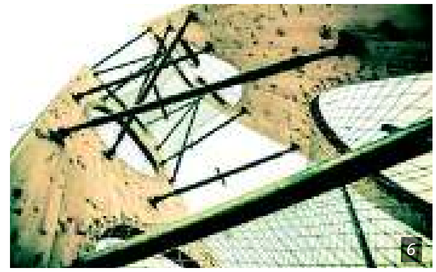
P. Romain discussed the evolution of a tennis dome product called "Airplay" starting with the improvement and replacement of three existing air halls. He identified the key components of foundations, envelope, inflation control and access. He finally stated that in spite of the success of these developments, attempts to market them as a product are dependent on other factors beyond functionality and design.
R. Luchsinger defended the Tensairity concept, and presented a high-performance wing dedicated to harvest wind energy at high altitudes, which saves the requirements for land, towers and foundations. A live load to dead load ratio of more than 270 was predicted using standard kite materials (Fig. 10).

The Tensairity concept was also applied to arches by J. Roekens and to inflatable beams as considered by J. C. Thomas and Q. T. Nguyen.

D. Ströbel dealt with multi-chambered ETFE cushions. He included form finding, static analysis and cutting pattern generation into a holistic calculation. A completed model was analysed under external loadings by taking into consideration the gas-laws for multiple chambers and any boundary conditions. Noticeable pneumatic structures shown during the dedicated session were balloons for scientific applications (A. Bown, Fig. 11), the London 2012 Water Polo Venue (M. Birchall), the Perpignan Claira Commercial Centre, the Splash & SPA in Rivera Monteceneri (S. Lombardi, Fig. 12) and the temporary textile pavilion at Politecnico di Milano (A. Zanelli).

Adaptable, transformable, deployable

Movement was also discussed in the Symposium. V. Beatini proposed a flexible, self-supporting structural system, based on a series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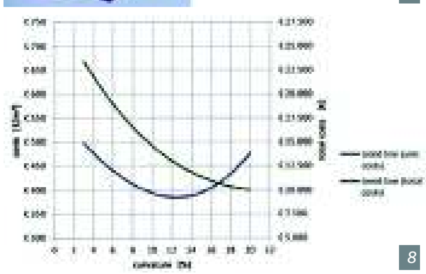
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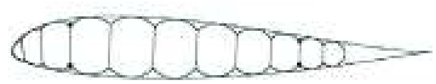
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Figure 6. "cut.enoid.tower", KoGe Institute
Figure 7. Parameterized details of column connections
Figure 8. Unit and total cost related to edge cable curvature
Figure 9. Modern Tea House, Frankfurt 2007
Figure 10. Inflatable wing section with two Tensairity elements

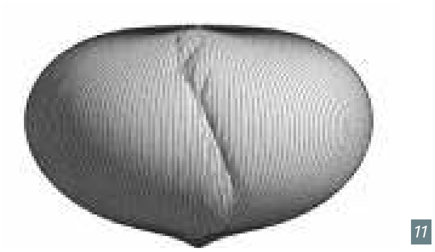


Figure 11. Simulation of balloon instability
Figure 12. Splash & SPA, Rivera Monteceneri

Figure 13. National Stadium, Warsaw
Figure 14. BC Place Stadium, Vancouver

Figure 15a-b. Foldable umbrellas of the external courts of the Medina Haram Piazza

of rigid voussoirs, connected by a cable passing through them, which forms the skeleton of whatever profile. She also presented a frame as a mechanism, foldable from a planar configuration to multiple and varied hypar shapes, alternating high and low points.
K. Roovers was concerned with deployable scissor structures, based on the angulated scissor component, and developed a geometric design method, based on mathematics, to convert continuous surfaces into scissor grids with angulated components. The attachment of membranes to these structures is a complex matter that requires further research.
C. Paech showed two of the largest retractable membrane roofs recently completed: the National Stadium in Warsaw (Fig. 13), and the BC Place Stadium in Vancouver (Fig. 14).

In a special session dedicated to eye-catching projects, J. Bradatsch from SL-Rasch showed the foldable umbrellas of the external courts of the Medina Haram Piazza, where 250 26x26m shading umbrellas had been installed to shelter more than 100.000m^2. Previous experiences were improved through numerical simulations, wind tunnel tests and physical modelling that result in close agreement. An interesting special feature was the minimization of energy by keeping the stability of the centre of gravity during the folding and unfolding processes. The general views of the ensemble (Fig. 15) were indeed really impressive and emphasized by J. Bradatsch citation of Augustinus: "Beauty is the brilliance of truth".

New concepts and non conventional structures

"Re-thinking" projects and ideas focused on active bending elements and hybrid structures.

L. de Laet opened the topic with elastically-bent linear elements integrated with supporting systems for membrane structures to provide more freedom in design and to reduce the required quantity of external supports (Fig. 16).

J. Lienhard, defending the integration of elastically-bent beam elements, offered a great potential for new shapes and highly-efficient structural systems, while B. Philipp emphasized the necessity of assuming elastic members from the beginning in the design process, and showed equations needed to simulate these hybrid structures.

A different approach was presented by P. D'Acunto. A full-scale temporary lightweight pavilion for the grand staircase of the ETH Science City Campus has been designed with individually-bent panels of plywood, adjusting the bending behaviour to achieve the required curvature. The system was stabilized with a sequence of cables (Fig. 17). A non-linear static parametric digital model, based on the bending energy of the panels, has been calibrated with physical tests and employed to explore various design solutions.

The "membrane restrained girder," a three-chord truss with flat membranes connecting the chords, was introduced by H. Alpermann. The membrane between the upper chords raises the buckling load and the membranes on the sides act as diagonals bracing the spreaders. It was found that the connection of the membrane and the chords has a large influence on the load-bearing capacity.
K. Kawaguchi focussed attention on the application of membranes as safer ceiling systems for large rooms than of gypsum boards or metal louvers due to the damages caused by earthquakes.

ENVIRONMENTAL ISSUES AND LIFE CYCLE ASSESSMENT

J. Cremers chaired a special session dedicated to the environmental impact of membrane materials and structures. He reviewed the main concepts of LCA (Life Cycle Assessment), EPD (Environmental Product Declarations), Building Assessment Systems, CPR (Construction Products Regulation) and the TensiNet LCA Working Group, presented in TensiNews nº 23.

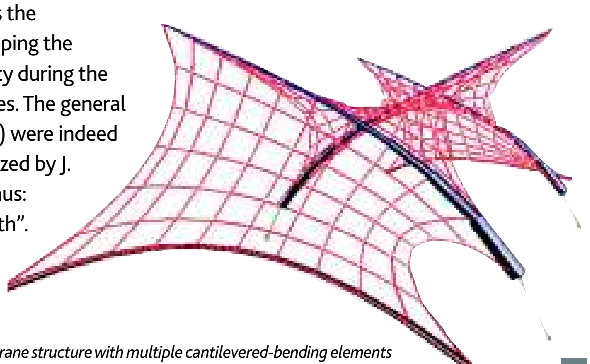
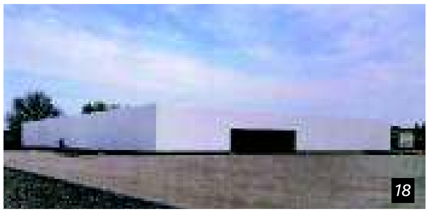


Figure 16. Membrane structure with multiple cantilevered-bending elements
Figure 17. AA/ETH Pavilion



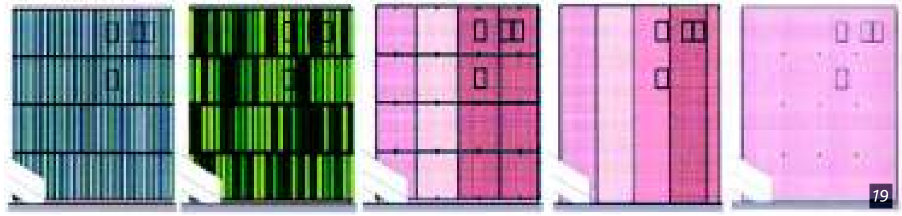


Figure 18. Memorial in Sachsenhausen
Figure 19. Five types of translucent cladding systems

The audience celebrated the findings of W. Sobek of environmental concerns of the building industry. Consumption of resources, wastes, energy, emissions, pollution, toxicity and global warming cause us to change the question from "which is more lightweight?" to "which has less embodied energy?" During a transitional period, there has been a reduction in the consumption of materials, energy, waste and emissions. His trend was illustrated by the performance of the three-layered roof of the Suvarnabhumi International Airport in Bangkok, the cantilevered altar for the Pope in Freiberg, which was made of anything borrowed or recycled, and the most modest building with no apparent structure nor details of the Memorial in Sachsenhausen (Fig. 18).

Going into specific issues, P. Teuffel looked at the application of Aerogel in combination with membrane structures to evaluate the potentials for natural day lighting, and J. Llorens furnished acoustic in situ measurements of textile roofs to formulate design and conditioning recommendations for textile enclosures.

H. Suo assessed the winter energy performance and actual energy saving of a pneumatic sport hall in Italy, using the dynamic energy simulation software ESP-r. The results show the dynamic behaviour of membranes, focusing on the low thermal inertia, the role of solar gains, infiltration losses and long wave radiation of the sky. The energy demand reduction achieved with double membranes with respect to single ones was quantified.

Recycling PVC-coated polyester membranes was exposed by F. Fournier. Its benefits were quantified and proven in order to convince the different actors of the industrial chain to allocate time, energy and financial resources to implement this action. Several cases were mentioned, highlighting, among others, the Lord's Cricket Ground in London, the German Pavilion in Shanghai 2012, the Kuala Lumpur Stadium and the Tennis Hall in La Grande Motte. She also mentioned "Texytool," a dedicated software for measuring the reduction of impacts, including the fabrication of custom-made panels, accessories, packaging and transport.

J. Chilton presented the results of a preliminary study that aimed to quantify the embodied energy consumed in the construction of three recently built examples of ETFE foil-covered roofs of different configurations. They demonstrated the efficiency of this construction system when compared to glazed roofing. He also noted that the strict application of values per m^2 stated by the EPD can be misleading, depending on the geometry and configuration.

C. Monticelli focused on five types of translucent cladding systems, analyzing the life cycle assessment of three lightweight textile façades and two translucent common systems currently available in the market (Fig. 19). Interesting conclusions arose, modifying existing common notions, and drawing attention to some aspects of design. On the one hand, it was revealed that there is no linearity between impact and weight. On the other hand, the impact of transportation costs resulted low compared to the manufacturing process.

Figure 20. Energy collector textile building
Figure 21. Entrance canopy, Istanbul

Referring to design, the frame/surface ratio and the fixing system significantly affect the results. Maintenance was not considered and could be an area of improvement for future research.

In the final presentation, R. Wagner unveiled an energy-efficient textile building (Fig. 20). It is based on a translucent, multi-layered, double-curved, pre-tensioned membrane structure with high thermal isolation, that collects solar energy through heating air up to 140ºC. The main challenges were collecting and storing solar gains, protecting from losses while avoiding the heating of the interior space. She invited the audience to learn more about the demonstration building by attending Techtextil in Frankfurt.

CLOSING SESSION

in honour of Prof. Dr. M. Ihsan MUNGAN

F. Dansik, of the Organizing Committee, closed the Symposium honouring Ishan Mungan, a tireless figure, teacher and researcher in the field of shell and spatial structures. He was involved for nearly 40 years with the International Association for Shell and Spatial Structures and was awarded an Eduardo Torroja medal in 2009. The legacy that he lovingly, intelligently and generously built during his entire life will always be remembered by those whom he touched, especially the younger generation, whom he mentored and carefully ushered in to the field of architectural structures. They will benefit from his influence far into the future.

OTHER ACTIVITIES

Apart form the presentations, other activities offered during the Symposium included a classical Turkish musical performance, an opening cocktail (including raki) served on the seashore, the regular TensiNet Annual General Meeting, the seemingly endless Bosporus cruise with dinner and dancing, and finally, the technical (Fig. 21) and historical tours. The proceedings of the symposium are available. See also bookrevue page 16.

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