REPORT

TENSINET SYMPOSIUM 2013
[RE]THINKING LIGHTWEIGHT

TEXTILE ROOFS 2013

arenas, protective zones, stadiums and coverages

CHINA - DENMARK - FRANCE - GERMANY
ISRAEL - ITALY - LUXEMBURG
SWITZERLAND - USA

Esmery-caron © Sergio Grazia / SL-Rasch © Sefar Architects
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TENSINET ETFE WORKING GROUP - [RE]THINKING LIGHTWEIGHT STRUCTURES PROCEEDING - FLEXIBLE COMPOSITE MATERIALS
Dear Reader,

We proudly look to a lot of successful activities since the last TensiNews. The ETFE working group has finished and published the ETFE Guide, the result of 4 years work. It is a state of the art document presenting basic information, different design approaches and perspectives for the future development. Beginning of May we had an excellent TensiNet symposium 2013 - [RE]THINKING lightweight structures in Istanbul, with more than 150 participants. The three days were full of interesting presentations from a wide range of professionals and researchers.

TensiNet was again one of the main sponsors of the student competition at Techtextil, and TensiNet was present on Textile Roofs 2013 in Berlin.

Many working groups are actually going on. The Specification and Eurocode Working Group is very active. Many countries have already established their national standards committee, and the core group meets regularly. The group is actually working on the master document and on background documentation. Furthermore the different countries are now asked to compare the safety approach in the actual master document with their code of practice. The ETFE working group has been asked to contribute to the Eurocode Working Group with a chapter on ETFE foil. The Analysis and Materials Working Group will initiate a follow-up Round Robin exercise. The results of the first exercise have been presented in different symposia and they have been published in “Engineering Structures.” The LCA working group is preparing a series of new meetings and is inviting to join the Working Group. The Pneumatic Structures Working Group would like to organise an “onsite workshop” to learn from real projects.

During the Symposium in Istanbul we held the annual general meeting and a TensiNet Partner meeting. The new board has been elected during this partner meeting. Vice-chairs are Heidrun Bögner-Baltz, John Chilton and Peter Gosling. The secretary is Marijke Mollaert. I am proud to announce that I have been elected to be the new chair.

This issue of TensiNews contains again interesting projects in membrane and foil, reports about the TensiNet symposium, the Students Competition at Techtextil and Textile Roofs. I hope you find it of great interest and I will be glad to see you at one of the next TensiNet events.

Yours sincerely, Bernd Stimpfle
Paturiz Shade Solutions, recently installed a 1,440m² shade structure in Naharia, Israel. The brief was to create a shade structure for a Skateboard Arena located in a windy coastal environment. The company designed a unique structure with a breathable knitted HDPE fabric from Gale Pacific called Synthesis Commercial 95. Due to the knitted construction of the fabric air will flow more freely through the membrane resulting in more comfortable conditions beneath. Paturiz went one step further and designed purpose built holes into the fabric canopy to allow even further airflow to compensate for the high velocity winds (Fig. 1 and 2). Winds of up to 130km/h are frequent in this region and the holes are designed to allow airflow both from above and below the canopy. This is intended to relieve the stress loading on the overall structure and ensure the long life of the fabric. It also allowed for additional light transmission and created a unique aesthetic element for the design.

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**SYNTHESIS COMMERCIAL 95 TECHNICAL DATA**

**FABRIC PERFORMANCE**

<table>
<thead>
<tr>
<th>Property</th>
<th>Warp</th>
<th>Weft</th>
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<tr>
<td>Tensile Strength</td>
<td>635N/50mm</td>
<td>2494N/50mm</td>
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<tr>
<td>Elongation at break</td>
<td>95.6%</td>
<td>70.4%</td>
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<td>Wing Tear</td>
<td>187N</td>
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<tr>
<td>Bursting Pressure</td>
<td>3500kPa</td>
<td></td>
</tr>
<tr>
<td>Bursting Force</td>
<td>2146N</td>
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</tr>
</tbody>
</table>

**GENERAL CUTTING GUIDELINES FOR TENSION STRUCTURES AND AWNINGS**

Patterns should be cut about 2.5% less in the width and about 5% less in the length.

The above listed % is an approximate range the fabric can be stretched when applying over a tension structure. The % can differ depending on the size of the tension structure.

The fabric can be sewn. The uses of polyester trim or sewing a hem are the recommended finishing process.

More information on www.synthesisfabrics.com

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**Skateboard Arena**

BREATHABLE FABRIC SUITS HOT COASTAL CONDITIONS

Naharia, Israel

**Figure 1. Aerial view of the fabric canopy**

**Figure 2. Additional holes to relieve the stress loads as well as for extra airflow and light transmission**
An "Haute Couture" stadium

ESMERY CARON has just completed the fabric covering of the Léo Lagrange stadium stands in Toulon, France. This new sports complex, designed by the Archi5 architecture firm, is located at the East entrance of Toulon. The structure, a white sail spread across the sports fields, has been thought over in coherence with the specific landscape of this neighbourhood: the mountains on one side and the sea on the other.

Both a technical and architectural challenge, the metal-textile structure literally floats above the stands, evocative of a big moored sailboat. The tubular framework of the covering is made of three main arches measuring 120 to 150m, depending on the location, and culminating at a height of 25m. Trials have been performed in a wind tunnel on a model loaded with sensors. Before implementation, a final series of numerical wind simulations has reassured designers and builders.

In order to perfectly adapt the cover to the metallic structure, Esmery Caron has completed several studies on modelling, cutting and shaping. The software used by its internal Design & Engineering Dept was ForTen, a system for tensile structure design, analysis and pattern making. Three months were needed to assemble the fabric using high-frequency welding assembly, in its specialized finishing workshop. After assembling and setting up the framework, the membrane was installed by the Esmery Caron teams with a double lacing technique, using four cradles and protection equipment for working at heights. Thomas Dryski, an architect at Archi5 said: “We have concentrated all the built volumes of the tournament and public welcoming zones within a covered public gangway designed like a jetty, evocative of the historical links between Toulon and the Mediterranean Sea. The stake was to strip the sail, in order to hide its technical aspects. The complexity of the steel structure was mainly structural, a difficult game between the balance and refinement of the structures in regard with the large spans. The fabric of the covering, the metal and the non-reflective glass constitute a volume that captures the subtle coloring of the natural light. The covering membrane takes the colours of the sky and landscape. At night, the cover, lighted from inside, is transformed into a lighted ribbon, transforming it into a true light wave, fully expressing its function in both the sports and events areas”.

Founded in 1897, and involved in Textile Architecture since the early 70's, Esmery Caron is located 70km west from Paris, France.

Name of the project: Stand covering at the Léo Lagrange stadium in Toulon
Location address: Toulon (Var), France
Client [investor]: Toulon Provence Mediterranean Town Community
Function of building: Stadium stand covering
Year of construction: 2009 to 2013
Architects: Archi5
Multi-disciplinary engineering: Renaudat
Structural engineers: Ingerop & Renaudat
Consulting engineer for the membrane: Ingerop / Esmery Caron
Main contractor: Archi5
Supplier of the membrane material: Serge Ferrari
Manufacture and installation: Esmery Caron
Material: Architectural membrane (Type 4, 100% PVDF)
Covered surface (roofed area): 3000m²; Length=182m; Width=15,6m
In TensiNews 5 (November 2003) the idea of a cushion belt structure was first published. Now, 10 years later, for the first time the patent protected “Bekaert-Belt” system, using belts made of parallel steel cables embedded in UV stabilized Poly Urethane supporting large span ETFE foil structures became reality.

The Institute of Membrane and Shell Technologies (IMS e.V.) of the Anhalt University, Germany did hold onto the idea and kept on with its research testing and experiments (Fig. 1). Finally after a small first experimental building cover at Bobingen (Fig. 2) the IMS team was confident in the idea and looking for a first application for a representative larger scale building. Fortune struck as the Saxony-Anhalt Building Ministry was looking for a less expensive solution of a transparent roof for its residence in Berlin. The initial idea was a horizontal heated expensive glass slab. Unfortunately the roof was not allowed to touch the surrounding historical building and therefore columns had to be placed inside the yard. The tasks that had to be fulfilled were many. First of all it is a simple rain protection in order to enable outdoor events like exhibitions. At the same time it had to be transparent, as all offices of the building are getting their natural light from the inner yard. To make things even more difficult, natural ventilation of the closed inner yard and heat protection had to be guaranteed.

The solution was a wing shaped overlapping object hovering over the yard with a vertical gap of about 2,5m from the sloping historical roofs. The covered area is 375m² (Fig. 3). The wing consist of parallel fish belly girders. Between the top arches pneumatic cushions with intermediate lower belt support are placed. The size of the cushion, about 5,50m to 15,00m was bigger than the possible span of the foil would allow. So the cushions needed additional support provided by the belts. Between the lower curved profiles a single mechanically stressed anticlastic foil with the Bekaert-Belts is introduced. This way there are five parallel enclosed volumes in the 2 layer foil cushions between the top arches and one big volume without air support in the lower enclosed area under the cushions. The wing shape was chosen to enhance the natural ventilation of the yard without any mechanical device (Fig. 4).

Only at the fourth side of the yard, a recently build new part of the residence with a flat roof was permitted to be touched. There the wing has a small overlap of only 50cm to avoid rain. Only at this side the structure is horizontally stabilized transferring all horizontal loads into the existing new building by two small columns (Fig. 5).

The advantage of using belts compared to cables lies in the fact, that belts do have a flat surface in contradiction to cables who may rub holes in the foil. Belts with their flat surface will not slide on the foil. Put in sleeves they can take upload and download forces. Belts can crossover and be joined by a pin in the middle. This way huge spans without rigid steel profiles are possible.

Although everybody was enthusiastic and supportive of the project, it took four years and two Minister Presidents of Saxony-Anhalt, till finally Finance Minister Bullerjahn had the courage to decide to go for it. The convincing argument was that the Anhalt University with its Institute IMS e.V. and master program in membrane structures as well as the company Novum Membranes, willing to build a first cushion belt structure, are situated in Saxony-Anhalt. So it became a political issue to show the technical ability and research in this field at the...
After the first “sail” that students of the School of Architecture of the UPM (Technical University of Madrid) designed and placed in the central courtyard of the new pavilion of that school, which was published in this newsletter 19 (September 2010) students of successive courses have been hoisting new “sails” under the direction and supervision of professor Juan Monjo-Carrión and architect Javier Tejera.

Students participate in the design and calculation of the sails and proceed to cut the patterns. These are welded in a specialized shop and the tailored sail is brought to the school where students help to raise it. So far two extra sails have been placed with a colour sequence that seeks to complete the rainbow ones. The second sail, red, is an asymmetrical and inverted cone-shaped one (Fig. 1 & 2). It is hanging and tightened from its four corners, and has an internal floating mast that helps to produce and maintain the conical shape. The mast is braced at its upper end from the four corners, allowing the formation of the inverted cone. The third sail, orange, is shaped as a linear conoid with an intermediate arch downward (Fig. 3 & 4). It’s hanging and tightened also from its four corners, and has an intermediate cross brace that keeps the arch in place. The three sails are executed with mesh fabric type SOLTIS 86 donated by FERRARI (Fig. 5).

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Belts and cables
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Client
BLSA - Saxony-Anhalt

SCHOOL OF ARCHITECTURE OF MADRID SPAIN
UNIVERSIDAD POLITÉCNICA DE MADRID

Design, fabrication and hoisting
OF THE SECOND AND THIRD “SAIL”
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 on 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 fiberglass 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 paneling 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...
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. Dansk) 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 Claire 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

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
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 100.000m². 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.
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 m² 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.

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 140°C. 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 from 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 Bosphorus cruise with dinner and dancing, and finally, the technical (Fig. 21) and historical tours. The proceedings of the symposium are available. See also the bookreview page 16.

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FOIL CUSHIONS MADE OF 3M™ DYNEON™ ETFE

COMBINE LIGHTWEIGHT ARCHITECTURE AND ENERGY EFFICIENCY

Maximum transparency

World Trade Organisation building, Geneva, Switzerland

Context

During expansion of the World Trade Organisation building complex at the heart of Geneva, the focus was on optimum energy efficiency and architectural elegance. The previously open inner courtyard of the Centre William Rappard now features a transparent domed roof made of ETFE foil cushions. It offers a high degree of freedom of form coupled with exceptionally good heat insulation properties. The NOWOFLON ET 6235Z foils are made of the high-performance 3M Dyneon ETFE material. The Centre William Rappard was built in the 1920s and was the first building in Geneva designed specifically for an international organisation. The World Trade Organisation (WTO), which is responsible for the regulation of international trade and business relations, has been based here since 1995. In addition to around 750 employees, almost 1,000 delegates and ambassadors from the WTO’s 159 member states now use the complex for meetings, conferences and training seminars. In 2008, the WTO, in conjunction with the Swiss authorities, decided to renovate and extend the existing building. An international competition to design a new extension attracted 115 entries and was won by Stuttgart-based architects Wittfoht.

Energy efficiency and good insulation properties

As with all building projects for UN organisations, strict regulations applied for the WTO project with regard to energy efficiency. The tender stipulated compliance with the Swiss MINERGIE-P standard defining low-energy construction methods. The permissible values correspond with those for a 3-litre house (heating oil consumption averages only 3 litres per square meter per year). The original building’s open inner courtyard planted with trees now features a transparent roof made of pneumatically-supported, triple-layered foil cushions affording extremely good heat insulation properties (Fig. 1). The foil cushions were calculated and constructed by Swiss company Texlon, a specialist in hangar construction as well as foil and membrane constructions. The company, which operates throughout Europe and Central Asia, has countless foil roofs to its name.

Triple layered foil cushions

The roof is formed of a total of 104 triple-layered foil cushions of which 22 feature an opening mechanism (Fig. 2). The cushions lend the domed roof a distinctive curved form. Due to the special steel support structure, Texlon calculated a total of 26 different three-dimensional cuts and forms for the foil cushions of around 3m x 3.5m in size. The individual foils were manufactured in the company’s ETFE welding plant, which is unique in Switzerland. For the WTO roof, Texlon sought to further develop the profiles commonly used. This further development enabled the fitters to make fine adjustments while clipping the foils in place as well as allowing for easier re-tensioning. These foil cushions weigh about 95 percent less than a comparable glass construction, and their extremely fine support structure enables unbroken views of the skies over Geneva. The foils allow both visible light and the ultraviolet UV-A light essential to plants to penetrate virtually unfiltered.

The unique features of ETFE foils

The foils were extruded by Siegsdorf-based specialists Nowofol Kunststoffprodukte GmbH & Co. KG. The NOWOFLON ET 6235Z foils made from 3M Dyneon ETFE are the only foils to have been used in architecture for more than 30 years – this means unsurpassed experience in all types of climate. 3M and Dyneon are brands of the 3M Company. NOWOFLON is a brand of Nowofol Kunststoffprodukte GmbH & Co. KG.

Solution

The NEWOFLON ET 6235Z ETFE foils come in a thickness of 12-300μm. The company has the production capabilities to produce foils that are both transparent and of almost any RAL colour. 3M Dyneon ETFE is Nowofol’s material of choice. This high-performance material from the fluoropolymers family affords virtually universal chemical resistance and meets the B1 fire class criteria (according to DIN 4102). The tensile strength can reach up to 50N/mm² and the elongation at break more than 300 percent. For extrusion of the foils, Nowofol requires neither stabilisers nor softeners, which can evaporate over time and compromise the roof’s positive qualities. Due to the foils’ extremely smooth surface on which fungi and bacteria are unable to take hold, rain is sufficient to keep the roof clean. Texlon has tailored the stability of the roof cushions according to the wind and snowfall expected for Geneva from 100 kg/m².

NOWOFLON ET 6235Z foils were manufactured in the company’s ETFE welding plant, Texlon sought to further develop the profiles commonly used. This further development enabled the fitters to make fine adjustments while clipping the foils in place as well as allowing for easier re-tensioning. These foil cushions weigh about 95 percent less than a comparable glass construction, and their extremely fine support structure enables unbroken views of the skies over Geneva. The foils allow both visible light and the ultraviolet UV-A light essential to plants to penetrate virtually unfiltered.

TENSINews Nr. 25 – September 2013

Name of the project: Courtyard of Centre William Rappard, WTO building
Location address: Geneva, Switzerland
Architects: Wittfoht
Calculation, manufacture and installation foil cushions: Texlon
Material: triple layered foil cushions in NOWOFLON ET 6235Z (3M Dyneon ETFE)
A new green house
for the Botanic garden of Aarhus, Denmark

Context
An elliptical cupola structure forms the envelope for a new green house in the botanical garden of Aarhus. It is used for plant cultivation thus tropical and subtropical plants can be grown in an environmentally controlled area. ETFE cushions are used, which do not block the UV radiation (Fig. 1).

Project
The primary structure consists of ten arches in each direction, longitudinal and transversal. The maximum arch span is approx. 41m and the maximum arch rise is approx. 17.5m. The arch distance varies form the dome base to the dome apex (between 1.6m and 4.9m). The dome is symmetric by one axis, and covered with ETFE-cushions. They are double layer cushions towards west, north and east and triple layer cushions with integrated shading toward the south and in the zenith of the dome (Fig. 2).

Steel brackets are attached to the main steel structure to carry the aluminium extrusion profiles, which form the perimeter of the ETFE-cushions. The aluminium profiles follow a 3 dimensional curve, and are bended and drilled in 2 directions. Under the extrusion profile is a gutter to accumulate condensate. Some of the cushions are used for pneumatic shading. These are the triple layer cushions, with outer and middle layers which are printed. The middle layer can be moved by changing the air pressure from the in- to the outside. When the inner layer is close to the outer layer, the shading is more effective. The rest of the cushions are transparent with double layers. In total there are 34 triple layer cushions and 90 double layer cushions, which are supplied by a central blower unit. Different pressure levels can be applied, normal, half snow and full snow. Furthermore the blower system provides a differential pressure to form and to move the middle layer of the cushions. In the zenith of the roof two triangular windows are also covered with ETFE-cushions. These can be opened to provide natural ventilation or as smoke exhaust in case of fire.

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DOME MADE OF SOPHISTICATED DOUBLE AND TRIPLE LAYER ETFE CUSHIONS

Name of the project: Botanic garden Aarhus
Location address: Aarhus
Function of building: green house
Type of application of the foil: roof and facade
Year of construction: 2011 to 2013
Architects: C. F. Møller
Structural engineers: Søren Jensen
Consulting engineer for the foil: formTL ingenieure für tragwerk und leichtbau gmbh
Main contractor: BK Teknik A/S
Foil cushion contractor: Ceno Membrane Technology GmbH
Supplier of the foil material: Nowofol
Manufacture and installation: Ceno Membrane Technology GmbH
Material: ETFE- cushion
Covered surface (roofed area): 1145m² (1800m²)

Figure 1. The dome new green house made of ETFE cushions © Quintin Lake
Figure 2 a - b. The primary structure made of 2x10 arches and finished with 124 ETFE cushions (double and triple layer) © Quintin Lake
At the secondary school in Lössnitz, a small town in the Ore Mountains, a new route was planned with the redesign of the external premises - 'Learn outside with all senses' - thus the motto. In addition to green areas and playing facilities, an impressive "Classroom in the open" forms the focal point of the overall complex, affectionately created. Constructed as an amphitheatre, it provides space for up to 300 scholars simultaneously (Fig. 1a and b).

Since 2011, the open air room is protected by a membrane roof made from polyester fabric coated with PVC. With a diameter of 22m, it covers a ground area of approx. 340m². Due to the high snow load of 160kg/m², for the size of the roof relatively solid material had to be used, from the so-called Type IV, with high tensile strength and resistance to tear propagation.

**PROJECT 1**
"A classroom in the open", secondary school in Lössnitz

One of the most modern school complexes in Germany, for 2,600 scholars, has emerged in Duisburg. Three vocational schools were combined into a building ensemble with a total of 56,000m² gross floor area. A particular architectural highlight is the covered foyer area between both main buildings, this so-called "Magistral" breaks the austerity of the volume of the building and simultaneously provides a covered recreational yard for the scholars (Fig. 2a and b). The atmosphere here is friendly and flooded with light, particularly due to the transparent ETFE roof construction with its light, filigree steel construction. A total of 28 identical, dual-layer foil cushions cover the complete area of 1,009m². Each cushion is approx. 13,90m long and 2,70m wide.

**PROJECT 2**
A transparent roof for "Magistral", Vocational college in Duisburg

The modern membrane construction sets innovative accents in the architecture for schools and training facilities. Integrated into a well-planned, overall architecture concept, the light graceful canopies contribute to a protected and comfortable environment that, if nothing else, can result in an increased readiness for the scholars to learn and identification with the respective training facility. Four interesting projects in which Ceno Membrane Technology GmbH was involved are presented.
PROJECT 3
A new "living space", Max-Planck-Gymnasium in Lahr

Due to the change to full-day operation, there was a requirement to extend the area of the Max-Planck-Gymnasium. In addition to all of the required functionality, the school management also paid particular attention to provide a high atmospheric quality for abidance for scholars and teachers. Initially, a new construction was considered, but the possibility of using the old building structure was soon recognized to cover the existing inner courtyard of 1.200m² (Fig. 3a and b). An open and communicative room was provided using a new transparent ETFE foil roof, which offered large potential regarding efficiency and also architecturally.

The school facilities, such as refectory, kiosk, library and all-day rooms in the form of coloured building cubes were situated under the new roof with sufficient space. In addition to the enormous gain in area for utilization the heating requirement was also significantly reduced, due to the light and UV permeability, as well as the thermal insulation property of the pneumatic ETFE construction.

PROJECT 4
4.300m² protected recreational areas, European school in Luxembourg

In 2012, the second European school in Luxembourg was completed. Within the framework of the overall new construction, large zones of the recreational areas were covered, a total of 5 roofs made from dual-layer foil cushions (Fig. 4a, b and c). The upper layer of the ETFE foil cushion is matt on one side, whereby, intensive radiation is prevented but, simultaneously, ensures a pleasant light that does not glare.

<table>
<thead>
<tr>
<th>Year of construction</th>
<th>2011</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planning / Architect</td>
<td>Town of Lahr, Structural Engineering Dept.</td>
</tr>
<tr>
<td>ETFE-construction</td>
<td>Ceno Membrane Technology GmbH</td>
</tr>
<tr>
<td>Material</td>
<td>three-layer ETFE foil-cushions (upper foil 200μm, middle foil 150μm, lower foil 200μm) upper and middle foil partially printed for the purpose of shading</td>
</tr>
</tbody>
</table>

Anne Bosse
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<table>
<thead>
<tr>
<th>Year of construction</th>
<th>2012</th>
</tr>
</thead>
<tbody>
<tr>
<td>Architect</td>
<td>Michelpetitarchitecte, Luxembourg</td>
</tr>
<tr>
<td>ETFE-construction</td>
<td>Ceno Membrane Technology GmbH</td>
</tr>
<tr>
<td>Material</td>
<td>ETFE foil (upper and lower foil 250μm)</td>
</tr>
</tbody>
</table>

Figure 3a-b. New "living space" © Oliver Kern

Figure 4a, b - c. Protected recreational areas © Bohumil Kostohryz
The Design Recommendations for ETFE foil Structures are a product of over 4 years work by TensiNet ETFE Working group. Although ETFE is a widely used material, it is still a young material compared to other materials as steel, wood and concrete. A European standard is not available nor is extensive research on mechanical properties. These design recommendations present current knowledge and compare different design concepts. Therewith it is a 'state-of-the-art' report, not intending to be comprehensive. However, as TensiNet is involved in the preparation of a Eurocode on Membrane Structures (CEN/TC250 WC5), these recommendations will be used as input for the Eurocode on Membrane Structures. This Guide recommends safety requirements which need to be considered for the design, calculation, manufacture, installation, maintenance, operation, examination and testing of ETFE foil structures. This can be applied to double- and multi-layer ETFE cushion structures or single layer tensioned ETFE membrane structures. The field of application of this Guide includes all kinds of ETFE covered structures. The content of this Guide brings together the different existing concepts as far as possible.

TensiNet Symposium 2013
[RE]THINKING Lightweight structures
Proceeding

The proceedings contain the full papers presented at the TensiNet Symposium 2013 in Istanbul. Contributions are clustered around several topics under the general theme [RE]THINKING lightweight structures.

Papers on ETFE show that this material is becoming increasingly important for tensioned surface structures. Several papers report on recently built STIMULATING and EYE-CATCHING PROJECTS and are oriented towards architects, designers and decision makers. Papers on ADVANCED CONCEPTS inspire visions for daring applications in the future, while contributions on PNEUMATIC STRUCTURES illustrate how to apply air as a lightweight building material.

FLEXIBLE COMPOSITE MATERIALS
in architecture, construction and interiors

Textile architecture has been captivating humanity for many centuries. In recent years and decades, the emergence of innovative materials has created new opportunities to utilize this fascinating material in the fields of architecture, construction, and interiors. Textiles derive their fascination from the special forms these fabric structures make possible and from their unusual character as soft materials. Together with their functional and structural properties, they possess a range of capabilities equally suitable for spectacular and everyday building tasks. This book deals with technical textiles in three sections: in the first chapter, the material is introduced with its specific properties; the second chapter deals with its uses in the areas of architecture, textile facades, solar protection, and interior design, with special attention to finishing techniques and construction principles. The third chapter illustrates the various fields of application with a selection of 20 international built projects.
The Flower Expo combines an indoor exhibition hall and outdoor exhibition area. The indoor exhibition hall is divided into general gallery and thematic gallery. The outdoor exhibition is mainly about plant landscape. The 8th China Flower Expo will be held at the lakeside of West Tai Lake in Wujin District, Changzhou City, Jiangsu Province.

Project
Beijing Space Frame Consulting Co. and Shanghai Tent Membrane Structures Co., Ltd. were involved with the engineering of the indoor exhibition building named "Special Hall". Figure 1 shows the sketch of the winning project, designed by Shanghai Sunyat Architecture Design Co., Ltd. The project is 82mx50m, 22m high and has a surfaced area of about 6000m². The winning project was further developed by using a monolayer steel grid shell. This kind of structures look slim and are eye-catching. Similar famous steel grid shells are the covering of the courtyard of the British Museum and Sun Valley at Shanghai World Expo Axis. A light single layer made of ETFE was used to complete the construction. The architect set out the design principles as followings: 1/ no changes on the shape; 2/ the grid should be regular and uniform; 3/ the ETFE should be a single layer; 4/ the ETFE roof should be less divided and the unit should not be a diamond shape. The client principle is simple, always mindful of the cost-saving. The bionic design looks like a big fish. In China a fish can symbolise happiness and richness. This unique shape is found out by the architect with the program "Rhino Nurbs surface" and is really different from Frei Otto's physical model shell. This form of a shell is uncommon in engineer area. The software program SAP2000 was used to build up a model with area elements for checking whether the structure could work well in the light of the 1st design principle outlined above. After applying the DL+LL (dead load and live load) and analysing, the stress-strain diagram shows only that the round joint support over ground is not demonstrated enough and that more column support to the middle of the shell is needed. Having added 41 inner columns afterwards, it works well with respect to 1st design principle. The 2nd design principle is the challenge of how to develop the grid taking into account:
  • the shape is not the analytic surface nor the form-finding result based on tension or pressure;
  • Membrane Strength Limit: the max. span for 250μm thick ETFE single layer is about 1.7m;
  • fabrication and installation may be difficult to handle;
  • artistic requirement and
  • cost limit.
According to above it was decided to develop the grid following the below rules:
• set the warp beam as Fig. 2;
• limit the max. distance of warp beam to 1.7m;
• connect the link beam to warp beam and try to make the angle between 45° and 60° for stable capability as well as the architect likes this form;
• the detail connection for link beams and warp beam is crossing-line-weld. The 3D shape of the project is very complicated; it was needed to make the 3D shape to 2D spline or line to simplify it.

After the discussion with the steel factory engineer, it was decided to realise the warp beam in a plane as 3D curved piped are difficult to fabric. To find out the warp line a section cutting was used, referring to the membrane cutting theory. Then the warp line was divided and the link beam added. Together with the architect the design was adjusted for a couple of times. Figure 3 shows the final grid model.

At current stage, working on the engineering analysis could be started. The wind coefficient is different from most of common structures. It was even impossible to find the value directly from the standard. Mr. Geng from Tent Co., in cooperation with the University Tongji, did the cooperation with the University Tongji, did the Computational Fluid Dynamics analysis as numerical wind tunnel. Parts of the values are shown in Figure 4.

The loads case:
Pre-stress (PL): 1.0 × 1.0kN/m for membrane, Snow Load (SL): 0.35 kN/m², Wind Load (WL): 0.40 kN/m², Seismic Load: Chinese Standard, the first vibration mode is 0.475s, Temperature Load: ±30°C.

To estimate the safety of the structure, the analysis model was build up in two ways: 1/ all the connections of the grid are rigid, no relax of the degree; 2/ relax the moment of link beam end. The nonlinear analysis is OK for both models. It’s necessary to finish the stability analysis. The load-deformation curve shows the stability safety factor is higher than 10.

According to Chinese standard, the result is safe. Detailing the design is a challenge. To achieve an optimal result for this project Shanghai Tent Membrane Structures Co., Ltd and Beijing Space Frame Consulting Co. developed a new clamping system to connect the ETFE membrane to the steel grid shell. The structure details refer to the figures 5 to 7 and the membrane details refer to the figures 8 & 9. The project is nearly finishing its installation (Fig. 10 and 11). The flower exhibition will be held from 28th September to 27th October 2013.

B. Stary and F. Neitzel welcomed the participants of Textile Roofs 2013 and introduced the four lecturers of the first morning session.

‘On Shapes, Forms and Structures’ was presented by J. Hennicke. The disquisition showed the great importance of different types of physical models and experimental techniques for the understanding and optimization of lightweight structures.

D. Ströbel and J. Holl introduced the software Easy as a modelling tool for cable nets, membrane structures and inflatable cushions. The form-finding and the statical analysis are performed in order to optimize the construction and to generate the suited cutting pattern. The developed add-on software allows creating a holistic model. Another numerical modelling tool Formfinder is presented by R. Wehdorn-Roithmayr. Besides the form-finding and analysis tools, different detailing solutions are proposed and a database with many forms and typologies is provided.

Finally, several ‘Digital Tools in Architectural Education’ are shown in the presentation of M. Feyerabend. The main principles are mentioned: a combination of physical and numerical modelling is needed. Furthermore, two projects are discussed more in detail: a swimming pool cover and the ‘Echolot’-pavilion student’s project (Fig. 1). The second day started with ‘From Tent to Textile Architecture’ by J. Groth. Although the design of tents uses the same approaches, some crucial aspects, like structure, materials and connections, need to be further investigated.

M. Kiefer gave an overview of some interesting projects all over the world. A variety of structural systems was shown, with small to large scale projects. The fascinating lecture of N. Fiedler impressed everybody. His passionate talk on a number of Brazilian projects contained a lot of different aspects and structural designs. Not only architectural structures, but also, for example, an undersea oil extraction system with membranes was shown (Fig. 2).

As it is known that acoustic and thermal insulation of single layer membranes is not always optimal, a lot of research is done on this aspect. F. Sahnoune clarified a ‘New Development in Façade and Acoustics’, where an interesting solution and some remarkable results are provided.

Lastly, K. Moritz guided us through some real scale material testing methods, and more specific the ‘Structural design and membrane analyses of ETFE-film-cushions’. The presentation showed several selected exemplary projects (Fig. 3).

The third day began with an expose by R. Wagner. Firstly, a theoretical overview of some interesting remarks on the determination of the material properties of membranes was discussed. Secondly, a research project of an ‘Energy efficient textile building with a solar thermal model and seasonal heat storage’ is thoroughly illustrated. In the interesting second lecture, J. Llorens discussed the problematic of acoustics in buildings and membrane structures, with the focus on concert halls and large sport facilities. Through a set of examples, the main attention aspects were stated and some possible solutions were mentioned.
The conceptual and structural design of membrane structures is one aspect. But what if the manufacturing and assembling techniques wouldn’t be able to follow the growing demand for textile architecture? M. Wallin showed us their new welding features in his presentation ‘Innovations in HF Welding’. Also a new technique for bending air inflated beams, called Tubeflexx, is presented. To close the last morning session, M. Mollaert introduced the (still ongoing) research that has been done on the integration of technical textiles in Kinematic Form Active structures. Experimental investigation of a case study is done in order to verify and optimize existing numerical models for membrane structures.

Workshops
During the afternoon sessions, three parallel workshops took place, allowing the participants to choose and shift as desired. The first session involved a physical modelling workshop, where the interesting brief introduction leaded to a creative set of small scale maquettes (Fig. 4). The other two were hands-on workshops, introducing numerical modeling tools by means of representative examples and exercises; on the one hand the Formfinder software was presented and on the other hand the Easy modeling tool.

Other activities
For those who arrived earlier in Berlin, an Ice Breaker Party was planned on the 16th of June. The richly filled table with snacks and drinks accompanied the interesting talks with the participants and organizers. Also during lunch break, there was a very pleasant and interesting atmosphere, whereafter a collective walk towards the workshops closed the morning session. On Monday evening, a Special Guest Lecture of GMP Architects was organized. A series of amazing projects was presented by M. Glass and L. Brögger. The detailed images of the different construction stages of the projects gave a very good impression of the whole! On Thursday evening, an excursion to the construction site of the Berlin-Brandenburg Airport BER (Fig. 5a and b) was planned, which was already introduced in the Monday evening lecture. After, a visit of the Gasometer (Fig. 6a and b) in Berlin-Schöneberg was scheduled. The impressionant membrane dome could be visited from the inside, whereafter we could join the BBQ situated next to the gasometer. As a closing event, the results of the Students Project were presented. During the preceding week, the students designed a goodlooking and clever roof system for the ruin of the Lindow Abbey in Brandenburg (See also Report on the Students Workshop TR2013). After this interesting presentation and fascinating Textile Roofs 2013, a Parting Drink was offered. It can definitely be said that the 18th edition was a succes! Thanks to the organizers and participants.

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Figure 1. Physical Model HochSchule Koblenz
(Martin Korzenski, Peter Harsch, Sebastian Gabler)
Figure 2a-b. Two projects of Fiedler Tensile Structures: Morro da Urca and MTV-VMB
Figure 3. Swimming Pool Neydens - © seele cover GmbH, Photographer: Matthias Reithmeier, Diamond Graphics, Augsburg
Figure 4. One of the small scale maquettes made during the physical modelling workshop
Figure 5a. Interior view airport Berlin-Brandenburg
Figure 5b. Airport Berlin-Brandenburg
Figure 6a and b. Gasometer at Berlin-Schöneberg
18th International Workshop of Design and Practical Realisation of Architectural Membrane Structures

Designing a Lightweight Cover for the Ruin of Convent Building of Lindow Abbey

The student’s project within the Textile Roofs Workshop 2013 is designing a lightweight cover over the ruin of the Convent building of Lindow Abbey north of Berlin. The abbey was founded in the 13th century and the Convent building was destroyed in 1638 during the Thirty Years War. The two gable and parts of the side walls could withstand the last 300 years. Dr. Borgmann president of the Stiftskapitel of Lindow Abbey was mainly responsible of organizing the funding and the work for fixing and reconstructing the walls in the last two years. Since May 2013 the inner space of the ruin is open for public events such as concerts, weddings and any kind of presentation related to the spirit of the location.

Extending the use of inner space a roof is necessary for protection against sun and rain and the students’ task is to develop a proposal for covering the inner space of the ruin within in one week.

The project is a cooperation of the TU Berlin (University of Technology Berlin), organizing the Textile Roofs Workshop and the KIT (Karlsruhe Institute of Technology). The universities are accompanied by the following professionals: Martin Glass and Lena Brögger, both employee of von Gerkan, Marg und Partners Architects, Stev Bringmann, architect and Sergio Leiva, civil engineer. Mr. Bringmann and Mr. Leiva are working as freelance designer of lightweight structures in Berlin. The eleven students from France, Germany, Poland and Rumania have at the first day the chance to visit the location together with the lecturers. Mr. Schwericke, Mayor of Lindow welcomes the group and they get a guided tour through the abbey site by Dr. Borgmann (Fig. 1).

The best way to learn designing membrane structures is by modeling and the support of the KIT is a model of the ruin in scale M 1:25 (Fig. 2). The model is set up at the Geodatenstand of the TU Berlin where the afternoon lectures of the Textile Roofs Workshop take place. The students get also input from the lectures and participants of Textile Roofs Workshop.

The dimension of the inner space of the ruin is app. 120m in length and 10m in width and approximately an area one third of the building (400 – 500m²) is to be covered providing a flexible outdoor use. The organization of the inner space in relation to the functions and the size for the cover is also part of the design proposal. The cover is only for weather protection without creating a separate indoor space. The visual interference especially with the gables of the historic building is a desired aim for the proposals. The view to the impressive and old trees surrounding the ruin has to interfere as less as possible with the new cover. From the exterior views the new roof is nearly invisible and is designed as an antipode to the massive and ancient walls. The technical requirements of the design are to minimize the forces resulting from the new cover acting on the ancient walls and to find solutions dealing with rain drainage and high snow loads if the roof is design as a permanent structure.

4 proposals

At the end of the week 4 different proposals are presented by the students to the Stiftskapitel of Lindow Abbey and the participants of the Textile Roofs Workshop. The results are discussed in an intensive and controversy way between the professionals, the students and the clients. The proposals are showing different solutions for the lightweight covers regarding to the ancient masonry walls and the impressive atmosphere of the location.

One of the projects has created a path through the ruin covered with a canopy made of arch supported membranes. The arches are changing the span depending on the prosed function underneath the roof.

Another proposal is to reconstruct the shape of the Convent building with a slender steel structure and filling the area between the rafters with a convertible textile membrane (Fig. 3).

The third proposal converts the pattern of the masonry made of rubble stone into a spatial steel grid filled with ETFE cushions to reach a high transparency under the roof.

The last design uses inverted umbrellas to cover specific places of function in the ruin and to keep the view open to the surrounding. The imagination is a kind of spiders web spanning between the ancient walls.

It is planned to continue the work on the designs and to present the final results in an exhibition at the city of Lindow and Lindow Abbey.

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Context
The request of the investor was to cover gasoline pumps using a structure having an appearance of lightness and having at the same time qualities of resistance to wind and snow load. The two structures with dimensions of 19,10m x 10m and 17,20m x 10m have been installed in Sora, located in the center of Italy.

Project
The structure has been calculated according to the following standards: a) NTC08 -“Technical standards for Buildings – Decree-law from the Ministry of Infrastructures and Transports – 14.01.2008”; b) UNI EN13782: 2006 European Standard “Temporary structures - Tents- safety”; c) Circular letter dated 02.02.2009 n. 617 from the Ministry of Infrastructures and Transports approved by the Higher Council of Public Works “Instructions for the application of the New technical standards for buildings”.

The same value for kg and daN is assumed. Accidental loads taken into consideration were the following: snow : qs = 81 kg/m² ; wind : qw = 75 kg/m²

The bearing frame consisting of a central frame and cantilevers made of hot dipped galvanised carpentry, duly painted according to the colour chosen by the customer. Due to the shape and the involved loads, the covering membrane was manufactured using a fabric with a Polyester reinforcement 2200dtex and double PVC–PVDF coating type 5, with a tensile strength of 9000 to 10000N/5cm – tearing strength of 1700N – weight per m² 1450 gr/m². Furthermore, the outer face has a special surface finishing named “TITAN”. It is a fluoridised resin to which a special degree of titanium dioxide is added. Both are conveyed in an acrylic resin. The known characteristics of fluoridised polymers (PVDF) in terms of resistance to ageing and to UV rays have been further improved.

The shape of the membrane has a double negative curvature, which is stabilized by pre-stressing. In the central part of the structure there is a rain-pipe conveying the water into the pillars, also acting as waterspout. The membrane is blocked at the central gutter and stretched towards the endpoints of the 10 cantilevers by means of metal plates fixed to the membrane itself and Diwit bar. Similar structures were already supplied in 2001 in Greece.

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\[\text{Antonella Fedeli: texarch@plastecomilano.com} \]

Name of the project: GASOLINE PUMPS COVERING
Location address: SORA – Frosinone - Italy
Client [investor]: VERFER SNC
Function of building: gasoline pump coverings
Year of construction: 2009
Architects: PM ENGINEERING SRL
Consulting engineer for the membrane: Eng. Dario Ravasi / Eng. Annita Roman
Main contractor: VERFER SNC - Italy
Supplier of the membrane material: NAIZIL SPA
Manufacture and installation: PM ENGINEERING SRL - PLASTECO MILANO
Material: NAIZIL EXTRA COVER – with TITAN finishing
Covered surface (roofed area): 190m² + 170m²
Three cupolas

COMBINING SILICONE AND PTFE COATED GLASS MEMBRANES

for the water park and spa "Splash e Spa Tamaro", Rivera, Switzerland

Context
On the 15th of June 2013 the "Splash e Spa Tamaro" was inaugurated at the foot of Monte Tamaro in Rivera, Switzerland (Ticino). A spectacular water park and spa with large pools, fantastic waterslides as well as themed saunas, steam baths, hamam, relaxation areas and specialized treatments. A great experience is promised in this relaxed atmosphere. The three themes with - large relaxing pools, - slides and - spa are located in three different cupolas, which vary in form and size (Fig. 1).

Project
Three domes with a primary steel structure made of radial lattice girders are covered with membrane on both sides. On the inside, towards the bath, a silicone coated glass membrane forms the space of the inner ceiling. On the outside a PTFE coated glass membrane covers the whole structure forming a continuous surface. The steel structure is not visible any more. Especially the detailing with a linear clamping on a perpendicular steel flat, which is also covered by a membrane strip, makes the steel structure disappear (Fig. 2).

The whole space within the two membrane layers is under air pressure, so that the membrane has its quite flat curvature towards the outside and follows the form of the cupolas. In the air space between the membrane envelope, a low E foil with an aluminum coating spans between the steel girders and reduces the loss of thermal radiation. Also this foil is not visible from the outside and is translucent so that even with the three layers of membrane and foil a slight daylight illumination exists. With artificial light from the inside the cushion volume, the atmosphere within the cupolas can also be influenced, and the appearance of the whole building gets interesting from the outside.
To continue the outer appearance of the membrane in the lower area in front of the concrete structure, the membrane structure changes from a cushion with synclastic curvature into mechanically tensioned panels with anticlastic curvature. This leads to an optical change in the base.

A special challenge was the intersection of the water slides with the membrane panels (Fig. 3 - 4). In total 6 water slides and the big “Tornado” start inside the slide dome, penetrate the membrane panels and continue their curvy run outside before they return to the inside of the dome again. The slides have to be isolated from all membrane forces, but must be included in the airtight structure. A clamped steel ring in the shape of the membrane couple the membrane stress. For tightening a so called “bellow”, a membrane stripe with a small radius was clamped between steel ring an slide to tighten the gap.

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Name of project: Splash e Spa Tamaro
Location address: Rivera, Switzerland (Ticino)
Client (Investor): Suisse Projects (kplan AG)
Function of building : covering of different bath areas
Year of construction : 2013
Architects : Suisse Projects; Marco Giussani Arch. SIA OTIA
Structural engineers: Airlight Ltd, Switzerland
Consulting engineer for the membrane: form TL ingenieure für tragwerk und leichtbau gmbh, Germany
General contractor: Garzoni SA, Switzerland
Contractor for the membrane: Canobbio SpA, Italy
Supplier of the membrane: Saint-Gobain and Interglass
Manufacture and installation: Canobbio SpA, Italy with Seilpartner, Germany
Material: PTFE Glass; Silicone Glass; low E foil
Covered surface (roofed area): 4040m² (6700m²)

Name of Project: Pierson Park Stage Cover
Location address: 238 W Main Street, Tarrytown, NY 10591-3671
Client: Village of Tarrytown, NY
Function of the building: Outdoor performance stage
Type of application of the membrane: performance stage cover
Year of construction: 2013
Architects: RGR Landscape Architects
Structural engineers: David Bowick, Blackwell Engineering
Consulting engineer for the membrane: David Bowick, Blackwell Engineering
Main Contractor: ELQ Industries Inc.
Contractor for the membrane (Tensile membrane contractor): Tensile Integrity Inc.
Supplier of the membrane material: Serge Ferrari
Manufacture: Lightweight Manufacturing
Installation: Tensile Integrity Inc.
Material: Ferrari 902
Covered surface (roofed area): 75m²

Context
The Village of Tarrytown built out the recreational space at Pierson Park, Tarrytown, NY. Tensile Integrity Inc. with support of Blackwell Engineering, Depco, Lightweight Manufacturing, and Signature Structures provided a turnkey solution to protect the stage with coverage. The structure provides shade and protection from inclement weather.

Project
The unique double hypar shape is achieved using tensegrity cable and strut arrangements supported on the structural steel frame. Both the structural steel components and tensile membrane are designed to meet the loading criteria as required by building code. Design time and fabrication took approximately 8 weeks and when the structure was delivered to the project site it was built in under a week’s time. RGR Landscape Architects, ELQ Industries Inc. and the Village of Tarrytown are extremely pleased with the look and feel of the new stage area, and were further pleased to realize that although deployable as initially requested, the membrane can also be left in place permanently.

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The 12th student competition “Textile Structures for New Building 2013” took place this year. The event, which is held every two years, was organised within the framework of Techtextil 2013 by the trade fair and sponsored by the international association TensiNet. This competition, which has become established and popular in professional circles, received many entries both from countries inside and also outside the EU. The broad spectrum of entrants displayed a quality of work that was of a remarkably high level, and this reflects the standard of the competition, which has been organised in an extremely successful and professional manner for many years.

Student competitions are particularly important for the students themselves. On the one hand, the opportunities for the up-and-coming generation to compete against each other on an international platform (and develop their skills further) are becoming increasingly rare; on the other hand, participating in this competition provides an opportunity to carry out a detailed study of the subject area of textile construction. The competition brief states its objective as follows: “The competition sets out to identify innovative approaches and solutions capable of concrete realisation, which use textiles or textile-reinforced materials.” As soon as the judging process began, it became apparent just how much enthusiasm, inventiveness and construction had gone into the different pieces of work – time and again, we were pleasantly surprised by the level of creativity.

Due to the broad diversity of projects submitted the jury decided to retain four prize categories as well as two special prizes with a total prize money amounting to € 8.000.

**Macro Architecture:**
- 2nd Prize: Adaptive Soft Structure (Nattapong Phattanagosai)
- 3rd Prize: Tensegrity Membrane Tower (Pavel Borůvka)

**Micro Architecture:**
- 2nd Prize: Textile Structures for biomorph Architecture (Apolka Temesi)
- 2nd Prize: METAMORPHOSIS (Réka Szabó)

**Environmental and Ecology:**
- 1st Prize: Tissues Founds - L’unité flottante, inhabiting Alexander (Maria-Dolores Parrilla Ayuso)
- 2nd Prize: Trans’skin (Friedrich Gülzow, Hannes Brandl, Maurice Fingler)
- 3rd Prize: OL INVADERS (Oihana Lasuen Oleaga, Laura del Val Marijuán)

**Composites and Hybrid Structures:**
- 2nd Prize: ICD / ITKE Research Pavilion 2012 (Manuel Schloz, Jakob Weigele, Sarah Haase, Markus Mittner, Josephine Ross, Jonas Unger, Simone Vielhuber, Franziska Weidemann, Natthida Wiwatwicha)

**Special prizes:**
- Honorable mention: Acoustic Wave (Eileen Dorer Li)
- Honorable mention: City Lights (Ina Nikolova)

The competition brief outlines a further objective as follows: “In addition, the competition sets out to strengthen contact between the young generation, the universities, the technical textile industry and broad sections of the construction industry.” In the case of several projects, which have already been successfully implemented – e.g. in the form of prototypes involving extensive team building – this is exactly what has been achieved. We consider this type of training to be particularly productive as it enables students to put their own ideas into practice and to recognise their constraints at an early stage. We hope that the next round of submissions in this student competition will continue to set precedents and produce outstanding pieces of work. (Prof. Stefan Schäfer)