TEXTILE HYBRID M1
THE WIND RESPONSE

TENS-SCL 2012
S(P)EEDKITS

PROJECTS
Foil constructions fit for the highest mountains
SÖLDEN, AUSTRIA
 contents

PROJECTS

4 Austria MAIN STATION
A NEW TRANSLUCENT MEMBRANE ROOF FOR THE HISTORICAL ROOF CONSTRUCTION

4 Austria MAIN STATION
NEW PLATFORM ROOF MADE OF ETFE

10 Iran EYE-CATCHING MEMBRANE CONES
BAZAAR GOL

11 France MOBILE COVERAGE
FOR THE CENTRAL PATIO AT THE GREAT MOSQUE

17 Austria DYNEON FLUOROPOLYMER MATERIAL FOIL CONSTRUCTIONS FIT FOR THE HIGHEST MOUNTAINS

21 Germany A SHOWCASE FOR FUTURE ENERGY CONSCIOUS MEMBRANE ARCHITECTURE
THE NEW ENERGY EFFICIENCY CENTER

RESEARCH

6 TEXTILE HYBRID M1 AT LA TOUR DE L’ARCHITECTE
RESEARCH ON HYBRID FORM- AND BENDING-ACTIVE STRUCTURE SYSTEMS

18 The Wind Response on Horn-shaped Membrane Roof and Proposal of Gust Effect Factor for Membrane Structures

REPORT

12 TENS-SCL 2012
LATIN AMERICAN SYMPOSIUM OF TENSILE STRUCTURES

16 ESSENER MEMBRANBAU SYMPOSIUM 2012

24 S(P)EEDKITS WP02 SHELTERS
RAPID DEPLOYABLE KITS AS SEEDS FOR SELF-RECOVERY

MISC

16 WEBSITE TO DISCOVER FORM-TL

24 ISTANBUL 2013 TENSINET SYMPOSIUM 2013
[RE]THINKING LIGHTWEIGHT
Dear Reader,

TensiNet Symposium is now quickly approaching – in less than one month’s time an international audience will meet in Istanbul – the modern and pulsing city connecting Europe and Asia. While preparing the event we have recognized an increasing interest in fabric structures with more than 80 abstract entries which reflects what we recognize in daily work life: Membrane and foil structures are a trend with overwhelming interest.

At the border of the Bosporus at Mimar Sinan Fine Arts University is starting off Wednesday morning with a session on ETFE which has become a constant besides the historically much longer used coated fabric materials for wide span structures.

For the afternoon we have planned a special event inviting locals to take part at presentations on eye-catching projects in order to catch their interest and build a platform for discussions and contacts. This first-day event will be closed with the opening of the exhibition of the main sponsors and posters.

The second day will be characterised by the topic “materials and analysis” and ends with small eye-catching projects.

Friday the presentations in the fields of the young working groups Pneumatic structures and Life cycle Assessment will take place. The symposium will be closed honouring Prof. Dr. M. İhsan Mungan followed by a Sightseeing tour on the Bosporus.

Again TensiNet is one of the main sponsors of the Student competition at Techtextil to engage architecture and engineering students to design fabric structures. The topic has been “Textile Structure for New Building 2013”. The award ceremony will take place at the opening of the exhibition. The award winning designs will be presented in a special show during Techtextil from 11 till 13 June 2013.

As an inspiration source I wish you a pleasant time with the new issue of the TensiNews including topics from stimulating small experimental projects to highly developed shelters. Cable supported fabric structures to air and spline supported membranes.
Main Station Salzburg, Austria

A NEW TRANSLUCENT MEMBRANE ROOF FOR THE HISTORICAL ROOF CONSTRUCTION

Context: A masterly, on-track achievement.
With the conversion of Salzburg Main Station from terminus and transit station to a transit station only, new design possibilities were created for the landmark barrel vault in the platform area. The final result is a skilful lighting effect and cosmopolitan atmosphere, protection from wind and weather, and conformity with the structural specifications. The greatest challenges were the historic arched roofs which were to be kept intact but relocated, plus the fact that a normal railway service was to operate during the redesign, reorganization, and renovation work.

Structural specifications for transit traffic
For over a century, the elegant arched roofs of the main station have been a landmark on the city skyline; their gently curving steel framework strong yet delicate to the eye of the passing traveller. However, the new requirements of a transit station coupled with analysis of weather observations over many years concerning snow and wind load meant changes were necessary for the longitudinal roofing structural system.

The contractor therefore specified the construction of a membrane roof including a substructure on the basis of the historical roof construction. For this reason, the

NEW PLATFORM ROOF MADE OF ETFE

Context
Salzburg Central Station, which was originally planned to be a mixed terminus station and a through station, has now been converted into a through station only. Four new station platforms have now been roofed over with a new platform roof design, and a 1908 historical half-timbered building, classified as an historical monument, have been integrated into this roof.

Concept
The roof design means that both the platforms and the railway line area have been given a connecting roof. The roof surface extends 327m in its longest extension towards the platform and 72m crosswise to the railway lines. The roof surface is divided up into five individual roof liners that
Austrian national railway (ÖBB) stipulated a translucent membrane roof made from PTFE fabric whereby just external loads – snow and wind – would be transferred onto the existing construction at precisely determined points.

The arched roof: from tradition to trend

SEFAR® Architecture TENARA® Fabric 4T40HF was the preferred choice of Architects kadawittfeld architektur from Aachen and build Eng. contractors Zeman & Co from Vienna in view of its flame resistance, water resistance and durability.

With the dismantling of the steel framework – around 2500 individual pieces with a total weight of 250 tons – and the reconstruction by Zeman, the two roof arches which were originally separated by a restaurant are now riveted directly together above platform 2 and platform 3. These are fitted with 1400 running meters of Sefar fabric, divided into 24 single panels. The membranes are arranged lengthwise in sections running from the eaves to the roof ridge, and in width they always take up the space between girders and rafters, or rafters and rafters. On the eaves, there is a two-level snow guard system fitted to the membrane construction.

A plus for comfort

The 1700m² covered area provides fixed protection from the elements and natural lighting which also matches the new structural situation, and Salzburg Main Station has been transformed into an inviting and agreeable international shopping mall. At the same time, the unmistakable, historical appearance of the main station has been preserved.

While in the past a large number of trains terminated at Salzburg Main Station, the new transit station is able to handle more train connections. As a consequence, east–west connections have improved and Salzburg Main Station is now integrated effectively into the trans-European network from Paris and Stuttgart to Bratislava via Vienna.

Ingo Thalhammer:
Ingo.Thalhammer@sefar.ch

Anne Bosse:
info@cono-tec.de

www.cono-tec.de

ETFE cushions: Ceno Membrane Technology GmbH
Planning for ETFE films: Consulting engineering office, Teschner
Material: ETFE film 250µm/300µm
Size: 161 ETFE film cushions with different geometries
Floor space: 6.013m²
Surface area: 6.313m²

Name of the project: Salzburg Main Station
Location address: Salzburg, Austria
Client (investor): ÖBB-Infrastruktur Bau AG, Vienna, Austria
Function of building: Train station
Type of application of the membrane: roof
Year of construction: 2011/12
Architects: kadawittfeld architektur, Aureliusstraße 2, Aachen, Germany
Engineers: Tichelmann & Barillas Ingenieure, Darmstadt, Germany
Main contractor: Zemann & Co GmbH, Vienna, Austria
Contractor for the membrane: Temme Obermeier GmbH, Raubling, Germany
Supplier of the membrane material: Sefar AG, Heiden, Switzerland
Manufacture and installation: Zemann & Co GmbH, Vienna, Austria / Temme Obermeier GmbH, Raubling, Germany
Material: SEFAR® Architecture TENARA® fabric 4T40HF
Covered surface (roofed area): 1700m²

run parallel to the platforms, which are made up of various types of roof, whereby 2 roof liners are made of a transparent ETFE film design: a total of 161 rectangularly-angled pneumatic elements made of 3-layered ETFE film.

The individual cushions have a span of 2.60m to 3m (centre distance) or - in the connecting area to the historical half-timbered building - the element lengths vary between 13m and 24m. The steel substructure is made of modules with a maximum width of 4.53m. The modules are formed by minimum-tension arched girders, which are rigidly connected to the eaves.

The rise of the arch in the control ranges is 1.30m or 1.80m. In the connecting area to the historical half-timbered building, classified as an historical monument, the rise of the arch varies between 1.80m to 3.10m.

Anne Bosse:
info@cono-tec.de
www.cono-tec.de
TEXTILE HYBRID M1
at La Tour de l’Architecte
Monthoiron, France

RESEARCH ON HYBRID FORM- AND BENDING-ACTIVE STRUCTURE SYSTEMS

Context
The Textile Hybrid M1 at La Tour de l’Architecte is an outcome of the combined research, with the students of the University of Stuttgart, on the subject of textile and bending-active material behavior for new typologies of lightweight structures being developed at the Institute for Computational Design (ICD) by Sean Ahlquist and Institute for Building Structures and Structural Design (ITKE) by Julian Lienhard. The Textile Hybrid M1 is situated at the historically protected site of a stone tower, built in the 1500’s, in Monthoiron France. The tower is based on a design by Leonardo Da Vinci from the 16th century, which brought the owners to the idea of making the tower usable for exhibitions. The authors led a design studio with Students from the University of Stuttgart to explore the possibilities of engaging the tower space and developing a cover through form- and bending-active structures. On the basis of a spatial program, such a textile hybrid system was developed where short-cutting of forces produced a minimization of the loading on the tower. In the context of this project, the M1 was developed as a prototypical pavilion (Fig. 1 a-b).

Research project
The M1 structure showcases the research on hybrid form- and bending-active structure systems. The scientific goal of the project was the exploration of formal and functional possibilities in highly integrated equilibrium systems of bending-active elements and multi-dimensional form-active membranes. The resulting multi-layered membrane surfaces allowed not only for structural integration but also served a functional integration by differentiating the geometry and orientation of the membrane surfaces. The structural concept is spatially and technically oriented to the design of a canopy whose exertion of force is minimal to the surrounding context, abutting buildings adjacent to the tower and staying clear of areas containing sensitive archaeological material. At the same time, its spatial presence on the site is maximally articulated. The longest span, of approx. 8m, provides cover to a region where one of the foundations for the tower’s stone buttresses sits (Fig. 2). The minimal external structural exertion was accomplished, at multiple scales, through a macro-system of interwoven bending rods that form leaf-like shapes, and a meso-scale differentiated cell logic. The minimally invasive nature of the lightweight structure was a necessity given the delicate condition of the neighboring stone tower. Aspects of the structural logic were also amplified to investigate the potential for the complexity of the material system to accomplish an articulated spatial experience.

Computation of material behavior
Critical to the development of such complex integrated form- and bending-active hybrid systems was the calibration of design and analytical studies done through both physical experiments and computational methods, within the context of a design studio (Fig. 3). The computational means were continually advanced and calibrated via studies of physical behaviors at varying scales. Such prototyping was necessary to understand the dynamics of the self-organizing system as well as test the relationships between varying material parameters (comparative stiffness and pre-stress between composite rods and textiles) and accomplishing a stable form. The design methodology spanned multiple computational environments and degrees of specificity. For
generative studies, a behavior-based modeling environment, developed in Processing through the research of Sean Ahlquist, was engaged (Fig. 4). The open (Java-based) programming environment allowed for complex topologies to be developed and altered, quickly registering feedback from prototypical physical studies. As both a design avenue and method for material specification, advanced Finite Element simulation in Sofistik® was utilized. Through methods developed by Julian Lienhard, different topological arrangements of macro-level rods and membranes could be studied. The parameters of the complex equilibrium system were explored to determine the exact geometry and evaluate the structural viability. Custom programmed methods in Sofistik allowed for great degrees of displacement to be calculated in order to form-find the rod positions, starting as straight beam elements that were gradually deformed into interconnected curved geometries and finally reshaped by pre-stressed membrane surfaces (Fig. 5a-b). The geometric data therein was determined by the physical form-finding models which defined the lengths and association points for all rods. This form found structural analysis model allowed verification of the geometrical shape including its residual stress, as well as analyzing the deformations and stress levels under external wind loads. Furthermore the form-found membrane surfaces could be processed directly by the textile module of the software for patterning (Fig. 6a-b). Thus, all three design models; the physical and both generative and specific simulation techniques informed each other in this iterative design process.

Textile Hybrid System
The tectonic strategy for the structure was based on textile logic across scales and details, using Glass Fiber Reinforced Plastics (GFRP) and textile membranes for the main structural parts, as well as traditional Japanese lashing techniques for the nodes (Fig. 7a-b). The global form orients the structure towards an existing arched wall which once defined a large domed space, also overlapping an area that holds the foundation of one of the tower’s buttresses below ground. The longest span of the structure is designed to run across this part of the courtyard, preventing any of the structure from invading the area where the tower foundations sit below. At the macro-scale of the structure, the leaf-like geometries of the rods are interwoven relying upon various lashing and lacing techniques to lock the topology into a rigid frame. The tectonic methods are continued at the base of the structure where the rods are tied into bundles and laced to the GFRP foundation posts. Together with the membranes, the structure advantageously accumulates multiple layers, following previous research in Deep Surface Morphologies, and a structural elasticity. Such features enable the system to withstand varying stresses of wind, rain and snow yet rebound to its initial form-found state, while also mediating spatially the same forces via multiple differential layers. The cells provide a similar structural functionality at a smaller localized scale, but are more oriented towards offering an integrated strategy for spatial differentiation. Working to disintegrate the homogeneous nature of the textile membrane, the cells are constant in their topology, yet differentiated in their form. Utilizing Polyamid textiles for tensile stiffening in the cells and variation of light transmittance, the cell surfaces are articulated at more minute scales in comparison to textile membranes (Fig. 8c).

The integrated structural system is accomplished with glass-fibre GFRP rods of diameters ranging from 3mm-24mm in combinations with textile membranes as continuous surfaces and open-weave meshes. The highly elastic rods gain their stiffness from active bending into curved leaf shaped modules
Figure 6a-b: Unrolled geometry of rods and membrane generated with FEM
which are networked into a global structural system. Stress stiffening effects are activated by further deformation of the system through the integration of a pre-stressed membrane surface, and thereby creating a fully textile hybrid system. The structure is comprised of 110 meters of GFRP rods, 45m² of membrane material covering an area of approx 20m² and anchored to the ground with only 3 foundations resting against the existing stone structures which neighbor the tower. In total, the building weighs approximately 60 kilograms (excluding foundations), with a clear spans ranging from 5 to 8 meters (Fig 8a-c). Such high performance in the lightweight structure was reached by following a number of principal design rules found in most biological systems:

- Heterogeneity
- Anisotropy
- Hierarchy
- Redundancy
- Integration

A key feature in the design was the structural integration and heterogeneity; leaving the limits of strictly categorized building structures by accumulating different load bearing strategies in an associative system. The anisotropy of the fibrous materials was used as a driving force in the design and form-finding process of the material system. This system was featured on two hierarchical levels; a macro-system of interwoven bending rods that form leaf-like shapes, and a meso-scale differentiated cell logic.

The very nature of the system demanded simultaneous study of how structural equilibrium is formed and determination of the spatial performative capacity of the result. As such, the design methodology was formed to track both, articulation of material properties and differentiation of spatial consequences. M1 serves La Tour de l’Architecte as an exemplification of innovative structures generated of experimental means, as well as provide fundamental function for meeting, workspace and archaeological study within the complex of buildings as the site undergoes redevelopment. For on-going research, the building serves as a prototype for hybrid form and bending-active structures in their realization, as well as computational design methodologies for their generation.

Sean Ahlquist
Institute for Computational Design (ICD)
Prof. Achim Menges

Julian Lienhard
Institute of Building Structures and Structural Design (ITKE)
Prof. Jan Knippers

<table>
<thead>
<tr>
<th>Name of the project:</th>
<th>Textile Hybrid M1 at La Tour de l'Architecte</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location address:</td>
<td>Monthoiron, France</td>
</tr>
<tr>
<td>Client (investor):</td>
<td>The Armbruster Family</td>
</tr>
<tr>
<td>Function of building:</td>
<td>Research structure, courtyard cover</td>
</tr>
<tr>
<td>Year of construction:</td>
<td>2012</td>
</tr>
<tr>
<td>Architecture and engineering:</td>
<td>Sean Ahlquist, Julian Lienhard</td>
</tr>
<tr>
<td>Students:</td>
<td>Markus Bernhard, David Cappo, Celeste Clayton, Oliver Kaertkemeyer, Hannah Kramer, Andreas Schoenbrunner</td>
</tr>
<tr>
<td>Supplier of the membrane material:</td>
<td>Serge Ferrari</td>
</tr>
<tr>
<td>Manufacture:</td>
<td>Esmery Caron</td>
</tr>
<tr>
<td>Material:</td>
<td>Ferrari Precontaint 402 Translucent, Ferrari Batyline XP55, Penn Polyamid textiles</td>
</tr>
<tr>
<td>Covered surface (roofed area):</td>
<td>25m²</td>
</tr>
<tr>
<td>Funding:</td>
<td>DVA Stiftung, The Serge Ferrari Group, Esmery Caron Structures</td>
</tr>
</tbody>
</table>

Fig 7a-b: Lashing details for the GFRP rod assembly

Fig 8a-c: Individual components of the hybrid system: Bending-active GFRP Structure, attached form-active textile membrane, internal cell structure.

Fig 9a-d: The textile hybrid M1: Internal view of multilayer membrane system with integrated cells. External view in the context of the tower ruin.
Context
Bazaar Gol (The Flower Market) is located in a small valley to the west of recreational area of Abbas-Abad lands. The Abrisham Bridge II connects the two sides of this small valley together and therefore provides a pedestrian-only link between Norouz and Safarhaye Asemani Parks. Two membrane cones which form part of this structure cover an area of 2056m² above this market. What led to the design of Abrisham Bridge II and its membrane coverings was the aim to create a distinctive landmark for Bazaar Gol in Abbas-Abad lands (Fig. 1 & 2).

Objectives
For the membrane roof and the bridge, the following objectives had been determined:
- Linking the two sides of the valley;
- A special and attractive design to build a monumental structure;
- Protection from wind and rain for the stalls of the market;
- Eliminating direct solar radiation that can disturb ongoing activities;
- and last, an easy installation.

Membrane material
To meet our needs as mentioned above, a PVC-PVDF coated polyester membrane was chosen to provide a great view along with lightness and translucency.

Description of the design
Taking advantage of axial forces and avoidance in use of bending moments in the design of this bridge has resulted in significant weight reduction and enhancement of its aesthetic appearance. Tare affixed at centre to a hinged spindle-shaped truss column and from sides to the foundation and central arches of the bridge.

Building process
Construction works started with the concrete casting of the foundations. When the iron anchorages were placed, the bridge and masts were installed, with high precision. Masts were temporarily stabilized with safety cables. The next step was to clamp the membrane together (which was fabricated in 3 large pieces in order to ease the installation process) and fix it on the ring. After that the whole membrane was elevated to the top of the mast to be fixed and finally pretentioned (Fig. 3).

Leila Araghian:
info@dibats.com
www.dibats.com

Name of project: Bazaar Gol
Location of project: Tehran, Iran
Year of Construction: May 2011
Architect: Diba Tensile structures
Engineering: Massimo Maffeis Engineering and Consulting
Manufacturing, Fabrication & Installation: Diba Tensile Structures
Material: Verseidag PES-PVC-PVDF (2x1700m²)
Covered Area: 2x1028m²

Figure 1. Plan view
Figure 2. View from the market place & from the bridge
Figure 3. Installation of the membrane
Concept
This project is a mobile device able to cover the central courtyard of the Great Mosque of Paris, with overall dimensions of 29m long and 20m wide (Fig. 1). This cover is divided into two parts: the first part is parked at the north side of the patio, the second part at the south side. Each part is made of a motorized arch, able to pull the current following arches. When the two motorized arches are in contact, at the centre of the patio, the cover is closed. The structure is composed of 9 arches, supported by rails able to move up and down along supporting columns (Fig. 2). The coverage installed on the structure is made of polyester fabric, high strength, PVC coated, protected by coatings limiting the adhesion of dirt.

Principle of operation
The operation consists to park the cover: 4 arches are parked at the north side of the patio, 5 arches at the south side. The movement is made using four electrical motors moving the two central arches. When the arcs move, pantographs equipped with cables guide the fabric during the folding phase. When the two half-cover are parked the supporting rails move down along the support posts. The reverse operation allows covering the patio (Fig. 3). All these operations are done automatically, from electrical control panel, under limited climatic conditions.

Jean Marc Marion
AIA Ingénierie Agence de Lyon
jm.marion@a-i-a.fr
www.a-i-a.fr

Name of the project: Mobile coverage for the central patio at the Great Mosque of Paris
Location address: Paris, France
Year of construction: 2012
Client: SOCIETE DES HABOUS ET DES LIEUX SAINTS DE L’ISLAM
Architects: A.T.I.C., Versailles
Multi disciplinary Engineers: AIA Ingénierie, Lyon
Main Contractor: Normandie Structures, Étrepagny
Supplier of the membrane: Ferrari
Surface project: 580m²
Total cost: €860.000 (excl VAT)
The Fifth Latin American Symposium of Tensile Structures was held in Santiago de Chile in September 2012. It was organized by the School of Architecture of the Pontifical Catholic University of Chile and chaired by the architect Juan I. Baixas. It was the fifth in a series of symposia that began in São Paulo in 2002, followed by Caracas in 2005, Mexico City in 2008 and Montevideo in 2011. Over three days, 6 lectures and 24 presentations were given to 161 participants from 18 countries and 4 continents. The main topics focused on recent projects, as well as new applications, basic concepts, features, materials, design, software, testing, installation and education.

Main lectures
R. Santomauro opened the Symposium with “The fifth material” and referred to membranes as the fifth material for architecture after stone and concrete, timber, metal and glass. He discussed a series of Uruguayan case studies and pointed out the main aspects that must be taken into account in every design, such as client expectations, use, materials, experience, cost, durability and functionality (Fig. 1).

In “The butterfly and its skin”, N. Goldsmith attempted to define what a pavilion is, using a set of carefully chosen examples ranging from exhibition pavilions and music venues to add-on enclosures such as access halls and stalls. He explicitly mentioned the human skin (and described Thomas the Apostle placing his hand on Jesus) as the largest human organ; it contains nerve endings and veins and responds to pressure, temperature and touch. Skins in buildings do not perform as well as human skin but their capabilities for multifunctional enclosures are improving. ETFE foil pillow systems, shading devices (Fig. 2), illumination screens and rainwater collectors were mentioned. He summarized the history of architecture as six milestones: Egypt, Greece, Gothic, Renaissance, Modernism and ETFE—a visual journey from mass to membranes.

During the question-and-answer time, he clarified that solar protection on façades has to be planned from the beginning to avoid incurring additional structural costs.

“Taut structures” by R. M. Pauletti, began with windmills, umbrellas and the Golden Gate Bridge, and showed how tensile structures work. They are light because they weigh less than the loads. Pre-stress (rather than material) provides stiffness, and frequency (a significant property for flexible structures) depends on tension. They are luminous, deformable and funicular (following the load paths) and have a double curvature that provides stability. Paradoxically, these characteristics configure the possible form (Fig. 3), whereas rigid structures (steel or concrete) provide much more freedom (Fig. 4).

F. McCormick (Buro Happold) presented the environmentally friendly 2012 London Olympic Stadium. He focused on the roof, which was designed to prevent wind from interfering with potential world records. Commenting on the installation process, he astonished the audience with the accuracy of the positioning of the last compression ring segment that achieved a tolerance of a few millimetres for a total size of 340m x 260m (Fig. 5). The vertical enclosure was made of

Figure 1. P. Pinto & R. Santomauro: Automotora Bariola
Figure 2. FTL: Mesa Arts Center
Figure 3. Flexible structures are not free-form structures. R. M. Pauletti: Fortaleza church
Figure 4. Rigid structures provide much more freedom. F. Gehry: Guggenheim Museum, Bilbao
Figure 5. Olympic Stadium, London, 2012
Figure 6. C. Hernández: Testing apparatus and procedure for measuring the influence of humidity, temperature and wind on the pretension of hypars
Figure 7. Auxiliary structure for the installation of the petals. Venezuela Pavilion. Hanover 2000
vertical textile strips and was dismantled after the Games because it was not safe enough to be permanent. To conclude, he announced that it would be possible to climb the Millennium Dome by means of a fabric walkway from June 2012 onwards.

In “Loss of pre-stress in textile roofs due to climatic conditions”, C. Hernández (from the Experimental Construction Institute, UCV, Caracas) showed the design of a testing apparatus and procedure for measuring the influence of humidity, temperature and wind on the pre-tension of hypars (Fig. 6). He observed an initial loss of pre-stress that slows down with time. The phenomenon accelerates if temperature cycles are applied. He extrapolated the results for up to six years and observed a logarithmic tendency towards stabilisation.

J. Llorens’s lecture was entitled “Influence of the installation process on the design of tensile structures”. He presented the aspects of the installation process of tensile structures that have to be considered in the design if feasibility and affordability are to be achieved. The first part of the lecture introduced the main characteristics of the erection process, means of operation and the list of actions to be completed. In the second part, the implications of the site, climate, means of transport and elevation, labour, terms of delivery, auxiliary structures (Fig. 7) and temporary stability were illustrated using case studies.

Current research
In “Architectural textiles as envelopes for buildings”, A. Bibiana designed the enclosure for a hotel in Santiago de Cali, Colombia, where the climate is tropical with few variations, heavy rains and solar brightness. He achieved a U value of 2.11 W/m²K for two membranes and a cavity that is much better than the 2.43 W/m²K of the conventional masonry wall. Adjustable shading devices were needed in glazed openings.

“Textile as a material for architecture. Hybridizations and adaptations to conform small scale enclosures in existing buildings”, given by I. Burdiles, showed the possibilities and restrictions of synthetic textiles and explored the forms of tensile membranes applied to closed, permanent and comfortable small spaces (Fig. 8). M. Mortera and J. V. Correia looked for applications of bamboo to geodesic domes and tensegrity structures based on joints that can be tied in a simple manner or specially designed with tailor-made devices (Fig. 9).

http://www.coroflot.com/LILD

C. Gutiérrez in his presentation “Material shade of a digital archetype. Parametric design in search of new expressions in tensile surface structures” theorized on the improvement of the repertoire of shapes and types through digital speculation. N. Torres was more pragmatic and showed the “Tensegrity ring” of D. Peña (Fig. 10) and a deployable stage of her own (Fig. 11).
Testing methods
R. Radillo revealed a step forward in measuring stresses, strains and the Young modulus of fabrics through electronic speckle pattern interferometry and the visualization of static and dynamic displacements of specimens with optically rough surfaces. The speckle patterns are compared with holograms of reference.

Design
In “The whole process of materializing tensile roofs”, W. Runza summarized the tasks involved in the design and installation of tensile structures: feasibility analysis, form finding, structural approach, simulations, detailing, production, transport and installation, illustrated with the Puerto Madero Café in Buenos Aires. He showed a video of the erection of the roof of the Norcenter Shopping Center in Buenos Aires, which was accompanied by “The abduction from the Seraglio” by W. A. Mozart (Fig. 12). R. Sastre compared discretization methods and software alternatives. He commented on the precision achievable and highlighted accuracy as being highly dependent on the values adopted for loading. He also referred to “Pre-stress of membranes: how and when. Simulation” and its values, and how to take these values into account in static analysis, an iterative process in which every local action influences the whole. To make the task shorter, he recommended an inverted method of introducing the final values for pre-stress and relieving them step by step while controlling the deformations and reactions. “Globalization of tensile structures?” was the question asked by P. Pinto. She claimed the adaptation of the high-tech exhibitionist technology developed in Europe, the USA and Japan to the Latin American cultural and social context and economic possibilities (Fig. 13). She mentioned the emergency situations that frequently occur, the need for solar protection and the availability of local materials such as bamboo.

Realisations
G. Castro: “ETFE. First design in Latin America”. It is a shopping mall in Bogotá: http://www.castrorojas.com
J. I. Baixas: “Two pneumatic wings” were two experiences of low cost self-construction with polyethylene that nostalgically recalled the youthful optimism of Instant City in Ibiza, and the Domebook, Shelter and Whole Earth Catalogue publications by Lloyd Kahn and Stewart Band.

P. Valenzuela: “Tensile membranes for small architecture”. Valenzuela focused on design and detailing and mentioned the use of stiff edges when a membrane is being connected to existing buildings: http://www.wagg.com.ar
D. Jimenez: “Juventus Stadium, Turin”. The Stadio delle Alpi was built in 1990 for the World Soccer Championship (Fig. 14). It was demolished in 2008 because the athletics track meant that spectators were too far from the playing field. The new Juventus Stadium reduces the lightness of its predecessor considerably because it replaces the tension ring with four latticed beams and the membrane with heavier metal sheets with less deformation (Fig. 15).

Education
In “Teaching tensile structures”, R. Garrido showed a teaching and dissemination experience on tensile structures that took place at Peruvian universities two years ago. It is led by the digital media lab, a theoretical-practical laboratory of the School of Architecture at the San Martin de Porres University in Lima, Peru that aims to develop technical, analogue and digital principles for application in architectural production. It generates creative and critical knowledge of digital technology based on networks of thought and research tools. http://laboratoriomediosdigitales.blogspot.com.es

Presentation of products
N. Gazali: “Glass-PTFE membranes”.
N. Gazali: “Textile envelopes and ETFE. Possibilities”
G. d’Anza “ixForTen 4000. One of the most complete solutions in the field of tensile structure engineering”: www.forten32.com
“The Naizil range”: http://www.naizil.com

Other activities
Françoise Fournier, in representation of Serge
Ferrari, offered the welcome toast under the awning of the Fifth Symposium (Fig. 20). There was the possibility of visiting the city of Santiago de Chile, and particularly the Laguna Sur, Las Parcelas, Monte Tabor and Del Sol metro stations (Fig. 21).

Highlights of the symposium
During the Fifth Symposium, the following utterances were recorded for posterity: “If the cables and membrane are removed and the structure stands, it is not a tensile structure.” G. Castro

“If the cables and membrane are removed and the structure stands, it is not a tensile structure.”

“Membrane engineering needs computational modelling.” D. Ströbel

“Durability is twice the warranty.” S. Delano

Conclusions
The presentations, discussions and debates held during the Fifth Symposium highlighted the consolidation of the trend noted in 2011 in Montevideo towards maturity and development of tensile structures implemented in Latin America. Particularly noticeable was the incipient adaptation of designs and technology to environmental, cultural, material and social contexts.


Josep I. de Llorens, Dr. Architect, ETSAB/UPC

ignasi.llorens@upc.edu

LA TENSORED
THE LATIN AMERICAN NETWORK OF TENSILE STRUCTURES

The Fifth Symposium was also the occasion to meet the members of the Latin American Network of Tensile Structures. The steering committee, regional coordinators and treasurer were appointed. The participants decided to develop the Network’s statutes and set up its website http://www.latensored.org. The VI Symposium in São Paulo from 8 to 12 September 2014 was announced, and representatives of Argentina, Guatemala, Mexico and Peru showed an interest in organizing the VII edition.

TENSANTIAGO STUDENT COMPETITION

The competition for design projects that make use of textile, cable or tensegrity structures, which was open to architecture and engineering students, received 18 proposals. The jury, composed of G. D’Anza, J. Baixas, N. Goldsmith, J. Llorens, F. McCormick and R. Santomauro, gave the award to A. Montes for “Tensile structure for emergency evacuation systems” (Fig. 16). It is an original idea whose seductive architectural presentation does not disguise the need for further technical development.

The following finalists were chosen.

D. Buzeta: “Suspended footbridge made of bamboo”, a realistic approach to the use of a Chilean endemic bamboo under tension (Fig. 17).

E. Reyes: “Fungitens”, a proposal of floating walkways on the flooded streets of Belén. They are complemented by natural lighting provided by Neonothopanus gardneri, a luminous fungus of South American rainforests (Fig. 18).

G. Zamorano: “Urban roofs” (Fig. 19) develops a flexible and adaptable roof for areas struck by natural disasters, such as Chile and Haiti. It is easy to transport and build and shelters those working in post-catastrophe situations. It collects rainwater and uses resources efficiently.

Figure 21. Del Sol transfer station, Santiago de Chile
The Essen Laboratory for Lightweight Structures (Essener Labor für Leichte Flächentragwerke, ELLF) and the Institute for Metal and Lightweight Structures (Institut für Metall- und Leichtbau) together arranged the “Essener Membranbau Symposium 2012” in Essen on September the 28th. More than 100 guests from the praxis and the research of membrane construction, representatives from the membrane material producers, manufacturers, test facilities and building control authority appeared. They enjoyed the multifaceted and detailed presentations about membranes and used the possibilities for vital discussions.

Professor Ewald Bubner (emeritus of the University of Duisburg-Essen), who accompanies membrane structures since the beginning of methodic research and development in the second half of the 20th century, showed the development of lightweight structures from the past until now, from membranes made of animal hair to technical textiles and foils. He also described the different methods to construct lightweight buildings in the diverse times.

Klaus Saxe (University of Duisburg-Essen, Laboratory for Lightweight Structures, ELLF) presented a detailed description of the material behavior of ETFE-foils. In conclusion of that he proposed an analysis and design procedure based on DIN EN 1990. He accentuated that for ETFE-foils the serviceability limit state rather than the ultimate limit state is decisive for the design.

Professor Natalie Stranghöner and Jörg Uhlemann (both University of Duisburg-Essen, Institute for Metal and Lightweight Structures) contemplated the possibilities and limits of covering the material behavior of coated fabrics in the analysis. They illustrated to what extend the results of the structural analysis depend on the selection of biaxial test data for the determination of elastic constants.

The aspect of form finding and particularly numerical methods for form finding were intensively shown in the presentation of Professor Kai-Uwe Bletzinger (TU Munich). He revealed the uncertainty of this planning phase for flexible structures. At the same time he pointed out possibilities to get better results from the form finding analysis.

Christian Böhmer (Montageservice LB) as a representative of the membrane installers talked about the specific problems of transport and assembly of membrane constructions. Problems may arise due to the planned field size or the packaging and the assembly method. These aspects require an efficient planning particular for glass fabrics.

The analysis of damage events was the topic of Professor Herbert Schmidt (Engineering office Prof. Schmidt & Partner, emeritus at the University of Duisburg-Essen) for his presentation about “Forensic Engineering”. He explained the basic procedure for the analysis of structural collapses with examples of damaged membrane and steel structure elements. This procedure is based on a collection of all facts and their classification. Potential causes are gathered and evaluated, impossible ones are excluded afterwards.

At the end of the symposium Gerd-Michael Schmid (engineering office form TL-ingenieure für tragwerke und leichtbau) presented new application areas for structures from fabrics and foils on the basis of up-to-date projects of his office. The examples showed the miscellaneous possibilities of membrane constructions and illustrated that tensile structures can be build with a high grade of perfection today. Mister Schmid pointed out that tensile structures are still at the beginning of their development and that a great evolution potential exists for the future.

The day ended with a visitation of the ELLF laboratory and with more possibilities for discussion. The proceedings contain the papers of all lectures: Klaus Saxe, Natalie Stranghöner (Ed.): Essener Membranbau Symposium 2012, Shaker Verlag, Aachen, 2012. In the light of the good feedback the organisers look forward to the next Essener Membranbau Symposium to be held in 2014.

Jörg Uhlemann, University of Duisburg-Essen, Institute for Metal and Lightweight Structures
joerg.uhlemann@uni-due.de
http://www.uni-due.de/iml/
Foil constructions fit for the highest mountains

Sölden, Austria

DYNEON FLUOROPOLYMER MATERIAL FOR ARCHITECTURAL APPLICATIONS REMAINS DURABLE EVEN UNDER EXTREME CONDITIONS

Context

Strong gale-force winds, deep snow, temperature variations of up to 60 degree Celsius and intense UV radiation: Constructions high up in mountains face extreme requirements that could only be fulfilled by solid structures until now. Environmentally-friendly lightweight constructions are now conquering this climatic zone. The elegantly sculpted foil constructions of the Gaislachkogl cable car at the valley, middle and mountain stations blend harmoniously into the mountains in the Ötztal Alps. The mountain station is 3.040m above sea-level, making it the highest foil construction in the world. The foils are extruded from 3M™ Dyneon™ ETFE high-performance plastic and are extremely tear-proof, UV-resistant and highly transparent. The Gaislachkogl cable car opened in 2010 and serves one of the most popular winter sports areas in the Austrian region of Sölden. The first section carries up to 3.600 passengers an hour from the valley station (Fig. 1), 1.363m above sea level, to the middle station, located at 2.174m above sea level. This section is the highest-capacity single cable gondola in the world. The highest three-cable gondola in the world climbs onwards and upwards from the middle station to an altitude of 3.040m (Fig. 2). The cars roll on two cables and the third cable pulls the large cars in a more energy-efficient manner than other designs.

First time to use foil architecture high up in the mountains

The stations were designed by Johann Obermoser Architects, an Innsbruck-based architecture firm. They are sculpted and deliver maximum transparency. In addition, foil architecture has been used high up in mountains for the first time. Texlon, a Swiss specialist in hangar, foil and membrane construction, implemented the design. The company operates in Europe and Central Asia and has already built numerous foil roofs. “We designed the cover of the mountain station for wind loads of up to 300km per hour,” says Adrian Imfeld, Marketing Director at Texlon. Using glass was not feasible for technical reasons.

Material with high requirements

The prerequisite is the extremely high tear-resistance of the Nowoflon® ET 6235Z foils extruded by Nowofol Kunststoffprodukte GmbH & Co. KG, based in Siegsdorf, Germany. Depending on the application, the foils reach thicknesses between 12 – 250μm. A human hair is 70μm thick by comparison. Nowofol manufactures both transparent and coloured foils. The company also uses ETFE from Dyneon GmbH as a raw material. This high-performance material is non-flammable, resistant to UV exposure and provides near-universal chemical resistance. The latter is particularly important as direct UV radiation is up to 60 per cent higher in the mountains than in lowlands. In addition, snow and ice reflect 90 per cent of the UV rays. Such high levels of UV radiation age traditional plastics significantly. 3M™ Dyneon™ ETFE works against this way. And there are more advantages. Thanks to the specific properties of the 3M Dyneon ETFE high-performance polymer, the Nowoflon® ET 6235Z foils have a low-energy surface that does not allow snow to gather and a normal rain shower cleans the foils. This significantly lowers maintenance costs. More and more architects all over the world are turning to light foil constructions to develop their own designs and environmentally efficient building practices. Texlon made the foils at the Gaislachkogl cable car with just a single layer as the stations will not be heated. In contrast, multi-layer foil cushions are normally used for closed buildings as they have very good heat insulation properties.

About 3M & Dyneon

3M captures the spark of new ideas and transforms them into thousands of ingenious products. Our culture of creative collaboration inspires a never-ending stream of powerful technologies that make life better.

Dyneon, a 3M Company and part of the Advanced Materials Division, is one of the world’s leading fluoropolymer producers. Dyneon is focusing on development, production and sales of fluoroplastics, Polytetrafluoroethylene (PTFE) and specialty additives.
The Wind Response on Horn-shaped Membrane Roof and Proposal of Gust Effect Factor for Membrane Structures

Wind loading is the most dominant load for membrane structures. Especially, the conic shaped membrane roof, namely the horn-shaped membrane roof, has characteristic curved surface shape. Therefore, it is expected that the aerodynamic characteristics around this roof are very complicated. On the other hand, since the membrane is low stiffness material, the response of membrane structure depends on the pre-stress. Therefore, a setting value of pre-stress is the most important factor of the membrane design for the wind load with turbulence.

From these backgrounds, this research focuses on the one-unit horn-shaped membrane roof and indicates representative wind pressure on it, using wind tunnel test which was under the turbulent flow. Additionally, we evaluated the responses of membrane roof for the wind load by the response analyses. Finally we suggest the gust effect factor for membrane structure, namely “Gfm”, as the new evaluation technique of the wind load for the membrane structure, and indicate some examples of Gfm value.

1. Definition of “gust effect factor for membrane structure (Gfm)”

1.1 Original gust effect factor GEF

The “gust effect factor” (GEF) was originally suggested by A.G. Davenport in 1961. The GEF is a dimensionless coefficient that quantifies the effect of turbulence on wind pressure distribution and enables the assessment of maximum external loading and internal forces in the structure from the analysis of the mean wind pressure scenario. The GEF is employed by code of many countries.

Generally, the GEF is calculated by the ratio between the maximum load effect and the mean load effect shown in following equation, figure 1 and figure 2.

\[
\text{GEF} = \frac{\text{maximum load effect}}{\text{mean load effect}}
\]

1.2 “Suggestion of gust effect factor for membrane structure (Gfm)”

The original GEF value was given on the assumption that the building consist of rigid structures. However, the membrane structure has a characteristic of low stiffness and resists only tensile force. Additionally, the membrane structure needs the initial tensile force to resist the external load as the wind load. For all these reasons, the value of average membrane stress obtained from dynamic response analysis disagrees with membrane stress obtained from static analysis. Therefore, this paper suggests new type of the gust effect factor for the membrane structure which is calculated based on the concept of the GEF, namely “Gust effect factor for membrane structure (Gfm)”. The Gfm is obtained from follows;

\[
Gfm = \frac{\sigma_{\text{dynamic, max, i}}}{\sigma_{\text{static, max}}}
\]

in which \(\sigma_{\text{dynamic, max, i}}\) is the value of the maximum membrane stress on the element number ‘i’ during 600sec from dynamic response analysis using the time history wind load, and \(\sigma_{\text{static, max}}\) is the value of the maximum effective stress for the average wind pressure during 600sec (Fig. 3). Since Gfm value takes account of the membrane pre-stress, this value can be used as the design wind load without the dynamic response analysis to design the membrane structures.

2. Wind tunnel test

2.1 Outline of test

This test measured wind pressure coefficients on the stand-alone model of horn-shaped membrane roof using the Eiffel type wind tunnel as shown in figure 4. The turbulent boundary layer flow was made by the roughness blocks, the spires and the trips. Table 1 shows conditions in this test. It was assumed that a model scale was 1/100 and that a velocity scale was 7/27 at the full scale wind speed 34m/s. In this case, time scale was 11/125.

The 100mm x 100mm square based model was used in this test. Major parameters were three types of rise-span ratio, namely h/L=0.1, 0.2 and 0.3, and the presence of walls. Six types of model were prepared for this wind tunnel test. The outline of models and measurement taps show in figure 5.

These models were made from acrylic plastic. As for the open type model, the roof depth was about 5mm in order to measure both sides of the roof at the same time (Fig. 6). Additionally, wind directions were only four types which were 0-deg., 15-deg., 30-deg. and 45-deg., because of symmetry form of roof. Airflow conditions which were the average wind speed profile, the turbulence intensity, the power spectral density of fluctuating wind speed and the scale of

<table>
<thead>
<tr>
<th>Table 1: Conditions of wind tunnel test</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Wind tunnel facility</strong></td>
</tr>
<tr>
<td>Eiffel type wind tunnel</td>
</tr>
<tr>
<td><strong>Flow</strong></td>
</tr>
<tr>
<td>Boundary Turbulent Layer Flow</td>
</tr>
<tr>
<td>(Urban Area; Terrain 3 in The Building Standard Law of Japan)</td>
</tr>
<tr>
<td><strong>Sampling speed</strong></td>
</tr>
<tr>
<td>500Hz</td>
</tr>
<tr>
<td><strong>Sampling time</strong></td>
</tr>
<tr>
<td>30sec</td>
</tr>
<tr>
<td><strong>Wind velocity</strong></td>
</tr>
<tr>
<td>About 7 m/s at z=35mm</td>
</tr>
<tr>
<td><strong>Rise-span ratio h/L</strong></td>
</tr>
<tr>
<td>0.1, 0.2, 0.3</td>
</tr>
<tr>
<td><strong>Model scale</strong></td>
</tr>
<tr>
<td>100mm x 100mm (model: full =1:100)</td>
</tr>
<tr>
<td><strong>Wall</strong></td>
</tr>
<tr>
<td>Open type / Enclosed type</td>
</tr>
<tr>
<td><strong>Wind direction</strong></td>
</tr>
<tr>
<td>0-degree, 15-degree, 30-degree, 45-degree</td>
</tr>
<tr>
<td><strong>Number of test on each model</strong></td>
</tr>
<tr>
<td>Five times</td>
</tr>
</tbody>
</table>
turbulence for this test (Fig. 8). The velocity gradient $\alpha$ was 0.2 and the turbulent intensity around the roof was about 0.3. This wind was simulated natural wind in the urban area, namely “terrain 3” in the Building Standard Low of Japan.

3. Results Obtained from Wind Tunnel Tests

Distributions of wind pressure coefficient ($C_p$) and fluctuating wind pressure coefficient ($C'_p$) on each model are indicated in figure 7. The $C_p$ and the $C'_p$ changed the distributions depending on the presence of the wall. Particularly, the $C'_p$ of the enclosed model was larger than that of the open type. These results may cause some effects on the response of membrane, since the membrane structure is generally sensitive structure for the external force such as wind load with turbulence.

4. Response analyses under wind load

4.1 Analysis conditions

Static analysis and dynamic analysis were carried out based on following conditions. Simulation models, material conditions and a calculation method of the wind load are shown in figure 8. The shape of the basic model is horn-shaped membrane roof covered over the plan of 10m x 10m. Additionally, this model has a ring and a strut to keep stable of membrane surface in the middle of roof. And the spring at the lower end of the strut resist only compressive force. Rise-span ratios of the roof are 0.1, 0.2 and 0.3, and initial tensile forces of the membrane, i.e. “pre-stress”, are 1kN/m, 2kN/m and 4kN/m. A damping on the dynamic analysis was given by the Rayleigh damping model and a damping constant of this membrane was assumed 3% in this paper.

The external forces are the wind loads obtained from the wind tunnel test on Section 3. Average wind pressures were used in the static analysis and time history wind pressures were used in the dynamic analysis.

4.2 Results of response analyses

Effective stresses which were obtained from static analyses at the wind velocity pressure of $455\text{N/m}^2$ are shown in figure 9. And results obtained from the dynamic analysis are shown in figure 10. This figure shows the time history effective stress on the middle points of the
span on the membrane which model is h/L=0.2 under the wind direction 0-degree. The fluctuation of the enclosed type was stronger than the open type as for the membrane stress. The static analysis result shows that stress distribution changed depending on rise-span ratio. And the value of maximum effective stress of the enclosed type was smaller than that of the open type. On the other hand, the dynamic response analysis indicated that the dynamic response correlates highly with the "Cp'" value. And maximum stress of the enclosed type is larger than that of open type. This study shows that the result of dynamic response analysis leads to the opposite result of static response.

5. Examples of Gfm calculation
The Gfm value was calculated for the stand-alone horn-shaped membrane structure according to the equation (2). "σ_{dynamic,max}" and "σ_{static,max}" are the result of the average static response analyses and the dynamic response analyses. Figure 11 shows the Gfm value on each element on the PS1000 and h/L=0.2 model under the wind direction 0-degree. And all of results, i.e. the results of five times per model analysis were indicated in the same figure. In calculation of Gfm, stress value of zone-F was reduced to half of original value based on the assumption that the membrane of this zone was generally laminated. This figure indicates that the presence of the wall is one of the key factors to evaluate the Gfm value, and the value of it increases with distance from the circumference of the model.

In the same way, another parameter was calculated and plotted the maximum value of all elements for each parameter, respectively (Fig. 12). The value of the enclosed type is larger than that of the open type. And the larger the value of pre-stress become, the smaller the value of Gfm became. But the wind direction has little or no effect on the Gfm value.

Finally, the comparison between the Gfm value and the original GEF value which is 2.5 under the same conditions as the wind tunnel test based on the Building Standard Law of Japan are show in figure 13. This figure shows the average value of Gfm and liner approximation of Gfm on each model and ratio of Gfm to GEF. The value of PS1000 and PS2000 on the enclosed type, and PS1000 and PS2000 on the open type, h/L=0.1 and 0.2 exceed Gfm/GEF =1.0. This study grasped the fact that the low pre-stress model, which is designed using the present GEF value, doesn't perform the design criteria.

6. Conclusion
The membrane structures are designed on the assumption that pre-stress is provided. On the other hand, the usual GEF value has been used for the calculation of the wind load in many countries. This paper shows the value of the GEF correlate with the value of the initial tensile force of the membrane and suggested the gust effect factor for membrane structure, namely Gfm, which is taken into account the initial tensile force of the membrane. This value can be used instead of the original GEF according to form and pre-stress. This paper shows some examples of Gfm value for membrane structure. This concept can be used successfully in other type of tension structure.

Yuki Nagai
Sasaki Structural Consultants
yuki.nagai@mac.com

Akira Okada, Naoya Miyasato & Masao Saitoh
Nihon University
The current approach in reducing CO₂ emissions as part of international and national climate protection policies is based on people's consciousness about the increasing threat of the greenhouse effect and of limited energy resources for a steadily growing global population. Although the building stock is far more challenging, energy efficient architecture is also a need for new buildings. The new Energy Efficiency Center of "Bayerisches Zentrum für Angewandte Energieforschung e. V." (ZAE Bayern) in Würzburg, Germany, aims to stand out as a reference building which implements innovative techniques, serves demonstrational purposes, and to set new standards (Fig. 1).

The building will be used for research and development in the field of energy optimized buildings and allows to be scientifically tested for a range of novel developments. Hence, the project not only involves integral planning, but also putting an innovative building into operation. The new building itself involves innovative, energy efficient materials, components, and systems, all of which are to demonstrate their applicability for both old and new houses. The building is designed to be easily extendable and is equally devoted to energy efficiency and aesthetic architectural design.

A broad range of different membrane materials and technologies are applied for the building envelope. The membrane roof of the main two-story office area is segmented into eight pieces of single-layer PTFE/glass according to the floor plan organisation (approx. 1050m²) (Fig. 2). It is pre-stressed and fixed by a combination of linear edge clamping (2 or 3 sides) and custom corner plates. The material used is Sheerfill II HT EverClean featuring a TiO₂-coating. The roof areas between the PTFE/glass segments which clearly show the architectural structure of the building (stair cases, circulation) are covered with single-layer ETFE (250μm, fritted, approx. 350m²). Obviously, the two membrane solutions for the main building part do not fulfill thermal insulation requirements but provide weather protection, shading and give distinction to the building's architectural design.

The northern lower part of the building is a one-story laboratory wing (technicum). It is covered with 2-layer cushions made from PVC/PES (Précontraint 702, approx. 30 m²) which are thermally insulated using a translucent fibre material (Fig. 3). The membrane materials have been selected to meet requirements for light transmission, g-value and thermal insulation. The cushions show an overall U-value of 1,0W/m²K. The value is valid for the full covered area including the edges, not only for the cushion centre.

To achieve this, Hightex has developed a new thermally improved cushion clamp profile (Fig. 4). It features a "thermal break" by separating the two membrane layers. The Uf-value of this profile is a major improvement compared to standard cushion clamp profiles, the performance is roughly doubled.

Name of the project: Energy Efficiency Center

Location address: Würzburg, Germany

Client (investor): Bavarian Center for Applied Energy Research (ZAE Bayern)

Function of building: research building including offices, laboratories and a technical center

Type of application of the membrane: single-layer pre-stressed fabric and foil, and multi-layer insulated cushions

Year of construction: 2012

Architects: Lang Hugger Rampp GmbH Architekten, Munich, Germany

Structural engineers: SSF Ingenieure AG, Munich, Germany

Contractor for the membrane (Tensile membrane contractor): Hightex GmbH, Bernau, Germany

Supplier of the membrane materials: St. Gobain, Serge Ferrari

Manufacture and installation: Hightex GmbH, Bernau, Germany

Materials: PTFE/Glass, ETFE, PVC/PES

Covered surface (roofed area): approx. 1700m²

Jan Cremers, Director Technology, Hightex GmbH, D-Bernau

jan.cremers@hightexworld.com

Gabriele Müller, Project Manager, Hightex GmbH, D-Bernau

gabriele.mueller@hightexworld.com

www.hightexworld.com
Context
After a first year of meetings and workshops the S(P)EEDKITS - Work Package 2 on SHELTERS, guided by the Shelter Research Unit (LU), proposes a sequence of potential solutions to develop kits for a Safe house unit (Type 1), Multipurpose unit (Type 2), Progressive House unit (Type 3) and Hospital unit (Type 4).

The project will provide kits that can be pre-positioned and mobilized very quickly and easily, that are modular and adaptable, low cost, high-tech in their conception but low-tech in use. These anticipated kits can literally improve the lives of millions of peoples the first hours, days and weeks after a major disaster and this for years to come.

Work Package 2 on SHELTERS
IFRC-SRU, Bertrange, Luxembourg 7th & 8th February 2013

Vincent Virgo, research officer of IFRC - Shelter Research Unit hosted the multidisciplinary team in the head office of the Red Cross Luxembourg.

For Type 1 two university teams, Vrije Universiteit Brussel and Politecnico di Milano, have worked on the development of an ultra light weight safe house unit the so called “clever roof”. The idea of the “clever roof” is to optimise a standard tarpaulin of 4mx6m by adding structural elements to obtain a self-supporting roof. These structural elements are partly included in the kit but will also be completed by materials available on location (to reduce costs of transport). The clever roof can be used in different formations: placed on the ground, lifted with struts and cables or just hanging between existing supports (like trees). The unit can also be multiplied (linear or raster) to obtain a larger scale protection. Another idea is to connect this Type 01 unit to the Type 02 Multipurpose unit to enlarge its scale and application possibilities, and can also be used as roofing for water and sanitation facilities.

The first principle of the clever roof is based on the introduction of a ‘bending active arch’ as structural element (Fig. 1). The standard tarp is divided into a square of 4mx4m for the roof part and a strip of 2mx4m as an overhang or overlap for wind protection. In the square the bending active arch can be placed along several geometric lines depending on the needs and the possibilities to connect: along 1 or 2 diagonal(s), a midline, a side, etc. This bending active arch can be a part of the kit or can be completed by materials available on location. Eventually inflated arches could be used as well. Another issue beside the structural elements is an optimisation of the standard tarp by verifying different materials possibilities such as polyester PVC, insulated material, ‘interconnected double layer’ material, etc. Important for the fine tuning of the tarp will be its adaptability by introducing open and closed parts or openings for the sides and the roof to respond to changing climate conditions. Also the introduction of a second shading layer, even larger than the tarp or unit could be interesting for climate and cultural optimisation. Finally the Safe house unit has to be “accepted” by their inhabitants. A personal touch by providing paint could be helpful in this process.

The second principle of the clever roof is based on the introduction of different folding lines to obtain a tridimensional reshaped form of the tarp of 4mx7m (Fig 2). On the tarp several folding lines are added. By partly closing these folds, using zippers or velcro tapes, a large variety of shapes can be made. To achieve sufficient stiffness an additional frame with local materials could be used. This tarp can be used for the Type 1 as well as for the roof of the Type 3 Progressive House unit.

For Type 3 Progressive House Unit, Polimi together with the firm Sioen has been investigating the different components of the unit (foundation, floor, walls, structural elements and roof). They were mainly focused on the development of a self-supporting textile wall with the possibility to incorporate struts. During the meeting at Red Cross Luxembourg the participants had the opportunity to learn from several field experiences in which the Red Cross was involved. Finally the participants were invited to set up a frame tent within one hour (Fig. 3). This “small experience” will be very helpful in the progress of the development.
of S(P)EEDKITS. Point of interest will be to provide in the kit a user guide or at least a list of instructions how to set up (procedure – first attach then tension); list of components; indication of connections point; indication where to attach the ropes; etc.

General Annual Meeting
A few weeks ago the General Annual Meeting was organised in Gouda hosted by WASTE. Topics for future work will be the connection details, the package control (dimensions and weight), the use of local materials, the use of a shading layer, the cultural adaptability, etc...

A workshops with students of both university VUB and Polimi is foreseen this summer.

The S(P)EEDKITS project is a collaboration between: Centexbel (BE), Shelter Research Unit (LU), Netherlands Red Cross (NL), Sioen Industries (BE), Vrije Universiteit Brussel (BE), Politecnico di Milano (IT), De Mobiele Fabriek (NL), WASTE (NL), Practica (NL), D’Appolonia (IT), Internationales Biogas und Bioenergie Kompetenzzentrum (DE), Millson BV (NL), MSF Nederland (NL) and Norwegian Refugee Council (NO).

S(P)EEDKITS has received funding from the European Union’s Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 284931.

Evi Corne - Vrije Universiteit Brussel
evi.corne@vub.ac.be
Guy Buyle - Centexbel
guy.buyle@centexbel.be
www.speedkits.eu

formTL is specialised on wide-span, light, translucent, easy mountable and geometrically free formed covers and structures. They design with steel, aluminium and wood, cables and cable-nets, membranes and foils, glass and flexible heat insulation material. formTL designs stadium roofs, temporary stands, sport and bath facilities, event- and fair buildings, sculptures, atria roofs and façades, animal and plant houses, avaries, mobile roofs.

For an interesting overview of the projects

www.form-tl.de/en/projects.html

One of the smaller projects is the White Noise Art-Pavilion. The art-pavilion „White Noise“ was inaugurated at the Biennale Salzburg 2011. The innovative design of the mobile pavilion should create a prominent symbol for the agile contemporary art production of Salzburg.

With its mobility, the pavilion shall raise the awareness of art on site and culture also outside of the metropolises. The pavilion consists of five segments, which can be used single or assembled, just as required. The structure consists of curved square tubes QR 50, a membrane, spanned between the arches, functions as climate cover and water bearing layer. The pavilion spans 140m² without supporting pillars.

Architect: soma ZT, Salzburg/Vienna
Covered area: 140m²
Material: Valmex FR900 PVC/PES Typ II
Customer: CENOTECH and Unterfurtner Metallbau
Prominent experts in the membrane architecture and engineering world will introduce each plenary session. The keynote speakers Markus Balz & Christoph Paech (sbp), Matthew Birchall (Buro Happold), Shajay Bhooshan (Zaha Hadid Office), Jürgen Bradatsch (SL-Rasch), Jan Cremers (Hightex), Peter Gosling (Newcastle University), Rogier Houtman (Tentech), Ken’ichi Kawaguchi (Institute of Industrial Science, the University of Tokyo), Feike Reitsma & Patrick Vaillant (IASO), Alar Ruutopold (Saint-Gobain), and Werner Sobek (Werner Sobek Stuttgart GmbH & Co. KG) have already confirmed. The keynote lectures will be followed by presentation of the related papers.

**ETFE ADVANCED CONCEPTS**
**INTERESTING & EYE-CATCHING PROJECTS**
**[RE]THINKING Analysis & Materials**
**PNEUMATIC STRUCTURES**
**[CLOSING THE LOOP] Life Cycle Assessment for Membrane Materials and Structures**