BELTS IN TEXTILE ARCHITECTURE
BENDING-ACTIVE MEMBRANE STRUCTURE

BC Place Stadium
AN ICONIC LANDMARK

ART meets HIGHTECH
“LEVIATHAN” FOR MONUMENTA 2011
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Looking forward to future TensiNet activities we are happy to launch the next TensiNet Symposium 2013 which will be held in Istanbul (TR) from Wednesday the 8th till Friday the 10th of May 2013. The Symposium with the title [RE]THINKING lightweight structures will cover different topics such as Recent Projects, [RE]Thinking Analysis and Materials; ETFE Applications; Pneumatic Structures and [Closing the Loop] Life Cycle Assessment for Membrane Materials and Structures. The keynote speakers Werner Sobek (DE), Alar Ruutupool (USA) and Jan Cremers (DE) have already confirmed to give a lecture at the event. The call for abstracts will be distributed soon.

The next TensiNet Partner meeting will be organised at Buro Happold on Wednesday 27th of June just before the start of the 2nd International Conference on Flexible Formwork (www.icff2012.co.uk) in Bath (UK). Matthew Birchall (WG Pneumatic Structures) and Jan Cremer (WG Life Cycle Assessment) will have their first Working Group meeting, while Peter Gosling (WG Analysis and Materials) and Marijke Mollaert (WG Specifications Eurocode) will report about the recent progress in their WG discussions. With the Working Group activities we try to establish state of the art documents and hence disseminate progress in material development, technology and calculation methods.

In the current TensiNews issue the mentioned projects range from small canopies or inflatable event covers up to the large sport facilities. The renewal of the membrane to extend the lifespan of a construction has been done in several cases, while the application of inflatable membrane structures is growing. In the academic institutions interesting research was done. At the Institute of Building Structures and Structural Design (University of Stuttgart, DE) a new type of bending-active membrane structure was developed and realized in collaboration with students from the Hochschule für Technik in Stuttgart. At the Karlsruhe Institute of Technology (DE) a research on “Belts in textile architecture” was finalised. The TensiNet Association is establishing an overview of recently or currently conducted research in the domain of Fabric Architecture performed in Europe, which could be a basis for more active networking in research activities. The number of members of the TensiNet Association is only slightly varying. We welcome Sefar AG, who is taking over the technical textiles activities from Core, as a TensiNet Partner! The fact that workshops like Textile Roofs in Berlin (www.textile-roofs.com) and master classes like the Master of Engineering in Membrane Structures in Dessau (www.membranestructures.de), the Postgraduate MEng program Membrane Lightweight Structures in Vienna (ccp.tuwien.ac.at/engineering/school/membrane lightweight structures) and the first Tensile Architecture Master in Madrid (www.structuralia.com/Arby) gain success confirms the increasing interest from architects and engineers in Tensile Surface Structures. Still building on a lightweight future.

Following an initiative of Prof. Jan Cremers from Hightex, a new working group has been founded which will focus on the subject of Life Cycle Assessment (LCA). The aim of this group is to review the current status on materials and typical membrane structures with regard to LCA issues. As building certification becomes more and more standard this subject will also touch our part of the building sector. The status reached so far is very heterogeneous and inconsistent for the typical materials we use. On the level of structure types, there is hardly any information available so far. The LCA Working Group will identify and describe steps that could be taken within the TensiNet association to achieve a coherent data base to work with. It should also be as open and transparent as possible to gain a maximum of credibility. The idea is to present a kind of road map how to proceed at the next meeting. During the setup in Barcelona (November 2011) and afterwards, there was great interest to cooperate in this working group from different sides. But of course we still invite others to join us. If you are interested, please send an email to Jan Cremers from Hightex: jan.cremers@hightexworld.com.
BC Place Stadium

Context
"BC Place" in Vancouver Canada was first opened in 1983 as part of the World Expo 1986. The original roof was one of the largest air inflated domes and has become one of Vancouver landmarks. However, after a significant tear in the fabric skin and consequential deflation early January 2007, it became apparent the roof system has approached the end of its life cycle. At this stage it was decided to initiate a major rejuvenation project, which included beside major renovation of all stadium facilities also a new roof and a highly translucent facade.

Project
In contrary to most other stadium facilities BC Place hosts throughout the year not only sporting events but also trade fairs and concerts. Therefore the use is predominately a closed facility. One of the design criteria for the roof was that it must be able to carry all the snow loads.

The structural principal of the new roof system was introduced by Schlaich Bergermann and Partners from Stuttgart in Germany and is based on the spoke wheel system. At the perimeter 36 steel masts are placed onto the existing concrete structure. An upper steel compression ring and a secondary lower tension ring of a bundle of endless cables stabilize 36 cable trusses that run into the centre node (Fig. 2 and Fig. 3).

About two third of the roof is a fixed fabric roof of PTFE/Glass membrane with 36 bays spanning between the cable trusses and rest on concentric series of 9 arches. The fixed roof also has a lower mesh fabric membrane. The centre third of the roof is a retractable fabric roof of 36 inflatable cushions made of PTFE fabric. The cushion design became necessary for the retractable portion of the roof of BC Place to take on the wind and snow loads. At fair weather, the roof can be opened up to 7500m² of sky.

To retract the roof, large deflation units installed in the centre node extract the air from the cushions. The deflated membrane quilt of 36 cushions, attached to 9 sliding carriages each running along the 36 lower radial cables, is pulled towards the centre. The folded membrane is then parked inside a vertical moving garage. The centre node is 60m above the playing field (Fig. 4 and 5).

To deploy the retractable roof, the membrane quilt is pulled over the glazing skirt at the transition to the fixed roof. The inflation of the cushions to 500Pa then stabilizes the whole roof structure. An additional inflated closure ring at the perimeter of the retractable roof presses against the glazing skirt to seal the fabric roof structure against wind and rain. 72 load sensors on the hanger cables track the snow load on the roof and, at higher loads, trigger increased air pressures of 1000Pa and 2000Pa.

At the perimeter of the stadium between the existing concrete structure and the steel compression ring, a single layered ETFE facade was installed. 4 horizontal frames, each about 20m long and 2m high with 13 vertical arches span between the 36 steel masts. These facade elements are spanned with fritted ETFE foil. All facade elements are fitted with LED light elements between the arches, which can be electronically controlled to the whole spectrum of colours, so the whole facade can be illuminated with astounding light effects.

BC Place Stadium with its prominent steel columns, the retractable roof, and illuminated facade is in many ways the first and very unique of its kind. Since the opening ceremony in September 2011 it has become an iconic landmark for Vancouver and British Columbia.

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Replacement of the sails

WITH UPDATED TiO₂-COATED PTFE FABRIC MEMBRANE

Canada Place, Vancouver, British Columbia, Canada

Project
Designed by Canadian architect Eberhard Zeidler, Canada Place is one of the country’s most recognized architectural landmarks. After 25 years of exemplary service, the famed fabric roof at Canada Place in Vancouver was updated with a new tensile roofing system from Birdair, Inc. Birdair also served as roofing subcontractor for the original Canada Place fabric sail installation in 1985. The structure’s current roof was retrofitted with 8,474m² of TiO₂-coated PTFE fiberglass fabric membrane that matches the original five-sail design (Fig. 1 and 2).

Properties
PTFE, or polytetrafluoroethylene, makes up the membrane, while non-toxic and flame-resistant TiO₂ (titanium dioxide) provides self-cleaning capabilities that significantly reduce the need for its maintenance. The material is also highly durable, weather and fire resistant, and has a projected life expectancy exceeding 20 years.

Replacement
Located on the Burrard Inlet waterfront of Vancouver, the construction team had to replace the roof while keeping the structure closed at all times to protect it from high winds. The new roof was erected underneath the old roof as a “tent within a tent.” Rope access technicians installed one new sail at a time and, upon completion, carefully removed the old roof. The final survey showed that the new sails, once tensioned, were nearly identical to the original (Fig. 3).

Recycling
At the end of the project, Birdair donated unused and slightly used construction materials, including access platforms, hoisting ballasts and temp brackets, to the British Columbia Institute of Technology for use in their skilled trade programs. To repurpose the old roof, Canada Place has partnered with Architecture For Humanity Vancouver to recycle the sails, which will be used for humanitarian purposes at home and abroad.

Context
The $21-million project was financed through the Infrastructure Stimulus Fund, a key component of Canada’s Economic Action Plan, which is aimed at creating jobs and supporting industry, while contributing to the economic health of the country. Construction on the retrofit project began in July 2010 and was completed in March 2011.

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Figure 3. Erection of the new roof
Context
This project is a temporary inflatable pavilion, designed and erected at the Lille Métropole Musée d’Art Moderne, d’Art Contemporain et d’Art Brut (LaM). The structure was commissioned for the reopening ceremonies of the LaM in September 2010, after 5 years of public closure to refurbish and extend the museum. This custom inflatable structure was designed by 2hD Architects, in collaboration with Inflate, who also carried out the fabrication and installation (Fig. 1).

Project
The client’s challenging brief had a very practical, an experiential, as well as a symbolic dimension. On a pragmatic level, the pavilion needed to be very easily and quickly erected, to accommodate 350 people, and adapt itself to public ceremonies, dining, conference and theatre/cinema uses with minimal adaptation costs. The design achieves this whilst also allowing for breakout space, or for combinations of the above functions. Within the first 2 opening days, the pavilion was used in succession for all the functions mentioned. Experientially, the design needed to fit within the park grounds, to sit well amongst the illustrious outdoor sculptures, to have a diaphanous, enticing appearance and to offer a unique spatial experience, as well as guiding visitors towards the museum’s entrance. At the same time, the pavilion should respect a clear visual hierarchy with the existing museum building and its newly built extension. Symbolically, the structure was also to become an iconic projection of the museum’s image to the public and, as such, should be unique and recognisable. A number of locations in the park were considered, but were eventually narrowed down to one, close to the main park entrance, to fit with landscaping constraints. The pavilion site lies next to the subtle original brick buildings of the museum, within its extensive sculpture gardens, and overlooks the surrounding country park.

Design
The form of the structure was designed to respond to the various use situations discussed with the client. Key to this flexibility was the visual division of the large unified internal space into two sub-spaces, a large one defining the focal point of the pavilion and a smaller one that could operate as a breakout space and articulate the flow of public into the pavilion (Fig. 2). The structural form quickly evolved towards two main air beams spanning across the footprint, visually defining sub-spaces inside the large enclosure and echoing the two large glazed doors opening towards the sculpture park and the canal (Fig. 3). These air beams reinforce a pressurised double-layer translucent skin that encloses the space. The structure is pressurised between these two textile layers, meaning that the structure did not require an airlock. This approach as chosen to maximise the visual connection with the surroundings and ease the flow of public in and out of the pavilion. The structure was pressurised by 15 centrifugal fans (12 active plus 3 backups), of 1.5 kW power each, equipped with noise silencers and wired to a pressure-sensitive alarm system (to monitor the inflation level). The translucent skin is made of two layers of white Rip-Stop nylon and the spanning and peripheral air beams were fabricated from white PVC coated polyester membrane (Fig. 4). Due to the tight deadlines and budget, the manufacturer, Inflate, was involved at a very early stage of the design process, during 2hD’s feasibility study in May 2010. The proposed structure was the largest custom-designed structure ever fabricated by the manufacturer, but this close collaboration was key in controlling costs and fabrication time, integrating a number of standardised construction details and components developed by Inflate on previous projects.

Installation and use
The structure was fabricated in China from June 2010 and was delivered to site packed in a small trailer in September 2010. Although the actual inflation of the structure only took 10 minutes, the preparation work on site took several days (Fig. 5). Landscaping work had not been completed on time and instead of a smooth lawn on the designated installation site, the structure had to be installed on uneven ground with poor drainage, recently damaged by earthwork vehicles. This was complicated by staffing issues, requiring the installation work to be carried out...
by the small team working around the clock.

The pavilion was nonetheless completed on time for the ceremonies during which it was used for press conferences, a VIP lunch, a vernissage reception, visitor orientation and cinema projections.

The quality of the space and the dramatic light created by the enclosure, vibrant inside during daytime, and acting as a glowing beacon in the park at night, attracted much praise from the visitors and the client (Fig. 6 and 7). This pavilion received an Award for Architecture by the Royal Institute of British Architects East Midlands and was shortlisted for the World Architectural festival Awards 2011.

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Awards: RIBA East Midlands award (Winner of “out of region” category) World Architectural festival Awards 2011 (shortlisted in Display category)

LAVA's Digital Origami Emergency Shelter is a concept for an inhabited molecule. The design is based on a water-molecule, referencing the Japanese Metabolist movement’s idea of prefabricated capsules as living space. The base molecule can be shipped as a flat pack, cut out of local plywood, or dropped off by a helicopter. The interior can then be carved out of wood, cardboard, newspapers or other locally available materials. The project plays with ideas of prefabrication and personalised inhabitation, as well as stacking of multiple units, while giving an opportunity for individual expression. Each unit contains a sleeping space for two adults and one child as well as a little space for eating and reading. Battery or solar operated LED light brings the shelter to life, turning it into a lantern, a sign of hope. The Emergency Shelter exhibition featured shelters by local and international architects and was on display on the Customs House forecourt Sydney, Australia from 1-3 September 2011.

The exhibition highlighted the need for emergency shelters in disaster zones and the role of the design and construction industry in the aftermath of natural disasters. The Emergency Shelter Exhibition hopes to raise awareness and aid for the thousands of people who have been displaced by Japan’s natural disasters.

For the exhibition LAVA created a scale model, made from CNC cut plywood sheets. In a real situation the flat pack would be folded into an origami molecule and filled with locally available material. LAVA worked with builder Keystone Project Group and Staging Rentals.

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Location: Villeneuve d’Ascq, France
Client: Lille Métropole Musée d’Art Moderne, Art Contemporain et Art Brut (LaM)
Architects: 2hD Architects (http://2hd.co.uk)
Fabrication and installation: Inflate (http://inflate.co.uk)
Budget: 136,000€
Completion: September 2010
Usable internal area: 360m²
Overall footprint: 400m²
Max dimensions: 40m (length), 15m (width), 19m (overall width), 8m (height)
Ground anchors: 500mm deep Terra-bolt screws every 2m of perimeter
Inflation system: 15 centrifugal fans (12 active plus 3 backups), 1.5KW power each, equipped with noise silencers. All fan units wired to pressure-sensitive alarm system.
Main surface materials: Rip-Stop nylon, white translucent
Air beams materials: PVC coated polyester, white
Doors: Polycarbonate doors on custom-made welded steel frames
Lighting: centrally controlled fluorescent tube enclosed in peripheral air beams
Flooring: modular polypropylene flooring panels (ROLA-TRAC™)
Talisman Centre
Tensotherm™ with Lumira™ Aerogel Roofing System

Calgary, Alberta, Canada

Project
Birdair, Inc. has completed the retrofit of the tensile roofing system for the Talisman Centre for Sport and Wellness in Calgary. Birdair served as the roofing sub-contractor for the full-service athletic facility, replacing the structure’s original 15,050m² tensile roof with an updated Tensotherm™ with Lumira™ aerogel, formerly Nanogel® aerogel roofing system. The original roof was installed in 1983 and the new Tensotherm roof maintains the facility’s external appearance while improving daylighting, insulation, energy efficiency and temperature control. Until recently, it was considered impossible to insulate a PTFE roof effectively without sacrificing its daylighting capability. Technological advances led to the development of Tensotherm by Birdair with others.

Properties
The Tensotherm roofing composite consists of a Lumira aerogel layer, a Cradle to Cradle Silver Certified™ insulating material by Cabot Corporation. Tensotherm is comprised of the Lumira aerogel sandwiched between two PTFE fiberglass membranes. The resulting composite material is less than two inches thick (40mm), yet delivers an insulation value of R-12 (U=0.47W/m²K) and natural light transmission value of 2.5 percent (Fig. 3).

By maintaining translucency, Tensotherm meets the facility’s need for increased natural lighting. This results in glare-free daylighting and contributes to a high level of energy efficiency by reducing the need for artificial lighting. The advanced system also offers maximum moisture control and superior sound attenuation. As the first facility in Canada to feature a Tensotherm roof, Talisman Centre will benefit from the material’s higher performance values. The aquatic facility’s humid interior atmosphere combined with Calgary’s extreme winters impacted the original fiberglass insulation system which was state of the art at the time of installation. Today, Tensotherm provides a permanent composite insulation system that is not adversely affected by moisture and gravity. The new Tensotherm roof is extremely durable, fade-resistant and will retain its brilliance over time. The roof is also water repellent, as the insulative material is hydro-phobic and doubles as a high-tech moisture management material that sheds water and prevents mold, mildew and rotting. With its minimal maintenance requirements, superior durability and longevity, Tensotherm’s capabilities will not deteriorate over time. Tensotherm will contribute to cost savings in regards to the facility’s electrical, HVAC and operational requirements. Tensotherm™ is a patent pending product of Birdair, Inc.

Context
Talisman Centre is one of the most heavily-visited multi-use sports facilities in North America. First opened in 1983, 1,800 people use the facility each day. Current daily facility users range from Olympic caliber athletes to community members. A renewed Talisman Centre will help provide sport and wellness services to the 40,000-plus new residents and 60,000-plus additional day commuters estimated to be living and working in downtown Calgary between now and 2035.

Replacement & Recycling
Retrofit roofing construction on Talisman Centre began in January 2010 and was completed in March 2011 (Fig. 4 and 5). The facility’s previous roof was recycled and will be used by the City of Calgary Parks & Recreation to construct parking shelters for their equipment.

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Name of the project: Talisman Centre
Location address: 2225 Macleod Trail South, Calgary, Alberta, T2G 5B6
Client [Investor]: Owned by The City of Calgary and operated by the Lindsay Park Sports Society
Function of building: Multi-sport complex
Type of application of the membrane: Roof
Year of construction: January 2010-May 2011
Architects: Neil Jaud Architect INC, Calgary, Alberta, Canada
Structural Engineers: Geiger Engineering, Suffern, NY
Multi disciplinary engineering: AD Williams Engineering, Inc, Calgary, Alberta, Canada
Consulting engineer for the membrane: Birdair, Inc, Buffalo, NY
Main contractor: Dominion Construction Management, Calgary, Alberta, Canada
Contractor for the membrane [Tensile membrane contractor]: Birdair, Inc., Buffalo, NY
Supplier of the membrane material: Birdair, Inc., Buffalo, NY
Manufacturer and installation: Birdair, Inc., Buffalo, NY
Material: Tensotherm™ with Lumira™ aerogel
Covered surface (roofed area): 15,050m²
At the Institute of Building Structures and Structural Design (University of Stuttgart, Germany) a new type of membrane structure was developed and realized in collaboration with students from the HFT Stuttgart under the supervision of Prof. F. Buchmann (Fig. 1-2). The structure features 7.5m long glass fibre rods that pre-stress the membrane by means of elastic bending. With a span of 11x12m this is one of the first large scale membrane structures that uses such a technique.

The use of elastically bent beam elements as intricate support system in membrane surfaces offers a great potential for new shapes and structurally highly efficient systems in mechanically pre-stressed membranes. While common camping tents have used this technique for a long time, very few membrane structures are known that use bending active support systems in larger scale. The term “bending-active” was introduced by the author to describe curved beam or surface structures that base their geometry on the elastic deformation of initially straight or planar elements [1]. Highly efficient structures can be realized with the use of elastic bending [2].

Incorporating elastic beams (sail battens) in a membrane surface enables free corners to be created which are stabilised solely by the beam which in turn is restrained by the surface. Owing to its elasticity, the beam partially adapts to the curvature of the surface, but can carry compressive forces because it is restrained against buckling by the membrane. As a result tension forces in the corners can be short cut by the beam, which leads to a significant reduction in anchoring forces of the entire membrane structure.

It was found that offsetting the beam elements to the membrane surface with the help of tailored pockets increases the structural stability. In the project shown here the pockets had a maximum offset of 12cm to the membrane surface which gradually diminished towards the corner points in order to tangentially reach the cable edge (Fig. 3). One of the biggest challenges was the pre-stressing of the membrane; a special pulling device was built in order to connect the corner plates to the end of the glass fibre rods (Fig. 4). PTFE spray was used to reduce friction between the glass fibre rods and membrane packed in this process.

The form-finding was realized with the finite element Software SOFISTIK which enabled a simultaneous form-finding of the pre-stressed membrane and elastically bent beams into an interdependent equilibrium system (Fig. 5). Special coupling elements where used in order to simulate the offset connection of the beam elements to the membrane surface with tangential slip.

After the successful test setup in Stuttgart (Fig. 2) the structure was mounted by students from HFT Stuttgart and the ENA Morocco as a court yard shading for an architecture school in Marrakech in March 2012 (Fig. 1).

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Reference
Luxembourg

Patinoire de Beaufort

Context
Beaufort is located in the “Mullerthal Region, Luxembourg’s Little Switzerland” in the east of Luxembourg bordering Germany. Main attractions are the old castle, the open-air swimming pool and the artificial skating rink. In 2008 the idea was defined to cover the skating rink to save energy, to increase the attractiveness, to get a weather independent skating facility and furthermore a year-round place for any kind of events. The attendance decreased gradually, so that the “Syndicat d’Initiative et du Tourisme” as operator started a research and an internal idea competition between its members. Based on first rough ideas the client met with the architect Michael Kiefer, expert in the field of textile architectural projects. Kiefer and his team provided a variety of different possibilities. The head team of the Syndicat decided to go with the most ambitious and creative solution which has the potential to create a landmark on the site.

Kiefer finalized the design study in order to receive the approval by the municipality and by the two co-financing ministries. During 2010 the funding was confirmed. Kiefer’s team restarted by then with detail design, final structural analysis and preparation of the tender documents. In March 2011 all contracts had been signed, work on site started punctually in April 2011 and was finished precisely end of October 2011. Enough time for the preparation of ice and the opening ceremony, which took place on the 11-11-11 in the presence of three Ministers. “With the roof, a dream came true” proudly said by Françoise Bonert, president of the Syndicat in her opening speech.

Project
Three cones added along the longitudinal axis give the sculptural look of the 2.600m² large roof structure. The white shining surface welcomes the guests from far. Appropriate for winter time the appearance gives associations like snow, hilly landscape, freshness. Each cone-ring is carried by one pylon. Cables are holding them backwards, running over a pair of smaller pylons into the foundation body. All pylons base at one centre point. Their inclined position remind on a crane system. The counterpart of the tie back cables consist in the huge membrane cones, which are fixed at their edges either punctual at perimeter struts or continuously along a smoothly bended truss girder. The concept reacts onto the existing circumstances. The site with surrounding buildings allowed very limited anchoring space in South, East and West direction. Only in the North, vertical to the length of the ice-rink, exists a free area with ideal foundation conditions. Ground samples were taken at all anchoring points with exceeding tension or pressure forces. The foundation concept varied from tension anchoring and concrete foundation bodies, executed with high quality facing concrete. Pylons, three truss girders are joined by site welding. Transport of the large elements led to a logistic challenge due to the small and winding roads around Beaufort. After installation of all structural steel elements, the three membrane elements were spread out onto prepared ice rink ground, jointed and fixed to the cone rings. A smart concept of lifting tools allowed lifting the rings simultaneously towards their fixation points. Many spectators joint that big lift. The complete roof acts as enormous lamphashade, which illuminates indirectly the ice rink. The membrane surface appears as an attractive sign in the landscape and generates a spectacular interior space by day and night.

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Figure 1 and 2. External and interior night view
Figure 3. Aerial view
Figure 4 - 5. Connection detail Tennect
Figure 6. Cone-rink lift during installation
Figure 7. Drawing - facade
The railway station in Hamburg-Barmbek is with its 60,000 passengers on working days one of the major transport hubs of the Hanseatic city. Currently a new bus station is built. Together with the architects the engineers of formTL gmbh, Radolfzell designed the structure of the V-shaped light roof for the bus platforms. It nearly seems to float – on slender columns, with illuminated, inflated foil cushions. End of 2011 the first of two phases of construction was finished.

Context
The ravages of time and the multitude of passengers have left their marks on the railway station in Hamburg-Barmbek. An urban development and an architectural replanning of the railway station area became necessary. In 2004 the city of Hamburg and the Hamburger Hochbahn AG have invited to a competition which was won by a design team managed by the architect’s office ap plan mory osterwalder vielmo gmbh / berlin with a vision of a new architectural and urban quality in Barmbek’s complex of station buildings and its surroundings. The concept includes delicate, organisational of value interventions in the station’s basic body and in the station’s wall. The west and east counter areas get new entrance buildings and become an urban link between the northern and southern districts. One part of the new construction with a clinker brick wall on the south side of the station, is designed like its historical archetype on the north side, so the entrances are connected architecturally. So a homogeneous appearance of the building arises. At both sides of the station platform roofs with integrated illumination are built. The new infrastructure system optimizes the linking between the carriers train and bus as well as taxi and bicycle stations - a station of short ways will result.

Sky like foil cushions
New stretched roofs over the transfer areas allow the passengers to reach the busses of Hamburg’s ÖPNV relaxed – weather protected and on illuminated ways, during the night too. The roof installed in height is made of steel and foil completely. They consist of Y-shaped columns at intervals of 15m which support wings with integrated cushions. The Y-columns are made of thick-walled tubes, the Y-shaped cast nodes and the two cantilever arms are made of conic tubes. They are founded rigidly with special base points on concrete piles. The 15m long and 8,5m wide wings consist of a central beam, two border beams as well as in between welded wing girders at intervals of 2,5m which form a sub-grid. The bays between the wing beams which are inclined differently are filled with ETFE-foil cushions. With Ethylen-Tetrafluorethylen (ETFE) formTL relies on a extremely durable plastic foil without flexibilisers, with a weight of only 600 g/m². Even as a white foil the translucent high-tech material transmits 40% of the visible spectrum and give a kindly shadow during the day. The neon tubes which are integrated invisibly in the border beams provide a gentle luminance along the bus stops during the night. This gives a feeling of security during the night. The neon tube can be reached directly or through openings form the outside. The conduction is made of stainless steel and goes invisibly inside the structure.

Until end of 2011 a 55m long roof element as well as one of 115m length have been realised at the south side of the railway station. In spring 2012 the constructions on the North side of the railway station will start, where another 265m of steel-foil-roof will be installed. Latest by then the railway station with its floating illuminated wings will be an unique urban sign of that district.

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Introduction
Textile belts are well known and improved in field of lifting and safety technology. Belts are used uncoated, are coated considering abrasion and mechanical wear or are protected by jackets. Available on the market are belts which are coated after weaving with PVC or PUR and are applied to the tarpaulins of trucks. The requirements to these belts are different to belts applied in textile architecture. The strength is lower, the elastic stiffness is nearly irrelevant, varying stresses under tension, creep, relaxation are low and UV-protection is less compared to the term durability of building covers which should last at least 30 years. Scientific and technical work is still missing to transfer the requirements of building technology to belts for applications in textile architecture. The mechanical properties of the belts are not well known, the influence of the weaving to the stiffness and the material laws are unknown. The length of anchoring the forces in the belts is based on experience. Belts have no specific properties for their use in membranes for building covers and the design methods are less developed.

Normally steel cables are used in membrane structures to carry high forces. Edge details made by belts are limited to small span covers to approximately 8 m span depending on the external loads. These belts are normally sewed in textile pockets which are again sewed or welded onto the fabric of the cover. The yarns need to be UV and abrasion resistant as well as weatherproof in case of sewing the belts onto the fabric. The most critical point of sewing is the precise strain of the seam. The seam has to withstand the strain for pretensioning the whole structure without rupture. The stitching has to be carried out while tensioning the membrane and the belt by hand. This causes an uneven strain along the seams depending on the experience of the person using the sewing machine.

The disadvantages of sewed details are the fact that the seam is not watertight, the destroying of yarns and the seam getting dirty over the years. Dirt is collected along the yarns of the seams. If tightness and appearance are important the seams are either protected by an additional tape or coated with liquid coating compound (Fig. 1). The most common use of belts in the corners is to collect the tangential forces along curved boundaries additional to the boundary cables. The tangential forces are less compared to the stresses in the cables. The function of these tangential belts is to prevent sliding of the membrane along the cables which requires a separate anchoring of both load carrying elements. The belts are added in an additional and costly work procedure; in most cases belts are missing or the membranes are clamped to steel plates in the edges.

Belts are often used in retractable roofs and are improved in several structures in the last two decades. Steel cables are easily to roll up but hardly to fold and are limiting the folding of the membrane in the storing position. Most retractable roofs are for shading and rain protection, they are closed in case of high wind loads or snow loads. The requirements considering load carrying behaviour are less, the forces along the boundaries are lower and belts are suitable in this case.

New development
The weaving technique of belts allows the manufacturing of belts with specific properties related to the different requirements. The warp can be produced with nearly straight yarns and leads to nearly constant stress and strain behaviour with less influence of the change in the geometry of the yarns. Another possibility is the weaving with a stress dependent behaviour and provides advantages for the use of belts in membrane covers. If the stiffness of the belt is increasing in relation to the tension force the belts are flexible during the pretensioning of the membrane and are getting their stiffness if the required tension force is reached. The yarns of the belts can be hardened to increase the stiffness by elongation under thermal treatment. The density of the yarn in weft direction is important for in plane bending of the belts. The belts are more flexible and less bending stiff if the distance of the yarns is higher caused by increasing the shear deformation of the yarns against each other. In the same way the belts can be produced with a given in plane curvature helping to adjust the belts to curved boundaries of the membranes.

The disadvantages of belts such as the extensive sewing, the protection against UV radiation and the fact that belts are not watertight at the stitches are reduced if the yarns themselves are coated providing UV protection and the belts can be welded onto the membrane. The coating of yarns is a well known method to protect yarns against environmental impacts. In a research and development project with two university, one research institution and two industrial partners these method is developed further for applications in textile architecture. The basic idea of the project is the coating of high strength yarns, for example made of polyester or polyethylene, the weaving of belts with the coated fabrics and the welding of the yarns directly to the membranes (Fig. 2). The advantages are obvious, the yarns are fully protected against environmental impacts such as humidity, UV-radiation, pollution etc. The coating can be treated to become flame retardant or can be made of not burnable flour polymers. If this coating has the same or similar chemical compounds as the coating of the membrane, then welding is easily possible. In case of PVC or THV coatings the belts can be applied by HF welding on the membranes. Furthermore the connection is tight against humidity and water and the strain behaviour can be better defined compared to a sewed connection.

Figure 1. Edge detail with a belt in a sewed pocket
Figure 3. Belt of coated yarns (Weaver: Guth & Wolf, Göttersloh, Germany)
Figure 4. Stress and strain behaviour and Seam strength in an uniaxial tension test (KIT, Labor Bautechnologies)
Figure 5. Demonstration building (manufactured by Walter Krause GmbH, Walheim)
The breaking strength and the elastic stiffness are determined by the material of the yarns, the texture and the width of the belts. The load transfer between membrane and belts is determined by the stiffness, strength and adhesion of the coating and defines the length of anchoring the belts.

The tasks needed to be solved within the project are derived from the presented idea of producing belts of already coated yarns and welding these belts onto coated fabric. The most important points are:

- Selection of the yarns
- Selection of the coating
- Coating of the yarns
- Weaving of belts with the coated yarns
- Determination of the ultimate strength of the belts
- Stress- and strain behaviour of the belts
- Load transfer between belt and fabric
- Wealdability of the belts
- End terminals of the belts
- Design and construction of a demonstrator

The list of requirements for the yarns is large and some of them are strength, sensitivity against lateral pressure, foldability, flame retardant, adhesion, compatibility of the coating, handling, ecological and economical aspects.

To ensure the success of the project a polyester yarn PES 2200 dtex is chosen. The parameters for the coating are good behaviour for the application onto the yarns, good adhesion, resistance against lateral pressure, UV resistance, flame retardant and long term durability. A PUR coating is a common method for protecting yarns in the outdoor furniture industry and is used for further steps.

The produced belts have 120 yarns in warp and weft. Up to a force of 400N the belts are very soft and between 400N and 5kN tension force the stress and strain relation is relative constant. At a force of 5kN the belts get softer till they break. The design force is given by the ultimate force reduced by the safety factor for the material, which is 6 to 7 for belts in the lifting or safety industry. This means the design force of the developed belts is 1kN which is very low. The safety factor is 3 to 4 for the membrane itself. Further investigations are necessary to develop a design method which allows a higher load carrying capacity of the belts and ensures enough safety against failure.

In the next step the welding of the belts is examined. Different samples are tested with respect to the size and the arrangement of the connection between belt and fabric. The results show a very good adhesion between belt and membrane. In all test the membrane failed before the connection of belt and fabric lost strength. The adhesion between the two coatings is strong enough as well as the adhesion of the coatings to the yarns of the belts and the fabric (Fig. 4).

The critical point of the load transfer from two directional fabric to a unidirectional belt is the fabric at the end of the belt. The low shear stiffness of the coating of the membrane introduces high stresses in the fabric and causes cracks in the membrane at the end of the belt. This application requires an additional reinforcement of the membrane to ensure a better load transfer into the membrane.

The handling and different solutions for welding the belts onto the membrane is verified in a test. The cover has a size of 10m in length, 3m in width and is spanned into a given steel frame. The cover is made of several parts testing the connection between belt and fabric. The results show a very good adhesion between belt and fabric and demonstrating the feasibility of the belts.

The partners are the University of Applied Sciences Munich, KIT department building technology, ITV Denkendorf, Güth Wolf as manufacturer of the belts and Walter Krause GmbH as manufacturer of the textile structures.

Acknowledgement
The presented work is the summary of the research project “belts in textile Architecture”, founded by the German Ministry of Education and Research with in the programme FhprofUnt in 2007 – 2009. The partners are the University of Applied science Munich, KIT department building technology, ITV Denkendorf, Güth Wolf as manufacturer of the belts and Walter Krause GmbH as manufacturer of the textile structures.

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The design corresponds to a roof for a multifunctional sport court with a disposable area of 46x24m². It was decided to cover this area with a textile fabric geometrically defined by four hypar surfaces squared into a steel structure. The particular of this design is that the four supports are placed in the middle of the edges and not in the corners as it is habitual, so the structure has a four wing roof with 23m of cantilever in the larger and 12m in the shorter direction. Precedents of this solution, obtained from other applications are introduced. The composition of hypars for textile roofs has the merit to optimize the structural behavior like shell hypars do. The challenge was to design a structure to solve a great size commitment.

Between several geometrical possibilities the composition with four similar forms connected was chosen (Fig. 1). The perimeter beam was substituted by a steel frame stabilized with cables (Fig. 2). This 20x20m² solution is useful for instance to roof two paddle courts. For a rectangular shape a 30x20m² area was proposed which covers two tennis courts and a grandstands, like shown in Figure 3 where supports have been reinforced by adding a new branch. These two proposals had never been built but were useful to propose a cover over a new playing ground for multifunction purposes for a 40x20m² area. Because the real dimension would be 46x24m² it was necessary to extend the roof by reinforcing the steel frame. Moreover it was necessary to add new elements like a sliding fabric wall and to consider the possibility of drainage directly to the sink. Finally a new version was adopted for the same proposal, in which the dimension was 46x24m² and were the steel structure was been reinforced.

After a few considerations the structure was completed with the following additional improvements (Fig. 4):
- Stabilizing cables into the lateral frames;
- Sliding curtain wall to close and open the lateral enclosure;
- Ventilation system on the crown of the roof.

The structure consists in pipes of Ø323.8 for the main pieces and Ø120.5 for the secondary ones.
the Aachen architects’ office OX2architekten presents the outer slim form as a “saving hand”, juxtaposed to the existing clinic building. Two inclined steel girders support the platform’s vertical main load. Due to the non-homogeneous subsoil, the loads are diverted into the subsoil via piles. The complete steel substructure is encased by an approx. ca. 32m wide and 96m long membrane of white glass / PTFE fabric. Due to the changing radii of curvature, the total was split into 5 membrane fields. Their edges are attached by piping rails to a secondary subassembly which is independent of the actual girders. The membranes were cut according to local measurement following assembly of the secondary construction. The steel supporting structure disappears in full under a formative membrane facade. The development building is faced in a multi-coloured, scaled sheet metal facade.

All pieces are prepared in the factory and transported to the site to be assembled by welding (Fig. 5). This dimensioning needs to provide transversal stiffeners crossing over the roof to resist lateral tension of the fabric, three pieces for each wing and a corner diagonal stiffener (Fig. 6).

The analysis has been carried out with a membrane analysis for the tensioned fabric and by means of the SAP2000 software for the steel structures and by substituting the membrane by its forces on the steel structure (Fig. 7). After the steel structure was completely finished the fabric was raised in four pieces (Fig. 8).

In Figure 9 the constructive detail of the corners is shown with the solution to connection the roof and the two lateral pieces and to tension the whole assembly together. Once the main works had been finished the lateral sliding curtain walls (Fig. 10 and 11) and electrical supplies have been installed. The focus is on projecting the light to the roof and not to the ground because this provides a more uniform level of light.

REFERENCES:


Félix Escrig:
performance@arquired.es
José Sanchez

Fig. 1. Four hypar geometric composition in two different compositions
Fig. 2. Proposal to cover two paddle tracks with a cantilever four wings roof with a height of 6 to 10m (square plan)
Fig. 3. Proposal to cover two paddle tracks with a cantilever four wings roof stands included with a height of 6 to 10m (rectangular plan)
Fig. 4. Particular of singular pieces:
   a) The main support in the larger border
   b) Solution of the corner
   c) The main support at the shorter border
   d) The crown where the main girders are crossing
Fig. 5. Manufacturing the structural parts at the factory
Fig. 6. Mounting the structure with pieces necessary to achieve complete rigidity
Fig. 7. SAP model for the structural analysis
Fig. 8. Erection of the fabric roof
Fig. 9. Corner connection detail
Fig. 10 and 11. Air view and interior view of the building included the lateral curtain walls

Name of the project: heliport platform, RWTH Aachen University Clinic
Building owner: University Clinic Aachen
for the University Clinic Aachen: Bau- und Liegenschaftsbetrieb NRW
Building and real estate management NRW Aachen subsidiary
Architect: OX2architekten, Aachen, Germany
Supporting framework planner: stahl + verbundbau gmbh, Dreieich, Germany
Membrane construction: Ceno Tec GmbH Textile Constructions, Greven, Germany

Name of the project: Roof over an uncovered sport multifunctional field in the Cartuja of Seville.
Location address: Seville
Client (investor): Junta de Andalucia
Function of building: to shadowing a sport field
Type of application of the membrane: Roofs and Canopies
Year of construction: 2010
Architects: Félix Escrig and José Sánchez
Multi disciplinary engineering: Performance S.L.
Structural engineers: Performance S.L.
Consulting engineer for the membrane: Performance S.L.
Engineering of the controlling mechanism: Performance S.L.
Main contractor: SANROCON S.A.
Contractor, manufacture and installation membrane: ARQUITECTURA TXTIL S.L.
Material: Roof: Naizil Type III
Wall: VALMEXTF 400 MEHELER
Covered surface: 1104m²
Anish Kapoor's "Leviathan" is a spectacular masterpiece of art which shows textile material's potential for sculptural expression. The artist has been familiar with membrane materials for decades, his enigmatic 'Marsyas' for the Tate Modern in London of 2002 just to mention one highlight. This temporary sculpture of 155m in length was comprised of three steel rings joined together by a single span of PVC membrane. Like other Kapoor projects this was also constructed by Hightex.

His sculpture 'Leviathan' for last year's MONUMENTA exhibition in Paris' Grand Palais was a huge dark blood red structure where the membrane skin was only stabilised by internal air pressure. The visitors were not only able to view the outer skin but also to experience the inner space by entering the sculpture through an airlock. The inside perception was a sensational space experience with enormous height dominated by the dark red light transmission through the skin. Depending on the weather conditions, the shadows of the iconic iron/glass structure of the Grand Palais which has been built for the World Expo in 1900 was made visible on the inside. In the sunlight, very sharp and precise shadows of the structure were cast on the curvy surface, but the moment the sunlight was interrupted by a cloud passing by, the atmosphere changed completely to an indifferent space where the visitor easily lost any sense of distance to the then gloomy red skin (Fig 1 and 2). The material which appears Aubergine-like in top view has a surprisingly different dark red colour in transmission.

Hightex was responsible for the engineering, production and erection of the artwork. The entire surface of the sculpture is made of a single piece of PVC-coated polyester membrane with a surface area of approximately 12.100m². The "walk-in" sculpture is approximately 100m long, 34m high and weighs approximately 11 tons. It is an inflatable sculpture, clamped to the ground and entrance arch and in a Bordeaux-red colour specially chosen by the artist. The membrane was prefabricated in 4 separate pieces which were then welded together on-site in the Grand Palais. The seams are between 60 and 80mm in width. The air supply system had a capacity of 20.000 m³/h for each blower (main and reserve). The sculpture took less than 2 hours to fully inflate. Hightex installed the sculpture in only 8 days.

ART meets HIGHTECH

Anish Kapoor's "Leviathan" for MONUMENTA 2011
Grand Palais Paris, France

Each year MONUMENTA invites an internationally-renowned artist to turn his vision to the vast Nave of Paris' Grand Palais and to create a new artwork especially for this space. MONUMENTA is an artistic creation on an unparalleled scale, filling a space with an area of 13.500m² and a height of 35m. Anish Kapoor’s ambition for the Grand Palais was to create an aesthetic and physical shock, a colourful experience that is poetic, meditative and stunning, measuring itself against the height and light of the Nave, an interior that seems somehow greater than the exterior.

**Name of the project:** Anish Kapoor’s "Leviathan", MONUMENTA 2011
**Location address:** Grand Palais Paris, France
**Client (investor):** White Dark Limited, London, UK, and Réunion des Musées Nationaux, Paris, France
**Function of building:** Artwork
**Type of application of the membrane:** air-supported walk-in sculpture
**Year of construction:** 2011
**Artist:** Anish Kapoor
**Multi disciplinary engineering:** Hightex GmbH
**Structural engineers:** Aerotrope Ltd, Tensys Ltd
**Membrane Engineering:** Hightex GmbH
**Contractor for the membrane (Tensile membrane contractor):** Hightex GmbH
**Supplier of the membrane material:** Serge Ferrari S.A.S.
**Manufacture and installation:** Hightex GmbH
**Material:** PVC-coated polyester fabric
**Covered surface (roofed area):** 12.073m²/73.000m³

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**Mark Nolan,**
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Hightex Group is a specialist provider of large area architectural membranes for roofing and façade structures. Hightex has been involved in the construction of a number of high profile buildings including Cape Town Stadium and Soccer City Stadium in Johannesburg, the Wimbledon Centre Court retractable roof, the roof of the Suvarnabhumi International Airport in Bangkok. Recent projects include the new stadia of Warsaw, Kiev and Vancouver.
ETFE Fluorothermoplastics are polymerized since more than 30 years by Dyneon. 3M™ Dyneon™ Fluoroplastic ET 6235 raw materials have been the first in the market to be used for films and cushions in architectural applications like roofings or facades of i.e. sports stadiums, shopping malls, greenhouses and leisure areas. In a next pioneering step, Dyneon, together with its partners Nowofol Kunststoffprodukte and Vector Foiltec, initially generated an Environmental Product Declaration (EPD) for architectural ETFE membrane cushions made from Nowoflon ET® 6235 Z film out of 3M™ Dyneon™ ETFE resins.

Presented at the International Congress for Sustainable Construction 2011 in Stuttgart, the EPD verifies the environmental performance of Texlon® ETFE cladding systems against quantified environmental data based on the ISO 14040 series of standards.

Constructions based on Nowoflon ET® 6235 Z film out of Dyneon ETFE as “eco-economic” alternative to glass offer improved eco-efficiency standards and energy consumption at a fraction of the costs. With increasing demand for scientifically verified environmental performance statistics, EPD’s are a fundamental resource for global markets towards sustainable design and construction for future generations. Texlon® ETFE is so far the only ETFE system in the world with an EPD affording simplification of sustainable energy credits in accordance with building certification systems like BREEAM, DNGB and LEED. In close cooperation with external experts for sustainability (PE International) a full Life Cycle Assessment (LCA) has been successfully created as part of the pre-condition for the EPD, too.

One of the most popular applications for ETFE membrane cushions is the Eden Project in Cornwall, UK. It is the world’s largest botanical biome with thousands of tropical plants growing under perfect conditions.

The EPD document with the declaration number EPD-VND-2011111-D can be downloaded in English or German at www.bau-umwelt.com, the website of the “Institut Bauen und Umwelt e. V.”.

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Context
In May 2011, Textil Bau GmbH received an order to provide roofing for the Gasometer in Schoeneberg, Berlin for the “Guenther Jauch” ARD television programme. At very short notice, an experienced team capable of handling this demanding project had to be put together. The 11th September 2011 was the deadline for Guenther Jauch’s first live broadcast from the Berlin Gasometer. The roof had to be attached to the existing Schoeneberger Gasometer giving consideration to aspects of historical heritage preservation. For this reason, a pneumatically fitted construction in the form of an air-inflated structure was designed which is inflated by the inner pressure of the gasometer alone.

Project
The purpose of the roofing is to cover the entire interior of the gasometer with a diameter of 60m to provide a second roof over the existing fabric roof of the former “Bundestagsarena” in the centre of the gasometer. The former roof was not suitable for the demands of a television studio. In particular rain and the adjacent railway line caused a great deal of noise and interference within the interior. The existing steel structure was erected at the beginning of the last century according to the principles of a telescopic gas container. Originally, a large steel dome formed the top of the gasometer. This dome and the telescopic container were removed later after the plant was decommissioned.

Until then, the dome was not only functionally but also artistically a typical element of the gasometer ensemble. The ensemble was placed under historical heritage preservation in 1994 (Fig. 1 and 2). The actual challenge for the new roof consisted of designing a functional roof within a tight budget and considering historical heritage preservation demands, getting permits and installing it within a very short time span of only 4 months. For this reason, in close consultation with the inspecting structural engineers and the Berlin Senate, procedures for approval were, in this particular case, processed in record time.

Before the presentation of planning that was ready for approval, various solutions for a new roof were considered. Firstly, variations were examined that attempted to distribute wind and snow loads in the existing structure of the gasometer above the lower steel boiler. These considerations had to be abandoned as the required reinforcement of the existing steel structure would have been too extensive and not feasible within the time limit. The loads of a new suspended construction were not compatible with the original load bearing concept of the gasometer.

The original concept of a gas container was then reconsidered and a variation with an air supported roof as employed for conventional air-inflated structures such as tennis halls was pursued. Apart from the advantages of a large support-free span, there was the structural advantage that in an air-inflated condition, only hoop stress appeared at the lower edge of the roof which could relatively easily be inserted into the existing steel ring of the gasometer at a height of approximately 16m. With deformation of the roof caused by wind and snow, stress only occurs in this area which was considered manageable with the result that it became the main argument in favour of employing the air-inflated structure.

To keep the intervention on the existing steel structure to a minimum, only a steel clamping section was attached to the inner circumference of the gasometer where the roof of the air-inflated structure was hermetically sealed and connected. This section can later be removed again so that the intervention on the existing stock is minimal. This work was undertaken by a Berlin company, “Wilking Metallbau”, after the parallel renovation work on the gasometer had advanced to the stage where the clamping section could be installed.

Before the installation started, a redundant support air compressor system for the air-inflated structure was developed in consultation with the companies “Elinic” and “Nolting” which was installed by the client as were door locks and appropriate air ducts. The air compressor is supplied by a biogas operated block heating power station.

The custom-made roof membrane required a great amount of experience and reliability and was undertaken by the company “Karsten Daedler” in Trittau. They undertook the challenge of custom-making a 3.500m² roof in one piece. The main arguments in favour of this method were the cost and time saving incurred by dispensing with installation joints. A system was developed with the planners and the installation team whereby the large membrane could be custom-made in one piece inside the hall by joining with seams as straight as possible and with the minimum amount of lifting and moving. The material chosen is “Duraskin B4915 PVC-coated polyester fabric” by “Verseidag” that manifests the required resistances and the amount was available at short notice in one batch.

Before production, the entire circumference of the gasometer of approximately 200m had to be measured. According to these data,
the actual system for the air-inflated structure was established by the Berlin Engineering Office “ib-Zapf” as well as the associated statics of the roof membrane with all the connection details. After determination and approval of these documents and the cutting layouts, the cutting was done. As the circumference of the gasometer is not perfectly round which was discovered after measuring, it was extremely important to provide the individual pattern pieces with explicit alignment and labelling in order to be able to correctly produce and install the membrane. To be precise, the circumference is actually a polygon with 48 sides. The individual panels were cut and simultaneously labelled and numbered very quickly using a fully automatic CAD supported cutting machine. The production was completed within 3 weeks. It was imperative to have a large hall, modern HF machines and a keen team of experienced membrane producers who ensured that the planned installation timetable could be met.

For loading, the membrane was folded, according to a predetermined folding plan, in the middle of the hall measuring 3.500m² required a lot of manpower as the total weight of the membrane was almost 6 tons. Before folding, diverse fittings had to be mounted for lifting the membrane and for later connection of accident ropes. Then the package in the hall was loaded onto a truck and driven directly to the gasometer in Berlin.

The particular challenge of the installation in the gasometer was to lift the membrane above the existing 25m dome without touching it to avoid damage to both the dome and the new roof membrane.

To ensure this, the company “3dtex” from Berlin commissioned with the installation, planned and optimised the installation process in advance virtually and CAD supported as well as using a scale of 1:100 functional model. It proved advantageous that the physical model enabled the installation team of 10 installers and industrial climbers to become well-prepared for the task.

The permissible lifting load per suspension point on the membrane was severely limited. For this reason, a rope system had to be developed which equally distributed the membrane’s weight of almost 6 tons between 12 suspension points. This was achieved using several bypass systems with rope pulleys – upper lashing on individual suspension points was avoided in this manner. The rope system was operated by two electric rope winches that were attached to the gasometer at a height of approximately 70m.

As the lack of space in the gasometer did not allow the membrane to be spread out on site, it was lifted directly from the truck which was driven into the gasometer, at first vertically up to a height of approximately 50m and subsequently pulled into the horizontal by means of manual winches over the existing dome. Simultaneously, the rope system opened out the membrane so that when it was subsequently lowered above the dome, the membrane could also be lead to the circumference of the gasometer and attached by clamps (Fig. 3).

Only after the redundant air compressor was put into operation did the industrial climbers install firstly the emergency ropes required in case of accidents and subsequently 27 dome lights for natural smoke ventilation and tested it all.

Thanks to close communication and target oriented cooperation of all the parties involved, the project was able to be successfully carried out from the idea up to punctual completion so that the first TV programme could be transmitted live from the gasometer in Schoeneberg Berlin and every Sunday evening since (Fig. 4 and 5).
Fifth International Conference on Textile Composites and Inflatable Structures

Structural Membranes 2011

Barcelona

The “Fifth International Conference on Textile Composites and Inflatable Structures” was held in Barcelona in October 2011. It was organized by the International Centre for Numerical Methods in Engineering (CIMNE) and chaired by E. Oñate (UPC) and K.U. Bletzinger (TUM). It was the fifth of a series of symposiums that began in Barcelona in 2003 and will continue in Munich in 2013.

At the three-day conference, 8 lectures and 85 presentations in 15 technical sessions were given to 118 participants from 25 countries and 3 continents. The main topics were textile composites and inflatable structures, which have become increasingly popular for a variety of applications in civil engineering, architecture, aerospace engineering and other fields. Typical examples include membrane roofs and covers, sails, inflatable buildings and pavilions, airships, inflatable furniture and airspace structures. The ability to provide numerical solutions for increasingly complex membrane and inflatable structures is advancing rapidly as a result of remarkable advances in the development of computer hardware and the increasing maturity of computational procedures for nonlinear structural systems.

Significant progress has been made in the formulation of finite element methods for static and dynamic problems, complex constitutive material behaviour and coupled aero-elastic analysis. Structural Membranes 2011 addressed both the theoretical bases for structural analysis and the numerical algorithms necessary for efficient and robust computer implementation.

Main Lectures

The main lectures in the plenary sessions were devoted to inflatable structures for space vehicles, zoomorphism and bio-architecture, Tensairity structures, the Expo Axis in Shanghai, parachutes, membrane moulds, shape optimization and tubular inflatable structures (Fig. 1 and Fig. 2).

Figure 1 and 2. A tubular inflatable structures sheltered the coffee breaks (J. Marcipar and E. Oñate)

Conclusion

In keeping with its objectives, Structural Membranes 2011 collected and disseminated state-of-the-art research and technology for the design, analysis, construction and maintenance of textile and inflatable structures.

A significant part of the conference presented advances in new textile composites for membrane structure applications, as well as in innovative design, construction and maintenance procedures.

The next international Structural Membranes conference will be held at the Technical University of Munich (TUM) in 2013. Further information will be made available in the Conferences section at http://its.cimne.com/cdl1.
TECHNICAL SESSIONS

The specialized technical sessions were organized by guest experts and focused on design (Fig. 3 to Fig. 6), test methods (Fig. 7), thermal properties and photovoltaics (Fig. 8 and Fig. 9), inflatable structures (Fig. 10 and Fig. 11), applications (Fig. 12 to Fig. 15) and realizations (Fig. 16 and Fig. 17).
LITERATURE

Construction Manual for Polymers + Membranes.
MATERIALS. SEMI-FINISHED PRODUCTS. FORM-FINDING. DESIGN

Author: J.Knippers, J.Cremers, M.Gabler & J.Lienhard
Language: English (also available in German and Italian)
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Edition DETAIL publishes a series of “Construction Manuals” devoted to materials used in architecture, including load-bearing structures, building envelopes and interior fitting-out. So far they have dealt with the main innovative aspects of building technology, such as glazing, interiors, timber, construction materials, roofs, façades, energy, steel, concrete, masonry, refurbishment, components, systems, acoustics, sound insulation and more. Now, it is the turn of polymers and membranes, a new class of modern synthetic materials that are widely used in everyday life and in buildings. These materials can be found in technical applications in seals, insulation, pipes, cables, paints, adhesives, coatings and paving, and more visible uses such as façades and roofs. To introduce polymers in architecture, a historical overview considers the dream of the polymer house and the development of tensile surface structures and translucent envelopes, including their potential, the challenges they involve and current trends. The basic materials (polymers, fibres, adhesives, coatings and natural fibre-reinforced polymers) are described, together with their production system and processes. Whereas most of the literature deals with these materials separately, here they are all covered in the same volume. Following this review of basic materials, some semi-finished products are examined. They comprise reinforced and unreinforced polymers, foils, and coated and uncoated textiles. Physical properties of buildings (including thermal insulation, light and heat radiation, moisture, sound and acoustics, fire, soiling behaviour and durability) are explored in detail. The controversial environmental issues are also introduced and the contributions of these materials to ecologically efficient building design are highlighted, despite the obvious disadvantages such as high energy consumption during production, extensive use of fossil fuels and unsatisfactory recycling. The most educational section of the manual relates load-bearing structures to forms in both tensile membrane and rigid polymer designs, drawing attention to the formation of active or funicular structures with reference to calculations, testing, quality control and industrial safety. For practitioners, the section “Building with polymers and membranes” is a valuable complement of M. Seidel’s Tensile Surface Structures. A Practical Guide to Cable and Membrane Construction, because it considers building with semi-finished polymer products, free-form polymers, foils, textile membranes and complex building envelopes, including design solutions for roofs, envelopes and details. Finally, a selection of examples is presented, including the applications that contribute significantly to appearance and form. Although previously published in the Detail magazine, these examples are now presented together, illustrating aspects of building technology, the influence of polymers in construction and the future of polymers in architecture.

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Camden Markets Walkway
A new canopy

Context
Camden Markets carnival atmosphere famously attracts people from all walks of life and is popular with Goths and Punks who live and work alongside the more traditional antiquities and clothing traders. Up to 150,000 visitors are attracted to this ancient and historic market area which is situated just away from the centre of London and is now home to many new nightclubs and restaurants. Due to increased visitor numbers the area has attracted substantial development funding and a sympathetic facelift is taking place. In an area where the unusual and bizarre is common place, it takes something visually striking to attract the passersby’s attention. This new canopy signposts the entrance to one of the newer restaurants which has opened up in a recently refurbished building.

Concept & Design
The virtue bestowed upon this unique SEFAR® Architecture TENARA® fabric material through its construction is the high translucency, up to 40%, and a blemish free consistency which ensures that under both natural and commercial ambient lighting conditions, the light striking the smooth curves of the fabric is diffused evenly lifting the whole structure and making it appear to fluoresce.

Construction
The twisted, eccentric steel framework which carries the fabric is pieced together from many irregular and compound curves making the geometry of each protruding frame unique. Needless to say the patterning of the fabric was a monumental task, and yet what has been achieved fits so comfortably. The installation, set as it is against a backdrop of muddled coloured glass curtain walling set in steel grey frames promotes the fabric so that it appears to shine like a pearl unearthed in this most unlikely of habitats.

Covered surface: approx. 200m²
Material: SEFAR® Architecture TENARA® fabric 4T40HF
Supplier of the membrane material: Sefar AG, Heiden, Switzerland
Manufacture and installation: Base Structures Ltd, Bristol, UK
Main contractor: Stanley Sidings Ltd, London, UK
Structural engineers: Tony Hogg Design, Bristol, UK
Consulting engineer for the membrane: Tony Hogg Design, Bristol, UK
Supplier of the membrane material: Sefar AG, Heiden, Switzerland
Consulting engineer for the membrane: Tony Hogg Design, Bristol, UK
Main contractor: Stanley Sidings Ltd, London, UK
Structural engineers: Tony Hogg Design, Bristol, UK
Manufacture and installation: Base Structures Ltd, Bristol, UK
Year of construction: 2010
Type of application of the membrane: Covering of Walkway
Function of building: Walkway
Client: Stanley Sidings Ltd, London, UK
Location address: Chalk Farm Road, Camden, London, UK
Architects: ESA, London, UK
Bilingual Spanish and English

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New Juventus Stadium

The innovative “black and white” structure as well as enhancing the display of football also introduces a new concept: not a stadium that takes life on the days of the match only, but throughout the week. A sort of agora, an open place spacious and full of services: from bars to restaurants, from stores to baby parking.

At a later stage the east side of the stadium will accommodate, the Juventus Museum, the Company’s registered office and a number of sport fields for Juventus Football Schools in addition to some green spots. The new Juventus stadium does not answer to urban criteria and football requirements only: the project is eco-friendly, respectful of the environment. The entire architectural plan was developed to guarantee a low impact on the city surroundings by dismantling the Stadio Delle Alpi and re-utilizing the materials thereof.

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Client: Consfer
Completion: 2011
Architectural design: Arch. Zavanella (Studio Gau), Arch. Suarez (Studio Shesa)
Engineering: Prof. M. Majowiecki, Prof. F. Ossola
Design: Giugiaro, Pininfarina
Membrane and detail design: Canobbio SpA
Membrane and foil engineering: formTL gmbh
Material: Ferrari PES/PVC with PVDF protection and ETFE film stripes
Covered area: 22,000m²

The suspended structural system of the roof

The roof structure is composed by a suspended main structure and secondary reticular trusses. The suspended main structure is illustrated in the Figure 1. At the four intersection joints a system of 4 stay cables (105mm, about 93m length) suspend the main structure at the heads of two main columns. Each head is then anchored to ground by a system of 6 stay cables (105mm, about 128m length). To ensure the stability of the main structure with respect to uplifting and dragging wind action the 4 main nodes are anchored to the ground and to the main grand stands with a vertical restraint stay and a sub-horizontal stay respectively. A pretension field is put into the stay systems to ensure the necessary stiffness and the bi-lateral functionality, in order to reach this goal each cable has at least one adjustable terminal. Secondary trusses at about 11m distance are placed between the inner roof edge (formed by the main trusses) and the outer edge (formed by the top of the grand stand frames). Each truss has a span of about 40m and has one straight bottom chord and two curved top chords. The internal height at mid span is about 2.60m (Fig. 2). Each couple of secondary trusses is connected at mid span by a reticular transverse to ensure lateral stability. The steel sheeting with an alternating empty-full pattern is placed between the trusses (Fig. 3). Finally, a covering composite membrane is placed over the discontinuous sheeting layer (Fig. 4).

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A three-day symposium where the Plenary sessions will refer on the one hand to the Tensinet Working groups with [RE]THINKING Analysis & Materials (Peter Gosling); ETFE (Rogiør Houtman); PNEUMATIC STRUCTURES (Matthew Birchall) and [CLOSING THE LOOP] Life Cycle Assessment for Membrane Materials and Structures (Jan Cremers).

On the other hand interesting projects will be presented.

Prominent experts in the membrane architecture and engineering world will introduce each plenary session.

Werner Sobek - Recent work. The work of Werner Sobek is defined by premium design on the basis of high-class engineering combined with sophisticated green technologies. His studio works on all types of buildings and materials. Special emphasis lies on lightweight load-bearing structures, high-rise buildings and transparent facade systems.

Jan Cremers - Life Cycle Assessment for Membrane Materials and Structures - Status Quo and Future Challenges. Jan Cremers is Director Technology of Hightex GmbH in Bernau, Germany, a leading systems engineering company, which designs, fabricates and installs large area, cable supported, lightweight membrane roofs and façades worldwide. He is also teaching Building Technology at the Hochschule für Technik in Stuttgart.

Scientific Committee
- Gorun Arun - YTU, Yildiz Technical University, TR
- Matthew Birchall - Buro Happold, UK
- Andrew Borgart - TUDelft, NL
- Markus Balz - SBP, DE
- Heidrun Boegner-Balz - Labor Blum, DE
- John Chilton - University of Nottingham (UoN), UK
- Jan Cremers - HfT Stuttgart, DE
- Fevzi Dansik - Mimar Sinan Fine-Art University, TR
- Peter Gosling - Newcastle University, UK
- Rogier Houtman - Tentech, NL
- Rolf Luchsinger - Empa, CH
- Marijke Mollaert - Vrije Universiteit Brussel, BE
- Juan Monjo-Carrío - Technical University of Madrid, ES
- Meltem Sahin - Mimar Sinan Fine-Art University, TR
- Sinan Mert Sener - Istanbul Technical University, TR
- Filiz Piroglu - Istanbul Technical University, TR
- Werner Sobek - Werner Sobek Stuttgart GmbH & Co. KG, DE
- Bernd Stimpfle - form TL, DE
- Patrick Teuffel - TU Delft, NL
- Jean-Christophe Thomas - University of Nantes, FR
- Erdogan Uzgider - Istanbul Technical University, TR
- Rosemarie Wagner - Karlsruhe Institute of Technology, DE
- Alessandra Zanelli - Politecnico di Milano, IT

Organizing Committee
- Fevzi Dansik - fabricArt Membrane Structures
- Meltem Sahin - fabricArt Membrane Structures
- Emre Pusat - Verseidag-indutex GmbH

Call
Abstracts should not be longer than 300 words and should indicate the topic(s). Papers should not be longer than 2500 words and 10 pages figures included. Abstracts and papers will be reviewed by the scientific committee.

- [RE]THINKING Analysis & Materials
- ETFE
- PNEUMATIC STRUCTURES
- [CLOSING THE LOOP] Life Cycle Assessment for Membrane Materials and Structures
- RECENT PROJECTS

Timing - deadlines
- abstract submission - Monday 3rd September 2012
- abstract acceptance - Monday 29th October 2012
- paper submission - Monday 10th December 2012
- paper acceptance - Monday 4th February 2013