from the beginnings up to today

**FLUOROPLASTICS IN MEMBRANE ARCHITECTURE**

**PROJECTS**

Modernization
OF THE MUNICIPAL STADIUM

Spider
TEXTILE ARCHITECTURE PROJECT

**ARTICLE**

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Forthcoming Meetings

TensiNet Meetings
Thursday 14/04/2011
10:30 - 11:00 Welcome
11:00 - 12:30 Partner meeting (1/2011)
12:30 - 13:30 Light lunch
13:30 - 16:00
  Working Group Meeting "Specifications" (Marijke Mollaert);
  Working Group Meeting "Analysis & Materials" (Peter Gosling);
  Working Group Meeting "ETFE" (Rogier Houtman)
16:00 - 17:00 Visit Mehler Texnologies factory

Location:
headquarter Mehler Texnologies GmbH, Rheinstrasse 11, D-41836 Hückelhoven, Germany
The European Commission funded this project under the ‘Competitive and Sustainable Growth’ Programme from 01.03.2001 to 31.08.2004. The main results of this project were the European Design Guide for Tensile Surface Structures, the website www.TensiNet.com with database and library, and the fact that the group of partners became known as the TensiNet Association.

After three years of funding this group decided to continue the main activities like the preparation of a Eurocode Part for Membrane structures (CEN/TC250 WGS), the support of student competitions (Techtextil’s Student Competition 2007, 2009 and 2011) and workshops (Textile Roofs Workshop since 2001), the organization of the TensiNet Symposia Designing Tensile Architecture in Brussels (2003), Ephemeral Architecture: Time And Textiles in Milano (2007) and Tensile Architecture: Connecting Past and Future in Sofia (2010) and publishing the TensiNews, arriving now at the 20th issue.

The TensiNet Association became the main communication platform for professionals and those interested in tensioned membrane constructions in Europe. Special thanks go to the Board of the last six years for pushing the association to the current strength and expansion.

TensiNet counts now 200 Members. Current partners encourage more and more architects, engineers, material producers, fabricators and others to become member of the TensiNet Association and are looking forward to intensify the Working Group activities, to publish good practice guidelines, to be present at specialized conferences and events, to prepare the next TensiNet Symposium in 2013, and last but not least to enlarge the creative and qualitative application of tensioned technical fabrics in the built environment.

Other goals are to get scientific results into practice and to promote research in the field of tensile surface structures. During the recent years effort was put in writing proposals (like for the COST-Action – not successful) or in participating in research projects (like Contex-T, www.contex-t.eu and S(p)eedkits, proposal currently under evaluation).

Design exploration for natural fluid shapes, which especially suits the use of ‘flexible’ materials, is a key issue gaining importance in modern architecture. The future of tensile surface structures still contains several challenges, be it in the field of new materials (fibers, coatings, foils, insulation …) or new applications: small or large span, low or high tech (connections play so an important role), expressive, low or even no curvature, energy harvesting, earthquake proof, mobile, retractable etc. New techniques (like textile formwork) are just at the beginning of their potential implementation.
Canopy at Courtyard
Amsterdam, The Netherlands

In cooperation with Frijters Architecten Rotterdam, Tentech has designed a freestanding canopy on the courtyard of an Office building in Amsterdam. The canopy was designed and realized within the very short time span of 2.5 months. An existing flower box, measuring 7x7m, was transformed into a lounge area with seating's positioned on the concrete walls of the flower box, covered by a canopy. Important design parameter was the total weight, it should be enough weight to resist uplift and it should not be more than the former weight of the flower box. The amorphous, freeform canopy forms a striking contrast to the orthogonal stone grid of the courtyard.

Rogier Houtman
office@tentech.nl
www.tentech.nl

<table>
<thead>
<tr>
<th>Name of the project</th>
<th>Canopy at Courtyard Amsterdam</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year of construction:</td>
<td>2011</td>
</tr>
<tr>
<td>Architect:</td>
<td>Tentech in cooperation with Frijters Architecten</td>
</tr>
<tr>
<td>Structural Engineer &amp; membrane consultancy:</td>
<td>Tentech</td>
</tr>
<tr>
<td>Contractor:</td>
<td>Buitink Technology</td>
</tr>
<tr>
<td>Steel:</td>
<td>Galvanized and powder coated</td>
</tr>
<tr>
<td>Fabric detailing:</td>
<td>Stainless steel</td>
</tr>
<tr>
<td>Membrane:</td>
<td>Ferrari 1002</td>
</tr>
<tr>
<td>Covered area:</td>
<td>105m²</td>
</tr>
</tbody>
</table>

Shading for the Synergia square
Ruta, Montevideo, Uruguay

An interesting shading project for recreational outdoor places was realised for the business area at Ruta. The shading optimises the use of the outdoor relax and lunch area. A range of metal structures composed of arches like a tree branches out from the centre support the membranes. The membranes have a shape of hyperbolic paraboloid stretched by 6 points. The prestressing was achieved by stretching each vertex of the membrane (Ferrari 1002 S - Type II). The metal structures were in parts fabricated in the workshop and with bolts assembled on the site. The membranes were produced simultaneously in the workshop and in one day installed on the site.

Roberto Santomauro
tenso@sobresaliente.com
www.sobresaliente.com

<table>
<thead>
<tr>
<th>Name of the project</th>
<th>Synergia Square</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location address:</td>
<td>Ruta, Montevideo, Uruguay</td>
</tr>
<tr>
<td>Year of construction:</td>
<td>2009</td>
</tr>
<tr>
<td>Client (investor):</td>
<td>Zonamerica Business &amp; Technology Park</td>
</tr>
<tr>
<td>Function of building:</td>
<td>recreation place</td>
</tr>
<tr>
<td>Roof design and project:</td>
<td>Sobresaliente Ltda.</td>
</tr>
<tr>
<td>Roof structural engineer:</td>
<td>eng. Marella &amp; Pedoja</td>
</tr>
<tr>
<td>Roof fabricator and contractor:</td>
<td>Sobresaliente Ltda.</td>
</tr>
<tr>
<td>General project:</td>
<td>Dovat&amp;Asociados – estudio arquitectos</td>
</tr>
<tr>
<td>Material:</td>
<td>Ferrari 1002 S</td>
</tr>
<tr>
<td>Covered surface (roofed area):</td>
<td>212m²</td>
</tr>
</tbody>
</table>
Heart Space Canopy
St Bartholomews Secondary School, Newbury, UK

Context
Originally established in 1466, St Bartholomews is a secondary school in Newbury. A new purpose built campus has recently been built on the existing school playing fields and features wedge-shaped blocks that stand two storeys at their perimeter, rising to three storeys at the central point overlooking a communal courtyard, the ‘heart’ of the school.

Project
Buro Happold provided multi-disciplinary engineering for the project, including the detailed design of a tensile fabric canopy over the courtyard. The fabric canopy shelters the communal courtyard from the weather, allowing the space to be used for whole school assemblies.

The brief for this courtyard canopy was for a covering that:

• provided shelter from the wind and rain;
• was translucent so as to illuminate the space with diffuse natural sunlight;
• was relatively inexpensive;
• needed minimal internal supporting structure;
• could be installed quickly;
• was architecturally expressive.

Although other material options were considered, the team realised from the outset that a tensile fabric membrane canopy was the obvious solution to these requirements.

The area to be covered was elliptical in plan, spanning approximately 30m in one direction and 40m in the other. The canopy was to be kept structurally separate from the surrounding buildings but could gain lateral stability from two lift shafts located towards the perimeter. Initially Buro Happold produced three scheme designs (Fig. 1)
1. The Double Arch – This option consists of two arches spanning between the two lift shafts and a horizontal perimeter truss supported at regular intervals by a series of columns. Fabric membrane spans either side of the two arches down to the perimeter truss while polycarbonate panels provide cover between the two arches.

2. The Saddle – The geometry is created via a ‘horizontal’ perimeter truss which is supported on columns all the way around. The fabric membrane is connected continuously to the inner chord of the perimeter truss.

3. The Double Conic – As with the previous two options, the fabric membrane is connected continuously around its outer edge to a horizontal perimeter truss, while in the centre it is pushed up into a double conic shape via two leaning masts. The masts were set on an angle due to sight lines required within the space for school assemblies.

In early 2008 the option “Double Conic” was selected. The leaning columns were designed with pin connections at the base in order to avoid large moments in the foundations. This resulted in slightly increased stress in the fabric membrane, and thus a type 4 PVC coated polyester fibre fabric membrane was required with a reinforcement patch around the top of each of the masts. A valley cable was also added between the two masts to support the membrane and reduce deflections, and small radial belts were added in pockets below the fabric as a safety precaution in order to support the masts in the event of a major failure in the fabric. To create the pin connection in reality a simple ‘sand-pot’ type connection was utilised due to cost and practical considerations.

The canopy was completed in August 2010 in time for the new school term (Fig. 2)

The design was carried out by Jo Smith and Matthew Birchall of the specialist Spatial and Surface Engineering team at Buro Happold. Base Structures were appointed to fabricate and install the canopy, with the final details being developed with the design team to suit the proposed method of erection and tensioning (Fig. 3).

Jo Smith, Buro Happold Ltd
Joanne.Smith@BuroHappold.com
www.burohappold.com

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**Name of the project:** Heart Space Canopy for St Bartholomews

**Location address:** Newbury, UK

**Client (investor):** West Berkshire County Council & St Bartholomews School Trust

**Function of building:** Courtyard covering for secondary school

**Type of application of the membrane:** Double conic fabric membrane canopy

**Year of construction:** 2010

**Architects:** Scott Brown Rigg Ltd

**Full Multi disciplinary Engineering Services:** Buro Happold Ltd (including Spatial and Surface Engineering of the canopy)

**Main contractor:** Willmott Dixon Construction Ltd

**Sub-contractor for the membrane (Tensile Membrane Contractor):** Base Structures Ltd (including Fabrication and Installation)

**Supplier of the membrane material:** Verseidag Seemee UK Limited (Verseidag type IV PVC coated polyester fibre)

**Covered surface (roofed area):** Approx. 1200m²

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**LITERATURE**

"European Design Guide for Tensile Surface Structures" goes (very) international

**Spanish edition**

Arquitectura Textil - Guía Europea de Diseño de las Estructuras Superficiales Tensadas

Brian Forster, Marijke Mollaert
Editorial Munilla-Leria
Translation: Carmen O. Menéndez
Coordination Spanish edition: Juan Monjo Carrió
ISBN: 978-84-89150-82-9
Pages: 326, soft cover
Published: 2009

**Chinese edition**

Brian Forster,
Marijke Mollaert
China Machine Press
ISBN: 7-111-20143-4
Pages: 292, soft cover
Published: 2010

**Proceeding TENSINET SYMPOSIUM 2010**

**Tensile Architecture: Connecting Past and Future**

16-18 September 2010, UACEG, Sofia

Heidrun Bögner-Balz, Marijke Mollaert
Pages: 382, soft cover
Published: 2010

25€ (order www.tensinet.com)

**Textile Hüllen**

Bauen mit biegeweichen Tragelementen

Materialien, Konstruktion, Montage

Author: Seidel, Michael

Language: German

Size: 234 pages (hardcover)

Editor: Ernst und Sohn, Berlin (2008)

ISBN-10: 3-433-01865-0


**Tensile Surface Structures**

A Practical Guide to Cable and Membrane Construction

Materials, Design, Assembly and Erection

Author: Seidel, Michael

Language: English

Size: 368 fig. (196 colored fig.), 234 pages (hardcover)

Editor: Ernst und Sohn, Berlin (2009)

ISBN-10: 3-433-02922-9


A very interesting book ideally suited in particular to Engineers but also Architects and Contractors who may be interested in projects involving the principles of design and construction of cable and membrane structures.

**Ungekünstelte Kunst**

Ein Dach für das Passionstheater Oberammergau - Art without artifice - A canopy for the Oberammergau Passion Play

Author: Judith Eiblmayr, Martín Zigoń, Michael Seidel, Matthias Pfeifer

Language: German, English

Size: 21 x 26 cm, 114pages (hardcover)

Editor: Karlheinz Wagner (2010)

ISBN: 978-3-9502951-0-8
The shear properties of coated fabrics are very important in tensile structures as they allow to deform flat sheets into double curved shapes. However, few investigations have been done so far on the shear response of such materials. Because of the lack of reliable data and standard test methods, a common rule is to consider the shear modulus to be equal to $1/20$ of the tensile stiffness.

In the last decade, the first test methods for estimating the shear modulus of coated fabrics have been proposed based on uniaxial bias tension, T-shaped specimen, or picture frame. Another method presented by Bögner and Blum consists in the biaxial loading of a cruciform specimen where fibres in the central part are oriented at $45^\circ$ with respect to the loading direction. Such test allows to apply a biaxial loading during the shearing but it requires a specific sample. A new test method, the shear ramp, is here presented and compared to the biaxial loading of a $45^\circ$ sample.

The proposed method enables to apply a shear loading to a cruciform specimen loaded in the fibre directions. More details about the theory, experimental set-up and validation of the shear ramp can be found in References.

**A new test method for measuring the shear properties of coated fabrics**

**Test protocols**

Cruciform specimens were tested on our biaxial test machine. The machine (Fig. 1) has five actuators with a load cell on each side that enables to control the stress in each strip of the sample independently. As a result it is possible to obtain a non uniform load distribution on each side of the specimen.

The shear ramp (called thereafter Shear $0^\circ$) loading consists in the biaxial loading of a cruciform specimen where the applied stresses vary linearly on each side. A theoretical study of a square plate loaded by such a shear ramp, as presented in Figure 2, allowed to estimate the shear stress distribution in the sample based on Airy stress functions for both isotropic and orthotropic materials. It has been found that the shear stress in the centre of the sample could be estimated by:

\[
\tau^{0^\circ} = \frac{3}{8} \Delta \sigma_B
\]

The second test method (called thereafter Shear $45^\circ$) uses a specimen where fibres are rotated in the central part. In the case of a square plate where the material is oriented at $45^\circ$ with respect to the loading direction (Fig. 2), a pure shear stress is obtained in the material coordinate system if tension and compression are applied to the plate with equal tensile and compressive stresses $\Delta \sigma_x = -\Delta \sigma_y = \Delta \sigma_B$:

\[
\tau^{45^\circ} = \frac{1}{2} (\Delta \sigma_x - \Delta \sigma_y) = \Delta \sigma_B
\]

It must be emphasized that for both methods a pre-stress $\sigma_0$ has to be applied prior to shearing in order to avoid compressive stresses in the membrane.
In order to define these areas of interest, the shear stress distribution was determined in the cruciform specimens using finite element analysis and compared to the theory [7] and first estimations of Eq. (1) and (2). The results in Figure 4 show that the shear stress distribution is almost uniform if one considers a 150 mm wide square in the centre of the sample, represented by the gray areas. However, in both cases there is an important difference between the first estimations and the predicted shear stresses. Therefore stress correction factors must be used in order to obtain a better estimation of the shear stress from Eq. (1) and (2).

Test results and comparison

Based on the experimental results and on finite element analyses, the stress correction factors were estimated for both Shear 0° and 45° [8]. Because the stress distribution strongly depends on the material elastic properties, two sets of factors are given for PVC/polyester and PTFE/glass in Table 1. The use of correction factors avoids further needs of finite element calculations for estimating the shear properties.

<table>
<thead>
<tr>
<th>Material type</th>
<th>Shear 0°</th>
<th>Shear 45°</th>
</tr>
</thead>
<tbody>
<tr>
<td>PVC-polyester</td>
<td>0.74</td>
<td>1.14</td>
</tr>
<tr>
<td>PTFE-glass</td>
<td>0.86</td>
<td>1.2</td>
</tr>
</tbody>
</table>

Table 1. Stress correction factors

Comparison between Shear 0° and Shear 45° is presented in Figure 5 for three different materials. The engineering shear strain is equal to the shear angle and is calculated from the needle extensometer measurements. The shear stress for the graphs on top is estimated based on Eq. (1) and (2) [9]. In that case there is a significant difference between the stress-strain curves that are obtained with the Shear 0° and the Shear 45° method. If the correction factors of Table 1 are applied then it can be seen on the bottom graphs that the shear stress-strain curves are very similar. An estimation of the shear modulus can be obtained from a linear fit of the corrected curves. Based on the experiments it is found that the shear modulus lies between 9 and 17 kN/m for PVC-polyester fabrics and between 37 and 58 kN/m for PTFE-glass fabrics [10].

Conclusion

A new test method has been proposed that allows to measure the shear response of coated fabrics with a special biaxial test performed on a fibre-parallel cruciform specimen. The shear ramp can therefore be integrated within the test process of a material together with the estimation of the tensile moduli on a single test specimen. The shear stress can be estimated with Eq. (1) in the centre of the sample but for more accuracy a stress correction factor must be used (Table 1). The proposed method has been compared to a currently used shear test protocol and has given similar results. The shear ramp has been so far validated for PVC/polyester and PTFE/glass coated fabrics for shear angles up to 35° [8].

REFERENCES

Modernization of the Municipal Stadium

A tensioned membrane roof

Poznan, Poland

Context

Although the only stadium for Poland’s forthcoming EURO 2012 event that has been refurbished as opposed to rebuilt, the grand Municipal Stadium in Poznan will be the country’s biggest football ground when completed. The €160 million redevelopment of the home of reigning Polish champions and current Europa League participants Lech Poznan has been a mammoth project with renovation work starting in 2003 and only finishing in September 2010. The modernization of the Municipal Stadium in Poznan was taking in consideration the whole roof as well as all tribunes and related public areas.

Project

The stadium, the only one designed for the EURO 2012 event to be fully designed and realized by Polish companies, is an example of modernisation and valorisation of the local architecture potentiality and the competitive and professional local execution. The architectural design has been much more indicating the fulfilling of the three main architecture rules: durability, utility and beauty. Dramatic design, light transmittance and functionality for example by providing full tribune coverage which established main criteria’s for the stadium investors. Not at last, the project should be durable and not superimpose the budget, a real challenge for the technicians and the execution companies. The back side of the stadium (free of membrane covering) will be the façade of a hotel, integrated into tribune 2 and with special access to the stadium VIP area (Fig. 1).

Tensioned membrane roof

Modern fabric materials in modern architecture can shape space, enabling architects to sculpt 3-dimensional areas in a manner that would not be possible with any other type of material. This kind of architecture is offering much more: the designer is able to play with light and use this for natural illumination of the space, softening it, fusing it, sharpening it or shaping it. This creates mood and ambience to reflect architectural intent, resulting in an energy saving covering system by approaching the elementary need of being in touch with nature. The dynamic shape and form of membranes allow new possibilities to become reality. In no other sector of architecture do form and load distribution depend on each other as greatly as they do in membrane construction, hence, these represent the perfect marriage between architecture and engineering. As in nature, the course of forces that are shown in the form and shape can fascinate not only architects and engineers, but also the wider public as well, especially those who can appreciate the equilibrium between aesthetics and functionality. In particular for this project following points are relevant:
- Dynamics design intended as curved, adaptable, living and connecting well the surround ambience (tough natural forms, elements like light etc.) allows to create a state of the art architecture;
- Higher mechanical strength in direct relation with reduced material weight/mass allows filigreed support structure when compared to classic, heavier construction materials like steel, concrete, wood, glass etc.;
- When compared with other classic construction methods and materials tensile structure are offering immediate reduction of whole support structure need and consequent costs and environmental impact saving;
- Short execution and delivery time and reliable. In comparison with classic architectural solutions there is a low need on heavy construction site accessories (cranes, etc.);
- Superior aesthetic in comparison with other materials and great natural light transmission helping in release quite and suffuse sunlight distribution;
- Longstanding appearance protection trough weldable PVDF lacquering, reducing fabrication risk, easy installation and low maintenance need;
- Possibility in reproduce light effects due to the material high translucency, recreating dramatic choreographies at night time;
- Fully recyclable materials, in line with current safety and quality standard as per European REACH requirements.

Data on loads

Side membrane tension (in the direction of the roof arches) - 5.10 kN/m (510kg/m) longitudinal tension membrane (transverse to the above direction) - 2.1 kN/m (210 kg/m). Elongation tests are been carried out especially to verify the weft direction with a tension of 13kN/m, (1300 kg/m) estimated maximum life load. The elongation ratio is been of 3.5cm with a pattern width of 2.50m, approx. 1.3%.
Technical description to the tensile roof

Roof covering structure

The steel structures of the roof are covered with VALMEX MEHATOP F multi-layered coated type IV fabric membrane. The material is connected to steel guides (pipes Ø44.5x6.3mm), running along the crosswise system axes and to the edges. The shape of the roof surfaces is formed by steel arches (supported on crosswise systems), supporting and stretching the membrane upwards, producing a typical arch supported form.

Membrane tension system components (Fig.5)
- Along the edges of the components, every 25cm galvanized sheets of 120X90X2mm will be mounted to the membrane using steel rivets Ø6.
- The membrane will be connected to the guide (pipe Ø44.5x6.3mm) with U-type hooks from 4X40mm galvanized flat bars, with the Ø14 opening for M12 screw.
- On the screw connecting U-type hook with the membrane use M12 X 80 cl. 8.8. acc. to PN-85/M-82101 with ZN hexagonal head and nut M12 cl. 8 acc. to PN-82148, geared, galvanized. Secure with locking pin 3.2 x 25 acc. to PN-82001 ZN. Screw-thread length – 45mm.
- The lower part of the membrane has a hot-pressed slat enabling the support of drain pipe of 150mm in diameter.

To note that this choice leaves almost no possibility for site adjustments and therefore an exact steel structure and pattern geometry as well as a very precise estimation of the material elongation properties, here absolutely constant, are of crucial importance.

U-type hooks base – every 25cm; 4 pieces per 1m. Single hook load:

\[ N = \frac{28.8}{4} = 7.2kN \]

Membrane material

- Trade name: Valmex ® MEHATOP F Type Valmex FR 1400 Mehatop F – Type IV.
- Type of coating: PVC with top coat finish weldable PVDF-lacquer on both sides, protected against microbial and fungal attack, UV-protected, low-wick
- Flame retardancy: BS 7837, DIN 4102: B1
- Total weight: 1350 g/m² EN ISO 2286-2
- Tensile strength (warp/weft): 8000/7000 N/50 mm DIN EN ISO 1421/V1
- Tear strength (1) (warp/weft): 1200/1200 N DIN 53363
- Adhesion (1): 26 N/cm LB 3.04-1
- Cold resistance: -40 °C DIN EN 1876-1
- High Temperature: +70 °C LB 3.15
- Light transmission: >6% Note, Val. DIN 54004, DIN EN ISO 105 B02
- Crack resistance: no cracks @ 100000 x DIN 53359 A
- Base fabric material: PES DIN ISO 2076
- Yarn count: 1670 dtex DIN ISO 2060
- Weave: P 3/3

Paolo Giugliano:
P.Giugliano@mehler-texnologies.com
© MTX Mehler Texnologies

Name of the project: Municipal Stadium Miejski w Poznaniu
Facility Address: 61-553 Poznań ul. Bułgarska 5/7
Main use: Football (Lech Poznan football Club)
Architects and engineers: Modern Construction Systems Sp. z o.o.
General constructor: AK-BUD Kurant
Roof material: Mehler Texnologies Mehatop F Type IV 1400 FR 7270
Roof area: 52.000m²
Playfield dimensions: 105 x 68m
Capability: 43.000 seats
A restaurant canopy
Breaking the routine
of planar and geometric lines
Palladium Shopping Center
Istanbul, Turkey

There are many different methods to create roofs. Both with texture and a different three-dimensional aesthetics membrane architecture adds harmony of movement to a project. The architect, who designed the Palladium shopping mall in Istanbul, decided to use the membrane architecture as the product of such a thought. This structure was used for a very special terrace with an average height of 16m in the form of a ship, which is going to be used as a restaurant, covering an area of approximately 450m². This radial type of tensile membrane is carried is by four posts with an average height of 11m. All the steel ropes and posts that are used along the border are anchored to the structural columns and beams in the façades. The structure is 38m high and its maximum width is 18m. All structural elements are tied together with security ropes. Offering service since 2007, this structure has become an inseparable part as well as a landmark of the Palladium shopping mall with its feature of creating a domestic and relaxing space due to its aesthetic and form.

Location Address: Istanbul, Turkey
Client: Tahincioğlu Holding
Function Of Building: Restaurant Canopy
Year Of Construction: 2007
Architect: Ender ERGÜN
Contractor: Kozken İn"aat Taah.Ve Turizm A.Ş.
Supplier Of The Membrane Material: Ferrari
Manufacture And Installation: Tensaform Membrane Structure Co.
Material: Ferrari Precontraint 832
Covered Area: 450m²

Mehmet YILMAZ: info@tensaform.com: www.tensaform.com
Swimming pool covers

CWG 2010 GAMES VILLAGE

New Delhi, India

The Games Village developed for the Common Wealth Games 2010 held in New Delhi, India has recreational facilities including Swimming Pools. These swimming pool facilities were proposed to be covered with membrane roofs. McCoy Architectural Systems Pvt. Ltd. has recently and successfully completed this project, with designing and executing the structural steel as well as the membrane roof for these pool covers.

Design

The overall scope has four structures: the Main pool (Practice Pool) with the entrance Canopy and the Leisure pool with large, medium, and small covers. The overall design is the same for all structures. The form is a simply supported elliptical profile with intermediate vaults earlier proposed in Glass, now executed in a translucent membrane to allow in more light. The ellipse is divided into four spans. The lens-shaped area’s between the arches are covered with translucent membrane (Fig. 1).

Main Pool (Practice Pool)

The plan shape is elliptical with major axis measuring 83m and minor axis measuring 54m with a height of 14.8m, covering an area of approximately 4500m² (Fig. 2). The main structure has an architecturally aesthetic Canopy in front (Fig. 3). The inimitable architecture has added value to the aesthetics of the Games Village and now stands as a part of the Common Wealth Games History.

Leisure Pool

The plans of the 3 leisure pools are also of elliptical shape: The Large cover has a major axis measuring 40m and minor axis measuring 26m and covers an area of 903m²; The Medium cover has a major axis measuring 34m and minor axis measuring 21m and covers an area of 730m² and the Small cover has a major axis measuring 30m and minor axis measuring 15m and covers an area of 730m² (Fig. 4).

The overall design is that of a simply supported structure. The columns have been designed using a universal ball joint detail due to restriction of not transferring the moments onto the existing piling of the foundations. A convoluted process to achieve the correct design and sizes, with an equally challenging execution process has resulted in a stable and aesthetically appealing form. The geometry has main columns with a ring beam around. The span divided by the arches forms an interesting overall form of the main ellipse. Fixed edge detailing has been used for the membrane. An aluminium keder profile has been used for tensioning of the fabric and coated GI cables have been used to stabilise the intermediate arches.

Materials

Steel - The structure has been executed using high quality of Mild Steel as per IS standards finished with paint of a high Performance Polysiloxane System.

Membrane - Different types of on Both Sides PVDF lacquered Membranes from Mehler Texnologies have been used for the various pool covers. Main Pool: Valmex FR 1400; large cover of Leisure Pool: Valmex FR 1000; medium and small cover Leisure Pool: Valmex FR 900. The High Translucent membrane for the intermediate arches is Valmex FR 900 HTL Valmex FR Mehatop.

Accessories - Swage ends in SS of grade 304. Cables used are coated GI cables. All structural steel members including bolts, nuts and welded connections have been hot-dipped galvanised.

Execution

The entire Project has been executed in a span of about 24 weeks. The project successfully executed by Mccoy Architectural Systems Pvt. Ltd. is a testimony of their Design and Operational abilities. Though complex in execution due to site constraints and structural elements involved, the result is a unique architectural emblem in Membrane on the skyline of New Delhi adding to the glory of the City and the Common Wealth Games.

Name of the project: Commonwealth Games Village 2010
Location address: Commonwealth Games Village, Akshardham Temple Off Road, Delhi
Client (Investor): The Delhi Development Authority
Function of building: Commonwealth Games Village Practice Avenue
Type of application of the membrane: Covering of Swimming pool
Year of construction: 2009 - 2010
Architects: Suresh Goel & Associates
Engineering of the controlling mechanism: McCoy Architectural Systems Pvt. Ltd.
Main contractor: McCoy Architectural Systems Pvt. Ltd.
Contractor for the membrane, manufacture and installation: McCoy Architectural Systems Pvt. Ltd.
Supplier of the membrane material: Mehler Texnologies

Material:
- Main pool Valmex FR 1400 (3300m²); medium sized Valmex FR 1000 (1200m²); two small sized Valmex FR 900 2x900m² & skylights between all the structures Valmex FR 900 Highly Translucent
- Covered surface (roofed area): 6000m²

Figure 1. Position of the 4 pools
Figure 2 & 3. Main Pool covering with front Canopy
Figure 4. Leisure Pool coverings

© Faraz Aqil
faqil@meher.in
www.mehler-technologies.com
ARTICLE

Context
70 tons of ETFE (Ethylen and Tetrafluorethylene) foil is installed in Portugal’s largest shopping Mall Dolce Vita Tejo close to Lisbon, the world second largest ETFE project. More than 350 pneumatic roof cushions out of ETFE cover a surface of 42.000m² and improve the indoor climate of the building with a unique construction concept. The new Shopping Center is located at a major highway intersection ten kilometers out of the city center. 300 million Euro were spent to construct this commercial complex with an interior sales area of around 120.000m². A total of 300 shops, restaurants and food stalls share this area. A huge cinema with eleven halls, an amusement park, public squares and 9.000 car parking spaces were realized. With this innovating mixture of commerce and entertainment between 15 and 18 million guests are expected annually (Fig. 1).

Building
The visitor enters the building from the atrium, Entree of the Shopping Mall, and Europe’s largest, fully covered square. 72 multilayered pneumatic cushions create the enormous membrane roof (Fig. 2). From here the visitor enters the great shopping world which consists of the rectangular shaped mall complex with its shopping passages and two bridging units enclosing the atrium together with a smaller rear-mall (Fig. 3). The over all design was done in cooperation between the architecture office Promontorio, Lisbon and RTKL, London. Hightex GmbH was contracted for planning, manufacturing and installing the entire membrane roof structure.

Membrane roof
All along the shopping passages the roof cushions accentuate the way through the commercial complex, protecting the inside from wind, sun and rain and allowing diffuse and gentle daylight to enter. The roof consist mainly out of rectangular shaped four-layer cushion modules with an average surface around 100m². For ETFE cushions the span of ca. 10m is unusually wide and could only be realized with corresponding material thickness and an appropriate sag of the cushion of around 4m. As the material is only stressed by tensile forces, which is the ideal loading to achieve minimized material sections, pneumatic cushions can be con-
structured with a minimum of weight. Therefore
the supporting steel structure of the roof could
be designed very filigree and reduced. In combi-
nation with the extremely large cushion for-
mats the roof is transferred into a light
transmission and light-flooded ensemble. An-
other advantage of the material lies in its duc-
tility. An eventual collapse of the structure will
be indicated well in advance and will allow for
remedial action in contrast to brittle glass. Es-
pecially for overhead use this material behavior
produces increased safety. Even in case of fire,
the material is melting locally and acts as an
automatic smoke funnel.

Climate concept
Each cushion is made of four layers forming
three air chambers. The inclusion of air increases
the thermal insulating properties of the roof
structure and protects the building from heat
and in winter from the cooler outside
temperatures. However, with annual average
temperatures in Lisbon of around 17°C the more
critical criterion is the overheating protection
of the building. The climate concept of the
cushion roof is supported by further aspects.
The upper layer consists of two hexagonal
silver printed ETFE foils with an additional
double layer on the second, inner foil which
reduces the solar heat load of the building.
Also the lowest layer facing to the inside of the
building is designed with the same pattern to
screen against direct sunlight. The south-facing
side of the upper layer is fabricated in white
ETFE foil creating the diagonal structure in a
way that only towards the north a transparent
view through the cushion construction is possi-
ble. The sub-layer of the cushion is printed ex-
actly the opposite. Here the coating shields on
the northerly side of the cushion. With this
staggered arrangement a kind of shed roof is
created to block incident radiation (Fig. 4). This
diffused light coupled with the regular diagonal
structure of the cushions creates a moving and
rhythmic roof structure that can be played by
light effects (Fig. 5).

Fabrication and installation
More than 350-ETFE cushions were prefabri-
cated in the factory off site. After determining
their form, the individual cutting patterns were
calculated. The pieces were cut out, heat
welded together, and hermetically sealed. As
readymade cushions they were transported to
Lisbon. On site, the pillows were placed in its
final position, rolled out on the roof and pulled
by heavy clamping tools onto the supporting
steel structure. With extruded aluminum pro-
fles, the cushions were clamped onto the re-
spective steel flanges and sealed. After
connecting them with the air line, compressed
air inflates the cushion structure into its oval
shape and stabilizes the roof structure against
external loads (Fig. 6).

Summary
With the realization of the roof construction of
the shopping mall Dolce Vita Hightex GmbH
achieved a decisive step towards intelligent
building envelope technology in membrane
structures. Besides the enormous spans and the
resulting savings of supporting structure, the
cushion roof in Lisbon sets a new accent in the
area of energy optimization by the combination
of three means: partial silver printing, a
low-e layer and a multi chamber cushion.
The interplay of function and design is man-
aged in an impressive manner and may be
regarded as a milestone in the development of
membrane structures and ETFE cushion
projects in particular.

Gregor Grunwald, Markus Seethaler
Gregor.Grunwald@hightexworld.com
Markus.Seethaler@hightexworld.com
www.hightexworld.com

Name of the project: Shopping Mall Dolce Vita Tejo,
Lisbon
Client: Charmartin / ING Real Estate Development
Completion: 2009
Architect: RTKL, London / Promontorio, Lisbon
Structural Engineering: Atelier One, London
Membrane Construction: Hightex GmbH, Rimsting

Fig. 1. Aerial view on the shopping mall Dolce Vita and plan. © HT
Fig. 2. The atrium, a square covered by 72 multilayered
pneumatic cushions. Interior view and top view on the middle
part where totally transparent cushions are installed. © FG
Fig. 3. Interior views of the mall area. © HT-FG
Fig. 4. Detail of the cushion roof.
Fig. 5. View through cushions towards north & light effects
Fig. 6. Installation of the cushions. © HT
© Pictures (as indicated): Hightex GmbH (HT) Fernando
Guerra/FG+S (FG)
Case study
Turkey

Rising Tide

Rising Tide is a Charter yacht for events registered in Turkey. During strong sun, passengers do normally not have any shade on the yacht. To provide a comfortable journey to the client it is important to have some shade on the deck. Using the two existing poles/masts a double cone was designed to fit the deck. By using special fixing accessories and zippers the shading structure is detachable and can be re-installed or dismantled in no time.

"Rising Tide" is a good example for using the material Airtex Top as proper tensile architecture material although it was mainly developed for big umbrellas or small shade canopies. This project showcases the Polyester fabric with acrylic coating in a different perspective.

Kashif Ahmed
k.qureshi@mehler-texnologies.com
www.mehler-texnologies.com

Name of the project: Rising Tide
Location address: Turkey
Client (investor): Sailing Yacht Rising Tide
Function of building: Charter yacht for events
Type of application of the membrane: Sun shade covering
Year of construction: 2010
Architects & multi disciplinary engineering: Advance membrane System Pte Ltd
Contractor for the membrane, manufacture & installation: Advance membrane System Pte Ltd
Supplier of the membrane material: Mehler Texnologies GmbH
Material: Airtex Top (100% polyester light-weight fabric coated on one side with acrylate and impregnated with a finish based on Teflon)
Covered surface (roofed area): 110m²

The summer amphitheatre of the Regional Culture Centre (Regionalne Centrum Kultury) in Kolobrzeg has been extended in the form of a lightweight roofing over the summer stage and seats. The roofing of the stage has been designed as a tensile structure (bars and cables) consisting of a supporting structure in the form of rigid round posts on flexible guys and the flexible load-bearing structure of the roofing. The roofing is a membrane made of polyester fabric with PVC coating stretched between the cable system.

Paolo Giugliano
p.giugliano@mehler-texnologies.com
www.mehler-texnologies.com

Name of the project: Sun shading covering of the summer amphitheatre
Location address: Kolobrzeg, Poland
Function of building: open air amphitheatre
Type of application of the membrane: Covering of open air infrastructure
Year of construction: 2010
Architects/engineering: Mellon Architekci, AIGMA
Grzegorz Maliszewski, KONTENT
Manufacture and installation: PBI Kornas, POMBUDMET
Jan Klukowski, KONTENT
Supplier of the membrane material: Mehler Texnologies
Material: VALMEX® FR 1400 MEHATOP F Type IV, colour White
Covered surface (roofed area): 855 m² (L32.00xW29.50xH11.58m)
Context
In 2011 the Federal Horticultural Show (BUGA) will take place in Koblenz, Germany. As this event will be carried out in multiple locations in Koblenz, an efficient transportation concept is required. To transport visitors directly from the venue places on the west side of the river Rhine to the east side, a temporary ropeway system was built in 2010 and will be removed 3 years later. The ropeway is located in the UNESCO World Heritage Site “Upper Middle Rhine Valley” and the stations are both located nearby historic buildings. Due to these conditions, the roofing of the stations were supposed to be light, soft and ephemeral objects, blending into the existing surroundings while showing their temporary character.

Project
Though the requirements and dimensions for the lower and upper station differ, a similar design was required to obtain a connecting appearance (Fig 1 & 2). This was achieved by using the same design principle and adapting it for each station. The main bearing structure is built up of a backbone and alternating twisted bow-like girders in transverse direction, each of them adjusting to the overall requirements. The bearing structure is mounted on a concrete slab 4 meters above ground, which also serves as installation platform for the ropeway drive system. All roof girders consist of glue laminated timber, forming the frame for the main membrane panels. Each of these membrane panels are fixed on all four sides by means of linear keder edge profiles. Hence there are no undefined edges of the relatively narrow panels, which resulted in a high demand for accuracy in cutting pattern and erection of the roof (Fig. 3). In side view, the main panels seem to softly shuttle from the alternating high to the low points. In contrast, the lower end of the panels end on a horizontal line, at the same height as the concrete slab, giving the roof a floating appearance. The back end of the roofing is covered with double layers of mesh fabric, thus generating a moiré effect which allows the visitors a diffuse view of the ropeway technology covered by the roof. So-called spoilers frame the roof at the front and back. These elements were executed with a cladding membrane on a steel substructure. For both the spoilers and the mesh backplanes a silver colour was chosen to contrast with the white, translucent membrane of the main panels.

Werner Sobek, Albert Schuster, Sven von Boetticher, Martin Synold
albert.schuster@wernersobek.com
www.wernersobek.com

Figure 1. Upper station © Werner Sobek Design
Figure 2a. Lower station © Markus Palzer
Figure 2b. Lower station © Zooey Braun
Figure 3. Detail of the highly translucent membrane panels © Markus Palzer

Ropeway Stations
Koblenz, Germany

<table>
<thead>
<tr>
<th>Name of the project:</th>
<th>Koblenz Ropeway Stations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location address:</td>
<td>Koblenz, Germany</td>
</tr>
<tr>
<td>Client [investor]:</td>
<td>Doppelmayr Seilbahnen</td>
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<tr>
<td>Function of building:</td>
<td>Ropeway stations (hill and valley)</td>
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<td>Type of application of the membrane:</td>
<td>Façade and roof</td>
</tr>
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<td>Year of construction:</td>
<td>2009 / 2010</td>
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<tr>
<td>Architects:</td>
<td>Werner Sobek Design</td>
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<td>Structural engineers:</td>
<td>neueHolzbau / HP Gasser</td>
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<td>Consulting engineer for the membrane:</td>
<td>Werner Sobek Stuttgart</td>
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<tr>
<td>Main contractor:</td>
<td>HP Gasser</td>
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<td>Contractor for the membrane (Tensile membrane contractor):</td>
<td>HP Gasser</td>
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<tr>
<td>Supplier of the membrane material:</td>
<td>Verseidag, Heytex, Ferrari</td>
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<tr>
<td>Manufacture and installation:</td>
<td>HP Gasser</td>
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<td>Material:</td>
<td></td>
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<td>Main panels:</td>
<td>Verseidag Duraskin B1617 highly translucent</td>
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<tr>
<td>Vertical mesh backplane:</td>
<td>Ferrari Solits 86 (double layer)</td>
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<tr>
<td>Front and back spoilers:</td>
<td>Heytex AS572 silver</td>
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<tr>
<td>Covered surface (roofed area):</td>
<td>2 x 850m²</td>
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<tr>
<td>Membrane area:</td>
<td>2 x 1300m²</td>
</tr>
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</table>
Spider

Textile Architecture Project at Pädagogische Hochschule

Ludwigsburg, Germany

Context

In February 2009 we were invited by "Vermögen und Bau Ludwigsburg" to carry out a study for the renewal of a 35 year old textile structure in the campus of the Pädagogische Hochschule in Ludwigsburg. The structure had been the eye catcher in the campus. The students named the structure to the point "spider". Five elliptical bended beams of laminated wood spread radiating from a center point towards the outside. Length, span and radii of beams varied strongly and the outer foundation points were placed on two different levels. The beams carried five expressively saddle-shaped membrane surfaces. The structure covered in total approximately 500m² area, which was used as outdoor facility of student artists. The "spider" was a strong identification sign of the whole campus (Fig.1).

Due to this fact the owner decided in autumn 2009 to invest in the renewal of the textile structure as part of a total renovation of the outdoor environment of the campus.

Concept

All parts of the structure like membrane, cables, assembling including the wooden beams had to be replaced. Based on exact survey data's of beams, shape and
border cables we developed a 3D system line model for form finding, membrane stress and structural analysis. After a careful research we decided with the client to execute the new structure with elliptical bended steel tubes. We tried to reach a smooth and slender structure to reduce the impact of the structure as much as possible. To maximize this effect we choose for all beams the same diameter and increased just the wall thickness according to structural needs (Fig. 2).

For one of five fields we could not rely on survey data as it was ripped off at an early stage and replaced through some cables. There has been obviously limited access into the structure. Therefore we decided to change the fixation geometry. Instead of two border cables and one tie down cable to the existing railing, we adapted the concept of one single border cable running from base point to base point of the related steel tubes. With that measure we gained a wide and open access from the upper platform below the structure.

The foundations had to be partly reinforced in order implement the new anchor plates of the steel tube arches.

The steel structure and all clamping profiles are all in the same light grew color as fine contrast to the white color of the membrane surface.

Assembling

For assembling details we used „Tennect“, a prefabricated assembling system, as base for our design. Especially the pin-jointed fixation with ball holder, ball and thread bar allowed a systematic fixation of the border cables with maximum tolerances and the possibility of prestressing the cables. The angle of border cables can alter up to +/-20°.

For linear fixation along the steel arches we choose a profile of „Tennect“, which can be described as clamping-keder profile. It works like a typical keder profile, but can also be clamped like a typical clamping bar. The membrane stays unpunched, the membrane can be stressed alongside the profile. Vertical to the profile all angles are possible.

Conclusion

The task was very interesting and intensive for us. We could study details, analysis and cutting pattern out of a time, in which no form finding and FEM tools were available, in which all detailing had been kind of improvisational. But we learned also which creative forms and shapes had been realized with former methods. Parallel we could adapt all by using newest technology in engineering and detailing.

Beside we learned the benefits of ready-made solutions. It was a pleasure to work for the project “spider” and we are happy that we could help to prevent the “spider” from vanishing.

Michael Kiefer, Kiefer. Textile Architektur
michael.kiefer@k-ta.de
www.k-ta.de

Figure 2. The new structure “Spider” and his details.
From animal or plant products to synthetic raw materials
The use of membranes for structural applications is nearly as old as human history itself. Whereas early materials were based almost exclusively on animal or plant products, this has developed over the course of history to membranes which are predominantly fabricated from synthetic raw materials. Today’s technical highlights of this work are constructions based on high-performance fluoropolymers. The key features of such materials, also designated as ETFE or PTFE, is the almost universal chemical resistance and wide service temperature profile ranging from roughly -100 up to +260°C. The excellent UV- and weather-resistance properties of these fluoropolymers result from their intrinsic molecular structure without the need to incorporate additives or stabilizers. Fluoropolymers are also intrinsically flame-resistant. The non-stick properties of PTFE-coated membranes and ETFE films make them exceptionally dirt repellant and thus virtually self-cleaning. The long service life of fluoroplastic membranes, which can extend to decades, is also a result of the above-mentioned chemical and thermal properties. Significant economic benefits are therefore provided in comparison with products based on other materials.

Fluoropolymer materials for architectural applications
The formability of these membranes, combined with their outstanding tear and puncture resistance, has specifically made it possible to achieve previously unheard of span widths. This enables architects to design entire supporting structures that use less material, are lighter in weight and do not have distracting supporting columns – while at the same time allowing much greater freedom of design. These benefits have made fluoroplastics the material of choice in membrane architecture.

Dyneon has for more than 30 years been a pioneer in membrane architecture and offers the world’s most comprehensive portfolio of fluoropolymer materials for architectural applications. Already in the mid-1980s, the first sensational projects were realized, including the glass-fabric membrane sail coated with 3M™ Dyneon™ PTFE “La Grande Arche” in Paris which remains in place (Fig. 1).

Predestined for the roofing of large areas, such as public spaces, airport buildings or grandstands, the advantages of membrane architecture using fluoropolymer materials can be seen today at nearly every World Cup Soccer match and at the Olympic Games. (Fig. 2). The Eden Project in England (Fig. 3), completed in 2002 was the world’s first large...
ARTICLE

This project employing transparent films made with 3M™ Dyneon™ ETFE raw materials. It is today one of England’s largest tourist attractions, and an exemplary object and inspiration for architects and building owners from all over the world. In addition to many other projects, such as indoor swimming pools, shopping malls and botanic gardens, the most recent highlights in constructions with ETFE films are the Astana Experience Center in Kazakhstan completed in 2010 (Fig. 4), and the world’s first, trend-setting large facade for an entire building in Hamburg made with ETFE films (Fig. 5). Both projects placed their faith in the excellent performance of 3M™ Dyneon™ ETFE polymers. The unique opportunity to combine flexible, mobile structures, such as giant sun umbrellas, mobile roofs or large mobile tent systems, with the outstanding properties of fluoropolymers is provided by the yarns made of PTFE from which fabrics are produced and which are then coated with 3M™ Dyneon™ THV. The coating of this transparent, high-performance fluoropolymer additionally seals the open-pored fabric. The smooth surface thus produced makes the fabric impervious to bacteria and dirt because there are no voids in which they can settle. 3M™ Dyneon™THV, composed of special fluorinated co-monomers, is produced exclusively worldwide by Dyneon, and represents the latest state of the art for the combination applications named above.

Towards sustainable production technologies

The trend is moving not only toward developing new membrane products for consumers, but also toward achieving sustainability in the manufacturing processes used to produce them. The aspect of employing sustainable production technologies is being increasingly defined as a central issue that is critical to being successful in the market. Researchers at Dyneon have installed the most advanced recovery and reuse processes for exhaust gases, waste water and operating materials, and are continually developing these processes further. This is intended to ensure that the duality of fluoropolymer materials for membrane architecture and their compatibility with future standards is taken into account in order to benefit both the environment and consumers.

Helmut Frisch
hfrisch@mmm.com
www.dyneon.eu

Figure 1. La Grande Arche, Paris, France
Figure 2. Olympia Berlin, Germany
Figure 3. Eden Project, Cornwall, England
Figure 4. Astana Experience Center, Kazakhstan
Figure 5. Facade of ETFE films for the Unilever building,
Hamburg, Germany
Saint-Gobain Performance Plastics is now offering the well known SHEERFILL® – PTFE Glass- Membranes with a highly functional top coat called EverClean.

This top coat uses Hydrotect® technology, which is based on the photocatalytic properties of a special type of Titanium Dioxide. Due to the modified coating SHEERFILL Architectural Membranes provide several functionalities which we believe will help to grow the market for tensioned membrane structures. For many sports events but also for public buildings the environmental aspects are becoming more and more rigid. One major characteristic of EverClean modified membranes is its air purifying properties, which turn harmful nitrogen oxide (NOx) into harmless substances. A large negative impact to the environment and human beings comes from NOx (NO, NO₂) in the air. With NOx floating in the air under sunlight, it forms photochemical smog and acid rain, significant forms of air pollution. Children, people with lung diseases such as asthma, and people who work or exercise outside are particularly susceptible to adverse effects of smog such as damage to lung tissue and reduction in lung function. With EverClean on membranes, it converts NOx to NO₃⁻ and washes down to the ground. It can still prevent NOx from forming smog and acid rain. The efficiency of 1.000m² EverClean modified surface in terms of air purifying properties equals approximately a 7.000m² green field or 70 deciduous trees. Thus EverClean can help to achieve “green” properties for environmentally sustainable constructions for events and public buildings.

An additional benefit is the decomposition of organic residues on an EverClean membrane structure in the presence of UV irradiation from the sun, by generating constantly activated oxygen, catalysed from the EverClean coating. This prevents the membranes from developing algae, fungus or bacteria growth and keeps the structure looking bright and clean over its lifetime. Also the heat reflection keeps constant over many years reducing the number of cleaning cycles.

As EverClean is reacting as a catalyst it will not be used up. The functionality is permanent and does not decrease over time. Due to the additional functionalities of EverClean, we hope that it makes tensile structures in general more interesting for architects or building owners who are looking for environmentally sustainable solutions with a high acceptance with the public.

Roland Keil
Roland.Keil@saint-gobain.com
www.chemfab.com
The appearance on the International Motor Show IAA of Mercedes-Benz, smart, AMG and Maybach was concentrated on the inside of Frankfurt’s festival hall, which had its 100 anniversary in 2009. With its once visionary steel structure it was Europe’s biggest self-supporting hall (Fig. 1).

Project
An illuminated, light membrane structure of mesh fabric with more than 5000m² surface area is spanned over the exhibition room which created interesting light spots for the exclusive presentation of Mercedes-Benz, AMG, Maybach and smart. The membrane structure consists of 110 pattern joined with 60mm HF-seams. To put the cars into proper light, all 27 lens-shaped cuts were integrated in the patterns. The exhibited cars could be illuminated directly with spots installed behind these cuts. Two rings of 10 and 8,5m diameter and a pneumatic membrane ball with 13m diameter form cone tops and low points. A 12mm circumferential steel cable has kept the 110 to 60m sized room installation under tension and provided a wrinkle free surface.

Membrane
The semi-transparent spherically bended membrane surface was used as light and projection surface. The clever use of the illumination allowed an individual control of the transparency of the fabric. Illuminated from behind the mesh became transparent and offered a view on the historical dome structure. Illuminated from below the fabric lost its transparency and showed like a cinema screen the projected light shows (Fig. 2).

Ecological design
The energy consumption for the hall and stand illumination is reduced by about 40% due to the installation of the impressive textile structure. The vertical alignment of the membrane with one cone top and one low point created a stack-effect, optimized the hall thermally and offered a power reduction of the ventilation system.

Construction
A challenge was the historic steel structure. The structure is designed for wind and snow loads but not for additional loads from installations. During the fair in September there will be no snow so this amount of load could be used for the fixation of the membrane. 42 tons of prestress has been introduced into the dome. Basic nodal loads were the suspending load for the cone top, a lead-filled ring with a weight of approx. 3,5 tons at the lowest point of the membrane as well as the pneumatic membrane ball which depressed the membrane with its 13m diameter as well with a load of 3,5 tons. The high pretension was necessary to tension the stiff fabric wrinkle-free and to compensate little inaccuracies from the manufacturing process. The material has a breaking strength of 7t/m and it could even be walked on during the assembly (Fig. 3). With its 600g/m² very light and recyclable membrane structure, the architects achieved to allegorize sky, atmosphere and climate, as expression of an ecological and efficient mobility.

Bernd Stimpfle: bernd.stimpfle@form-tl.de
www.form-TL.de © PICTURES ANDREAS KELLER
Students design a shelter for disaster relief

Description of the task

The students were asked to design a tent for disaster relief: a basic, elementary family tent (~6m x 4m), rapidly deployable, low cost and durable, compactly foldable, adaptable to different configurations, light weight and easily transportable, fire resistant ... Traditional shelters can be considered as inspiring examples.

Vitja Pauwels & Matthias Moyaert

Their design is based on the traditional ‘yurt’, used by Mongolian nomads. The tent is easy to set-up and to dismantle, can be folded into a compact package and is light-weight. The designed shelter consists of a primary (external) structure in which the membrane is tensioned. The structure, made of a scissor linkage for the wall and a bundle of beams for the roof, can easily be set up. Depending on the location different membranes (light translucent, insulated ...) could be used. The plan is a twelve angle (side = 1,14m), the covered surface is 14,5m², which allows that 4 persons can live in this tent. Units can be combined by removing 1 scissor and adding a frame.

A physical model has been made to illustrate the deployment of the scissor linkage and the final set-up.

The numerical form finding has been performed with the form finding software EASY.

Picalausa Evelien & Roosens Sandy

The first design ‘The egg’ was based on a wooden construction filled with inflated cushions. Finally foldable units consisting of aluminium beams with foldable membrane panels have been proposed.

Yves Govaerts & Kelvin Roovers

The concept is based on the structure of the honeycomb. Units can easily be joined together. The tent consists of an inner and an outer tensioned membrane with the supporting frame in between. The following pictures show the setup of the frame and the form finding of the different tent layers. If 3 units are joined together an additional pole is placed in between.

The analysis has first been done for the membranes for 1 unit.

Next both inner and outer membrane have been combined with the supporting structure.

In this case the supporting structure takes both the action of the inner membrane and the action of the outer membrane. Next units are combined into a double and a triple configuration.