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Germany
265 ETFE FOIL CUSHIONS
HIGHLY TRANSPARENT FILM

China
2 PROJECTS IN SHANGHAI

UK
WIMBLEDON’S HIGH-TECH HEAVEN

Spain
THIRST PAVILION

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concrete from fabric molds

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During the last few months the TensiNet Association has contributed to several activities: The yearly Textile Roofs 2009 Workshop (11th to 13th June) attracted a large group of interested participants (www.textile-roofs.de). The last Partner Meeting (15th June) took place in Frankfurt. It was decided to organise the next TensiNet Symposium in Sofia, Bulgaria, in September 2010. 20 TensiNet members attended the Working Group ETFE (15th June) in Frankfurt and discussed a first draft of the state-of-the-art document (for more information please contact Rogier Houtman). At the Techtextil Student Award ceremony, co-sponsored by TensiNet, interesting student projects were shown. The exhibition of these projects during the Fair (16th to 18th June) was successfully arranged by Jürgen Hennicke (http://techtextil.messefrankfurt.com/frankfurt/en/messebesuch_n4141.html). During the Buildtech Symposium (16th June) several TensiNet members contributed with presentations on recent projects or research. Another positive development is that two new Partners have joined the TensiNet Association - Fabricant Membrane Structures (TU) and Sioen (BE) - while Buro Happold (UK) upgraded its membership to become a TensiNet Partner.

An important objective of the TensiNet Association is to start the standardisation process. A proposal for the standardisation of the “materials, fabrication and installation of membranes” has been sent to the standardisation community of the European countries CEN/TC250 as a first step in establishing a Eurocode. The CEN/TC250 discussed (1st July) their medium-term strategy until 2013 and agreed that the development of the Eurocodes on Glass, FRP and Membrane Structures should be achieved as follows: preparation of technical rules in the form of technical recommendations as ‘Scientific and Technical Reports’, after acceptance by CEN/TC250, adaptation of it into a CEN Technical Specification and upon the agreement of CEN/TC250, conversion into a Eurocode Part. This process will be established step by step. The next important event is the Annual General Meeting 2009, which will be held at the Centro Cultural La Beneficencia, on the 30th of September, during the IASS 2009 conference in Valencia. In conjunction with the Annual General Meeting the results of the Working Groups will be presented and interesting projects recently completed by TensiNet members will be reviewed. The Annual General meeting will be followed by the Working Group Meetings for Analysis & Materials (Peter Gosling) and ETFE (Rogier Houtman). TensiNet Members can also participate in the IASS Working Group 6 "Tension and Membrane Structures" organised by Prof. Masao Saitoh and Prof. Ken’ichi Kawaguchi on the 29th of September. We hope to meet you all in Valencia!

Marijke Mollaert

Forthcoming Events


Name of the project: Riviera-on-Dneper restaurant
Client: Riviera Hotel
Function of building: Restaurant boat
Primary function of the tensile structure: Protection against sun, rain, etc.
Temporary or permanent structure: Permanent
Convertible or mobile: Mobile
Year of construction: Summer 2009
Engineering, manufacture and installation: Tent Module Company (www.tent-m.com.ua)
Materials: Aluminum and membrane
Supplier of the membrane material: SIOEN Industries
Type of membrane: Type 1 membrane based on PVC coated fabric with special membrane lacquer
Covered surface: 144m²

Restaurant boat, Ukraine

SIOEN Industries is the supplier of the membrane material (product T1107) for this interesting project in Kiev, Ukraine.
The “Kleiner Schlosshof” is the central meeting place within the Dresdener castle complex and is accessible from the Hofkirche, the Taschenbergpalais and the Schlosstrasse.

A new roof for the Castle’s "Kleiner Schlosshof", Dresden, Germany

The roofing according to designs by Prof. Peter Kulka has seen the creation of a 640m² foyer area. The transparent membrane cushion roof consists of a load-bearing lattice shell with ETFE-membrane cushions fixed into the lattice structure. Weighing about 84 tonnes, the dome has been assembled accurately to the last millimetre using 3D plans. Precise preparations were required in order to achieve this goal. Only a tolerance of 30 to 40mm was allowed. The dome consists of a total of 200 individual parts, 50 of which were prefabricated. The load-bearing structure is a double-vaulted lattice shell of welded rectangular steel profiles. Some of these profiles are also used to supply the cushions with compressed air.

The lattice shell – which hovers over 30m above the courtyard – was filled one-by-one with a total of 265 membrane cushions. The cushions are of stable, extremely lightweight and weatherproof plastic construction. Both the load-bearing structure and the cushions take the form of a rhombus with a maximal side length of 2.8m and a maximal diagonal length of 4.1m. Once integrated into the roof structure the cushions were filled with compressed air at 800 Pascals. The membrane area is in total 1420m² for a plan of 41m x 25m.

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Since the summer of 2008, a highly transparent film roof from CENO TEC made of the high performance material Dyneon™ ETFE spans the atrium of the “Bürohäuser Köln Rheinhallen” (North side) and of the “Bürohäuser Köln Rheinpark” (South side). With a total floor space of 160.000m², this is currently Europe’s largest superstructure construction site, where the new headquarters of the RTL Media Group and the new location of the HDI Gerling Insurance Company will be housed within sight of the famous Cologne Cathedral and Cologne’s “Altstadt” (oldest part of town).

When built, back in 1928 on commission from the mayor of Cologne at the time, Konrad Adenauer, the Rhine Halls were considered to be the most modern exhibition halls in all of Germany. Now eighty years later, they are being converted to a modern office complex for the TV broadcaster RTL and the Gerling Insurance Company, which is part of the Talanx Group.

The design created by the Cologne architectural office of Hentrich-Petschnigg & Partner GmbH & Co.KG divides the Rhine Halls into two halves along the north-south axis with a 150m long by 26m wide, light-flooded atrium. The biggest cushions have a dimension of 26m x 24.3m, 26m x 29.7m and 26m x 33.7m. After the original building complex, which with its distinctive brick facade is protected as a historical monument, was renovated, a highly transparent film roof made of Dyneon™ ETFE was spanned over the atrium.

The highly transparent roof consists of five multilayered film cushions of roughly 26m by 30m each. They are distinguished by their exceptionally high light transmittance of around 90% for the visible spectrum. In addition, they guarantee 100% protection against harmful UV-C radiation. The distinctive highlight of the roof is that cables are used to suspend the film cushions over the 26m wide atrium. The cables, placed every 60cm to form a kind of web, give the entire construction exceptional stability yet a feeling of lightness. The films of Dyneon™ ETFE have a tensile strength of 11.5kN/m while weighing only 1 to 1.5 kg/m². They are extremely tear and puncture-resistant as well as resistant to hail stones.

The company CENO TEC GmbH, located in Greven, handled the entire project planning for construction of the roof, fabricated the ETFE film cushions, built the steel structures, cables and blower system, and completely installed the roof. The films themselves were produced with a thickness of 250µm by the Upper Bavarian company NOWOFOL Kunststoffprodukte GmbH & Co.KG. In addition to a performance life of at least 25 to 35 years, the films made of Dyneon™ ETFE feature very high resistance to the most diverse environmental factors such as UV radiation, chemicals, solvents and various climatic and weather conditions. To manufacture the films, NOWOFOL needs neither stabilizers nor plasticizers which can evaporate over time thus negatively affecting the excellent properties of the roof construction. The extremely smooth surface of the film does not provide fungus or bacteria a place to take hold even after years of use. It is virtually self-cleaning with just a simple rain shower. An additional feature of the CENO TEC film cushions made of Dyneon ETFE is that they have good sound and thermal insulating properties. A further benefit of films made of Dyneon™ ETFE, especially for large structures, is that they feature very low flammability and are classified as fire class B1.

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**Highly transparent multilayered film cushions**

Atrium of the Cologne office building Rhine Halls & Rhine Parc, Germany

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Name of the project: Kölner Rheinhallen (Cologne Rhine Halls)
Location address: Kölnmesse Service GmbH, Messeplatz 1, Köln, Germany
Function of building: New headquarters of the RTL Media Group and the new location of the HDI Gerling Insurance Company
Year of construction: 2007/2008
Architects: Hentrich-Petschnigg & Partner GmbH & Co.KG
Engineering: sbp & form TL
Membrane producer: NOWOFOL Kunststoffprodukte GmbH & Co.KG
Supplier of the membrane raw material: Dyneon GmbH
Manufacture and installation: CENO TEC GmbH
Material: Dyneon™ ETFE 250 micron, on the outer film a pattern is printed (33% to 50%)
Covered surface (roofed area): 4.000m²
An alternative natural material for temporary tensile structure

Uncoated Abaca Fabric

1. INTRODUCTION
This study focuses on the promising material which is abundant in the Bicol Region, Philippines, the abaca fabric. For many years, the abaca fabric has been utilized as a decorative material for export and domestic products. In the history of abaca industry, such fabric was never considered as a prime construction material. Within the framework of this study, the material strength of uncoated abaca fabric is tested for its structural use, specifically for temporary tensile structure. Fabrication and construction of a full-scale hypar form are tested and subjected to the full provisions of the National Structural Code of the Philippines concerning temporary structures. This study compares the membrane stresses generated by the FORTEM 3000 software for tensile structures with the physical test results of uncoated abaca fabric supplied by the Philippine Textile Research Institute (PTRI) Testing Laboratory. Traditionally, hand-woven abaca fabric is best known for its tribal community identity. This study focuses on one hand-woven abaca fabric distinctively made within the Bicol Region, the Pinukpok. Pinukpok is an exquisite silk made from abaca fiber which is abundant in the Bicol Region, produced by literally beating the fiber using a huge wooden mortar and pestle. Constant beating of the fiber brings out its sheen and softness characteristic of silk fabrics.

Study Objectives
This study aims to test various hand-woven abaca textiles as an alternative material for temporary tensile structures. Primarily, this study seeks to promote the use of a biodegradable and eco-friendly abaca textile as an alternative material for temporary tensile structures. In addition, the following sub-objectives are also considered:

- a. To test the validity and acceptability of pre-selected handwoven abaca fabric using a weaving reed of 30 dpi (dot per inch).
- b. To enhance the applicability of abaca fabric in constructing lightweight structures.

Scope and Limitation
This study focuses on pre-selected hand-woven Pinukpok abaca fabric within the Bicol Region. The material testing was conducted in the laboratory of the PTRI, specifically, the tensile strength, elongation and tearing strength per 5 cm strip of fabric. Pinukpok abaca fabrics were joined together by mechanical sewing and all seams were tested using a 5 cm strip of fabric. To test the validity of the uncoated hand-woven abaca materials, a full-scale hypar tensile structure was fabricated and tested using the applicable dead load, live load and wind load as specified in the National Structural Code of the Philippines.

Reliability of Abaca Fiber
Based on the PTRI research publication, the Bicol Region produces three varieties of abaca fabric, namely, Abruab, Itolaus 45 and Tinawagang Puti. The tensile strength of the Abruab variety ranges from 31.90 kg/m/g ((kg per m) per (gr of fabric per m²)) to 35.70 kg/m/g while that of the Itolaus 45 variety ranges from 34.96 kg/m/g to 48.93 kg/m/g and the Tinawagang Puti variety ranges from 33.06 kg/m/g to 36.60 kg/m/g. As a rule of thumb, the following requirements were faithfully followed during the selection process of the abaca fiber:

- a. Hand-stripped abaca conforms to the S2 and S3 designation and has an excellent fiber grading.
- b. Machine-stripped abaca conforms to the S-S2 and S-S3 designation and has an excellent fiber grading.
- c. Fiber length is 4.49 mm and 4.37 mm for machine and hand-stripped fibers, respectively.
- d. Fiber diameter is 20.74 microns and 20.79 microns for machine and hand-stripped fibers, respectively.
- e. Moisture content is 8.40% and 8.64% for machine and hand-stripped fibers, respectively.

2. LITERATURE REVIEW
With the development of an indigenous fiber into textile material and the creation of the Philippine Tropical Fabric (PTF), the PTRI pioneered the research and development of a natural fabric found in abaca, pineapple and banana. The institute further standardized the quality of fabric produced in the Philippines for commercial applicability. The PTRI published the “Samay Bulletin,” a technical and semi-technical publication of the PTRI. It contains articles pertaining to different researches and activities related to textiles. Furthermore, the institute published another related source book “Kalamata,” which contains PTF weave designs and features innovative handloom-woven products from indigenous fibers.

The Abaca Plant
Abaca is a perennial plant which grows in the Bicol Region. It resembles the banana plant but is smaller in size. A mature abaca plant consists of about 12 to 30 stalks radiating from a central root system. Its group of stalks ranges from 6 to 15 feet high. These stalks are made up of a central core which is encircled by overlapping leaf sheaths, each bearing a frond of 3-6 feet long and about 12 inches wide (Villafuerte-Abonal, 2006) (Fig. 1).
Abaca Fiber Material Conversion Process

The material conversion process officially starts when the abaca plant reaches its maturity period which ranges from 18 to 24 months after it has been planted. Harvesting or simply cutting down the plants involves a tedious process that requires the separation of the leaves and trunk of the abaca plant. During the harvesting, the abaca stalks are cut close to the ground. After cutting the stalks, the entire leaf sheaths are separated from the stalk and flattened using a tuxying knife to extract the fiber from within. Once the fibers are recovered from the leaf sheaths, the hand stripping method is employed. Hand-stripping of abaca fibers is a very strenuous task. The tuxy is inserted between a block and the serrated stripping knife and pulled with force from the tip end of the tuxy. During the process of hand-stripping, the weight of the fibers recovered varies from 1.5% to 2% of the freshly cut stalks. Then the stripped fibers are dried in an open area to prevent molds and weevils from affecting the quality of the fibers.

State of the Art

Except for the study conducted by Hagad (2005), which establishes the properties of S2 grade fiber from 12 commercial abaca varieties found in the Philippines, the current study is different from all the studies conducted by the Philippine Textile Research Institute. In order to bridge the gap between the present and past research works, the current work is focused on the material properties of the pre-selected abaca fiber and investigated the tensile strength of handwoven abaca fabric following the EN ISO standard for Uniaxial strip test. It also investigated the behavior of mechanically sewn seams and determined the capacity of joined materials. Furthermore, this study is a pioneering work which fuses the technology developed by Frei Otto and the Institute of Lightweight Structures by using the abaca fabric (Fig. 2) for a temporary tensile structure in lieu of the tested poly vinyl chloride coated polyester fabric.

3. RESEARCH DESIGN

This paragraph is a description of the research methodology, testing instrument, loading assumptions and the computational method used in this study.

Methodology

The testing of the uncoated abaca fabric was implemented at the PTRI of the Department of Science and Technology. Abaca fabric samples were submitted for testing of its mechanical properties. The representative samples came from the same variety and quality of the fabric that was used for fabricating the abaca hypar temporary tensile structure.

EN ISO Standard for Testing Fabric Materials

a. The Tensile Strength test follows the EN ISO 13934-1:1999 Textiles-Tensile Properties of Fabrics – Part 1: Determination of Maximum Force and Elongation at Maximum Force Using the Strip Method. Zwick/Roell Tensile Strength Tester Z005 (CRE) with 5 KN full scale load, a rate of extension of 20 mm/min, and a pretension force of 2.0 Newton were used in the PTRI to test the uncoated handwoven abaca fabric. Four specimens with 50mm width and 200mm gauge length were tested.

b. The determination of mass followed the ISO 3801-1977: Textiles – Woven Fabrics – Determination of Mass per Unit Length and Mass per Unit Area. Five specimens were tested using the J.A. King Pneumatic Sample Cutter SASD-677 equipment.

c. The Tearing Strength test followed the ASTM D1424-07: Standard Test Method for Tearing Strength of Fabrics by Falling-Pendulum Type (Elmendorf Apparatus). Five specimens were tested using the Elmendorf Tearing Strength Tester.

d. The yarn number, denier, ASTM D1059-01: Standard Test Method for Yarn Number Based on Short-Length Specimens. The Zweigle Twist Tester D311 equipment was used to test the ten specimens.

Loading Assumptions

Basic loading assumptions were taken from the National Structural Code of the Philippines (NSCP C101-01) and the ANSI/ASCE 7-95, Minimum Design Loads for Building and Other Structures. Form Finding and Analysis

With the advent of computer-aided design software, the researcher used the FORTEN 3000 (licensed copy) – A System for Tensile Structures Design and Manufacturing software developed by Gerry D’ANZA and Baku Group DT. Form finding is a computer process by which the physical form of a membrane structure is generated. This involves a mathematical computation which uses one of the following: a) the force density method, b) the non-linear finite element methods, and c) the dynamic relaxation method. FORTEN 3000 software algorithm employs the static geometrical nonlinear analysis using a Newton-Raphson method for form-finding and analysis of membrane stresses. Cutting Pattern is a module contained in the FORTEN 3000 software which produces the final layout of tensile fabric for production purposes.

4. ANALYSIS AND INTERPRETATION

The researcher would like to emphasize that this study does not in any way substitute the tested and proven materials used in tensile structures, i.e., woven polyester textile coated with poly vinyl chloride (PVC), woven glass textile coated with poly tetra fluoro ethylene (PTFE) and ethyl tetra fluoro ethylene (ETFE). This study only tests the applicability of uncoated abaca fabric in construction industry as sun shade. As a guiding principle, the researcher follows the advice of his late mentor, Prof. Jose Ma. De Castro, Professor Emeritus of the College of Engineering in the University of the Philippines, in finding ways and means to address the growing problems encountered in Civil Engineering practices and materials development in the local construction industry.

Mechanical Properties of the Abaca Fabric

In order to simplify the description of the two samples that were submitted for testing at the PTRI, the following samples shall be known as:

SN 1332-08 - Sinamay Fabric with Design (a fabric with strand of different color, design without any structural concern)
SN 1333-08 - Sinamay Fabric without Design

These simplifications were necessitated to ease the evaluation of parameters and methods in the preceding sections. Based on the physical testing results obtained by the PTRI, the following mechanical properties of the abaca fabric were found:

a. Breaking Force, N - Two samples under the label PTRI SN 1332-08 and PTRI SN
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1333-08 were submitted for testing procedures. The SN 1332-08 yielded a breaking force on warp of 410N and filling of 380N, while the SN 1333-08 sample yielded a breaking force on warp of 440N and filling of 140N, respectively.

b. Tensile Strength, N/m - Two samples under the same label were tested to determine the tensile strength of the fabric by strip method. Sample SN 1332-08 yielded a warp strength of 12800N/m and a filling strength of 10980 N/m, while sample SN 1333-08 yielded a warp strength of 15200N/m, and a filling strength of 4600N/m.

c. Average Elongation, % - Sample SN 1332-08 exhibited an elongation on the warp direction of 3.4%, and 3.2% on the filling direction while sample SN 1333-08 yielded an elongation of 3.2% on the warp direction, and 3.4% on the filling direction.

d. Mass Per Unit Area, g/m² - Sample SN 1332-08 yielded a mass of 92g/m², while sample SN 1333-08 yielded a mass of 60 g/m².

e. Tearing Strength, N - Both samples SN 1332-08 and SN 1333-08 were untearable. SN 1332-08 tearing occurred at the opposite direction for warp and filling, while SN 13308 failed due to slippage.

f. Thickness, mm - Thickness of both materials were measured using SDL Digital Thickness Gauge. Sample SN 1332-08 yielded a 0.84mm thickness, while SN 1333-08 yielded a 0.32mm thickness.

g. Yarn Number, denier - Sample SN 1332-08 yielded a 253.08 denier on the warp direction and 261.36 denier on the filling direction, while SN 1333-08 yielded a 351.72 denier on the warp direction, and 17712 denier on the filling direction.

Evaluation of Results

With respect to the loadings, the dead weight of -18.25 kg/m², and a leeward quarter load of -11.16 kg/m². The displacement of -20.08 kg/m², a center half load wind loadings were taken from NSCP code for other areas. The membrane s11 stresses (Fig. 5) indicate a maximum value of 176.876 kg/m near the corner plate connection and a minimum value of 22.109 kg/m in other areas. The reaction forces (Fig. 6) on the 4.0m mast is 3522.27 kg while that of the 2.0m mast is 2015.84 kg.

The reaction forces on the two cable stays which hold the 4.0m mast are 1465.47 kg and 1489.89 kg, respectively, while the reaction forces on the two cable stays which hold the reaction forces on the other mast are 1366.75 kg and 1386.42 kg, respectively.

Cutting Patterns

To fully implement and construct the form which was generated by the software, a flat cutting pattern was laid out first, using the FORTEN 3000 software which includes both a cutting pattern and production modules. Since the hypar is symmetrical in its centerlines (x-axis and y-axis), patterning was implemented to take into consideration the symmetry in order to ease the production and fabrication stages.

Figure 7 indicates the cutting pattern for the left and right half of the hypar. This cutting pattern consists of nine patterns on each side with a width ranging from 0.65m to 0.08m and a length ranging from 8.79m to 0.11m. Tabulated coordinates of the sides and welding markers were indicated on the pattern. A stretch compensation corresponding to the test results of 3.4% and 3.2% were adjusted along the weft and warp directions, respectively.

Fabrication and Construction of Tensile Structure

After the patterning has been completed, a CAD drawing of the 18 patterns was exported to JPEG files. Since the researcher was unable to find a cutting machine that would have directly cut the patterns, a tedious process of converting all the 18 CAD drawing files into JPEG files was implemented. This process was done so that the JPEG files can be modified by Photoshop and printed on tarpaulin media using a commercial plotter, which is readily available in the market. Figure 7 indicates the printed pattern that was cut into 18 patterns. It presents the finished products which served as the templates that were used to cut the abaca fabric pattern. Joining the abaca patterns (Fig. 8) through sewing was painstakingly implemented using a conventional sewing machine. The primary structure (Fig. 9) was fabricated using galvanized pipes for mast, mild steel plates for corner plates and anchor base plates. The cable, frame turnbuckle, shackle straight “D,” and wire thimble are made of stainless steel materials. The connection of stainless cable to the turnbuckle and shackle were implemented by using aluminum ferrules and a half tonne hydraulic crimper instead of using a cable clip or swagging machine.
CONCLUSIONS AND RECOMMENDATIONS

Based on the outcome of the fabrication and installation of the uncoated abaca tensile structure (Figure 5), the PTRI testing results, and the analysis and interpretation of results, the following conclusions were deduced:

a. With regard to the main objective of this study, it is evident that the stresses and deformations exhibited in Figures 3, 4 & 5 clearly show that it can withstand the external loadings imposed on it. The membrane s11 stress levels of the abaca fabric ranges from 671.241 kg/m to 56.234 kg/m, while the ultimate stress of abaca fabric based on PTRI test results ranges from 1304.79 kg/m to 1119.27 kg/m. Using a safety factor of 2.0 for temporary structures, the maximum permitted stress is 652.40 kg/m which is slightly lower than the membrane s11 stress level of 671.241 kg/m. Therefore, the uncoated abaca fabric can be utilized as an alternative material for temporary tensile structures.

b. With regard to the sub-objectives of this study, Figures 8 & 9 clearly show that the pre-selected uncoated abaca fabric can be fabricated with ease and constructed as temporary tensile structures.

c. A yarn number that is equal to or higher than 253 denier can be utilized as an alternative material for temporary tensile structure.

d. With respect to the enhancement of the applicability of the abaca fabric in the field of construction, Figure 9 clearly justifies the use of the material in the construction industry.

e. With the successful construction of the first abaca tensile structure in the Philippines, the applicability of the abaca fabric in the construction industry opens a new and promising horizon in the near future. It is recommended however that further study be conducted on the following subjects:

   a. Test the long term effects of weathering and enhance the life span of uncoated abaca fabric;
   
   b. Test the applicability of different weaving reed or yarn number of abaca fabric.

Finally, it has to be noted that this study does not cover the designed wind speed brought about by tropical typhoon that frequently enters the Philippine Area of Responsibility.

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Salvador R. Aldecoa recently finishes his Master Membrane Structure (MMSt) from the Anhalt University of Applied Sciences and the Institute for Membrane and Shell Technologies e.V., Dessau, Germany.

REFERENCES


PTFE umbrellas for three stations
Shanghai Subway Station Line 6, China

The three stations of the Shanghai Subway Station Line 6 are covered by 16 inverted umbrellas each. The umbrellas are shaped with a cable borderline at the high point and have a drainage system integrated at the lower part. It is known that PTFE can absolutely not be folded. In the designed configuration it was a problem how to weld the last FEP (fluorinated ethylene propylene copolymer) film seam successfully to make the whole into the shape of an umbrella. The common way is to use aluminium clamps to put the last two welded pieces together and wrap over the clamps some film of the same type. However, the client insisted that the umbrella should be a whole unit and they did not agree to change the way of connection.

SAINT-GOBAIN
Roofing tensile membrane structure

The Expo Boulevard is a 1km long channel which is designed to connect the entrances of major pavilions of the 2010 Shanghai World Expo Park and also the elevated pedestrian walkway. Consisting of 2 floors underground and 2 floors above the ground the Boulevard is a large-scale, multi-functional combination of transportation, commercial activities, catering, entertainment and exhibition services. The six 40m high horn-shaped structures of the “Sunny Valleys” divert sunlight into underground levels of the Expo Boulevard and collect rainwater for use after recycling. In these six valleys there are about 10000 joints and every joint has a different angle and position. So the construction has to be very precise. Saint Gobain Performance Plastics supplied more than 100.000m² PTFE Architectural Membrane for the roofing tensile membrane structure covering the whole Boulevard to create an innovative, spectacular spatial visual effect.
So when the fabric was being welded and installed we had to find a solution for the following problems:
1. How to make the last welding seam?
The last welding seam was welded on site with a width of 10cm.
2. How to manage the installation?
First the welding desk was positioned according to the 3D shape of the welding seam, next the welded fabric was wrapped around the steel structure and then it took five minutes to weld the last seam.
3. How to drain the rainwater?
The rainwater is evacuated through the bottom circle of the inverted umbrella. The steel columns supporting each umbrella were designed to be equipped with drainpipes and were galvanized inside from top to the bottom to create an integral drainage system that is unperceivable. These columns are connected to the underground-drainage system of the subway station.

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The Stadium is built inside the DY Patil Vidyanagar campus. The DY Patil is the latest addition to Mumbai’s list of cricket venues and at the moment the largest membrane roof in India. With all the essential ingredients to host internationals, the DY Patil Stadium boasts of 9 tennis hard courts, 4 indoor badminton courts and an Olympic sized swimming pool, apart from big dressing rooms and a green outfield.

A unique feature of the stadium is the cantilever membrane roof which eliminates the need for any supports thus providing the spectators with an unobstructed view of the match from any place within the stand. First requirement for this project was to design a cost effective stadium roof which shall be easy and faster to execute. Considering this issue, the selection of the material was very important. Hence, the customer decided to go for tensile structure for the stadium roof.

17m Cantilever roof trusses are designed with rear side tie supports in round pipes to have an uninterrupted view of the cricket ground and the spectators. The profile and the placement of roof trusses is worked out in such a way that there will be no water logging on fabric as well as air escape will take place naturally to avoid up lift of wind. The use of tensile fabrics added an aesthetic value to the stadium roof as well as it has reduced the consumption of steel. The shape of the membrane roof was developed in order to avoid any natural shadow on the playground whereas it also able to grant sun protection to the spectators.

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Project Name: International Cricket Stadium & Sports Complex, Maharashtra, India

Location: Nerul, Navi Mumbai, Maharashtra, India
Client: Dr. D.Y. Patil Sports Academy
Architect: Hafeez Contractor
Structural Design: Eco Designs Pvt Ltd.
Steel Fabrication & Execution: DAS Offshore. CBD
Fabric Manufacturer: Skyspan Asia
Fabric Installation: Mc Coy Architectural System
Type of Fabric used: Mehler Valnex FR1000 (Type III) - Both side weldable PVDF
Year of Completion: 2008
Total Area: 9300m²

Cost: RMB 380 Million (including Sunny Valleys, Steel Structure and Membrane Structure)

Name of the project: 2010 Shanghai World Expo Boulevard Roofing Structure
Location address: Shanghai, China
Client (investor): Shanghai Expo Land Holding Co., LTD
Function of building: multi-functional combination of transportation and commercial services
Year of construction: 2009
Architects: East China Architectural Design & Research Institute Co., LTD + SBA Design office, Germany
Structural engineers: East China Architectural Design & Research Institute Co., LTD
Consulting engineer for the membrane: Shanghai Taiyo Kogyo Co., LTD
Main contractor: Shanghai Construction Group
Contractor for the membrane (Tensile membrane contractor): Shanghai Taiyo Kogyo Co., LTD
Supplier of the membrane material: Saint-Gobain Performance Plastics Corporation
Manufacture and installation: Shanghai Mechanized Construction Co., LTD
Material: PTFE Coated Fabric (SHEERFILL I)
Covered surface: 70.000m²

Saint-Gobain Performance Plastics is also supplier of FEP and PFA (perfluoroalkoxy) for welding PTFE fabric membranes and ETFE for film membrane constructions.

It’s scheduled to be completed by the end of 2009.
The Expo Boulevard project is not only a landmark project in the Expo district, but will also be a city landscape architecture of Shanghai in the future.

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TENSINEWS NR. 17 – SEPTEMBER 2009
THIN-SHELL CONCRETE FROM FABRIC MOLDS

DIRECT-CAST FABRIC-FORMED THIN-SHELL VAULTS / BEAMS

Example 1: Double-curvature funicular shell cast directly from a single hanging flat sheet of fabric

In this construction a single flat rectangle of fabric is hung from a simple perimeter frame and used as a mold to form a double curvature vault. A simple frame is provided to support the edges fabric (Left above). The fabric is stretched lengthwise to remove any wrinkles, and stapled to the sides of this frame (Right above).

Instead of conventional steel reinforcing this vault was made with carbon grid reinforcing. Carbon reinforcing allows for a very thin section - only 3 cm (1 in) thick. Carbon, unlike steel, does not require an extra concrete covering to protect it from corrosion.

INTRODUCTION
Some of the work illustrated here closely follows methods of funicular shell formation pioneered by Heinz Isler, who used small-scale funicular models to determine full-scale construction geometry and structural behavior of reinforced concrete thin-shells. Our work is aimed at making full-scale hanging fabric molds using powerful industrial fabrics - essentially scaling-up Isler’s model-making method into full-sized shell molds. The maximum size of these structures has yet to be determined. Our early small full-size constructions are illustrated here as indications of the potential for “self-forming” funicular fabric molds.

Our work at CAST uses a simple set of construction tools, fasteners, and technologies. We do not “tailor” our fabric molds into pre-set curvatures - we use only flat sheets of fabric taken right off the role. The shell geometries illustrated here are given to us by the natural deformations of these simple flat-sheets, and are, in this sense, “found”, “natural”, structures. The goal of this work is to invent simple and beautiful structures that consume less material in construction, while opening new degrees of freedom to architects, engineers and builders in both high- and low-capital building cultures.
This construction used the same curved edge supports as the previous example, but in this case a central “keel” was used to control the bottom curvature of the mold. This keel, made of two layers of 3/4” plywood, holds two flat sheets of fabric sandwiched between them (Bottom Left, Bottom Centre). 1/8” plywood “feathers boards” were placed at the ends of the mold rig (seen Below) to ensure that the loaded fabric follows a smooth and fair transition to the flat support areas at either end of the vault.

When the concrete (a portland cement mortar) is troweled onto this mold, the fabric deflects downwards slightly under the weight. This shell was reinforced with carbon fibre, allowing a thickness of only 3 cm.
NEW FABRIC
FOR MAKING FABRIC-FORMED RIGID MOLDS

Woven, high density, polyethylene or polypropylene fabrics can be manufactured with a smooth waterproof coating on one side, and a fuzzy non-woven fabric welded to the other side. When concrete is applied to the fuzzy non-woven side, the fabric will permanently adhere to it, providing a smooth, permanent, plastic-coated release surface for a mold. Concrete will not adhere to the smooth polyethylene or polypropylene coating of these fabrics. No oils or other release agents are needed, though the use of such release agents will prolong the life of these molds.

Prototype mold fabrics have been produced for CAST by Fabrene Inc., a manufacturer of industrial plastic fabrics. The (limited) test data for one such fabric (Fabrene “Development Product W756”) is shown below. This particular product adapts an existing fabric commonly used for inexpensive fabric covered agricultural and storage shelters. It is manufactured in 3 m (10 ft.) wide roles. It can be heat-welded into larger sheets, or reinforced in multiple layers. Stronger fabrics are also available for this application if required.

<table>
<thead>
<tr>
<th>PROPERTY</th>
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</tr>
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<tr>
<td>UNIT WEIGHT</td>
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<td>1” TENSILE STRENGTH</td>
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<td>NOMINAL THICKNESS</td>
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FABRIC-FORMED RIGID MOLD FOR PRECAST THIN-SHELL VAULTS

Lafarge Precast Factory, Winnipeg - April 2007

This prototype rigid funicular fabric-formed mold is intended as formwork for thin-shell GFRC stay-in-place pan formwork for cast-in-place (CIP) floor slabs. The funicular compression shell shape given by these formwork pans allows a CIP concrete slab to span in pure compression between the integral support beams, thus reducing concrete and deadweight.

A simple open frame is constructed to support and suspended a flat sheet of fuzzy-backed formwork fabric. A uniform thickness of fiber-reinforced concrete is placed over the fabric. In this case a sprayed shotcrete was used, though hand-application of the concrete is also possible. The edges were reinforced with steel rebar. The fuzzy fabric backing adheres to the concrete, producing a plastic-coated mold for precast production of stay-in-place formwork pans or thin-shell funicular compression vaults.
FABRIC-FORMED RIGID MOLD FOR THIN-SHELL VAULTS
Full-Scale Prototype, C.A.S.T. Lab, Winnipeg - 2009

[1-2] The 5-meter prototype vault mold constructed at CAST was produced in the rig shown above. This rig provides a straight central spine and catenary-curved longitudinal edges. A single flat sheet of fuzzy-backed formwork fabric (Fabrene W756) is placed over this rig, and selectively pre-tensioned. A thin, uniform layer of GFRC will be placed on this fuzzy-backed fabric to make a rigid mold for producing thin-shell vaults. Note that the pre-tensioning device used is simply twisted ropes.

[3] This photo shows the double curvature produced by pre-tensioning along the centre-line of the fabric sheet. The cut in the fabric controls where the induced curvature along the center-line begins

[4] End of the formwork rig prior to loading with points of pre-tensioning shown. A start-condition force of ~40 kg is delivered to the centre of the sheet, and a mild ~12 kg at the edges. Edge forces are increased to remove folds as the fabric is loaded with concrete. Load cells are used to keep track of the prestress force applied.

[5] Glass fiber reinforced concrete (GFRC) is placed on top of the fabric, causing this formwork membrane to deflect under the uniform applied load.

[6-7] The first thin layer of GFRC is placed over the entire fabric sheet. We did this by hand, though industrial methods include spray applications that are faster and more uniform. Then, a series of stiffening ribs, and a continuous glass fiber mesh, are added to strengthen the mold and give it sufficient rigidity to be lifted, flipped over, or transported.

[8-9] The views from beneath the formwork rig show the preliminary shape of the fabric sheet before it is loaded (Left), and after it has taken the full weight of the wet GFRC (Right). The weight of the concrete gives the fabric sheet its final structural geometry. The resulting rigid fabric + GFRC construction will be lifted and turned over, providing a smooth polyethylene-coated mold.

[10] Turning the mold over

[11] The photo shows the fabric-formed GFRC mold completed, prior to turning it over for use. This mold weighs less than 500 kg (1000 lb).

[12] Finished fabric-formed GFRC mold turned over, showing the coated polyethylene release surface. The next step is to make a 3-D laser scan of the mold geometry as required for the structural analysis/design. After structural design is completed, a prototype thin-shell vault will be constructed with this mold.

By generating new forms directly through play with physical matter, the solutions to full-scale construction are contained in the forms and methods themselves. In this way the designer is placed in the very centre of construction knowledge. This method empowers a designer to bring new architectural ideas into constructed reality.

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Wimbledon’s **High-tech Heaven**

GORE™ TENARA® Architectural Fabric

Covers Wimbledon’s Centre Court

2009 sees the start of a new era at Wimbledon, where the traditional tennis matches play to a worldwide audience. For the first time, a huge roof will roll out over the Centre Court when rain threatens to interrupt the legendary tennis tournament. W.L. Gore & Associates have significantly contributed to the technological achievement of British firm of architects Populous and British construction company Galliford Try by providing the 5200m² of roofing fabric, whose properties are ideally suited to Wimbledon’s new high-tech heaven. English summer rain has been a faithful companion of the oldest international tennis champions from the start. Finals have been interrupted or delayed, and the 14-day competition has sometimes had to be prolonged because the weather didn’t want to play ball. The British tennis world took it philosophically. But for the many world visitors and the TV channels broadcasting the matches in over 130 countries, the interruptions meant headaches for everyone. So the All England Lawn Tennis & Croquet Club decided at the turn of the millennium to incorporate an extremely sophisticated, high-tech roof into the historic Centre Court (which dates from 1922). The retractable roof is made of GORE™ TENARA® Architectural Fabric. Unveiled at a Centre Court Celebration, the concertina-design roof contains approximately 5200 m² of the fabric. The fabric was selected in part for its unparalleled ability to let light pass through while offering reliable protection from the elements. Play at Centre Court still feels like it’s outdoors, even when the roof is closed. This is important both to maintain the traditional experience for players and spectators, and to enable cameras to capture high quality images for broadcast. The roof will be closed for inclement weather, and an air flow system will ensure a comfortable environment within the stadium.

The roof comprises two styles of the fabric, the major part allowing 40% light transmission and some allowing 20%. The two styles are precisely placed to prevent shadows or bright spots on the court. The ability of the fabric to flex and fold without wear was another critical factor in its selection. The design of the roof, and the ability of the fabric to fold into a relatively compact space for storage, contributed to the addition of 1200 spectator seats to the stadium. For most of the year, the open roof will be folded into its housing for storage. The unique characteristics ensure that it won’t crack, crease or develop mold and mildew while stored. The flexibility of the fabric has also enabled the roof to be closed in only ten minutes, eliminating lengthy rain delays of the tournament. The roof will be closed for inclement weather, and an air flow system will ensure a comfortable environment within the stadium. The retractable roof is built in two sections, one with four bays and the other with five. The fabric was joined using high frequency welding, and is supported by ten steel trusses. Wheels move along tracks to open and close the roof, aided by a series of hydraulic jacks and arms. The roof spans approximately 77m across the court, and has a clearance of over 16m to accommodate high balls. GORE™ TENARA® Architectural Fabric is a fluoropolymer-coated fabric woven from ePTFE (expanded polytetrafluoroethylene). It uses unique, patented double-coated technology to provide high light transmission along with the flexibility and drape of fabric. The high-strength ePTFE is unaffected by damaging UV rays, acid rain and other environmental challenges, providing durability that carries a 15 year warranty.

Carole Boisdron
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www.tenarafabric.com/wimbledon.html

<table>
<thead>
<tr>
<th>Name of the project:</th>
<th>Retractable roof Wimbledon’s Centre Court</th>
</tr>
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<tbody>
<tr>
<td>Location address:</td>
<td>Wimbledon, UK</td>
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<tr>
<td>Function of building:</td>
<td>Sport Stadium</td>
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<td>Type of application of the membrane:</td>
<td>cover tennis court</td>
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<tr>
<td>Year of construction:</td>
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<td>Architects:</td>
<td>Populous</td>
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<td>Main contractor:</td>
<td>Galliford Try</td>
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<td>Supplier of the membrane material:</td>
<td>W.L. Gore and Associates</td>
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<tr>
<td>Material:</td>
<td>GORE™ Tenara® 4T40, GORE™ Tenara® 4T20</td>
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<tr>
<td>Covered surface:</td>
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In the centre of Athens in Piraeus Street (Municipality of Tavros) a multi storey shopping mall “Athens Heart” has been built. In Greece temporary covered areas are seen as open space, and allow so a higher usage of the land. This is the reason why many shopping malls in Greece are covered with a retractable roof.
The atrium of the shopping mall Athens Heart is covered with a membrane roof. The membrane panels can be reeled parallel to open the atrium. The goal during the design was, to find a light roof with direct view to the blue sky. The solution is a northlight roof, with highly translucent membrane panels giving shadow from the south, and with a transparent cladding on the north side of the parallel steel girders to allow the direct view, and the entrance of the cool northern light.
The main structure consists of 13 crescent-shaped tri chord trusses with a length between 13m and 60m. These trusses span freely over a length of up to 50m, with one top chord and two bottom chords. The trusses are sitting on a perimeter beam, which distributes the load to the building columns of the concrete structure. The front truss in the south towards Piraeus Street has two top chords and one bottom chord. With the bottom chord it is supported vertically by the steel canopy sitting in front of the glass façade. On the east side the trusses are fixed in all directions on the perimeter beam, and on the west side it has a slotted hole, allowing deformation perpendicular to the perimeter beam.
Where the concrete structure is divided with expansion joints, also the perimeter beam is divided, to allow movement in case of earthquake. The movement of the concrete building due to earthquake can be more than 20cm in any direction. The diagonally orientated trusses are covered on their north side with 2 ETFE cushions each. The cushions are double layer, and are clamped to top and bottom chord, to close the atrium. The inner side of the cushions is formed by the diagonals of the trusses on which the cushion is sitting directly. Between the top chord of one truss, and the bottom chord of the neighbour truss one layer of silicone coated glass fibre membrane is spanned. The membrane is attached with travellers to an aluminium rail, and can be opened and closed with a motor driven cable pull system. Spindle driven breaks anchor the roof on the western end. The membrane is attached with 1.2m distance to the rail. This leads to a reasonable size of the folds, and keeps the attachment forces low. To minimize the sag of the loose membrane, especially in the parking position, adjustable web belts have been introduced between the travellers.
To allow the movement of the membrane in between the trusses, the distance of the rails has to be kept constant over the complete length. Therefore the northern bottom chord follows a splined curve with equal distance to the neighbour top chord. The chosen silicone coated glass fibres are highly translucent. Together with the ETFE the shopping mall has a very convenient ambient light, even on cloudy day, and the atrium is an area where the people like to stay.

Name of the project: “Athens Heart” Shopping Mall
Location: Athens, Greece
Client: Pasal Development S.A.
Project Management: Ioannis Lilikakis
Architecture: Conran and Partners / Diarchon
Structural design, concrete structure: Stefanos Diamantaras
Structural design, Membrane, Foil and steel including supervision of those works: formTL
Steelcontractor: Kataskevastiki Elefsinas / Dimitriou SA
Membrane and Foilcontractor: Claus Markisen, Textilbau, Tritthart Ingenieure and Montageservise SL.

1. View to the north - 2. View to the south
3. Longitudinal section - 4. Detail section
5. Open membrane panel - 6. Rail and membrane attachment
Multifunctional inner and outer membranes

Promising results have been reached in optical properties for reflection of heat radiation. The surfaces have been modified by deposition of metals/metal oxides with PVD and CVD (Physical Vapour Deposition and Chemical Vapour Deposition). Surface treatment by fluorination, siliconisation and sol-gel formulations on membrane coatings have been developed to create easy-cleaning or even self-cleaning surfaces which would guarantee a life-span with an attractive optical impression of up to 60 years (Fig. 1). The bulk and surface properties of membrane materials for sound control, thermal insulation and moisture control could be enhanced by integrating aerogels. It is further applicable to intelligently combine different material types, in particular 2D/3D non-wovens or foamed materials for active thermal properties. Super absorbent materials are also integrated in the membrane composition to solve the condensation problem. The use of modified functionalised nanoparticles and intumescent systems have proven very encouraging to dramatically improve the fire retardancy, but only if translucency is not required. Integration of thin solar cells and joining techniques like HF-welding and gluing into the new membrane materials were successfully optimised. In support of designing and combining many different features, artificial aging and large scale tests have been made and further tests of the functional properties are currently being studied.

Use of novel textile based components for textile architecture

A new composite combining a mineral matrix (phosphatic binder: Vubonite®) and Eglass fibres textile reinforcements has been developed. Two manufacturing processes are considered for industrial production: pultrusion and compression. The composite plates are bonded together and allow for the realization of different geometries of beam. The modification of flexural behaviour and particularly shear resistance are obtained by braiding technology. The optimization of the confinement depends on the different parameters (braiding angle, nature of fibres, volumic percentage, etc…) and the impregnation of external reinforcement by Vubonite® maintains the adhesion with the initial support. As new cables using high modulus and high tenacity fibres and specific anchorage have been developed for textile architecture, they can be valorised for pre-stressing the confined hollow beams. The mechanical performance of sub-structural elements (beam and column) has been confirmed through experimental tests. Meanwhile, it is very important to note that failure is shown at a large deformation level due to specific cracking mechanism. The main interest of this new composite corresponds to a high level of fire safety associated to an innovative and effective construction process.

Modelling building physics and fire safety

To obtain good acoustical comfort in membrane based buildings, calculation models are written for single- and double layered membrane systems, incorporating impervious membranes, permeable membranes and microperforated membranes. Permeable and especially microperforated membranes can be easily designed and tuned to have high sound absorbing properties in certain frequency regions. However, extra layers of poro-elastic (higher damping) or rigid elastic (higher mass) materials are necessary for good sound insulating systems. The evaluation of the thermal comfort in spaces covered with translucent membranes requires an accurate modelling of the radiant and convective heat transfer at the surfaces. A coupling strategy covering a building energy simulation program (EnergyPlus) and a CFD program (Fluent) has been studied and codes have been written to import the geometry from CAD tools and to generate input files for all programs. EC fire safety regulations and performance-based fire concepts and the physical laws of construction. In the history of contemporary architecture, this position relates to that of rare innovators like Victor Horta, Frank Lloyd Wright, Auguste Perret or Jean Prouvé. It also links to the premises of the Modern Movement concerning the necessity of symbiosis between form, function and technique. Notable in this respect has been their continuous research into sustainable development with a strong emphasis on integration into the urban or rural environment. Though sometimes spectacular, their work never
safety engineering methods are taken into consideration to ensure the overall fire safety of the textile building. A LES (Large Eddy Simulation) type CFD code and a sub-model for hole opening in membranes have been validated against small-scale tests. Further validation of the modelling is planned by full-scale testing. Presimulations of the large-scale validation experiments have been conducted.

Testing and modelling structural behaviour and architectural aspects of tensile structures

There are four innovative elements in the new design for fiber cable terminations, which were validated through extensive fatigue and creep testing:

- The fibers are inserted on a male “conical” element, which is compressed and heated against a female casing causing radial pressure all around the cable, as it is tensioned. The special geometry of the “conical” and casing elements ensure uniform shearing along the entire cable length.
- Under compression, bonding of the fibers by an autogenous binding is succeeded by controlled melting of a small fraction of their periphery.
- The cable termination design has the ability of accommodating microsliding and flexing within a PET-arnite suitable busing, located at the termination entrance.
- The synergy in stiffness between the casing, the matrix produced by epitaxial crystallization of the melted fraction of the initial fibers, together with the fibers and the final conical element, result in an essentially improved fatigue strength and creep resistance.

Set-up of demonstration

Six different demonstrators have been developed to present some technologies and/or materials newly developed (Fig. 2):

- Demonstrator 1 – a foldable structure for kinetic architecture, which is characterized by variable location, mobility, geometry or movement. It is to create spaces and objects that can physically reconfigure themselves to meet changing needs. The kinetic behaviour was investigated through construction of a ¼ scaled model made by plywood.
- Demonstrator 2 – it consists of a one story, one bay three-dimensional frame whose elements are made by Vubonite® reinforced by glass fibre fabrics. It is to investigate the possibility using this new material to build supporting structures with good fire resistance properties. The demonstrator was tested with satisfactory results.
- Demonstrators 3 & 4 – both demonstrators consist in thermo-boxes to evaluate membrane thermal properties but differ in their dimensions. It is possible to perform a quick preliminary assessment of the newly developed membrane materials through the small thermo-boxes and successively testing the selected materials through the large thermo-boxes. The materials will be mounted on the Demonstrators 5 and 6.
- Demonstrators 5 & 6 – they are sufficiently large structures specifically thought to demonstrate membranes, cables, and belts. The supporting steel structure of one of the demonstrator has been realized while the other demonstrator is still in the design stage.

Knowledge management in Smart Innovation Networks

The effective management of knowledge – which is constantly acquired, developed and exchanged throughout the project – has been established in order to enable the deliberate sharing of knowledge as a valuable but intangible resource. To achieve this, several methods and technologies for knowledge management have been carefully selected and implemented.

From the beginning of the project, available knowledge has been analyzed and knowledge requirements of the different partners have been identified to derive a domain-specific knowledge structure. Together with models of knowledge and information flows between partners, this structure has been input for the design of a collaboration platform which enables partners to share their knowledge effectively.

This platform allows, e.g. the exchange of documents and contact data, the presentation of new ideas and developments to, as well as the ordering of materials from other partners, or the coordination of the various tasks of the innovation activities. In order to facilitate knowledge exchange and the coordination of innovation activities, smaller sub-groups (context-T Innovation Networks) have been established focusing on the development of specific product features. The creation of these networks not only provides an efficient knowledge flow within the networks, but also supports an easy exchange of experiences across networks. Additionally, services regarding Life Cycle Assessment and Intellectual Property Rights are provided to support the networks.

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Fabric Architecture: Creative Resources for Shade, Signage and Shelter

Author: Samuel J. Armijos
(www.fabricarchitect.com)

Fabric Architecture is a resource catalogue devoted to celebrating membrane structures. With over 300 examples of awnings, tents, umbrellas, and tensioned membrane structures from around the world, it is the reference book for ideas and inspiration. As an added feature, there are six fabric samples included in the book: PTFE from Saint Gobain, Coated PVC and PVC mesh from Ferrari, HDPE from Multiknit, Silicone coated fiberglass from Atex and Gore’s Tenara. The book can be used as a reference guide, course book, a selling tool or as a gift for your employees, clients, family and friends.

Language: English	Size: 28.4 x 25.7 x 2.5 cm, 476 colour photos, 304 pages (hardcover)
Editor: W. W. Norton & Co., 1 edition (Nov 2008)
Internet sale: www.wwnorton.com

Figure 2. Demonstration
Thirst pavilion
Zaragoza 2008, Spain

International Expo “water and sustainable development”

Idea
The International Expo “Water and Sustainable Development” that took place in Saragossa during the summer of 2008 in the Ebro’s banks required the creation of buildings for housing the exhibition contents. One of these buildings was the Thirst Pavilion, located in the Expo area named Thematic Plazas, which mission was to transmit the need of water for the humankind and the consequences suffered by the environment for satisfying that need. For reach such objective, architect Enric Ruiz-Geli, conceived the building as an enclosed building, a spherical segment of 46m diameter in plan, having a height of 16m, remem-bering a big morula, being externally composed its skin by a macro “porosity” reticule of reinforced fiberglass polyester shells, being those “pores” filled by means of EFTE cushions.

Construction of the pavilion
In base to the Basic Project, Expo published the competition for the construction of the Pavillon, which was adjudicated to the Contractor Ferrovial, but they haven’t got the properly knowledge to afford the construction of the polyester shell and EFTE cushions, so they subcontracted Comercial Marítima for such building jobs. Due to the degree of development of the project, detailing engineering assistance was needed for the polyester shells and ETFE cushions and for building the Pavilion, which was made by Arenas&Asociados. The polyester shells could be manufactured thanks to the sailing contacts between José María Lastra (Comercial Marítima) and Francisco Abeledo (Hércules Marine), who could manage to get all the shells on time. It must be said that another Polyester manufacturer had abandoned the project a few months before the Expo Opening and the Pavilion was in a serious danger of not being built.

EFTE cushions
EFTE cushions appeared in the project as an idea, but they weren’t defined, so they required a detailing engineering job, made by Arenas&Asociados, who subsequently submitted to Comercial Marítima the data needed for patterning and manufacturing. The Pavillon had 82 two layered ETFE cushions, having different dimensions all of them. It could be said that they had “circular” section, varying their diameter between 2.8m and 9.8m, but maintaining always a rate sag/diameter of 0.15 for each of the two layers of the cushion. The size of the cushions decreased from bottom of the building to top helicoidally. As previously was said, the cushions were composed by two layers, having both a thickness of 200μm, being the external transparent and the silvered inner one. Due to the silvered coating, the sun rays were reflected, providing to the Pavilion an interesting appearance of a set of water drops. Inside the cushions, led diodes were installed for night illumination, blue and white were the colors selected.

Three sets of seven diodes, two blue and one white were introduced in each cushion. At night, a global blue radiosity in the Pavilion was achieved thanks to the silvered layer because it reflected the led’s lights. Furthermore, the initial idea was covering the Pavilion with a salt crust of 5cm of thickness, and for that reason the cushions were provided with brine water vaporizers, but at last, during the Expo, the salt didn’t grip properly in the external ETFE layer and the water vaporization was forgotten. For gripping the salt on the external ETFE surface was needed the application of a latex gel, but this solution lost the transparency of the ETFE, making it translucent, and hindering the light reflection in the silvered layer. The cushions were inflated with an internal pressure of 30kp/m² (3mbar) which allowed them resisting all the external actions, wind and snow according to the local codes, without slackening or having stresses higher than 21N/mm² in any of the cushion.
layers. To control the stresses, the strain is controlled, avoiding the high plastic behavior of the ETFE.

Glass reinforced polyester shells
The Pavilion skin, with the ETFE cushions, was completed with white reinforced glass polyester shells, contrasting the whiteness of the shells with the brightness of the cushions.

Each shell was a segment of the spherical envelope of the Pavilion, covering the holes that the cushions didn’t fill, limiting with three cushions and having three axes forming 120° between them. Manufactured by Hercules Marine, each shell had a global thickness of 48mm, with an upper layer of 5mm, a lower of 3mm and a middle one of 40mm. The external layers were composites, fiberglass reinforced polyester, with 40% of biaxial fibers of 600g/m². The inner layer was composed by polyurethane foam, lightening the shell. The thicker upper layer was for resisting external loads acting directly over the surface. These shells had a great importance; because they bear the reactions transferred by the ETFE cushions and transmitted those reactions and the loads acting over them to the supporting steel frame by means of three EPDM bearings located in the shell vertices.

Concerning the force transmission between cushions and shells, Arenas&Asociados studied that phenomena, designing the polyester edge, a rigid composite of fiberglass reinforced polyester of 13mm of thickness and 60mm length. In this edge, the aluminium cushion frame was bolted to the polyester. At last, this rigid union wasn’t enough adequate, because its stiffness wasn’t able to afford the big geometrical imperfections registered in the construction of steel frame, which had collapsed during its erection for a badly proposed stage construction, due to a bad engineering study by the steel contractor, who didn’t understand that a shell structure works properly when it is finished, it must be said, when forces follow form, but in the staged construction, provisional bearings are needed and they were almost neglected.

This error damaged some elements that even weren’t replaced, only the bolts, and delayed the time for finishing the building works, but at last it was possible to finish in time. Added to the geometrical imperfections we have to take into account the thermal effects, but they were considered dividing the aluminium and steel frame in segments. Those geometrical problems caused the failure of some ETFE cushions, because its geometry couldn’t fit the hole where they must be installed.

Finally, thanks to the efforts of José María Lastra, and his interest in achieving a perfect result, he re-patterned the cushions with geometrical problems until they fit correctly. As conclusion, flexible connections based in neoprene are better than rigid unions.

Real scale Model
Due to the complexity of the project, the Property and the Architect, asked for a real scale model, which was made by Comercial Marítima, Hércules Marine, and the engineering support of Arenas&Asociados. In Hércules Marine’s workshop a real scale model of one cushion was made. The model included the steel frame support, the polyester shells and the ETFE cushion with its aluminium frame, led illumination and brine water vaporizer. It was inflated to the service pressure, 30kp/m² (3mbar), being the model successful, and permitting to obtain conclusions such deciding not applying the latex gel for salt gripping for achieving a better transparency in the external ETFE layer, or painting in white the aluminium cushion frame.

Conclusion
Despite of the success achieved by the Pavilion architecture, it was decided by the Expo Authorities that it would have to be dismantled, what was already done; but it is going to be rebuilt in Valladolid by its council, who bought it.

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Name of the Project: Thirst Pavilion
Location address: ExpoZaragoza fairground, Saragossa, Spain
Client: ExpoZaragoza2008
Function of building: Thematic exhibition
Type of application of the membrane: Structural Façade
Year of construction: 2008
Architects: Enric Ruiz-Geli (Cloud-9). Basic Project
ETFE, polyester and pneumatic engineering: Santiago Guerra Soto & Guillermo Capellán Miguel (Arenas&Asociados)
Main Contractor: Ferrovial
ETFE Membrane Contractor: Comercial Marítima
Polyester Contractor: Hércules Marine
Manufacture and installation steel structure: Cometal
Manufacture and installation Polyester Polymer: Francisco Abeledo (Hércules Marine)
Manufacture and installation ETFE Cushions: José María Lastra (Comercial Marítima)
Material supporting frame: structural Steel
Material shell covering: reinforced glass polyester shells
Material cushions: ETFE
Material frame cushions: aluminium
Covered surface: 1662m²

TENSINEWS NR. 17 – SEPTEMBER 2009
Buquebus
Bus & Cars parking
Port of Montevideo, Uruguay

At the transit area in the port of Montevideo a covered parking for bus and cars was asked for those travelling with the ferry connecting Montevideo and Buenos Aires. The objective of the parking roof is to provide rain and sun protection.

The inflatable cloud, commissioned from FRANTZEN et al architects, was developed, manufactured and installed by Buitink-technology. CityLed from Venray has illuminated the cloud from inside with LED lighting controlled by computer.

The inflatable cloud is built up from about 140 different cutting patterns, generated by Tentech BV in EASY VOL and Rhino. The translucent fire resistant fabric provided with transparent, round openings. The cloud hangs in stainless steel cables. The cloud was installed in un-inflated situation which means hung in the cables and than inflated. The cloud is kept under pressure by a small 220V air system that measures the pressure and fills with air when the pressure is below a certain point. The inside pressure varies between 20 and 30mbar.

Name of the project: Light sculpture for main office TomTom
Location address: Amsterdam, The Netherlands
Client: TomTom, Amsterdam
Function of building: Sculpture
Type of application of the membrane: 2008/2009
Year of construction: 2008
Architects: Frantzen et al Architecten BV/ Jo Coenen Co Architecten
Consulting engineer for the membrane: Tentech BV, Utrecht, The Netherlands
Engineering of the controlling mechanism: Buitink Technology
Main contractor: Frantzen et al Architecten BV
Contractor for the membrane: Buitink Technology
Supplier of the membrane material: Heytex
Manufacture and installation: Buitink Technology
Material: PVC coated polyester fabric
Covered surface: 30m²

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The Inflatable cloud
The Netherlands
The project covers the VIP tribune of the “Monumental Stadium”, property of the Colo Colo Football Club and located in the city of La Florida, state of Santiago, Chile. The purpose of the project was to replace the existing coverage, which was of metal plates and was in poor condition, with a cover of greater aesthetic quality. The new cover is part of the total renovation of the stadium.

The complexity of this project has two special peculiarities:

- The first is the architectural design, this should accommodate the irregular configuration of the concrete beams and pre-existing conditions and it should be consistent with them. It should also make a way to evacuate rainwater and be aesthetically compatible with the existing building as part of the facade.
- The second one, the configuration and structural system, resting on concrete beams structurally independent, this structure should be flexible enough if an earthquake took place because the buildings would move in different directions, this is achieved through tri-articulated arches.

The structure and the membrane were fully built in Lima (Peru) and the structure was designed to be completely disassembled. It was moved to Chile to be assembled only using bolts for assembly work and some drilling and welding to the existing beams. The result of the project was a success in itself and meets customer requirements.

It was the first project that Cidelsa did for the most important football club of Chile. This project served as a letter of introduction from the company for the following 3 stadiums that were developed and build in 2008: The Municipal Stadium German Becker at Temuco with a covered surface of 23000m², the Bicentenary Stadium of La Florida at Santiago with a covered surface of 8300m² and the Municipal Stadium Nelson Oyarzun Arenas at Chillán with a covered surface of 8300m². New designs for more stadiums are planned.

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The designers developed a simple, self-supporting structure with independent membranes. The area is covered without internal supports to optimize the parking facilities and all the rainwater is directed to the edge perimeter. The membrane is stretched over 5 arches, prestressed and stabilized by 4 cables. The structure is composed of 5 metal arches with a span of 34.47m, separated each 9m. Longitudinal stability is given with 3 lines of beams (one central and two intermediate) and a perimeter 3 dimensional beam which is also suitable for anchoring the intermediate cable turnbuckles. The structure was produced in the metal workshop, for parts, then assembled on site and the final assembly and welding was performed in place with the help of cranes. The arches are made of round pipes 8”, 4” and 2¼” and the anchorage plates in 1¼”. The membrane was produced simultaneously in the workshop, and once the structure was finished, the membrane was installed in 8 days. The membranes are made of polyester fabric PES HT 1100dtex, 6x6 threads per cm with PVC coating, UV protection on the outside, a weight of 900g/m² and a breaking load limit of 38daN/cm.

The prestressing was performed by tying the ropes: intermediate cables through the central modules and edge cables in the extremes modules. Of all the possible options the prestressed PVC membrane is the better one from the point of view of shape and aesthetics, as well as translucency of sunlight, without of ultraviolet or infrared radiation.

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The covered surface: 2500m²
Material: Precontraint 902 S
Manufacture and installation: Cidelsa
Supplier of the membrane material: Ferrari
Contractor for the membrane: Cidelsa
Main contractor: Municipality of Santiago
Engineering of the controlling mechanism: Cidelsa
Consulting engineer for the membrane: Aldo Rodríguez

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The new cover
VIP Tribune

Name of the project: Monumental Stadium of Colo Colo
Location address: Santiago, Chile
Client (investor): EBCO
Function of building: Football Stadium
Type of application of the membrane: Cover VIP Gallery
Year of construction: 2008
Architects: Guillermo Carella
Structural engineers: EBCO
Consulting engineer for the membrane: Aldo Rodríguez
Engineering of the controlling mechanism: Cidelsa
Main contractor: Municipality of Santiago
Contractor for the membrane: Cidelsa
Supplier of the membrane material: Ferrari
Manufacture and installation: Cidelsa
Material: Precontraint 902 S
Covered surface: 2500m²

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Name of the project: Buquebus Bus & Cars parking
Location address: Montevideo, Uruguay
Year of construction: 2008
Architects (design and project): Roberto Santomauro / Patricia Pinto
Structural engineers: Marella & Pedoja
General project: Julio Cesar Ortega
Roof fabricator and contractor: Sobresaliente Ltda.
Material: PVC coated polyester PES HT 1100dtex
Roofed area: 1925m²
MEHLER TEXNOLOGIES TENSILE ARCHITECTURE DESIGN SOFTWARE

Following the 1st technical guideline for tensile structure, an extensive and practice-based general information on tensile architecture booklet, Mehler Texnologies is increasing its efforts in promoting and sharing technical knowledge on this amazing architectural art. In order to facilitate the first approach to the tensile architecture world, Mehler Texnologies is pleased to present this unique and easy to use software for design of tensile structures, Mehler TensileDraw. The software is an AutoCAD and RHINO fully compatible and integrated plug-in software package, a really useful tool in 3D model design: it can design complicated tensile surfaces and simulate well balanced force stress distribution without complicating handling, file exportation and related compatibility problems (Figure 1 - Mesh Balance).

The application can calculate the form of complex geometry fabric structures thanks to the generation of a warp and weft beam mesh reproducing orthotrophic behaviour of the fabric material (Figure 2 - Cone Mesh). The software has been engineered by MTEC s.r.l well proven, fully functional software, but simplified in a way that enables anyone currently using those most common in drafting programs capable of generating tensile structures. A step-by-step guide accompanies the user in the design process with interactive and intuitive explanation of the commands and functions. Additionally, the software is able to reproduce different boundary characteristics, is able to permit modification of the designed shape to interact with the master design surround, and deliver preliminary information like membrane surface area, length of the perimeter boundary and level of pre-stress on the membrane surface. This enables architects and designers to quantify, much better than complicated sketching, the initial design impact and evaluate therefore the preliminary related costs (Figure 3 - Cone). Mehler TensileDraw is the free version of Tensile Draw, a more complex software able to deliver (in addition to the free version) preliminary attachments loads, geodesical lines orientation and water pounding areas on the designed surface. The full version is available on developer webpage.

Both versions deliver a print-out of the design results including preliminary information on surfaces, loads and proposed material strength (previous application of living loads) (Figure 4 - Cone report). With the release of this software, Mehler Texnologies intent is to support and increase valid help to all those professionals and non-professionals interested in creating tensile structures, avoiding initial difficulties in designing and increasing the general interest toward this amazing and environmentally friendly form of architecture.

TensileDraw has been developed with experienced partners and the Institute for Membrane and Shell Technologies, Associated Institute of the Anhalt University of Applied Sciences, Germany, for didactics scopes with the intention of generating a valid and immediate support to architects, planners and students. Moreover, Mehler Texnologies will contribute to interactive support with the first coated fabrics forum, to be joined at www.mehler-texnologies.com.

In conjunction with our long-term experience, closer cooperation with specialized partners and the high quality REACH conforms products offered to our customers, Mehler Texnologies is offering once again proven and reliable support to the market.

The software as well as the technical guideline can be downloaded free of charge on Mehler Texnologies’ website:

www.mehler-texnologies.com

INTERNATIONAL "TEXTILE STRUCTURE FOR NEW BUILDING" COMPETITION FOR STUDENTS AT TECHTEXTIL 2009

The International “Textile Structure for New Building” Competition for Students was held for the 10th time in 2009. As at previous competitions, the review of this year’s competition is cause for great satisfaction. The large number of entries from many countries and the high standard of the works submitted confirm that the competition’s approach is correct and should be pursued without compromise. Held for the first time in 1993, the competition aims to promote textile building by awakening the interest and enthusiasm of students for a method of construction that is characterised by a great potential for innovation and numerous opportunities for enriching architecture as a whole. It is the students of today who will work with textiles and design the textile buildings of the future. As tomorrow’s architects they will have a great influence on the appearance of our urban landscape. Therefore, it is important to promote their work and to give them the opportunity to work with new materials. The works submitted are impressive evidence of the chances offered by textile constructions. As in previous years, the jury awarded prizes in four categories, in order to honour the diversity of the themes selected.

Prof. Dr.-Ing. Werner Sobek

Organizers: Techtextil and Tensinet Association - The Tensinet Association sponsors this International Competition.

CATEGORY 1: MACRO ARCHITECTURE
1st PRIZE: Once Upon A Time – Rocio Pina Isla
2nd PRIZE: Temple of Nature – Varun Amar Kaushik & Bhairabi Kachari
3rd PRIZE: Deforming realities – Mina Yaney
SPECIAL MENTION: Laboratorium Blum – Lago Gonzalez Quelle & Erez Amitay

CATEGORY 2: MICRO ARCHITECTURE
1st PRIZE: Transportable Children’s Play-ground Structure – Barbara Rodriguez Pando & Carmen Matienzo Tunon

CATEGORY 3: ENVIRONMENT AND ECOLOGY
1st PRIZE: Algae Solar Dryer – Pamela Cancino
2nd PRIZE: Give me shelter – Eva Spielberger & Elisabeth Weiler

CATEGORY 4: COMPOSITES AND HYBRID STRUCTURES
1st PRIZE: Mobile LED-Matrix – Manfred Wuits
SPECIAL MENTION: Fifana – Gerlind Baloghy
HONORABLE MENTION: Plus-minus Exhibition stand – Nora Haase-Aschoff, Mathias Hackmann, Sebastian Kron, Philipp Kuner, Julian Lutz, Philip Hinrichsmeier & Fabian Pfeiffer