

REPORT

## TEXTILE ROOFS 2015

### EXPO 2015 MILANO

FEEDING THE PLANET, ENERGY FOR LIFE

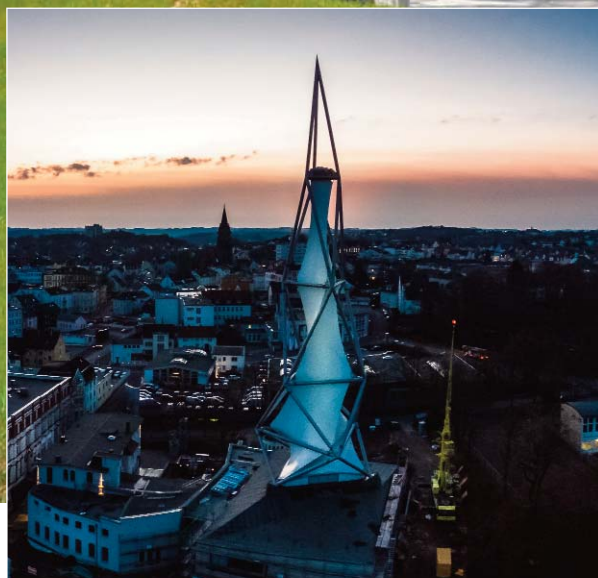
PROJECTS

THE SWAROVSKI CRYSTAL WORLDS

"NEW ERA OF WONDER"

PHÄNOMENTA

A TOWER MADE FROM (ALMOST)  
NOTHING BUT GEOMETRY!







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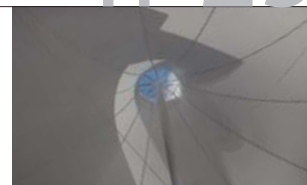
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# contents



## PROJECTS

PAGE

- 4 **Bangladesh** TENSILE CONES  
RADISSON BAY VIEW HOTEL
- 5 **Austria** THE SWAROVSKI CRYSTAL WORLDS  
"NEW ERA OF WONDER"
- 6 **Switzerland** RETRACTABLE MEMBRANE ROOF  
AN ADAPTABLE WEATHER PROTECTION
- 7 **Azerbaijan** BAKU 2015 EUROPEAN GAMES PARK
- 10 **Germany** PHÄNOMENTA  
A TOWER MADE FROM (ALMOST) NOTHING BUT GEOMETRY!
- 10 **Germany** MEHLER REPLACES MEHLER AFTER 37 YEARS  
ELSPE GRANDSTAND CANOPY

18



FEEDING THE PLANET, ENERGY FOR LIFE

## REPORT

- 8 POLITECNICO DI MILANO  
RESEARCH AND EXPERIMENTATIONS



16  
**TEXTILE ROOFS  
2015**

- 17 "TEXTILE STRUCTURES FOR NEW BUILDING" 2015  
SPECIAL GRANT FOR THE 13<sup>TH</sup> STUDENT COMPETITION
- 24 INTERNATIONAL MEMBRANE SYMPOSIUM 2015 IMS  
E.V. ANHALT UNIVERSITY, GERMANY
- 26 FISHING FOR FORM  
FORM-RULE|RULE-FORM SYMPOSIUM 2015
- 28 UNIVERSITY OF NOTTINGHAM END OF YEAR SHOW  
PAVILION 2015

## ARTICLE

- 24 **WELD YOUR IDEAS** AT FORSSTROM'S  
NEW HF WELDING CENTER, SWEDEN

## CALL

- 16 TENSINET - COST ACTION TU1303 SYMPOSIUM 2016  
NOVEL STRUCTURAL SKINS 26-28 OCTOBER 2016

## MISC

- 25 **BOOKREVIEW**  
FABRIC STRUCTURES IN ARCHITECTURE  
LIGHTWEIGHT LANDSCAPE

This TensiNews gives a short description of a few recent membrane projects built for the 'Radisson Bay View Hotel' (Bangladesh), the 'European Games Park' (Azerbaijan) and 'Phänomena' (Germany). An 'Adaptable Weather Protection' (Switzerland) is presented, a renewed structure 'Elspe Grandstand Canopy' (Germany) and the very poetic installation for the 'Swarovski Crystal Worlds' (Austria).

This issue also includes the reports of (1) Fishing for Form, Rule-Form symposium 2015 organised by KOGE, University of Innsbruck, (2) the International Membrane Symposium 2015 organised by Anhalt University and (3) the international workshop Textile Roofs 2015 held in Berlin. There is also a description of the research and experimentation possibilities at Polimi Textiles' HUB.

Till the end of October the Expo 'Feeding the planet, energy for life' takes place in Milano. Several TensiNet members were involved in the realisation of some of the pavilions and shading systems (page 18-23).

The TensiNet Association is active in the COST Action TU1303 'Novel structural skins' ([www.novel-structuralskins.eu](http://www.novel-structuralskins.eu)). This COST Action had a meeting on the 8<sup>th</sup> and 9<sup>th</sup> of September at the University of Minho (Guimarães, Portugal). The plenary lecture by Martin Tamke from CITA (DK), entitled 'The Tower – an interdisciplinary collaboration in the framework of COST', showed innovative results emerging from the collaboration between various COST Action partners. Raul Fanguiero (UMinho, PT) introduced the Fibrenamics International Platform for the knowledge transfer between universities and companies as well as some new developments. In addition, the five Working Groups of the Action discussed during parallel sessions various aspects and future challenges related to Novel Structural Skins, like new applications, aspects related to LCA and acoustics, and the development of case studies and physical models as 'educational pack'.

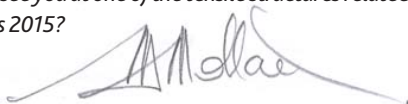
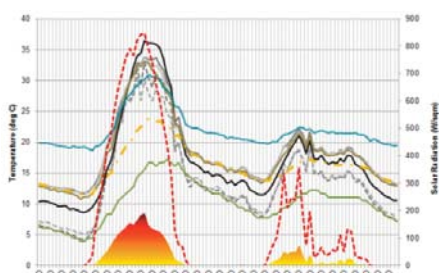
The Eurocode working group CEN TC250 WG5 finalised and submitted the Scientific and Policy (SaP) report 'Guideline for a European Structural Design of Tensile Membrane Structures made from Fabrics and Foils'. The TensiNet Eurocode working group, CEN TC250 WG5 and the COST Action TU1303 WG5 'From material to structure and limit states: codes and standardisation' will further cooperate to establish the Technical Specifications, which is the second step in obtaining a Eurocode for 'Membrane structures'. The COST Action TU1303 WG5 also decided to organise a Round Table session for experts in the domain of tensile surface structures to raise awareness for the development of this Eurocode. The aim is to discuss the importance of the specific Eurocode and to increase involvement.

The COST Action TU1303 WG5 organises the training school 'EUROMEM - From uncertainties to partial safety factors calibration: application to tensile membrane structures, discover the birth of a Eurocode', at the University of Nantes from the 29<sup>th</sup> of September till the 1<sup>st</sup> of October 2015. More information can be found at <http://euromem.sciencesconf.org/>

The TensiNet/COST TU1303 Symposium will have the same theme as the COST 'Action Novel structural skins' and will take place at Newcastle University, from the 26<sup>th</sup> till the 28<sup>th</sup> of October 2016. Several interesting keynote speakers have already confirmed their presence, such as Patrik Schumacher (Zaha Hadid Office), Julian Lienhard (structure GmbH), Carl Maywald (Vector Foiltec), Raul Fanguiero (Minho University), Martin Tamke (Royal Danish Academy of Fine Arts, School of Architecture), Gordon Mungal (ARUP), Al Fisher (Buro Happold), Jan Knippers (Institut für Tragkonstruktionen und Konstruktives Entwerfen) and Jürgen Wacker (Wacker Ingenieure). If you are interested to present a paper, please submit your abstract before the deadline on October 15<sup>th</sup> (see also <http://conferences.ncl.ac.uk/tensinet2016> and page 16-17).

We hope you enjoy this issue and look forward to see you at one of the tensile structures related events, perhaps already at Structural Membranes 2015?

Yours sincerely, Marijke Mollaert

## CORRECTION TensiNews 28

Apology: in the n° 28 of TensiNews, the figure 8 on page 11 should have been attributed to Paolo Beccarelli, John Harding and John Chilton.

## Forthcoming Events

### Structural Membranes 2015

Barcelona, Spain | 19-21/10/ 2015

<http://congress.cimne.com/membranes2015/frontal/default.asp>

### 9<sup>th</sup> Aachen-Dresden International Textile Conference 2015

Aachen, Germany | 26-27/11/2015

[www.aachen-dresden-itc.de](http://www.aachen-dresden-itc.de)

### Textile Roofs 2016

Berlin, Germany | 2-4/05/2016

<http://www.textile-roofs.com/>

### IASS 2016

Tokyo, Japan | 26-30/09/2016

<http://www.textile-roofs.com/>

### TENSINET - COST ACTION TU1303 SYMPOSIUM 2016 Novel structural skins

Newcastle, UK | 26-29 Oct 2016

## Forthcoming Meetings

### Partner Meeting 2 and Annual General Meeting

Tuesday 20 October 2015 at 18:45

Location: Master room, Building A3, Campus Nord of the Technical University of Catalonia (UPC), Jordi Girona 1-3 (08034) Barcelona  
<http://congress.cimne.com/membranes2015>

## CALL Cost Action TU1303 TRAINING SCHOOL EUROMEM

From uncertainties to partial safety factors calibration: application to tensile membrane structures, discover the birth of a Eurocode.

This training school will be organized at the University of Nantes from the 29<sup>th</sup> of September till the 1<sup>st</sup> of October 2015. The number of places is limited.

Registration will be free for members of the Cost Action TU1303 (registration fee is 200€ for researchers and 400€ for industrial participants). Only about 10 early career researchers from the Cost Action can be reimbursed.

Joined to the training school a WG4 and WG5 meeting is scheduled. As this meeting is not foreseen in the Work and Budget Plan for 2015, again only a few participants/early stage researchers will be reimbursed.

More information can be found at <http://euromem.sciencesconf.org/>



CHOUDHURY RANA

## RADISSON BAY VIEW HOTEL

### Tensile cones

#### Chittagong, Bangladesh

#### Introduction & context

Radisson Bay View Hotel (RBVH) is situated in Chittagong, which is the largest port city in Bangladesh. RBVH is an ambitious five star hotel to serve Chittagong as an international business and cultural center to host international seminars, symposiums, conferences, events and expos etc. as well as a resting place for business travelers, entrepreneurs, transit passengers and visitors. The tensile membrane roof is situated upon the main entry between annex block and 20 storied tower block with an area of 665m<sup>2</sup>. It will serve as main entry porch to the building.

#### Structural system

Chittagong city is located close to the sea and is quite windy. The structural design of the 8 tensile cones are done according to BNBC code considering 260km/hr wind speed. The membrane roof is consisted of 8 cones of 8mx8m size, 20m above ground level and 15m above entry porch level. Each cone is supported by a flying mast of 4m height which is suspended by 4 PVC coated 12mm wire cables. The membrane material of the cones is PVDF coated white polyester fabric. The profile of the supporting steel structure is H which acts as a gutter to drain out rain water to adjacent terraces. The supporting steel structure is painted in black while the flying mast and top ring are painted in white color. The top ring of the flying mast is weather protected by acrylic transparent sheet which allows daylight and air circulation into the space beneath it. There is a 65mm air gap between the acrylic sheet and the top ring to allow air flow. Acrylic sheet is extended 150mm to protect interior from rain water.

#### Impact and impression

The 15m high and 24m wide entry porch gives a grand impression while entering the building. The translucency of the white fabric creates an excellent impression. The shadow of the concrete beam frames from background creates an ever changing play of shadow from morning to afternoon on the tension fabric of the entry porch. At night LED lights illuminate the Tensile Membrane which is also very pleasing to see. In terms of thermal quality the white color and conical shape of the membrane reflects most of the solar radiation and keep the interior cool.

Also due to the height of the entry porch, which is 15m above the floor, a gentle, cool, airy environment is created in the entry lobby.

#### Construction & Erection

Construction of the steel is done locally. The erection procedure was labor intensive since labor is cheap and the location of the inner cones were very difficult to be reached by heavy crane since there was little effective work space for crane. The steel scaffolding was done on the entire lobby area. A temporary deck was built on the scaffolding 13.5m above the floor level. With the help of chain pulley and temporary scaffolding the steel and fabric was erected in place. It took about a week to fit and erect all 8 cones.

#### Conclusion

The tensile Membrane Entry Roof is the largest tensile membrane structure ever constructed in Bangladesh. As tensile structures are quite new as system in Bangladesh it was difficult to manage and to coordinate this project. After all it is successfully completed. People who were involved in this project are delighted to see the happy faces of the visitors while entering the building.

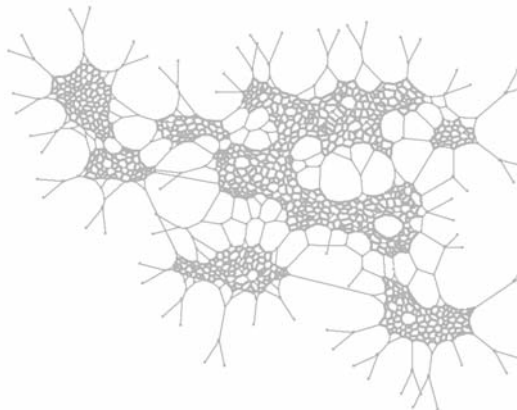
Project Name	Tensile Membrane Entry Roof in Radisson Bay View
Location	Chittagong, Bangladesh
Client	Sena Hotel Development Ltd. (SHDL)
Year of Construction	October, 2014
Consultant	Vistaara Architects Pvt Ltd.
Project Architect	Ar. Golam Morsalin Choudhury Rana
Contractor	Paradigm-Drishik Consortium
Steel & Membrane	ALM Steel Building LTD.
Material	PVDF coated PES fabric
Covered Area	665m <sup>2</sup>

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 www.tensogroup.blogspot.com  
 www.alm-tmsl.com



# "New Era of Wonder"

## Wattens, Austria



### Introduction

Together with a planning team of architects, engineers, cable manufacturers, installation company, and so forth we were responsible for the detailed design, structural analysis and detailed planning of the supporting cable net structure of the Swarovski Crystal Worlds in Wattens near Innsbruck (Austria).

### Project

In front of the beautiful alpine panorama, the Swarovski Crystal Worlds extend over an area of about 1.500m<sup>2</sup>. In its longest dimension, the cable net structure amounts to about 130m. The structure is set to a total of 116 columns and is connected with more than 3000 cables to a network. At the junctions the cables are knotted together with discs. The entire structure is pushed up on pressure props or rather pulled down over pull props and thus placed under tension. Basis for the draft of the entire construction represents a so-called three-dimensional Voronoi diagram. Voronoi diagrams are natural phenomena which are occurring in a variety of scientific

fields, such as biology, chemistry, meteorology, et cetera. They also feature interesting mathematical properties and relationships which finally reflect themselves in exciting geometric structures.

Difficulty at the execution of such a network is that these many nodes, with their different angles and directions, must be brought together in a very closely space at one point. Also the architects emphasized special efforts for an elegant and unobtrusive solution at the detailed design of these points. That manages the disc on a smart and chic way. Three ropes can be connected force-fit with each other and provide an ideal solution to knot Voronoi networks. This innovation makes the cable net structure with its clouds in different shapes and sizes, according to the design of the French-American artist duo Cao and Perrot, to a real artwork.

The clouds are formed from stainless steel mesh and hung in the rope net structure. Then the clouds are decorated with thousands of tiny crystals and form a huge, in many different colors and shapes, glitzy sea of clouds.

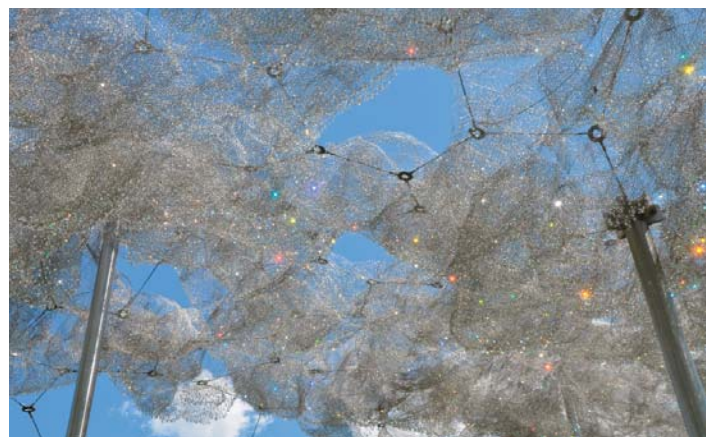
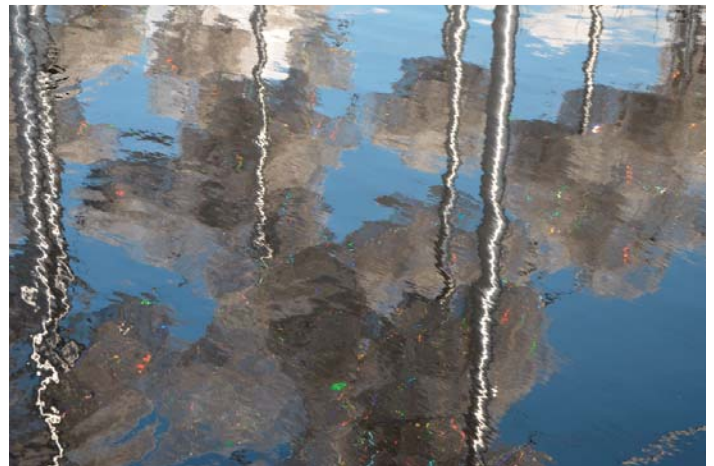


Figure 1. The Swarovski Crystal Worlds

Name of the project:	Swarovski Crystal Worlds
Location address:	Kristallweltenstrasse 1, 6112 Wattens, Tyrol Austria
Client (investor):	D. Swarovski KG
Function of building:	Park, landscape, artwork
Year of construction:	2015
General planning:	s_o_s architekten
Architects:	s_o_s architekten - Andy Cao, Xavier Perrot/ cao   perrot studio
Structural engineers:	Tobias Schlaich, Tobias Lüdeke/ Kiefer. Textile Architektur
Main contractor:	Montageservice GmbH
Supplier of cables/ discs:	Carl Stahl GmbH
Manufacture and installation:	Montageservice GmbH
Surface area:	1500m <sup>2</sup>



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Figure 2. Connection detail - discus

## AN ADAPTABLE WEATHER PROTECTION FOR THE INNER-CITY SHOPPING STREET

Buchs, Switzerland

# Retractable Membrane Roof

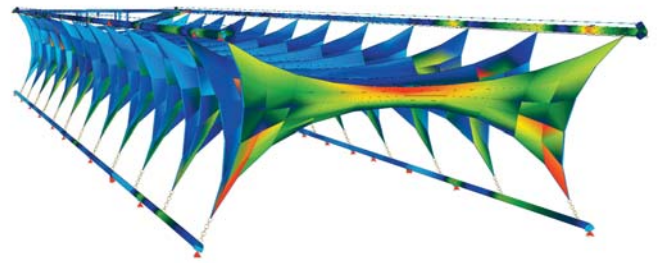


Figure 1.  
FEM Simulation  
© str.ucture



Figure 2. General view and detail of the convertible roof shopping street Metzgergasse © Bernd L. Göllnitz Bildgestaltung

### Context

It is always the desire of retail and catering to make shopping streets more attractive. So far only suburban shopping malls manage to provide protection from all weather conditions. In Buchs, Switzerland (Canton St. Gallen), an inner-city shopping street has now been designed as an exceptional meeting place with adaptable weather protection.

### Project description

A retractable membrane roof covers the 50m long Metzgergasse in the heart of the city and can be opened and closed within 5 minutes, at the touch of a button. The street area is completely covered by the 525m<sup>2</sup> fabric roof and provides protection from rain and sun. The pedestrian zone is significantly valorised through the design and functionality of this project. The adaptive roofing provides the site with significant economic benefits, since even in bad weather, the public space is fully available and can be used for a variety of events.

The convertible roof is opened and closed longitudinally along 4 parallel rails. When open, it takes on a very spatial wave geometry. The textile fabric is stretched between curved ridge and valley belts thereby forming a sequence of dynamic elements with an average height of 6.50m above street level. The folded membrane is 'parked' at the north end under a canopy between the buildings forming a gateway to the Metzgergasse. During deployment, the membrane is transversely pre-stressed to provide optimal stability for wind loads (Fig. 2).

A particular challenge in the foothills of the Alps is always the strong foehn winds, which are typical in the Swiss-Austrian Rhine Valley. Therefore, the relevant wind loads for the roof construction were determined through precise experiments in the wind tunnel.

The selected membrane made of polytetrafluoroethylene (Teflon) is chemically inert, UV-resistant and non-fading, the natural color is white.

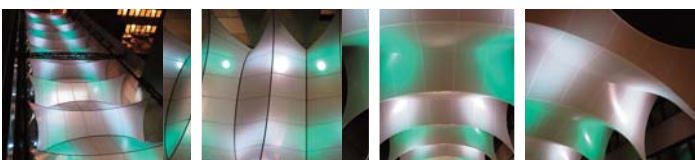










Figure 3. An illuminated covered space at night © Nikolai Kugel Stuttgart

The PTFE fabric of the Swiss company SEFAR is also characterised by an extremely high translucency of 38% and corresponds aesthetically and qualitatively to the highest standards available. The colored LED lights in the textile canopy provide good lighting at night to effectually illuminate the covered space (Fig. 3).

With an interdisciplinary planning team of architects from Nikolia Kugel arch22 and the engineers from str.ucture, this project continues the unique Stuttgart lightweight tradition. The planning team has been consistently developing the technology of retractable membrane structures to advance structural optimisation and functional design of such unique lightweight structures. This enables a highly efficient use of resources and leads to the inherent elegance of lightweight design (Fig. 4).

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 <https://vimeo.com/121039713>

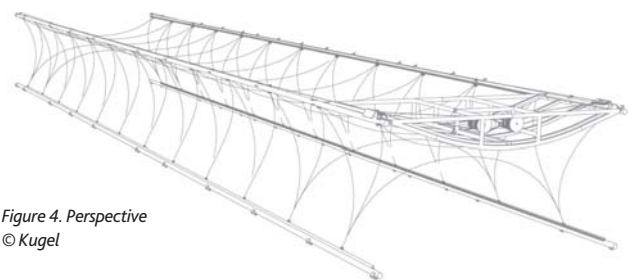


Figure 4. Perspective  
© Kugel

Location:	Buchs (St. Gallen), Switzerland
Client:	Alliva AG, Mauren
Planning of membrane roof:	Architect: Nikolia Kugel arch22 Engineer: str.ucture GmbH
General Planning:	Architect: Kaundbe AG Engineer: Ferdy Kaiser AG
Steelworks:	Heinrich Rohlfing Stahlbau GmbH / Tuchschnid AG
Membrane manufacturing:	A. Arnegger GmbH
Planning:	April - July 2014
Construction:	November 2014
Completion:	December 2014
Membrane:	Sefar PTFE Membrane
Span:	53m x 10,4m
Covered area:	525m <sup>2</sup>
Retraction time:	5min



# BAKU 2015 EUROPEAN GAMES PARK

## Azerbaijan



Figure 1. Pergolas - Tensioned triangular pieces of fabric provide shades.

Figure 2. Village Facade - Vertical coloured membrane stripes.

Figure 3. Main Field Facade the in/out wave movement of the membrane facades.

Figure 4. European Games Park Area - Main stadium - inside view and cross section.

### Introduction

The European Olympic Committee (EOC) decided in December 2012 to organise the first edition of the European Games in 2015 at Baku, Azerbaijan. From now on the games will take place every four years. The European Games were organised from 12 till 28 June and 6.000 athletes have struggled in 20 sports (16 Olympic sports and 4 outside Olympics).

Beside the existing venues temporary and new buildings were erected such as the 68.000 capacity National Stadium. Baku 2015 European Games Park intended to be the landmark of the city with its size, scope and architectural design.

### Design

The design of the European Games Park was made by the Spanish Pujol Arquitectua Company.

The organization of the First European Games in Baku had to face, as well as many other major sport events, the problem of being equipped with adequate facilities for some sports that only exceptionally require a high number of spectators.

In an annex next to the Aquatic Centre, the organizers of the European Games in Baku found the ideal place to locate buildings which, on a temporary basis, would host sports such as water polo, beach volleyball, beach soccer and 3x3, placing them around a Sports Park. The temporary nature of these sports facilities is clearly expressed through the selection of materials and building solutions characteristic of ephemeral architecture.

Thus, along with the removable structures surrounding the play-fields of each of the various sports, extra accommodation is foreseen so that the competitions are carried out in the best conditions.

Locker rooms, office areas, meeting rooms, VIPs lounges, etc. have been arranged using containers which adapt their strict measures and lim-

itations to each of the assigned functions. They are grouped according to height and floor by means of a structural grid set up with pillars, beams and metal slabs. A careful choice of PVC fabric of different colours contributes to establish a formal and chromatic sense of unity that brings out the whole.

Design of the Pergolas around the European Games Park

Pujol Arquitectua Company decided that it was necessary to create some kind of shadow on this extensive asphalted area exposed to direct sunlight during very hot summers. It was important not to interfere with big clusters of people walking through the venues, that is why they designed a minimum impact on the ground with only several columns. Tensioned triangular pieces of fabric were designed with the colours of the Venues and a perforated membrane type was chosen to reduce the wind loads (Fig. 1).

Design of the fabric of the Village Facade

For the design of the Village Facade vertical pieces of membrane were used. The membranes are perforated, see-through and coloured, which create a vibration of colours to these facades (Fig. 2).

Design of main Fields Facades

The temporality of the European Games Park was one of the reasons

to create fabric wrappings around the arenas, as a way of enclosing the areas. The in/out wave movement of the facades creates a singularity to the wrapping around the main stands. At daytime and during the night the wallwasher lighting also creates shadows and increase this particularly geometry (Fig. 3).

### Project

TENSAFORM was involved in the implementation of the textile roof and the facade for the European Games Park Area (water polo, beach volleyball, 3X3 basketball and shooting area) (Fig. 4).

TENSAFORM has chosen textiles manufactured by Serge Ferrari: Ferrari 1202 S standard White membrane material for the roof covering and Ferrari FT 381 mesh membrane material for the facades. The colours red blue, turquoise and the yellow were used in order to increase the light transmittance. The manufacturing of the membranes for the European Games Park, having a membrane surface of approximately 30.000m<sup>2</sup>, was manufactured by Tensaform company at its manufacturing factory located at an area of 10.000m<sup>2</sup> in Malkara. A team consisting of around 70 supervisors completed the installation.

Mehmet YILMAZ  
 Mehmet.yilmaz@tensaform.com  
 www.tensaform.com

Name of the project:	Baku 2015 European Games Park (textile roof and facade)
Location address:	Baku, Azerbaijan
Client (investor):	Securo Limited
Function of building:	Sport Complex
Type of application of the membrane:	roof covering and facade
Year of construction:	2015
Architects:	Pujol Arquitectua
Consulting engineer for the membrane:	Tensaform Membrane Structures Industry Trade INC.
Main contractor:	Securo Limited
Contractor for the membrane:	Tensaform Membrane Structures Industry & Trade INC.
Supplier of the membrane material:	Serge Ferrari
Manufacture and installation:	Tensaform Membrane Structures Industry & Trade INC.
Material:	Ferrari FT 381 Mesh membrane & Ferrari PVC 1202 S membrane
Covered surface (Facade & roofed area):	30.000m <sup>2</sup>

# POLITECNICO DI MILANO **RESEARCH AND EXPERIMENTATIONS** AT POLIMI TEXTILES' HUB

## Introduction

A group of researchers at Politecnico di Milano is focused on developing the technological advancement of technical textiles applied in different areas of interest. Two principal activities are the essence of the research work. The first one is considered more theoretical and born in 2008, with the creation of a multidisciplinary research cluster on innovative textiles, named ClusTEX. Since the beginning of the experience, which involves different partners with different scientific backgrounds, the aim is the collaboration in the development of innovative textiles suitable in different branches, such as lightweight structures, architecture and interior design, aerospace and nautical engineering. The ClusTEX's purpose is the scientific research in a broad sense, based on the propositional knowledge and on the creativity typical of design. The second one is more pragmatic and comes to light from the necessity to communicate with the world outside universities, which requires technical laboratory services. The Textiles' HUB (Heuristic Understanding in Buildings), operative since March 2015, is a laboratory focused on testing the potentiality of membranes, foils and technical textiles, applied in the constructions field. The ClusTEX and the Textiles' HUB operative levels are linked in the creation of a meeting point between the scientific world and the production area of innovative textiles and composite materials. The ClusTEX activities are mainly focused on an experimental approach, while the Textiles' HUB facilities are able to give a service to a wider number of firm and manufacturers, in term of products certification and quality control. The network of Textiles' HUB combines the specific skills of researchers and designers from five different departments, working in the field of building technology, product and industrial design, structural engineering, materials chemistry and building energy.



Figure 1 and 2. ClusTEX pavilion, the meeting point of its multidisciplinary research group and support location for colleagues and students involved in the based research on lightweight materials.

## Applied research on textile based materials

The operative core of Textiles' HUB is the biaxial mechanical tension test station, for biaxial mechanical experiments on different advanced materials for various applications: technical textiles, non-woven fabrics, coated and reinforced membranes, elastomers, polymeric and composite materials. Since the textiles are more and more applied for creating complex forms, and are used also combined with other materials, additional equipments have been disposed for developing the research on these high performance "new skins". Beside the biaxial machine, other machineries are employed: the thermal welding torch for ETFE, a servo-hydraulic mechanical tester (dynamometer) and a spectrophotometer (UV-VIS-NIR). With the support of the thermal welding machine, which measures 600mm in the bar length and has a temperature range between 20°C and 300°C allowing the welding of different types of textile materials, the activity of Textiles' HUB focuses also on prototype realization. The structures studied are: tensile structures, tents, pneumatic constructions, form-active systems and ETFE cushions, textile and polymers based lamps or design objects, tensioned ceilings, textile partitions, false walls, textile wallpapers. At the moment the research group is focusing on the realization of prototypes for the field tests of two European Researches in which Politecnico di Milano is a partner involved. On one side the attention is put on the study and test of deployable kits for emergency situations, developed inside the project S(P)EEDKITS<sup>1</sup>. On the other side the work is related to technical textiles and thin materials for energetic retrofitting, which is the main topic of the research EASEE<sup>2</sup>. The design and the experimental process are supported with dedicated softwares: ixForten, Lectra Design Concept 3D V4R2 and RhinoMembrane for the management of design and production process of membranes and SimaPro 8.03 for supporting the environmental analysis.

## Evaluation of mechanical performance with biaxial rig

Both uniaxial and biaxial tensile tests can be performed with the biaxial rig set up on two squared steel frames, designed for an estimated maximum force of 175kN on each side. The actuators are based on a brushless motor, equipped with an absolute encoder. The maximum speed is 240mm/min and the positioning resolution is equal to  $\pm 0.05$ mm. Each actua-

tor is equipped with a force transducer, which measures the force applied, allowing accurate control of the linear displacements of the actuator. The force transducers have been calibrated following the Quality System of the Politecnico di Milano.

Twelve electromechanical actuators, three on each side of the squared rig, compose the biaxial test machine. The actuators are free to move transversally and each one is adjustable independently from the others. The maximum load applicable is 50kN per each actuator on two opposite sides, that is 6 load cells connected with the respective 6 actuators, and 25kN for the remaining ones, while the minimum stress value is 1kN. It provides a graphical interface that enables the system to be easily controlled by the user. The controlling system regulates the test, recording the data of mechanical stresses generated in the samples, and operates both in force and displacement control. The graphics show in real time the mean values of the applied force and the elongation of the sample. The transduction of the strain is done by four linear potentiometers or by a Digital Image Correlation system without contact, and the images post-processing allows the measurement of the full field strain, on the external surface of the sample during loading.

## Flexibility in the test planning: from conventional to special configurations

The biaxial machine has been designed and built with a high degree of adaptability, combining the different skills of involved researchers with different test configurations: it is possible to test different sizes of samples and high variation of polymeric films. The wide range of forces and transversal movement of engines allows to test different materials, from technical textiles or carbon fibres composites employed in construction field, which should withstand high loads, to biomedical tissues, which are tested in small samples and support lower stresses. The samples are fixed to the bars by means of special clamping system, which allows testing models from 10 to 100cm of wide. The particular configuration of the biaxial rig offers freedom to test samples in mono- or bi-axial tension, but also other types of systems not compliant with the traditional models (e.g. biaxial tests for compensation value, for E-modulus investigation), as follows. In the recent experience the experimentation has dealt with particular and customized re-



quirements: from the application of the biaxial test procedure for the characterization of membranes with a new coating applied on traditional fabrics by an innovative industrial plant, to special and less conventional configuration tests.

- The test campaign regarding the characterization of a fabric with a new coating aimed to determine strength by biaxial tests, elongation at break of the specimens by monoaxial ones and determination of the tear strength of the specimens in the pants shape.

- In the field of tents, a campaign of mechanical tests had the objective of performing the real conditions geometry of a tent system "anchoring system - textile configuration" and the mechanical resistance of the textile reinforcements strips, aiming to characterize, verify and improve at the same time the details of the tent architecture and the textile manufacturing of new products, intended to be tested directly in the field. The reference values, imposed during the test, are the result of a previous structural analysis and calculations for the design.

- A monoaxial test campaign, with a real condition configuration, on innovative composite textiles mechanically based on rigid components, under development in an industry applied research, has been performed, in order to test and characterize the mechanical behaviour and the resistance of the new composites for architecture facades coupled with their anchoring systems.

- High resistance fibre composite multi-axial textiles have been objective of the experimental campaign in order to assess and observe the biaxial tensile mechanical response and structural integrity of a complex structure designed for aerospace: through biaxial test coupled with Digital Image Correlation (DIC), assessed the behaviour under intensive high loads, derived from preliminary analytical calculations

and by a campaign of FEM structural analysis.

- A study of the integration of photovoltaic cells on flexible substrates, such as membranes and fluoropolymers, investigated and validated the performance of stretchable organic photovoltaic, their mechanical responses, through a coupled electrical-mechanical test methodology, in order to verify the effect of external loads on the electrical properties of OPV conductive layers. Through a series of tensile tests on different substrates and various conductive layers commonly employed by OPVs, this work clarified the property difference among different OPV electrode layers under stretching strains, therefore providing valuable information for subsequent building product development towards OPV integration into membrane structures.

Forthcoming facilities of Polimi Textiles' HUB To implement the Textiles' HUB equipments the university has provided a financing, which will allow new arrangements of test within the year. The research group of Polimi Textiles' HUB has predisposed the purchase of new machineries: a climatic chamber for the biaxial machine, which allow to test textile materials under stress in extreme temperature conditions (temperature range - 40°/+200°C), a double ventilated climatic chamber, which has the possibility to set different temperatures in the two-controlled environments, and a spectrophotometer FT-IR equipped with integrated sphere and optional for testing the light transmittance of membranes with a specular behaviour.

#### CONTACTS:

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[www.textilearchitecture.polimi.it](http://www.textilearchitecture.polimi.it) | [www.polimi.it/cluster/clustext](http://www.polimi.it/cluster/clustext)  
[www.polimi.it/en/scientific-research/research-structures/interdepartmental-laboratories/textiles-hub-interdepartmental-textiles-and-polymers-research-laboratory/](http://www.polimi.it/en/scientific-research/research-structures/interdepartmental-laboratories/textiles-hub-interdepartmental-textiles-and-polymers-research-laboratory/)

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<sup>1</sup> 7<sup>th</sup> EU FP Collaborative Project S(P)EEDKITS, THEME [SEC-2011.4.2-3], Rapid deployment of shelters, facilities and medical care resources following a major disaster - Integration Project. <http://www.speedkits.eu/>

<sup>2</sup> 7<sup>th</sup> EU FP Collaborative Project EASEE "Envelope Approach to improve Sustainability and Energy efficiency in Existing multi-storey multi-owner residential buildings", Large Scale Integration Project Call identifier FP7-2011-NMP EeB.2011-3 "Energy saving technologies for buildings envelope retrofitting".

<sup>3</sup> More information on <http://wood-skin.com/mechanical-behavior/>

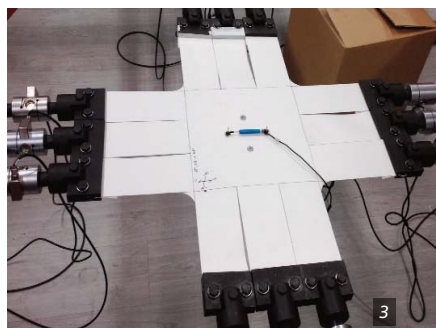


Figure 3. Cruciform sample of textile with an innovative coating prepared for performance evaluation. © NTT (New Textile Technologies GmbH).



Figure 4. Mechanical test simulating the geometrical real conditions of a tent system. © Ferrino Spa.



Figure 5. Test for characterizing the mechanical behaviour of the new composites for architecture facades. © Woodskin<sup>®</sup>.

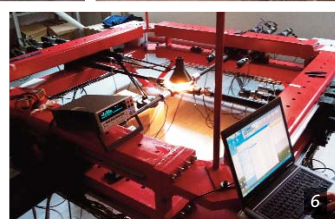
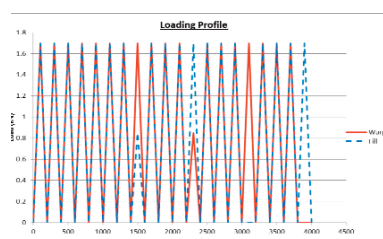


Figure 6. Mechanical and electrical performance test of OPV integrated on ETFE

Graphic 1. Load profile of the biaxial test



Graphic 2. Comparison of deformation warp-fill in force control of the biaxial test

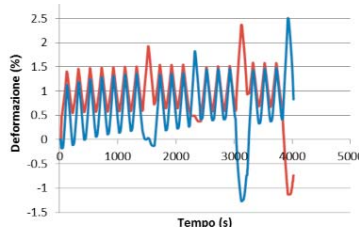




Figure 1. Panorama © Carsten Krämer

#### Context

The striking steel membrane structure visualises the dynamics of the Earth's rotation in the PHÄNOMENTA Science Centre in Lüdenscheid. The new extension of the PHÄNOMENTA has the potential to be a famous landmark or even an icon of engineering and architecture. Interdisciplinary collaboration with KKW Architekten, WERNER Bauingenieure and formTL Ingenieure created an expressive tower made from steel, which is based on the draft of a feasibility study by Schneider+Schumacher, with a helical membrane stretched over its interior. Applying the tower-in-tower principle, this primary structure encloses a Foucault pendulum that is suspended separately from a secondary bearing structure. This logical separation enables the pendulum to move freely of the wind and vibrations of the primary structure, thus allowing visitors to observe the Earth's rotation.

#### Project

The tower is just one part of the expansion to PHÄNOMENTA: a two-storey extension offers an additional 1.400m<sup>2</sup> of exhibition space, with zones characterised by expressive shapes. On the one hand, this ensures the functionality of the exhibition space and, on the other hand, is a result

A TOWER MADE FROM (ALMOST)  
NOTHING BUT GEOMETRY!

## PHÄNOMENTA

Science Centre  
Lüdenscheid, Germany

of the requirements on the tower's geometry. Since the concrete building with monolithic design also serves as a foundation for the steel structure, the frame is continued by diagonal supports in the concrete structure. The clear optics of the tower is based on triangular bays made of circular pipes that are welded airtight. A demanding three dimensional analysis is required, especially for nodes where up to six pipes are joined with various angles. Membrane stress due to pretension and wind are guided directly into the nodes, which minimises bending in the structure. In order to install the tower in individual segments, revisable bolted connections were arranged in the steel tubes, covered with special semi-cylindrical metal sheets. This allowed to avoid site welding and gives still a homogeneous appearance.

The membrane helix inside the steel structure has a light and filigree appearance - "a structure that is almost nothing at all," - and yet it is still quite impressive visually. The helix consists of just three components: 990m<sup>2</sup> of membranes, three form defining cables and nine link elements including accessories. These few elements are sufficient to allow the membrane to follow the rotating and tapered tower. While the maximum enveloped geometry grants to be collision free from the structure, the

MEHLER TECHNOLOGIES GMBH

ELSPE GRANDSTAND CANOPY Germany

## Mehler replaces Mehler after 37 years

#### Context

Since 1<sup>st</sup> July 1978 the 4400 spectators of the famous Karl May festival have been sitting under a fabric roof. After the Olympic structure in Munich the membrane roof in Elspe was one of the biggest, winter proof covers in Europe.

#### Structure

Four masts with a diameter of up to 1,50m hold two 72mm thick steel cables with a length of more than 100m. The 127m long fringe of the membrane is stabilized by a polygonal rope. The membrane is up to 77m long and 32 – 40m wide. It is fixed to 9 knots of the steel cable system and beside of 8 points at the fringe to a 65m long concrete wall.



Figure 1. 4 steel posts of the primary structure hold both of the 100m long main cables © Koch Membranen




Figure 2. The Canopy seen from Winnetou's point of view © Koch Membranen



minimum enveloped geometry prevents from contact with the inner pendulum structure.

The helical curve has a particularly striking effect at night, when the seams of the back-lit covering and the shadow of the ropes converge upwards in a cone shape, giving the tower an even taller appearance. Light management of the LEDs is part of the technical building equipment.

The Foucault pendulum suspended from the inner secondary structure not only demonstrates to visitors the rotation of the Earth, it also visualises the time passing. In the space below is the Phänorama: a 360° projection of Lüdenscheid and its surrounding area, controlled by the natural period of the 30m long pendulum like an huge kaleidoscope.

 Bernd Stimpfle  
 bernd.stimpfle@form-tl.de  
 www.form-tl.de

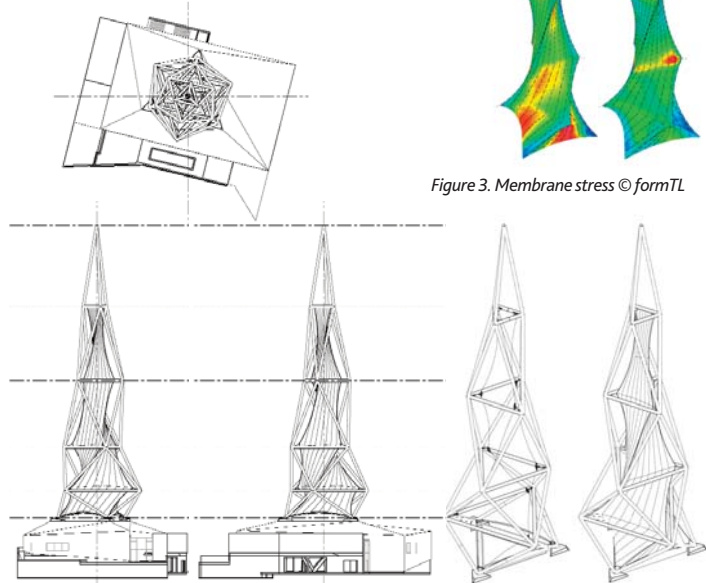


Figure 2. elevations view, isometry view and plan view © formTL

Figure 3. Membrane stress © formTL

## Fabric

Mehler Technologies developed an individual membrane: as close as possible to the original material from 1978, bearing the same green colour. The experts of Koch Membranes say: "Altogether the classical membrane roof in Elspe is a good example for maintaining and developing a sustainable construction. A well done fabric construction is more than ever a fast, reliable and economic way of construction with a high degree of publicity."

For Mehler Technologies the supply of the new fabric was an opportunity in two ways: on the one hand the dismantled fabric gave an excellent proof under real life conditions. Better than any artificial weathering tests this makes clear that the fabric material lasts 37 years and more – even under heavy snow loads

during winter time which are very common in the Sauerland region where the festival tent is located. Continuous on site tests over the past years had already shown that the fabric was not in danger of coming down. Tensile strength was still considerably high and the fabric would certainly have lasted even another dozen years. In the end it was a decision for optical reasons: the festival company wanted to have a bright new colour impression. It's clear enough that they made a material decision on save grounds: of course they wanted to use the same material that had shown an outstanding performance over the last 37 years. Given that today's material science is even farther in terms of choosing the right chemicals for a long lasting and sustainable coating, the actual project might be charged off even

Name of the project:	PHANOMENTA Science Centre
Location address:	Lüdenscheid, Germany
Function of building:	Museum
Year of construction:	2015
Client:	Stiftung PHANOMENTA Lüdenscheid
Architect:	KKW ARCHITEKTEN, Altena
Structural design steel and concrete structure :	WERNER Bauingenieure, Menden
Architect + feasibility study:	Schneider+Schumacher, Frankfurt/Main
Structural design membrane helix:	formTL
Steel contractor:	ingenieure für tragwerk und leichtbau gmbh, Radolfzell
Membrane contractor:	Heinrich Rohlfing GmbH, Stemwede
Membrane installation:	Membranhelix: A. Arnegger GmbH, Leutkirch together with KTA Radolfzell and Wolfgang Mühlherr, Konstanz
Material:	Pastors Membranworks, Ravensburg
Structure:	Ferrari Précontraint 1202S2
Surface area:	Mechanically prestressed Membrane facade 990m <sup>2</sup>



Figure 4. Installation of the membrane at night  
© Alexander Ring



Figure 5. PHANOMENTA at night  
© Alexander Ring

more easily. Apart from having loads of testing material of a 37 year old membrane, Mehler Technologies was able to provide the new material which promises an even better performance. Therefore a new article on the

Elspe project is due not earlier than in the TensiNews edition of 2065!




 Mehler Technologies GmbH  
 Mehler Technologies GmbH  
 www.MehlerTechnologies



Figure 3.  
Detail of the lower membrane fringe © Koch Membranes

Name of the project:	Elspe Grandstand Canopy
Location address:	Zur Naturbühne 1, 57368 Lennestadt-Elspe
Client (investor):	Elspe Festival GmbH
Function of building:	Shelter for visitors
Type of application of the membrane:	tensile roof
Year of construction:	2015
Engineering:	Teschner Ingenieure
Contractor for the membrane:	Koch Membranes GmbH
Supplier of the membrane material:	Mehler Technologies GmbH
Installation:	Montageservice GmbH
Material:	Valmex Mehatop F, Type V
Covered surface (roofed area):	2.600m <sup>2</sup>

# TEXTILE ROOFS 2015

*Textile Roofs 2015, the twentieth International Workshop on the Design and Practical Realisation of Architectural Membranes, took place on 11–13 May at the Deutsches Technikmuseum Berlin, and was chaired by Prof. Dr.-Ing. Rosemarie Wagner (Karlsruhe Institute of Technology, KIT) and Dr.-Ing. Bernd Stary (Berlin Academy of Architectural Membrane Structures, AcaMem). It was attended by 92 participants from 22 countries covering three continents. Once again, the attendance demonstrated the success of the event, which has become firmly established since it was first held in 1995.*

## 20 Years of Textile Roofs.

### A summary.

Prof. Dr. Arch. Josep Llorens from the School of Architecture of Barcelona summarized in 30 minutes what has happened over 20 years, stating briefly: "Textile Roofs has delivered what it has promised." In 1995, the primary objectives were established as "providing fundamental practical information as well as presenting the state-of-the-art in textile roof engineering to facilitate technology transfer and to increase confidence." From 1995 to 2015, 1,479 participants from 69 countries covering 5 continents, certify that these objectives have been fully satisfied (Fig. 1). The balance of activity also includes 239 lectures by 93 speakers, 3 fabrication workshops, 7 student seminars and the Asia 2003 edition given in the Tongji University, Shanghai. These lectures and workshops covered the aspects that characterize tensile surface, together with the properties of the materials used and their environmental conditions, including some pragmatic concerns such as installation, cost, and durability. Increasing from 48 participants in 1997 to 100 in 2000, a grand total of 1,479 have attended "Textile Roofs" between 1995 and 2015 (Fig. 2). It is noteworthy that proportions between attendees from Germany, the rest of Europe, and the rest of the world have remained steady.

Textile Roofs has also facilitated the creation of -TensiNet, the multi-disciplinary association for all parties interested in tensioned membrane construction (<http://www.tensinet.com/>), master courses in Dessau ([\[institute.org/membrane-structure-programs.html\]\(http://www.institute.org/membrane-structure-programs.html\)\) and Vienna](http://www.ims-</a></p>
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(<http://mls.tuwien.ac.at/>) and the Berlin Academy of Architectural Membrane Structures, AcaMem (<http://www.acamem.de/>).

Nevertheless, the best indicator of the success of these workshops is the announcement of the upcoming 2016 edition: <http://www.textile-roofs.com/>.

## Homage to Frei Otto

Jürgen Hennicke, IL - University of Stuttgart & Vienna University of Technology.

Jürgen Hennicke summarised the ideas of Frei Otto (1925–2015) who passed away last March, after receiving the 2015 Pritzker Architecture Prize.

Interests of Frei Otto may be represented by the following figures: skeleton of Lyriospyris (Fig. 3); Bedouin tent (Fig. 4); Roman convertible roof (Fig. 5), and Chartres Cathedral 1194–1250, that strongly impressed him (Fig. 6). These works were captioned: "Most of the things we are doing today are not new" because they summarize most of the principles of nature and experimentation developed at the Institute for Lightweight Structures (IL) at the University of Stuttgart.

The Institute for Lightweight Structures was founded in 1964, and over the years, 150 people have worked there. They did not concentrate on a single thing, but - wanted to cover the entire field, searching the laws of Nature to create that which is new. The methodology was experimental, starting from

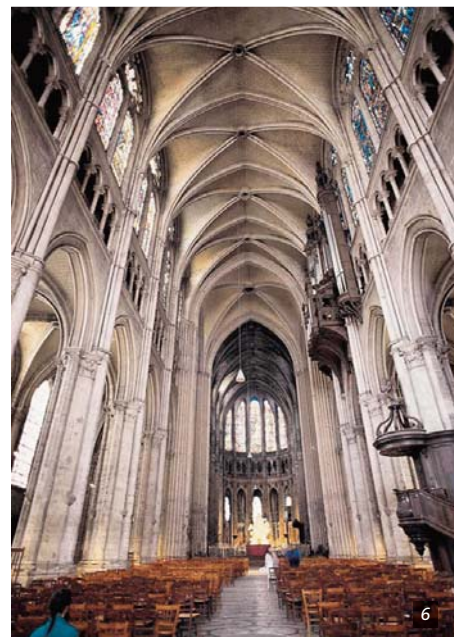
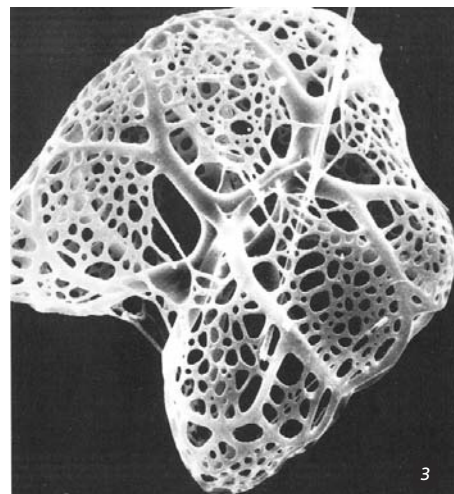


Figure 3. Skeleton of Lyriospyris (IL 33).

Figure 4. Bedouin tent.

Figure 5. Pompeii amphitheatre, 1st C.

Figure 6. Chartres cathedral 1194–1250.



Figure 1. World of Textile Roofs 1995–2015: 69 countries from Africa (3), America (11), Asia (22), Europe (31) and Oceania (2).

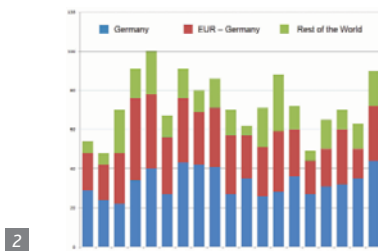


Figure 2. From 48 participants in 1997 to 100 in 2000, a total of 1,479 attended "Textile Roofs" between 1995 and 2015.



the process of form shaping based on physical modelling. Sources of inspiration were fisherman nets and spider webs, catenaries, suspended bridges, yurts, cantilevered systems, grid shells, air-inflated systems, and trees, among many others.

The research delved into construction methods that could be highly effective with very little material used to fulfil common objectives and demands of people, upgrading the built environment by avoiding conflicts with nature and ensuring our survival through sustainability, a fourth principle to be added to Marcus Vitruvius' (80/70 BC to 13 BC) philosophy: *firmitas, utilitas, venustas* – that is, solid, useful and beautiful.

A complete biography of Frei Otto is available at: [www.pritzkerprize.com/2015/biography](http://www.pritzkerprize.com/2015/biography)

### Computational modelling of lightweight structures

Dr. Dieter Ströbel, Technet GmbH:

<http://technet-gmbh.de/index.php?id=63&L=1>

Dieter Ströbel outlined fundamental aspects of the design concerning analytical form finding, static analysis, add-ons, and cutting patterns. Starting from the restrictions of physical modelling, he raised the problem of finding the form of a mechanically or pneumatically-stressed, double-curved surface made of a flexible material which can only bear tensile forces. He chose the force density method and expounded it step-by-step, showing possibilities and results.

The static analysis is based on a non-linear system that requires approximate values, material properties (simplified or extended with shear stiffness), and external loads provided by codes or tests. Relevant considerations include material directions, cables, struts, bending elements, and gas law (in case of pneumatic structures).

Automatic form-finding, patterning and optimization have been developed for balloons, car-shades, the Astana cable tower, silos, and textile halls.

And finally, patterning is needed because doubly-curved surfaces cannot be represented on a plane without distortion. In addition, planar strips have to be as straight as possible, the width of 2D strips should be as wide as possible, geometrically-developed surfaces have to be corrected, corresponding seam lines must have the same lengths, and cutting drawings have to be transferred onto the fabric. Dr. Ströbel concluded by stating that computer models must be correct, precise, complete, and generated in a fast manner for mass production, making use of information from diverse experts.

### The design of tensile architecture

DI Dr. Techn. Robert Roithmayr

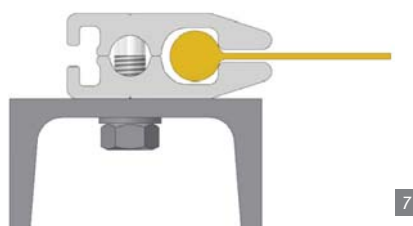
Robert Roithmayr presented the design process of tensile architecture based on the software "Formfinder Architectural Design System" (<http://www.formfinder.at>). He began by mentioning the players of the design, namely the building owner, the architect, the engineer, and the manufacturer.

He showed the potential of "formfinder" to sketch easily a design from scratch and recommended checking "formfinder" databases for types, built examples, details, and materials.

Useful advice was given regarding the influence of sags in the quantity of forces, deformations, and waterponding situations. Double curvature, the number of corner points, proportions, and directions of the mesh were also reviewed as project variables that influence the outcome.

Referring to details, three interesting options were mentioned:

- Tennect aluminium profiles for linear fixation of membrane borders (Fig. 7) ([http://www.tennect.com/fileadmin/files/tennect/specification\\_sheet\\_welt-section.pdf](http://www.tennect.com/fileadmin/files/tennect/specification_sheet_welt-section.pdf))
- The Tennect clamping and fastening system for point or linear fastenings that connects elements and the forces acting on them are adjusted in the direction of pull (Fig. 8) ([http://www.carlstahl-architektur.com/fileadmin//downloads/pdf/br oschueren/produkt/Carl\\_Stahl-TENNECT.pdf](http://www.carlstahl-architektur.com/fileadmin//downloads/pdf/br oschueren/produkt/Carl_Stahl-TENNECT.pdf))
- Carl Stahl X-LED light module system for architectural illuminations (Fig. 9) ([http://www.carlstahl-architektur.com/fileadmin//downloads/pdf/br oschueren/produkt/Carl\\_Stahl-X-LED.pdf](http://www.carlstahl-architektur.com/fileadmin//downloads/pdf/br oschueren/produkt/Carl_Stahl-X-LED.pdf))



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Figure 7. Tennect aluminium profiles.  
Figure 8. Tennect clamping and fastening system.  
Figure 9. X-LED light module system.

### Multifunctionality of membrane material

Dr. Ing. Thomas Stegmaier,  
ITV Denckendorf

[www.itv-denckendorf.de](http://www.itv-denckendorf.de)

A wealth of applications of textiles and fibres have been developed by the German Institutes for Textile and Fibre Research -Denckendorf (DITF). Textiles are soft, cosy, warming, resistant, and they act as barriers against impacts, weather, liquids, and chemicals. Dr. Ing. Thomas Stegmaier showed that they can also be hygienic, air cleaning, protective, form-changing, thermal insulating, fire retardant-, sound-absorbing, and they act as actuators and/or sensors.

The shielding effect against electromagnetic waves was highlighted. Humans are permanently exposed to artificially-generated electric and magnetic waves that may produce an increased rate of cell division, an impairment of the immune system, an increased risk of cancer, the malformation of embryos, the shifting of biological processes, interference with cardiac pacemakers, the sensation of flickering before the eyes (artificial snow), fatigue, nausea, insomnia, and the impairment of learning ability, among other effects. Conductive filaments with soot parts provide protection against high-frequency, electromagnetic waves that may be measured in terms of the quantitative shielding effect and the quality of sleep.

Another property of textiles for architecture is the capability of form change. Some of them admit bending, and therefore, they can be folded and rolled. This property facilitates the transport and installation process and allows for the use of retractable and pneumatic roofs and actuators for a wide range of applications. (Fig. 10).

Other interesting possibilities were mentioned, such as the incorporation of lighting, acoustically-effective textile walls, multilayer textile heating, and sensor technology used in floors to detect, for example, the presence, position and, movement of people.



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Figure 10. Buildair large scale portable hangar built with low pressure inflatable tubes.

## Msheireb - Heart of Doha, Qatar, retractable shade canopy

Thomas Hermeking, PFEIFER

<http://www.pfeifer.de/en>

Based on the old tradition of the "Seville awning" (Condesa de Lebrija House, Seville, Fig. 11), a 90x34=3.060m<sup>2</sup> retractable shade canopy has been engineered by Burns McDonald with sbp New York and Pfeifer in Doha (Fig. 12).

Some data:

- 30 Foldable strips composed of 30x36 =1.080 framed panels (2.80x1.40m) sliding through 60 main strands (2 main strands per strip).
- 80 to 400kN load per strand, depending on the load case (up to 29.6m/s wind).
- Serge Ferrari Précontraint 1002 membrane, gold colour on the top and white underneath. Due to the dimensions of the roof, the traditional lightweight flexible solution based on strips of fabric sliding by hand between ropes was converted into a series of stiff, aluminium-framed panels hung from steel strands, and operated by powered engines. Aluminium was chosen to frame the panels due to the ease of manufacture and maintenance, a good stiffness/weight ratio, and resistance to corrosion. In addition, the connection of the membrane is clear and adjustable with no need for in-situ welding of the membrane. Prior to the installation, a 1:1 scale mock-up was tested.

A comparison of the final solution with the traditional "Seville awning" calls to mind the statement made in a previous edition of Textile Roofs: "Changing the scale means much more than changing the size."



Figure 11. "Toldo sevillano". Condesa de Lebrija House, Sevilla.  
Figure 12. Retractable shade canopy, Doha.

## Flat tensioned building skins. A work show.

Dirk P. Emmer, Temme/Obermeier

<http://www.to-experts.com>

Dirk Emmer submitted several applications of flat-tensioned building skins used for climate protection and aesthetics. The building skin protects the inner structure and the occupants, regulates energy impact or loss, and reveals the architect's design intentions. Membranes for building skins provide lightness in weight, light-transmission control, large-span cladding, and a very long lifespan of the facility with low maintenance.

## Recent developments in composites

Farid Sahnoune, Serge Ferrari

<http://www.sergeferrari.com>

Serge Ferrari has recently come up with innovations in the composite-coated textile industry: the PRÉCONTRAIT TX30 with a design life of 30 years, featuring the Taxyloop process of recycling and the Batyline Aw series of micro-perforated, acoustic absorbents. The new fabric PRÉCONTRAIT TX30 is an application of the Crosslink technology that strongly bonds the PVDF top coat, thus providing:

- Higher resistance to photo-oxidation and micro-cracks,
- A more stable and smoother surface that prevents dirt in-grain,
- Easier and more efficient cleaning of the even surface.

To test longevity, accelerated weathering is needed, provided that the main ageing factors are considered. In this case, an accelerated weathering protocol has been established based on the photo-oxidation of the surface. In this way, it is possible to predict 30 years' behaviour in 7.500 hours (312,5 days). Surface evolution after ageing 30 years: the standard PVC/PVDF shows lots of cracks and exposed yarns. Minor traces of oxidation affect the surface of the PRÉCONTRAIT TX30 Crosslink PVDF. It was concluded that TX30 is an alternative to glass/PTFE because it is less sensitive to folding, is resistant to dirt, is competitive in price, and is recyclable with a warranty of up to 25 years.

## Two case studies

Dipl.-Ing. Martin Glass, gmp Architekten

<http://www.gmp-architekten.com/start.html>

In recent years, participants in Textile Roofs have become accustomed to expect the impressive presentations of Lena Brögger and Martin Glass. At the 20<sup>th</sup> anniversary of Textile Roofs, not to be outdone, Martin Glass presented the FC Krasnodar (Krasnodar, Russia)

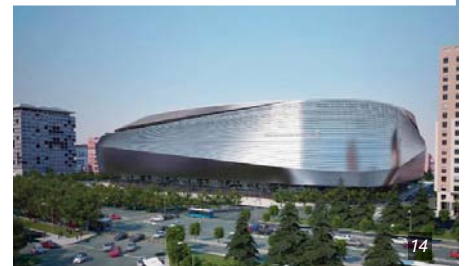


Figure 13. FC Krasnodar Stadium.

Figure 14. Santiago Bernabeu Stadium, Madrid

and Santiago Bernabeu (Madrid) stadiums. The FC Krasnodar stadium is a double-layered, radial-tensile roof that contains, not only the usual sound equipment, but also gas heaters that made the design, installation, and operation considerably more difficult (Fig. 13). The Santiago Bernabeu Stadium in Madrid was built in 1947, and was successively enlarged - in 1954, 1982, 1988, and 2002. The new design includes a retractable roof and a sheet metal wrapping that transforms the stadium into an autistic object with respect to the city (Fig. 14). It is another collaboration between gmp Architekten and Schlaich Bergermann und Partner.

## Gyor Sport Arena

Ms. Ildikó Györ, Graboplan Kft

<http://www.graboplan.hu/eng>

Graboplan Tent Manufacturer and Technical Confection Ltd is an Hungarian company especially interested in the design, manufacture, and installation of lightweight roofs above stadium tribunes, as well as tensioned membranes suitable for temporary and permanent use, such as sports and entertainment facilities, culture, shopping, industry, warehousing, military purposes, aircraft hangars, etc.

Ms. Ildikó Györ presented the recent realizations of the new Audi Arena in Györ and the refurbishment of the old one. The multi-purpose Audi Arena Györ is the newest and most modern hall in Hungary. (Fig. 15). Its construction was completed in November 2014, right before the Women's EHF European Handball Championships. The hall seats 5.500 spectators and its main structure is made of reinforced concrete and steel-trussed arches. The textile envelope is installed on a steel framework fixed to the concrete structure with adjustable, sliding brackets (to accept tolerances) and special sections to receive Keder sections and LED's. A special feature of





this envelope is the printing of the fabric that needs to be related to the cutting patterning in order to maintain the design.

The renovation of the old Arena was also based on wrapping the building with decorative panels, thus demonstrating, together with the new one, that textile façades are a new growing market for fabric architecture.

### World-leading at the HF welding arena

Mikael Wallin, Forsstrom High Frequency AB  
<http://www.forsstrom.com>

The lecture of Mikael Wallin was quite academic, as he defined and explained the basics of high frequency welding. High frequency welding is the joining of materials by supplying HF energy in the form of an electromagnetic wave (27.12 MHz) and pressure to material surfaces. PVC and PU are the materials most commonly used with HF welding. There is a wide range of HF welding machines. Each machine has been developed to suit different types of manufacturing. Knowledge and experience for every need is available. Machines can be stationary or travelling. As an application of the HF welding machines, Mikael Wallin also presented Forflexx and TubeFlexx. Forflexx makes it possible to join flexible, PVC and PU-coated fabrics with metal attachments for the production of truck and boat covers, tarpaulins, tents, structures, oil booms, and the universal corner plate developed with Formfinder and Horst Dürr. On the other hand, TubeFlexx is a production technology for faster and easier production of arched tubes.

Mikael finally invited the audience to visit Forsstrom's HF welding centre in Lysekil, Sweden where a complete machine line of HF welding machines, an eyelet press, cutting machines and a tensile tester are available. (see also page 24)

### The future in membrane design Modular systems

Frank Molter, Hightex  
<http://www.hightexworld.com>

After summarizing the characteristics of the most widely-used materials for structural membranes, Frank Molter opted decisively for modular systems because the current

challenges of membrane architecture are:

- To establish membranes as a standardised building material.
  - To increase the utilisation of membrane architecture by increasing the awareness of its advantages to a wider number of architects, namely: lightness in weight, self-cleaning properties (ETFE and PTFE), installation time, ease of replacement or repair, and energy efficiency of the product itself, among others.
  - To develop a module-based construction system, which permits numerous options.
- In order to reach these objectives, membranes have to be developed as a standardised product by developing a modular system, especially for façades. The energy efficiency that can be reached also needs to be demonstrated, and the disseminating of lectures on membrane materials in traditional education and research forums should be sought after. Three examples illustrated success in the aforementioned objectives: the Training centre of the Mountain Rescue Bavaria in Bad Tölz (Fig. 16), the "Miroiterie Flon" building in Lausanne (Fig. 17) and the Alnwick garden visitor centre and pavilion in Northumberland (Fig. 18).

### Sustainability of buildings with membrane façades

Thomas Reber, HP Gasser AG Membranbau  
<http://www.hpgasser.ch/en>

Thomas Reber dissertation was centred on façades, energy, low cost (Fig. 19), aesthetics, non-flammable materials, roofing (Fig. 20), sails, air-supported and industrial halls.

Figure 19. City Cube detail, Messe Berlin.



Figure 20. Amphitheatre Wiltz LU.

Figure 15. Audi Arena, Győr.

Figure 16. Training centre of the mountain rescue Bavaria in Bad Tölz.

Figure 17. "Miroiterie Flon" building in Lausanne.

Figure 18. Alnwick garden visitor centre and pavilion in Northumberland.

### Mechanical testing of membranes

Dipl.-Ing. Kai Heinlein, Karlsruhe Institute of Technology (KIT)  
<http://www.kit.edu/english>

Kai Heinlein reported on two research projects: TransMem and WindTent, which were based on testing membranes.

The TransMem project started from a new kind of textile fabric made of warp and weft mono filaments in unidirectional layers connected with an additional filament with 8 (warp) x 56 filaments per cm<sup>2</sup> that revealed, as was expected, different behaviour.

A biaxial test setup has been developed with an optical deformation sensor, spindle lifting, and climate heating equipment for a specimen size of 1x1m, tensile area 0.6mx0.6m, maximum load of 83kN/m, and optical strain measurement area 0.12x0.12m (Fig. 21). The results will be presented next year.

The WindTent project explores the behaviour of temporary and permanent tent halls enveloped by low pretensioned flat membrane surfaces submitted to wind gusts. The KIT tasks are the analysis of the material properties and behaviour (PVC-coated PET fabric type 0 of Sattler AG) and the modelling and measurement of the wind impact. Regarding the viscoelastic material behaviour, it has only been measured at the PVC coating due to the shear. On the other hand, the damping of PVC coated PET fabric resulted fast (ratio  $\approx 0,078$ ) and the steady-load tests did not reveal any effect on the material properties. Other conclusions of the research concern the need for the development of new experimental setups and programs.



Figure 21. Biaxial test set up developed at KIT.

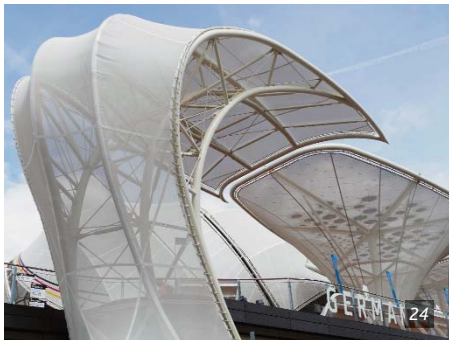
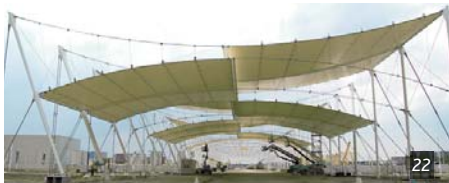


Figure 22. Cardo-Decumano-Secondario-Tornellerie: 70.000m<sup>2</sup> under construction.

Figure 23. Cardo-Decumano-Secondario-Tornellerie: 70.000m<sup>2</sup> at work.

Figure 24. German Pavilion: 2.050m<sup>2</sup>

Figure 25. Kuwait Pavilion: 2.000m<sup>2</sup>

### Special guest lecture **EXPO Milano and its membrane structures.**

Dipl.- Ing.(FH) Frank Höreth,  
TAIYO EUROPE GmbH

[www.taiyo-europe.com](http://www.taiyo-europe.com)

Catalogue of Taiyo Europe pavilions for the EXPO 2015: "Feeding the planet. Energy for life". (Figures 22 to 25). (see also page 18)

### Student Project Week

"Roof for the main entrance of the Berlin Museum of Technology"

The subject was a roof for the main entrance of the museum to make it more visible. The final presentation took place at the closing of the Workshop. There were three proposals:

- 1 Alessandra Bruè & Pauline Chavassieux were inspired by the Leonardo da Vinci design shown in the museum (Fig. 26). Two triangular wings made of slender ribs and pretensioned membrane mark and protect the entrance, flying and contrast with the brick masonry of the façade.
- 2 Ana Duque, Santiago Garcés & Carlos Novella resorted to three saddles for signalling the approach to the museum from Trebbiner Strasse (Fig. 27).
- 3 Sebastián Gallardo & Antoine Taloid were inspired (in their plan) by the three circles of the logo of the museum (Fig. 28). Their design was the largest and most structurally-demanding of the three.

Prof. Dr.-Architect Josep Llorens  
School of Architecture, UPC, Barcelona  
 [ignasi.llorens@upc.edu](mailto:ignasi.llorens@upc.edu)

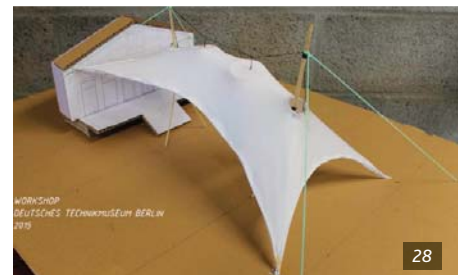


Figure 26. Alessandra Bruè & Pauline Chavassieux.

Figure 27. Ana Duque, Santiago Garcés & Carlos Novella.

Figure 28. Sebastián Gallardo & Antoine Taloid.

The Twenty-first International Workshop on the Design and Practical Realisation of Architectural Membrane Structures will be held on 2-4 May 2016.

Its format will be similar to that of TR 2015, with seminar-style lectures and hands-on activities. It will be preceded by the student seminar and sponsored by AcaMem, gmp, Serge Ferrari, KIT, Carl Stahl, Technet and TensiNet: <http://www.textile-roofs.de>.



**TensiNet**



## TENSINET COST Action TU1303 SYMPOSIUM 2016

NOVEL STRUCTURAL SKINS IMPROVING SUSTAINABILITY AND EFFICIENCY THROUGH NEW STRUCTURAL TEXTILE MATERIALS AND DESIGNS  
WEDNESDAY 26, THURSDAY 27 AND FRIDAY 28 OCTOBER 2016 NEWCASTLE UNIVERSITY, UNITED KINGDOM

The TensiNet - COST Action TU1303 Symposium 2016 will be organised by the TensiNet Association, COST Action TU1303 Novel Structural Skins and Newcastle University as hosting university.

The symposium will be the fifth of a series that

began in Brussels in 2003: *Designing Tensile Architecture*, and continued in Milano in 2007: *Ephemeral Architecture: Time and Textiles*, Sofia in 2010: *Tensile Architecture: Connecting Past and Future*, and in Istanbul in 2013: *[RE]THINKING Lightweight Structures*.

The theme of the COST Action TU1303 (2014-17) is *Novel structural skins - Improving sustainability and efficiency through new structural textile materials and designs* and will also be the leading theme of the upcoming Symposium.

The 3-day event will start with an 'open session' (Wednesday afternoon and evening) to attract an audience of architects, engineers, academics and professionals involved in the design of *Novel Structural Skins*. Prominent experts in the architectural and engineering world will present

inspiring projects to demonstrate to the audience the multitude of possibilities that lightweight structures have.

Since the COST Action TU1303 will be in its last year of funding, members of the Working Groups will present state of the art papers on recent research and interdisciplinary work performed in the frame of the COST Action. The priorities of the Working Groups are described below. WG1 'New applications of structural skins and new concepts' has 3 sub-groups (a) Adaptable skins and structures, (b) bending-active structures and (c) fabric formwork. Various topics are considered, such as methods for adaptable tensioned structures, advanced systems capable of changing properties, such as light transmission, light reflection and/or shape, shell structures made with membrane scaffolding, hardening tensioned membranes for composite or shell structures with textile reinforcement and self-tensioned membrane structures with an advanced interaction between bending and tension elements.

WG2 'Sustainability and Life Cycle Analysis of structural skins' is focusing on novel structural skins in which structural membranes and advanced tex-





Figure 1. Happy faces during the award ceremony at Techtextil 2015.



Figure 2. 1st Prize in the Macro Architecture Category - Aviary at Bujalcayado, Guadalajara by Leyre Mauléon (ETSAM)

## SPECIAL GRANT FOR THE 13<sup>TH</sup> STUDENT COMPETITION “TEXTILE STRUCTURES FOR NEW BUILDING” 2015

The 'Textile Structures for New Building' student competition is organised every two years within the framework of the Techtextil trade fair. The brief states: "This competition is designed to identify innovative thinking and innovative solutions to problems, featuring construction projects capable of concrete realisation which use textiles or textile-reinforced materials. A further aim is to encourage students and new entrants to the professions. The competition is further intended to strengthen contacts between the younger generation, the universities, the technical-textiles industry and broad sections of the building industry."

The student competition, on the one hand, invites students to work in their studios with textiles and design textile buildings, and on the other hand, offers the up-and-coming generation to compete at an international

level. The student competition runs in a successful and professional manner since several years. The TensiNet Association is a dedicated sponsor. This year the 13<sup>th</sup> edition of the 'Textile Structures for New Building' student competition took place. The competition received many entries, mostly from the EU. It was a pleasure to go through the quite different pieces of work. Most contributions contained inspiring elements, widening the applications offered by weaving, integrating multi-physics or hybrid construction, showing creativity, innovation in appearance and change of scale as well as technical progress and poetic interpretations.

In its meeting of the 6<sup>th</sup> of March 2015 the jury decided to retain the following prize categories: Category 1: Macro Architecture; Category 2: Composites and Hybrid Structures; Category 3: Material Innovation

Overall, the jury awarded 3 first prizes (1 prize of €1.500 for each category), 3 second prizes (1 prize of €1.000 for each category), and 1 third prize (€500 for category 2). A special mention has been awarded to a project in the category Micro Architecture. The jury congratulates the winners and wishes them a lot of success. The jury thanks Techtextil and especially Michael Jänecke for the effort put into the organisation of this fascinating student competition. New students are already invited to take part in the next 'Textile Structures for New Building' student competition scheduled for 2017. The list of winners and a summary of the projects can be downloaded at [http://www.tensinet.com/files/Techtextil\\_Competitions/TechTextil\\_competition\\_2015\\_EN.pdf](http://www.tensinet.com/files/Techtextil_Competitions/TechTextil_competition_2015_EN.pdf)

*Prof. Dr.-Ing. Marijke Mollaert  
Chairperson of the Jury, April 2015*

tiles are the pivotal elements of the eco-innovation processes. Several aspects are investigated, such as environmental impacts (e.g. embodied energy) being part of life cycle analysis' of membrane structures, the lifetime of temporary and removable buildings, the end of life treatment of fabrics and foils.

WG3 'Building physics and energy performance of structural skins' considers the thermal and acoustic performance of structural skins. Single layered, multi-layered and adaptable membrane and foil structural skins are analysed for permanent and semi-permanent building enclosures in diverse climates and for a wide range of functions. Increasingly these require a controlled internal environment, which necessitates enhanced thermal performance of the skin.

WG4 'Materials and analysis' is focusing on the characterisation and advanced simulation of membrane and foil materials and advanced simulation of their structural application. Different experimental methodologies and results from round robin exercises are discussed and compared with the outcomes from numerical simulations that partners are currently conducting. A key objective is to establish the coupling between simulation and material characterisation so as to enhance the optimal application of membrane and foil materials for buildings. The main research topics are (1) measurement of the biaxial tensile stiffness, shear stiffness, uniaxial and bi-

axial tear properties of a range of textile and foil materials; simulation of these tests with the tools used for the analysis of building skins, (2) the interpretation and use of test data and the collection of typical material data and (3) the application of Stochastic Finite Element Analysis, adopting probabilistic approaches to the analysis of building skins.

WG5 'From material to structure and limit states: codes and standardization' considers the different regulations for the design of structural membranes throughout Europe. A common standardised approach is needed. The WG investigates the design rules based on a semi-probabilistic approach, dealing with the integration of uncertainties of tools and parameters like for models and materials. The WG focuses on the definition of specific limit states where not yet existing, like for inflatables, in view of the need to evaluate partial safety coefficients. Additionally, research results concerning load characterisation (wind loading on complex shapes, interaction with snow deposition etc.), reduction factors for joints, safety coefficients etc. are collected and compared.

Abstracts with respect to the above mentioned topics have to be uploaded before the deadline of October 15<sup>th</sup>. Up to date information is available at <http://conferences.ncl.ac.uk/tensinet2016>.



MILANO

## FEEDING THE PLANET, ENERGY FOR LIFE

*For the realisation of the EXPO MILANO 2015 site quite a few of the TensiNet members were involved from concept phase, over production of the membranes until installation on site. Contributions from formTL (engineering office), Mehler Technologies (Material producer), Sioen (Material producer), Haraoka (Material producer), Taiyo Europe (Manufacturer and fabricator) and Canobbio Textile Engineering (Manufacturer and fabricator) were brought together for this TensiNews 29 edition.*

### Context

The Universal Exposition is a fair that takes place every 5 years at an assigned country. The scope of the event is to choose a theme and to gather as much countries as possible in one place, so each can build their pavilions and show their interpretation of the proposed theme. From the first exposition made in London in 1851, the Expo has left its footprints in the hosting city, for instance the Cristal Palace (London 1851), Biosphere (Montreal 1967), and the Eiffel tower (Paris 1889), structures that are now famous worldwide.

This year Milano is the hosting capital of the Expo with the theme "Feeding the planet, Energy for life" which provides an opportunity for the entire world to reflect and seek solutions to the production of food, and how we can make this processes more sustainable.

The Expo 2015 started on the 1<sup>st</sup> of May and will be open until the 31<sup>st</sup> of October, there are more than 140 countries and 20 million visitors are expected. The huge exposition area is built like an ancient Roman village (Cardo and Decumano), a main street, with the country pavilions along both sides of the avenue, and a second street, crossing the site from North to South.

Tensile construction is the favoured design feature at the Expo 2015 – the exposition could as well be a huge showcase for fabric architecture.

Lightweight pavilions are not only erected for a whole range of countries but also for organisations which are in the broad sense related to "food". As



the climate in Milan can be in summer quite hot also walkways, resting places and garden areas are covered by fascinating tensile constructions.

Taiyo Europe was one of the first foreign companies to arrive at the Expo area; they signed their first contract with the client ConExpo 2015 S.c.a.r.l. in July 2013, the scope of this project was to cover the two main streets (Cardo and Decumano) (1). After this project, other projects came up: the "Pergole e Spalliere" (2), with their client ConExpo 2015 S.c.a.r.l., which are structures in garden areas in order to protect visitors from the sun using membranes and trees; the "Algae" project (6), with the client Ecologic-Studio LTD, an innovative canopy where the shadow is created by the photosynthesis of the algae; the canopy of the Japan Pavilion (7), with the client Takenaka Europe GmbH; the German (3), Kuwait (4) and Mexico (5) pavilions with the client Nussli.

Taiyo Europe is located in Germany near Munich and is the subsidiary of the Taiyo Group, which is one of the biggest membrane companies in the world specialized in membrane and ETFE architecture. As market leader and company with decades of tradition, Taiyo is proud to have contributed to the EXPO 2015, where people of different countries, different religions and different cultures can meet in one place and discuss about different themes peacefully. Taiyo Europe, together with other companies, was involved in the first 7 projects described.

## DECUMANO AND CARDO PROJECT (Taiyo Europe and Mehler Technologies)

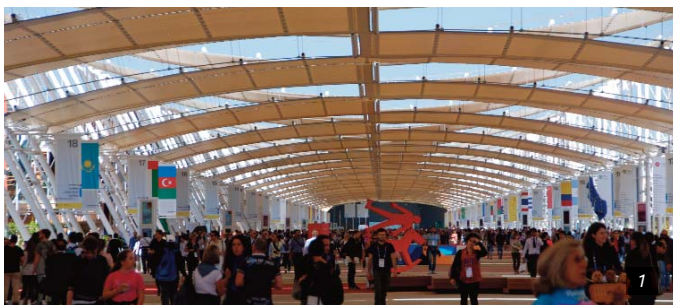


Figure1. Drawings and images of the covered walkways © Taiyo Europe

Also for Mehler Technologies it was challenging to be part of such an aspiring and huge project that is visible from a distance of 400km. Besides the big conglomerations a satellite is only able to see the Chinese Wall as single building – in this sense the ephemeral structure

of the fabric shading system in Milano competes with a thousands of years old linear structure on the other side of the world. Mehler Technologies provided the material for the huge sun shading systems of the Expo 2015 paths.

### General description

In ancient Rome, the main street that crossed the village from East to West was called "Decumano" and the perpendicular one from Nord to South was called "Cardo". These are also the names of the two main walkways of the Expo exhibition area. As Milan gets quite hot during summer the designers of the Expo area decided to cover the two axes in a way that the old Romans would certainly have appreciated as well: it seems that the fabrics are only loosely fitted to the grid system. Taiyo Europe was chosen to cover these two streets which together are around 1.700m long with a covered surface close to 70.000m<sup>2</sup>. This structure represents one of the biggest PVC roofs in Europe.

Moreover the street called "Percorso Secondario", which connects the Decumano and the West access was covered. This is a structure made of ETFE cushions for a total surface of 2.000m<sup>2</sup>. The Decumano is composed by a modulus of around 50m that is reproduced 30 times, one after another, interrupted only one time at the intersection with the Cardo, which is also composed by such modulus. The Secondario structure is a 200m long strip. At the end of it we can find the West access that has a dimension of around 100m x 20m.

### Project overview

The structure is composed by more than 400 steel columns of 17m height; supporting and stabilizing cables are connected to the



## PERGOLE E SPALLIERE PROJECT



Figure 2. Covered garden areas "hortus"  
© Taiyo Europe

### General description

You can find this project at the "hortus" spaces that are scattered around the exhibition area. The world "Hortus" comes from the ancient Latin and means garden, in fact these areas imitate the typical gardens that visitors can find in Italy. There are more than 40 structures installed in 6 different "hortus", where visitors can take a break from the sun while tasting the typical Italian food or picking the fruits directly from

(Taiyo Europe)

the trees growing around the "Spalliere". This project was the last project completed by Taiyo Europe at the Expo, just a few days before the inauguration.

### Project overview

The Pergola structures are composed by different modulus. In general, each composition is built with steel columns supporting the beams where the cables are connected. The roof, made of PVC-Mesh membrane, has a total surface of 1.600m<sup>2</sup> distributed in more than 270 panels. The Spalliere structures have a pentagonal shape without membrane; the walls are made with steel cables where the rampant trees can easily grow up. Taiyo Europe's scope of work was the delivery and installation of the steel structure and PVC membrane.

Function of the building:	Covering the garden area
Type of application of the membrane:	Roof
Client:	ConExpo 2015 scarl
Designer:	Arch. Franco Zagari
Tensile membrane contractor:	TAIYO EUROPE GMBH
Project manager:	Andrejus Cernysevas / Site manager: Simone Toso
Consulting engineer for the membrane:	Maffei Engineering Spa
Material manufacturing:	PVC: Serge Ferrari
Covered surface area:	PVC: 1.600m <sup>2</sup>

columns and more than 2000 steel beams were installed between the cables in order to support the membrane. Taiyo Europe's scope of work was on the one hand, to install the steel provided by the client and on the other hand to install more than 300 PVC panels of Mehler fabric, some of them processed in Europe and some in the sister company in Australia; one of the biggest challenges was to coordinate the work without blocking the other companies that were working on the pavilions area. The Decumano was, in fact,

the only access to the working areas of all the country pavilion, so during the most busy phase, more than 9.000 people were working on the entire Expo jobsite. The membrane used to cover the Decumano, Cardo and Percorso Secondario is a special PVC material with two different colors: white on the top and beige on the bottom. This came from a study of the "Politecnico di Milano" that investigated how to create a good microclimate under the membranes in order to assure the best comfort for the visitors. The asymmetrical shape of the



## GERMAN PAVILION (Taiyo Europe)



Figure 3. Iconic membrane trees of the German pavilion © Taiyo Europe

### Project overview

Taiyo Europe's scope of work was the delivery and the installation of the PVC mesh and ETFE membrane. Each tree is composed by two panels that are connected at the floor level; the inner panel is underneath the pavilion and it is protected by a second ETFE "skirt" where it is possible to project images and pictures. The first and the last tree are slightly different because the starting tree is completely outside of the structure and composed by a single PVC panel; the tree n.5 is the biggest one and, with its stair, represents the passage for the visitors from the ground floor the first floor. If you look closely at the central blossom you will see three long membrane strips, a black, a red and a gold one: the German flag. The organic, flowing design of the pavilion creates and unforgettable image.

### General description

The German pavilion tries to reproduce the landscape of the typical rural areas of its country; stylized trees emerge from the ground alongside the external exhibition area. The roofs of the trees resemble tree blossoms and they not only protect visitors from the sun and the heat, but also give a stylish edge to the whole pavilion. The 6 trees, with an average height of 12m, are composed by a steel structure which replicates the trunk and the branches of a tree with the PVC mesh giving a final modern tree shape. Four of these trees are surrounded by an ETFE "skirt" around the trunk.

Function of the building:	Show area
Type of application of the membrane:	Architectural shape
Client:	ARGE
Designer:	Schmidhuber Partners
Tensile membrane contractor:	TAIYO EUROPE GMBH
Project manager:	Andrejus Cernysevas / Site manager: Simone Toso
Consulting engineer for the membrane:	Maffei Engineering Spa
Material manufacturing:	PVC: Serge Ferrari
Covered surface area:	ETFE: 250m <sup>2</sup>

structure has this objective, in fact the "up and down" structures of the membranes not only allow the air to circulate but also helps avoiding the "tunnel effect". It is good to see tensile structures in a way that seems natural – indeed a straightforward approach to this ephemeral structure. Here it is easy to imagine that there will be a second life for these fabrics after the Expo closes its gates. If

the Expo organization doesn't leave the Decumano on site for future uses, Taiyo Europe, and Mehler Technologies have ideas at hand to recycle the membrane as shelters for refugees. As the structures at the Expo follow a rather simple cutting pattern, it would be easy to recycle the material for tents.

Figure 1. Drawings and images of the covered walkways © Taiyo Europe

Function of the building:	To cover the main streets
Type of application of the membrane:	Roof
Client:	ConExpo 2015 scarl
Designer:	Ufficio di piano Expo 2015, Studio Tecnico Majovicki
Tensile membrane contractor:	TAIYO EUROPE GMBH
Project & Site manager:	Simone Toso
Consulting engineer for the membrane:	Maffei Engineering Spa
Material manufacturing:	PVC: Mehler Technologies GmbH, Valmex FR 1000 Mehatop F, Type II
	ETFE: Pati SPA
Covered surface area:	PVC: 68.000m <sup>2</sup> / ETFE: 2.000m <sup>2</sup>

## KUWAIT PAVILION (Taiyo Europe)



Figure 4. Sails referring to the landscape of Kuwait © Taiyo Europe

### General description

The theme of the Kuwait Pavilion is "Challenge of Nature" and the idea of the designers is to show visitors how water, food and energy can be a challenge in a country like Kuwait. Sand floors and huge sails, which replicate the typical landscape of this fascinating country, build the entrance of this pavilion. In front of the pavilion visitors walk between 8 PVC mesh sails that are beige during the day and multi-colored during the night, thanks to LED lights installed at the base of each structure. After crossing the sails, the visitors arrive at the entrance door of the pavilion, a door that is actually a waterfall. Then they will enter a structure made of PVC, where the "power of water" is explained.

### Project overview

This pavilion is characterized by two different PVC membranes, each with different colors and shapes, which make this pavilion very unique. The central part, characterized by a big saddle shape, is built with a PVC material in the particular onyx color; the sails (8 on the frontal part and 4 in one side) are realized with a PVC mesh material. Taiyo Europe was in charge of the delivery and installation of the membrane. The biggest challenge was the installation of the saddle composed by only one panel of more than 600m<sup>2</sup>, considering that this panel is supported only in two points (the front arch and the back portal) and that the space on site was very limited.

Function of the building:	Show area
Type of application of the membrane:	Architectural shape
Client:	Nussli SRL
Designer:	Studio Italo Rota & Partners
Tensile membrane contractor:	TAIYO EUROPE GMBH
Project & Site manager:	Simone Toso
Consulting engineer for the membrane:	Maffei Engineering Spa
Material manufacturing: PVC:	Serge Ferrari
Covered surface area: PVC:	2.000m <sup>2</sup>

## MEXICO PAVILION (Taiyo Europe)



Figure 5. Pavilion as a sculpture made of PVC mesh printed leaves © Taiyo Europe

### General description

The idea of the architect Francisco López Guerra was to celebrate the most important cereal of Mexico, thus the shape of the pavilion recreates a big corn cob. Taiyo Europe participated in this challenge covering the structure with 19 PVC mesh printed leaves. We were also in charge of the delivery and installation of the ETFE facades, the ETFE cushions covering the dome above the entrance sculpture, as well as the PVC velaria placed on the restaurant on the roof of the pavilion. This was the most complex pavilion built by Taiyo. Its complexity was due to the fact that the access area around the pavilion was very small, in fact, a big part of

the installation had to be made through rope access. Another challenge was the clients' request for different types of materials, that is PVC printed mesh, PVC full material and ETFE.

### Project overview

As mentioned before, the external skin of the pavilion consists of 19, 15m height leaves, each one with a different shape and a different PVC printed mesh. Behind the leaves hides the façade of the building and most of it was made with a double ETFE layer provided and installed by Taiyo. The ETFE is also used on the roof but in this case, 6 triple layer cushions cover the entrance dome.

Function of the building:	Show area
Type of application of the membrane:	Architectural shape
Client:	Nussli SRL
Designer:	Francisco Lopez Guerra
Tensile membrane contractor:	TAIYO EUROPE GMBH
Project manager:	Peter Herbert / Site manager: Simone Toso
Consulting engineer for the membrane:	Maffei Engineering Spa
Material manufacturing: PVC mesh:	Serge Ferrari
Material manufacturing: ETFE:	Nowoflon ET
Covered surface area: PVC mesh:	3.000m <sup>2</sup>
Covered surface area: PVC full material:	150m <sup>2</sup>
Covered surface area: ETFE façade:	1.000m <sup>2</sup>
Covered surface area: ETFE cushions:	250m <sup>2</sup>

## FOOD DISTRICT BIOREACTOR ALGAE PROJECT (Taiyo Europe)



Figure 6. Bioreactor made of 2 layered ETFE cushions © Taiyo Europe

This futuristic project designed by ecoLogicStudio wants to open new doors to the bio-digital architecture. A controlled flow of energy, water and CO<sub>2</sub> generates not only a natural process of photosynthesis, but also allows the algae to grow.

This is the perfect combination because the algae creates a natural shadow underneath the ETFE roof. Taiyo Europe's work comprised the design of the 2 layered ETFE cushions of this bioreactor.

This project, with a surface of 80m<sup>2</sup>, was the quickest project done by Taiyo at the Expo: the design, fabrication and installation were completed in less than 3 weeks.

The surface is covered with 27 double-layered ETFE cushions, welded in a way that the water filling them flows along a "zig-zag" way.

Function of the building:	Show area
Type of application of the membrane:	New sustainable architectural shape
Designer:	Ecollogicstudio LTD
Tensile membrane contractor:	TAIYO EUROPE GMBH
Project manager:	Andrejus Cernysevas / Site manager: Simone Toso
Consulting engineer for the membrane:	Maffei Engineering Spa
Material manufacturing: ETFE:	Nowoflon ET
Covered surface area: PVC:	80m <sup>2</sup>



## JAPAN PAVILION

(Taiyo Europe & Sioen)

### General description

This pavilion is one of the biggest pavilions at the EXPO, but for Taiyo it represents the smallest project. Their Our scope was to deliver and install the canopy covering the central court and the membrane covering the entrance handrail. More than the form or aestheticisms, for this area of the Japanese Pavilion the architect looks at the physical and functional characteristics of a tensile architecture solution.

### Project overview

The space is covered with a lightweight membrane construction made of white PVC-PES membrane. The roof structure on the central court has a double slope shape and is built from rectangular and round pipes. This structure is fixed on the perimeter directly on the roof of the pavilion and is supported by 4 columns. The total weight of the steel

structure is approx. 19 tons. The whole area is covered by a one-piece assembled surface made out of FLUOMAX™ T2 fabric. The almost square covered area size is approximately 540m<sup>2</sup>. By means of white-painted clamping plates made out of steel, the membrane is held along the steel structure. The agreeable white tone of the SIOEN fabric used for this project is generating a particular, suffuses and pleasant translucency above the event area, which create a satisfying well-lit ambience and protect visitors from direct sunlight and weather. Two opposing ramps lead directly to the Event Plaza. When the visitor access the pavilion, they find a

handrail covered by a PVC membrane, the scope of this handrail was to create a kind of labyrinth before reaching the main part of the exposition. Edged these ramps with balustrades made of glass, the sections between these handrails were also covered with the same white PVC fabric to create weather protection and a unique

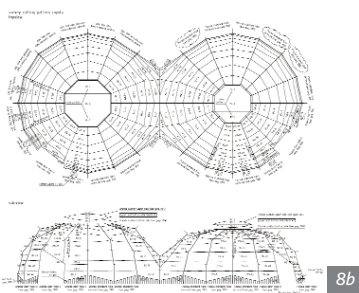
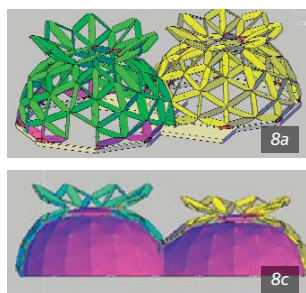
Figure 7a Roof structure on the central court and wooden facade © Sioen

Figure 7b Membrane covering the entrance handrail © Taiyo Europe

smooth light-paths between the corridors below those elements. The glass parapets serves also as supporting structures on which the fabric is clamped by means of stainless steel strips.

Function of the building:	Show area
Type of application of the membrane:	Architectural shape
Client:	Takenaka Europe GmbH
Designer:	Atsushi Kitagawara Architects
Tensile membrane contractor:	TAIYO EUROPE GMBH
Project manager:	Claudia Kraus / Site manager: Simone Toso
Consulting engineer for the membrane:	Maffei Engineering Spa
Material manufacturing: PVC:	Sioen Coating, Fluomax range, product code: T2106F
Covered surface area: PVC:	540m <sup>2</sup>

## COPAGRI PAVILION (formTL and Canobbio)



COPAGRI, an association of agricultural producers brings Italian farmers together. On the expo they present their approach for the use of natural food, all linked with the Italian tradition, on a marketplace, a hall for cooking presentations, and two rooms for tasting Pizza and Ice-cream 100% made of organic ingredients. For the inside a transparent PVC foil is attached to the nodes of the primary structure. The seam layout corresponds to the timber structure.

The top is closed with white PVC-polyester cushions. Between these cushions and the foil is a gap that allows for natural ventilation, and along the bottom line is a PVC-polyester mesh that allows for ventilation as well. After the Expo, the pavilion will be dismantled and can be used at another place. It covers an area of 560m<sup>2</sup>. The lower part made of 800µm Cristal foil and Serge Ferrari mesh FT381 has a surface area of 860m<sup>2</sup>, the two top cushions made of Serge Ferrari 402 S2 have a surface area of 115m<sup>2</sup>.

Figure 8a: Isometric view timber model © formTL

Figure 8b: Seam layout © formTL

Figure 8c: Section with foil and membrane model © formTL

Figure 8d: Pavilion see from the outside © Canobbio

Function of the building:	Exhibition Pavilion
Architect:	EMBT
Membrane contractor:	Canobbio Textile Engineering s.r.l.
Membrane Engineering:	formTL ingenieure für tragwerk und leichtbau gmbh
Supplier of the membrane material:	Serge Ferrari
Membrane Installation:	Canobbio Textile Engineering s.r.l. and Montageservice LB GmbH
Supplier of the membrane material:	Serge Ferrari
Material Cushion:	Serge Ferrari Précontraint 402 N (HT)
Inner foil:	Texout Cristal Plus 800
Mesh:	Serge Ferrari Solits FT 381
Structure: Membrane domes fixed to timber structure and pneumatic cushions	
Surface area:	560m <sup>2</sup>

## CHINA PAVILION (formTL, Canobbio and Hiraoka)

The China Pavilion wants to convey the Chinese concept and meaning of 'Field of Hope' through the creation of a curved roof that floats on a wheat field, and provide a platform for the presentation of China by communicating the importance of sustainable development.

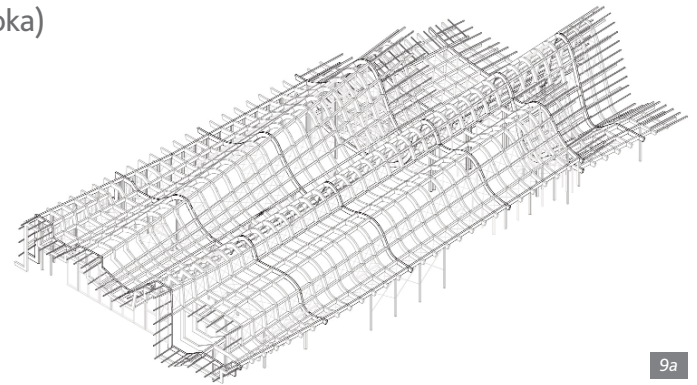
### Project overview

It is a contemporary structure that includes an area of about 3.000 to 4.000m<sup>2</sup> including spaces used for exhibition and auditorium. A scenic passage through the wheat field and the auditorium includes both a bridge and suspended walkways. The roof is manufactured with high translucency (64%) polyester PVC Japanese fabric. This fabric, SX 1800 H from Hiraoka & Co. Ltd, is particularly suitable to improve natural lighting and provide good weather resistance. The roof was designed as an element that floats on the 'Field of Hope' with natural light and elegant shapes that combine exhibition spaces with the platform. The architectural concept of the cover is designed as a wooden structure and was inspired by a series of scenic views, both rural and civic. The civic and rural shapes are connected longitudinally by purlins that form a flat surface. One of the characteristics of Chinese traditional buildings consists in the elegance of the shape obtained by the use of curved surfaces. The importance of aesthetics in Chinese architecture is in fact underlined in the northern and southern ends of the covering, which seem gently hanging. It has been designed a mixed structure with steel and wood with great spans, requested by the extensive public spaces within the pavilion. The project solution must then create wide spaces and, at the same time, include structural forms that should be efficient and elegant. Moreover, it was given great importance to the construction sequence, especially considering the installation time that were very tight. A system of eco-friendly bamboo panels was designed parametrically and based on the undulated surface of the cover. The system of panels in bamboo was configured so that the natural light illuminates the exhibition space. The roof structure consists of 38 curved wood or steel rafters. The roof is covered between the rafters 2 and 35 with membrane panels.

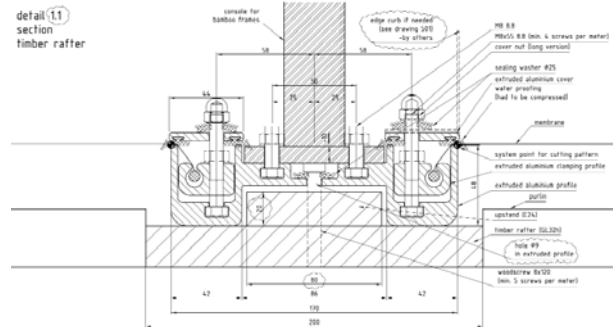
An extruded aluminium profile is fixed on the rafters. The membrane is attached with a keder profile and covered with an aluminium strip. In the middle of the extrusion profile are two rails which allow to attach the bamboo frames sitting over the membrane layer.

The membrane panels are strips spanning between 2 rafters and running from one end to the other end. The form was found from a flat strip, which got then its equilibrium under prestress and self weight which created very low sags. The sharp edges were formed with tubes under the membrane. Edges to the outside are pressing against the membrane, edges towards the inside have a pocket which is tensioning the membrane. In lower areas mesh membrane is inserted in the panels over a gutter to allow the drainage. Two reference panels have been used for the analysis under snow and windload. The maximum deflections are around 13cm.

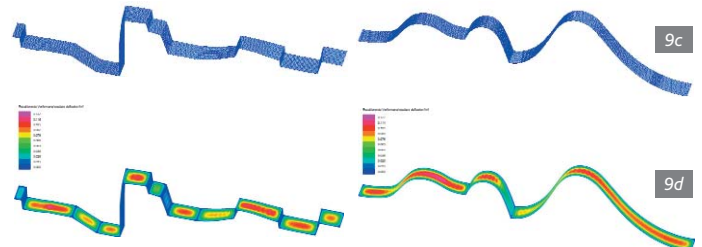
The bamboo panels sitting on top of the rafters are covering the membrane surface which can hardly be seen. From inside the high translucent membrane plays with the light and the shadow of the bamboo.



9a



9b



9c

9d



9e

9f

Figure 9a: Primary structure © formTL

Figure 9b: Extrusion profile © formTL

Figure 9c: analysed reference panels 02-03 and 23-24 (isometric view) © formTL

Figure 9d: deflections in the reference panels © formTL

Figure 9e: Membrane and bamboo installation © Canobbio

Figure 9f: Pavilion with membrane cladding and bamboo panels © formTL

Function of the building:	Exhibition Pavilion
Architect:	Studio Link-Arc LLC, Tsinghua University
Main contractor:	Bodino Engineering s.r.l.
Tensile membrane contractor:	Canobbio Textile Engineering s.r.l.
Membrane Engineering:	formTL ingenieure für tragwerk und leichtbau gmbh
Supplier of the membrane material:	Hiraoka & Co. Ltd
Material:	PVC-coated polyester SX 1800 H (high translucent)
Structure:	Membrane strips in-between timber and steel rafters
Covered area:	1860m <sup>2</sup>
Surface area:	2585m <sup>2</sup>

## FERRERO PAVILION (Mehler technologies)

As „Feeding the Planet - Energy for Life“ is the theme for this year's Expo, Ferrero is present as well. In their pavilion, which is dedicated to the company's social initiatives, the fabrics of Mehler Technologies add to the playful outlay of the structure. Here as well, recycling plays a crucial role in the concept. The Mehler fabrics will be carefully dismantled after the show. Ferrero plans to reuse all of the material in one of the educational centres of their Social Enterprise.



## MALAYSIA PAVILION (formTL and Canobbio)

The Malaysian pavilion with the theme "Towards a Sustainable Food Ecosystem" has the shape of 4 seeds coming from the rain forest. They are closed and open with timber beams, wooden bridges and material made of rice husk. From seed 1 to 4 the visitor travels with regard to a sustainable food eco-system:

- Seed 1 "Our Home – For Now and the Future" (Diversity of Malaysia)
- Seed 2 "Haven of Biodiversity" (Protect and Preserve)
- Seed 3 "Seeds of Change" (Present and Future)
- Seed 4 "Colours of Malaysia" (Music, Arts & Culture)

The membrane is nodal fixed to the timber structure and linear fixed along the lower edge and along openings. A special detail has been created in order to minimize the dimension and have an internal surface with just membrane to allow projections without visible steel details. The distance between the timber structure and the membrane is 150mm.

Seed 1, 2 and 4 have been patterned with longitudinal strips. Seed 3 is elliptical in section. Due to the material width it had to be patterned with single rectangular pattern. Seed 4 has at the lower end catenary cables. Seed 2 and 3 are combined and have an intersection line.

The total surface area is 1730m<sup>2</sup> (Seed 1: 270m<sup>2</sup>, Seed 2: 380m<sup>2</sup>, Seed 3: 860m<sup>2</sup> and Seed 4: 220m<sup>2</sup>). The used material is opaque Serge Ferrari 702 light grey.

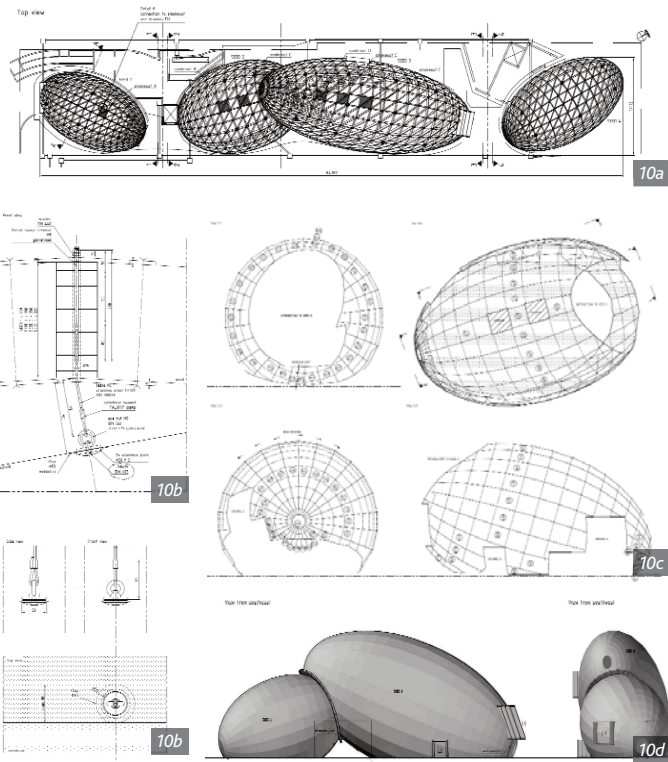


Figure 10a: Seed 1 to 4 © formTL  
Figure 10b: Nodal fixation detail © formTL  
Figure 10c: Patterning layout seed 3 © formTL  
Figure 10d: Seed 2 and 3 with the interface © formTL  
Figure 10e: View from the outside © Canobbio  
Figure 10f: Seed 1 - View from the inside (above);  
Seed 2 - View from the inside (below) © formTL

Function of the building:	Exhibition Pavilion
Architect:	Serina Hijias
Main contractor:	Bodino Engineering s.r.l.
Tensile membrane contractor:	Canobbio Textile Engineering s.r.l.
Membrane Engineering:	formTL ingenieure für tragwerk und leichtbau gmbh
Supplier of the membrane material:	Serge Ferrari
Material:	Précontraint 702 S2 light grey (opaque)
Structure:	Membrane domes fixed to timber structures
Surface area:	Seed #1: 270m <sup>2</sup> , #2: 380m <sup>2</sup> , #3: 860m <sup>2</sup> , #4: 220m <sup>2</sup>

## IRAN PAVILION (Mehler technologies)

The Iranian pavilion comes along with the theme "Global Sofreh, Iranian Culture". The concept aims at conveying God's blessing to the people all around the world. Old wisdom plays another important role as this is seen as the clue to solving the planet's feeding and energy challenges. Tradition, sustainability and openness to diversity serve as the three main themes of the Iranian pavilion designed for Expo Milano

2015. The concept was prepared by the team led by local architect Kamran Safamanesh. The three themes are summarized by an object that conveys them all: the Sofreh, a square of fabric that identifies the set table, one of the most important objects for the culinary culture of Iran. The Pavilion's architecture is derived from this image in the form of an open structure, similar to a tent. Clear enough that Mehler fabrics

are the optimal means to build these features. They playfully join in the pavilion's structure – here

again the visitors appreciate the shading functions of the fabrics.

Function of building:	Representation
Type of application of the membrane:	outside freeform sculpture
Client (investor):	Islamic Republic of Iran International Exhibitions Company (IIEC)
Architects:	Kamran Safamanesh
Multi disciplinary engineering:	
first phase:	Rah Shahr Architectural Consulting Engineers,
second phase:	Italian studio RPA S.r.l.
Contractor for the membrane:	Maffei Engineering SpA
Supplier of the membrane material:	Mehler Technologies GmbH

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General info: [www.expo2015.org/en/index.html](http://www.expo2015.org/en/index.html)

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machines perform with high precision and reliability to guarantee the quality of the final product. At the welding center, Forsstrom provides a tensile strength tester to secure the high quality of the welds. The tensile strength

## REPORT

# INTERNATIONAL MEMBRANE SYMPOSIUM 2015 IMS E.V. ANHALT UNIVERSITY, DESSAU-ROSSLAU, GERMANY

*From March 20 to 22, IMS e. V. and Anhalt University had invited international specialists and partners as well as various industries working in the field of textile and membrane building to an International Membrane Symposium in Dessau-Roßlau, Germany. On the occasion of the start of the 10<sup>th</sup> IMS master course in Membrane Structures the Symposium took place in the middle of the current attendance weeks of this distance learning program at Anhalt University, located next to the famous Bauhaus Building.*



Visiting the Gondwanaland in Leipzig

Three exciting days filled with speeches, panel discussions and an excursion to Gondwanaland in Leipzig ended on Sunday evening with the Grand Opening of the 10<sup>th</sup> master program Membrane Structures.

Professor Off, director of IMS and initiator of this symposium was very satisfied in relation to participation, input and the results of this event. He wanted to encourage a debate between lecturers, students and the industries as a result of the current situation and requirements on the membrane market worldwide. In result of the symposium new ideas and cooperations may be developed. New impulses have been given to improve the educational situation in this special field of textile building. Last but not least the symposium has been a very good platform for the 150 participants to meet specialists from all over the world, exchange experiences and meet new partners and friends to extend the private and professional network. That was and still is one of the main intentions of the work of IMS e.V. besides the master program.

In addition to the Symposium Prof. Dr. Robert Off and his IMS team had to manage another very exciting and important event. After two years of preparation and together with the Anhalt University IMS e.V. received the committee of experts in order to renew the accreditation of the Master



tester is also available for customers who want to test the strength of their own materials or prototypes.

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The audience at Anhalt University

Program Membrane Structures. Since this program is worldwide unique it was very important for IMS to achieve the authorization to continue the academic way of education in this very special field. Finally, IMS is able to announce that the Master Program Membrane Structures received re-accreditation until 2021. Professor Off and his team take this as a strong confirmation in their efforts teaching membrane structures.

✍ Heike Kleine  
✉ heike.kleine@ims-institute.org  
🌐 www.ims-institute.org/

# BOOKREVUE

## Fabric Structures in Architecture



**Publisher:** Woodhead Publishing & Elsevier  
*in association with The Textile Institute*

**Edited by** Josep Llorens,  
*Barcelona School of Architecture (ETSAB), Polytechnic University of Catalonia (UPC)*

**ISBN:** 978-1-78242-233-4

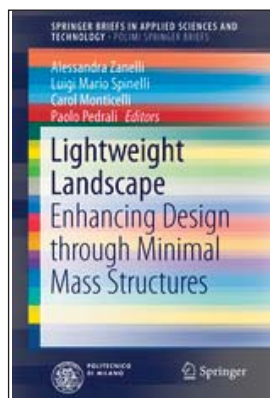
**Language:** English | **Published:** 2015

Membranes are increasingly being incorporated into buildings, and understanding the behaviour of the materials used is essential in developing fabric architecture. *Fabric Structures in Architecture* is an essential text that covers various aspects of how textiles and foils and their properties are used in building construction, with particular focus on tensile structures. The book begins with an historical overview of the development of membrane structures in architecture. Part One covers their fundamental principles and explores fibres, coatings, foils, and multi-layered tensile architectural structures from their origins to contemporary types. Part Two discusses a range of design considerations, with chapters on lighting, acoustics, and thermal behaviour in architectural fabric structures. In this part, installation and failure modes are presented. Part Three examines the applications of membranes in architecture, presenting a series of unique case-studies from around the world that examine works in North America, Latin America, Europe, China, and Japan. *Fabric Structures in Architecture* is a unique and important reference text for textile manufacturers, architects, engineers, postgraduate students, and academic researchers in structural membrane science. Professor Josep Llorens teaches Architectural Technology at the Barcelona School of Architecture. His research focuses mainly on experimental designs and works, particularly in the field of tensile structures and textile architecture. The results have been presented in international conferences and received global recognition with exhibitions and publications: <http://orcid.org/0000-0001-5566-3037>.

✍ José I. de Llorens, ETSAB/UPC | [ignasi.llorens@upc.edu](mailto:ignasi.llorens@upc.edu)

## Lightweight Landscape

ENHANCING DESIGN THROUGH MINIMAL MASS STRUCTURES



**Publisher:**

**Springer International Publishing, PoliMI SpringerBriefs**  
**Edited by** Zanelli, A., Spinelli, L.M., Monticelli, C.,  
Pedrali, P. (Eds.)

**ISBN:** 978-3-319-21665-2 | **Language:** English | 2015

*Examines the merits of lightweight materials and membrane structures in terms of design and the environment*  
This book explains how lightweight materials and structures can be deployed in buildings to meet high environmental and aesthetic standards and emphasizes how the concept of lightness in building technology and design dovetails with the desire to enhance landscape. The first part of the book, on lightweight construction, aims to foster the use of membranes within the specific climatic context and in particular considers how lightweight materials and innovative technologies can enrich the quality of temporary spaces. The second part focuses exclusively on landscape, presenting novel approaches in the search for visual lightness and the quest to improve urban spaces. Particular attention is paid to the Italian experience, where the traditional appreciation of brick and stone has limited the scope for use of lightweight structures and membrane materials, often relegating them to a secondary or inappropriate role. The reader will come to appreciate how this attitude demeans a very advanced productive sector and neglects the ancient tradition of temporary architecture.

✍ Alessandra Zanelli, POLIMI

## FORM-RULE | RULE-FORM SYMPOSIUM 2015

FISHING  
FOR  
FORM

The "Fishing for Form" 2015 Symposium took place on 16–17 January at the Institute of Design|unit koge. Structure and Design, University of Innsbruck, chaired by Günther H. Filz, Dean of Studies at the Faculty of Architecture, along with Christian Scheiber and Walter Klasz. Two days of invigorating lectures were opened by Stefano de Martino, the Dean of the Faculty. The lectures were preceded by two workshops, which addressed rules to the relationship between form and structure. The topic was amply discussed under multiple viewpoints and experiences. The ensemble of presentations, as can be seen in the short summaries that follow, are a significant contribution to the contemporary debate about commitment of form, as outlined by Martin Francis, who also contrasted style and utility.

The full program of the Symposium is available at: [http://koge.at/wp-content/uploads/2015/01/150105\\_fr15\\_schedule\\_www.pdf](http://koge.at/wp-content/uploads/2015/01/150105_fr15_schedule_www.pdf), and the lectures will be collected in the book: "FORM - RULE | RULE - FORM 2015".

## Lectures

Günther Filz addressed in multiple ways the dialogue between form and structure. He discussed several approaches to the process of generation, mentioning as examples self-organization, interaction, irregularity, addition, folding sheets or active bending, among many others, which were illustrated by a wealth of examples (Fig. 1).



Figure 1. Koge, 2014: Double-layer gridshell.

Josep Llorens presented an outstanding example of brick masonry optimization through form, basing his subject on the wine cellars (nicknamed "wine cathedrals" for their magnificence) of Cesar Martinell (1888–1973), which were built in Catalunya, Spain. In these projects, beams and lintels were replaced by balanced arches, and joist beams and slabs were replaced by Catalan vaults (Fig. 2). The technique has recently been revived in developing



countries due to its geometric flexibility, ease of erection, low cost, and high efficiency.

Figure 2. Cesar Martinell, 1921: Sant Cugat Viticulture Cooperative.

Annette Bögle challenged what is supposed to be done by the engineer in most architectural designs, and she advocated their participation in the generation of forms far beyond a possible structural analysis. Interaction, communication, dialogue, sharing, exchange, empathy, critique, and even group dinners enable creativity in engineering, that allow finding new solutions and clarifying the relationship between form and structure.

Richard Horden alluded to personal references as the starting point of initial designs. They may

be derived from other buildings, works of art, nature, environment, shapes, objects, climate, lines, tendencies, memories, or thoughts. He gave several examples of his work, mentioning his own influential references, depending on every situation, mood, and spirit, as in the case



of the two-storey house overlooking Slade Gardens in London, where the adjacent ash tree - influenced the design (Fig. 3).

Figure 3. Richard Horden, 2014: Ingleton Street Private House, London.

Switbert Greiner showed his fascinating world of structural design and exhibited "a strong interest in the living and non-living structural forms found in nature, as well as in the procedures with which handmade and industrial materials and components are created" (Fig. 4).



He focused on the technical design of supporting structures and art objects, as diverse as membranes; lightweight, convertible, botanical, and inflatable structures; solar dishes; and Olafur Eliasson sculptures.

Figure 4. Retired fisherman weaving a wicker creel.

Franz Sam speech could be summarized with his own statement: "If you want to do crazy things, you have to dominate the form." He capitalized on his collaboration with Coop Himmelb(l)au (Fig. 5) and his teaching skills, emphasizing the need for mastering form, not only as a shape, but also from the materialization point of view including materials and techniques.

Figure 5. Coop Himmelb(l)au, 1988: Rooftop remodelling, Falkestrasse, Vienna.



"Where does the form touches the ground?" was a significant question that could be added to that of B. Fuller: "How much does your building weigh, Mr. Foster?"

Enrique Soriano & Pep Tornabell went over the creation and optimization of lightweight structures through computational design and physical modelling. Their method relies on active bending that provides form, flexibility, resistance, and efficiency. Their works are based on elastically-deformed plywood such as the pavilions made possible by an enthusiastic crew of students (Fig. 6). They are now ready to embark on useful applications.



Figure 6. E. Soriano & P. Tornabell, 2013: "Big O", toroidal thin gridshell of wood, HelloWood Festival, Csórompuszta.

Walter Klasz introduced the latest project of unit koge: "A cloud of snow," an artificial cloud used to produce powdered snow (Fig. 7). The cloud consists of two envelopes: the cloud chamber and the outer shell. In the cloud chamber water droplets are mixed with ice to produce snowflakes. It is protected from solar radiation and wind by the outer shell, a spherical tetrahedron made of three membranes tensioned by spatially bending-active curved wooden beams. The entire structure is extremely lightweight and rests on a tripod, resulting in an economic means of producing snow and it is an ecological alternative to traditional snow cannons. More information at:

<http://koge.at/?p=4291#more-4291>



Figure 7. Koge, 2014: Cloud of snow, Obergurgl-Hochgurgl.



Christian Scheiber started with John Constable clouds to expound "formless thinking" including variability, shift, dynamic constant changes, lack of precision, irregularity, vagueness, suspension, sliding images, and unconsciousness. The least volatile reference was the "Passing Cloud" by Tiago Barros, a bunch of nylon-covered balloons floating in the air (Fig. 8). He mentioned a hydro meteorological model to draw formless shapes.



Figure 8. Tiago Barros, 2012: *Floating in the atmosphere on top of a cloud.*

André Ihde tried to characterize the design process defining parameters, requirements, interactions, and rules to build a holistic, flexible, and parameterized planning system; to handle complexity; and to gain deeper understanding of the dependencies. Expected benefits are the reduction of planning risks and iteration loops, thus enabling sensitivity analyses and multi-criteria optimizations to better accomplish the more targeted client demands.

Martin Francis began recalling favourites of technical design in architecture headed by Joseph Paxton's Crystal Palace, Hyde Park, 1851. They were followed by other designs related to his practice, especially mentioning the glass boxes at La Villette and the Louvre Pyramid in Paris. The bulk of his talk was divided between yacht design and the technical development of large sculptures (Fig. 9). He also distinguished between architecture (style and practicality) from sculpture (style over practicality) mentioning as corresponding examples the British Museum Court Roof and the "Musée des Confluences" in Lyon.

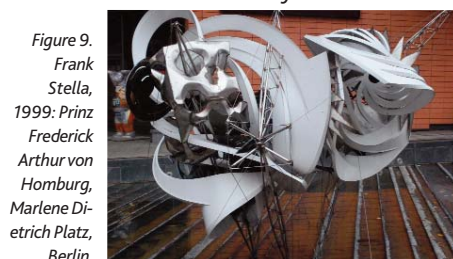


Figure 9. Frank Stella, 1999: *Prinz Frederick Arthur von Homburg*, Marlene Dietrich Platz, Berlin.

Clemens Preisinger showed the possibility of enhancing geometry by adding algorithms that improve structural efficiency. Different approaches were shown for the optimization of struts (European Central Bank) and diagonals (Skylink of the Frankfurt Airport). Even more committed to such design were the topology adjustment of the "White Noise Pavilion" in Salzburg and the deformation and mass optimization of the CIAB Pavilion in Beijing (Fig. 10).



Figure 10. Zaha Hadid with Karamba Parametric Engineering, 2013: *CIAB Pavilion (Candela revisited)*, digitally designed and manually manufactured, Beijing.

In "Towards a poetic of performance," Dario Parigi advocated the inclusion of complexity into the design process as a source of inspiration, since computational tools allow the expansion of opportunities for creative work when the problems are too complex to be solved purely on designer intuition. He presented as a case study reciprocal structures whose design was based on the use of load bearing elements which, by supporting one another along their span and never at the extremities, compose a spatial configuration without any clear structural hierarchy (Fig. 11).

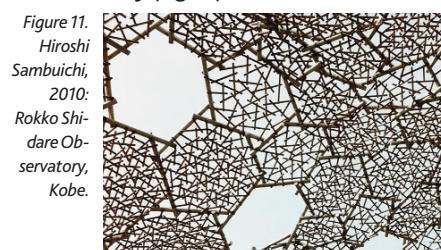


Figure 11. Hiroshi Sambuichi, 2010: *Rokko Shidare Observatory*, Kobe.

Michael Wihart discussed bio-inspired strategies for the design of soft and cellular pneumatic structures. Not seeking immediate architectural solutions, but rather researching some of architecture's fundamental conditions, soft machines embody ideas of architecture as a partially transformable, compliant, sensitive, and sensual body. Michael's most recent series of soft machines ranging from soft mechanical hybrids to silicone composites, are inspired by developments in soft robotics and studies of soft-bodied organisms such as molluscs and medusas



(jellyfish) (Fig. 12).

Figure 12. Michael Wihart: *Soft Machine*.

Marijke Mollaert's presentation ranged from the adequacy of technical textiles to kinematic structures: for instance, to make lightweight, adaptable façades or roof systems. To verify the feasibility of kinematic form-active structures with fabric, she designed and tested a full scale prototype comparing the geometry, reactions, and strains measured in the model with the same values predicted by a computer simulation (Fig. 13). The results showed potentials-successes and difficulties.

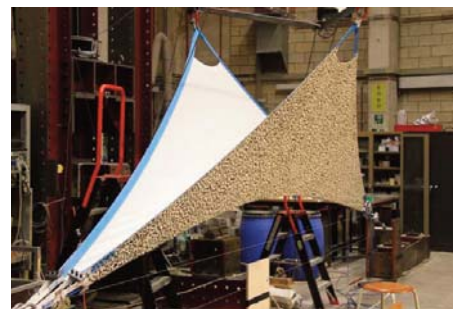


Figure 13. Marijke Mollaert, 2014: *Testing a full-scale prototype to verify the feasibility of kinematic form-active structures with fabric.*

## Workshops

Graphic optimization of trusses.

Graphic statics, spreadsheets, physical modeling, and testing were presented in the workshop conducted by Josep Llorens with the objective of simulating and improving the distribution of forces on trusses. Load paths  $\sum (p \cdot \ell)$  were computed and compared, and every truss was physically modelled and tested (Fig. 14).



Figure 14. Josep Llorens Koge Workshop 2015: *Graphic analysis and testing of trusses.*

Potentials of bending-active structures on complex topologies.

Enrique Soriano and Pep Tornabell from CODA (<http://coda-office.com>) led a research-based workshop exploring the potentials of bending-active structures on complex topologies resulting in digital simulation, several scaled models and the full-scale structure "Blättersturm" (Fig. 15).

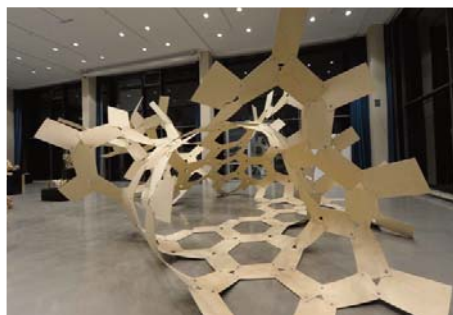


Figure 15. E. Soriano & P. Tornabell Koge Workshop 2015: *"Blättersturm"*.

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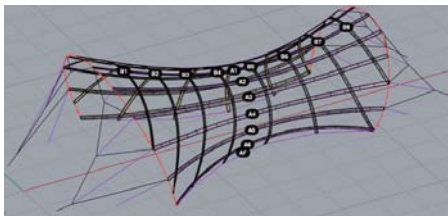
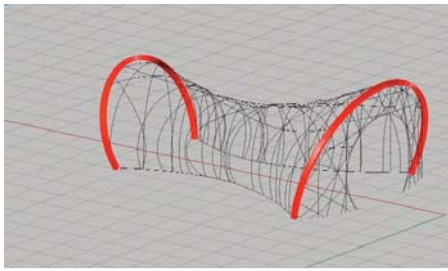


Figure 1. 3D computer graphics, computer-aided design software and plug-ins for the parametric design.

### Introduction

In 2015 the University of Nottingham, Department of Architecture and Built Environment commissioned a new pavilion for the End of Year Show. The main objective was to commemorate the 50<sup>th</sup> Anniversary of the department with a pavilion designed and built by the staff and students, and able to offer an insight into the annual teaching activity. The pavilion was designed Dr Paolo Beccarelli (University of Nottingham) and Dr John Harding (Visiting Tutor from Ramboll) and backed by the Architecture and Tectonics Research Group (Prof. John Chilton) and supported by a team of technical staff and volunteers from the Department of Architecture and Built Environment and eleven students from the MArch Space Enclosure Studio.

### Project

The design was based on the extensive use of commercial 3D computer graphics and computer-aided design software (Rhino3D) combined with modern plug-ins for the parametric design based on a visual programming language (Grasshopper) (Fig. 1). The shape and the details of the pavilion were optimised in order to minimize the complexity of the manufacturing, the amount of material used and the health and safety risks. Based on two timber arches and a grid of fabric strips arranged in a saddle shaped surface, the pavilion measures 12m in length and 3.5m in height. Twenty-three strips 150mm wide and 2440mm long were cut from 6.5mm plywood (Russian birch) and assembled into two lightweight arches having a radius of 2.75m and 1.90m respectively. The final curvature was achieved by bending the laths within the elastic range of the timber and connecting three layers of plywood with two courses of shear blocks placed at an average distance of 500mm. The membrane

# END OF YEAR SHOW PAVILION 2015

## UNIVERSITY OF NOTTINGHAM

grid is a catenoid minimal surface between the two rigid arches modelled using Rhino Grasshopper. The cutting pattern, 11 strips in the longitudinal direction and 8 strips in the transverse direction, was calculated using a simple script, which generates a spreadsheet with the length of the strips and distances between the nodes. Finally, the main orthogonal grid (strip 100mm wide) was stabilized by a set of diagonal fabric strips of different widths (25mm, 50mm and 100mm) connected at each node with 12mm eyelets.




Figure 2. Installation of the pavilion.

The tensile force developed by the tensile grid on the arches was counterbalanced by a set of tieback tendons arranged in a similar grid, with a flexible edge obtained using a boundary rope anchored to the ground. Resistance to wind forces is provided by the double-curved geometry and the initial pretension of the membrane which was achieved through the rotation of the arches (in the longitudinal direction) and the anchoring along the perimeter of the pavilion by means of removable anchors hammered into the ground.

Two main sponsors, SIOEN Industries NV and the North East Timber Trade Association, supported the project providing the PVC coated polyester fabric and the timber for the construction, respectively. SIOEN Industries NV cooperated actively with the University of Nottingham to select the appropriate fabric. The EASYFLUO™ Type 1 products chosen for the Pavilion skin are prestressed PES-PVC compounds with a weldable PVDF lacquered finish. SIOEN acted as sponsor for the student work and supplied the necessary material for this project free of charge."

The pavilion was manufactured and installed by a group of eleven students in four working days and will remain on display during the summer between June and September.

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 [www.nottingham.ac.uk/engineering/departments/abe/index.aspx](http://www.nottingham.ac.uk/engineering/departments/abe/index.aspx)

Name of the project:	End of Year Show Pavilion 2015
Location address:	University Park, Nottingham, UK
Client (investor):	Department of Architecture and Built Environment, University of Nottingham
Function of building:	Exhibition
Type of application of the membrane:	Covering
Year of construction:	2015
Designers:	Paolo Beccarelli, John Harding, John Chilton
Structural engineers:	John Harding
Consulting engineer for the membrane:	Paolo Beccarelli
Supplier of the membrane material:	Sioen Industries
Manufacture and installation:	MArch Space Enclosures Studio: Andika Visono Boenjamin, Johnson Enyenih, Yuezong Liu, Zaid Nachan, Muygech Sok, Kai Song, Xinggong Xuan, Yichi Zhang, Wen Zhang, Chunhui Zheng, Jing Zhou
Material:	SIOEN EASYFLUOTM / FR T1101E / NON-FR T1001E / 730 GR
Covered surface (roofed area):	30m <sup>2</sup>