

REPORT

STRUCTURAL MEMBRANES 2013

ARTICLE

LONDON OLYMPIC GAMES 2012

WHAT HAPPENED TO THE SERGE FERRARI COMPOSITE MEMBRANES?

RESEARCH

SPEEDKITS DISASTER SHELTER 'CLEVER ROOF'

PROJECTS

BUILDING WITH AIR - BUS STATION CANOPY

[RE]THINKING LIGHTWEIGHT STRUCTURES
LIGHT IS BEAUTIFUL, LIGHT MOVES



Bus station Aarau © Niklaus Spoerri, Zürich ▲

Tents on top of the Towers of the King Abdul Aziz Endowment Project, Makkah, Saudi Arabia @ sl-rasch ►



Buro Happold
www.burohappold.com



Canobbio S.p.A.
www.canobbio.com



CENO Membrane
Technology GmbH
www.ceno-tec.de



Dyneon
www.dyneon.eu



FabricArt
Membrane Structures
www.fabricart.com.tr/



Form TL
www.Form-tl.de



Heytex Bramsche GmbH
www.heytex.com



Hightex GmbH
www.hightexworld.com



Mehler Technologies
www.mehler-
technologies.com



Messe Frankfurt
Techtextil
www.techtextil.com



Naizil S.P.A.
www.naizil.com



Saint-Gobain
www.sheerfill.com



Sefar
www.sefar.com



Serge Ferrari sa
www.sergeferrari.com



Sioen Industries
www.sioen.com



Taiyo Europe
www.taiyo-europe.com



technet GmbH
www.technet-gmbh.com



Verseidag
www.vsinidutex.de

TensinewsINFO

Editorial Board

John Chilton, Evi Corne,
Peter Gosling, Marijke Mollaert,
Javier Tejera

Coordination

Marijke Mollaert,
phone: +32 2 629 28 45,
marijke.mollaert@vub.ac.be

Address

Vrije Universiteit Brussel (VUB),
Dept. of Architectural Engineering,
Pleinlaan 2, 1050 Brussels, Belgium
fax: +32 2 629 28 41

ISSN 1784-5688

All copyrights remain by each

author

Price €15

postage & packing included

contents

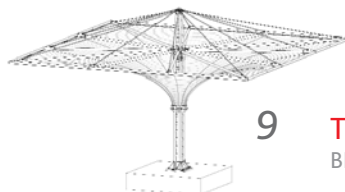


PROJECTS

PAGE

4

Uruguay 2122 HOTEL ART DESIGN
A SEASHELL SHAPED COVER



9

Germany UMBRELLAS FOR CARTHAGO CITY
DEVELOPING AN EXPANDABLE MODULAR ROOF COVERING

19

Turkey A SHOPPING MALL CANOPY
BREAKING THE ROUTINE OF PLANAR AND GEOMETRIC LINES

Germany THE "PARKTHEATER"
NEW STAGE COVERING



UK CARRIED BY WAVES UP INTO THE SKY
INTERNAL CEILING TERMINAL
AT HEATHROW INTERNATIONAL AIRPORT

14

Switzerland BUILDING WITH AIR BUS STATION CANOPY



26

Morocco TEXTIDÔME
COVERAGE OF THE WASTEWATER TREATMENT PLANT

27

Norway DRIVING AIR UPWARDS

10

[RE]THINKING LIGHTWEIGHT STRUCTURES
LIGHT IS BEAUTIFUL, LIGHT MOVES

This article summarizes the keynote lecture of Jürgen Bradatsch given during the Tensinet Symposium in Istanbul, 2013.



PAGE

REPORT

6

STRUCTURAL MEMBRANES 2013
INTERNATIONAL CONFERENCE
ON TEXTILE COMPOSITES AND INFLATABLE STRUCTURES

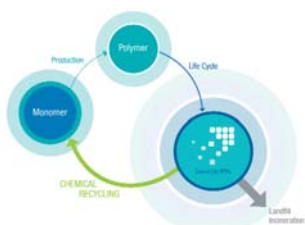
23

IASS 2013 BEYOND THE LIMITS OF MAN

ARTICLE

16

LONDON OLYMPIC GAMES 2012
WHAT HAPPENED TO THE SERGE FERRARI COMPOSITE MEMBRANES?
INITIAL ENVIRONMENTAL ASSESSMENT, ONE YEAR AFTER THE GAMES...

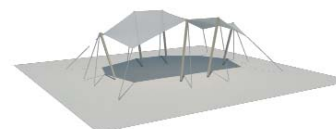


18

'UP-CYCLING'
WASTE STREAMS OF PERFLUORINATED POLYMER MATERIAL

24

SPEEDKITS
DISASTER SHELTER 'CLEVER ROOF'



28

COST ACTION
ON NOVEL STRUCTURAL SKINS

MISC

PAGE

9

BOOKREVUE
ATOPIC ARCHITECTURE AND MEMBRANE STRUCTURES

Edito
Dear Reader,

Since the last TensiNews many activities were going on. The Eurocode working group is preparing a state of the art report which should be ready by the end of this year. This is the first step towards a technical specification and then towards an Eurocode. A first working group meeting took place end of January, the next will be on the 2nd of April. The ETFE working group is contributing to the Eurocode working group with a chapter on ETFE foil. Matthew Birchall has presented on the TensiNet meeting in Gendorf the draft document "European Design Guide ANNEX 6" on pneumatic structures. Beginning of April the first pneumatic structures working group meeting will take place in Paris. The working group intends to finalize the document by the end of this year.

TensiNet members are involved in the COST Action on 'Novel structural skins - Improving sustainability and efficiency through new structural textile materials and designs', which was officially launched end of last year. A kick-off meeting took place and Research Clusters have been defined. The COST framework is funding network activities of researchers. If interested, you are invited to participate.

TensiNet was present on Structural Membranes 2013 in Munich last October, and TensiNet will be present at Textile Roofs 2014 in Berlin. We started the preparation for the TensiNet symposium 2016. Different locations are under discussion, and we would like to call for a topic.

On the Tensinet Symposium 2013 in Istanbul Jürgen Bradatsch gave a keynote lecture "light is beautiful, light moves" presenting the work of SL Rasch. We are happy to present an article about this lecture.

Beside many interesting projects, recycling is a subject of this issue with articles about the recycling of the membranes for London Olympics and about the up-cycling of fluor polymers. Josep Llorens prepared a report about Structural Membranes 2013 held in Munich last October.

I hope you enjoy this issue and I look forward to see you at one of our future events.

Yours sincerely,
Bernd Stimpfle



Forthcoming Events

4th Roof China Exhibition

Guangzhou, China | 12-14/05/2014
www.roofchina.com

Textile Roofs 2014

Berlin, Germany | 26-28/05/2014
www.textile-roofs.com

MARAS 2014 International Conference on Mobile, Adaptable and Rapidly Assembled Structures

Ostend, Belgium | 11-13/06/2014
www.wessex.ac.uk/maras2014

IASS-SLTE 2014 symposium

Brasilia, Brazil | 15-19/09/2014
www.ias2014.org

Essener Membranbau Symposium 2014

Essen, Germany | 26/09/2014
www.uni-due.de/iml

Aachen - Dresden International Textil Conference

Dresden, Germany | 27-28/11/2014
<http://www.aachen-dresden-itc.de/>

TECHTEXTIL 2015

Frankfurt, Germany | 4-7/05/2015
www.techtextil.messefrankfurt.com

Forthcoming Meetings

TensiNet Meetings

AFNOR, Paris, France | 2/04/2014

10:00 - 15:00 CEN/TC250 WG5

core group meeting

15:00 - 16:00 WG Pneumatics

16:00 - 18:00 Partner meeting (1/2014)

Location: AFNOR,
11 Rue Francis de Pressensé,
93571 La Plaine Saint-Denis cedex,
France



"From membrane form to rigid shell"

Within the scope of a two years research project the IMS Dessau e.V. executed a very promising and tempting project dealing with the conversion of membrane structures into concrete shells. Together with various partners from industry and university an interdisciplinary team was formed. The combination of an extensive material research, the survey of the process technology of application and the direct evaluation formed the core of this research. For further and detailed information we would like to refer to the next issue of Tensinews 27. We are very much interested in cooperating with new partners to proceed and extend this research. For direct discussion contact Robert Off or Henning Duerr via www.ims-institute.org.

A SEASHELL SHAPED COVER FOR THE OUTDOOR COFFEE AND BAR AREA



Context

In order to protect from the hot summer and rainy winter the outdoor coffee and bar area of this new hotel in Punta del Este (one of the most important resorts in south America), a roof was required. Since the area to be

covered wasn't "orthogonal", conventional materials were not a solution; in addition, the municipality only allowed the use of "light" materials that could be easily removed. The solution had to be clearly a fabric roof.

2122 Hotel Art Design

Punta del Este, Uruguay

Name of the project:	2122 Hotel Art Design
Location address:	Av. Pedragosa Sierra entre Roosevelt y San Ciro, Punta del Este, Uruguay
Function of building:	Hotel
Cover Function:	Roof for the outdoor bar and coffee hotel
Construction year:	2012
Roof design and project:	Sobresaliente Ltda.
Roof structural engineer:	eng. Marella & Pedoja
Roof fabricator and contractor:	Sobresaliente Ltda.
Supplier of the membrane material:	Serge Ferrari
Material:	serge ferrari 1002 S.
Covered surface:	75m ²

Project

The tensile structure had to connect two higher buildings located at both sides of the terrace

(Fig. 1). Sobresaliente Ltda. designed a seashell shaped roof that offers a very attractive view both from the inside and the

DEVELOPING AN EXPANDABLE MODULAR ROOF COVERING

TRITTHARDT + RICHTER

Ravensburg, Germany

Umbrellas for Carthago City

Context

Well known and successful German manufacturer of mobile homes "Carthago" opened a new sales maintenance and fabrication facility called "Carthago City" near Ravensburg (Southern Germany) in spring 2013.

One idea of the architectural concept was to provide a membrane covered area for exhibition and weather protected parking of brand-new mobile homes. Prime requirement was to protect the fairly expensive cars from hail during summer time (Fig. 1). Second request was to have a flexible modular system which allows expanding the covered area later by similar modules. So after a short preliminary design stage büro für leichtbau was assigned to develop 16x16m funnel shaped non-collapsible umbrellas.

Project

Besides a satisfying overall visual appearance of the ensemble, which is almost granted by default when building funnel shaped umbrellas, our main focus was to develop a

very reduced near minimized steel structure. In this special case it obviously makes sense to spend a little more time thinking of simplification and

optimization because the design was meant to be built at least nine times.

One of the basic concepts of the structural design was to subdivide the umbrella into two main items: The shaft, which is a four-girder column with an additional drainage tube in the centre axis and the upper top-part including the circumferential frame with 12 radial suspended arms and the membrane surface with low-point ring (Fig. 2 & 3).

This design allowed a very efficient and easy assembly and erection on site. In a first step the shaft is fixed and adjusted on cast-in embeds.





outside. The structure combines laminated wood curved beams and a steel structure. The fabric is a PVC membrane, type Serge Ferrari 1002 S. Since the outdoor area is used throughout the year, the roof has an horizontal perimeter that allows lateral PVC closings (Fig. 2).

The manufacturing process took one month, the structure was performed simultaneously in

different workshops (steel structure, wooden beams and membrane). The structure assembly was done in a few days and the fabric was installed in one day. The pre-stressing was performed over the laminated beams at the extremities by an adjustable system with a double clamp bar. In the free edges, stainless steel cables with screw terminals are used to allow stretching (Fig. 3)

The roof offers a very fashionable, luminous and enjoyable place for tourists, and a solution for the client.

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

Figure 1. General view
 Figure 2. The seashell shaped roof - external and internal view
 Figure 3. Connecting details



Figure 1. Weather protected exhibition area for mobile homes
 Figure 2. Axonometric of the 16x16m umbrella module

Figure 3. Top and bottom view - detail
 Figure 4. Erection of the structure
 Figure 5. General overview

Independently the upper part is assembled nearby on ground level on an auxiliary device which allows a very easy clamping of the outer membrane border to the frame. After pre-assembly on ground level the entire 16 x16m top element was lifted by mobile crane, fixed on the shaft and in a final step the low-point ring was pulled down to induce the necessary membrane pre-tension (Fig. 4).

In a first stage approximate 2300m² modular roof covering was realised by 9 similar 16x16m non-collapsible umbrellas. The

overall height of each umbrella is 10m with a non-overlapping circumferential membrane border at 7m. The gaps between the adjacent umbrellas are closed by metal-sheets. The funnel shaped umbrellas are made of primary steel structure S 355 and PVC-coated polyester membrane Type III (Ferrari 1202 S2).

**büro für leichtbau
 Tritthardt + Richter**

Dirk Richter
richter@bfl-tr.com
www.bfl-tr.com



Name of the project:	Carthago Umbrellas
Location address:	Aulendorf, Germany
Client (investor):	Carthago Reisemobilbau GmbH
Function of structure:	weather protection for exhibition
Type of application of the membrane:	Covering with mechanically prestressed membrane
Year of construction:	2013
Architects:	büro für leichtbau Tritthardt + Richter
Structural engineer foundation:	ML-Ingenieure GmbH
Structural engineers steel:	büro für leichtbau Tritthardt + Richter
Consulting engineer for the membrane:	büro für leichtbau Tritthardt + Richter
Contractor for the supply and installation steel structure:	Friedrich Bühler GmbH & Co.KG
Contractor for the membrane and membrane installation:	Arnegger GmbH
Supplier of the membrane material:	Serge Ferrari
Material:	Ferrari 1202 S2
Covered surface (roofed area):	9x256m ² = 2304m ²

STRUCTURAL MEMBRANES 2013

VI INTERNATIONAL CONFERENCE ON TEXTILE COMPOSITES AND INFLATABLE STRUCTURES

The "Sixth International Conference on Textile Composites and Inflatable Structures" was held in Munich in October 2013. It was organized by the International Centre for Numerical Methods in Engineering (CIMNE) and chaired by E. Oñate (UPC) and K.U. Bletzinger (TUM). It was the sixth of a series of symposiums that began in Barcelona in 2003. The next conference will again be held in Barcelona in 2015.

At the three-day event, 8 lectures and 91 presentations in 13 invited and contributed sessions were given to 122 participants from 25 countries and 4 continents. The main topics covered building physics, materials, testing, and advanced methods for analysis and simulation. A wide range of different applications were also shown for dealing with adaptive and deployable structures, active bending, parachutes, inflatable arches and beams, roofs and façades. Environmental and energy issues were also considered, both in regard to life cycle analysis, and the capture and storage of solar heat.

Main lectures

P. Gosling began the plenary lectures with an introspective look into how material properties are considered in the design. He referred to the round-robin exercise carried out to understand the current state of analysis practice, which has high levels of variability. He suggested a neural network to represent the strain/stress behaviour of the membrane.

K. Göppert entertained the audience with a wealth of impressive achievements by Schlaich, Bergermann und Partner. Most interesting were the new roofs and façades on existing buildings, such as the renovation of the Bay Arena in Leverkusen (Fig. 1).

Observing the thermal behaviour of polar bear fur and skin, and taking into account the amount of energy provided by the sun, T. Stegmaier presented a solar, active roof based on a selective, multilayered membrane. It consists of a transparent insulation (on the top), a black collector (in the middle) and heat insulation (at the bottom) (Fig. 2).

M. Mollaert and S. Pellegrino expressed concern about folding membranes. The first speaker addressed whether a retractable membrane system could be stable in intermediate configurations. The second speaker covered hinges for tightly- packaged thin-shell structures.

M. Fritze impressed everyone with the parachute dance, which was devised to improve the average descent speed, fluctuations and contacts by means of modifying the geometric porosity with windows and gaps (Fig. 3).

K. Linkwitz told the gripping story of the patterning of the Munich Olympic Stadium cable roof. He was contracted to produce the cutting pattern by photogrammetry. As he

realized that the accuracy was insufficient, he was forced to deduce a new method that was heretofore entirely unknown (later called "force density"). According to his memory, the most exciting moment of the experience was the first uplift of the cable net (Fig. 4). The result was a major achievement.

R. Rossi confronted the difficulty of simulating the wrinkling in low-pressure inflated tubes subjected to wind by separating the structure (the tube) from the fluid domain (the wind), adding nodes at the interface and performing local subdivisions (Fig. 5).

Invited and contributed sessions

The invited sessions were organized by guest experts, which focused on adaptive and deployable structures, advanced methods for analysis, active bending, building physics, detailing, case studies, installation process, space applications, materials, fluid-structure interaction, and environmental impact.

Design

B. Philipp addressed the problem of the lack of unified approaches and standards as a limiting factor to the further propagation of architectural membranes. The material properties, loads, load combination, safety factors, non-linearity and design tasks make the simulation a challenging task. The development of tensile structures is far from being finished.

"Selected examples for the optimization of cutting patterns for textile membranes" was the contribution of D. Ströbel. He showed fast and automatic "Easy/Technet" patterning tools to solve the costly and time-consuming engineering process of cutting patterning. He introduced different flattening theories, and focused on optimizing procedures based on variables such as width or position.

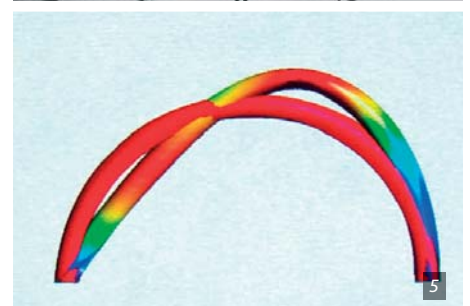


Figure 1. Renovation of the Bay Arena, Leverkusen - K. Göppert

Figure 2. Solar-active roof, Denkendorf - T. Stegmaier

Figure 3. The "parachute dance", modifications on the geometric porosity - M. Fritze

Figure 4. Erection of the cable net of the Munich Olympic Stadium - K. Linkwitz

Figure 5. Low pressure inflated tubes under wind simulation - R. Rossi

R. Pauletti presented the implementation of a simple wrinkling model by using both the tangent or secant stiffness-matrices. He compared the results obtained for the membrane roof of the "Memorial dos Povos de Belém do Pará" (Fig. 6), and concluded that the finite difference approximation provides a systematic, straightforward way to keep quadratic convergence, which requires the sole definition of force vectors.

A. Habraken described an approach aimed at significantly saving structural materials by increasing efficiency by means of adaptability to static and dynamic environmental conditions. He categorized the structural adaptability in passive adaptability, using flexibility (Fig. 7) and active adaptability controlling the structure with actuators.

"People just want to have a price before the design is fixed" was the statement of R. Wehdorn to introduce a simple tool designed to foresee the influence of the primary variables in the final cost. Variation of membrane and edge curvatures and inclination of guying cables were analyzed for a 10x10m four-point sail. This study is expected to lay the basis for the inclusion of cost-influences in design guides and software applications, such as "Formfinder".

Realisations, recent projects

J. Oliva presented two cases of designing membranes on existing buildings. The first one, for the University Drama Centre in Mexico City (Fig. 8), included an improvement of the lanterns over what was experienced previously ("The design and application of lanterns in tent structures", SM 2011). The second case covered the cafeteria of the new campus housing the National School for Higher Studies in León (Fig. 9).

D. Campbell from Geiger Engineers proved the compatibility of insulation and translucency requirements with the applications of Tensotherm, a combination of PTFE-coated fiberglass and Aerogel insulating blankets. It has been used for the roof replacement at the Dedmon Center Gymnasium and Pool in Radford, and the Talisman Center in Calgary (<http://www.makmax.com/business/tensotherm.html>).

"Irregularity" was an arguable concept put forward by G. Filz to present the tensile sculpture "cut.enoid.tower" (Fig. 10). It merges different structural members into an overall system such that irregularity is necessary in order to achieve a state of equilibrium.

J. Tejera's presentation was concerned with textile façades, an emerging field application of structural membranes. He lucidly listed these façades' main characteristics and focused on the protection of the Oasis Hotel curtain wall located in subtropical Lanzarote (Fig. 11 & 12). He applied the BAT Tenso Textile façade framing system, and managed to reduce the prescribed wind loads by modelling the complete façade with the CFDTex calculation method developed by himself. The results look promising, in view of the large quantity of glass façades oriented to the west that have been built in hot climates.

Multilayer textile cladding was also discussed in "Textile and film-based building envelopes, lightweight and adaptive" by F. Schmid. A fabric envelope was described by P. Casaldàlga in "The Magical Lleida Technology Park as an example of environmental building rehabilitation strategy."

A membrane installed 17 stories above ground was the topic of C. Armendariz (Fig. 13). The requirements were challenging, because the building was fully operational. Additionally, anchors, supports and membrane had to be adapted to the existing rooftop terrace and views. Nevertheless, the result was successful,

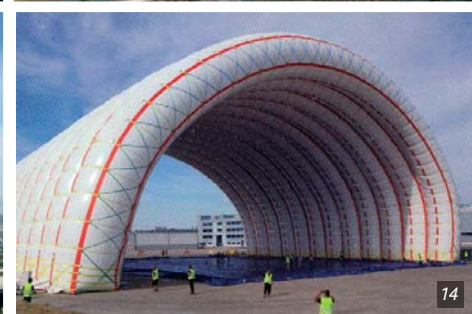
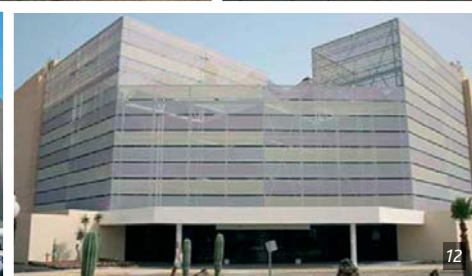
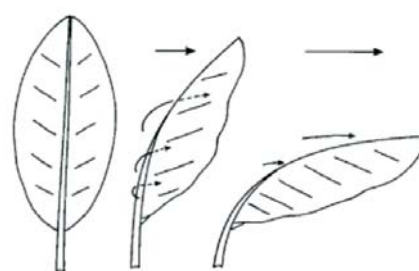


Figure 6. Membrane roof of the "Memorial dos Povos de Belém do Pará" - R. Pauletti

Figure 7. Passive adaptive behaviour of a banana-leaf - A. Habraken

Figure 8. University Drama Centre, Mexico City - J. Oliva

Figure 9. Cafeteria, León - J. Oliva

Figure 10. "cut.enoid.tower" - G. Filz

Figures 11& 12. Initial state and after retrofitting Oasis Hotel, Lanzarote - J. Tejera

Figure 13. Terra Alta Sky Lounge, El Salvador - C. Armendariz

Figure 14. Pressurized arches for portable hangars - J. Marcipar

and the project opened the door to similar applications.

J. Marcipar presented a remarkable application of pressurized arches for portable hangars (Fig. 14). A wide range of clear spans (from 15 to 54m) can be accommodated for aeronautical maintenance, defence, emergency, industrial and corporate utilisations. The length can be easily extended by the addition of arches. A variety of doors or end enclosures provide adaptability.

ETFE

R. Houtman presented "Design recommendations for ETFE foil structures" (available at <http://www.tensinet.com>). Afterward, F. Reitsma showed the ETFE modules for the San Mamés Stadium in Bilbao. He pointed out the twisting of the frames (Fig. 15) and their specially-developed laminated tubes (Fig. 16).

The optimization of clamp profiles, from a thermal efficiency viewpoint, were examined by B. Urban in "Thermo technical optimization of membrane clamp profiles regarding static and assembly engineering aspects" (Fig. 17).

W. Pösl featured the accomplishment of the project announced in "Structural Membranes 2011" (TensiNews n° 22, Fig. 9, p. 21) for the roof of a waste management vehicle maintenance facility of Munich. It includes thin-film solar cells in the middle layer of the three-layered, inflated ETFE cushions that shelter the space (Fig. 18). The energy collected operates the ventilation units, which pressurize the cushions. Surplus energy is fed into the public grid.

Regarding the embodied energy of ETFE cushions, J. Chilton compared three cushion panels of different shapes, sizes and

configurations. He concluded that geometry and configuration are at least as significant as the values provided by the "Environmental Product Declaration." In addition, for all three examples, the energy embodied is less than half that with a glass roof, demonstrating the advantage of ETFE foil cladding systems. F. Weininger dealt with the hardening effect of ETFE foil and its application to the Coca-Cola Beatbox, London 2012 (Fig. 19). The hardening effect was also covered by R. Blum in "On the mechanical behaviour of ETFE films" and J. Llorens in "Tension anchors for structural membranes".

Figure 19. Hardening effect of ETFE foil, Coca-Cola Beatbox, London 2012 - F. Weininger

Conclusions

Structural Membranes 2013 perpetuated the trend of previous editions, grouping experts, researchers and practitioners, who presented their latest findings, as the participants who also attended Structural Membranes 2011 in Barcelona could verify. It is expected that this trend will continue, because as B. Philipp stated: "The development of tensile structures is far from being finished. Important research is needed to solve the mentioned problems and face the arising challenges."

✍ *Josep I. de Llorens*
 📁 *ETSAB/UPC*
 💻 *ignasi.llorens@upc.edu*

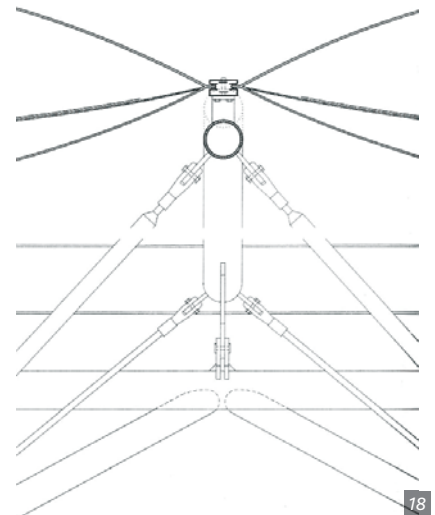
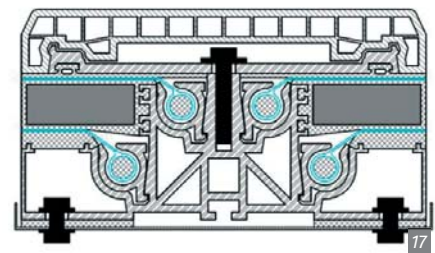
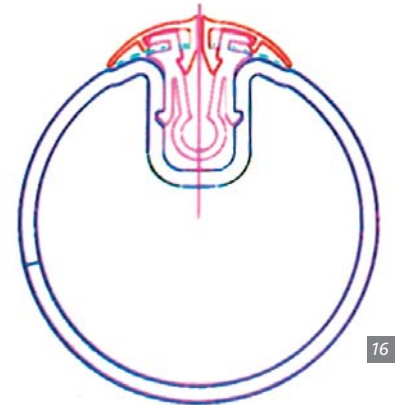
Figure 15. Detail of the twisted ETFE modules for the San Mamés Stadium in Bilbao - F. Reitsma

Figure 16. Special section for clamping ETFE modules - F. Reitsma

Figure 17. Detail of the optimized clamp profile - B. Urban

Figure 18. Detail of the three-layered ETFE cushion - W. Pösl

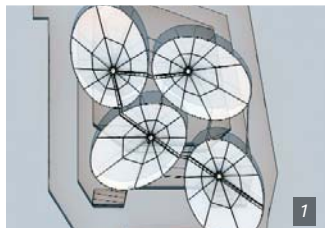
Figure 19. Hardening effect of ETFE foil, Coca-Cola Beatbox, London 2012 - F. Weininger



More information:
<http://congress.cimne.com/membranes2013/frontal/default.asp>

The Proceedings of the Conference are available at:
<http://congress.cimne.com/membranes2013/frontal/doc/ebook%20Membranes%202013.pdf>

The next international Structural Membranes conference will be held in Barcelona at the Technical University of Catalonia (UPC) in 2015. Further information will be made available in the "Events" section at <http://its.cimne.com/cdl1>.



A shopping mall canopy

BREAKING THE ROUTINE OF PLANAR AND GEOMETRIC LINES

Erasta AVM, Antalya, Turkey

Context

The Erasta shopping mall is located in Antalya city which is on the south shore of Turkey. The mall was thought to be an open air concept to satisfy the shading needs as well as to increase the noticeability by adding a different image and aesthetic to the shopping mall. This shading structure should be flexible, different, beautiful and not ordinary or plane (Fig. 1).

Project

The introduction of a series of large "umbrella's" canopies within the shopping mall was used as a walking trail. The 4 structures cover an area of approximately 1240m². The "umbrella" canopy is designed as a reverse elliptical conical tensile membrane structure with a carried by 1 steel post with an average height of 25m and a maximum width of 2m diameter. The major axis of the elliptical conical canopy measures up to 23,25m and the minor axis up to 16,84m. The manufacture and installation of the system was finished in approximately 2 months. Offering service since 2013, this structure has become an inseparable part as well as a landmark of the Erasta Shopping Mall with its feature of creating a domestic and relaxing space due to its aesthetic and form (Fig. 2).

Mehmet Yilmaz
 info@tensaform.com
 www.tensaform.com

Figure 1. Drawings

Figure 2. The canopies used for shading as well as for lighting

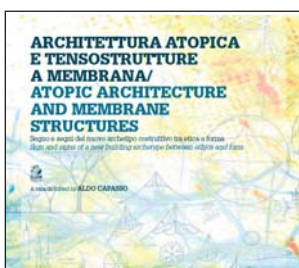


Name of the project:	Antalya Erasta Shopping Mall
Location address:	Antalya - Turkey
Client (investor):	Eroğlu Yapi İnş. Ve Gayrimenkul Geliştirme San. Tic. A.Ş.
Function of building:	Shopping Mall
Type of application of the membrane:	Reverse Umbrella Canopy
Year of construction:	2013
Architects:	Tolga ÇETİN
Multi-disciplinary engineering:	Mehmet YILMAZ
Structural engineers:	Mehmet YILMAZ
Consulting engineer for the membrane:	Bora ÇETİN
Engineering of the controlling mechanism:	Mehmet YILMAZ
Main contractor:	Eroğlu Yapi İnş. Ve Gayrimenkul Geliştirme San. Tic. A.Ş.
Contractor for the membrane (Tensile membrane contractor):	Tensaform Membrane Structures Co.
Supplier of the membrane material:	Serge Ferrari
Manufacture and installation:	Tensaform Membrane Structures Co.
Material:	Ferrari Fluotop 1202 T2
Covered surface (roofed area):	1240m ²

BOOKREVUE

ATOPIC ARCHITECTURE AND MEMBRANE STRUCTURES

Sign and signs of a new building archetype between ethics and form



Publisher: CLEAN EDIZIONI Napoli www.cleannedizioni.com

Edited by Aldo Capasso

On the twentieth anniversary of the International Symposium on "Architecture and lightness", held in Naples in 1993, this book aims to appraise the innovative archetype of structural lightness: membrane tensile structures - a technology that Frei Otto has pioneered since the

'50s leading to the birth of contemporary textile architecture. Textile architecture is read through the "sign and signs" of the designers: sketches, drawings, graphics and photos that run through the pages of this publication. A rich thread of images and words connects the prologue to the epilogue recording the ideas and achievements within the "visions" of the designers, modelling space with the "bearable lightness" of textiles. Designers and researchers from different disciplines analyze textile architecture defined as "atopic" by Renato De Fusco - an architectural language that confirms the ideas of Eduardo Vittoria, highlighting how a technology goes beyond its own specificity to represent "... one of the inventive components of design thinking."

ISBN: 978-88-8497-242-2 | PAGES: 455 HARDCOVER |

LANGUAGE: ITALIAN/ENGLISH | PUBLISHED: 2013 |

This article summarizes the keynote lecture of Jürgen Bradatsch given during the Tensinet Symposium in Istanbul, 2013. Jürgen Bradatsch is Chief Architect (CTO) of SL-Rasch Special- and Lightweight Structures, leading an international team of architects and engineers of multiple different discipline. He was directing the design, engineering and build of a great number of international recognized Lightweight Structure Projects. This includes the continuous research and development of advanced scientific methods for the design and engineering of permanent, mobile and convertible technically most efficient lightweight structures, to improve human conditions for public spaces and buildings. Innovative technology that well integrates with traditional cultural context and historical environment as extraordinary and unique solutions of Lightweight Architecture.



Figure 1. Shading Project for the Piazza of the Prophet's Holy Mosque, Madinah, Saudi Arabia, 2011 – the umbrellas will opening position

[RE]THINKING LIGHTWEIGHT STRUCTURES

light is beautiful, light moves Jürgen Bradatsch

We are all part of nature but we never will be able to build like nature. Manmade objects will always be artefacts - and in the best case they are pieces of art. So we develop science that is aiming to understand nature and to create the kind of know-how and technology that enables us to build consistent with nature. To find the minimal shapes for Lightweight construction we study and apply self-forming processes that follow the physical laws of tension equilibriums. The search and the goal of "form finding" by applying self-forming processes is a philosophical design ap-



Figure 2. Soap film models were used at first as a way to study the self-forming process. They are always inspiring objects

proach with respect towards creation. Form must naturally arise within the stated conditions without pretension or stile - arbitrariness is excluded.

Form finding as an iterative, scientific process that is applying the most advanced physical and numerical models to develop the objective and optimized solution and this is for the complete design process from first form-finding till detail design. In this the searching for the form and the form-finding never ends in themselves, but their goal is with the least material and energy cost to create optimized minimal structures that improve the quality of our buildings and our environmental conditions in coexistence with nature.

Searching for the minimal in architecture is searching for the essence of the material form. Focusing on the essential also enables us to integrate with a given environment without damaging or competing it, but respecting its "genius loci" and completing it.

During all times high cultures searched to optimize and to reach the technical limits of the structural systems for their buildings and created „lightweight structures“. High cultures also used lightweight construction to carry ornament. And this again not in an arbitrary decorative way but to enhance pure structure, that is following the abstract mathematical geometric system. By applying symbols of the respective culture in order to show the hierarchy of its different members, the structure becomes readable and meaningful for the beholder.

Light is beautiful – light moves and creates sheltered spaces of architectural excellence. (Re)thinking Lightweight Structures for me includes a period of about 28 years of work when Bodo Rasch and me started to develop convertible solar powered 5m x 5m umbrellas structures in 1985.

The period between developing these first 5m x 5m umbrellas and the extraordinary actual umbrella projects with convertible membrane structures of more than 50m span includes almost three decades of intensive research and development of scientific methods to improve the design of lightweight structures and to develop materials, aiming for an architecture where overall form as well as each element of it form a unique entity.

Such Lightweight Architecture of course is not a one man achievement, but the result of the work of the international and interdisciplinary SL-Rasch Lightweight Structure team, including Architects, Civil- and Mechanical Engineers, Physicists, Software Specialists and Artists. Our team is continuously developing most advanced design methods, that in combination with computer aided manufacturing, allow to build Lightweight structures of highest precision, safe performance and longest life - convertible structures for the improvement of environmental conditions and innovative structures that integrate with traditional cultural context and historical environment.



Figure 3. Shading Project for the Piazza of the Prophet's Holy Mosque, Madinah, Saudi Arabia, 2011 – in final opened position

Design and Engineering

Minimal shaped lightweight membrane structures are flexible by their nature and show quite large displacements under external loads. Such structural membranes have thicknesses of 1mm or even less in real scale and so it is technically almost impossible to build small scaled membrane models for physical wind tunnel testing that would behave elastic similar as real scale. Therefore it became necessary to develop alternative models for the analysis of the large umbrellas in turbulent wind. During the last 10 years it was mainly the achievement of our senior engineers Dr. Alex Michalski and Bernhard Gawenat supported by Dr. Eberhard Haug (ESI France) to develop, to calibrate and to verify numerical elastic computer models that simulate and analyze the aero-elastic behavior of strongly deflecting structures in natural wind conditions.

This FSI – fluid structure interaction is an iterative process between CFD-wind load analysis and CSD structural response. On the one side (CFD) the wind loads that are resulting from a turbulent wind field with a natural gust frequency distribution are analyzed for the initially pre-stressed membrane shape structure. On the other side (FSI) this particular wind load situation is applied to the elastic model that deforms. In the next step the wind loads are determined for the deformed structure and these new wind loads are again applied to the elastic deformed model entering a CFD-FSI

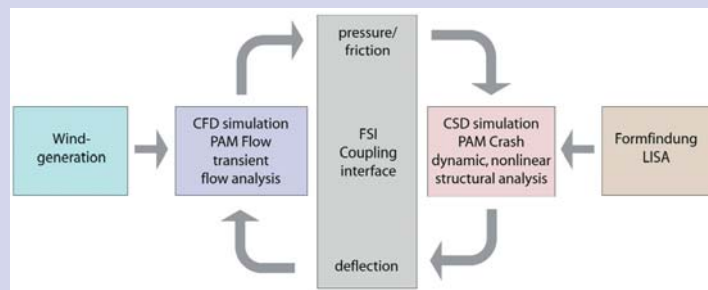


Figure 4. Diagrammatic explanation from FSI (Fluid – Structure Interaction) Computer Methodology (by ESI-Group)

cycle that is calculated for milli - second steps in reality and for this reason is lasting hours and days to compute the aero elastic response (reaction forces, movements, dynamic load amplifications) of the deflected structure for some minutes in real time.

Since this Computational wind simulation is not yet fully recognized by the building authorities as a standard method, like the physical wind tunnel is, we had performed and evaluated scale 1: 1 wind tests with a 29mx29m umbrella for the calibration and verification of our computer model method. The real scale tests were made in cooperation with Company Liebherr, Germany, who is one of our industrial partners to realize our design and engineering for large span umbrellas.

The simultaneous measurements of the turbulent wind field as well as the physical response of the flexible umbrella structure including the measurements of membrane deformations and the stresses and strains in the single members of the umbrella steel frame gave us the data basis to calibrate and to verify our numerical design method. And when we finally compared the results of the physical measurement with our numerical FSI simulation, we had to discover that our initial 3d CFD mesh was too coarse to catch the energy of all

the very small turbulences. After refinement of the numerical model we could achieve adequate accordance of real measurement and numerical simulation within a range of less than 25% - whereas the numerical result in general gave the smaller values. And further runs had proven that the finer the CFD mesh is modeled the closer the simulation meets the real behavior of the flexible structure.

This gave us good reason to increase our compute power, to allow for the simulation of CFD models with 60- 80 Mio elements for the development of an umbrella with more than 50m span. First numerical simulations of the aero dynamic behavior of this new structure showed that our invest-



Figure 5. Prototype of a 29m umbrella for validation of FSI methodology, Germany, 2009.

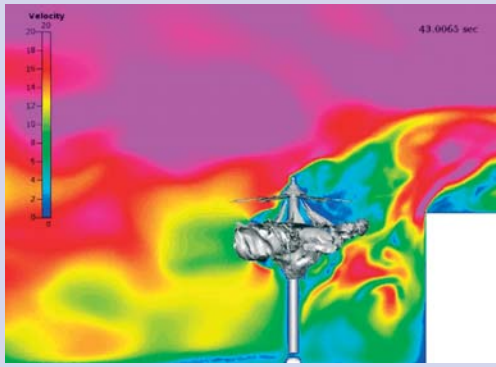


Figure 6. Shows one instant of the computer simulation for 53m umbrella's behavior in partially folded position, with gust wind speed of 25 m/s at 30m height.

ment was worth it. The dynamic amplification of the reaction loads for this large flexible membrane structure was much larger than estimated and expected from our experience with previous umbrella structures and finally a tuned mass damper had to be integrated to reduce the extreme dynamic loads. So without the FSI simulations we would neither have discovered the problem nor had found, as well as had proven, an adequate solution to solve it. This example also illustrates how sometimes you have to add special engineered portions of weight in order to keep your overall structure lightweight.

Our convertible large umbrella structures are designed to be safe for all max. wind loads in both open and folded position. Yet the operation of the umbrella has to be limited to certain wind speeds depending on material weights and size of the loose membrane areas exposed to wind. And the numerical CFD/ FSI method again is the only tool to analyze and predict the behavior of the partially folded membrane without prestress under wind loads and to evaluate the critical wind speeds up to which the folding umbrella structures still may be safely operated.

We search not only for the *Minimal Surface*, but we search altogether for the *Minimal Structure*. Structures where each its members (from foundations till arm tip) is specially shaped according to its particular structural function and loading. This is to minimise the use of materials and sectional dimensions, as well as the consumption of energy for production, transportation, erection and operation. It finally results in the most elegant architectural appearance of a functional, optimized, unique lightweight structure.

In the case of the 26m Madinah Piazza Umbrellas we have achieved a foldable arm system which reduces the single diagonal arm length from 17m (34m in total) in stretched position to 12m in folded position and the umbrella that is shading an area of 650m² folds to a most compact arm

arrangement with a section of only about 5m² – which is less than 1% of the covered area.

For automatic controlled operation a central mounted electro mechanical drive shaft was developed to actuate the complete umbrella operation. The operation time for folding and pre-stressing is approximately 3 minutes. It requires quite small drive forces due to a kinematic system that avoids the strong lifting for the centre of gravity of a quite balanced foldable steel frame. Only approx. 2 kWh electrical energy is needed for the unfolding and pre-stressing of a 650m² shading structure, this is equivalent to ca 0,003 kWh per 1sqm of shade per day, that reflects approx. 70% of the sun's radiation (~1.0 kW/h/m²)

The umbrellas provide all advantage of an industrially produced modular shading system, that is pre-assembled in factory, for precise, safe and durable operation, for controlled handling and transportation as well as for fast and clean erection. The umbrella is demountable, may be shifted and may be re-erected in a new position. This way the umbrellas provide a flexible as well as an expandable shading system.

Membrane Material Development

It was a long way of research during some generations of umbrellas to develop the actual technically advanced fabrics for high performance membrane structures. The 'stuff of our dreams' without questions is woven from pure Polytetrafluorethylen (PTFE). No other natural or synthetic material does provide the same combination of material properties and characteristics. And without PTFE it would just not be possible to build such kind of centrally folding umbrella structures, while this is the only material that combines at the same time 100% UV-Stability with highest flexibility and strong mechanical resistance.

The first large scale application of PTFE architectural fabrics was for the 17m X 18m umbrellas in the courtyards of the Prophet's Holy Mosque in Madinah, 1992. And since then we are continuously developing for each new application technical advanced open weave PTFE fabrics together with specialist weavers. Fabrics, that are highly tensile and flexible, that provide highest seam strength, that are relatively water tight as well as dirt repellent and, finally and most important for shading structures that are highly reflective to sun light. Our projects prove and verify the performance and aging process from PTFE in convertible structures application. The umbrellas at the Courtyards of the Prophets Mosque Madinah were 20 years in daily operation: pre-stressing and folding - more than 14-15.000 times open and closed. During all this time there was no major corrective maintenance needed, but mainly just visual inspection and cleaning. In 2012, after 20 years, the structurally still integer umbrella membranes were replaced for an overlapping rainproof membrane



Figure 7. Top view of the Umbrellas for the Piazza of the Prophet's Holy Mosque, Saudi Arabia. Additional membrane sails were designed to cover the mechanical parts at the umbrella center. This increases the shading and unifies the architectural appearance of the different umbrella members from above, which is the view point from surrounding buildings.



Figure 8. Assembly of Umbrellas in the Piazza of the Prophet's Holy Mosque, Madinah, Saudi Arabia. The Umbrellas are pre-assembled in factory and allow a clean and fast erection as well as relocation, if needed



Figure 9 and figure 10 show the Umbrellas for the Courtyards of the Prophet's Holy Mosque, Madinah, Saudi Arabia 1992 - during the day (Figure 9) and in the evening (Figure 10). In 2010 we replaced them, after 20 years in daily operation, - pre-stressing and folding more than 12-15.000 times under extreme high sun radiation -, for an overlapping umbrellas solution. One of the membranes has been tested in laboratory to proof the quality of the PTFE fabric after those years of use in order to calibrate the safety factors for aging in currently projects.



Figure 10. Sun set, it is a moment of great relieve in Arabia. The Umbrellas are folded, opening the courts for the cold night sky, to liberate the energy accumulated during the day. Building masses and floorings cool all night long to provide comfort for people underneath the shades during the next day of sun.



Figure 11. In the cold winter nights the Umbrellas in the Courts as well as in the Piazza of the Prophet's Holy Mosque stay opened to protect people from the cold radiation of the night sky.

arrangement. New and larger membrane structures were mounted to the modified umbrella frames with arm extensions and adjusted umbrella drives for an overlapping arrangement of structures.

This gave us the exceptional chance to test samples of the used PTFE membranes that had been for 20 years in daily operation and that had been exposed to highest UV radiation. Extensive laboratory testing did proof that the tensile strength of this PTFE fabric was reduced for some few percent only in 20 years of operation. These results give good reason to reconsider and to adjust the safety factors for material aging that we are applying for the dimensioning of our actual membrane structures.

Lightness for Convertibility – to control climatic conditions

The convertible umbrella structures are more than a shading roof only. In open stretched position they are shelter from sun, from rain and from the cold night sky. In folded position they allow natural energy radiation exchange between sky and ground. The consequent operation of the convertible umbrellas in order to control the amount of radiated energies for the different situations of day and night and during the seasons lead to significant improvement of the climatic comfort of the convertible sheltered space.

In the late Arabian summer afternoon the umbrellas are folded, when the sun's radiation to the ground gets less than the radiation from the ground towards the relatively cool blue sky, to start liberating the heat that was accumulated during the day. Till next sunrise great amounts of energy can be radiated to the black night sky. Flooring, soil and building masses get cold for the next day to provide climatic comfort for the shaded space. In the cold winter nights the umbrellas stay open stretched to shelter the covered space from the radiation of the cold night sky.

We are performing long term measurements of the climatic conditions underneath the convertible umbrellas at the Madinah Piazza and the results of these measurements proof that the operative temperature that people feel underneath this convertible shading roof is about 2-3°C below air temperature, due to the relative cooler flooring and this is a great improvement compared to the climatic conditions underneath permanent shading roofs. Even during the very hot summer months (May to August with 45°C and more) the convertible membrane roofs keep the Wet Bulb Global Temperatures at average below the ratings that are still considered acceptable for humans. For further reduction of temperatures during the very hot summer months, we have added a misting fan system to the umbrellas to provide additional evaporative cooling for further reduction of the ambient temperatures and further improvement of the climatic comfort underneath the umbrellas.

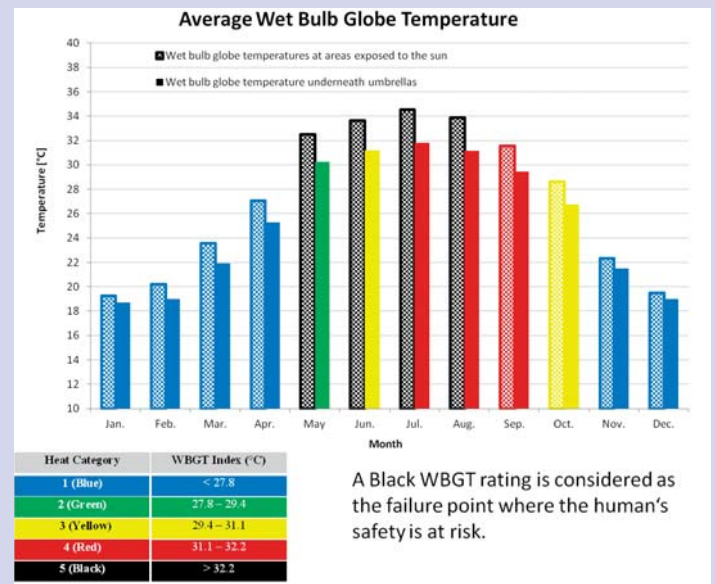


Figure 12. Average Wet Bulb Globe temperatures underneath the convertible shading at the Madinah Piazzas do not reach the black rating and keep about 2-3°C less than without shading.

Aesthetic of the Ephemeral - Mobility

From the beginning mankind is using tents as lightweight, mobile climatic shelter. Still expressing the lightness and the aesthetic of the ephemeral, we have today the design methods, technology and materials, to build lightweight structures that are enduring and serving for decades. Lightness allows for Mobility. Mobile Architecture that is offering the comfort and quality of permanent structures opens new possibilities for a flexible urban development, when land and building shall not be attached forever. Mobile lightweight structures for medium- or longer term use at temporary available land, following the urban development of our cities.



Figure 13. Mobile Round Tents for Showrooms, in Leonberg, Germany, 2000 - Lightweight structures as multi layer insulated tents for all year use, also during the cold German winter. The tensioned membranes are stretching between peripheral compression ring and mast top – the membrane's tension forces are most efficient balanced within the structure. For this reason such pointed round tents can be anchored without heavy ground works. The complete tent with its modular façade system can easily be demounted and re-erected in another location.



Figure 15. Prophet's Holy Mosque in Madinah 1950-60 - Old Ottoman Mosque including the Green Dome and the first Saud Extension - Palm groves were still close around the city center.

Always searching for solutions with least impact to the environment, and avoiding permanent concrete ground works. We have made our experience with Mobile Lightweight Structures for all year use on the 49th latitude as well as for the 23rd latitude. We developed multilayer insulated membrane structures that are heated or air conditioned to provide climatic comfort for extreme environmental conditions. But unlike solid buildings lightweight insulated lightweight membrane structures do not waste energy to heat or to cool building skins



Figure 16. Prophet's Holy Mosque with Piazza in Madinahh 2012 – (Figure 16 umbrellas opened, Figure 17 umbrellas folded)



Figure 14. Tents on top of the Towers of the King Abdul Aziz Endowment Project, in Makkah, Saudi Arabia, 2012 are located in approx. 220m-250m, each with a covered area of 3.000 - 4.000m². These Tower tents are covering restaurants as well as representative spaces and provide all required comfort for the extreme climatic conditions of Saudi Arabia.

with high masses for times, when these buildings are not in use. For large tent covered spaces additional comfort is provided by convertible membrane elements that were developed to control the interior air flow and to adjust the conditioned air volume according to daily or seasonal changing environmental conditions.

Umbrellas for the Piazza of the Prophet's Holy Mosque in Madinah

The excellent experience with the technical and architectural performance of the 12 umbrellas (17m X 18m each) that are shading the two large courts at the 1st Saudi Expansion of the Prophet's Mosque in Madinah since 1992 encouraged the client to decide for our proposal to install additional a total of 250 umbrellas (26m x 26m each) at the large Piazza surrounding the Mosque. This arrangement of large umbrellas is covering all together an area of about 150.000m² to offer shaded space for prayer and for safe circulation for about 350.000 - 400.000 people during the pilgrim seasons in Ramadhan and Hajj. This extraordinary convertible membrane shading roof is the largest one built and is an innovative architectural solution for an outstanding task without any reference or sample. Lightweight architecture to provide a most distinguished space and climatic comfort supposed for people coming from all over the world to visit the Prophets Mosque in Madinah.

Madinah is located in a wide open plain approx. 600m above sea level and is surrounded and sheltered by low mountains. It is a place with plenty of groundwater in a depth that palm trees easily can reach - an Oasis, famous since always for its delicious dates. The "genius locus" of Madinah is the character of the oasis with its promise for a pleasant pause to travelers, a



Figure 17. What a dramatic change in the architectural appearance of the Piazza when 150.000m² of roof are folding away in minutes only, animating people and urban environment.

safe and peaceful place to meet and to find rest and comfort. During the last decades rapid urban development banished and displaced the palm groves from the city center to far behind the distant outskirts of the new modern Madinah. But today it is the very lightness and the convertibility of the umbrella structures that bring some of the character of the Oasis back to the city center, giving a new expression to the genius locus of Madinah.

The lightness and convertibility of the umbrellas stays in contrast to the solid structures of the newly built environment. They form a soft transition between Mosque and city and their pleasant shade invites people to stay.

The umbrellas form a convertible shading roof in urban scale, a space in between the city and the Mosque. The translucent membrane roof creates a soft transition and reception for those arriving and departing and provides pleasant shade for those that stay. Gaps in this umbrella roofing give view to the main building axis and provide orientation for people, create skylight openings, casting lanes of light in between shade, organizing people movements and activities.

Getting folded in the summer evening the convertible umbrellas allow people to share the moment of great relief, when the sun is setting and to enjoy the blessing of being in the open under the pleasant nighttime firmament – and what a dramatic change in the architectural appearance of the Piazza when 150.000m² of roof are folding away in a few minutes only from day to night, daily and during the seasons, bringing vitality to the urban environment.

Membrane vaulted spaces of superior architectural quality with its very own character of umbrella lined avenues – magnificent but never monumental. Being outdoor and yet being sheltered, climatic comfort in a well-defined space but not enclosed and not completely covered. 24 hours a day participating with the sky during hot days and during summer nights. The reflections and transmissions and the color of light through the double curved membranes is permanently varying in relation to the changing position of the sun as well as of the beholder. This altering light conditions underneath the umbrellas creates an animated ambience that stimulates people to stay attentive and alert. It also creates the very special open and light ambience for the huge crowds of pilgrims not to get stressed and to stay calm even if the densities get high.

And the umbrellas integrate well with the traditional architecture of the Mosque. Their minimal shaped translucent membrane structures create a vaulted textile roof that does not compete with the solid stone building but creates a covered space open to all sides to link the Mosque together with the city. Membrane vaults with changing appearance all day long, providing endless rich impressions of building and people in the play of light and shade.

It is a large scale convertible shading roof to shelter people of all ages, different gender, different ethnic and cultural origin. A partially covered Piazza to provide space for people to safely move, to meet, to rest and to recover, a space for breaking the fast in great communion during Ramadhan, a space to densely crowd together and to communicate – but not feeling narrow and tight. And finally it's a space to pray - and to find peace! We cannot built heaven on earth but we shall spend all scientific and artistic effort to develop the objective best solutions for our buildings. Not to separate heaven and earth, but to bring both together as close as possible.

*„Beauty is the brilliance of the Truth“
(Plato)*

✍ Jürgen Bradatsch
✉ juergen.bradatsch@sl-rasch.de
🌐 www.sl-rasch.de
📁 all pictures @ sl-rasch

Figure 18 to Figure 21. Umbrellas for the Piazza of the Prophet's Holy Mosque in Madinah. Different



impressions of an innovative technology that well integrates with the traditional cultural context - an extraordinary and unique solution of Lightweight Architecture.

LONDON OLYMPIC GAMES 2012

WHAT HAPPENED TO THE SERGE FERRARI COMPOSITE MEMBRANES? INITIAL ENVIRONMENTAL ASSESSMENT, ONE YEAR AFTER THE GAMES...

Several factors contributed to Serge Ferrari Group's active participation in building construction - especially sports facilities - for the London Olympic Games 2012. These included the Rhône-Alpes Group's know-how embodied in the technical performance characteristics of its composite materials, its capacity to innovate especially through its phthalate-free product references, its multiple commitments to architects, engineers and prime contractors in favour of lightweight architecture, convergence between its manufacturing culture and its sustainable development-based requirements.

London's Olympic project was forcefully publicised at the time of the British capital's candidature: to organise the most sustainable Olympic Games of modern times. Serge Ferrari succeeded in meeting the drastic criteria imposed by the Olympic Delivery Authority (ODA) - in charge

SPORT FACILITY 1 - LONDON AQUATIC CENTRE (LAC)

A majestic building expressing water's fluid geometry and reflecting the supple beat of a manta ray's wings, the LAC bore two temporary structures extending from its long-term central section. These lightweight structures were designed to shelter spectators during the swimming and diving competitions. Dismantling of these "wings"... the 25.000m² of Serge Ferrari composite membranes were detached from their peripheral fixings and removed between the end of October 2012 and

mid-January 2013 (Fig. 2). The dimensions of the roof panel are 40mx7m on average, these of the facade panel are 20mx6m on average. The building's capacity was reduced from 18.000 seats during the Olympic Games to 2.500 seats in its final configuration. Embodying the environmental approach adopted by the organisers, the temporary roof and facades were dismantled, transported and recycled at the Group's Taxyloop® recycling facility in Ferrara, Italy (Fig. 3). These London consignments enabled the Serge Ferrari recycling plant to produce 23 tonnes of 2nd generation raw material (fabrics, unwoven materials, bolt ropes, etc.), reducing their environmental impacts by 50% (based on a Life Cycle Assessment conducted by independent environmental consultant EVEA) to provide savings of 4.629m³ of water and 41 TeqCO₂, based on ISO Standards 14040 and 14041.



Figure 2. Above: configuration with "wings" during the Olympics. Below: configurations after dismantling

Life Cycle Assessment

Précontraint® 1002 S2 & Stamisol® FT 381 / Operational unit = 1m² of composite membrane

Type of impacts	Précontraint® 1002 S2			Stamisol® FT 381		
	Taxyloop® Recycling	Incineration	Landfill	Taxyloop® Recycling	Incineration	Landfill
Resource depletion - Kilograms eq. Sb	0.024	0.151	0.151	0.015	0.083	0.082
Global warming - Kilograms eq. CO ₂	2.572	4.757	4.104	1.29	3.66	3.29
Water consumption - Litre	139.6	341.3	339.6	87	234.5	233.5
Energy consumption - Megajoule eq.	59.7	103.3	103.3	43.3	80.7	80.7

Project: London Aquatic Centre
 Project Architect: Zaha Hadid Architects
 Structural Engineer: Tensys
 Fabrication/Installation Contractor: Architen Landrell Associates (ALA)
 Serge Ferrari composite membranes for roof: Phthalate-free Précontraint® 1002 S2. Total area: 18.000m²
 Serge Ferrari composite membranes for facades: Stamisol® FT 381 Total area: 7.000m²

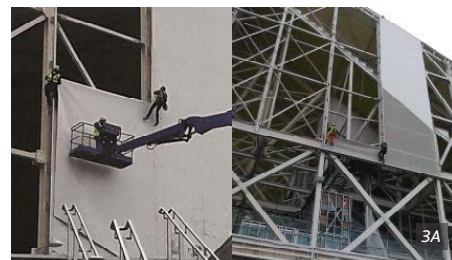


Figure 3. A spectacular operation in 5 steps:
 A. dismantling -
 B. receipt of composite materials for sorting -
 C. shredding -
 D. treatment at Taxyloop Ferrara plant -
 E. 2nd generation raw material

of designing and building the facilities and infrastructures - by offering not only its composite membranes with their minimal environmental footprint, but also their 100% recyclability through the Taxyloop® process (Fig 1). These composite materials also offer re-utilisation alternatives through their re-deployment in a similar context or in new applications.

In relation to the original ambitions announced by the organisers and the site conversions scheduled over the 18 months following the Olympic Games, what initial assessment can we make concerning metamorphosis of the sports and event facilities built using Serge Ferrari composite membranes? Let's take a closer look...

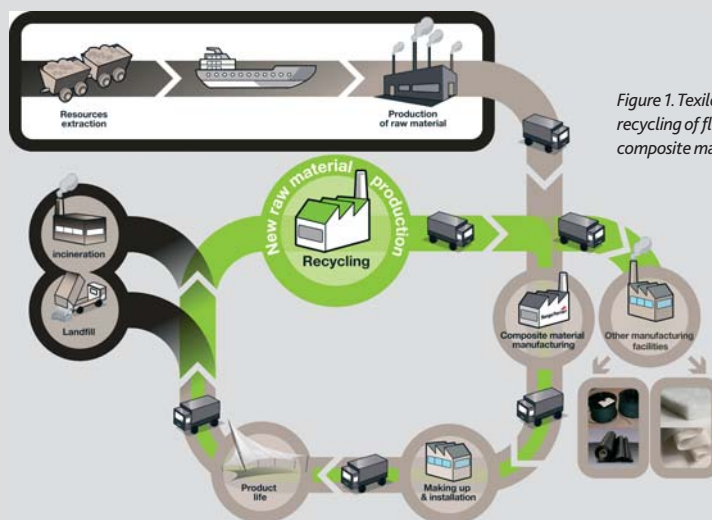


Figure 1. Taxyloop® - recycling of flexible composite materials

SPORT FACILITY 2 - OLYMPIC STADIUM

By selecting Précontraint® 1202 S2 composite membrane for the stadium roof and entrance canopies; Populous, a world renowned architectural firm took full advantage of the lightness, strength and recyclability of Serge Ferrari composite material in total compliance with the organiser's environmental strategy. The stadium received the World Stadium Congress 2012's "Award for the most sustainable stadium" (Fig. 4). The Olympic Delivery Authority (ODA) specification requirements included dismantling and removing the composite membranes. Main contractor Balfour Beatty was awarded the demolition contract on 3rd July 2013 and the

removal of the 112 roll widths forming the lightweight roof was started in autumn 2013. The composite membranes will then enter the Taxyloop® recycling chain to give birth to 2nd generation raw materials. During the Olympic Games, the composite material covered two-thirds of the spectator stands (ensuring



protection from bad weather), shielded the competition area from the wind (ensuring certification of potential records) and was the key to controlling light transmission (limiting dazzle incompatible with TV broadcasting technical requirements). Voted the most ecological stadium in the history of the Modern Games, the structure's capacity will be reduced from 80.000 seats to 35.000 in so-called Legacy mode. West Ham Football Club will take possession of the stadium in the summer of 2016. The British Government has granted the club a 99-year long lease.

Figure 4. General view and inside view of the Olympic stadium



Project:	Olympic Stadium
Project Architect:	Populous
Structural Engineer:	Buro Happold
Fabrication/Installation Contractor:	Seele Cover GmbH
Serge Ferrari composite membranes for roof:	Précontraint® 1202 S2 Total area: 33.000m²
Serge Ferrari composite membranes for Awnings (12 modules displaying stand accesses):	Précontraint® 1202 S2 Total area: 5.000m²

SPORT FACILITY 3 ROYAL ARTILLERY BARRACKS

Located the Woolwich arsenal, the three buildings hosting the shooting events were very quickly dismantled. The flexibility and lightness of the Serge Ferrari composite membranes allowed this operation to be efficiently and rapidly managed. The modular character of the membranes - along with their translucence and aesthetics - enables them to be re-used in a similar context and why not during the forthcoming 2014 Commonwealth Games in Glasgow (Fig. 5)



Figure 5. Aerial view of the Royal Artillery Barracks

Project:	Royal Artillery Barracks (RAB)
Architect:	MAGMA Architecture SARL
Fabrication/Installation Contractor:	Base Structures
Serge Ferrari composite membranes for external envelope (3 separate buildings):	Phthalate-free Précontraint® 1002 S2 Total area: 22.500m²
Serge Ferrari composite membranes for internal covering:	Phthalate-free Soltis® 92 Total area: 14.000m²
Serge Ferrari composite membranes for Ballistic screens:	Phthalate-free Stamisol® FT 371 Total area: 10.000m²

INTERNATIONAL BROADCASTING CENTRE



Figure 6. Membrane bioclimatic facade of IBC

Located in the heart of a 45 hectare green space, the largest park created in Europe in the last 100 years, the former Press Centre will be redeveloped around a mixed programme combining flats and public housing. Lightweight, durable and offering exceptional outward transparency, the composite membrane bioclimatic facade will hence enjoy an extended life based on a long-term application (Fig. 6).

Project: International Broadcasting Centre (IBC)
 Architect: Allies & Morrison
 Fabrication/Installation Contractor: Architekten Landrell Associates (ALA)
 Serge Ferrari composite membrane for facade: Phthalate-free Stamisol® FT 381 - Total area: 4.500m²

ANCILLARY RECONVERSION

Located on the Olympic Games site and the city centre, structures housing event services represented a total area of 230.000m² in the form of "Chinese hat"-type structures or tents dedicated to storage and logistics.

Clad in Précontraint® 702 S2 composite membrane, these temporary structures have been given a second life in application/rental terms. Their impeccable aesthetics (ensured by their S2 surface treatment), lightness, durability and modular design effectively facilitate their re-use.

✍ Françoise Fournier
 ✉ francoise.fournier@sergeferrari.com

💻 www.sergeferrari.com
 www.texyloop.com

✍ Christine Marchand, Ad'hoc Presse
 ✉ contact.adhoc@free.fr

ARTICLE

'UP-CYCLING' WASTE STREAMS OF PERFLUORINATED POLYMER MATERIAL DYNEON INTRODUCES A GROUND-BREAKING NEW PROCESS

Introduction

Dyneon GmbH in co-operation with InVerTec and the University of Bayreuth has developed an innovative new technology for recovering about 90% of the monomers split from fluoropolymers during manufacturing and 'up-cycling' them back into the manufacturing process. Closing the fluoropolymer recycling loop is a major breakthrough in respect to true sustainability for these precious materials which are indispensable in a range of industrial applications such as linings in the chemical industry and automotive parts (Fig. 1). In recognition of this, the project was funded with a €1 million grant from the German Bundesministerium für Umwelt. Dyneon GmbH has joined forces with the University of Bayreuth's materials processing department and the associated Institut für Werkstoffverarbeitung e.V., a process-engineering institute, to design and build a demonstration plant that will be operational in Gendorf in September 2014. Together, they have engineered a model plant that uses a carefully designed and controlled multistage pyrolysis process in a fluidized bed reactor.

The process integrates seamlessly into existing fluoropolymer production lines. The pyrolysis

decomposes perfluorinated polymers, with a very high recovery rate into gaseous monomers, which are cleaned before being fed back into the manufacturing process.

Enormous potential for environmental protection As well as saving valuable resources that would be needed to produce monomers for the manufacture of fluoropolymers, the new process drastically reduces waste and emissions as demonstrated by Dyneon's laboratory test results in figure 2.

Project scope and technical challenges

Dr. Klaus Hintzer, 3M Corporate Scientist, explains that there is no question that this project's technical challenges are enormous, but they are minimal in the light of the realisation of what it means to the sustainability of fluoropolymers. And it's only the beginning. This first industry-scale high temperature fluoropolymer recycling plant is expected to process 500 metric tons of fluoropolymer waste generated from Dyneon's plant and other sources in the first year. Initially, the plant will process fully fluorinated polymer materials, such as waste streams, off-specification materials, PFA, FEP and unfilled PTFE, scrap sourced from moulding, sintering and

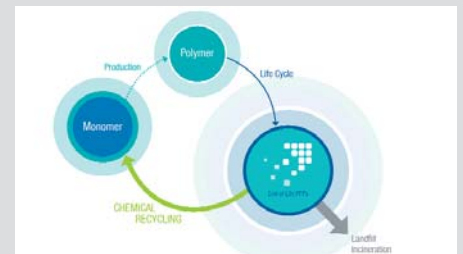


Figure 1. Up-cycling process - closing the fluoropolymer recycling loop

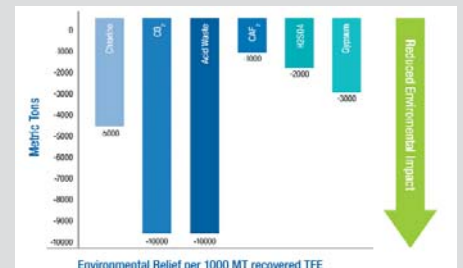


Figure 2. Laboratory test results - Reduction of waste and emission

machining operations. In a later phase, it will process PTFE compounds containing different types of fillers.

✍ Helmut Frisch
 ✍ Judith Seifert
 ✉ jseifert@mmm.com
 ✉ upcycling@3m.com
 💻 www.dyneon.eu/up-cycling



KIEFER TEXTILE ARCHITEKTUR

NEW STAGE COVERING FOR the "Parktheater" Plauen, Germany

Context

In 2013 the open-air theater in the urban park of Plauen finally gets a roof over the spectator area. The tent structure made of textile fabrics covers an area of 1000m². The roof levitates at a height of around 17m. This creates space and distant view between the stage and roof. The tent is stretched over a length of about 45m and a width of approximately 32m. Plauen well-known because of the „Plauener Spitze“ is the fifth biggest city in the Free State of Saxony in Germany. At the western outskirt area of the city you find a large park, which slopes gently from east to west and offers a panoramic view to neighboring hills. The grandstand is in a large plane platform and is embedded by the oblique hanging around (Fig. 1). The stage adapts perfectly to the terrain and runs parallel to the slope. In the sixties the area was planned as an open-air theater.

Around the nineties the society covers the stage. Since 2000 they also wanted a cover for the tribune. Ultimately in autumn 2012 the financing was clear. Shortly before the beginning of the season 2013 the inauguration took place with a concert by the famous German singer "Nena".

Project

A filigree frame construction made of thin steel tubes shaped like a giant bend carries a double high point with textile membrane surface structure. Towards the stage the roof ends on a falling steel arch. The arch is secured by two tension rods. In opposite, along the higher access level, four struts with spread tie downs serve as fixation points for the border cables. In the grandstand area the membrane is attached directly to the steel arch (Fig. 2 and 3). The high points are covered by transparent, light polycarbonate-

panes. The reinforcement of the membrane in the area of high points is due to the static requirement (Fig. 4).

Conclusion

The „Parktheater Plauen GmbH“ received a new emblem. About 1500 seats are covered now. The roof including complex foundation work was finished in about 3 ½ months. There is no shorter way, and it is only possible in a close and

trustful cooperation between owner/client, designers and executors, which was certainly the case.

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

Figure 1. Cross section - embedded tribune

Figure 2. general view of the tribune cover

Figure 3. Connection details

Figure 4. Internal view on the double highpoint

Name of the project:	Stage covering for the "Parktheater" Plauen
Location address:	Parktheater Plauen, Wolfsbergweg 2, 08523 Plauen
Client (investor):	Parktheater Plauen GmbH
Function of building:	Roofing
Type of application of the membrane:	PVDF-PVC/PES fabric, Type 5
Year of construction:	2013
Architects:	Michael Kiefer/ Kiefer. Textile Architektur
Structural engineers:	Tobias Lüdeke/ Kiefer. Textile Architektur
Consulting engineer for the membrane:	Tobias Lüdeke/ Kiefer. Textile Architektur
Main contractor:	Hunschede: Prebeck GmbH
Contractor for the membrane (Tensile membrane contractor):	Koch Membranen
Supplier of the membrane material:	Mehler Technologies
Manufacture and installation:	Koch Membranen/ Wilfling Membrane Service
Material:	Valmex Mehatop F 1600 Type 5 Mehler Technologies
Covered surface (roofed area):	1000m ²



Carried by waves up into the sky

TERMINAL 2A AT HEATHROW INTERNATIONAL AIRPORT, UK

1. PROJECT

Background

Terminal 2A is the next step of the transformation of Heathrow International Airport. Its main purpose to improve the journey of each individual passenger. Partner airlines will be closer together and the new terminal building will be a significant improvement for flight connections. The project started in 2009 with the demolition of the old Terminal 2 (Queen's Terminal), giving place for a new, modern building. In May 2010 under control of HETCo (general contractor) 75 subcontractors and more than 200 suppliers started the construction work of the new 56000m² terminal building. 20 million passengers are expected per year and around 35000 people will work on the project. The opening is planned on the 04th of June 2014.

Architectural concept (Fig.1&2)

The undulating shaped roof guides the passengers through three zones: check in, security and departures. Therefore function and shape are deeply integrated allowing passengers to easily orientate themselves in an intuitive way (Fig. 1). Terminal 2A has been designed to be as energy-efficient as possible. One element of the environmental strategy aims to reduce the CO₂ generated by the terminal by 40 %. The use of the natural lighting from the northern facing windows is diffused and reflected within the terminal by the use of a fabric roof lining (Fig.2). The combination of the geometry and the reflective properties of the fabric will allow good light quality. In addition to the use of natural lighting, there are large overhangs which provide shading on the East and West facades in order to minimise solar gain. The LEDs behind the membrane ceiling gradually change colour throughout the day. This means that although the passengers will not be aware of the changes, the lighting environment mimics the effects of a typical sky. Warm colours at sunset and sunrise, a bright blue during the day, and an indigo blue at night.

Primary steel structure (Fig. 3)

The Primary Structure of the terminal building is a complex steel structure.

The main wavy shape of the roof is created by 10 pieces of 252m long Vierendeel-trusses (hereinafter: V-truss). The spacing between these trusses is 18m. The V-trusses are supported by columns from below in every 18m.

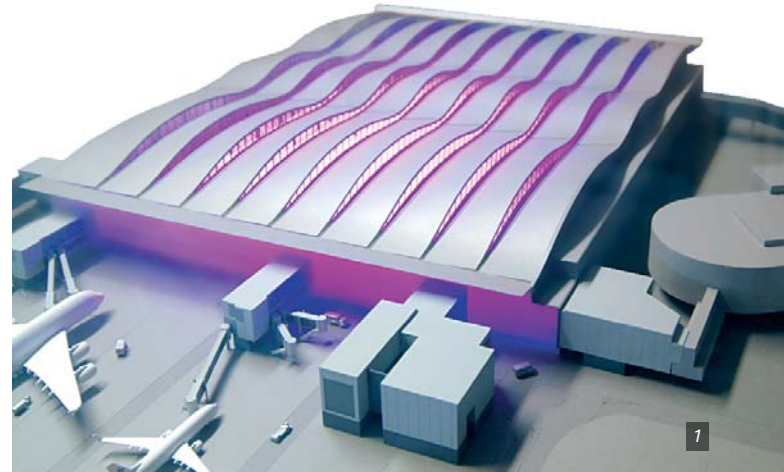
The top and bottom chord of the V-trusses are 400mm x 400mm box sections. The 18m span between the V-trusses is bridged perpendicularly by Pratt-trusses ("N-trusses") in an inclined way.

These connect the top box section of the one with the bottom box section of the opposite V-truss. The spacing between these Pratt-trusses is 4.5m which consist of an I-beam top and bottom chord and rectangular hollow section web members. The slope of these trusses are different on each axis, because of the wavy shape of the V-truss.

2. MEMBRANE OVERVIEW

Material

The inner membrane ceiling is used to cover the main primary steel structure and the steel trapezoid profile roof from underneath. The



smooth curved surface gives a nice appearance to the inner space. For the main membrane we used ATEX 3000 TRL perforated silicon coated glass fiber fabric produced in the UK. This fabric is used from architectural point of view with an optical advantage of high light transmission (about 40%) and with optimal acoustic properties. Working with this fabric with its lightly adhesive surface was a bit challenging. Especially focusing on the handling during the membrane fabrication as well as during the installation procedure. For the single layer ETFE foil under the windows in an inclined position we used an opalescent white ETFE 200µm with about 42% light transmission. This decision was made after several lighting tests and material comparisons.

Scopes and surfaces (Fig.2)

The scope of Taiyo Europe was the full service of design, engineering, material, fabrication, delivery and installation for secondary steel, membrane clamping systems, fabric and ETFE.

The project consists of 850 main membrane panels and 450 ETFE panels. The total surface area of the project is 56000m² ATEX material

as well as 3700m² ETFE foil.

Until now the Heathrow Terminal 2TA has been the biggest project of Taiyo Europe's history with respect to the total surface area.

3. TYPICAL MEMBRANE PANEL

Size & shape (Fig.4)

The typical membrane panel is surrounded by 2 V-trusses on its shorter „BACK“ and „FRONT“ sides and by 2 Pratt-trusses along its long „SIDES“.

On the long „SIDES“ the fabric is connected to the bottom chord of the N-trusses from underneath using special adjustable hanging brackets, secondary steel and clamping system.

On the shorter „BACK“ side the panel is connected to the top chord of one V-truss, and on the shorter „FRONT“ side to the bottom chord of the adjacent one.

The shapes of the typical panels are basically 20m long and 4.5m wide inclined flat shapes with a special strong curvature on the „FRONT“ side, around the bottom box section of the V-truss from underneath. All typical membrane panels have a different shape because of the different slopes of each truss.



General detail issues

To avoid any possible problems on site we followed some basic rules for the detail development. In order to keep the correct design positions of the secondary steel and to bridge the possible primary steel tolerances we developed an exact but flexible adjustable bracket system. These brackets connect the primary steel to the secondary steel elements. The special architectural request was to develop some kind of clamping system, where nothing from the secondary steel would be visible, and also most of the aluminium extrusion and bolts would be hidden.

Typical long „SIDE“ detail (Fig.5)

The special upside down U-channel secondary steel is located underneath the bottom chord of the N-truss and is connected to it by the adjustable hanging brackets. The aluminium keder profile is located inside the U-channel fixed by bolts which connect two panels to each other. The tensioning of the panels is achieved by tightening the bolts of the aluminium profile upwards through the U-channel.

„NOSE“ and „RING“ details (Fig.6)

The so called „NOSE“ is a special clamp, which gives the curvature on the front side of the membrane its shape. The clamp is on both sides of the typical panels each 4.5m apart from each other, with a radius of 300mm. To ensure the correct curved membrane shape on the front side was one of the most challenging points of the project.

Every 18m the „NOSE“ meets the column of the primary steel. To avoid the collision with the membrane we used a so called „RING“ detail. This is a special clamp around the column. The expectation for this detail was to tension the membrane from underneath by tightening the bolts of the aluminium-clamps in the secondary steel connection upwards. We made several tests and mockups to figure out the correct pattern adjustments and the best clamping solution for this strongly curved part. We had to keep in mind the type of tensioning as well as all of the requirements regarding the appearance of the details.

4. TYPICAL ETFE PANEL

(Fig.7)

The ETFE panels are located on the front side of each membrane panel as a straight extension of the curved „NOSE“ area on the top. These are sloped underneath the window and perpendicular to it. The sizes of the glass window as well as the size of the ETFE panel are dependent on their position. Due to the undulating shape of the main V-truss each frame has a different size. The flat ETFE always has a width of approximately 4.5m, but the height of the panel is variable between 0.5m up to 2.5m. The steel frame is powder coated and consists out of beams with rectangular hollow sections. The ETFE foil has been tensioned to the frame on the floor, and the full preinstalled frame is lifted into its final position where we can open it to have access to the LED lighting system located behind the frame.

5. INSTALLATION

To analyse the correct and effective installation procedure with respect to all detail issues, Taiyo Europe made several full scale mockups of the typical panels at the factory as well as on site.

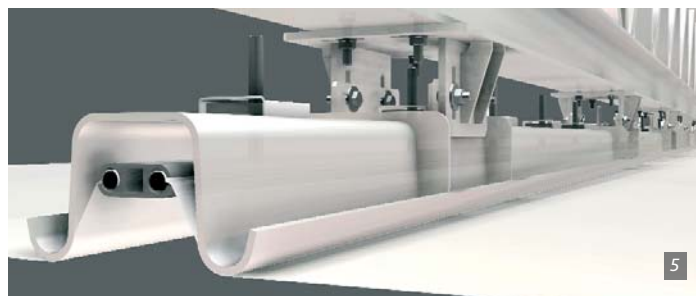
The installation started in June 2012 taking all the experience we collected during the mockup assembly with us and was finished by the end of the year 2013.

The limited access on site made the installation quite a complex task. Certain areas were only accessible to work on for specific time intervals, while admittance of the machinery was also constrained. Several teams were working parallel to each other on site. In order to avoid the overlapping of teams working in the same space at the same time we had to follow a strict time management system.

The secondary steel installation took place during day, and the membrane installation team worked by night. Working on and handling the main membrane, with its special and sensitive surface was a challenge for the working team.

6. ABOUT TAIYO EUROPE

Taiyo Europe is located in Germany near Munich. Taiyo Europe is the subsidiary of the Taiyo Group, which is one of the biggest membrane



LOCATION ADDRESS:	HEATHROW, LONDON (UK)
CLIENT:	HEATHROW AIRPORT LIMITED (HAL)
FUNCTION OF BUILDING:	AIRPORT, TERMINAL 2A
TYPE OF APPLICATION OF THE MEMBRANE:	INTERNAL CEILING
YEAR OF CONSTRUCTION:	2012-2013
ARCHITECTS:	BASIC CONCEPT: FOSTER + PARTNERS
LEAD ARCHITECT:	LUIS VIDAL + ARCHITECTS
CONSULTING ENGINEER FOR THE MEMBRANE:	MAFFEIS ENGINEERING S.P.A.
MAIN CONTRACTOR:	HETCO (JOINT VENTURE BETWEEN FERROVAL AGROMAN AND LAING O'ROURKE)
TENSILE MEMBRANE CONTRACTOR:	TAIYO EUROPE GMBH
MATERIAL (FABRIC):	ATEX 300 TRL; SILICON COATED GLASS FIBER
SUPPLIER (FABRIC):	P-D INTERGLAS TECHNOLOGIES LTD.
COVERED SURFACE AREA (FABRIC):	56000m ²
MATERIAL (ETFE FOIL):	NOWOFOL ET 6235 Z; ETFE FILM; 200µm; WHITE
SUPPLIER (ETFE FOIL):	NOWOFOL KUNSTSTOFFPRODUKTE GMBH & CO.
COVERED SURFACE AREA (ETFE FOIL):	3700m ²

companies in the world specialized in membrane and ETFE architecture with an approximate annual turnover of 340 mio. €.

We are proud to take part in this big, complex and challenging project in the UK. We are happy to have left our positive, qualitative mark on this complex and eye-catching terminal building.

Taiyo Europe GmbH
Zoltán Endre Simon
Dipl. Ing. (U) Structural Engineer
z.simon@taiyo-europe.com
www.taiyo-europe.com

Figure 1. External overview
Figure 2. Internal overview
Figure 3. Primary steel structure
Figure 4. Typical membrane panel
Figure 5. Typical „SIDE“ connection detail
Figure 6. Special „NOSE“ and „RING“ connection details
Figure 7. Typical ETFE panel



BUILDING WITH AIR

Bus station canopy

Aarau, Switzerland

Context

Recently, the Swiss city of Aarau, a cantonal capital, has gained its own cloud in the shape of an organically formed bus station canopy with a reflective and semi-translucent skin. The roof hovers, so to speak, above the forecourt of the railway station. However, unlike its meteorological namesake, this cloud provides protection from the rain and snow.

As part of the construction of Theo Hotz's new railway station in Aarau, the station forecourt and bus station have been given a new face. Existing fixtures have been removed and the underground car park relocated so that the bus stops can now all be accommodated within Bahnhofplatz. Mateja Vehovar and Stefan Jauslin have designed a bus station canopy which looks as light as a feather, with the idea of creating a haven of calm between the busy Bahnhofstrasse and the new railway station. This has created a welcoming zone for commuters transferring between the Swiss Federal Railways and Aarau's regional buses, and a hangout for night owls which radiates metropolitan flair.

Project

At the centre of the air-cushioned membrane canopy is an organically shaped opening. The contrast between the semi-transparent surface and the open air intensifies the impression of lightness and the feeling of being out in the open, yet essentially protected from the elements. This impression has been encouraged by a series of strategic decisions: the use of a translucent membrane, both clear and blue-dyed, with a finely balanced print (by Stefan Jauslin with Paolo Monaco), the supports with their slight slant towards one axis which disappear into the cushion and carry the "cloud", the varying distances between the membranes and the support structure inside, a technical infrastructure fully integrated into the steel construction carrying water, air, electrical and sensor technology, as well as the irregular network of stainless steel cables below and above the cushion which is designed to give the membrane the required span. These multiple amorphous membrane bays break up the overall shape. They provide the numerous reflections and plays of light on the membrane skin, triggered by the linear luminaires arranged in line with the supports.

The internal supporting structure is faintly discernible. Viewed obliquely, the supports fade into the background and the canopy gains volume. Regardless of how light and simple the cloud appears, its design necessitated a skilled team of planners good at communicating, and close coordination of all the parties involved. For this reason, Vehovar & Jauslin Architektur brought in formTL at an early stage as a specialist to deal with the support structure and membrane skin. formTL had a particular interest in ensuring that the design provided by Vehovar & Jauslin would be feasible, and in bringing out its lightness and filigree nature. This was achieved by basing the planning and realisation on three factors: the planning team directed by suisseplan Ingenieure consistently pursued the aim of building the most airtight cushion with the most economical form of operation. The consortium entrusted with the membrane cushion now consisted of committed specialist firms. Moreover, formTL was given full control of the structural planning, integration with the building services engineers, invitation to tender, management of specialist construction work and quality control.

By fastening the three-part upper and lower membranes to the curved outside tubing separately, it was possible to achieve the simple and structurally clean detailing of the cloud. With 1070m² of covered area and



a volume of 1810m³, the roof of the bus station is the world's largest single-chamber membrane air cushion. Four 120m long polyethylene tubes under the road supply the pneumatic air cushion with recirculated clean, dry air, and another four tubes take the air back to the air control unit. Depending on the weather, the entire system comprising support air system, tubing and membrane cushion is maintained by sensors at 300 - 850Pa above the outside air pressure. As only the moisture has to be removed that is diffused over the 2140m² cushion surface, and both the cushion and the tubing are more or less airtight, the roof is highly economical to operate. Immediately after it was commissioned, the bus station canopy was included as an exhibit at the "architektur 0.13" exhibition held in Zurich. Between 26 April and 27 July 2014 the bus station roof can be seen at the exhibition entitled "Bauen mit Luft" (Building with Air) to be held in conjunction with a 10-year retrospective of formTL at the Air Museum in Amberg, Germany.

Gerd Schmid
info@form-TL.de
www.form-TL.de
 Niklaus Spoerri, Zürich

Figure 1. Day and night views of the bus canopy
 Figure 2. Erection of the canopy
 Figure 3. Structural details, lightning and patterns of the cloud
 Figure 4. Printing on the ETFE membranes generate specific effects

Name of the project:	Bus Station Aarau
Client:	Stadt Aarau, Switzerland
Function of the structure:	weather protection
Planning and civil engineering:	suisseplan Ingenieure AG
Architect:	Vehovar & Jauslin Architektur AG
Lighting:	Atelier Derrer, Zurich, Switzerland
Structural planning, invitation to tender, workshop planning, construction management:	formTL
Contractor for the membrane installation:	Ruch AG & Vector Foiltec GmbH
Supplier of the membrane:	Nowofol
Material structure:	Colour-coated steel structure with a colour coating in C4 (long) & stainless steel spiral cables, cable nodes of anodized aluminium
Material underground pipes for support air:	8 butt-welded polyethylene tubes of 250mm outer diameter in the supports: stainless steel tubing, 100mm internal diameter
Material membrane:	ETFE membrane, 250 µm (clear or dyed blue, and printed by the Reisewitz company)
Dimensions:	Eaves height: 7m / Length: approx. 42m / Width: approx. 39m / Height of steel structure: 0.4m / Height of cushion: 1.3 - 3.2m
Covered area:	1.070m ²



IASS 2013



BEYOND THE LIMITS OF MAN

The 2013 Symposium of the International Association for Shell and Spatial Structures (IASS) "Beyond the Limits of Man" was held in the Conference Centre of the Wrocław University of Technology in Poland from the 23th until the 27th of September. Among a series of interesting presentations on Spatial Structures, Structural Morphology and Environmental Compatibility lightweight tensile structures were exhaustively discussed in the sessions organised by Working Group 6 Tension and Membrane Structures.

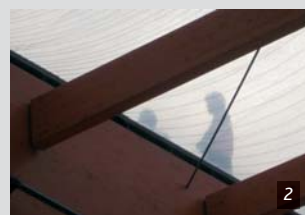
As stated on the website <http://www.iass-structures.org/index.cfm/page/TechAct/WG06.htm> the mission of WG 6 is to encourage and synthesize presentations, reports and publications on projects, designs and research related to tension structures, such as membrane structures, cable structures, tensegrities and hybrid structures. The current objectives are to organize sessions at IASS Symposia and Colloquia related to tension structures, to discuss and share the information about key trends and future issues about tension structures and to contribute to the organization and editing of Special Issues of the IASS Journal related to tension structures.

Tensile and Membrane Structures

A variety of New tensile structures in the Americas was discussed, covering different technical aspects like photovoltaics and parametric design. The New BC Place Stadium in Vancouver, Canada, was presented in more detail (Fig. 1). The different representations gave a very comprehensive and in depth description of this lightweight roof cover. The design and analysis of Air Inflated and Special Tension Structures was discussed through some examples; from shelters for disaster relief to large scale market coverings. Also Tensegrity Structures were highlighted during the WG 6 sessions, with presentations regarding their design, optimisation and controllability of the structural behaviour. In order to create adaptable building skins that respond to changing environmental conditions, Adaptive Membranes have been analysed, often combining structures with nature-inspired forms and concepts. Also the influence of temperature and aging on Materials was investigated, mainly on ETFE-films and PVC-coated membranes. Besides experiments and analytical calculations, the importance of Computational Problems for tensile structures was thoroughly discussed in different presentations.

Technical Tour

On Wednesday a technical tour took place, consisting of a visit of two technically interesting construction sites, namely the "Afrykarium", a new pavilion at Wrocław Zoo (Fig. 2), and The National Forum of Music, the New Concert Hall of the Wrocław Philharmonic Orchestra. Afterwards participants were invited to a visit of the historic part of the city and the Cathedral Island.



Silke Puystiens
silke.puystiens@vub.ac.be
<http://iass2013.pwr.wroc.pl/>

Figure 1. Interior view of the The New BC Place Stadium in Vancouver, Canada - © Christoph Paech / schlaich bergemann und partner
 Figure 2. ETFE-cushions in the roof of the "Afrykarium", the new pavilion at Wrocław Zoo

IASS 2014 The IASS-SLTE 2014 Symposium Shells, Membranes and Spatial Structures: Footprints will encompass the annual IASS Symposium and the 6th Latin American Symposium on Tension Structures. It will take place in Brasilia (Brazil) from 15th to 19th September.

SPEEDKITS DISASTER SHELTER 'CLEVER ROOF'

More and more disasters, either natural or man-made, occur worldwide. As a result, countless people are rendered homeless without any medical care, sufficient and clean water, decent sanitation or energy supply. In case of such an emergency, humanitarian organizations (like the Red Cross, Red Crescent Movement and Médecins Sans Frontières) send disaster relief items and skilled people to assist in rebuilding the affected sites. Such relief items usually consist of: water and sanitation requirements, nutrition, food, medical care and shelters. The focus of this paper will be on this last topic: sheltering.

Context

When looked to the emergency phase of a recovery intervention, the most used product by the humanitarian organizations are the tarpaulins (polyethylene sheeting of 4X6m). The versatility and low cost makes this product the default choice for many organizations. In the case of sheltering, this product is mostly distributed in addition with a shelter kit. Such a kit usually consists of some rope, a handsaw, nails, a shovel, a hoe, a machete, shears and a claw hammer. We can clearly see that structural components, to make a frame for the shelter, aren't included in the standard shelter package and need to be sent separately to the affected site. The set-up of a shelter is also done by the affected population itself and not by trained humanitarian officials. This makes that the know-how isn't on site, which can be detrimental for both the stability and the safety of the shelter (Fig. 1).

To clearly respond to an affected population it is better to have one shelter kit solution, with every component to erect the shelter in one package accompanied by a clear manual. To provide a better solution than currently existing shelter solutions, a new concept has been designed: the clever roof. The main function of this clever roof is to provide cover against heat and rain, so no necessity for walls. It will be the first shelter product arriving on site. Later this roof will be upgraded to a family

shelter by adding walls and increasing the internal comfort of the shelter. To greatly reduce the fabrication cost of the clever roof, there has been decided to start with a flat piece of membrane which we give some pretension and small curvatures.

First prototype

The first prototype forms a simple saddle shape with two high and two low points (Fig. 2). The high points are supported by columns of 2,1m and the low with columns of 1,8m. The difference in length is only 30cm, which can only produce a slight double curvature. The structural part of the fabric is 4x4m. The type of membrane used is a PVC coated polyester fabric (260 g/m²) produced by Sioen. The orientation of the fabric is in such a way that the fiber directions are parallel to the sides of the fabric (from high to low point and from low to high point). The membrane is tensioned between 4 poles and 8 tie down ropes (Fig. 3 to 4). In this set-up the membrane acts in a peculiar way. The sides of the fabric are visually well tensioned while the middle of the fabric sags under its self weight. The lines connecting the middle of opposite edges are not tensioned (no increase in length), while the sloped edges are stressed according to a non-negligible increase in length. A numerical calculation has been made to verify this experimental outcome.

The numerical simulation has been made in the



Figure 1. Shelters made of tarpaulins and 'collected' structural elements.

software EASY in the following way:

- The membrane is modeled as a cable net where each cable segment represents a strip out of the membrane parallel to the fiber directions
- To approximate the reality, no boundary cables are inserted
- In a first iteration a flat piece of membrane is modeled (Fig. 5)
- In the second iteration two opposite corner points are pulled upward and the other two corner points downward. Also a small component in the xy-plane is added to spread the membrane outwards (which also corresponds to the reality)
- The equilibrium shape is calculated by taking the following material properties into account: shear stiffness (10kN/m), crimp stiffness (70kN/m), Young modulus in both directions (210kN/m)

The material parameters don't correspond with the material properties of the actual model, but these numerical tests are simply to get a global view on the stress distribution in the membrane and visualize the stresses.



Figure 2. Prototype 1 forms a saddle shape with two high and two low points

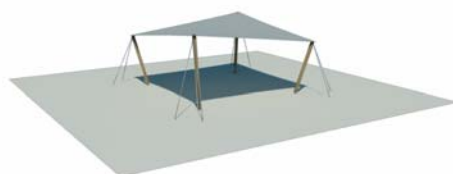


Figure 3 to 4. Connection details



Figure 5. numerical model - software EASY



In terms of stress distribution in the numerical model, the same conclusion can be made as in the experimental model. The four sides are tensioned while the middle of the membrane isn't (Fig. 6).

Second prototype

In the second prototype the positions of high and low points have been changed. The main idea is to use the membrane more optimal in terms of fiber orientation. The best way is to align the fiber direction with the direction of main curvatures. This principle has been tried out in the following model (Fig. 7).

The set-up of this experimental model is the same as before. The difference is in the size of the cover and the position of high and low points. The membrane has a span of 4x6m (instead of the 4x4m) and is also made of PVC-coated polyester fabric (260g/m²). Two high points with a height of 2m are positioned in the middle of both 6m sides. The four corners and the middle of the 4m sides are the low points with a height of 1.6m. The main principle curvatures are now in the direction of the fibers (from high to high point and from low to low point). Visually a more uniform tension in the membrane can be attained. However, further numerical investigation should quantify this increase in tension. The numerical model of the second prototype is constructed in the same manner as before. Because of the new boundary conditions posed on the membrane we can clearly distinguish a more optimized stress distribution in the fabric. In comparison with previous prototype this model has the possibility to be tensioned more uniformly. However, there is still a large stress difference between the middle fabric and the corners (Fig. 8). This last prototype has been tested in Sagnioniogo camp in Burkina Faso close by



Figure 7. Prototype 2 - in search to optimise tensioning

Ouagadougou (Mali refugees). The field test was made possible by the Luxembourg Red Cross. The following pictures show the different steps for set-up. The first is a simple clever roof. The second and third are a family shelter where the latter is more optimized in terms of internal climate, for example by adding a shade net (Fig. 9). Future research should further investigate the feasibility of the clever roof. One of the first steps will be to test this prototype under loading and look for appropriate and easy solutions to reinforce the structure. However, the initial concept of the shelter should always be kept in mind. In the end, we want to realize a shelter solution which is structurally withstanding but is cheap and minimal at the same time, is a lightweight solution but is also stable and stiff, with a simple and straightforward in set-up using a minimum of different elements in one shelter package, ... Eventually, it is a very complex matter where several contradictory parameters play an important role in the design process of a - at first hand - simple shelter. The research presented is done in the framework of the European project S(P)EEDKITS funded by the European commission (Project number: 284931).

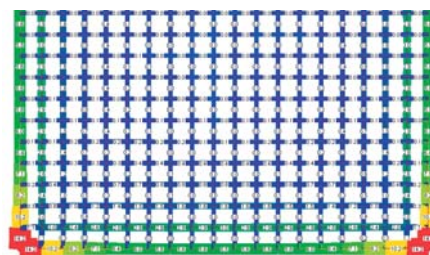


Figure 6: $dz=+20/-20cm; dxdy=0cm$

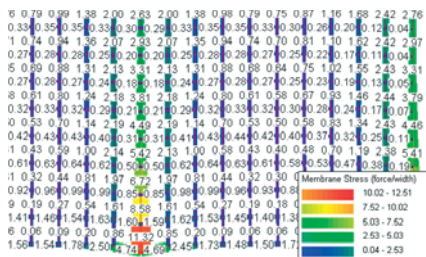


Figure 8. >
2 points long sides dx, dy, dz 2cm, 1cm, +15cm, midpoints short sides dy, dz 5cm, -20cm, corners dx, dy, dz 2cm, 5cm, -15cm

✍ Jan Roekens
✉ jroekens@vub.ac.be
✍ Marijke Mollaert
✉ marijke.mollaert@vub.ac.be
✍ Vincent Virgo
✉ Vincent.Virgo@croix-rouge.lu
🌐 www.speedkits.eu

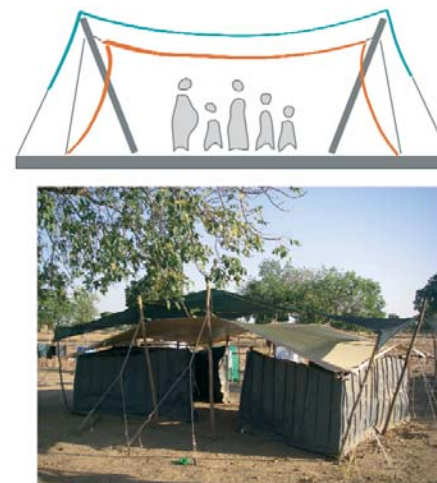


Figure 9. Testing of prototype 2 on location, refugee camp Burkina Faso

Casablanca,
Morocco

TextiDôme COVERAGE OF THE WASTEWATER TREATMENT PLANT

Introduction

Basins of sewage treatment plants are more frequently covered to contain odors and gases, limiting algal growth, and protect the watershed precipitation. One of the key issues of this project is to select a product with a long expected lifespan, because of the corrosive atmosphere of the hydrogen sulfide basins. The priority is to focus on solutions that ensure the least possible contact between susceptible materials to corrosion and stale air. Structural elements immersed in the effluent have to be avoided.

Project

Effective, aesthetic and durable, the TextiDôme covers the basins thanks to its considerable size (up to 80m in diameter without interior supports) (Fig. 1).

The suspended textile membrane (Ferrari membrane 1202S) confines odors and gases. The cover is supported by a galvanized steel frame on the outside, like a giant

spider's web (Fig. 2). The attachment of the textile membrane are located inside. The connection points are from stainless steel or galvanized steel (Fig. 3a and b). As

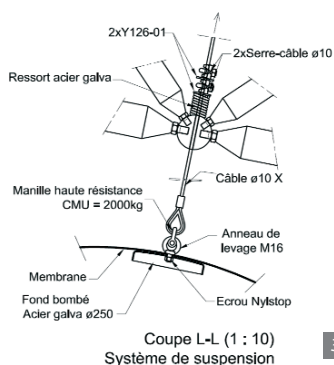
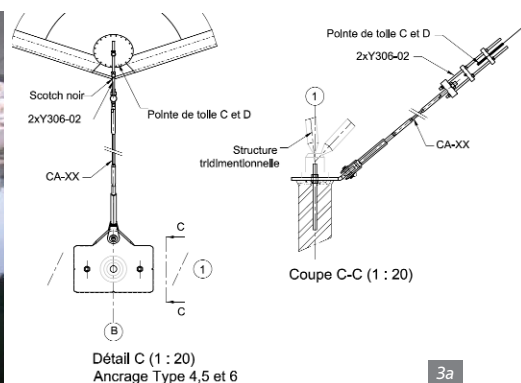
the atmosphere inside is extremely corrosive, rusting of the connection points may be possible. In this extreme case, the oxidized parts are visible and easy to change. The metal structure is the remaining non-corrosive area. The "TextiDôme" solution was adopted for the project to cover the STEP in Bouskoura, a structure with a covered surface of 2000m². It is the first realization in Morocco and Africa, which was completed in a record time of 4 months (Fig. 4).

Name of the project:	Construction of a wastewater treatment plant at Bouskoura
Location address:	Casablanca-Morocco
Client (investor):	CGI - PALMERAIE DÉVELOPPEMENT - GROUPE ADDOHA
Function of building:	Coverage of a treatment plant wastewater in the green city of Casablanca. The solution is the "TextiDôme"
Type of application of the membrane:	Tensile-structure coverage to contain odors and gases
Year of construction:	2013
Architects - Conception and patents:	PRAT-SA
Multi-disciplinary engineering:	PRAT-SA
Structural engineers:	USKON
Consulting engineer for the membrane:	PRAT-SA
Main contractor:	AMETEMA
Contractor for the membrane (Tensile membrane contractor):	AMETEMA
Supplier of the membrane material:	FERRARI
Manufacture and installation:	AMETEMA
Material:	Ferrari membrane 1202S
Covered surface (roofed area):	2000m ²

See also: <http://www.youtube.com/watch?v=qdg3DQo25dY&feature=c4-overview&list=UUr6Ak3TlhOkAjDV4eCFqmkQ>
Keywords on youtube: textidome, Bouskoura

✍ Malika Machal
✉ malika@ametema.ma
🌐 www.ametema.com
🌐 www.prat-sa.com

Figure 1. Section
Figure 2. Erection of the frame
Figure 3a. Connection points - lateral
Figure 3b. Connection points - suspended - Patented systems
Figure 4. Erection of the TheTextiDôme



Driving air upwards

VENTILATION TOWER Oslo, Norway

Sefar now on the road too Norway is well-known for its unspoilt nature and deep fjords, and now too for a special tunnel. Of course, the tunnel itself is underground but a striking ventilation tower has now been added to the city skyline of Oslo (Fig. 1). Like many large European or world cities, the Norwegian capital also struggles with rising levels of traffic and the air pollution associated with it. Especially affected are major intersections, and as the traffic increases so the skyline changes – in the case of Oslo, however, in a positive way. The Norwegians were

very keen to come up with a solution which demonstrated the Scandinavian lightness of touch, blended naturally into the landscape, and made downtown Oslo a little more peaceful again. The Norwegian Highways Authority drew its own conclusions and constructed a much utilized inner-city tangential beneath the earth. For the obligatory ventilation shaft extracting air from the tunnel, Textil Bau GmbH from Hamburg, the general contractor also responsible for engineering, agreed on a design using technical fabric. Both the client and general contractor



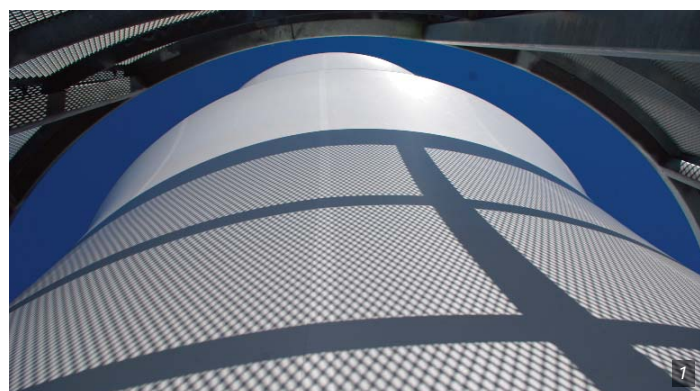
appreciated the effect the extracted gases would have on the shaft, so took steps to make the task of maintenance and cleaning as straightforward as possible. With this in mind, SEFAR® Architecture TENARA® Fabric 4T40HF was chosen for its exceptional dirt-repellent and self-cleaning properties.

New grandeur shapes skyline

With a membrane surface area of approx. 340m², a height of 19m, and up to 6.4m in diameter, the membrane tower is an outstanding eye-catcher. A primary galvanized steel construction forms the framework for the pretensioned membrane covering which is secured to the upper steel ring of the structure and to a ring of concrete at the base (Fig. 2 and 3).

Depending on the level of ventilation, the tower must be able to withstand internal wind speeds of up to 20m/s (45mph). For this reason, the membrane is supported by horizontal floating rings – steel rings with hollow square profiles – which form the two central points dividing the chimney effect required one more thing: the external membrane tabs at the base also had to be clamped at the angular section to secure a connection to the concrete ring. Only then was the tower airtight. To protect the fabric from vandals, the bottom third of the membrane was surrounded by a fence which will have creepers planted around it, giving the tower a sense of having “grown” within its urban surroundings.

 Sarah Dupont
 sarah.dupont@sefar.ch
 www.sefar.com
 Kim Lishke
 k.lishke@textilbau.de
 www.textilbau.de



FABRIC-TECHNICAL SPECIFICATIONS

Fabric material:	Fluoropolymer-coated fabric made from ePTFE fibers
Fabric width:	1.575m
Fabric thickness:	0.55mm
Surface weight:	1,080g/m ²
Highest tensile strength (ASTM D4851):	Warp 4000 N/5cm; Weft 4000 N/5cm
Trapezoidal tear resistance:	Warp 798 N Weft 752 N
Fire performance:	EN 13501 B-s1, d0 ASTM E84 – Class A; NFPA 701 – Small Scale – Pass
Light-technical specifications Grade of transmission:	38% (ASTM D1003, average 450–650 nm)
Degree of reflection:	59%
Absorption:	3%

Name of the project:	Ventilation tower Oslo, Norway
Client:	Norwegian Highways Authority
Function of building:	Ventilation of traffic tunnel
Year of construction:	2013
Planning:	ib zapf
Engineers:	Textil Bau GmbH, Hamburg
Main contractor:	Textil Bau GmbH, Hamburg
Supplier of the membrane material:	Sefar AG, Heiden (CH)
Manufacture and installation:	Tension rods: Pfeifer Seil- und Hebetechnik GmbH / Tailoring: K. Daedler e.K., Trittau / Assembly: IRA GmbH
Material:	SEFAR® Architecture TENARA® Fabric 4T40HF



Figure 1. Ventilation tower as part of the city skyline of Oslo © Felix Mediaa Lenning, Fa. DBC Bygg AS

Figure 2 A&B. Connection of the membrane to the upper steel ring © Felix Mediaa Lenning, Fa. DBC Bygg AS (A) & © Textil Bau GmbH, Hamburg (B)

Figure 3. Connection of the membrane to the ring of concrete at the base © Felix Mediaa Lenning, Fa. DBC Bygg AS

COST ACTION ON NOVEL STRUCTURAL SKINS

IMPROVING SUSTAINABILITY AND EFFICIENCY THROUGH NEW STRUCTURAL TEXTILE MATERIALS AND DESIGNS

Introduction

The COST Action TU1303, entitled 'Novel structural skins - Improving sustainability and efficiency through new structural textile materials and designs', was officially launched in November 2013 and will receive the next four years financial support for networking activities in the domain of structural textile materials and constructions.

COST is an intergovernmental framework for European Cooperation in Science and Technology, allowing the coordination of nationally funded research on a European level. COST does not fund research itself, but provides support for networking activities carried out within COST Actions. These COST Actions are bottom-up science and technology networks open to researchers and stakeholders, with a four-year duration.

Ambition and aim

The COST Action 'Novel structural skins - Improving sustainability and efficiency through new structural textile materials and designs' has the ambition to synthesise the current innovations and technologies from which to establish a platform on which the development of new advancements, products, and applications can be stimulated and produced. The goal of the COST Action is to build a coalition of researchers, academics, architects, engineers, contractors, asset owners, and policy makers that creates this platform. It will be achieved through the sharing of expertise, techniques, facilities and data, by establishing technical consensus, and developing European standardisation for the analysis, design, and realisation of multi-functional building skins.



Figure 1. Julien Lienhard. Bending-active membrane structure

The aim of the COST Action is to standardise the material and structural testing and analysis approaches within Europe, to inform the design of safer and more efficient structures, to harmonise the research on membrane and foil structural skins, to collate harmonised data and tools on energy performance and Life Cycle Analysis and to stimulate and deliver innovation and development of new structural skin products, adaptable systems and durable applications in the urban environment.

Research Clusters

Five Strategic Research Clusters are defined that focus on innovation, sustainability, energy efficiency, material analysis and standardisation of novel structural skins. Each Strategic Research Cluster is managed by a corresponding Working Group (WG): (1) new applications of structural skins and new concepts, (2) sustainability and Life Cycle Analysis of structural skins, (3) building physics and energy performance of structural skins, (4) materials and analysis, and (5) from material to structure and limit states: codes and standardization.

The Working Groups consist of all participants of the COST Action who want to contribute actively to the realisation of the goals and mission statement of the respective WGs.

The WGs will be flexible and welcome additional researchers when appropriate.

Kick-off meeting

The kick-off meeting of the Management Committee took place on the 5th of November in Brussels.

The MC elected the Chairs and co-Chairs for each of the five Working Groups:

- WG 1: Tim IBELL (UK) & Lars DE LAET (BE);
- WG 2: Jan CREMERS (DE) (Pending appointment) & Alessandra ZANELLI (IT) (Pending appointment);
- WG 3: Christoph GENGNAEL (DE) & John CHILTON (UK) (Pending appointment);
- WG 4: Peter GOSLING (UK) & Natalie STRANGHOENER (DE);
- WG 5: Jean-Christophe THOMAS (FR) & Marijke MOLLAERT (BE).

After the formal part, Martin Tamke (associate professor at CITA | Centre for Information Technology and Architecture) and Omer Soykasap (professor at Afyon Kocatepe University) presented their research (Fig. 2 to 4) and interest in the working groups. The MC welcomed the idea that during this COST Action exploring activities and hands-on workshops could be integrated in the working group meetings.



- Lars De Laet
- lars.de.laet@vub.ac.be
- Marijke Mollaert
- marijke.mollaert@vub.ac.be
- http://www.cost.eu/domains_actions/tud/Actions/TU1303



Figure 2. Research Martin Tamke. Images from the Digital Crafting network, Workshop Textiles and Fiber-based Materials in Architectural Construction – 24 August 2010.



Figure 3. Research Omer Soykasap. Innovative foldable & self-deployable shell structure made of woven CFRP composite material for covering large surfaces.

UPCOMING ACTIVITIES

Steering Committee 29/01/2014 - Paris, France

Working Groups & Management Committee meetings

25-26/03/2014 - Berlin, Germany

Working Groups & Management Committee meetings

29-30/09/2014 - Brussels, Belgium

FOR MORE INFORMATION ON THIS COST-ACTION, please visit http://www.cost.eu/domains_actions/tud/Actions/TU1303

and download the Memorandum of Understanding.

If you would like to joint this COST-Action and contribute actively to a Working Group, please contact tu1303@vub.ac.be.

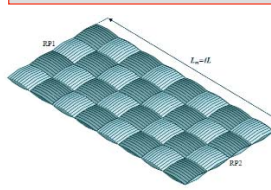


Figure 4. Research Omer Soykasap. Finite element modelling and simulation of textile composites for predicting the material properties.

