TensiNews

NEWSLETTER NR. 32
APRIL 2017
PUBLISHED TWICE A YEAR
PRICE €15 (POST INCL)
www.tensinet.com

NEWSLETTER OF THE EUROPEAN BASED NETWORK FOR THE DESIGN AND REALISATION OF TENSILE STRUCTURES

REPORT

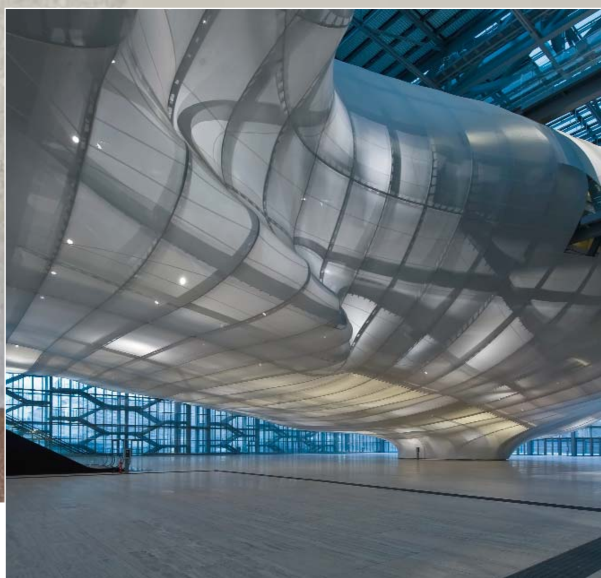
TENSINET - COST ACTION TU1303 SYMPOSIUM 2016 NOVEL STRUCTURAL SKINS

RESEARCH

CONCEPTUAL SMART TEXTILE AND BENDING-ACTIVE ARCHITECTURAL MODULE

PROJECTS

DEPARTURE UNDER THE STARS "ZORGVLIED"
WALK-IN CLOUD "NUVOLA"



Crematorion Zorgvlied © Digidaan ▲
Nuvola © Studio Moreno Maggi ▶

Tensinet 2017 partners

TensiNews INFO

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

ISSN 1784-5688

Price €15
postage & packing included

n°32

contents

Edito

Dear Reader

This is the first TensiNews which is distributed electronically only, except for Universities and public libraries. Based on the feedback we received from our readers the partners have decided to proceed with this type of distribution.

Half a year has passed since we held our TensiNet Symposium, together with the Cost action TU1303 at Newcastle University. It was a great success. The three days were full of excellent presentations from a wide range of researches and professionals. We are glad that Joseph Llorens prepared a report of this conference.

This issue of TensiNews contains articles about actual membrane and foil projects, as well as reports on new developments of industry and research institutions.

Two ETFE projects in England are presented. Both examples are combinations of timber and cushions. An extraordinary crematory has been realised in the Netherlands with a rising membrane. Two projects in Istanbul which have recently been realised are shown, a stadium roof and a second façade for a sports complex. It is a personal pleasure for me to write about the Nuvola in Rome, which has been inaugurated last October after 18 years. In Mexico an urban centre has been realized which received an award for design excellence.

Belgian and Italian researchers envision their result of a membrane with integrated sensors for biogas plants, and researchers from Portugal present the development of bending active structural modules with smart textiles.

We are again one of the main sponsors of the student competition at Techtextil, which will take place from the 9th of May at Messe Frankfurt. We invite you to join the award ceremony, and we will have the same day our partner meeting and two working group meetings (good practice and pneumatic structures). Many of us will be present in Berlin at Textile Roofs 2017, which will also take place in May. During Structural Membranes later this year in Munich, will have our annual general meeting and the next partner meeting.

Please enjoy this issue of TensiNews and I hope to meet you on one of these events.

Yours sincerely,
Bernd Stimpfle

Forthcoming Events

6TH INTERNATIONAL TEXTILE ARCHITECTURE SEMINAR – IMS

Lima, Peru • *24-26/04/2017*

http://www.membrane-symposium.org/fileadmin/content_membrane_symposium/Programa_VI__Seminario_Internacional_de_Arquitectura_Textil_IMS_-_PERU.pdf

TECHTEXTIL 2017

Frankfurt am Main, Germany • *9-12/05/2017*

https://techtextil.messefrankfurt.com

TEXTILE ROOFS 2017

Archenhold Observatory, Berlin, Germany • *15-17/05/2017* **http://textile-roofs.com/**

STRUCTURAL MEMBRANES 2017

Munchen, Germany • 09 – 11/10/2017

http://congress.cimne.com/membranes2017

Forthcoming Meetings

techtextil

TensiNet Meetings at Techtextil

9/05/2017

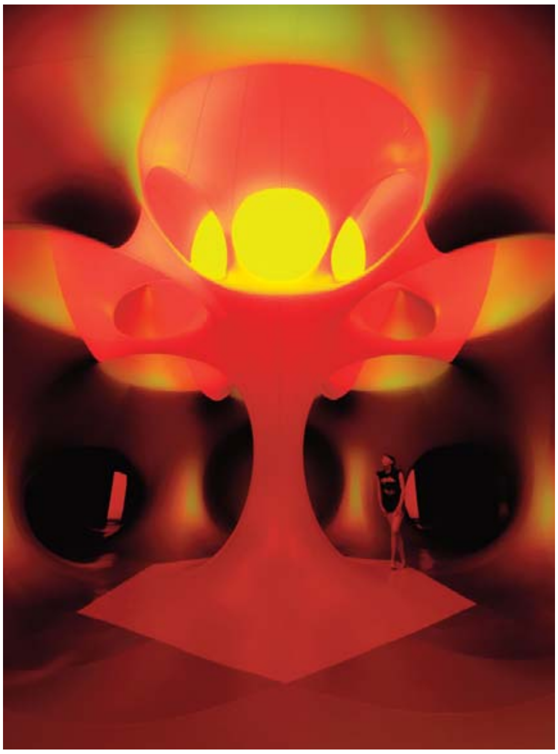
10.00-11.30 WG GOOD PRACTICE
11.30-12.30 WG PNEUMATIC STRUCTURES
12.30-13.30 BREAK
13.30-15.30 PARTNER MEETING
16.00-17.00 STUDENT AWARD CEREMONY

Brian Forster
Arup
1943 - 2016

We have just learned of and are sorry to report that Brian Forster, an original member of TensiNet and a Co-Editor of the European Design Guide for Tensile Structures, died on 5 September 2016 at the age of 73. He had suffered with Alzheimer's Disease for many years which he faced with extraordinary courage before he passed away peacefully.
Brian worked for Arup in the Building Engineering team in London before his retirement in April 2003. Brian is survived by his widow Gemma.

NEXT ISSUE

Architects of Air build *luminaria*: monumental membrane structures designed to generate a sense of wonder at the phenomenon of light. To celebrate their 25th anniversary, they are not only creating a brand new structure which will be revealed in May, but they are also promoting the skill of inflatable design through a series of workshops. More about Architects of Air and their latest *luminarium* in the September issue of TensiNews. Until then, you can find Architects of Air by checking: www.architects-of-air.com



Inside a luminarium
© John Owens Photography

CANARY WHARF STATION

London dock, UK

TIMBER AND FILM CUSHIONS CROWN BUILDING PUBLIC ROOF GARDENS

Introduction

Sailing ships and the worldwide maritime trade formed the basis for the British Empire over several centuries. The great era of wooden sailing ships is permanently engraved in the collective memory of Great Britain. The new underground station in Canary Wharf, London, has adopted precisely this elegant timber construction look. A fascinating roof construction of wood and lightweight film cushions now rises out of the water of the former East India Dock, where the tea clippers of the East India company used to dock. London is currently the scene of the largest infrastructure project in Europe. A new underground railway line with a length of 42km, the so-called Crossrail, is being built right across London. The new East-West connection is intended to bring an additional 1.5 million people to their destinations in the city in 45min and help them to bypass the unavoidable traffic jams in the City of London.

Floors under and above the waterline

The Canary Wharf Crossrail station, one of ten new stations, connects the business district with more than 100.000 workplaces along the new line. The new station was designed by the architects Foster & Partners. Three floors with shops and restaurants are situated below water level. Above the waterline the building rises up like a ship with further floors and a partly open rooftop garden. The station is crowned by a 30m high and 310m long timber roof construction covered with ETFE film cushions, which are illuminated after dark. The high performance material 3M Dyneon ETFE is extremely resistant to chemical effects of all kinds. Films made from 3M Dyneon ETFE 6235Z are very resistant to tearing and to UV radiation.

Roof cushions made of ETFE film

The curving support structure of the roof construction, manufactured by Wiehag GmbH Timber Construction from Upper Austria, consists of visible glued laminated spruce timbers. 780 triangular air-supported film cushions curve over it in an arch. ETFE films are fundamentally highly transparent and allow the sunlight with the UV-A radiation that is important for plant growth to pass through virtually without hindrance.

Printed pattern translucently scatters the light

For the Canary Wharf station, the majority of the films were printed with a pattern of a varying density in order to scatter the light with a pleasant translucence in plant-free areas. Seele Cover GmbH from Germany, the internationally renowned specialist for complex roof and facade constructions, began installing the triangular ETFE cushions even before the assembly of the timber construction was complete. The cushions were assembled in Seele's own production facilities. Seele was also responsible for the development, design, manufacturing and assembly of the aluminium clamping profiles, the made-to-measure cover plates to protect against the weather and the four air supply stations. The latter provide for the constant exchange of the air between the two-ply cushions via air distribution boxes. The company turns the visions of renowned architects for individual and often highly unusual constructions and building shells into reality. The roof and facade have a total area of around 10.000m².

Entire roof reachable without a crane

The position in the middle of a dock in London necessitated several special structural features. Although the surface of the film cushions is so smooth that they are largely cleaned by rain showers, the entire roof must be reachable for maintenance work without cranes. Abseiling workers can securely fix their respective position to a large number of invisible attachment points between the cushions. The airlines for the pneumatically assisted cushions, which are supplied by four blowers, run below these intersections. In addition, an elaborate system of gutters was installed for the drainage of the curved roof, since the drainage of the rain into the dock is not permitted. ETFE film cushions have proven themselves in architecture for over 30 years as a durable and extremely resistant material with high mechanical strength. The cushions verifiably withstand hail, driving rain and high snow loads.

Helmut Frisch
hfrisch@3M.com
www.dyneon.eu

Name of the project	Canary Wharf Station
Location address:	London, UK
Client (investor):	Canary Wharf Contractors Ltd
Function of building:	shops, restaurants, offices, metro
Year of construction:	2015
Architects:	Foster & Partners
Structural engineers:	Arup
Contractor for the membrane (Tensile membrane contractor):	Seele Cover GmbH
Supplier of the membrane material:	Nowofol Kunststoffprodukte GmbH & Co. KG, Siegsdorf, Germany
Manufacture and installation:	Seele Cover GmbH
Material:	3MTM DyneonTM Fluoroplastic ET 6235Z
Covered surface (roofed area):	11.500m²


© Digidaan

TENTECH - BUITINK TECHNOLOGY

ZORGVLIED CREMATORION

DEPARTURE UNDER THE STARS

Amsterdam, The Netherlands

Introduction

On the site of Zorgvlied cemetery in Amsterdam, architects' office GROUP A designed an extraordinary crematory. A pavilion which offers to accompany the deceased to the last moment. A design which aims to meet the needs of various groups with diverse cultural and religious backgrounds. It focuses on the actual burning of the body and the spiritual experience connected to this event. The upward direction and big skylight above strengthen the feeling of the rising departure.

Concept

The spiritualty of the building is materialized in a contrast of materials. The base of the building is made of stone as metaphor of heaviness, gravity and earthly. The cover is a membrane, showing lightness, clearness and heavenly. Evidently the quality and translucency of the membrane was of vital importance for the architect. Material of choice was Serge Ferrari TX-30, a strong material which, above all, is easy to maintain clean. Processing TX-30 is a specialized work, executed by Buitink Technology.

Structure

The shape stands out in the green surroundings of the cemetery. It also stands out from a structural point of view. Before the architect choose to use fabric as the pavilion's envelope, the geometry was already defined. A geometry which deviates from conventional membrane structures as the shape is not a typical minimal surface, it's not a shape which the fabric takes by nature. When working in the digital model of the project, Tentech tweaked and tuned tensions in different areas of the membrane - manipulated the 'natural' shape of the fabric - into the architects' design.

Materialisation

The digital model of the cover finally matched with the initial design. Next step was to materialize the project, to make an equally shaped physical membrane. To create this, the actual tensions from the digital model had to be introduced in the physical membrane. When engineering membrane structures, it is business as usual to adjust the patterns of a membrane to create pre-tension. In this project, the pre-tensions varies heavily in many areas of the cover. Tentech developed a routine to translate these pre-tensions in local adjustments of the patterns. It narrows or expends the patterns at certain points along the seams, which subsequently creates the required local pre-tensions, which in their turn defined the shape of the beautiful cover.

Material

PRECONTRAINT TX-30 is a new innovative material, developed by Serge Ferrari to guarantee both more natural light input and a useful life of over 30 years for demanding projects. The PVDF top treatment is CROSSLINKED using a reticulated process. It creates irreversible chemical links between the PVDF molecules and provides long term benefits. As a consequence of its high resistance, the flexible top treatment has to be abraded before welding.



Pictures of construction process
© Buitink Technology

Client:	Municipality of Amstelveen
Architect:	GROUP A
Structural engineer:	Breed ID
Membrane engineer:	Tentech
Main contractor:	Bouwbedrijf Van Schaik
Tensile membrane contractor:	Buitink Technology
Supplier of the membrane material:	Serge Ferrari
Material:	TX-30
Membrane surface area:	425m^2

Daan Rietbergen
Daan@tentech.nl
www.tentech.nl

Rienk de Vries
info@buitink-technology.com
www.buitink-technology.com






© Digidaan

REPORT

TENSINET - COST ACTION TU1303 SYMPOSIUM 2016

NOVEL STRUCTURAL SKINS

NEWCASTLE
26TH-28TH OCTOBER 2016

The TensiNet – COST Action TU1303 Symposium "Novel Structural Skins" was held in Newcastle in October 2016. It was organized by the TensiNet Association, COST Action TU 1303 Novel Structural Skins and the Newcastle University. It was the fifth of a series of symposiums that began in Brussels in 2003: "Designing Tensile Architecture," which was continued in Milan in 2007: "Ephemeral Architecture: Time and Textiles," in Sofia in 2010: "Tensile Architecture: Connecting Past and Future," and in Istanbul in 2013: "[RE]Thinking Lightweight Structures."

At the three-day conference, 65 presentations were given in 15 sessions, including 9 keynote speakers to 131 participants from 16 countries. The main topics were standardisation; materials and testing; form and design; thermal, acoustic, and lighting conditions; projects and realizations; durability; environmental issues; and life-cycle assessment.

STANDARDISATION

The process of creating a new standard for tensile membrane structures was introduced by Natalie Stranghöner. Comments on the "Prospect for European guidance for the structural design of tensile membrane structures" are available at https://ec.europa.eu/jrc/en/publication/eur-scientific-and-technical-research-reports/prospect-european-guidance-structural-design-tensile-membrane-structures-support. Two more presentations from the Vrije Universiteit Brussel were concerned with standardisation. One was regarding the partial factors for prestressing in accordance with existing Eurocodes, and the other addressed the wind pressure coefficient distributions for basic membrane shapes (J. Colliers).

MATERIALS AND TESTING

R. Fangueiro from the University of Minho presented "Fibrenamics. Fibre the future", an international multidisciplinary platform for the development of innovative products based on fibres, which is available at: http://www.web.fibrenamics.com/pt/. Dr. Fangueiro also reviewed the physical, chemical, and biological treatments of natural fibres in order to fully utilize their advantages in composite materials and to successfully utilize them in various industrial applications. Additionally, he presented LFS (Life Form Structure), a new composite material with the ability to change its shape according to the environmental conditions. It is a multilayer structure with a total thickness of around 6 mm, consisting of rigid PVC plates in the interior, bonded to a PVC-coated, high-tenacity, polyester membrane. In this configuration, the outer layer of the system is continuous while the interior remains discontinuous, enabling them to create a geometric matrix, which provides features of structural shape shifting.

ETFE film as a material was addressed by T. Yoshino, who dealt with the analysis of deformation under biaxial stress, taking into account biaxial creep characteristics. H. Bögner-Balz, presented her investigation of the yield point, yield conditions, hardening, behaviour under cyclic loading, and failure. Available Fluor polymeric products were also represented by the 3M Dyneon product range and the Solvay "Halar High Clarity" ECTFE film, a new fluorinated polymer with outstanding transparency, high thickness, excellent weather ability, and outdoor stability.

Knitted fabric was expounded by M. Schmeck, who proposed a method for making informed design decisions to support an intuitive way of understanding the structural system. The method consists of simulating the knitted fabric as a two-dimensional grid, which is calibrated by adjusting its geometry and the stiffness of its members to match the properties of a tested knitted membrane specimen.

Other contributions regarding innovative materials were the recent advances in sensor-embedded textiles (P. Heyse, TensiNews 30, pp. 10-11), the exploration of the possibilities of surface composite structures from inflatable moulds (D. Costanza), and the development of an ETFE-Phase Change Material to better manage the interior temperature of a greenhouse (P. Beccarelli).

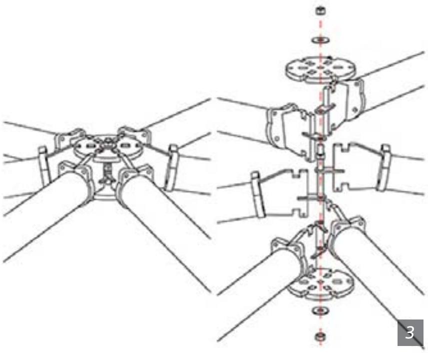
Testing and modelling were also considered with the appropriate determination of the stiffness and compensation values (B. Stimpfle) and the application of artificial neural networks to reproduce the mechanical behaviour of coated fabrics, including shear (P. Gosling). The importance of the post processing of the stress-strain data from biaxial tests and the principles for refined biaxial test procedures that meet the requirements of structural fabrics were approached by M. Van Craenenbroeck and J. Uhlemann, respectively.

FORM

Three presentations addressed different approaches to form. S. Bhooshan turned to social sciences to justify the spectacular formalism of the so-called "logical" forms of some projects, highlighting the new Mathematics Gallery at the London Science Museum, designed by Z. Hadid (Fig. 1). J. Lienhard explained what he meant by "pushing the boundaries of textiles in architecture," by asserting that it is possible to design starting with the form. He illustrated the hypothesis with the Mitoseum at the Saurierpark Bautzen, a large grid shell with inflated cushions based on the digital design of the steel nodes (Figs. 2 and 3).

H. Ibrahim expressed his concern with the great variety of membrane forms to develop novel tensile membrane structures and adaptable textile-covered building facades, integrating tensile photovoltaic membranes for energy harvesting and environmental control. That is why he introduced the development of the Grasshopper parametric tool to analyse the layout orientation, the effect of shadowing, and the maximum allowable deflection for the membrane surface under different loading conditions.

S. Brancart demonstrated a principle for deployable bending-active structures based on the interaction between a deployable grid and a restraining membrane, illustrated by a case study where the large interdependency of form and material behaviour requires a specific modelling approach (Fig. 4). He was followed by R. van Knippenberg, who discussed a typology of foldable structures, illustrated with the design of a pavilion which is able to be transformed into multiple configurations only by moving the support points (Fig. 5).



Bionic shapes were shown by J. Knippers in his presentation of a series of research pavilions which showcase the potential of novel design, simulation, and fabrication processes in architecture based on principles of nature: heterogeneity, adaptability, redundancy, hierarchy, and multi-functionality (TensiNews 30, pp. 18-19). The projects were planned and constructed by students and researchers within a multi-disciplinary team of biologists, palaeontologists, architects, and engineers (Fig. 6).

Regarding adaptive structures, A. Habraken demonstrated a practical implementation of a control system with actuators used to minimize the maximum stress in an arch of Plexiglas when externally loaded with varying static loads by active rotation of the supports.

The presentations of A. Holden and A. Campesato were more speculative. A. Holden introduced a flexible and real-time computational design modelling for the exploration of novel, form-active, hybrid structures that would enable designers and engineers to iteratively construct and manipulate form-active hybrid assembly topology on the fly. A. Campesato dared to achieve arbitrary designs by mixing biomimetics, tensegrities, injection moulding techniques, and 3D printing.

DESIGN

Form finding, structural analysis, cutting patterning, and detailing, together with form, which has been treated in prior presentations, were also of interest.

B. Philipp contributed with the application of a newly-developed isogeometric B-Rep analysis to the form-finding and structural analysis of structural membranes. The result of this approach is the possibility of performing mechanically-accurate form-finding (and follow-up analyses) directly within a CAD environment on a full NURBS-based CAD model.

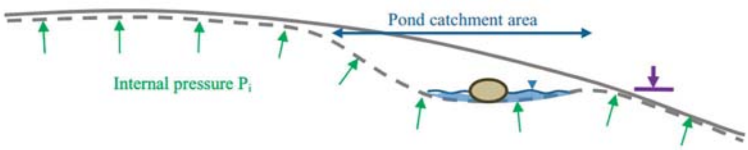
Referring to the structural analysis, J.C. Thomas considered inflatable beams. He showed his studies of the non-linear portion of the load-displacement curve, giving the analytical formulation that allows for obtaining the displacement between the wrinkling load and collapse. The case of an inflatable arch was also presented as an example.

Two presentations from the Technische Universität München were concerned with the generation of optimized cutting patterns. The first one went over a novel approach towards cutting pattern generation, minimizing the total potential energy arising from the motion of a planar cutting pattern to its corresponding three-dimensional shape. The second was an inverse approach, defining the nodal positions in the material configuration as design variables holding the fixed spatial configuration. In this way, the stress-free state of the cutting pattern, which is an important characteristic of the manufacturing process, is preserved.

Three expanded capabilities of analysis were explored by A. Bown. The first was hydraulic flow modelling, used to simulate unsteady fluid flow across an arbitrary mesh surface. The second was the time-stepped ponding that allows for cases where the pond load varies (Fig. 7). Finally, the third was the failure propagation collapse analysis to assess the potential for a failure propagation of a combined membrane and cable structure.

THERMAL, ACOUSTIC, AND LIGHTING CONDITIONS

D. Buck showed the simulation and test of a sport centre roof, consisting of a translucent multilayer and insulated membrane. Experimental and numerical simulations were performed concerning the air flow conditions within the cavity between the top membrane and the inner part of the roof. In addition, the air and moisture conditions within the venti



7

Figure 1. Zaha Hadid, 2016: London Science Museum Mathematics Gallery.
Figure 2. Rimpf Architekten, 2016: Mitoseum Saurierpark, Bautzen.
Figure 3.Digital design of the steel node by structure (http://www.str-ucture.com).
Figure 4. Physical models allow experimental insight in the behaviour of deployable & bending-active structures (S. Brancart et al.).
Figure 5. Adaptable pavilion for promotional purposes at festivals (R. van Knippenberg).
Figure 6. A. Menges, 2016: Elytra Filament Pavilion, London Victoria and Albert Museum. A modular, adaptive, fibrous canopy inspired by beetles and fabricated by a robot.
Figure 7. Seed event and subsequent rainfall causing hydrostatic loading onto the surface of a typical pneumatic structure (A. Bown et al).

lated air layer were investigated. The result is a methodical analysis and development of energy-efficient structural measures for buildings with membranes.

Two presentations dealt with the reduction of solar gains under ETFE roofs by adding a new material (H. Marx) or cooling the envelope by introducing a water spray system (A. G. Mainini). M. de Vita also addressed solar gains. Her case of study was an adaptive umbrella. She analysed its inner thermal comfort by means of the software package Energy Plus, which allowed the simulation of the performance in several climatic conditions.

Regarding the luminous environment, B. Lau showed through field studies that the selective use of transparent and translucent components in the ETFE envelope can offer architectural designers opportunities to create well-balanced, yet dynamic, illuminated scenes. On the other hand, A. Vargová referred to the night image of textile façades in contemporary architecture because the potential of membrane façades lies not only in their shape, but also in the ability to utilise light as a means of expression.

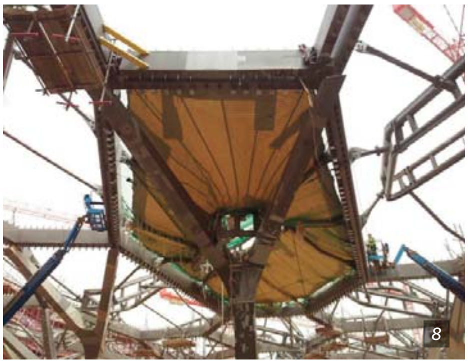
Acoustics were also present with V. Chmelik, who analysed the atrium of the Slovak Philharmonic, and D. Urban, who compared three large gathering places with multipurpose functions in Bratislava, together with several solutions for improvement of their acoustic situations based on transparent or removable products, such as polycarbonate, micro-perforate foils, or textiles.

PROJECTS AND REALIZATIONS

To provide shade and ventilation, a dramatic sculptural mixture of fabric and steel was designed by Z. Hadid for the KAPSARC, King Abdullah Petroleum Research Centre (Fig. 8). B. Whybrow described this astonishing, oversized structure, showing once again that structural membranes, if not designed as such, require an imposing steel structure, as happened at the Beijing Olympic Stadium. Insisting on the application of membranes and foils as a complement to steel structures, B. Stimpfle showed the use of PTFE-covered continuous stripes for sun shading over the Brickell City Centre in Miami (Fig. 9) and P. Romain showed a striking tram stop canopy in Lodz (Fig. 10).
A. Fisher contributed with the London Olympic Stadium transformation to retain its original running track whilst functioning as an economically-sustainable, multi-use venue. The fabric roof used during the games has been removed and replaced by a larger, solid roof. The stadium roof structure is the largest single-span and cable net in the world, 45.000m² in size, and 84m in height at its highest point (Figs. 11 and 12).

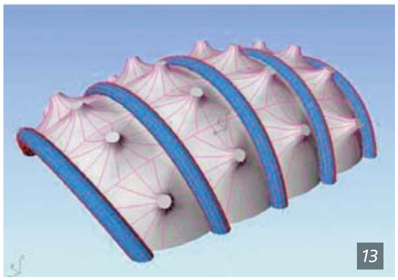
A wide variety of textile membranes and foils are used in façade applications. Ch. Paech discussed several options. The stadiums of Al Ain, Vancouver, and Cape Town illustrate different solutions for different purposes and locations such as those adopted for the 16 textile pavilions of the Indo-German Urban Festival, which are wrapped with different types of textile membranes in order to achieve different appearances. Other special applications are the replacement of the Munich Olympic swimming pool roof and the inner ETFE skin of the Madrid Memorial (Fig. 14).

A complete description of the two Ontario Celebration Zone temporary pavilions was presented by H. Jungjohann (Figs. 15 and 16). He highlighted the form-finding process, the wind loading simulation (wind tunnel tests were not

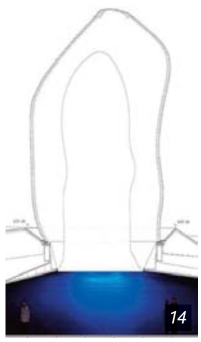


8

9



13



14

10

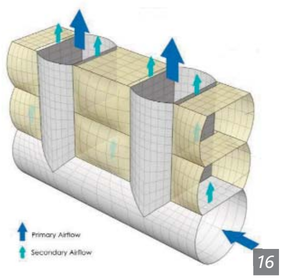
15

11

12

Figure 8. Installation of the canopies. KAPSARC (B. Whybrow).
Figure 9. 3D-shaped blades of PTFE-covered continuous stripes for shading. Brickell City Centre, Miami (B. Stimpfle).
Figure 10. Piotrkowska Street tram stop canopy, Lodz (P. Romain).
Figure 11. London Olympic Stadium during the Games (Al Fisher).
Figure 12. London Olympic Stadium after the Games (Al Fisher).

Figure 13. Semi-permanent, wide-span, inflated structure (B. Barton).
Figure 14. ETFE Memorial, Madrid (Ch. Paech).
Figure 15. The largest Ontario Celebration Zone Pavilion (H. Jungjohann).
Figure 16. Cutaway view showing primary airflow through span-wise arch tubes and secondary airflow through pillows with internal formers (H. Jungjohann).



16

available due to budgetary and time constraints), the structural design (assisted by Easy and SOFISTIK), the light foundations (Krinner Ground Screws), the fabrication (10 weeks), and the installation (1 week). It turned out to be a holistic approach due to the combination of architecture, structure, foundations, fabrication, and installation, compared to other cases presented, in which the form prevails.

A temporary pavilion divided into two canopies attached along the sides of a lorry was designed by Maco Technology and the University of Nottingham for events organized in conjunction with motorsport races (Fig. 17). The solution is based on bent aluminium profiles, designed to minimize the weight of the structures, and a double-membrane skin for waterproofing and solar radiation control. The design and manufacturing aspects were described by P. Beccarelli, who pointed out the challenging requirements of the client in terms of overall price, installation procedure, transportation volume, weight, and architectural appeal.

A novel, winterized textile partition to accommodate refugees during humanitarian crises was the topic of S. Viscuso. After the analysis of current literature, a set of requirements coming from users' needs was identified, and the current technologies in sheltering production were included. Finally, the most effective solution was prototyped and tested in the field (Fig.18).

An interesting description of the cable erection of the Krasnodar stadium suspended roof was carried out by D. Lombardini. The cable-supported membrane structure of the roof is based on the wheel spoke principle, with two steel box compression rings, one cable tension ring, and radial cables spanning between them, forming radial, cable trusses (Fig. 19). She completed the description with a video of virtual images which gave the appearance that all operations of assembly were very easy.

J. Llorens closed the series of presentations related to projects and realizations with the review of 80 interventions on historic buildings (Fig. 20). He revealed the characteristics that make structural membranes suitable for refurbishment. Because they are light, translucent, non-invasive, differentiated, reversible, and compatible, they can be integrated into the building layout, preserving its historic character and architectural configuration. Three design strategies have been identified and contrasted with the principles set by the International Council on Monuments and Sites. The complete list of interventions and links is available at: http://sites.upc.es/~www-ca1/cat/recerca/tensilestruc/REFURBISHMENT_web.pdf

ENVIRONMENTAL ISSUES AND LIFE CYCLE ASSESSMENT

C. Maywald headed an apology of ETFE, based on a comparative study between glass and ETFE (TensiNews 27, p. 21). C. Monticelli reported on the research results regarding the eco-efficiency principles in the field of membrane architecture, based on the application of the Life Cycle Assessment methodology. R. Fangueiro, the most conspicuous presenter of the Symposium, approached the durability of two architectural membranes: one produced with polyester fibre, coated with polyvinylchloride (PVC), and other produced with glass fibre, coated with polytetrafluorothylene (PTFE) at the initial stages of environmental exposure. M. Barozzi presented several examples of searching for effectiveness of dynamics applied to architecture. She found an increase in performance obtained by reducing energy consumption through the optimization of the building envelope, together with the minimization of energy use and the employment of raw materials (considering the embodied energy of building components).

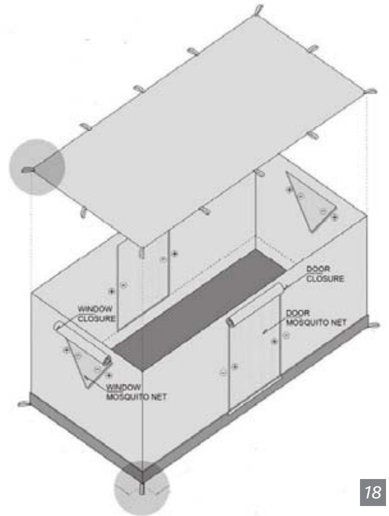
OTHER ACTIVITIES

Apart form the presentations, other activities offered during the Symposium included a guided tour to the Key, the University's new fabric structure working space reported on TensiNews 31, p. 6, the regular TensiNet Annual General Meeting, and, of course, the conference dinner served at the Great Hall (Fig. 21). The next day an excursion to the Alnwick Castle, Grounds and Gardens was foreseen.

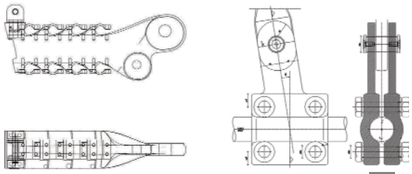
Other presentations are reported in TensiNews: J. Wacker (nº 31, p. 13); F. Sahnoune, (nº 31, p. 12); S. Chiu (nº 30, p. 8); K. Bernert (nº 29, pp. 10-11) and G. Grunwald (nº 29, p. 14).

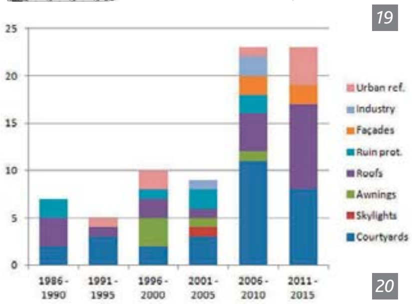
Josep I. de Llorens
ignasi.llorens@upc.edu
ETSAB/UPC


17



18


19



20

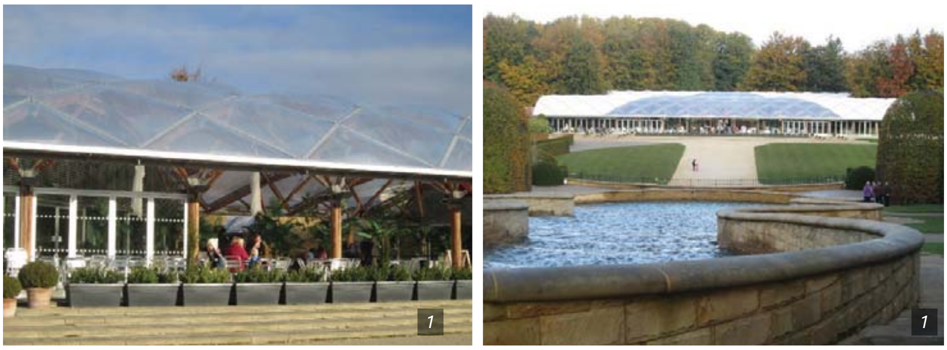

21

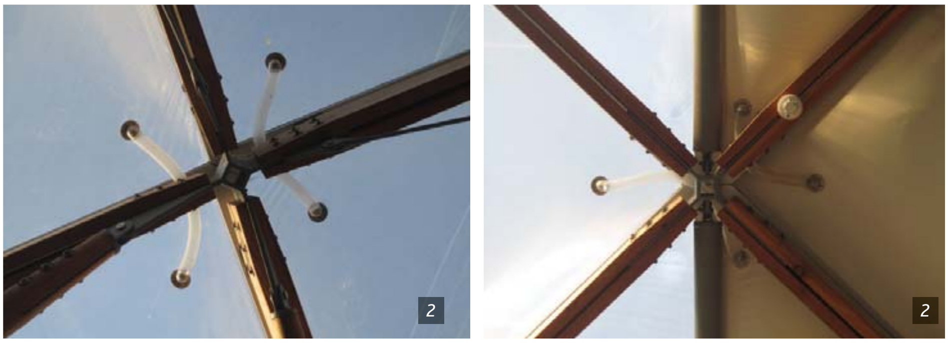
Figure 17. Linko demountable fabric pavilion for the motorsport sector (P. Beccarelli).
Figure 18. Isometric view of the final design of the emergency shelter (S. Viscuso).
Figure 19. Ring cable connectors (left). Hanger clap (right) (D. Lombardini).
Figure 20. 80 Interventions with structural membranes on existing buildings 1986-2015. An increase in the use of membranes over the last 30 years is clearly observed, led by applications in courtyards and roofs. (J. Llorens & A. Zanelli).
Figure 21. The magnificent wood-panelled and tiled Great Hall where the conference dinner was served. (Former Co-operative Wholesale Society warehouse, now Discovery Museum, by Oliver, Leeson, & Wood, 1897-1899).

Sustainable lightweight roofs

ALNWICK GARDENS VISITOR CENTRE AND PAVILION CAFÉ, UK

Saturday 29th of October an excursion to the Alnwick Castle, Grounds and Gardens was foreseen. The Alnwick Gardens have been open to the public since 2002 and a few years later the Alnwick Gardens Visitor Centre and Pavilion Café were built to welcome the increasing amount of visitors. A good opportunity to evaluate the situation of the large lightweight roof of these two buildings.





Name of the project:	Alnwick Gardens Visitor Center and Pavilion Café
Location address:	Alnwick,UK
Client (investor):	Alnwick Garden Trust
Year of construction:	2006
Architect:	Hopkins Architects
Structural engineer:	Buro happold
Contractor for the membrane (Tensile membrane contractor):	B+O Hightex
Dimension:	approximately 60x16m for each roof

Located on a site with and inspired by former glasshouses, Buro Happold with Hopkins Architects designed a timber barrel-vaulted structure with a diagrid roof grillage supported on timber columns. To maintain a slender diagrid roof framework and to reduce the structural depth the column capitals were tied creating a cable truss. For this innovative structure the local Wiltshire larch, besides its lightweight and strength, was chosen for sustainable reasons.

Unlike the similarity in structure for the Visitor Centre and Pavilion Café different type of foil cushions were designed for the inflated roofs (Fig. 2). Related to the degree of thermal and acoustic insulation and the degree of transparency, needed for solar protection, the cushions were compiled differently. They reflect the various functions of the spaces underneath:

- 2-layer ETFE cushions with a 30% frit pattern for the covered external area at the Visitor Centre;
- 3-layer ETFE cushions with a 70% frit pattern for the exhibition area in the Visitor Centre;
- 3-layer PTFE/ETFE/ETFE cushions for the Pavilion Café and function roofs, and an additional layer of Microsorber® for acoustic optimisation (Fig. 3) and
- 3-layer PTFE/Superquilt/PTFE cushions for the Visitor Centre (Fig. 4).

10 years after its construction the buildings are still in very good state, well maintained and enjoyable. Worth a visit!

Figure 1. The Pavilion Café at Alnwick Castle Gardens.
Figure 2. Different type of foil cushions.
Figure 3. 3-layer PTFE/ETFE/ETFE cushions for the Pavilion Café and function roofs, and an additional layer of Microsorber® for acoustic optimisation.
Figure 4. 3-layer PTFE/Superquilt/PTFE cushions for the Visitor Centre.

Evi Corne
Marijke Mollaert
www.tensinet.com

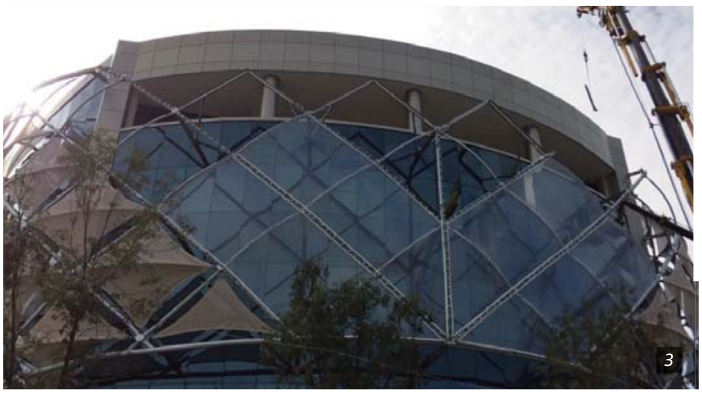
VAKIFBANK SPORTS PALACE

A COLOURFUL SECOND SKIN

Istanbul,Turkey

Introduction

Vakıfbank Sports Palace is the new Olympic sport complex located in Istanbul. Vakıfbank sports club was founded in 1986 and it became one of the motors of Turkish Volleyball by winning national and international championships and cups. Vakıfbank Sports Palace is regarded as one of the world's largest sport facilities: it is spread over nine floors and covers an area of approximate 30.000m². The main volleyball hall can accommodate up to 2.000 spectators and it has two training halls available for senior and youth teams. The players and the staff of VakıfBank are also provided with a first-class fitness centre, steam bath, rest rooms, rehabilitation rooms, press working room, press conference room and administrative offices. Vakıfbank Sports Palace complex was completed in 15 months with the support of one of Turkey's biggest financial companies, VakıfBank, which established the club some decades ago and has been supporting its activities for almost 30 years.



Design

The concrete building is covered with an additional façade composed of a steel grid with elliptical shape on which the membrane and the ETFE elements are anchored to. TENSAFORM has chosen for this second skin the colourful micro-climatic membrane Stamisol FT 381 (Serge Ferrari) and ETFE (NOWOFLON). The main goal of the cladding system is to give an extraordinary expression and a dazzling effect to the rather ordinary concrete building. Thanks to its mesh covered façade with the colours of the team, the Vakıfbank Sports Palace is acting as a landmark. Secondary the membrane facade provides shade and protects the building from regional climate changes.

Technique

Consoles anchored in the concrete wall of the main building support the additional frame. This steel grid follows the elliptical shape of the façade. To optimise the view no diagonal bars are provided in the section with an ETFE finishing.

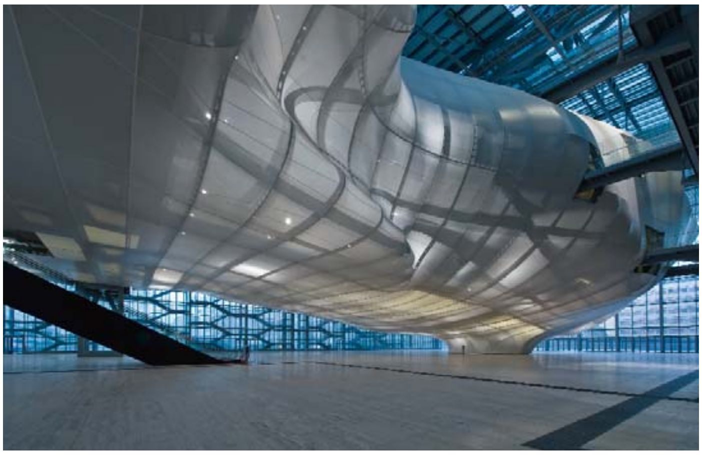
Figure 1. The gladding system attracts and protects.
Figure 2. Assembly of the metal frame to the concrete wall.
Figure 3. Fixation of the membrane and ETFE.

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

Name of the project:	Vakıfbank Sports Palace
Location address:	Istanbul / Turkey
Client (investor):	Türkiye Vakıflar Bankası T.A.O. Genel Müdürlüğü İnşaat İşleri Müdürlüğü
Function of building:	Sport Complex
Year of construction:	2015
Architects:	ESAT ÖZDEN
Multi-disciplinary engineering:	HALDIZ CONSTRUCTING
Structural engineers:	HALDIZ CONSTRUCTING
Consulting engineer for the membrane:	TENSAFORM MEMBRANE STRUCTURES INDUSTRY &TRADE INC.
Engineering of the controlling mechanism:	KIKLOP DESIGN ENGINEERING
Main contractor:	HALDIZ CONSTRUCTING
Contractor for the membrane (Tensile membrane contractor):	TENSAFORM MEMBRANE STRUCTURES INDUSTRY &TRADE INC.
Supplier of the membrane material:	SERGE FERRARI & NOWOFOL
Manufacture and installation:	TENSAFORM MEMBRANE STRUCTURES INDUSTRY & TRADE INC.
Material:	SERGE FERRARI STAMISOL FT 381 & NOWOFLON ETFE
Covered surface (roofed area):	Approx. 4320m²

SURPRISING WALK-IN CLOUD "NUVOLA"

New Centro Congressi, Rome, Italy



© Studio Moreno Maggi

Introduction

In Rome, in the district EUR, a new congress centre designed by the Italian architect Massimiliano Fuksas has been inaugurated recently.
The project consists of three elements, which the architect calls "Teca" (theca), "Lama" (blade) and "Nuvola" (Cloud). Located inside the Teca is the Nuvola, this is the central element of the congress and exhibition centre. Only fixed with few points to floor and building, this floating object is dominating the huge glass box.

Design process

The Nuvola is a membrane cladded steel structure. It has a length of 126m, a width of 65m and a height of 29m. Inside the Nuvola the visitor finds a café, foyers, meeting rooms and an auditorium for 2000 spectators.
Based on the Nurbs (Non-uniform rational Basis spline) surface provide by the architect, the steel consultant developed a concept that allowed to produce the steel geometry by slices cut in the yz, xz and xy plane (Fig. 1 and 2).

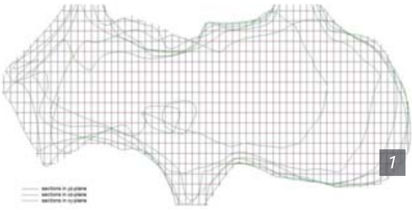


Figure 1. Sections of the steel structure.

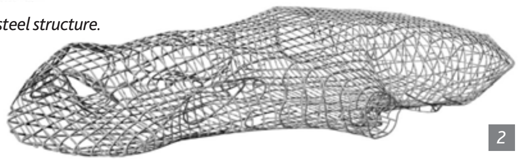


Figure 2. Steel structure computer model.

In some areas this created reasonable slices which can easily be covered with membranes, but in many areas the geometry was not ideal and made the shape development of the membrane very difficult.

A representative area of the structure has been identified for the analysis of the membrane envelope (Fig. 3 and 4). Due to the location inside the building, the membrane is loaded with internal overpressure, which have been determined in a wind tunnel test for the overall project.

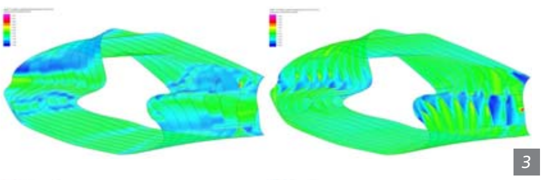


Figure 3. Loadcase wind suction warp and weft stress.

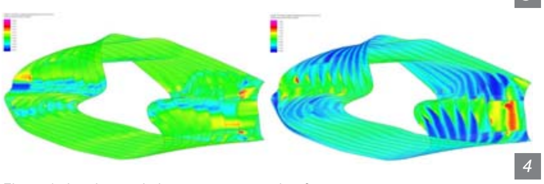


Figure 4. Loadcase wind pressure warp and weft stress.

The membrane material is a silicone coated glass fabric with an acoustic punch pattern, to improve the sound absorption. The raw material has a tensile strength of 52kN/m in warp and 40kN/m in weft. Due to the punched holes and the stitched seams the strength is reduced.

The steel structure has in a regular distance of typically 400mm steel studs, where the brackets of the secondary structure are fixed (Fig. 5). A detail has been developed that consists of a channel section screwed laterally to the studs. A slotted hole allows the height adjustment of the details. On the top, extrusion profiles are attached to fix the membrane panels. These extrusions can be moved in the plane of the membrane to compensate tolerances (Fig. 6 left). Where the membrane saddle is close to the steel structure a push up profile is redirecting the membrane around the steel structure. In some areas this push up profile is also used to pull the membrane, therefore the extrusion has a keder slot (Fig. 6 right).

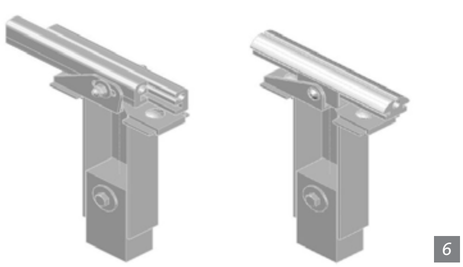


Figure 6. Isometric view attachment and push up detail.

Figure 7. Inclined and extended bracket.

The complex geometry of the project required details with different heights and angles. A reference line marking on the bracket is used to adjust all brackets at the proper level (Fig. 7). A parametric design in the Inventor software has been used to develop these brackets.

For the detail development and the workshop process of the attachment lines an automatic process was developed. The input data were reference nodes on each stud in one section, which has been offset and splined. Along this spline, the bended extrusion profiles have been generated with machine ready dxf files to cut from the straight profiles and with all bending and drilling information. Where the brackets are inclined, the profiles needed to be bended in two axes. In total approximately 6500 different pairs of clamping have been generated and approximately 180 different types of brackets.

Very important for the appearance of the Nuvola is the seam layout. The architects asked to align the seams as much as possible with the steel structure. The curvature is in many areas rather high, so that additional seams in between the steel gridlines were needed. In a long coordination process with the architect the final seam layout was adjusted to fulfil technical needs as well as the architect's basic idea.

The following figures (Fig. 8 and 9) show loop number 18 of this coordination, which is the finally agreed layout. The red lines show the borders of the membrane panels, formed by the clamping lines, the green lines show stitched seams in the panels.

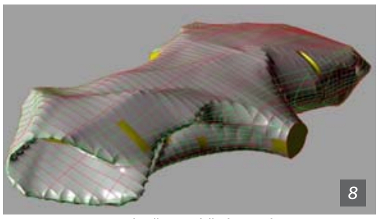


Figure 8. View on the "mouth" above the entrance.

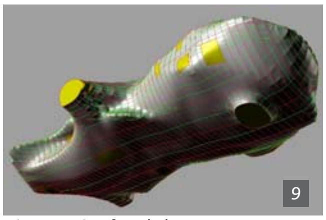


Figure 9. View form below.

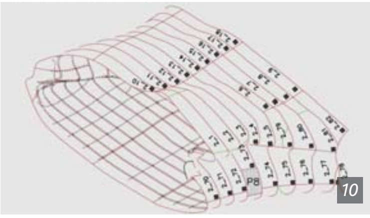


Figure 10. Cutting pattern in zone 2.

This agreed seam layout was the basis of the patterning model (Fig. 10). Many panels consist of only one or two pattern, but all complex panels consist of more patterns (Fig. 11).

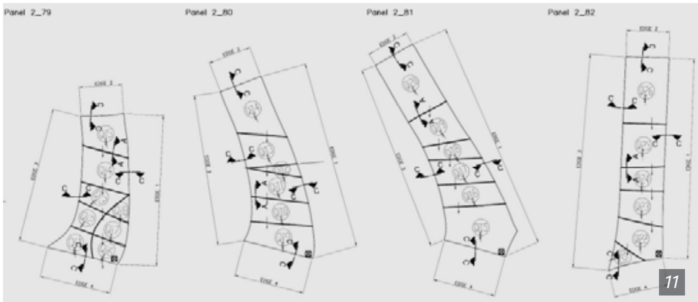


Figure 11. Panels in complex areas.

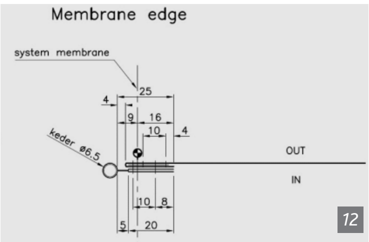


Figure 12. Membrane details.

The membrane is joined with stitched seams. The seam has been optimised with regard to the fabrication speed and to the resistance based on tests (Fig. 12).

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

Stefania Lombardi
stefania.lombardi@canobbiotextile.com
www.canobbio.com

Name of the project:	Nuvola del Nuovo Centro Congressi, Rome
Location address:	Via Christoforo Colombo, Rome
Client (investor):	E.U.R. S.p.A., Rome
Function of building:	Convention centre
Type of application of the membrane:	mechanically tensioned
Year of construction:	finished in 2016
Architect:	Massimiliano Fuksas, Rome
Consulting engineer for the membrane:	formTL, Radolfzell
Main contractor:	Condotte S.p.A., Rome
Contractor for the membrane:	Canobbio,
(Tensile membrane contractor)	Castelnuovo-Scrivia
Supplier of the membrane material:	Valmiera Glass UK, Sherborne
Manufacture:	Canobbio, Castelnuovo-Scrivia
Installation:	Condotte S.p.A., Rome
Material:	Atex 2000 with punch pattern WS 14
Membrane surface area:	14.400m²

CANOBBIO

Manufacturing process of the Cloud

The "Nuvola" (Cloud) was built within the "Theca" and is kept there in suspension, though connected at some lateral points. The interspace between the two bodies must be safeguarded as the Cloud symbolizes the connection between the city of Rome and the Convention Centre. The Cloud is a cocoon-like structure cladded by ±15.000m² (22.000m² manufactured) of highly advanced micro perforated noise absorbent fiber glass membrane coated with flame retardant silicone - ATEX 2000 WS 14. The centre is fully earthquake-proof – the stiffness of its vertical structure can withstand both light and heavy seismic waves. In addition, the building insulators present a horizontal rigidity that oppose light earthquakes, whilst its flexibility enables large oscillations with minimum accelerations in the case of tremors of a higher magnitude.

The manufacturing process of the Cloud was rather difficult: the main problem was that the sewing lines of the fabric had to match the skeleton of the structure. The tensioning system and the mechanical joining of the panels were designed to suite the dimensions of the sewing lines so that the cover, when viewed from outside, would not show marked traces. The number of the panels produced amounts to 580 and no one is alike. Each joint numbers 4 parallel sewing lines made by Tenara yarn counting a total amount of 350km (Fig. 13). The sewing machines had to be modified in order to avoid folding of the fiberglass and guarantee high precision in the assembly process. Many tests have been executed to guarantee a strong sewing without damaging the fabric itself; a number of 350 sewing tests and the same amount of border keder tests have been fulfilled.

To achieve the best results, several prototypes of the most difficult parts of the structure (The Mouth) were manufactured. The first prototype was meant to check the installation procedure, the tensioning system and the interfacing with the steel structure. The second prototype was to define the most stressed areas in the narrow points by minimizing the anticlastic bends. Some areas present a pre-tension ratio of 10/1. Installation tolerance was about 0,2%; if this number would be exceeded, the fabric would have been overstressed and consequently would torn in some critical points. The third prototype was to train the installation team and verify the external appearance of the fabric stretched to its final position; during night and day several light tests were fulfilled and all fixing and tensioning details checked (Fig. 14).

Figure 13. Manufacturing the 22.000m² fiber glass membrane.

Figure 14. Prototype 1.

CONCEPTUAL SMART TEXTILE AND BENDING-ACTIVE ARCHITECTURAL MODULE

The case of Paços dos Duques de Bragança [2016]

Innovations in technology gradually contribute to the transformation and adaptation of man to society, as seen through the instant communication. Within architecture is not different. Traditionally static, architecture now brings technological advances and design concepts such as dynamics, transformation and adaptability to the reality of buildings. The term kinetic applied in this scenario is related to the current search for movement in architectural design, taking into consideration that one of the advantages of cross information is to solve many environmental problems and thus increase the level of sustainability. In this context, it is possible to observe a great potential in the integration of adaptive structural principles such as bending-active structures and architectural membranes, presenting a relation between complex shapes and resistance based on the behaviour of the material, taking advantage of lightweight and flexible composition to achieve complex shapes and geometries, providing regular actions. This work aimed a conceptual development of a structural solution involving a kinetic concept integrated with adaptive structures principles corresponding to bending-active and textile structures. The design of this structure is justified by the possibility of submitting a solution – corresponding to a module – which can be incorporated in new or in existing buildings, as to be applied to façades or roofs. The light and flexible material, corresponding to the structural principles studied, integrated into the movement generated by applying the kinetic concept, can result in a solution that provides an independent response in order to adapt to the environmental conditions such as wind, rain and sun, and the users needs, improving the functional performance of buildings and generating a unique appearance as a landmark. In order to apply the module developed as a real problem solution, a courtyard cover is designed for he Paço dos Duques de Bragança building in Guimarães, Portugal – great historical, architectural and cultural building – answering to the demand for increasing space for existing uses and also enable new uses.

Introduction

Design and technology advances aim to respond to the needs of ever-changing man through the search for form or architectural elements that have the capacity to adapt to the user needs and the environmental in an independent way. Therefore, kinetics in architecture is based on the application of various concepts such as dynamics, transformation and adaptability in buildings. Aligned with this concept, other long-standing structural principles in the historical context of constructions such as bending-active and textile structures have been studied and incorporated in contemporary constructions along with kinetic, taking advantage of light and resistant materials that make such structures. In what concerns to membrane architecture, the dynamism condition is an incident due to the condition of light and flexible constructions, since the lightness of these structures allows the application of mechanisms and automatisms[1]. The same theory can be applied to the bending-active structures. Including active bending in the structures leads to a wide range of structural concepts that owe their kinetic behavior to the elastic deformation of the members[2].

The motivation of the structure developed was based on the interest of understanding how technological innovations have created a new panorama in the scope of architecture and engineering, modifying the static behavior that for a long time characterized most of the constructions. Besides, stands out the understanding how the integration of other areas of knowledge, integrated with new materials and different structural principles considered special, can represent a scenario of better functional performance in buildings, characterizing a solution for the sustainable construction and rehabilitation so sought in the current context. The architecture liberation of basic functionalities for the human comfort seen during the Modernism forced to resort to the use of technology to generate heath, cold, light and ventilation, in order to make the spaces more livable, leading to a higher energy expenditure[3]. As a consequence, human needs of comfort become again an extremely important point in architectural design, with the term sustainability being increasingly linked to new construction, making it quite necessary to find ways to reduce the environmental impact caused by this industry, through combination of new materials and techniques that can actively respond to climate change in order to improve building performance without compromising user comfort.

Adaptive Structures principles

Basically, the adaptive structural principles applied depart from their concepts of the same historical origin – the nomadic societies. The means of inhabiting man and defending himself from the intersperses at this time was based on tents, where the closure normally made of animal skins characterizes the origin of the membrane structures principle and the interlaced and curved elements, usually using soft wood, serving of support for the animal skin, correspond to the origin of the bending-active structures principle. That inhabiting way of the nomadic people carries other concepts such as portability and movement, since these tents are characterized by being easily assembled and dismantled, as well as easily transportable, seeing that the ancient civilizations lived in constant displacement in search of food and means of subsistence, characterizing the first vestige of the kinetic in architecture. Nowadays, the three structure principles have been incorporated in buildings, mainly at the level of constructive elements.

Architectural Membrane

Also known as lightweight textile structures, architectural membranes can be seen as flexible and adaptive systems that adjust to different environments according to the necessities, e.g. responding to climate variations[4]. Targeting their environmental efficiency, the organic shape, the minimum weight, the high flexibility, the translucency, the fast installation and low maintenance are pivotal aspects to be considered for the new constructions and what justifies the designers more and more appreciate membrane materials. Apart from that, the architectural membranes are able to stand environmental factors and structural loads when compared to conventional materials with similar mechanical characteristics[5]. In an actual context where the use reduction of natural resources is mandatory and the renewal in the field of architecture and engineering is necessary, the architectural membrane are increasingly claimed as innovative concept of a light and sustainable material for construction.

Bending-active Structure

Active bending is the utilization of large elastic deformation to create curved structures from initially flat or linear elements[6]. This structure principle is understood as a system of flexural elastic deformation. The elements are formed by means of a controlled elastic deformation in order to obtain the desired geometry. This results in residual stresses of flexion in the flexed elements, also called pre-stress[7]. Introducing the curvature only during the assembly of the structure, limits it's pre-fabrication to creating the components, evidently simplifying the production and transportation. Besides, the reversible elastic nature of active bending deformation, entails an inherent component transformation that can in many cases extend the transformational capacity and reduce the complexity of kinetic systems.

Kinetic Architecture

Kinetics in architecture nowadays is a technological development as the basis of a constantly changing society that influences the evolution of contemporary architecture in the sense of greater flexibility and adaptation in response to the evolutionary process of man and the dynamism of his environment. This term[8] is characterized by having a very broad concept in the context of architecture, since it can encompass simultaneously several areas of knowledge such as structural, mechanics and electronics engineering, based on the design of buildings in which mechanized transformations of the structures aim to alter the shape of the building in order to meet the user needs in the interior and adapt to the external climatic conditions. Therefore, kinetic architecture can be defined as constructions and/or constructive components with mobility, location and/or variable geometries[8]. This architectural principle is also characterized[9] by the design of spaces and elements that can be physically reconfigured to respond to new needs, through which an adaptive architecture is formed. Even more can be constituted by a series of interconnected elements, such as structure, connections, actuators, materials and control systems, which constitute a dynamic transition structure.

The module

In order to develop a smart architectural structure – corresponding to a module integrating the architectural membrane, bending-active elements and the kinetic concept – the following main guidelines has been followed:

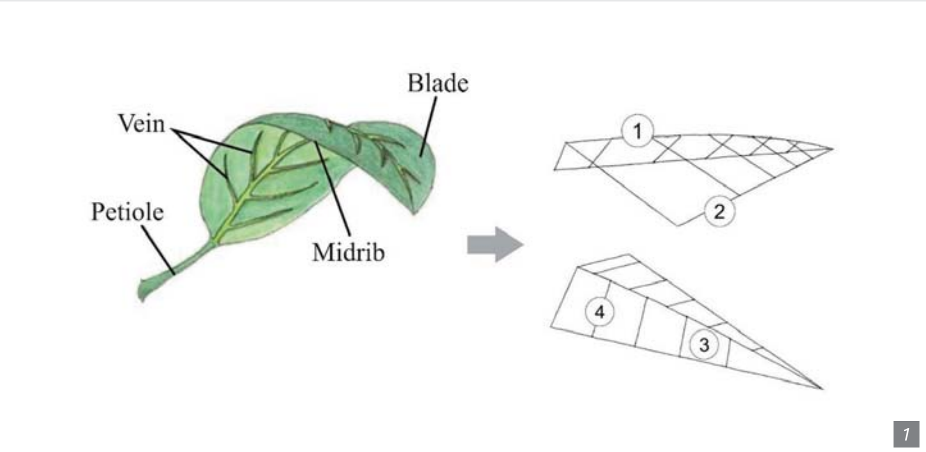
- Use of materials with structural capacity in order to resist the external actions and presenting low self-weight, also to achieve different shapes through a flexible behaviour;
- The structure may be incorporated into new constructions or rehabilitation/retrofit of existing buildings. In this context, the structural module can be applied to façades or roofs, where the light and flexible materials integrated into the proposed movement result in a solution that presents an independent response in order to adapt the environment and users needs, improving the functional performance of buildings.

Bringing to the structure development principles of biomimicry, science area that seeks to bring functions and behaviors found in nature and to incorporate in the architecture field, the structure concept is based on the leaves of trees or plants. The leaves present a diversity of shapes, colors and dimensions, being able at certain times of the year present changes, as shape, color and size. This ability to change through seasonal variations initially brings the concept of change to the structure design. From this, it followed a simple and structurally balanced spatial/formal configuration presenting, therefore, a triangular three-dimensional shape rereading the anatomical elements behavior of a leaf (Fig. 1).

Another important point of the leaves is the ability to resist – even presenting a thin surface – and to adapt/deform due to the forces, such as wind and rain, through their flexible anatomy, bringing the adaptability concept to the structure. Thus, the elements 1 and 2 (midrib and blade edge) must corresponding to bending-active elements; the 3 corresponding to the blade is represented in the structure with the use of architectural membrane (textile structure) and the 4 are the surface elements (vein) that in the structure must have rigid behavior, since the veins represent the leaf skeleton, giving structure and resistance to the blade.

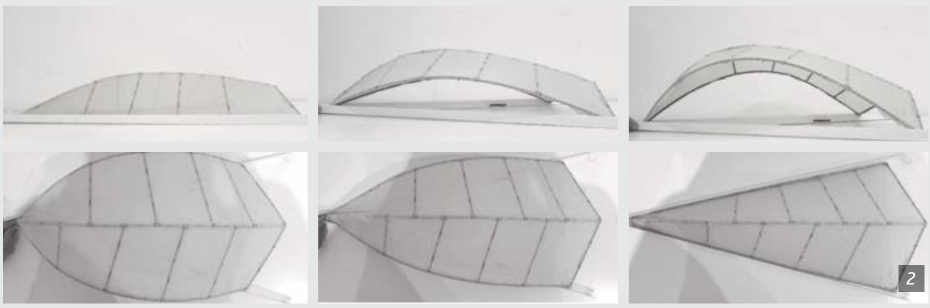
In general, the idea of the leaf for the module refers to concepts of change, movement, flexibility and adaptation, bringing a rereading of the form and mechanical behavior of an element found in nature to the reality of architecture and engineering. Additionally, the leaves may also bring other inspirations of incorporation into the structure, not only spatially and mechanically, but also at the functional level. Concepts such as self-cleaning, as can be seen in the ability to repel water from some leaves, or even color change during the year, may be important features found in leaves and that can be applied to the structure, more specifically to the membrane, through of innovative polymers that are capable of reproducing such capacities.

Defined the general shape of the structure, three physical models were developed, from which were taken important notes for the final definition of all the elements that compose the structure, and a final model was developed (Fig. 2). Using a composite material with carbon and glass fibers, and fabric with small elasticity, the model served to analyze the performance of the proposed structural set and, mainly, the behavior of the fabric according to the transformations and movements that the structure is subject. The movement in the model was generated by means of strands fixed in the connections of the triangle base, in order



1

Figure 1. Concept of the formal design based on the anatomy of a leaf.



2

Figure 2. Photos of the physical model – top and lateral views.

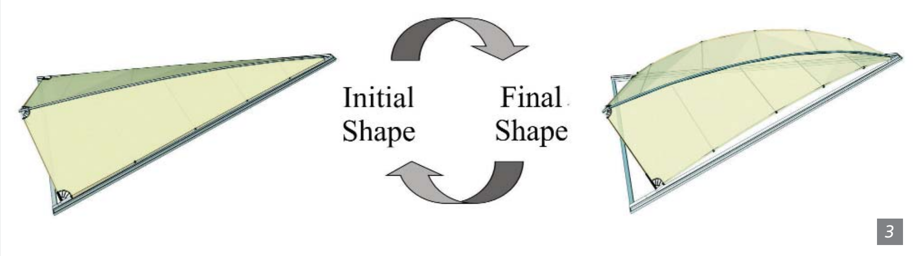


Figure 3. Structure reversibility.

to simulate the force mechanisms application for the structure transformation.

With this model it was possible to conclude that the structure works integrally, with the membrane remaining in tension during the movement and that depending on the elasticity modulus of the material used for the bending-active elements, it is possible to obtain a great transformation with little displacement and applied force on the connections.
The materials for composing the developed structure should follow parameters such as flexibility, strength and low self-weight, since two of the applied structural principles base their adaptability on the elastic behavior of the materials, which results in a global structure with reversible capacity (Fig. 3). This reversibility represents the formal change capacity of the structure caused by the movement mechanism that, when applying punctual forces, is able to alter and return to the initial form, corresponding to a structure with non-linear elastic behavior.

Based on these parameters for the materials definition, the use of fiber reinforced composites materials presents a constructive alternative of great efficiency when it is intended to have a good relation between mechanical properties and low weight. In addition, since the module represents an adaptive structural solution aiming the user ambient comfort, reducing the energy consumption of buildings, materials that present intrinsic characteristics durability, reduction of overall cost according to the life cycle, low power consumption for manufacturing and low weight for transportation, and assembly should be prioritized.
The definition of the membrane to be used is also a very important point for the structure. The membranes can present different compositions in face of service needs, as the most usual for structural design of PVC/polyester, PTFE/glass fiber or even the ETFE film. Usually, for the movable membrane structures design – such as folding and unfolding – PVC/polyester composite membrane are adopted. However, in the case of the studied module that presents a shape changes through the bending-active elements, the behavior of the membrane in relation to the global structure must always be tractioned to resist the external forces. In this context, the structure allows the adoption of all the membrane compositions and the definition of the type of membrane to be used is dependent on the functional needs or aesthetic issues.
Due to advances in nanotechnology, biotechnology and electronics, that investigate the materials properties and develop methods to alter and produce dynamic behaviors capable of providing the materiality of an interactive operation that can read and adapt to different surrounding conditions[10] the use of membranes allows architects and engineers greater freedom of creation, being able to think beyond their mechanical properties. Among the new functional and aesthetic capabilities is the ability to self-clean, change color and appearance in response to external influences or the ability to produce light through the use of chromic and luminescent polymers, or even photovoltaic capacity through the use of organic solar cells on the membrane surface.

Application study

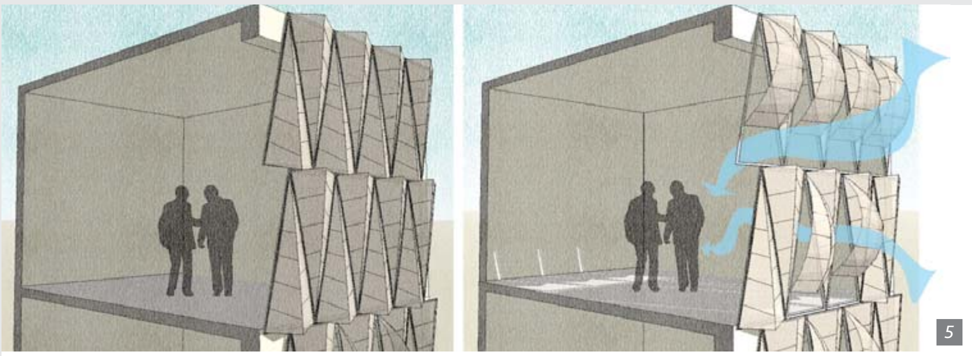
The design of the module is intended to integrate adaptive structural principles in order to create a structure that can be applied in new or existing buildings, or other appropriate situations, that the shape changes and adaptability are capable of functionally efficient architectural solution. As main application possibility the use in roofs or façades is highlighted.

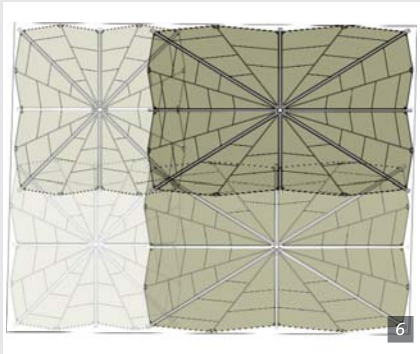
In order to exemplify this context, it was necessary to bring an application case with considerable relevance, so that the proposition would benefit a real problem. Thus, it was proposed to apply the structure in an existing situation, designing a cover for the *Paço dos Duques de Bragança* central courtyard. *The Paço dos Duques de Bragança* (Figure 4) is one of the most important buildings located in Portugal mainly about the history of the country. A medieval civil architecture example with peculiar characteristics in the Portuguese territory[11], the gothic language building dates from 1420 and it is organized in a quadrilateral layout, presenting a rectangular design as a central courtyard with the cloister that surrounds it. Currently, the building is used as one of the most visited museums in Portugal.

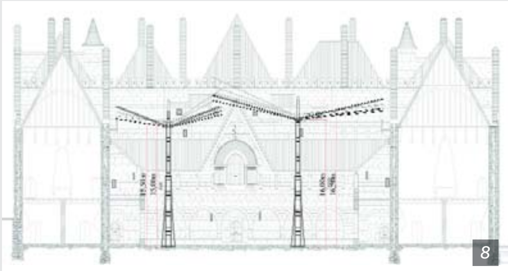
The incorporation of the module for this composition seeks to present an adaptive architectural and structural solution capable of protecting the central/internal courtyard space of the building of climatic variations, making it possible to use this space for new uses and for different purposes. Therefore the concept of a general kinetic structure is considered, with the capacity to change the shape, adapting to the users needs and the environment, where the proposition of the global structure followed some design guidelines:

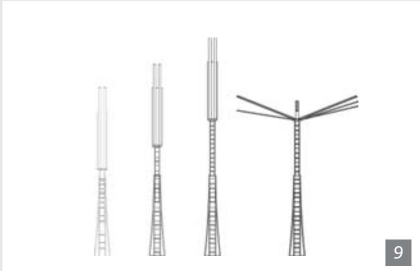
- The general structure should be independent with no fixation and support in the building structure, following concepts of maximum conservation and respect for the constructive system of the monument with high patrimonial value;
- It must respect all the architectural elements existing in the courtyard, important parts for building identification and characterization;
- Distinguish between the building and the new structure;
- Facility of assembly and disassembly also bringing as principle the reversibility of the structure, being able to be removed without leaving permanent intervention traces;

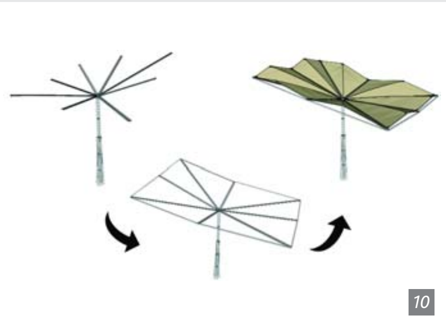
Figure 4. Superior view and courtyard of the Paço dos Duques de Bragança building in Guimarães, Portugal.











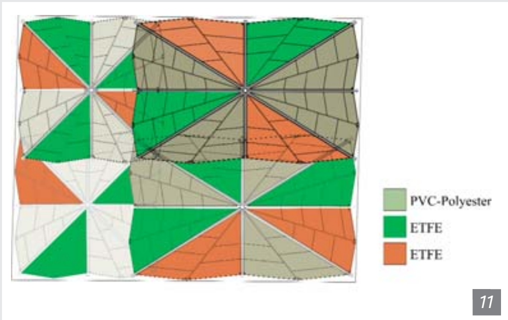


Figure 5. Structure concept based on a palm tree used for Façade application.
Figure 6. Top view of the cover composed by four independent structures.
Figure 7. The global structure based on a palm with eight modules.
Figure 8. Section demonstrating the height of the structures in relation with the building.
Figure 9. The global structure movement.
Figure 10. Assembly of the global structure.
Figure 11. The different membrane compositions of the modules applied to the cover.

- Ability to adapt to the environmental through the incorporation of the developed module, allowing the natural lighting and ventilation in the space with the shape and material changes.

Joining the concept for the development of the module based on the leaves with the parameters highlighted in the guidelines, the structure design to the courtyard cover started from the general idea of a palm tree (Fig. 5).

The palm is a plant that reaches in some species high heights, presenting the leaves only in the highest part, forming a tuff at the stem high end. Starting from the same conceptual origin of the module based on nature, it was found relevant to use a tree or plant to conceptualize the cover design, incorporating several studied modules that correspond to the leaves. Another point about the palm is that with only one support that corresponds to the stem it can have a large diameter treetop without the need for other ways of support to resist the external actions, bringing the concept of structural independence. Therefore, the cover proposal is composed by four structures that refer to four palms (Fig. 6).

In a square/rectangular composition, the structure is formed by eight base rectangle-triangle modules (Fig. 7). Basically, it is composed of the support column, the rigid bases and the light upper module structure. The column is a mobile lattice structure presenting an organic shape in the base with curved elements that resembles the stem shape, resulting in a larger area of base, and each structure presents a height difference due to their overlap.

The 'arms' inclination, in addition to the function of enabling the structure to conform to the building architectural elements, directs the rainwater to the falling pipe which is located in the structure center (Fig. 8). To facilitate the assembly of the structures, the proposition of the columns and the mechanized arms, resulting in a kinetic structure, enables the rigid structure to be positioned at the intended height independently. On a circular base with eight spaces where the arms are fixed with a rotating mechanism, the rigid bases initially positioned vertically take the final position when their final height has already been reached, beginning the opening in order of the structure from lower height to the higher height (Fig. 9).

After the rigid structures have been opened, there is the application of the locking between the arms for a greater structure resistance and also the upper light structure application already mounted, because their low weight makes easy to handle, fixing the three points of support (Fig. 10). Once assembled, each module will have independent operation through the endless motor mechanism able to change the shape through the active movement and the bending of the elements, allowing openings for the natural ventilation and ilumination of the space.

The kinetic modules composed of bending-active elements with architectural membrane for their closure should present different behaviors regarding the functional and mainly aesthetic aspects in the covering structure. The idea is bringing to cover – besides new concepts of architecture and engineering – a structure capable of interacting with the environmental and users, so that the incorporation of innovative materials present in addition to the functional parameters, a differentiated aesthetic becoming a featured element in the building (Fig. 11).

Essentially, the nude color modules are composed of semi-translucent PVC-Polyester membranes with organic solar cells to give photovoltaic capacity to the module, generating energy feeds to the led illumination present in the rigid arms of the structure. This semi-translucency allows users to see important building elements and diffuse natural light, but at the same time prevent the direct sunlight, obtaining better space comfort.

The green and orange/brown modules are composed of ETFE film, completely transparent with thermochromics polymers that, receiving the direct sunlight and the thermal energy gain, alter their color by changing the appearance and becoming more opaque to block the entrance of direct solar rays. These thermochromics modules must also contain luminescent nanomaterials enabling the film to emit light for a period of time after a thermal energy gain. Therefore, the thermal energy gain through the solar rays enables the module to change the color instantly during the day and allows to emit light during the night.
The images correspond to the modules behavior simulation in the cover courtyard application. The first perspective (a) corresponds to the structure in the initial transparent appearance without the gain of thermal energy. With the onset of direct sunlight (b), the ETFE modules change to the determined colors (c), demonstrating their luminescence at night (d). The color was based on the module concept inspired by the leaves, being the green representing a leaf in the period of spring/summer with high amount of chlorophyll and the orange-brown caused in the leaves during the autumn due to the decrease in temperature and the consequent reduction of chlorophyll production.

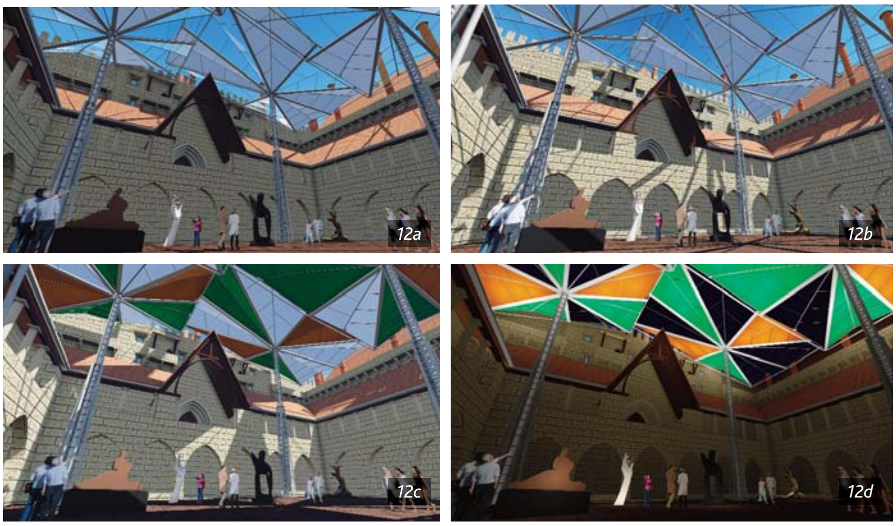


Figure 12 a-b-c-d. Module behavior simulation.

Conclusions

After studying and developing the structure through the empirical analysis of physical models, it was possible to successfully complete the objectives established at the beginning of the work. Thus, this research contributed to advance the knowledge in the area of special architectural structures, bringing something new that is the integration of three structural principles in the contemporary context as solution of functional problems in new and existing buildings, which have only been the focus of a few investigations in this scenario until today. It could be first concluded that the design of structures integrating architectural membranes with bending-active elements capable of formal alterations represents a high design complexity. It is extremely important to know the properties of the materials that compose these structures, as well as the understanding of the behaviour and the components that each structural principle encompasses, in order to find the ideal integration solution between them. In addition, it is also emphasized the need for multidisciplinary professionals from the creation phase.

Having as a conceptual inspiration an element from nature, the developed module had to refer the anatomy of the leaves of plants through the elastic capacity of the bending-active elements and the adaptable performance of the architectural membrane. However, in order to achieve that, specific connection elements had to be developed, designed for the adaptation of the general elements of the structure during the shape changes caused by the movement and in order to keep the membrane in traction at all stages. For this, the physical models in small scale were of total importance, because with them it was possible to reach the best form for the membrane to remain tensioned in all structure changes, and also prove the feasibility of creating a structure capable of integrating the concept of kinetic with architectural membrane and bending-active elements.
As a result, the development of a structure that is open for changes in dimensions and angulations was achieved, so as to be able to compose different applications. This flexibility allowed the design of a case study to be implemented as a courtyard cover of the Paço dos Duques building and could be easily applied in the real context, presenting the adaptive structures as a very efficient solution for interventions. Moreover, the application of new materials and new concepts in a context with high cultural value for the city and, consequently, for the country, aims to highlight even more the use potential of these kind of structures in the architecture field.
Also, through the incorporation of certain innovative materials in the architectural membrane, it is possible to obtain innumerable potentialities in the development of this type of structure, optimizing still more the functional performance, besides an aesthetic variety that give greater freedom of creation to the professionals of the construction field.

Msc. Archit. Luani Costa
Prof. Dr. Raul Fangueiro
Prof. Dr. Luís F. Ramos
Department of Civil Engineering,
University of Minho, Guimarães, Portugal

References

[1] Obata, S. H; Alonso, C. E. Mobilidade das arquiteturas têxteis e tensoestruturas. Paper for Exacta magazine, vol. 9, n. 1, p. 103-120. São Paulo, 2011.
[2] Brancart, S; De Laet, L; De Temmerman, N. Transformable bending-active structures: manipulating elastic deformation in kinetic and rapidly assembled structures, proceedings of the International Conference on Structures and Architecture (ICSA), Guimarães, 2016.
[3] Moreira, R. A. S. Novas possibilidades na arquitetura. Dissertation of Master in Architecture and Urbanism, University of Porto, 2013.
[4] Moreira REF. Utilização de membranas tensionadas leves na execução de estruturas especiais. 2012.
[5] Mérida KR, Fangueiro R. Arquitetura têxtil: liberdade de design, funcionalidade e sustentabilidade, 2012.
[6] Lienhard, J; Alpermann, H; Gengnagel, C; Knippers, J. Active bending, a review on structures where bending is used as a self-formation process, International Journal of Space Structure 28, p.187-196, 2013.
[7] Puystiens, S.; Craenenbroeck, M. V.; Mollaert, M.; Hemelrijck, D. V, Laet, L. Implementation of Bending-Active Elements in Kinematic Form-Active Structures: Design of a representative case study. Structural Membranes 2015: VII Internacional Conference on Textile composites and inflatable Structures. Barcelona, Spain. p. 368-378, 2015.
[8] Fox, M. A. Kinetic Architectural Systems Design in Transportable Environments 2, de Robert Kronenburg. London: Spon Press. p. 163-186, 2003.
[9] Razaz, Z. E. Sustainable vision of kinetic architecture. Artigo para o Journal of Building Appraisal, 5, 341-356, 2010.
[10] Sousa, J. P. Tectónica Digital: (Re)inventando a Materialidade. Arquitectura e Vida, p. 32-36, 2005.
[11] Brito, M. Paço dos Duques de Bragança em Guimarães: metamorfose da imagem na Época Contemporânea. Dissertação de Mestrado em Arte, Património e Restauro, Lisboa, Departamento de História, Instituto de História da Arte, Faculdade de Letras da Universidade de Lisboa, 2003.

La Folia

STANDALONE PAVILION

Design inspiration

La Folia is the new standalone pavilion from the Nomad Concept standard collection (Fig. 1). It combines a joyful design sail with a rectangular frame, offering a minimum covered surface of 45m². The name "La Folia" originates from the homonymous historical music. The very recognisable theme was reinterpreted innumerable times by many famous composers all over Europe, since at least the 16th century up till today. Literally, folia means festive joy or revelry in Portuguese and it has laid the foundations for the current carnival Folia de Reis. La Folia has an exciting rhythm, immersing the listeners completely in joy. Architect Amandus VanQuaille of Nomad Concept chose to compose a colourful frame as a 'musical framework' referring to this historical meaning. In contrast to the rigid orthogonal structure, representing the male world, he created a flamboyant organic form in textile, referring to the female dance movements. This musical theme – the contrast between 2 apparently opposite elements that merge together – is the architectural base for La Folia. In addition, one unit can be repeated in altered form analogous to the historical concept of the so-called "Variation on a Theme": the fundamental musical theme – here the architectural idea – is repeated in a varied form throughout a fixed framework.

Project

The purpose of the design was to create an all-round tensile product with a very straightforward installation. The result is an autonomous frame with a very dynamic and asymmetric membrane. Three different units of La Folia are introduced: by combining them it is easily possible to satisfy varying clients' needs and constraints (Fig. 2). The structure can be placed on the ground, on a terrace or on a roof. It can be installed standalone or against a wall. In a later stage, indirect light, sound and wind panels can be integrated in the structure.

Specifications

The membrane constructions of Nomad Concept are designed with in-house software and always realised down to the last detail with high qualitative materials. La Folia is engineered to withstand snow loads of 40kg/m² and wind speeds up to 90km/h. The framework is made of standardised marine grade stainless steel with a powder coating. The supporting beams have a squared section of 100x100x3mm. The basic unit has a squared base plan of 4,5x4,5m. There is a free headroom space of 2,5m. The textile roof extends in height to 4,9m and in plan to a rectangle of 6,5x7m. The main proportions of the frame obey to the classical "golden section" rule (Fig. 3).
To ensure esthetical architectural detailing, architect VanQuaille opted for internal cross components to ensure a clean and exact fitting between the standard beams (Fig. 4). The cross components are composed of plates which are laser cut, folded and welded mechanically according to the dovetail jointing principle (Fig. 5).
The precise CNC-folding method of the components allows a more accurate fitting of the beams than it would be the case when composing the crosses with welded standard profiles. With the use of these crosses the frame beams are joined together with reversible dry bolt connections, making disassembly and reuse possible.
The membrane material can be chosen out of a large range of technical textiles, with PTFE being the most durable. The latter lasts for plural decades with no fabric degradation allowing a permanent set-up outside throughout the year. Depending on the chosen fabric the membrane is welded or stitched. The cables and fixation terminals are made of stainless steel.

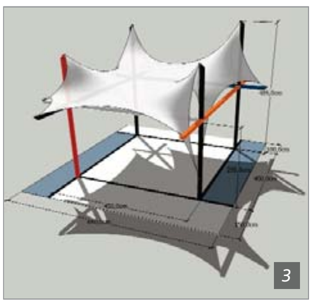
Conclusion

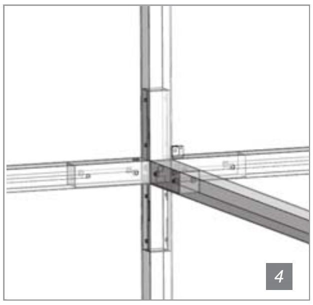
In conclusion, La Folia is a pavilion system designed for a wide variety of applications with the opportunity of combining different units into a large variety of shapes (Fig. 6).

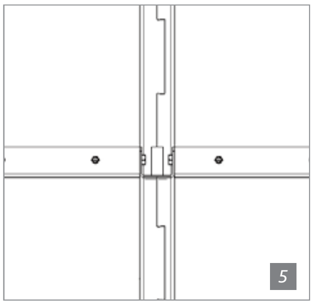
ir. Lara Alegria Mira
amandus@nomadconcept.com
www.nomadconcept.com

Figure 1. Standalone pavilion.
Figure 2. Combining the units generate various compositions.
Figure 3. Basic unit: stainless steel frame and membrane (PVDF-PVC or PTFE).
Figure 4 and 5. Internal cross component – dovetail.
Figure 6. Project De Persgroep.

Name of the project:	La Folia
Location:	product launch at Maison & Objet (Paris, France)
Function of construction:	Sun, rain and wind protection, standalone outdoor tensile pavilion for terrace or garden
Year of construction:	2016
Architect:	Amandus VanQuaille
Engineering, cutting pattern and installation:	Nomad Concept
Frame:	Fixed rectangular frame in stainless steel
Membrane:	choice between PVDF-PVC and PTFE







Maco Technology srl / Centexbel

Integrated sensors for the detection of ammonia and hydrogensulfide in biogas plants.

Context

Despite the development of a new generation of coated fabrics, the tensioned membrane structures for biogas plants are still quite problematic in terms of durability of the membrane, mechanical stability of the connections and overall structural behaviour of the structures.

The main failures are due to two main reasons: the early degradation of the coated fabrics, which lead to the progressive increase in the losses of gas and the subsequent reduction of the tensile strength of the membrane, and the rupture of the welded seams due to the decrease in the mechanical performance of the PVC coating due to the high temperature and chemical corrosion (Fig. 1 & 2).

Objectives

Maco Technology srl and Centexbel, within the activity of the EU funded research project MULTITEXCO, developed a new generation of sensors for the detection of ammonia and hydrogensulfide.

The main objective is to detect the misuse of a coated fabric through the irreversible colour change of the sensor and to simplify the legal controversies in case the manufacturer uses a coated fabric designed for other applications or when the client uses the biogas plant with a different substrate which releases concentration of gasses different from what considered for the initial design.

Existing Biogas plants as case study

Maco Technology is currently investing in the development of innovative structures for the biogas sector. Recent projects include Tensairity® roofs based on inflatable beams for square sewage basins with a span up to 50m or inflatable floating roofs for circular tanks with a diameter up to 65m.

The experience gained in the last years during the recladding of several existing biogas plants highlighted the inadequacy of numerous coated fabrics for heavy duty applications in presence of corrosive gases such as H_2S and ammonia. The problem has been investigated through detailed analyses of samples collected from biogas fermenters (where high corrosive gasses are likely to accumulate) selected as a case study due to the premature degradation of the coating.

Chemical analysis of deteriorated samples after biogas formation was performed using XRF, FT-IR and dynamic headspace. Samples showed various levels of deterioration, even on the same fabric. Despite the material used was specifically designed for biogas applications, the exposure to a different gas or to a higher concentration of corrosive chemicals, combined with inaccuracies during the manufacturing, lead to the early degradation of the PCV coating. The effect, which is anticipated by a change in the colour of the fabric, is more evident on the fabric panel with the edge of the fabric exposed to the internal atmosphere. The corrosive chemicals penetrated the fabric form the edge along the fibres and destroyed the protective coating from the inside.

The XRF analysis and the FT-IR analysis carried out highlighted that the failure of several membrane structures used in corrosive environments like biogas plants are related to the inadequacy of several coated fabrics for heavy duty applications in presence of corrosive gases such as H_2S and ammonia.

Development of sensors

For this reason, within the MULTITEXCO project, Maco Technology and Centexbel invested in the development of two sensors for the detection of ammonia and hydrogensulfide. The irreversible colour change allows to detect the exposure of the fabric to corrosive gases or to concentrations beyond the scenarios and the limits considered during the design.

For Maco Technology and for material producers the installation of these sensors offers an important technical and commercial advantage compared with other competitors. The irreversible colour change will prove the misuses of the fabric with no uncertainty and the consequent reduction of the costs related to expensive and time consuming legal controversies.

Pilot case

For this reason, Maco Technolgoy decided to involve one of his main clients in the biogas sector and validate the sensors on field through a pilot case. The brand new biogas plant is based in the Milan area and is designed to transform agricultural waste into fertilizers

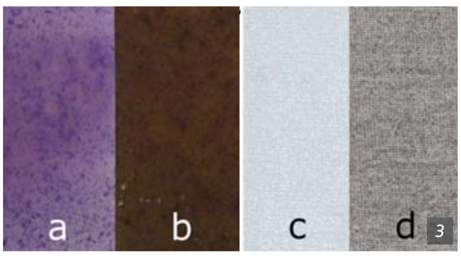


Figure 1: Degradation of a PVC coated polyester fabric due to the exposure to biogas.
Figure 2: Damages to the welded seams due to the high temperature that during a sunny day in the warm season reaches 66.5°C.
Figure 3: Chemical responsive coatings with irreversible colour change: left ammonia, right hydrogen sulphide, a and c are before exposure, b and d after exposure. Scale bar is 1cm.
Figure 4: The testing rig installed on the fermenter in correspondence of the membrane roof.

with the additional production of biogas used to generate the heat and electricity absorbed by the plant. Despite the "state-of-the-art" facilities, the client experienced a rapid degradation of the membrane roof which changed from green to brown in few weeks. A testing rig designed by Maco Technolgoy srl will offer the final validation of the first prototype of the sensors.
The sensors have been developed through a combined set of tests carried out at lab scale and in the pilot project. The XRF spectrum of the samples before and after the exposition to biogas highlighted that the damaged fabrics has a clear sulphur content that hint to the corrosive activity of sulphur containing products in the biogas fermenter. Therefore, the goal was to find two sensors able to detect ammonia and hydrogensulfide, the two main sources of corrosive chemicals. The task was not easy because the sensors had to be practical to install, irreversible and reliable during the expected life span of the structure (from 5 to 10 years).
The team selected a sensor based on an irreversible colour changing pigment to be integrated in the final structure by means of coated patches easy to apply in the key areas of the structures (Fig. 3).

The validation of the new sensors started with a set of preliminary tests at lab scale. To mimic the real conditions, a new test setup was constructed based on the fogging test. In this test, a known concentration of H_2S gas is formed at elevated temperatures (40°C) to which the fabric is exposed. The other side of the fabric is cooled down (18-20°C) to force condensation to occur (Fig. 4).
After the successful tests at lab scale, the sample has been installed in the pilot project be means of a testing rig designed by Maco Technology and able to put the sample directly in contact with the internal atmosphere of one of the fermenters (Fig. 4). The samples have been installed in August 2016 and the intermediate assessment carried out in November 2016 confirmed the expected long term performance of the sensors and the feasibility of the new product which will be sold by Maco Technology in 2017.

Credits

This new product has been developed by Maco Technology srl and Centexbel with the support of D'Apollonia spa and TexClubTec within the MULTITEXCO research project founded by the European Union through the FP7-SME funding scheme.

Paolo Beccarelli
info@macotechnology.com

Call for participation to the TensiNet Working Group Pneumatic Structures REACTIVATED

Pneumatic structures have a significant potential in the built environment. They can be effective responses for many applications, for example to fabricate wide-reach structures (roofs), or for big halls to protect sensitive objects (Fig. 1) or people (see Fig. 15 on page 8 of this TensiNews issue). They can take varied forms (Fig. 2-3). Pneumatic structures often are visually appealing and present the particularity of being active structures. Indeed, it is possible to control the internal pressure and thus the prestress in the fabrics. They are subjects of academic research (Fig. 3-4) and companies have at their disposal increasingly powerful tools to design them. Knowledge of the behaviour of these structures is increasing and materials and manufacturing techniques are constantly improving although there are always limitations to their use.

The main objectives of the WG Pneumatic Structures are to promote pneumatic structures, to follow and to collect advances in this field (architecture, design rules, calculation methods, manufacturing, etc.), to discuss evolutions and improvements and to disseminate good design practices.
One of the first tasks of the WG Pneumatic Structures will be to resume the work on Annex 6 of the TensiNet Design Guide: Recommendations for Pneumatic Structures, following the work of Buro Happold.
All interested parties are invited to contact Evi Corne (evi.corne@vub.be) and Jean-Christophe Thomas (Jean-Christophe.Thomas@univ-nantes.fr) (University of Nantes, Laboratory GeM).
The upcoming WG PNEUMATIC STRUCTURES meetings are scheduled during the TensiNet Meetings at Techtextil Frankfurt (Tuesday 9th May 2017) and during the final COST Action TU1303 Novel Structural Skin meeting.


1


2


3


4

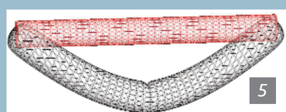

5

Figure 1: Inflatable shelter for solar impulse plane @Solar Impulse.
Figure 2: Inflatable cushions, Le nuage @Nicolas Pauli.
Figure 3: Tea house, museum fûr angewandte Kunst Frankfurt @ Uwe Dettmar, Frankfurt
Figure 4: Inflatable structure in the CSTB wind tunnel, Nantes, pHD Alexis Bloch, GeM.
Figure 5: Finite Element Analysis of an inflatable beam, GeM.

ARTICLE

Form-Finding and Cutting Patterns of Membrane Structures

The finite element analysis software RFEM allows for form finding and structural analysis & design of membrane and cable structures. In addition, the software provides the option to determine cutting patterns of tensile membrane structures and transfer them to a CAD program.

The form-finding and structural analysis of membrane and cable structures can be performed on the entire model. In this way, the elasticity of the substructure can be taken into account.

Form-finding of Tensile Membrane and Cable Structures.

The **RF FORM FINDING add-on module** searches for shapes of membrane and cable structures. The shape is calculated by the equilibrium between the surface forces and the natural or geometric boundary conditions. The prestressed model is then used as a basis for further calculations.

In the form finding process, it is possible to consider the self weight, any free loads and interior pressures. You can use both isotropic or orthotropic materials for the membranes.

The form finding process is performed iteratively according to the URS method (Updated Reference Strategy) by Prof. Bletzinger / Prof. Ramm, which is one of the most complex and accurate method.

Cutting Patterns of Tensile Membrane Structures.

The **RF CUTTING PATTERN add on module** generates very precise cutting patterns for membrane structures. Boundary conditions of the cutting patterns on curved geometry are determined by boundary lines and independent planar cutting lines or geodesic cutting lines.

The flattening process is performed according to the minimum energy theory.

It is possible to consider constant or linear compensations in the warp and weft direction. Furthermore, you can define welding and border allowances for the manufacturing process.

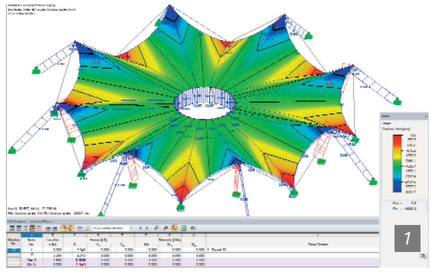


Figure 1.Cable tension force and contour lines after form-finding in RFEM.

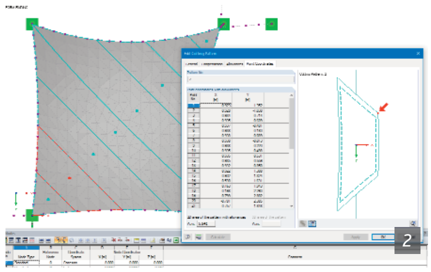


Figure 2. Displaying and editing a cutting pattern in RFEM.

Andreas Hörold
info@dlubal.com
www.dlubal.com

Figure 1. Top view - membrane roof with retractable roof above the tennis court.

LOW AND BONAR

ONE OF THE 2016 SHOW PIECES OF NANO MATERIAL

Garanti Koza Arena

Istanbul, Turkey

Introduction

It is almost two years ago that Turkey hosted the first ATP-tournament. Obviously the public's tennis enthusiasm was big enough to lead to a redevelopment of the sports complex in Istanbul, where Roger Federer won in April 2015.

The tennis stadium belongs to a sports center with numerous outdoor tennis courts.

The indoor tennis arena has 7000 seats. Its layout is designed for international tennis competitions and it includes VIP areas, a restaurant, athletes' work and service areas. Furthermore it is integrated into the tennis academy at the lower levels. In this it connects the club buildings with the most prominent tennis court.

Wrapped

Around 12.500m² Type III Nano material was used to wrap the tennis court and the grand stands into one uniform façade. At night the arena seems to glow within the surrounding outdoor tennis courts.

Apart from the highly translucent membrane with the Mehatop Nano lacquer the construction involves around 1.500m² TF 600. This is a mesh fabric with an extremely high tensile strength. The central part of the membrane roof is retractable.

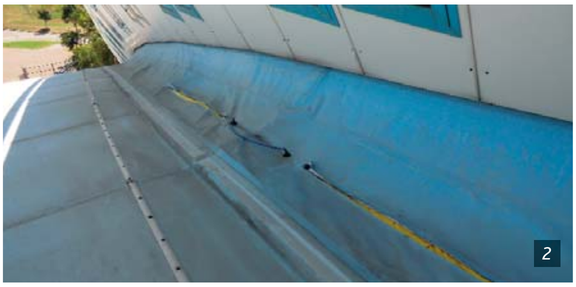
Name of the project :	KozaWOS- Koza World of Sports Arena
Location address:	Koza Wos Arena-, Esenyurt, İstanbul, TURKEY
Client (investor):	Garanti Koza Construction
Function of building:	Tennis Court Arena
Type of application of the membrane:	Saddle shaped & Retractable Tensile membrane structure
Year of construction:	2015
Architect:	Ofis 16 Architecture
Multi-disciplinary engineering:	Başkur Engineering
Structural engineers:	Başkur Engineering
Consulting engineer for the membrane:	Aykut Savaş -Etna Membrane structures
Engineering of the controlling mechanism:	Ali Ünal
Main contractor:	Garanti Koza Construction
Contractor for the membrane: (Tensile membrane contractor)	Etna Membrane Structures
Supplier of the membrane material:	Low and Bonar (formerly Mehler Texnologies)
Manufacture and installation:	Etna Membrane Structures
Material:	Mehgies® VALMEX® FR 1000 MEHATOP N - type III-(12.500m²) & Mehgies® VALMEX® TF 600-(art. No.: 7286.5246)-(1.500m²)
Covered surface (roofed area):	12.000m²

TAIYO EUROPE

SIOEN INDUSTRIES

NEW PVC ROOF FOR THE ARENA "L'ASTRONAVE"

Pesaro, Italy



Introduction

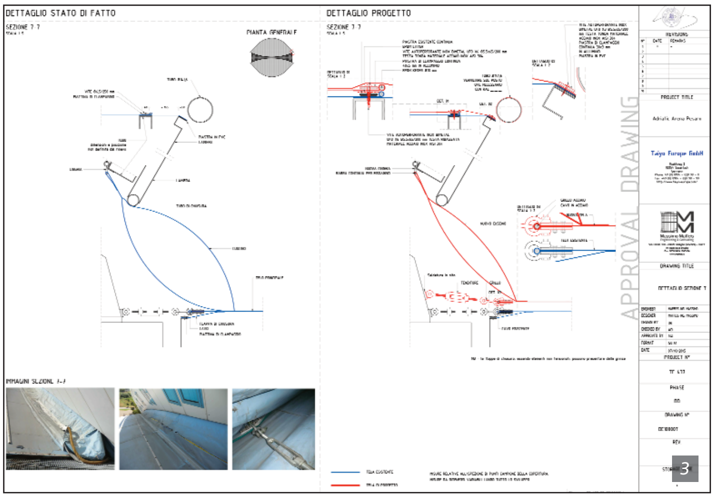
The "Adriatic Arena" in Pesaro, is one of the biggest sport structures in Italy with a capacity of 11.000 spectators. Due to its peculiar shape this arena is also known as "L'Astronave" (Spaceship) or "Coccinella" which means ladybug. The arena was built in 1996 and inaugurated by no other than Luciano Pavarotti! "L'Astronave" is used for many purposes: From basketball matches, concerts and exhibits, to hosting one of the most important festivals in Italy, the "Rossini Opera Festival".

Replacement of the old membrane roof

Taiyo Europe was called by the consortium SINEP Scarl to replace the old membrane roof and to solve water infiltrations that have been causing many problems for the last years.

In collaboration with Maffeis Engineering S.p.A. (Senior Membrane Engineer Antonio Diaferia) the typical fabric stress of the fabric roof under external load action (wind and snow) has been verified; then secondly the structure has been analysed with a nonlinear global analysis taking into account the second order effects. The analysis is performed with the finite elements software G+D Computing ® STRAND7. At least the fabric stress was defined (pretention has been set to 3.5 kN/m for the both main directions warp/fill, snow and wind load). The entire roof was replaced with a new PVC membrane from the company Sioen Industries NV. A series of new connection details has been developed to avoid new damage. For instance in order to avoid water leakage, every new clamping plate had now closure flaps, which meant that 9.000m of welding had to be made on site. The job took almost 4 months. Taiyo Europe and Sioen Industries are proud to have achieved a very successful result. A success confirmed by the "International Tennis Federation" when they chose the Adriatic Arena for their Davis Cup.

Figure 1: New roof © Taiyo.
Figure 2: Details of the damaged roof © Maffeis Engineering.
Figure 3: Example of a connection details (left existing – right new)© Maffeis Engineering.



Matthias Kleibel
Matthias.Kleibel@sioen.com
www.sioen.com

Name of the project:	New PVC Roof for the arena "L'Astronave"
Location address:	Pasero, Italy
Function of building:	sport, music
Year of construction:	2016
Architects:	Interstudio Srl
Consulting engineer for the membrane:	Maffeis Engineering Spa
Supplier of the membrane material:	Sioen Industries
Manufacture and installation:	Taiyo Europe
Material:	Fluomax T3 (T3108) Sioen (HIGH TENACITY PRE TREATED LOW WICK POLYESTER)
Covered surface (roofed area):	12.000m²

ARTICLE

2016 IFAI AWARD OF
EXCELLENCE
INTERNATIONAL ACHIEVEMENT AWARDS

FabriTec Structures
Urban Center
Guadalajara, Mexico

FabriTec Structures has been honored with a 2016 International Achievement Award (IAA) for design excellence in specialty fabrics applications. They received an Award of Excellence for its Urban Center Guadalajara project. The project was recognized in the competition's Fabric Structures, Tensile Structures, 600-2300m² category.

Project

Located in the south of the city, which has recently become an important residential and commercial center, Urban Center Guadalajara was conceived to become a landmark of the area. The remarkable lightweight structure is located in the main atrium of the shopping center. The nearly 2300m² membrane roof is both elegant and functional, reflecting the shopping center's unique style and sophistication.

FabriTec Structures, along with their Mexican partner, EHMS, designed, engineered, supplied, fabricated and installed the extraordinary roof structure that rises 15m above the ground level. The suspended roof is supported by six 22m high masts. From the top of the masts, a series of steel cables, totaling 418m in length, provide stability to the fabric roof and connects it with the building. The use of cables allowed the engineers to reduce the size of the steel members that support the structure; the result is a structure that spans 46m and is supported by nothing more than thin rolled steel beams.

The structure is maximized on the spans and actually working in tension and suspension. Access to the structure was very limited which made it quite a challenge.

The roof's Teflon coated fabric (PTFE) was chosen for its lightweight and translucent properties which will let natural light while reducing the heat island effect and blocking out heat. In addition, the durable architectural fabric will protect the main atrium from rain, as Guadalajara has a three-month long rain season in the summer.

Fabritec's Latin American Team and EHMS have been working together for almost 13 years and have completed many successful projects together.

International Achievement Award Competition

For more than six decades, IAA has recognized excellence in design and innovation, highlighting truly spectacular work in the specialty fabrics and technical textiles industry. The International Achievement Awards competition is sponsored by IFAI, a not-for-profit trade association whose over 1,600 member companies represent the growing international specialty fabrics and technical textiles marketplace. IFAI received a total of 296 entries from 10 countries that were submitted for 42 categories in this year's competition. Winners were selected based on complexity, design, workmanship, uniqueness and function. Judges included industry experts, editors, architects, educators and design professionals who were chosen for their knowledge in a particular field of study or product area.

Kathy M. Dumalski
kdumalski@fabritecllc.com
www.fabritecstructures.com