TensiNews

Newsletter of the European based Network for the Design and Realisation of Tensile Structures

www.tensinet.com

Newsletter Nr. 14 - July 2008 - published twice a year

Editorial

In the beginning of this year, TensiNet launched its new website www.tensinet.com. After some minor problems the website is now fully operational (85 visits/day), offering an easy access to the projects in the database, to the events calendar and to the library with the e-version of the TensiNews (up to September 2005) and the reports of the Textile Roofs workshops.

During the past months, TensiNet participated in several events. At the SAIE SPRING Fair (12th – 15th March, Bologna) TensiNet had a booth at the CORE EXHIBIT 'Building envelope innovation' showing new technological solutions in the area of membrane construction. Prof. John Chilton, Prof. Marijke Mollaert and Arch. Alessandra Zanelli gave a presentation during the seminar "Designing membranes in Europe and in Italy".
At the same event, TensiNet had its first Partner Meeting for 2008, at which the following main decisions have been taken:

- *Standardisation has to be seen as a technical mission. It is suggested to prepare a general draft from which the specific national codes will be derived. Peter Gosling will start the conversation on the CEN through the working group Analysis & Materials together with the working group Specifications coordinated by Klaus Gipperich, and make it a multi-WG-activity*
- *The status of 'founding partners' will no longer exist after 2008. Partners with a commercial interest should pay the full membership fee*
- *Although it is a substantial financial effort, the association will continue to distribute printed issues of the newsletter TensiNews*
- *TensiNet will continue to support the Techtextil Student Competition*
- *The next partner meeting will be coupled with the Annual General Meeting, planned the 10th of November in Stuttgart, which will contain presentations in the morning session, the Annual General Meeting after lunch, followed by the Partner Meeting during which the new board will be voted*
- *A new assistant Evi Corne will be employed part time from the beginning of August to follow up the day-to-day activities of the TensiNet association*
- *Bruce Wright of the magazine Fabric Architecture has shown interest in collaborating with TensiNet. Common publications are a possibility*
- *For the location of the upcoming TensiNet symposium in 2010 the association looks for a 'member university' in Eastern Europe (Warschaw, Prague, Budapest, Bucharest…)*
- *The association needs to attract new funds*

TensiNet co-sponsored the Textile Roofs event from the 22nd till the 24th of May in Berlin, organised by Prof. Lothar Gründig. Several TensiNet members gave a presentation: Prof. Lothar Gründig, Prof. Marijke Mollaert & Dr. Niels De Temmerman, Dr. Robert Wehdorn-Roithmayr, Dr. Dieter Ströbel, Francoise Fournier, Rogier Houtman, Feike Reitsma, Dr. Rainer Blum and Prof. Josep I. Llorens. The 'special guest' lecture 'designing, detailing and building with textiles - examples of projects with different fabrics' was given by Roberto Canobbio and Stefania Lombardi. The text of this lecture will be included in the next TensiNews.

Website & Database Working Group TensiNet
Analysis & Materials Working Group TensiNet
ETFE Working Group TensiNet
Specifications Working Group TensiNet

Several Working Groups have been established:
the Website and Database Working Group (marijke.mollaert@vub.ac.be),
the Analysis and Materials Working Group (p.d.gosling@ncl.ac.uk),
the ETFE Working Group with Rogier Houtman (rogier@tentech.nl)
and the Specifications Working Group (Klaus.Gipperich@ceno-tec.de).
Subscription to one of these groups is open to all TensiNet members who are willing to contribute. The work on the second version of the Design Guide will be discussed as the Working Groups progress

The next TensiNews will appear in the fall of 2008. If you would like to contribute an article, a project description, a research report, an event or another announcement, do not hesitate to contact marijke.mollaert@vub.ac.be or evi.corne@vub.ac.be.

Marijke Mollaert
Niels De Temmerman

TensiNet partners 2008

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www.architen.com

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

Ceno Tec
www.ceno-tec.de

Dyneon
www.dyneon.com

Ferrari sa
www.ferrari-textiles.com

Form TL
www.Form-tl.de

W.L. Gore & Associates
www.gore.com/tenara

IMS
www.ims-institute.org
www.membranestructures.de

Messe Frankfurt
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www.techtextil.de

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www.taiyo-europe.com

technet GmbH
www.technet-gmbh.com

Verseidag
www.vsindutex.de

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founding partners

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Technical University of Berlin
www.survey.tu-berlin.de

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Nottingham Trent University
www.ntu.ac.uk/research/school_research/sbe/index.html

Universidad Poletécnica de Madrid
www.aq.upm.es

University of Newcastle
www.ceg.ncl.ac.uk

Next TensiNet Meetings

Dear Tensinet members,

We would like to kindly invite you to the next Tensinet Meetings Monday the 10th November 2008 in Stuttgart. The program will be organised as follows: starting at 9:30 in the morning we will have four presentations (free for all TensiNet members) on the topics analysis, material development and environment, material modelling and project studies:

- *Prof. Dr.-Ing. K.-U. Bletzinger will talk about new developments for the analysis of membrane structures. Stress singularities which are arising from the theoretically based cutting patterns will be analysed.*
- *Labor Blum will present new materials and their importance for the environmental performance by simulation and measurement.*
- *Dr.-Ing. D. Ballhause will show extracted results of his thesis. The failure of uniaxially and biaxially stressed materials will be analysed on the basis of the Weibull assumptions of probability for the fracture of multi-filament yarns.*
- *Schlaich-Bergermann and Partner will present actual projects.*

After the lunch break the Annual General Meeting will take place.

Afterwards the Tensinet partners are invited for the Partner Meeting with which we would like to close the day.

During the breaks you can visit the experimental set-ups of Labor Blum.

For those TensiNet Members arriving on Sunday a visit of some new buildings can be arranged, like e.g. the new Mercedes-Museum, the new modern arts gallery and the new exposition halls. We would be glad to offer guidance.

Heidrun Bögner,
Chairperson of the TensiNet Association

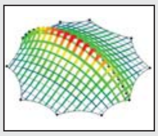
Forthcoming Events

IFAI Expo '08
Trade show and Symposiums
Charlotte, NC USA
21 > 23/10/2008
www.ifaiexpo.com

IASS 2008 & 3rd Latin American Symposium on Tensil-Structures
International Symposium - Acapulco, Mexico
27 > 31/10/2008
http://iass2008.unam.mx

Roof & Cladding India 2009
International Symposium
Chennai, India
23 > 25/04/2009
www.roofindia.com

Textile Roofs 2009
Workshop
Berlin, Germany
11 > 13/06/2009
www.textile-roofs.com



Techtextil 2009
International Trade Fair & Symposium
Frankfurt, Germany *16 > 18/06/2009*
techtextil.messefrankfurt.com

Structural Membranes 2009
International Conference Stuttgart, Germany
05 > 07/10/2009
congress.cimne.upc.es/membranes09

TensiNet Partner Meeting & Annual General Meeting
Stuttgart, Germany , *10/11/2008*
www.tensinet.com/agenda.php

TensiNews INFO

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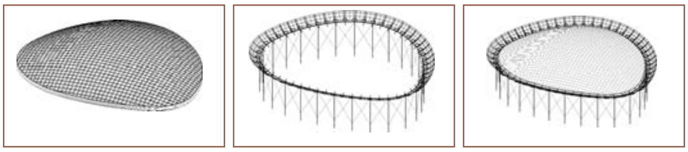
OPTIMISED FLEXIBLE DESIGN OF TENSILE STRUCTURES

Membranes have several advantages such as less weight, foldability, deployability and translucency but need to be tensioned to carry loads safely. The tension forces defining the shape of equilibrium need to be anchored which results very often in heavy steel structures or large foundation. Using cables for the boundaries allows a pleasant and light appearance but requires also a curvature.
The effort needed to connect wall elements along the curved boundaries is high and most results are not satisfying from an architectural point of view. The task which has to be solved is how to design boundaries which are carrying the tension forces either straight to fit with the walls - allowing the addition of a structural system - or curved with a minimum of mass.
The work which was carried consists of the description of the state of the art and the development of two structural systems which are demonstrating the innovative approach in the design of membrane structures.

State of the art

Typical in the design of membrane structures is the separation in the membrane itself and the supporting structures which leads to heavy beams, arches and columns. This is mostly based on the contractors involved in the projects, which are steel companies with no experience in membrane structures and membrane companies with less experience in conventional structures. In the literature this topic can not be found either from the theoretical point of view or from reports of built structures.
We know from several projects that depending on the design of the structure the interaction between membrane and primary structure helps to reduce the weight and size of the primary structure. One project has been the Galets, Expo Switzerland 2002. The maximum span had been approximately 100m. The interaction between the cushion and the steel structure reduces the weight of the steel structures of approximately 30%, fig. 1.



	Inflated cushion-Separated system	Steel structure	Whole system
Max. Bending moment		30 000 kNm	18 000 kNm

Fig. 1: Difference between separate and holistic design [www.technet-gmbh.com]

One of the results of the Contex-T project has to be that the knowledge of this structural interaction and the principle mechanical behaviour behind this interaction can be used as a design tool.

The principle is relatively old stabilizing compression members by tensioned elements but seldom used for load bearing structures in architecture. One typical example is the bicycle wheel with spokes, although by tensioning the spokes the compression in the wheel is increasing but reduces the buckling of the wheel and allows a more slender and lighter wheel, fig. 2.

<
Bending stiffness of the ring
No tension in the spokes

>
Without bending stiffness of the ring
Tensioned spokes

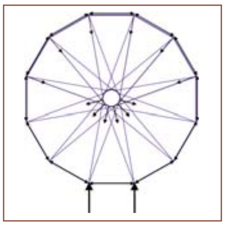


Fig. 2: Load and deformation of a wheel with spokes

New Development

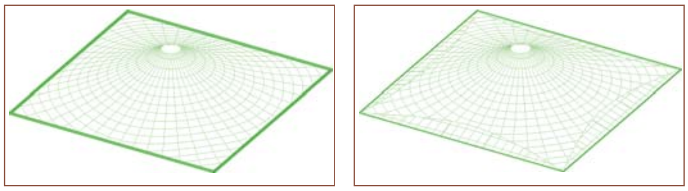
The advantage of straight boundaries is the easy connection to wall structures and the assembling of units to larger structures. The disadvantage of straight boundaries is that the beams have not only to carry the vertical load such as dead load, wind and snow but also the horizontal forces of the membranes which are depending on the reacting angle and are up to fife times higher than the vertical loads. The heavy beams are not satisfying when taking ecological and architectonic aspects into account.

The research which was carried out looked for solutions of straight boundaries which have less weight and a more exciting shape. The first solution is keeping the beams as box girder but changing the shape of the cross section depending on the reaction forces, for example triangular or trapezoid cross sections. This reduces the dimension in elevation but might cause more complex connections to columns and other beams.

Proposal I: straight boundaries

The first proposal we analysed was to dissolve the massive beams in suspended girders integrated into the membrane. This design was tested first in its behaviour for a typical high point membrane. The advantage of a high point membrane is if water sags or snow sags are avoided, no vertical loads are acting on the boundary beams and the dead weight of the beams is hanging in the membrane. In the first step a comparison between a hollow box girder and an integrated suspension beam was investigated.

The covered square has a span of 12m x 12m, the height of the centre is 2.5m. The tension stress in the radial direction is given by 2.0kN/m and in the tangential direction by 1.0kN/m.
The weight of the membrane is 0.015 kN/m² and the system is loaded with a uniformly distributed snow load of 0.75 kN/m². The weight of the beams is estimated to be 0.4kN/m and the dissolving of the beam reduces the bending moment.



	pretension	snow		pretension	snow
N [kN]	-12.89	-29.00	N [kN]	-21.66	-43.90
Mv [kNm]	10.46	3.65	Mv [kNm]	0.03	6.57
Mw [kNm]	11.69	67.35	Mw [kNm]	0.16	14.67

Fig 3: Comparison of the compression force and bending moments in the boundary beam

Further studies have to be carried out defining the relation of geometry and elastic stiffness of the cable, bending stiffness of beam, curvature and tension stress of the membrane. The elastic stiffness, tension stress and the orientation of the yarns of the membrane covering the area between boundary beam and cable also influences the load bearing behaviour and this needs a more detailed examination.

Further research has to be carried out, if the membrane serves as flexible support for the beams and reduces the buckling length which again allows a decrease of the cross-section and weight. Buckling upwards in vertical direction against the dead load and external snow load needs more energy and seems to be not realistic but has to be improved. Buckling downwards in vertical direction seems to be possible but is reduced by the stiffness and tension stress of the membrane if no sag occurs. Buckling outwards in horizontal direction is prevented by the tension stress of membrane. Buckling inwards is only prevented if some struts are connecting the boundary beam with inner cable.

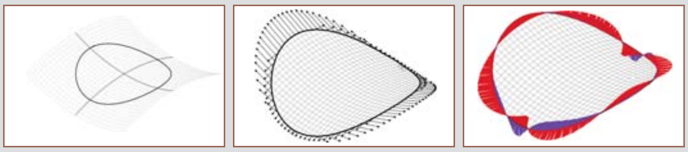
If the results of the theoretical examinations are feasible to reduce weight, size and dimension of the boundary beam the next steps will be to improve the construction method and detailing of the structure. Tasks which have to be solved are the process assembling of the structure and the process of tensioning which influences geometry and stress distribution in the membrane and rigid elements.

Proposal II: curved boundaries

Reducing weight and size of the boundary elements is possible if the boundaries are curved and designed as arches. The shape of double curved pretension membranes is defined by the tension stresses in amount and orientation on the curved surface. The result is the so called shape of equilibrium. The same principle is known for plane arches. The geometry is defined by the external load avoiding mass active bending in the arches, i.e. the geometry of the arch is a parabola if the load is a constant and uniformly distributed load over the span.

> p.4

The new approach will be looking for the interaction between the shape of equilibrium of the membrane and the supporting arches. Starting with the infinite shape of equilibrium of a tensioned membrane and cutting out a round piece, the reaction forces along the boundary are known. These reaction forces are acting on the supporting arch and introducing bending. The forces are not equal to the shape of equilibrium of the arch, see. Fig. 4



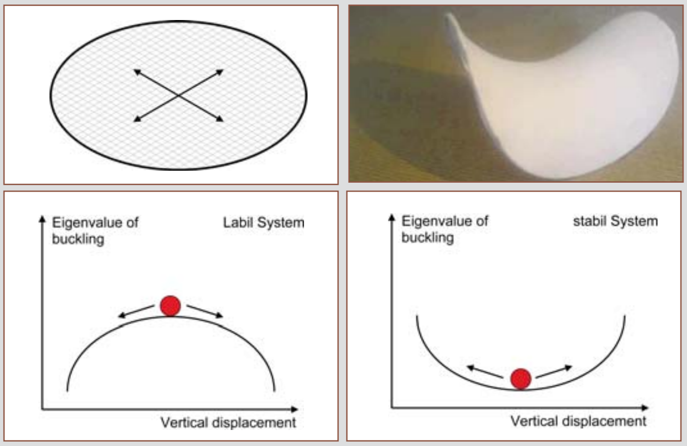
Infinite shape of equilibrium *Reaction stresses of the cut out* *Bending moment in the supporting arch*

Fig. 4: Interaction between boundary arch and membrane

The arch has to be flexible enough to move into a stable geometry but stiff enough to carry loads. Task derived from this constrains is how to define the shape of equilibrium for the arch and the membrane by optimizing the flexibility of the arch. For the first step we started with a well known phenomenon, the buckling of a spokes wheel. Already mentioned is the in plane stiffening of a spokes wheel by tensioning the spokes. The wheel starts buckling perpendicular to its plane if the bending stiffness is not large enough. Interesting is that in some cases it does not fail and moves into a stable situation. This phenomenon we took over to a membranes surround by a ring.

The second proposals is spanning a membrane between a flat ring, the ring requires a bending stiffness perpendicular to the surface. Reducing its stiffness the ring starts to buckle but moves towards a shape of equilibrium in a stable configuration, comparable to a fried potato chip see fig. 5. This geometry is defined as a shape of equilibrium between the tension forces in the membrane and compression forces in the ring.

The shape is depending on following parameter such as the compression stiffness, bending stiffness and the torsion stiffness of the ring on the one side and the behaviour of the membrane of the other side. The parameter, which are defined by the membrane are the orientation of the yarns, the elastic stiffness, the shear stiffness and the biaxial tension.



Flat ring, instable perpendicular to the membrane *Stable situation after buckling of the ring*
Fig. 5: Moving of a flat ring in a stable situation by tensioning the membrane

Using computer simulation with large deformation based on the exact geometry in the deformed shape it must be possible to simulate this post buckling situation depending on the above described parameter. The first step will be to look for the influence of the bending stiffness of the compression member and tension stiffness of the membrane depending on the size of the model, moving into the stable situation after buckling. In a second step the load carrying capacity of the model has to be considered. The results will show the applications for outdoor and indoor use of the system. The third step will be to look for an analytical approach improving the numerical results and getting design values. The final part is to build a prototype for demonstration.

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A NEW-CONCEPT

'Eye' and socket-type terminations are well known practices for anchoring high tenacity cables, each with its own advantages and disadvantages. Apart from cost-related issues pertinent to the aforementioned cable termination systems, the major drawback in all existing termination practices is the reduced strength, particularly in fatigue, experienced at these points.

No matter how strong the cable itself is, the load transfer from the tensioned cable to the anchor takes place within the limited cable termination length, in which high pressures combined with shear loading maxima mainly from friction, result in undesired stress concentration, hindering of the free sliding of the cable within the anchor and finally catastrophic failure. It is not uncommon that these failures are located at the entrance of the cable in the termination due to the high stress gradients existing there.

Furthermore, due to the non-uniformity of the shear stresses developed on the cable, the yarns are not equally stressed thus promoting failure in the most highly stressed yarns and overstressing the remaining ones which fail in turn in an avalanche-like effect.

One of the solutions for increasing the strength of socket-type cable terminations is described in the U.S. Patent No. 5713169 (1998) by EMPA, according to which a graded anchor composition of variable volume compliance along the length would counterbalance the negative effect introduced by the anchor geometry.
This graded composition is achieved by the use of filling particles with different dimensions and shapes including soft and hard plastic particles and elastomers up to steel particles to obtain a variation in the Young's modulus of the material up to 1:100 from the beginning to the end of the anchor.

However, practical limitations to achieve a continuously graded E-modulus distribution throughout the anchoring length generate discontinuities between the successive zones of graded composition which in turn give rise to local stress concentration and therefore non-constant shear stresses on the cable.

Design and mathematical model

A new quasi-conical anchoring system was developed (pending patent no. 20080100381GR) at IMMG, according to which the cable strands are compressed between a solid metallic anchor and a casing with optimized geometry so that uniform shearing along the entire length of the anchor is achieved. The polymeric fibers are not free inside the cable termination but they are encased in a matrix made from melting and epitaxial re-crystallization of a small portion of their own material under controlled heating and pressure. In this way no heterogeneous matrix material is introduced and full penetration of the matrix between individual fibers is guaranteed. The latter autogenous bonding technique can be substituted in part or in whole from high pressure impregnation on strands with a high-strength, very low viscosity epoxy adhesive creating a uniform matrix around the fibers. In order to model the mechanical behavior of the proposed casing – cable – anchor system let us consider the geometry and loading conditions of Fig. 1.

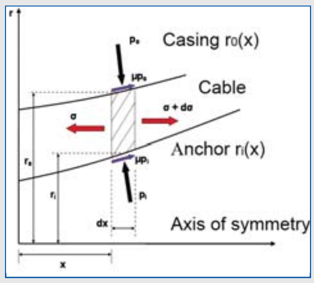

Fig. 1: Geometry and equilibrium conditions on an infinitesimal cable element

The inner surface of the casing and the outer surface of the anchor, which come in contact with the outermost and innermost fibers of the cable are given by equations $r = r_o(x)$ and $r = r_i(x)$, where $x = 0 \ldots L$, respectively as a function of the axial position x. These surfaces cannot be both arbitrary, since the equation of continuity demands that all cable cross-sections along the anchoring length are equal. This condition is expressed by the equation:

$$A(x) = \pi\left(r_o^2 - r_i^2\right) = \frac{\pi d^2}{4} = const$$

The above equation is non-linear, meaning that $r_o(x)$ and $r_i(x)$ cannot both be linear functions of x.

HIGH FATIGUE STRENGTH TERMINATION FOR POLYMER FIBER CABLES

The infinitesimal element of Fig. 1 is at equilibrium under the following stresses:
- A set of normal stresses $\sigma(x)$ and $\sigma(x)+ d\sigma(x)$ in the axial direction
- A set of pressures acting normal to the casing $p_o(x)$ and anchor $p_i(x)$
- A set of shear stresses due to friction acting parallel to the casing $\mu\, p_o(x)$ and anchor $\mu\, p_i(x)$

By solving the equilibrium conditions for the infinitesimal element we obtain the relation between the rate of stress reduction along the cable termination $(d\sigma/dx)$ and the pressure at any point $p_o(x)$:

$$\frac{d\sigma}{dx} = \frac{8p_o}{d^2} C_1(x) r_o(x)$$

Where d is the compressed diameter of the cable without the jacket, r_o is the radius of the outer casing and C_1 is a function depending on the geometry.
A schematic representation of the quasi-conical anchor assembly is given in Fig. 2.

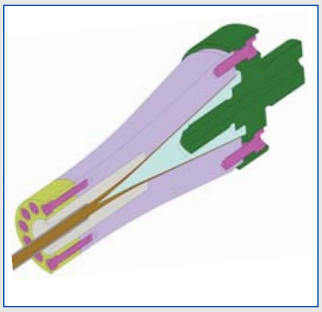

Fig. 2: Schematic representation of the anchor assembly

Both metallic parts are connected through a stainless steel flange at the rear. For reducing stress concentration at the entrance, a separate bushing made of PET ARNITE with special high curvature bellmouth geometry is placed at the entrance of the cable, so that a smooth transition from 0 to the half-angle of the casing cone is achieved.

The use of this high-strength, low-friction plastic bushing facilitates some slight movement of the cable as it is deformed without loosing its radial pretension or wear considerably.
The bellmouth radius ends tangentially on a hole to accommodate the cable without the jacket. As can be seen in Fig. 2 the diameter is soon after increased to be able to accommodate the jacket as well and finally at the front it ends with a curvature to reduce the stresses and the effect of accumulated flexural fatigue.
The outer diameter of the bushing evolves into a 2° half-angle conical geometry at its front so that it can be held in place and pre-stressed radially from a metallic end cap.

Bonding of the cable fibers

Despite the geometry however, it is understood that a suitable technique for bonding the fibers together without destroying their fibrous structure is necessary in order to achieve efficient load transfer between yarns and fibers without slippage, since it can be easily calculated that only a small percentage of the cable fibers (almost 2.2%) comes in actual contact with the casing and the anchor.

An autogenous bonding technique has been proposed and applied on liquid crystalline polymer fibers on a laboratory scale by Ward and Hine (Polymer Engineering and Science, 37(11), 1997), where they subjected liquid crystalline co-polyester fibers in controlled compression and heating to achieve selective surface melting of a small fraction of each fiber which enabled the formation of a fiber composite of high integrity, where the matrix phase is formed by epitaxial crystallization of the melted fraction on the initial fibers, retaining a high proportion of their initial strength and stiffness.

The procedure was repeated in the laboratory for VECTRAN HT fibers using a controlled heating-pressurizing-cooling program to produce the impressive matrix-fiber structure shown in Fig. 3.

Fig. 3: The VECTRAN HT fiber cable with its termination moulded in a quasi-conical shape using an autogenous bonding technique

An alternative procedure for bonding the fibers together with a matrix and then adhere the matrix-fiber composite on the metallic surfaces is to use a special high-strength, low viscosity epoxy adhesive under simultaneous high pressure and proper sonication to impregnate the fibers and achieve good wetting and uniform dispersion.

Experimental results

Extensive experimentation was performed on samples and anchor half and full-scale prototypes to obtain the required material properties (i.e. fiber strength and coefficient of static friction, change in strength as a function of temperature and pressure used in sintering) and also to validate the uniformity in load transfer (uniform shear stress) offered by the proposed design. Many different disciplines were used to test the validity of the proposed design including mechanical tensile testing, optical and electron microscopy, Fourier Transform Infrared Reflectance (FT-IR) spectroscopy of the individual fibers and of the sintered material etc. In Fig. 4 the obtained FT-IR spectrum is shown, where peaks at the wavelengths characteristic for VECTRAN were detected. The measured polarization of the 1413 cm^{-1} peak was lowered by sintering indicating a drop in the initial crystallinity from the formation of the binding VECTRAN matrix.

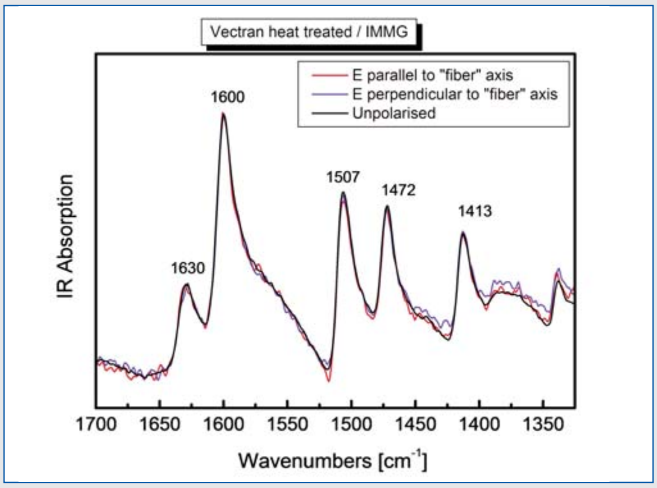

Fig. 4: FT-IR spectrum on sintered fibers

Full-scale mechanical testing was performed on a VECTRAN HT ∅ 12mm parallel strand cable produced by BEXCO. Two cable terminations at its free ends were manufactured and assembled at IMMG and its endurance to static loading (i.e. breaking force) and fatigue loading were tested in the large multiaxial fatigue machine at IMMG. Testing was performed according to the International Standard CI 1500 - 02.

Extensive testing revealed a high breaking strength exceeding 154 kN and also an exceptional resistance to high-cycle fatigue.
In fatigue testing the applied tensile load ranged between 8 and 33 KN in a sinusoidal manner with a frequency of ~1 Hz.
In Fig. 5 representative loading-unloading cycles taken at intervals of 50000 cycles are presented. Displacement is measured right at the entrance of the cable in the anchor to assess the amount of cumulative sliding in the cable termination. Even after 1 million cycles this sliding remains minimal (a few nm per cycle) with a distinctive saturation trend.

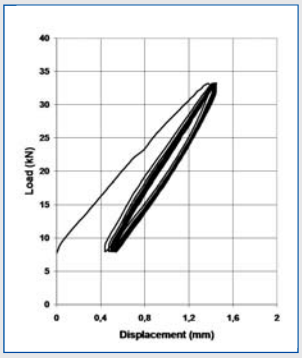

Fig. 5: Fatigue test results on the ∅ 12mm VECTRAN HT parallel strand cable anchored with the new cable termination.

Acknowledgements

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01


02


03


04

HOVERING ARCHIVES

Hovering archives was a temporary art project of 'Kunst in der Hafencity' in the port of Hamburg in summer 2006. The project was developed, designed, organised and built by visual artist Jens J. Meyer (sculpture), visual artist Katrin Bethge (projection) and architect Rolf Kellner, üNN (planning and organisation).

Hovering archives was supported by Hamburgische Kulturstiftung, HafenCity GmbH and Körber-Stiftung. Hovering archives won an Award of excellence in the category of architectural structures in the IFAI Awards 2007 at the IFAI EXPO in Las Vegas, U.S.

The Harbour City of Hamburg is one of the largest construction sites in Europe at the moment. A complete new neighbourhood is conceived right down town in the harbour section with the old storehouses, docks and empty spaces, featuring, aside from living and working, a new cruising terminal, a university and the new Philharmony.

The site of Hovering archives was located between two of the first buildings along the water with the background of an old storehouse.

The vision was to create a lively sculpture, hovering in the gap between these two new buildings.

In this rapidly changing urban area we chose the hourglass as geometrical shape for the sculpture. A symbol for time and time can only be perceived by change. The site determines the dimensions and so the installation reached up to about 26m, measuring in itself 18m and hovering 8m above the ground. The projection featured historical images of people working in the harbour, combined with detail views and overlaid by movement of water and colours.

Planning

Three models were built for planning the sculpture. In order to develop the form, finding the necessary anchoring points and to test variations of composition and cutting patterns different scales were used.

The first model (scale 1:100, 30cm x 20cm x 20cm) was foldable to fit into a normal DIN A 4 envelope for sending it to Hamburg for the jury presentation. Two plates of acrylic glass are separated by removable carbon sticks *(photo 01)*. The plates represent the façades of the two buildings.

The second model (scale 1:5, 3m x 1.6m x 1.6m) was stretched between ceiling and floor of the studio of Jens J. Meyer and Katrin Bethge in Hamburg *(photo 02)*. We used it to test cutting patterns, composition and details of the geometrical volume.

First projections on the 1:5 led to the decision to build a third model, just a part of the sculpture, but in the scale of 1:1 in order to get more information about the projection. We built a three-panel lower part of the sculpture (7m x 10m x 4 m) in the garden of the architect Rolf Kellner *(photos 03 and 04)*. This was necessary for Katrin to start working on the projection, testing angles and positions of the three projectors and choosing images to be used.

Statics

Statics, calculated by Wetzel & von Seht, Hamburg, were simple on one side. We could attach the ropes directly to the external steel structure of the building.

On the other side we had to deal with a brick structure. Each corner of the sculpture had to be safe for a tensile force of 1200daN. We used dowels, already existing in the wall for securing scaffolds, which have a permitted load of 300kg each.
So we divided the main ropes into 4, 5 or 6 thinner ropes and attached them to available dowels.

Additionally the rope company Liros tested the ropes to destruction with the special knots we are using. The 5mm rope had a breaking load of 270daN with knots. (390daN without knots), which represented a sufficient safety for the wall and the bricks.

Fabric

The fabric had to be a very elastic stretch material. For this two month temporary exhibition project we used a normal cotton/lycra knitted fabric, mainly to keep the costs down. The new developed UV-resistant Jelara (knitted Tenara with elastic Polyester) would have been too expensive.

Rope

For the load carrying main ropes we used a 12mm Liros Herkules (Polyester) with a breaking load of 3500daN. All the rest were Liros Flechtschnur (Polypropylene) from 8mm down to 3mm attached to the fabric with a special sailors knot. Polypropylene does not absorb water, which took some possible weight out of the installation. *(photo 05)*

Realization

The set up was scheduled for July 11th – 22nd and then we started.

First the buildings were connected with the 4 main ropes. Then the basic geometrical structure was installed with ropes, like a drawing in space. This is a very important phase, because this basic geometric shape is the overall form of the sculpture and at the same time gives the necessary structure for attaching the fabric in the right spots and tensioning it. This basic geometric form is shaped and adjusted with great care. It has to be exactly in position, creating exactly the geometric shape with the necessary dimensions and proportions. Nothing of this can be changed later, it is crucial to have it done as perfectly as possible before starting with the first fabric *(photo 06)*.

Next the second part starts and the fabric pieces are installed one by one, from top to bottom and from the outside to the inside. First they are set up in a rough position with the possibility to tension them later.

Each new panel is affecting the forces on the ropes, therefore the form of the structure and thereby the forms of already installed panels. *(photos 07 and 08)*
When all panels are installed, the fine tuning moves them to exactly the right position, opening or closing holes, fitting into the composition and form of the sculpture. Hovering archives was built in two sections. First the upper part was completely finished and then the lower part was installed. This was made in order to save some money for the big lift (47m), which was returned after 5 days of installing, leaving us just the small one, reaching up to maximum 25m. *(photos 09 and 10)*


5a

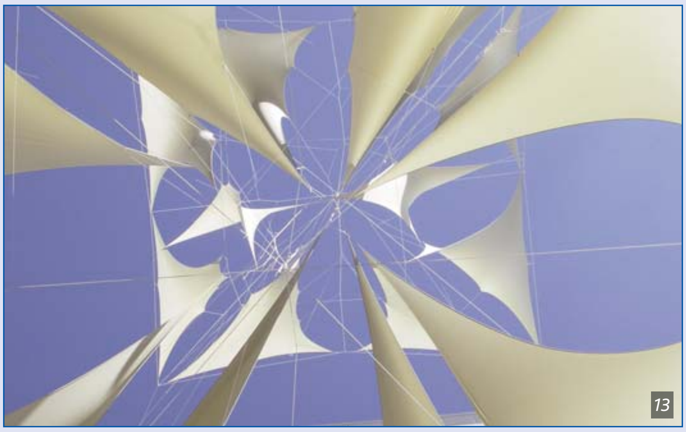

5b


06


07


08


09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Hovering archives - the sculpture

The hourglass creates a poetic form of visualizing time and change in the form of a temporary architectural structure. *(photos 11 and 12)*

Like an hourglass the sculpture of fabric and rope hovers between the houses of both the new and the old urban area. *(photo 13)*
At dusk, by means of projections, the sails become hovering witnesses of the history and continual process of everyday life at the future traditional harbour.


15


16

Hovering archives the projection

As a sign of these constant changes, old photographs are combined with analogous overhead-projections of processes that can be observed day and night at the harbour. Water, sand and mysterious flotsam are stirred by motors and wind, thus drawing constantly new images of structures and currents on the sails and on top of the old images. (photos 15 and 16)
Past and present things are taken apart into a variety of picture elements, the fragmentary character of our perceptions and memories can be experienced in space.

Pieces of fabric cross, segment and play on space. In the manner of a real-time movie, movements are shown as fleeting constellations in space. *(photo 17)*

A continually changing collage of real image fragments in space. Virtual, projected and real space melt into a new spatial experience.


17

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10


11


12

The Contex-T project

Contex-T is a EU-funded integrated project for SMEs that brings together a consortium of 30 partners from 10 countries. Each partner has been selected for its expertise and knowledge in the field. This has resulted in a multi-disciplinary group where high-tech SMEs, research institutes and universities integrate their activities to develop a new generation of multifunctional textile materials which will reshape the complete value chain of textile architecture.
The Contex-T project aims at transforming the traditional resource-driven textile industry into knowledge based sustainable and competitive industry by creating breakthrough innovation in the high-tech area of technical textiles for construction.
Because this area is a driver for innovation it will create significant spill-over to other important textile technological areas such as, but not limited to, protective clothing, automotive textiles, textile for transportation & packaging, fibre reinforced structural elements, upholstery materials, etc.

It addresses the development of new concepts and new knowledge in multi-functional technical textile materials using nanotechnology, nano-structured materials. Following a holistic approach, this project aims at developing a breakthrough in textile architecture, lightweight textile reinforced structures and the tension fabric structures industry.
The approach does not only comprise the development of new materials but also addresses the intelligent use of the materials in the applications.

The technology, which will be developed in this project, will lead to textile buildings of the future, which will combine creativity and aesthetics with multi-functional, resource-conserving materials utilization, short construction periods, long life and low costs and will lead to a new building technology for safe, healthy and comfortable shelters.

The main objectives of this project are the development of lightweight, secure, eco-friendly and economic buildings whose textile structures should last for up to 60 years and meet the highest demands. The building structures should also meet the requirement of being simple and quick to erect and also be capable of being adapted to individual customer wishes.

Contex-T research & development activities include:

- Development of new membranes with optimised acoustic properties, improved thermal insulation and moisture management, control of transparency with different types of radiation, easy cleaning properties, optimized fire safety properties, integrated power harvesting via solar cells and on-site stiffening of membranes
- Developments for supporting structures solving joining problems, reducing degradation due to corrosion by replacing steel cables by textile cables, for lightweight and fire-safe textile reinforced composites and the stability of structural systems
- Architectural and construction aspects of optimised flexible and integrated design and the design of intelligent kinetic structures.

For more detailed information about the European co-operation, please look at
www.contex-t.eu

or contact
Silke.Mueller@MesseFrankfurt.com

This research is being conducted within the framework of Contex-T, an EU-funded project involving more than 30 partners from the European technical textile industry and research institute. More info at www.contex-t.eu

A FOLDABLE SHELTER
A DEMONSTRATOR FOR KINETIC ARCHITECTURE

Contex-T is an EU-funded project which brings together a consortium of more than 30 partners from 10 countries in which each partner brings his knowledge and expertise in the field of textile membrane research, technology and construction to the table. Technical textiles are becoming increasingly widespread in the built environment as they become more widely available, their technical properties are enhanced and their lifespan is increased. Also, over the past few years, the functionality and calculation power of design and analysis software has been greatly increased and computer hardware has known an explosive growth in both technological advancement and availability.
These factors have contributed to the promotion and the realisation of tensile surface structures by supplying research institutes, architects, structural engineers, manufacturers and constructors with the means to design, analyse, realise and test tensile surface structures.

The contribution of the Department of Architectural Engineering of the Vrije Universiteit Brussel to this project consists of three parts:
- Organising training activities on the design and analysis of tensile surface structures
- Disseminating the expertise we have on deployable structures for architectural applications to the other partners
- Designing, analysing and building a small-scale architectural structure which can be transformed by unfolding it from a compact configuration to a fully deployed configuration

The demonstration building discussed in this article is primarily aimed at investigating the feasibility of a concept for a foldable membrane structure for architectural applications. The small-scale adaptable structure is added to a conventional, static construction to supply it with kinetic properties i.e. the ability to change its shape and configuration according to varying boundary conditions and architectural requirements.

General idea and background

M.A. Fox defined kinetic architecture as buildings, or building components, with variable location or mobility and/or variable geometry or movement. In the field of architecture, objects are conventionally static and responsive spatial adaptability is still relatively unexplored. Kinetic systems are currently being developed and integrated in the field of architecture to address society's increasing demand for flexibility and adaptability of the built environment. The goal is to create spaces and objects that can physically re-configure themselves to meet changing needs, thereby accentuating the dynamics of modern architectural space. Over the last few decades many sports and entertainment facilities have been built across the world. In order to be economically profitable, many of these (large-scale) venues require multi-purpose spaces that can be transformed to meet the specific needs of different activities. Retractable roof structures are a popular way of providing such adaptable environments.
New efficient lightweight systems for retractable roof structures are being investigated, to provide a fully fledged roofing solution in different configurations: not only in the final - completely closed - configuration but also in its most compact - completely open - form and in intermediate configurations alike.
In some experimental systems scissor-hinged-structures, structural membranes and actuating devices have been combined to form some sort of architectural organism capable of interacting with its surroundings.
Actuating devices have to be integrated in such a way that they can manipulate the internal cables and thereby control the tension in the membranes, keeping it at an acceptable level in different configurations of the structure.
Membrane roof structures which can be folded or deployed avoiding creasing or folding of the membranes (and thus increasing lifetime) are studied. Theoretical design, simulation of the deployment and small scale structures are being used to prove the concepts.

Existing technology for retractable roofs

Retractable roof constructions can have a stationary supporting structure or an integrated moveable supporting structure. *(Fig. 1)*
Adaptable roofs typically open/close by furling/unfurling the membrane. If not protected, the packed membrane can be harmed by frost and severe wind. Another disadvantage is that the intermediate configurations, between the fully compacted and the fully deployed state, are of no use as a stable structure. *(Fig. 2, 3 & 4)*

Typical foldable structures for small or medium span use scissor-like elements as their primary load bearing structure. This system does not always offer a good solution for the folding of the membrane, as it is bunched into a bundle, rather than neatly folded, when the structure is compacted. Also, during compaction, care must be taken not to let the membrane become caught between the bars or nodes, which could evidently lead to damage.The structural elements, which have to resist to bending, have to be dimensioned accordingly. *(Fig.5)*

In an auditorium in Jaen, Spain, a membrane is supported by a series of curved elements that run over two parallel rails on either side of the space. The arches are connected to each other by means of revolute joints, effectively creating curved scissor-like elements. *(Fig.6)*
Folding the membrane together with the supporting structure can offer a 'cleaner' solution. *(Fig.7 & 8)*

A wave-form, with a ridge and valley line, lends itself well to a folding action. The foldability can be improved by using
belts instead of cables for the boundaries. *(Fig.9)*

SL-Rasch developed a mobile spectator stand that uses a series of parallel scissor structures to which a membrane is connected.
In the final configuration, the membrane is tensioned by the scissor elements. The entire structure is a mobile structure, but the roof system itself shares some characteristics with a typical retractable roof. *(Fig.10)*

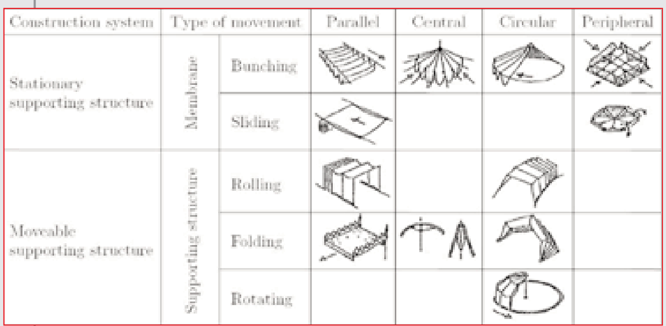


Fig. 1. Retractable membrane structures can be characterized by the ways and the means of their kinetic operability. Chart developed at ILEK

Fig. 2. All Weather Swimming Pool Düsseldorf-Flingern [CENO TEC]

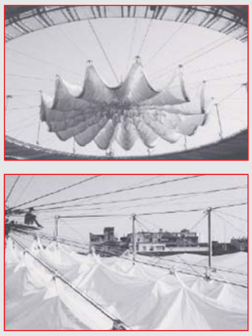
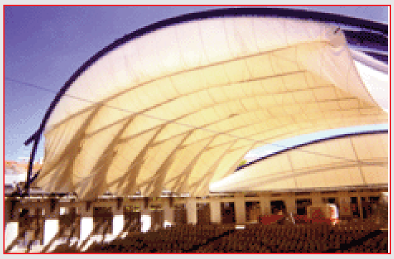


Fig. 3. Bullring at Zaragoza [Schlaich Bergermann und Partner]

Fig. 4. Convertible roof in Hamburg Rothenbaum [Werner Sobek Ingenieure]


Fig. 5. Cover of a swimming pool in Seville [F. Escrig]



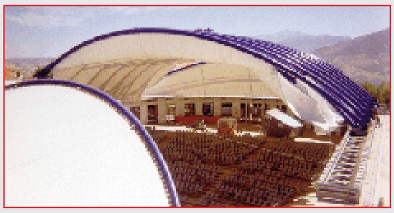


Fig. 6. Roof over an auditorium in Jaen, supported by arches which are hinged like a scissor structure [F. Escrig]

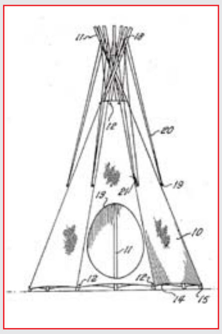
Fig. 7. Foldable Tepee [Patent 379.839 Tepee, 1953]


Fig. 8. Extendible Caravan with Tent Roofs [Stichting De Fantasie]



Fig. 9. Retractable Membrane Roof in the Courtyard of the City Hall in Vienna [Silja Tillner]


Fig. 10. Mobile spectator stand, using a scissor structure to support a membrane

The objective

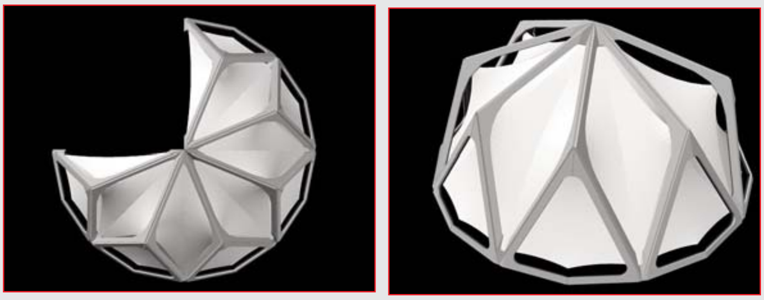


Fig. 12. Frame and membrane

The proposed 'deployable demonstrator' is in compliance with another subtask within the Contex-T consortium: 'Design of intelligent kinetic membrane structures'. The use of intelligent kinetic roofs will allow an appropriate use of coverings for open-air events, sports facilities, cultural activities etc.

A small adaptable roof (to protect outdoor activities from bad weather conditions) will be built as a 'deployable demonstrator', primarily aimed at investigating the feasibility of a concept for a foldable membrane structure for architectural applications.
The small-scale adaptable structure is added to a conventional, static construction to supply it with kinetic properties i.e. the ability to change its shape and configuration according to varying boundary conditions and architectural requirements.

The kinetic structure is dome-shaped and has a height and radius of 4.24m. In plan view, the structure covers a quarter circle (90°) in its most compact configuration, while in its fully deployed configuration it covers three-quarters of a circle (270°).

Inspired by origami, foldable plate structures are transformable structures consisting of triangular plates which are connected at their edges by continuous joints, allowing the plate linkage to be folded into a compact stack of plates. In this case, instead of using bulky plates, a combination of bar elements and foldable joints is used, with the same geometry as the plate structure it is derived from. This leads to a system which is as compactly foldable as foldable plate structures and demonstrates the exact same kinematic behaviour.

Conventional foldable plates, connected by line joints, form a discontinuous surface prone to water infiltration. Therefore, the primary load-bearing bar system is combined with a continuous membrane, which is hung from the nodes, to form a fully-fledged architectural shelter. *(Fig. 11, 12 & 13)*

All elements, as well as the overall system, have to be lightweight and easy to handle to improve the use over existing systems used nowadays for rental tents and temporary shelters.
For the primary structure a skeleton will be considered which folds and unfolds by means of line joints, allowing a single rotational degree of freedom between neighbouring elements. Where the foldable bars meet, this line joint is materialised in the form of a textile junction, still being true to the concept of being 'lightweight' and 'medium tech' and hereby avoiding complex kinematic metal joints.

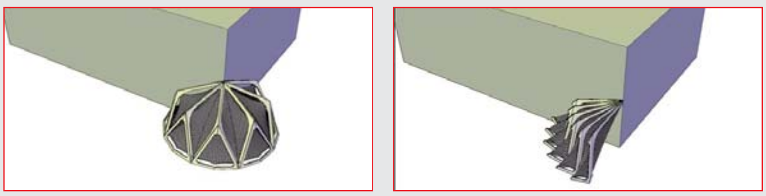


Fig. 13. Tensioned membrane in the deployed and folded configuration

It is the aim to not only assess the feasibility of the foldable system in its extreme positions, but also to investigate the intermediate positions in which the structure should equally be usable as an architectural shelter, withstanding wind and snow loads. This calls for a minimal level of pretension to be maintained in every position, which requires some sort of adaptable solution for connecting the membrane to the primary load bearing structure. At a later stage, the controlled tensioning or relaxation of the membrane could become automated.

Two separate systems will control the configuration of the structure: the first to open the 'mechanism' (manually, by a motor …) and the second to adjust the pretension of the membrane (being a function of the configuration).
It is the aim to maximize the use of textile in the building while avoiding the addition of unnecessary metal components as much as possible (apart from the rail, wheels,…).

It is the aim to look within the consortium for new materials such as composites for the skeletal structure and a very flexible, easily foldable technical textile for the textile junction and membrane canopy.

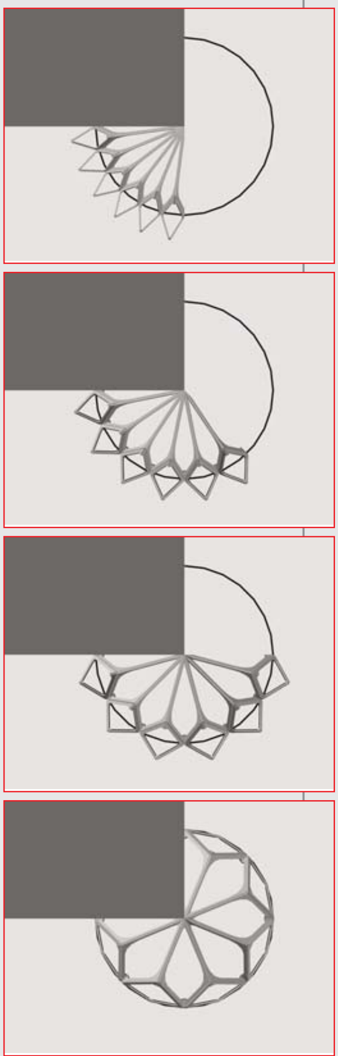


Fig. 11. Folding/unfolding of the supporting frame

Sketch models

Based on a foldable plate configuration, several models have been constructed to test the idea of an equivalent articulated bar structure as an 'adaptable' primary structure. The kinematic behaviour of the system has been demonstrated by means of several small proof-of-concept models. In the next stage bigger scale models will be built to investigate the feasibility of the textile junction and the foldability of the system in general. *(Fig. 14)*

A membrane with an appropriate folding pattern is integrated into the articulated bar structure. This way, the whole system can fold and unfold in a compatible manner. *(Fig. 15)*

Harry Buskes of Carpro let the students of the class Form-Active Constructions (1st Master Engineer-architect at the Vrije Universiteit Brussel) use his manufacturing facilities to build a proof-of-concept model of a single module to test the unfolding and tensioning of the membrane, a hands-on experience which was greatly appreciated by the students. The foldable element has been made at half scale with steel bars and a polyester PVC membrane. *(Fig. 16)*

The membrane element, consisting of two triangular pieces which are welded together, was tensioned in intermediate configurations. *(Fig. 17)*

To be able to combine several elements the foldable nodes or connections have to facilitate the required rotations. Folding lines have to intersect, which means that the folding lines should coincide with the theoretical axes of rotation without eccentricity. It is along these folding lines that the textile junctions are used. *(Fig. 18 & 19)*

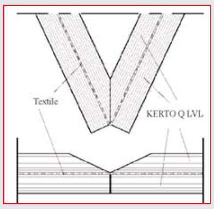
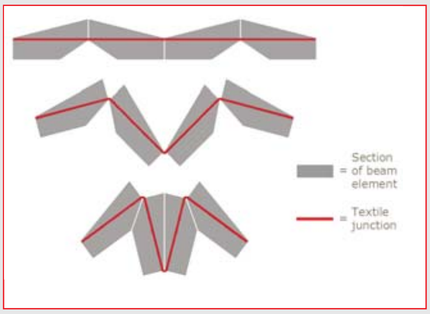


Fig. 18. Textile Junction

a. by Katharina Leitner [IASS2004]

b. for the 'deployable demonstrator'



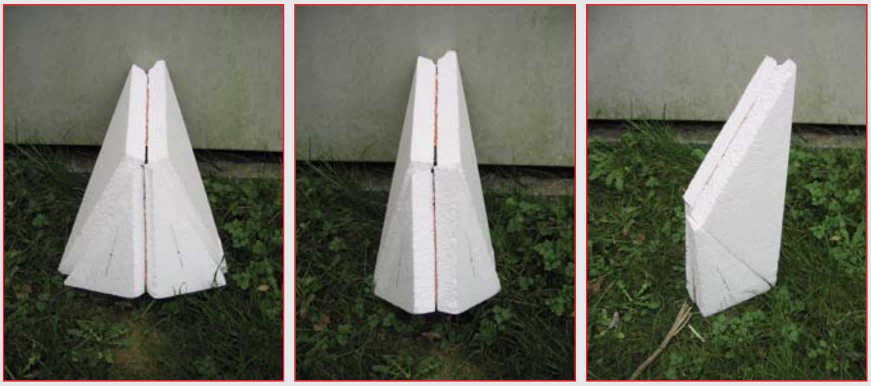


Fig. 14. Foldable plate model in polystyrene

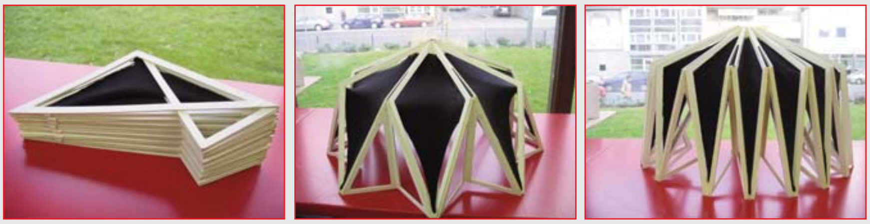


Fig. 15. (Un)folding of a small model

Fig. 16. Physical model [Carpro]

Fig. 17. Folding and unfolding the frame [Carpro]

Fig. 19. Foldable model with textile junctions

Applications

Based on the same primary structure, two typical applications are suggested. An adaptable roof can be made which can open and close frequently and which can stand in an intermediate state (for shading). In that case the membrane needs to be easily foldable, should reflect the solar radiation very well, should have a good light transmission (>6%) and needs to have a 'stable' behaviour during the lifetime of the roof (>20 years) to allow for a frequent adjustment of shape and pretension in different configurations (open <> closed).

On the membrane small circles as markings will be printed, which can visualise the pre-tension state in the different configurations. Another application for the adaptable roof is a covering which opens and closes according to the season (for instance swimming pools). In that case the membrane should be a double or multiple layer skin with flexible translucent thermal insulation, while maintaining a good light transmission (>6%).

The inner skin should act as a vapour barrier and the cutting and 'welding' of the insulation material should result in a shape which is compatible with the main skin.

Numerical modelling

The formfinding of the membrane has been done in the unfolded position (270º) with an average pretension in the membrane of 2kN/m and a maximum value of 7kN/m. The bars have been drawn in the model but are not integrated as structural elements. *(Fig.20)*

This membrane shape is then 'transformed' by placing the frame in position 2 (225º): the nodes of the bar system are moved to their new, partly unfolded position. In the radial direction the membrane tension increases up to 35kN/m. *(Fig.21)*

Next, the membrane shape is again transformed by placing the frame in position 3 (180º). Some links were controlled by setting an appropriate force density. In the radial direction the membrane tension increases up to 40kN/m. *(Fig. 22)*

Finally, the membrane shape is again transformed by placing the frame in position 4 (90º). Some more links were controlled by setting an appropriate force density. In this position, the membrane tension increases up to 50kN/m in the radial direction. *(Fig.23)*

These calculations are a first rough approximation to verify the behaviour of the membrane. The numerical simulation models the material behaviour in a simplified way (one constant value for the E-modulus in warp and one for the weft direction) and does not take the specific characteristics of the connections into account. An integrated model including membrane, reinforcements and beam elements is needed to have a better idea of the forces and deformations occurring in the individual elements.

Final remarks

A prototype will be built to get a better insight in the complex behaviour of the structure (frame and membrane as an integrated system) during the folding and unfolding procedure, including a rail and wheels to guide the movement of the frame. The textile cover will be made of PVC-coated polyester fabric, while the textile junctions will be made from Tenara and Vectran belts. For assembling the frame, the possibility of gluing or clamping with screws will be checked.
The connections between the membrane and the frame will be designed such that they allow the adjustment of the pretension depending on the configuration. It will have to be verified, by comparing different strategies, which elements have to be adjusted to what amount to properly introduce the pretension in the membrane in a specific configuration. Once the structural behaviour of the prototype has been fully assessed, the numerical modelling should be refined based on these experimental results.

Acknowledgement

The current research has been conducted within the framework of Contex-T. The authors thank all partners of the consortium for their valuable cooperation.

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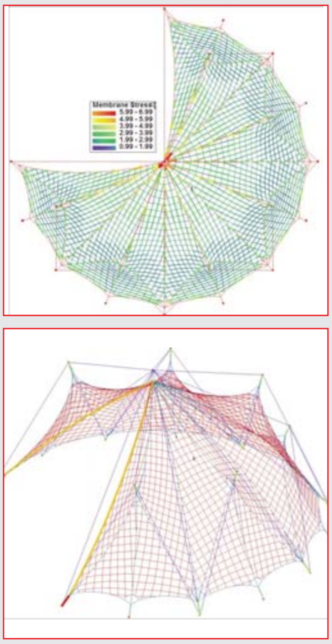

Fig. 20. Membrane in position 1 (270º)

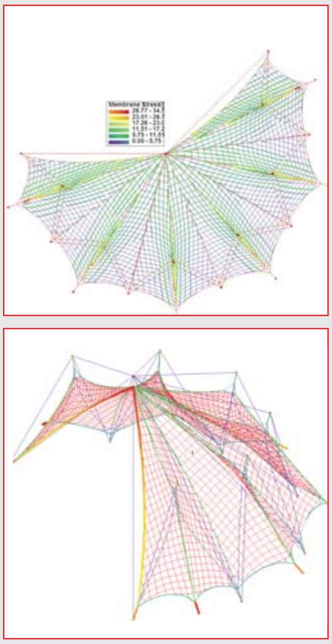

Fig. 21. Membrane in position 2 (225º)

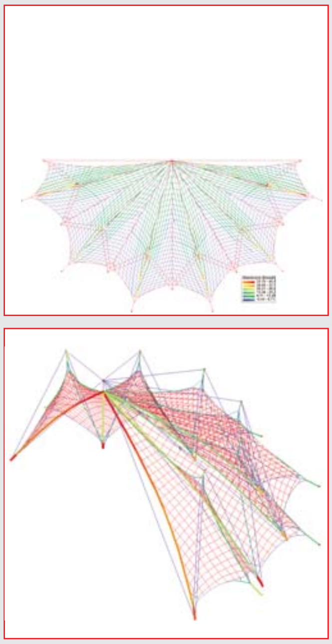

Fig. 22. Membrane in position 3 (180º)

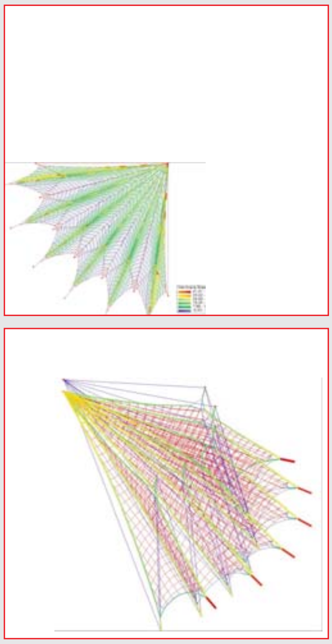

Fig. 23. Membrane in position 4 (90º)

Developing the Scope for the **Analysis and Materials Working Group**

At the meeting in Milan, the concept of beginning a Working Group on Analysis and Materials was well supported. The time has arrived to convert the idea into a functioning facility within TensiNet! The driver behind the Group is the linking together of testing and analysis, such that each are supportive and inform each other, rather than being considered independently as is generally the current practice.

For example, it is well known that current representations of fabric stressstrain behaviour are based on plane-stress assumptions, and tend to simplify the available data (e.g. use of secant elastic moduli). These planar representations can be manipulated to establish locally good correlations with test data. However, the corresponding elastic constants do not comply with plane stress theory assumed in the associated computational mechanics for analysis. Coated woven fabrics are not homogeneous materials: they are composites with the interaction of orthogonal yarns making them act as a constrained mechanism with relatively high levels of variability. In developing the scope of the working group, a number of questions can be considered, a small selection of which are listed as follows:

1. Is it necessary to complement the existing plane stress theory and develop alternative approaches to the description of architectural fabric behaviour?
2. Should alternative constitutive models / stress-strain formulations be explored?
3. What test information is required and how should it be collected?
4. What considerations should be given to large and small projects?
5. Are current analysis tools adequate?
6. The computational mechanics community is moving towards stochastic- based analyses. Is this something that should be explored to circumvent the issue of factors-of-safety and enable the specific inclusion of material characteristics, structure life, environmental conditions, etc, to be considered explicitly?
7. How can the Working Group support TensiNet?
8. Are there some EU funding mechanisms that can help the pace of research related to fabric architecture and associated activities?
9. …?

It is hoped that the Milan presentation and the article published in TensiNews nr. 13 will encourage members of TensiNet to join the Working Group on Analysis and Materials and to contribute to its activities. Every TensiNet member is invited to join! In the first instance, please email at p.d.gosling@ncl.ac.uk.

CENO TEC BUILDS 'FLOATING ROOF' FOR THE NEW TSG ARENA

In the face of international competition, CENO TEC has succeeded in winning the order for the textile roof in Sinsheim in Baden-Württemberg, Germany. The CENO engineers had already advised the general planners, agn Niederberghaus & Partner from Ibbenbüren, beforehand on the projected membrane roof. They can now look forward to the order worth a total of around € 5 million.

Building work on the ambitious project has already begun

The ground-breaking ceremony for the completely new TSG 1899 Hoffenheim stadium took place around 9 months ago. It will hold a total of 30,050 spectators, of which 25,150 will be seated. Not only that, the arena will have a business area with 1,200 business seats and 80 box places as well as a fan pub for 450 fans.

The textile roof is the landmark of the new stadium

agn's stadium architecture is orientated to the slightly hilly surrounding landscape. The plinth on which the building is founded is designed as an incision in the landscape. The main body, which is provided with a great deal of glass, allows the stadium to become ever lighter towards the top, until finally the membrane roof on its slim supports appears to float over the landscape as an organic form. White, translucent roof membranes underline the light, airy architecture. For optical and acoustic reasons not only the upper side, but also the lower side of the steel supporting structure is hung with the membranes. The roof resembles an over-dimensional, floating aircraft wing. This solution has already proven its merits in the textile roof of the Olympic Stadium in Berlin.

"PALACIO DE CRISTAL" ROOF, PARQUE DEL RETIRO, MADRID

At the end of 2007 the Museum Reina Sofía in Madrid decided to install a temporary roof for the artist Magdalena Abakanowicz sculpture exhibition planned in one of the most known places in Madrid, the "Palacio de Cristal".

This crystal palace was built inside the Parque del Retiro in 1887 for a Philippine Islands exhibition, inspired by the Crystal Palace built by Paxton in London 36 years before.

The building was made with a cast iron structure in a classic ionic style, and glass panels as the only closing. So the decision of making this roof was aesthetical but also regarding the inner comfort of the exposition space, due to the transmission of excessive sunlight inside of the Palace. The reduction of glare and of the thermal sensation due to radiation, through the installation of this filter, was a goal as important as the final artistic result.

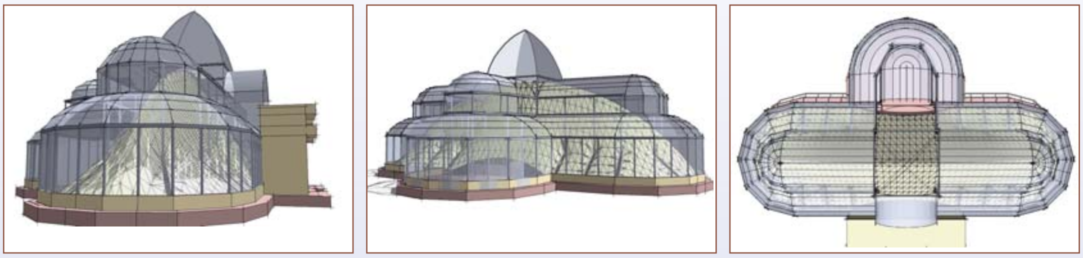

Figure 1. Renderings of the computer model

BAT was contracted in January 2008, after winning a national contest to design, construct and install the roof in coordination with the artist Magdalena Abakanowicz, Miguel Berroa as designer of the installation and Soledad Liaño as coordinator.

The first idea was to make a very light roof, so it would not be necessary to introduce large loads in the structure of the Palace. This was possible due to the temporary and inner nature of the job, without wind or snow loads and only planned for a 5 months lifetime. Also this premise fitted with the "untouchable" character of the building, catalogued and protected and which light structure was not supposed to support additional loads as the tension in common tensile roofs. So it was decided to use a textile material with high elasticity and lightness, in order to use only a really low prestress to obtain the form stabilised.

The design process started with a 3D modelling of the entire Palace, and the formfinding of the roof just to achieve a right geometry for the purpose of the exhibition. Later, a mock-up was made to check the viability of the roof geometry in the Palace. This job helped to determine the real position of the pillars-roof intersection points to be checked on the 3D model.
After several proposals, final geometry was planned as a ship keel, realised by means of an arch of 56m span, which was made in an aluminium extruded profile hanging from the roof structure with elastic cables and ropes and both ends anchored to the slab.
From this arch, the roof descends to both sides surrounding the light cast

Figure 2. Physical model

High-tech materials for functional use

A total area of 19,500 m^2 will be covered by technical textiles. The amount of material used will be around 60,000 m^2. Two different membranes will be used, depending on the function. The upper membrane that faces the outside is intended to protect against the weather whilst at the same time allowing light through onto the stands. 56 roof fields, each with 5 support arches, are hung with architectural membranes made of translucent PVC-coated polyester fabric (type III) having a dirt-repellent fluoropolymer coating. The lower membrane that faces the stands is intended to have an optically calming effect. A fine-meshed PVC-coated polyester screen fabric is used for this. A total of 750 steel frames will be hung with semi-transparent material. The roof edge glazing planned for the inside of the stadium is also part of CENO TEC's scope of delivery. Around 6,000 m^2 of polycarbonate panelling will provide for protection against the weather and translucence around the entire circumference of the playing field.

Ambitious goals have been set

The client, the 1899 Hoffenheim club, is pursuing ambitious goals. Not just as regards reaching the second division of the German football league, which has already been achieved, and the club's further professional league career, but also as regards the time schedule for the project. The intention is for the entire stadium to be completed by the end of 2008. An enormous challenge for the CENO TEC team also, because the entire planning and implementation of the stand roofing must already have been completed by the end of October.

For CENO TEC, the new stadium project means a further reference with a good public relations effect, considering that 1899 Hoffenheim reached the quarter-finals of the German Cup and that the 1899 arena is one of the possible venues for the 2011 FIFA Women's World Cup.

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General planning:	agn Niederberghaus & Partner GmbH
Membrane support structure planning:	form TL Ingenieure für Tragwerk und Leichtbau
Structural steelwork planning:	AHW Ingenieure GmbH
Architects:	agn Niederberghaus & Partner GmbH
Membrane construction manufacturer:	CENO TEC GmbH (D)
Design:	Arched membrane / flat stretched lower membrane frame
Type of membrane:	Coated polyester fabric with PVDF surface refinement

iron pillars between the central nave and the lateral aisles, so the roof adapts itself to the shape of the building which contains it.

The corners are fixed punctually to the slab at the bottom of external pillars, and the borders between corners are finished with pockets and ropes inside, stressed to put the membrane in tension.

The statical analysis needed to take into account the characteristics of the selected fabric: a polyamide/spandex knitted textile of around 90gr/m2, tissued especially for this job, but as a custom product without information about stress-strain behaviour.

Figure 3. The main arch

A first empirical test resulted in a strain >75% for a stress of 0.5KN/m, so the mock-up was also used to test some properties of the material, trying to have "scaled conclusions" from the model, which derived in the decision of not to "pattern" the roof, and only to cut flat panels with straight borders, to cut the borders shape from the 3D model and to apply compensations of 19% in warp and 26% in weft directions.

Despite this, due to the characteristics of the fabric, final "equilibrium state" was succeeded with a lot of different prestress conditions and always without any wrinkles on the surface, so the previewed compensation was only an orientation for the final geometry and some additional jobs needed to be done on site.

The roof was Merrow-Machine sewed with elastic thread in special whip stitches. This was made to allow a similar deformation along the seams than in the fabric itself.

It took almost 30 days to build the mock-up, the rest of the job was planned and designed in 15 days, manufactured including membrane sewing in 6 days, and installed in 8 days, 3 for the arch and 5 for the roof.

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tejera@batspain.com
www.buro-arquitectura-textil.com

Figure 4. The membrane attached to the arch

Client:	MNCARS (Museo Nacional Centro de Arte Reina Sofía) Miguel Berroa, Soledad Liaño
Design and Engineering:	BAT • Buró Arquitectura Textil Javier Tejera Parra, José Javier Bataller Enguix
Material:	polyamide/spandex knitted textile (90gr/m^2)
Manufacture & Installation:	BAT • Buró Arquitectura Textil
Suppliers:	MT-765 S.L., S. Moñita Pulido S.A., T. Rubio S.L.

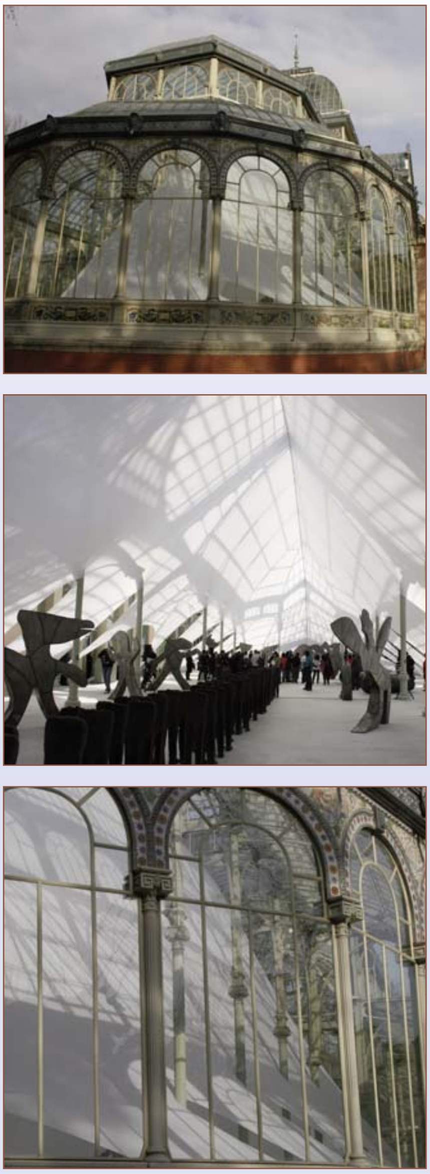


Figure 5. Finalised project

THE ZÉNITH DE STRASBOURG

Close to Strasbourg the 18th Zénith of France is situated. The Zéniths are concert halls for «musique populaire» from rock to pop up to musicals. These have to have multifunctional technical installations, a changeable stage as well as a sophisticated acoustic, space for at least 3000 spectators and need to be evacuated fast in case of emergency. Only if these standards are fulfilled, they are allowed to use the name Zénith. Since in 1981 Jack Lang came up with the idea of the Zénith-halls, the ministry of culture has set the general conditions, gives subventions and requires artistic minimum standards – concerning the architectonical design, too.

The in January inaugurated new Zénith of Strasbourg is with its 10.000 seats at present the biggest Zénith in France. Located on the lowlands at the gates of the community Eckbolsheim, nearby Strasbourg, the intention of Massimiliano and Doriana Fuksas can be seen immediately.
A landmark is created which is full of dynamism because of its elliptic shape and its ability to produce light effects by its translucent orange envelope.

Core of the building

The inner part of the building is not disclosed at first sight. It consists of a 30 cm thick reinforced concrete which is formed by the lines of different curve radii to achieve an optimization of maximum capacity and best view. The reinforced concrete was selected to have the best possible control over the acoustic.

Structure

The oval form was chosen as sculptural element, its monumental volume gets some easiness by the ellipses of the steel structure. 20 steel columns form a sort of access balcony around the massive core and build the primary structure for the façade structure which carries the membrane. 5 horizontal steel rings with a tube diameter of 50 cm enclose the whole building. Like the orbits of the planets they have different distances and inclinations (average distance 6m) this leads to more dynamic which is also suggested by the displacement and rotation of the ellipses.
The rings are anchored to the concrete core and to the ground.
They form connection levels for the façade covering. Between the rings run cables which constrict the membrane. These cables are not connected with the steel structure.
The inside curvature of the walls create an impressive shadow play and contribute to the feeling that the room is continuously in movement.
The entrance is integrated in a 5m high glass wall in the base structure of the Zénith which is covered with orange steel on the outside up to a height of 5m to achieve an impression of continuity with the upper part of the structure.
For the realization of the membrane façade different options were discussed:

- Saddle shaped membrane
- Cushion with negative pressure
- Cushion on a saddle shaped cable net
- Valley-ridge cable structure
- Cushion with positive pressure

The geometry developed by the architect was based on the idea of having the same membrane length at every location between two rings, so the wide areas were flat, and the small areas were curved.
In the wide areas this would give a reasonable shape, but in the narrow areas the difference of the two radii was approximately 90 m to 2 m.
To get equilibrium, we would need the same ratio; this means if for example the pretension in warp is 1 kN/m, the pretension in weft would be 45 kN/m. All generated saddle shapes looked very flat and completely different to the architect's idea.

Together with him, we found a solution with additional valley cables, to get a comparable overall shape, but this solution ended up with a very sharp geometry for an even stress distribution, so we increased the pretension in weft to keep the faces slightly curved. In the final form "form 6" we have a pretension of 1/3 kN/m, and the surface is still smooth.

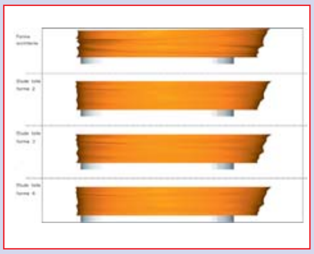
Membrane

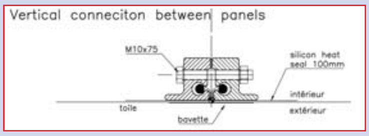
The light membrane is in contrast to the heavy building core and envelopes the building above the entrance area. It was one of the key issues of the project. Colour, translucency and surface quality were the main issues.

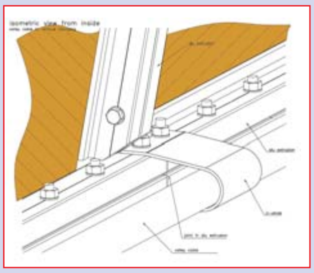
During the design phase most of the available membrane materials have been discussed. The orange colour was contradictory to the high translucency. For PVC and PTFE the translucency was only in the range of 6 to 7%. First it was decided to realise the project with Tenara, which showed in first tests a translucency of almost 20%. But due to time reasons, finally it was decided to switch to Silicone coated glass fibres, with which almost 14% could be achieved. Furthermore the new developed top lacquer reduced the dirt accumulation, so that no extensive cleaning is required. The used silicon coated glass fabric by Interglas Atex 5000 meets all aesthetic and mechanical requirements. It is not only translucent but is stress resistant, fire-resistant, hydrophobic and very formable. The material was delivered on 3 m wide rolls and manufactured and welded in the company Canobbio.

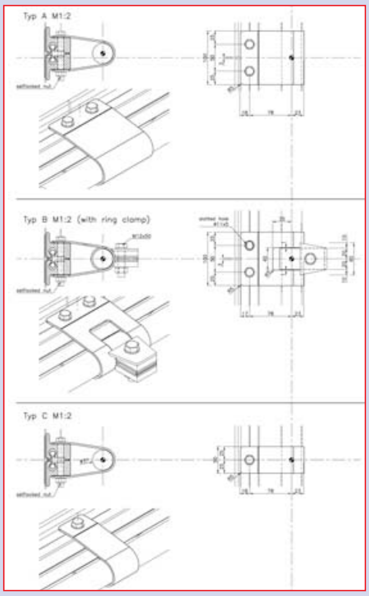
The silicon coated glass fabric which in architectural circles is said to be a contemporary building material, has a guaranteed life span of 10 years and an expected one of at least 20 years.

The shape of the 26.8m high façade changes continuously from the overhanging zones to more or less vertical zones. Between axis 7 and axis 18 the steel rings are connected with the struts, to the concrete structure. In the remaining axes the rings are attached to big inclined steel columns. Due to the irregular membrane shape









Customer:	Pertuy Construction
Architectural Design:	Massimiliano Fuksas Architetto
Membrane Design:	Form TL
Tensile Membrane Contractor:	Canobbio S.P.A . www.canobbio.com
Material:	silicon coated fibreglass (Interglas Atex 5000)
Year of construction:	2007
Membrane surface area:	12000 m^2

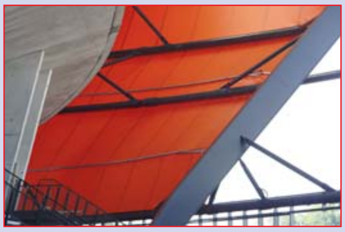
it was impossible to realize an even distributed membrane tension. The impact of self weight is different, and so the difference between nominal and real pretension is different depending on the height of the wall.

All membrane panels are fixed with an extruded aluminum profile developed for the project. This profile allowed minimizing the width of the joints and the closure flap could be kept small and be welded on a flat surface.This detail was initially designed for the Tenara solution, but tests had shown that with small modifications, like increased radius of curvature, it could be used also for the Atex material. This detail was used for all membrane attachments.
Along the valley cable two extruded profiles are fixed with U-straps to the cable. To fix the tangential forces along the cables some of the clamps are equipped with stopper clamps. Along the rings, the extruded profile is fixed to a continuous steel plate, but in principle with the same detail.
The vertical joint is connected to the horizontal joint, to allow the big deflections of the membrane. The seam layout was developed so that all seams lined up. Due to the long perimeter, it was easy to redistribute this, and the waste factor was still reasonable.

The membrane was divided in 10 sectors, and each sector was made of 8 panels. With the chosen prestress ratio, the stiffness increased in weft direction, and so the main tension was in weft. The maximum tension in warp is approx. 18 kN/m and in weft 30 kN/m. Therefore in the zones with the high tension the membrane had to be reinforced.
The corner details had to be reinforced as well. All membrane patterns were generated automatically as complete DXF files with all required detail information, and with control marks, to allow the exact line up in the façade.

Realisation

For the final decision on the material and the details a mock up was carried out. To prevent the membrane from damages along the rings an adhesive strip of neoprene was glued on top and on the bottom.

The steel installation started with the columns and the top ring. All rings were made of prefabricated arches and joined on site. To allow for the tolerances near these joints the steel-flat was made with slotted holes.
Mid of September in the first quarter all rings had been installed, so that the membrane installation could start. The concrete shell was finished within 18 month; the membrane envelope needed 10 weeks from the manufacturing to the assembly. After the manufacturing of the 80 panels of the facade, they have been transported on site and joined together.
During the assembly of the 80 stripes Canobbio used a trick. They developed a sort of „stretcher"on which the membrane was placed and transported into the height of the assembly. So the façade was closed bit by bit.

The extruded profile has been profiled to be parallel after joining the two panels together. During the installation the valley cables could not be completed, therefore the valley line had to be retained with auxiliary cables. So finally in the first half of December all membrane panels had been installed. Before Christmas all adjusting work and detailing work for closure flaps has been finalized.And the first light tests had started to illuminate the façade and the hall. In the wide areas the membrane is attached to the long steel columns, and in the narrow areas directly to the concrete wall

Especially in the evening hours, one can see that the final result is getting very close to the initial design. So the project was finished on time, and beginning of January the first concerts took place.

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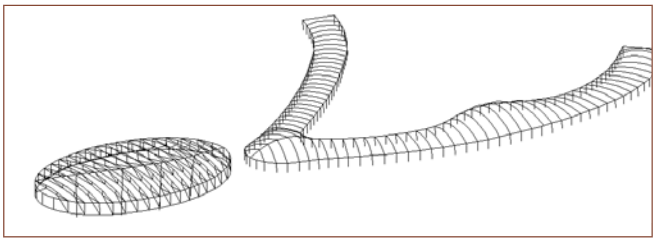


Meandering design of Arcade roofing. 94 different cushions, 112 in total

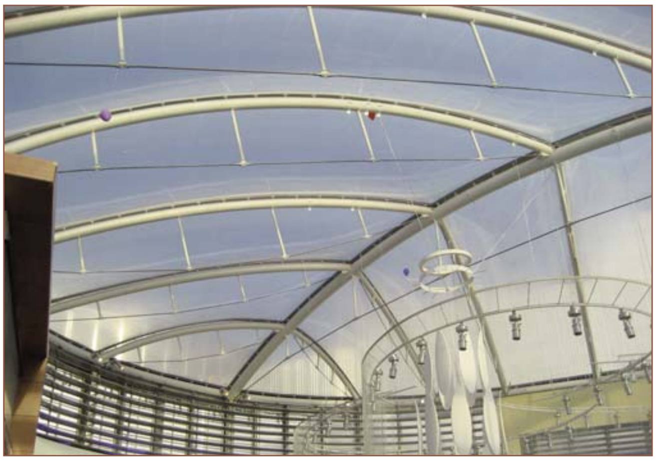
ETFE-CUSHION ROOF
ISLAZUL SHOPPING CENTRE MADRID

View at the malls (IASO, S.A.)

For the client Grupo LAR Agente Urbanizador,S.L the architect L35 Arquitectos designed a shopping mall with an interconnecting roofing over the arcade. The objective of the roofing is to give the visitors the feeling of being in an open air shopping centre in all zones of shops, bars and restaurants. To reach this goal a light and transparent cover is proposed with great translucency without disturbing the view towards the Spanish sky. The cover has a free form design, meandering through the mall. At the same time the applied material should have a high longevity, complete watertight, resistance to severe climatologically circumstances and very good long term preservation.
Therefore an ETFE cushion roof was proposed with two layers of 250µm ETFE-foil. The cushions are modular, following the main tubular steel structure, placed parallel or radial according the plan view surface to be covered.

STEEL STRUCTURE

The "lattice" pretensioned arcades, supported on steel tube pillars, are formed by tubular round steel tubes with a slightly curved shape in the upper part, with in the lower part solid tension rods. In between the tension rods and the upper arch, vertical round steel tubes absorb the compression forces in this structural "lattice" element. The arcades are only connected along the side girder without any connection along the arches. This gives an extreme lightweight sensation. As the cushions in between the suspended arches stabilize the arches horizontally, > p.16



The "lattice" pretensioned arcades

there is no need for interconnecting girders. In case of a cushion failure, the arches will deform strongly, but stay within the elastic range and therefore creating a safe and stable structural system. In the preliminary design the tension rods originally were designed as cables. To obtain more stiffness, it was chosen to use tension rods. This also implicated that there should be a very high accuracy of the steel production and a special pre-bending procedure has been developed to ensure that the steel structure has the required shape and pretension after installation.

DETAILING

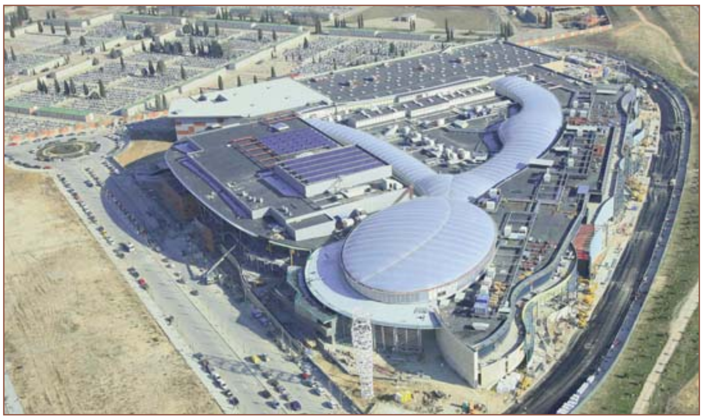
The cushions are fixed on aluminium profiles which are connected through bolt connections to the main steel structure with a condensation gutter in between. Experience of the glass facades was used to develop a special connection technique to ensure water tightness at the connection of the successive profiles. Each cushion consists of two layers of ETFE foil.
The upper layer is being printed on the inside part of the cushion with little silver coloured dots to improve the G-value. As the G-value depends on the location and sun intensity, a mock-up was build with 4 real-size cushions to measure the G-value of 4 different printing patterns. This also gave the client and the architect the possibility to evaluate the transparency of the different resulting cushions. Based on this research and G-values measurements a specific printing pattern is chosen.
To control the inner climate below the roof, there are horizontal lamellas situated with a height of approximately 2 m along the full perimeter of the roof. This creates a large ventilation capacity and therewith preventing the heating up of the air below the roof. To prevent an additional uplift on the roof at high wind speed, the lamellas can be closed. Also when the weather is not so well the lamellas will be closed.

The printing of the foil is only at the upper foil. The lower side is completely transparent. Both layers have a thickness of 250µm.
The cushions have a controlled inside air pressure of 300 Pa, inflated by dry air ventilators. The air reaches the cushions through a galvanised spiral steel pipe distribution system. The roof is divided into sections. Each section has its own blower unit and emergency unit.
Wind speed and snow are measured and with that input the internal pressure is altered consequently.


Inside view by night (IASO, S.A.)


Malls by night (IASO,S.A.)


Interior views, with additional membrane shading (IASO, S.A.)


Bird eye view of the finished roof (grupo LAR)

FORMFINDING AND STATICAL ANALYSIS OF CUSHIONS

For the analysis of the steel structure a governing load is determined which the air cushions apply onto the steel structure. As there is hardly any repetition in the cushion shapes, a procedure had to be determined to obtain a uniform looking cushion roof with no excessive cushion shapes. To determine the range of stresses that should not be exceeded, several long term tests were carried out on ETFE foil at high temperatures.
From this tests a stress level was derived that should not be exceeded during the formfinding procedure.
The resulting cushion shape is submitted to wind load for several critical cushions to determine the governing stresses in the ETFE foil.
It is assumed that under wind load the cushion acts as a closed body and an interaction takes place between the inner pressure of the cushion and the outer load. As the height of the arches is increasing with the span of the arch and sometimes even is enlarged, cushions can have strong curvature. Especially the lower foil has to follow strange curves. At the ends of the cushion it is often anti-clastic curved while in the middle part it is synclastic curved.
This results in patterns that start to be convex, gradually go to be concave and then again go to be convex. Therefore the distortion that is asked from the material must be spread out evenly.

Client:	Grupo LAR Agente Urbanizador,S.L.
Architect:	L35 arquitectos
General engineering and detailing:	I.A.S.O, S.A. (Spain)
Steel structure engineering:	Ramón Sastre (Architect) Eva Porcel (Architect) / IASO, S.A.
ETFE-cushion engineering:	Tentech,bv. (The Netherlands) I.A.S.O, S.A. (Spain)
Project management:	Bovis Lend Lease
Membrane manufacturing:	I.A.S.O, S.A. (Spain)
Installation:	I.A.S.O, S.A. (Spain)
ETFE:	10000m² (plan view 250µmETFE)
Soltis 92 (Ferrari):	1250m²
Batyline HM Tweed (Ferrari):	750m²
Inauguration:	April 2008

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FLYING CHANGE

Innovation Habitat

The project "Flying change" is a contribution of the UdK Berlin, created within the framework of "Innovation Habitat Berlin Charlottenburg".

Habitat seeks to develop the multifarious potential of this Berlin district in the fields of art, culture, science, and business, creating a network between them and integrating them in an international environment.

The event "Seven Days of Innovation" accompanied this initiative with various contributions in the form of exhibitions, workshops, discussions, and presentations. As part of "Innovation-week", we created a temporary exhibition-space, whose design and concept could be relatively freely developed. The limitations specified were the approximate area of the exhibition-space, the time available for execution and a fixed budget of 8000 Euros.

Concept

The idea was to come up with a space which could be understood as a spatial metaphor for innovation. We adopted the image of weightlessness to this end. The condition of floating has always exercised fascination and can be seen as a symbol for innovative ideas.
Thus, we came up with the idea of a flying construction, carried aloft by helium balloons and suggesting impermanent airiness.

The floating balloons create a flowing texture through their undulation that reacts sensitively to changes in the environment; in a manner reminiscent of a dress that first takes on a form and unfolds spatially through its wearer's movements.

We adopted the motive of transience not only formally but also programmatically in conceptualizing the space. Different performers from the fields of fashion, sound-design and the performing arts will stage their activities in the room, lending it their own character, just as a person lends his clothes a particular air. The stage with its flying dome above forms a platform for these activities.

The impermanent nature of the exhibit as embodied by the perceptible ageing the balloons undergo was an important feature for us, a gradual "withering-away" of the sheath that leaves behind the platform as furniture.

Design

On entering the raised platform through one of the two openings, visitors find themselves in a six meter high vaulted space, the raised corners of the platform further intensifying the focus on the centre of the space. These inclined triangular spaces offer seating in the form of round openings covered by broad rubber strips. On sitting down, the body's weight forms a depression, thus allowing a hold on the sloping surface. The centre, free of seating openings, creates a space for all kinds of activities. The light hull, made of balloons attached to a thin nylon net, creates a contrast to the monolithic wooden fundament. The exhibition-space appears to be permeable on account of the gaps between the balloons, their shifting nature intensifying the interaction with the surroundings.

Helium

Helium balloons of a certain size and volume have a static upward thrust, because helium is less dense than air. One of the conditions for the successful realization of our concept was that the upward thrust provided by the helium in the balloons had to be greater than the sum of the weight of the net and that of the individual balloons. A series of tests with elliptical balloons 20cm in diameter showed that an undamaged balloon can support approx. 90-93g.
The chosen nylon net had a weight of 13g/m^2. Since we planned one square metre of net per balloon, this condition could be met.
However, we also had to account for a continual loss of thrust (amounting to roughly 5g per week), since helium constantly escapes through both the balloon-membrane and seams, as well as through the valve.
Outdoor testing delivered additional knowledge about how buoyancy varies in relation to temperature, pressure and humidity. Precipitation leads to a considerable reduction of the balloons' load-bearing capacity, even total attrition, and a consequence of the additional weight of the water that adheres to the balloon-membrane. However, the balloons regain their original load-bearing potential on drying out.

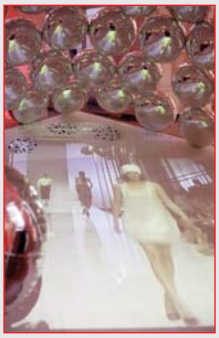
Temperature and pressure changes on the contrary led to changes in the balloon skin's appearance. With a rise in temperature, the gas within expands, so that the balloon's form appears more voluminous. On cooling, the internal pressure falls, so that the aluminium membrane no longer remains taut, developing creases as a result.
Thus, in order to realize our concept successfully outdoors, we would have had to employ a supporting construction to ensure the safety of the pavilion under conditions of precipitation and strong wind. Since our initial vision had been that of creating a flying, self-supporting construction, we chose to realize our concept indoors.

Modelling

The hull's shape is determined by the interaction of the helium balloons' buoyant force, the platform's shape, and the net's dimensions. We simulated this interaction in the conceptual phase with the aid of a catenary model, which we then turned inside out to obtain the desired form. Our goal was to find the right combination of materials for constructing the model that would permit realistic modelling. Through extensive testing, we were able to determine the correct ratio of the net's stiffness to the abstracted weight of the balloons. A flexible net, whose mesh size corresponded to the balloons' diameter in the ratio 1:20, turned out to be appropriate. Small metal weights served as sinkers. We were able to achieve the desired figure through repeatedly adjustment of the tethering cables. Finally, we measured the net's intersections through 3D mapping.
With Prof. Dr.- Ing. Christoph Gengnagel's support (Chair for structural Design), we were able to digitize the data using 3D modelling software. We could interpolate the hull-surface from the resulting scatter-plot and analyze it into a regular triangular net. We then subjected this net to the stress of its own weight using static program in order to eliminate calculation errors, finally drawing the blank on the basis of this data. In order to be able to form the curved cupola out of two-dimensional net sections, the hull-surface had to be divided into 14 segments and flattened. By joining these sections up, we were able to create a final model almost free of folds.

Construction

Owing to their different constructive and material concepts, we could realize the two elements, platform and hull, independent of each other. The platform is composed of a skeleton-construction covered with particle-board. We designed the sections in such a way that it was possible to separate the platform into trapezoidal sections each with one level and one sloping surface, enabling the transformation of the 50m^2 large platform into three separate seating elements after the event.
The platform, however, appears monolithic, since the separate elements interlock precisely and the whole is painted white.
Simultaneous to the construction of the platform, the net sections for the pavilion were cut out and > p.14



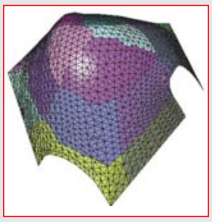
connected to the planned cupola. In order to be able to work effectively with the approximately 130m² of net surface, we had to use helium balloons to temporarily lift the net sections skywards. Once this was done, we could join the hull to the platform, creating a space in which one could move about. We could now "decorate" the net from top to bottom with helium balloons, using small quadratic net sections and curtain hooks to affix each balloon to the inner surface of the load-bearing net. In all, we used 160 balloons filled with a total of 150 litres of liquid helium.

Conclusion

The project was characterized by its experimental character from conception to realization.
By using materials from other contexts in new ways and through extensive modelling, we were able to achieve our vision of a flying construction. We thereby not only remained within budget, but were able to reduce costs to 6000 Euros.
Contrary to our expectation, the pavilion hull proved relatively stable and did not shift around.
The exhibit's appearance hardly "aged" over the display period of two weeks. To be able to experience the construction shrivelling, one would have to either increase the display period, or venture setting it up outdoors.
The visual and programmatic symbiosis between the exhibit and its users created a fascinating space. The silver balloons intensified the experience, since, in reflecting back what was taking place fractally, they gave the impression of being inside a cubistic painting. The cluster of convex reflecting surfaces split the images of the surroundings, people, and objects, offering a palette of different perspectives and creating multiple views with the same motif.
We see this exhibition-space, created as part of Innovation Habitat Berlin Charlottenburg, as a prototype for temporary concepts that is deserving of further development. We see potential for further development both in the size and shape of the pavilion, as well in the manufacturing process.

Katharina Löser
André Sternitzke
sternitzke@udk-berlin.de

Name of the client/building owner:	INNOVATION HABITAT Berlin Charlottenburg
Location address:	Berlin, Germany
Function of building:	Exhibition
Type of application of the membrane:	Covering
Year of construction:	2007
Covered surface (m²):	50
Total length x width x height (m):	8 x 7 x 6
Cable-net:	nylon
Material Fabric/Foil:	foil-balloon
Architects:	Katharina Löser, Mikulasch Adam
Engineers:	Dipl.-Ing. (FH) André Sternitzke, Dipl.-Ing Holger Alpermann, Prof. Dr.-Ing. Christoph Gengnagel




Almetyevsk Maydan, Ensemble of the holiday park


Colourful heavens


Summer light


Day time colour of an interior

Location:	Almetyevsk city, year 2003
Customer:	Municipality of Almetyevsk city
Investor:	Tatneft JSC,
Name of project:	City Festivity Center Maydan
Seasonality:	Whole-year coverage, designed for snow load
Architect-designer:	Anvar Khayrullin, ACL Forms
Head Constructor:	Sladkov V. A., ACL Forms
Production of metal structures:	TemPo, Naberezhnie Chelny
Design of metal structures:	KSACA, Kazan
Awning and installation:	Kamtent, Naberezhnie Chelny
Size of coverage:	4200 m²
Design Factors:	27 bays 14x9-12m h10-12m
Membrane:	Ferrari Precontrant 905 F3M

Awards: Silver diploma of the "Art of Building 2007" Competition, Russia


Kazan 1997 - Decorative construction "Read Bull" - Symbol of the year 1997


Decorative awning Fur-tree-horoscope


Decorative pavilion 'Buhara'

Location:	Kazan city, year 1997
Customer:	Directorate of National Cultural Center "Kazan"
Name of project:	Winter (New Year and Christmas) decoration of the festive territory with awning constructions
Seasonality:	Winter coverage, designed for snow load.
Architect-designer:	Anvar Khayrullin, ACL Forms, Kazan
Head Constructor:	Sladkov V. A.
Production of metal structures:	"Serp & Molot" Factory, Naberezhnie Chelny
Awning and installation:	MOTEKO, Naberezhnie Chelny
Design Factors:	1. 10x7m h7,5m; 2. d12m, h24m; 3. 8x(6x6)m; h8m
Membrane:	Ferrari 505
Awards:	"Design-97", best projects and implementations in nomination "Space Design" (Union of Designers of Russia)

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AWNING CONSTRUCTIONS OPPORTUNITIES AND TASKS

Customer, designer, industry considerations

Science and industry have dramatically improved the quality of awning materials, what influenced mainly their strength characteristics and operating life. It led to expansion of the bays and long life of the buildings and facilities in which new awning materials were used. However, the application field didn't expand greatly. Development of industry and high competition forces us to look for new application fields for awning constructions. On the other hand the modern urban environment contains lots of tasks and problems, we didn't know about before, the tasks and problems which can be solved only by the means of new awning architecture. Peculiarities of work of construction designer and sociologists, to whom it's so hard to communicate directly, do not give us the opportunity to react adequately to the problems of the modern city. Modern urban space is an object of research and permanent working field of an architect – the designer of architectural space. It's the key figure for understanding of the problems of urban space and formulating of clear architectural and space tasks for narrow profiled industry specialists, particularly in the field of awning constructions, for example, constructor, technologist and etc. There is no doubt that without money and the customer's creative participation in the process of realization of ideas, it is impossible to achieve any result. However the municipal customer doesn't always know about the existence of the problems that are not within his direct responsibility – providing the proper functioning of the municipal services, art and decorative provision of significant city events. Solving of urban space social, psychological, aesthetic problems is either postponed or often not done at all. Constructive dialog with the customer on behalf of producer is also an architect-designer prerogative. That's why this specialist should observe the problems of the modern city and poses the wide spectrum of design and architectural means simultaneously, including awning constructions, and should be able to apply them.

City and Emotions

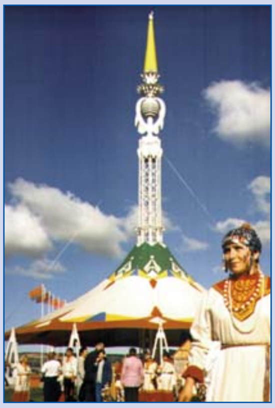
One of the problems that are minor from the point of view of urban systems' operation, but important regarding the psychological comfort, is the problem of "emotionally sterile" urban space of some urban districts of modern cities. Monotonous and gray space influences negatively the every-day psychological state of people, especially the formation of the child's consciousness. It's not a secret, that child's perception of the world is different from the grown-up's. Child's world, bright colourful and emotional, we, grown-ups, force into child's parks and gardens reservations. Now we consider urban space to be hostile and aggressive. More often colours and emotions are in the grasp of flat, pragmatic, loud and aggressive advertisements. The aim of any art is creation of emotions, if we speak about the creation of an urban space as an art. We avoid the big city, hiding ourselves in private spaces of its capsules it doesn't matter whether it is a flat, a car or an office. Trying to create our own individual world, we add something personal into this confined space. But why should we refuse to do it in the urban space? This way we don't let ourselves in the city and the city doesn't penetrate into our spaces, infinitely being hostile and aggressive to us. Let the city be unique and kind, let it belong to us; let's make ourselves comfortable in its stone palms. Let us entrust ourselves, as well as our children to the city. Let your own, bright child's world in the interior of the modern city; make it alive, which is one of the easy to perform tasks for the customer, architect-designer, and modern awning constructions. Only when they feel that the city belongs to them, the citizens will take part in the social life of the city, and that is a synonym to civil liability and pride for their own city.

Laboratories of forms

Experience in working with municipal customers reveals that the problems of the modern formation of urban space are, actually, similar in different cities. That's why we are working in two directions: broadening of the awning construction opportunities in the field of language of forms flexibility development, combining it with other means of urban design, and considering application of them in modern city conditions, for solving up-to-date problems and tasks that are set before the society.
In the hands of an expert, awning construction can become a mean of harmonization of modern urban space, which will become comfortable and humane. We believe that not all awning construction opportunities are used yet and that the tasks that are set before us are various.

Nizhnekamsk: Decorative awning near fair 'Buzovskiy' in morning light

Location:	Nizhnekamsk city, year 1996
Customer:	Municipality of Nizhnekamsk city
Name of project:	City Festivity Center Maydan, a tent for guests
Seasonality:	Whole-year coverage
Architect-designer:	Anvar Khayrullin, Kazan
Constructor:	Sladkov V. A., Kazan
Production of metal structures:	ZMK, Nizhnekamsk
Awning and installation:	MOTEKO, Naberezhnie Chelny
Design Factors:	D12m h16m
Membrane:	Ferrari Precontrant 905 F3M
Awards:	"Design-96", (Union of Designers of Russia) best projects and implementations in nomination "Space Design"



Nizhnekamsk Accent of Maydan

Nizhnekamsk Accent of Maydan awning interior

Location:	Nizhnekamsk city, year 1997
Customer:	Municipality of Nizhnekamsk city
Name of project:	City Festivity Center Maydan, a tent for guests
Seasonality:	Summer coverage
Architect-designer:	Anvar Khayrullin, Kazan
Constructor:	Sladkov V. A., Kazan
Production of metal structures:	ZMK, Nizhnekamsk
Awning and installation:	MOTEKO, Naberezhnie Chelny
Size of coverage:	1500 m²
Design Factors:	D30m h37m
Membrane:	Ferrari Precontrant 905 F3M
Awards:	"Design-97", best projects and implementations in nomination "Space Design" (Union of Designers of Russia)

Berezka Summer Stage

Under the awning

Detail Berezka Decorative Flowers

Berezka Decorative accent Flowers

Location:	Aznakaevo town, year 2005
Customer:	Directorate of Child Center "Berezka", Aznakaevo town
Investor:	"Aznakaevneft" JSC
Name of project:	Decorative composition "Flowers", Aznakaevo
Seasonality:	Whole-year coverage, designed for snow load
Architect-designer:	Anvar Khayrullin, ACL Forms, Kazan
Constructor:	Akhmetsagirov I.K.
Production of metal structures:	Kamtent, Naberezhnie Chelny
Awning and installation:	Kamtent, Naberezhnie Chelny
Design Factors:	3x D4-6,6m; h11-19,5m.
Membrane:	Ferrari Precontrant 505

The re-use of old buildings by renovating their inner courtyards

The covering of inner courtyards is a real appropriate application for textile architecture, especially in Belgian climate. Recently the students of the 3rd year in Engineering Sciences: Architecture of the Vrije Universiteit Brussel made a study trip to some tensioned membrane structures in Belgium.
Two of the visited membrane projects are covering the inner courtyard of an existing building: one membrane, built only a few months ago, has been constructed in a shopping centre in Tongeren and the other, built 5 years ago, consists of foldable umbrellas in Alden Biesen. Although both projects are different, they are able to give the courtyards a new attractive life. The translucent membrane roof creates a pleasant open air feeling and allows for using the space regardless of weather conditions.

Although both projects are different, they both are good illustrations of how straight and curved, stiff and flexible, old and new, outdoor and sheltered, historic and contemporate can be brought together.

Report written by
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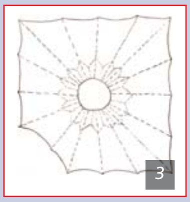
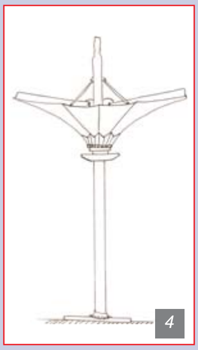
The architects had respect for the historic built environment, took enough distance from these monumental façades and added a (s)lightly poetic touch.

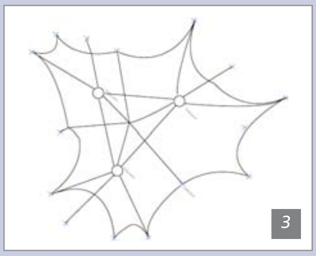
FOLDABLE UMBRELLAS IN ALDEN BIESEN, BUILT IN 2003

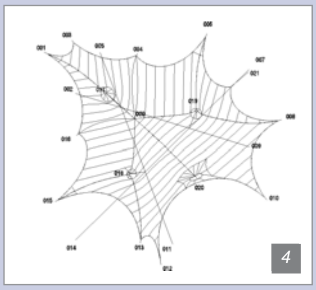
The Grand Commandery Alden Biesen (Bilzen) was the headquarters of a province of the Teutonic Order (established in 1190) in the land of Maas and Rhine. Nowadays Alden Biesen is a cultural centre of the Flemish Community. It is a congress centre as well as a cultural and tourist attraction. *(fig. 01 & 02)* Four umbrellas have been designed for the courtyard of the historic castle. Because the castle is a listed monument, the umbrella's have been built without 'touching' the building. Each umbrella is placed on a central pillar at a height of about 10m. The umbrellas slightly overlap to fully protect the space from rain. Rainwater is evacuated through the pillars.The plan of each umbrella is inscribed in a square of 13m x 13m. The umbrellas are adapted to fit in the irregular shape of the inner court and hence are all different. In the unfolded configuration the height of an umbrella is 3m, when folded the height is 8m. *(fig. 03 & 04)*

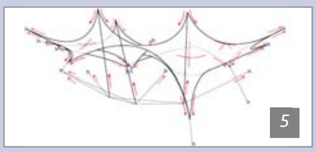




TENSILE CANOPY IN THE JULIANUS SHOPPING CENTER IN TONGEREN, BUILT IN 2008



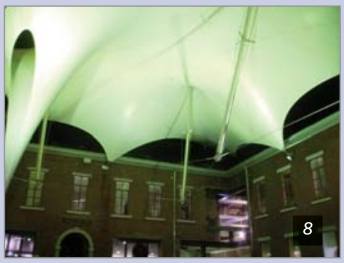




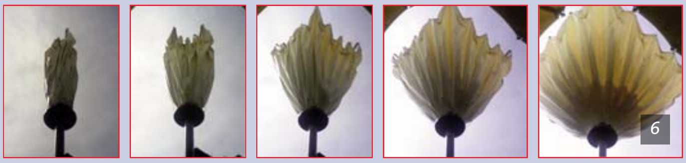
The historic Sint-Jakobs hospital from 1846 has been renovated to become a modern shopping center. *(fig. 01&2)* The membrane roof in the almost square courtyard is attached to the surrounding buildings at points either on the roof or on the façades. The formfinding had to be done within the model of the existing buildings, taking into account where the roof and the floors could be reinforced. The shape of the membrane roof is complex: 3 internal high points, supported by floating masts, one internal low point and boundary points at various heights ensure that the roof has enough curvature to float as a stable sail over a free span of 37m. *(fig. 03, 4 &5)*

The boundary cables are well curved, leaving some open space between the building and the tensioned membrane.

Moreover, the white Tenara fabric has a very high translucency, which ensures that the clouds can be seen through the roof. This contributes to the fact that the space, although fully covered, maintains a strong outdoor feeling. The contrast between the old brick building and the new, almost silky fabric roof, emphasises the character of both the monolithic straight walls and the lightweight curved textile they support. *(fig. 06 & 07)* The translucent membrane canopy in the almost square inner court covers terrasses and walkways, creating a pleasant relaxing area in the shopping center.
At night, light effects can animate the sculptural space. *(fig. 08)*



Name of the project:	Forum Julium, Tongeren
Location address:	Maastrichterstraat Via Julianus, 3700 Tongeren, Belgium
Architect for the membrane:	Amandus VanQuaille
Name of developer:	Heijmans Real Estate
Year of Construction:	2008
Consulting engineer (membrane):	ir. Marijke Mollaert
Structural engineer (main building):	ir. Jos Bastiaens
Contractor for the membrane:	The Nomad Concept, Amandus VanQuaille, www.nomadconcept.be
Supplier of the membrane material:	Gore
Material:	Tenara
Covered surface:	37m x 37m
Cost (without foundations):	€ 285.000 excl. taxes



The objective of creating an adaptable cover in the courtyard is fully realised: in winter the umbrellas, which stand folded, are unfolded (the computer controlled sequential unfolding takes 4 minutes for the 4 umbrellas) to shelter the space for outdoor concerts, while in summer they are operated according to the weather and either protect from rain or from too much sun. *(fig. 05 & 06)* The almost white PVC coated polyester fabric has enough tranclucency to allow the daylight to be only slightly filtered through the skin. The redness of the brick façades is reflected and creates a warm coloured ceiling. Once the umbrellas are closed, they appear white again. *(fig. 07, 08 & 09)* The inner courtyard has been used regularly throughout the past years and the system controlling the folding (as well as the setting of the pretension) of the umbrellas proved to work as expected. A thorough technical maintenance is performed every year.
(See also TensiNews 5)

Name of the project:	Alden Biesen, Bilzen
Location address:	Kasteelstraat 6, 3740 Bilzen, Belgium
Name of the client/ building owner:	Ministerie van de Vlaamse Gemeenschap
Year of Construction:	2003
Structural engineers:	Ney & Partners NV, www.ney.be
Contractor for the membrane:	Voilerie du Sud-Ouest (VSO)
Supplier of the membrane material:	Ferrari
Engineering of the controlling mechanism:	Flanders Projects and Advising NV(FPA)
Material:	PVC coated polyester
Weight of 1 umbrella:	450kg
Covered surface:	4 x 13m x 13m
Cost:	€ 941.500 excl. taxes

Julianus Tongeren

Background

Julianus is an urban renewal project and has been partly funded by an EU grant. The developer was Heijmans Real Estate. Heijmans Real Estate worked together with Holistic Architecture 50|5 on the architectural planning of what had originally been an urban competition entry.
The urban planners of Holistic Architecture 50|5 have redefined a central part of Tongeren - purposefully opening up the urban fabric. The idea was to create a continuous series of urban spaces along Clarissenstraat, Leopoldwal and Maastrichterstraat, using what used to be the Sint-Jakobs monastery/hospital as a pivotal point. A modern shopping promenade, a hotel, restaurants, offices, lofts, new underground parking and a multifunctional sheltered public space – which is where the tensile canopy is located – were to be accommodated.

Conversion

A conversion project of this scale and complexity touches on a wide range of issues including urbanism, conservation and architecture. When conversions are carried out, it is important to catch the attention of people viewing the project that an existing building has been repurposed.
By providing a clear contrast to the solidity of historic buildings, tensile architecture, when thoughtfully adapted and designed, can be a most appropriate answer to the requirements of conservation and representation.

The tensile canopy spanning the Julianus courtyard is the result of close collaboration between the architects of Holistic Architecture 50|5 and the architects of The Nomad Concept, who specialise in membrane architecture.

Translucency of the Tenara fabric [© Amandus VanQuaille]

Planning and design

The building, which had served as a monastery and hospital from the middle of the 19th century, was abandoned by the monks in 1970. After that it was used by the city administration until 2001 when it was deserted.
In the discussion about the character of the project, architect Juul Vanleysen from Holistic Architecture 50|5 raised the question of covering the monastery's courtyard.
A decision had to be made as to whether to use glass or fabrics for that purpose. Finally, a tensile structure was chosen as an answer to the courtyard's serene and somewhat sober expression. Only completely translucent materials were taken into consideration. Working together with the appropriate companies, The Nomad Concept experimented with various developments. Finally, their choice fell on GORE™ TENARA® Architectural Fabric because of its combination of enhanced strength, translucency and durability.

Despite its practical function as a sheltered gathering place, The Nomad Concept's design for the Tongeren sail had originally been a purely artistic, aesthetic vision. It was developed together with Holistic Architecture 50|5 in reaction to the building's serene and somewhat dark architectural expression. For this reason the sail had to have a pleasant feel to it. It had to be light and extremely translucent, even raising the luminosity by dispersing its light into the courtyard. The sail's spatial climax and the only point at > p.18

The membrane floating over the courtyard [© Amandus VanQuaille]

which it almost seems to touch the ground focalize on the one large tree in the courtyard.
Architect Amandus VanQuaille, from The Nomad Concept, designed the architectural sail in such a way that it appears to fly above the roof rather than being anchored to the façade.
The membrane even seems to escape gravity, not visibly touching the ground. The 'beak' in this zoomorphic form points towards the pond and the tree. The large scale of the membrane makes the tree look like a flower in front of a large beak.
However, even dynamic and agravic aesthetics have to be supported by appropriate structures. In the case of membrane architecture, engineering and design will always go hand in hand as the plastic form is of vital importance to the stability. Prof. Marijke Mollaert, who had worked on previous projects with The Nomad Concept, was chosen as consulting structural engineer for the membrane. Together with Ir. Jos Bastiaens, the structural engineer responsible for the stability of the building, a system of steel racks was developed to be inserted into the building. These supporting points had to be chosen in line with the historic construction's static capabilities.

The Membrane

The sail itself sports three high points supported by floating masts whose inclination emphasises the spatial orientation towards the solitary tree in the courtyard. In total it freely spans over an area of 37m. An internal low point channels rain water to a small pond in the courtyard.
The membrane was constructed using GORE™ TENARA® 4T40 which is extremely strong (80kN/m), translucent and 100% UV resistant. The Nomad Concept had acquired considerable experience with this fabric in previous projects. Their expertise in dealing with the issues relating to this fabric proved to be extremely beneficial.
The cutting patterns were carefully adapted to suit the design and the spatial context, running transversally to the direction of the flow of visitors. In the 'tail' area of the sail, the diagonal layout of the textile panels images a double fishtail. The patterns have been reduced to take into account the strain factors of the fabric in the direction of both the warp and weft. While appearing extremely fine and light due to its luminosity, the material thickness of GORE™ TENARA® 4T40 is actually quite considerable measuring 0.55 mm. Despite its strength and durability, the material evokes the feeling of Japanese paper art, in this case resembling a huge organic origami.

Mounting on site [©Marijke Mollaert]

Mounting on site

The mounting of the sail on site posed a significant challenge to all participants. As an object of special interest to the developers, architects, urban planners and conservators, the erection of the canopy was planned meticulously to coincide with the flow and deadlines of the construction on site. In spite of a severe storm with winds of over 110km/hour during the mounting process in March, the work was done as scheduled within three days.
The Nomad Concept had gathered together a most capable team comprising half a dozen specialists from shipyards, tent and chemical companies. Security issues were also well provided for. Prior to the erection, The Nomad Concept team had precisely planned the unfolding of the sail on site and had even constructed models to illustrate the mounting process.
It was thanks to the close and effective collaboration of all the parties involved, all working towards the same goal, that the desired result was finally achieved. In the early morning on 2 March a bottle of champagne was smashed against the sail's front pylon.

Amandus VanQuaille

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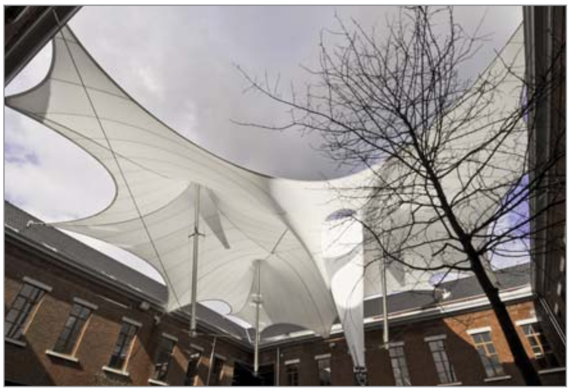

Figure 4. a. Three high points [© Robert De Wilde] *b. One low point [© Robert De Wilde]* *c. Main direction from the middle high point to the low point [© A. VanQuaille]*

GORE™ TENARA® 4T40HF Architectural Fabric

General description

This industrial-strength, flexible fabric is woven out of expanded PTFE fibres. It is water- and UV- resistant and offers a high degree of light transmission. It is available in two strengths and transparencies:
Type 1 (3T20HF and 3T40HF) with 3000N/5cm strength and
Type 2 (4T20HF and 4T40HF) with 4000N/5cm strength.
The fabric is radio frequency weldable.

Specifications

Fluoropolymer-coated fabric woven from expanded polytetraflourethylene (ePTFE) fiber
Weave: twill

Fabric Weight:	1080 g/m^2
Thickness:	0.55mm
Width:	1.57 m

Tensile Strength

ASTM D4851: Warp 4000N/5cm, Fill 4000N/5cm

Trapezoidal Tear

ASTM D4851: Warp 925 N, Fill 925 N

Light Properties

Light Transmission 45% (Photopic, 568 nanometer peak)

Chemical resistance

Tenara fabric resists all acids and alkaline solutions from 0 to 14pH and all organic solvents within the useful temperature range.

Flame Retardance

EN 13501: flammability classification B s1 d0

Maintenance

Tenara is naturally stain resistant. It can be cleaned with water, though the use of pressure cleaners is discouraged. Soil spots can be removed with ammonia or detergent; however, do not use solvents that contain ketones, acetone, or methylene chloride, as these will damage the fabric. Bleach can be applied to white fabric in any concentration.
Isopropyl alcohol can also be used for spot cleaning but is recommended only if mild detergents do not eliminate the spot.

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Completed Structure

THE CLYDEBANK 'SWAN'

A NEW CANOPY TO AN EXISTING BRIDGE

Clydebank Re-built and West Dunbartonshire Council are delivering a £2M programme of works to improve and regenerate a canal corridor in Clydebank town centre, Scotland. A central focus to the redevelopment was the construction of a feature canopy to an existing pedestrian bridge over the Forth and Clyde canal. Architects, RMJM, were inspired by the local wildlife to create a lightweight wing shaped canopy that invoked the image of a swan gliding in to land on the waterway.

A tensile fabric membrane canopy was an ideal material for the canopy, providing a lightweight, smoothly curved form and a white colour. The canopy is tensioned to a steel perimeter frame and given form by a series of curved circular hollow section arches, which push the membrane surface upwards. The lightweight perimeter frame to the membrane is supported by a primary steel frame mounted on four inclined columns fixed to the bridge structure. The columns incline towards their opposite over the water and nearly meet at the centre of the canopy. This arrangement of support leads to the canopy cantilevering 15 m either side of the central supporting columns, creating the impression of a pair of wings outstretched. The large cantilevers are given vertical support by cable ties from inclined masts on the structure centreline.

A PTFE coated fibreglass membrane material was specified for a long design life and superior self-cleaning properties. The membrane is fixed at the perimeter frame and simply bears on the arches.

The canopy structure, both steel and fabric, was constructed alongside the bridge on the canal bank. This allowed easy and safe access for the steel erection and fixing of the membrane. Once complete, it was lifted smoothly into place over the bridge in a single lift that took all of 3 minutes and 30 seconds!

Steel Frame on the Canalside

Fabric Canopy in place on Frame

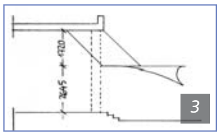
Canopy Structure lifted into place

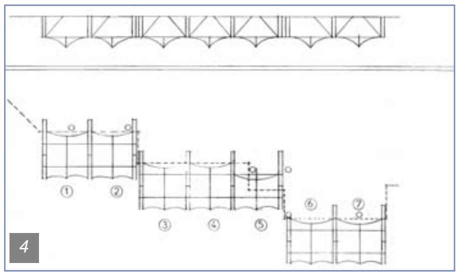
Mike.Dencher@
BuroHappold.com
www.burohappold.com

Client:	Clydebank Re-built / West Dunbartonshire Council
Location:	Clydebank, Glasgow, Scotland
Architect:	RMJM Architects
Multi-disciplinary engineering:	Buro Happold Ltd
Main Contractor:	Gray and Dick Ltd
Tensile Membrane Contractor:	Fabric Architecture
Material:	PTFE coated fibreglass

"BULEVAR MEDITERRÁNEO"

ROOF TERRACE, PALMA DE MALLORCA.





1. Palma de Mallorca sea front. The 5th floors are roof terraces.
2. "Bulevar Mediterráneo" scattered supports.
3. Elevation and plan
4. Section
5. and 6. The awnings are hung from the floor slab.

The sea front of Palma de Mallorca is bordered by a row of high buildings. Some of them are equipped with roof terraces on the 5) level, looking over the bay. In these cases, a protection is needed from the sun and from the neighbours living upstairs, because they are against noisy café bar terraces and throw out cigarettes, litter and all sorts of waste.

In the "Bulevar Mediterráneo" there is a bar on the intermediate roof terrace. The installation of awnings involved special difficulties because it was not taken into account in the design of the layout of the building. The supports are not aligned and their distances are not regular. Moreover, the damp-proofed floor and the scattered chimneys considerably complicate the placing of vertical elements.

The solution adopted in this case is a series of modules following their own rhythm and independent of the structural supports. They are hung from the ceiling above the roof terrace through U and circular hollow steel sections anchored to the concrete slab. Interferences with the floor and chimneys are thus avoided.

To obtain anticlastic surfaces, a horizontal frame including an arch was designed. As the arch goes downwards, the result is an alignment of white seagulls opening their wings to the view.

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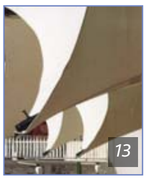


7. Structural connection.
8 and 9. The horizontal frame includes an arch pushing the fabric downwards
10 and 11. The modules follow their own rhythm
12. Wings framing the view
13. Detail

Client:	Bulevar Mediterráneo
Location:	Palma de Mallorca
Architects:	Llorens & Soldevila
Membrane:	PVC coated polyester
Roofed area:	8 x 4 x 4 m^2
Manufacturer and installation:	IASO, Lleida (Spain)

LIGHTWEIGHT BUILDINGS

TensiNet and Politecnico di Milano at the SAIE SPRING Fair,

BOLOGNA, 12TH-15TH MARCH 2008

The TensiNet Booth at Saie Spring 2008, Bologna, Italy

From the 12th till the 15th of March 2008 the first edition of the Saie Spring Fair for the building sector was organized in Bologna. At the "Cuore Mostra" the TensiNet Association together with the most representative universities and associations involved in the research of innovative shelters had the opportunity to exhibit their work.

The TensiNet exposition booth (32 m^2) was designed with the intent to disseminate the knowledge about tensioned membrane constructions. The main website (www.tensinet.com) and the new Italian website (www.architetturatessile.polimi.it) were directly consultable on two computers at the booth. The exhibition contained mock–ups of different types and technologies for textile coverings (kindly offered by some members of the Association): a pneumatic envelope made in PES/PVC and PVC crystal (made by Canobbio S.p.A, Italy), an ETFE inflated cushion with different surface treatments (made by Ceno-tec, Germany) and a multilayer insulated membrane (made by Architen Landrell Associated, UK). Each technology was explained with panels displayed on the walls of the booth near to the related mock–up.

In addition a great number of experimental models made by students of different European universities were exhibited in order to show other technologies available for the design of textile envelopes and their applications.

The booth was visited by a great number of people, students, architects and engineers who have appreciated the innovative shape of the models, their technologies and the information available on-line and on the panels.

The event offered great visibility for the activities of the TensiNet Association and we hope such event can help and stimulate the Italian architects and engineers to find innovative applications for textiles more and more.

During the Fair a seminar was organized with the title: "Designing membranes in Europe and in Italy. The role of the university research and of the TensiNet network" with the intent of diffusing the most innovative technologies in the fields of textile roofs developed in some European universities and in TensiNet. The seminar was very successful and the presentations of the three main lecturers Prof. Eng. John Chilton, Prof. Eng. Marijke Mollaert and Arch. Alessandra Zanelli were well attended.

All material of the exhibition has been documented in a small catalogue, edited by Arch. Cristina Mazzola.

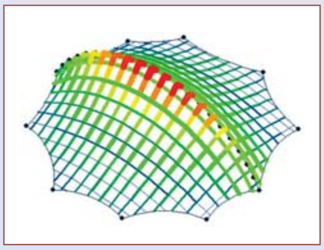
The new Italian website on textile architecture, Politecnico di Milano

For any information, please contact Arch. Alessandra Zanelli, alessandra.zanelli@polimi.it

www.architetturatessile.polimi.it

To order the catalogue of the Exhibition, please contact Arch. Cristina Mazzola, cristina.mazzola@polimi.it

TensiNet Partners at Saie Spring



TEXTILE ROOFS 2008

The Thirteenth International Workshop on the Design and Practical Realisation of Architectural Membrane Structures

(TECHNISCHE UNIVERSITÄT BERLIN)

Yearly this workshop organized by Prof. Dr.-Ing. Lothar Gründig, offers a comprehensive program of lectures presented by key figures from the membrane structures industry and research institutes in an informal tutorial environment. During the afternoons hands-on workshops are run for both computational and physical modeling.

The last event was organized from May 22nd till 24th 2008.

As usual the physical modeling session was led by Jürgen Hennicke of the University of Stuttgart. He started with an introduction on the use and importance of scale modeling, in general as well as for membrane structures.

Jürgen Hennicke explained in a very passionate yet structured way how to become relatively accurate and fast in expressing ideas, successively using soap films, lady stockings and stretchable fabric for models.

Further he emphasized the importance of such models for the design of tensile structures, not only before the computer calculations start, but also as an everlasting three dimensional means of communication and a helping tool while shaping the structure.

After some practical tips about making the soap films and cutting the fabric, it was time to get at work and make the models.

The next Textile Roofs International Workshop is planned from June 11th till 13th 2009 at the Technische Universität Berlin.

The physical models

Jürgen Hennicke at the workshop

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www.textile-roofs.de