

TensiNews

A THEMATIC NETWORK TO UPGRADE THE BUILT ENVIRONMENT IN EUROPE THROUGH TENSILE STRUCTURES

www.tensinet.com

NEWSLETTER NR. 7 - SEPTEMBER 2004



TensiNet IS A EUROPEAN FUNDED PROJECT IN THE 5TH FRAMEWORK PROGRAMME (GROWTH)

2

European Design Guide
for Surface Tensile Structures

[Tensinetpartners](#)

[Forthcoming Events](#)

3

Umbrellas for the Chamber of
Commerce, Würzburg
Mobile and convertible booth
for election campaign

4

Grandstand Tent Cover
for the open-air theatre
in Scherenburg, Germany

5

Lightweight with large span:
Tensairity®

6

Bubbles in the snow
Textile Grandstand Roofing
for the New "Fôrãdio
Intermunicipal Faro-Loulé"
on the Algarve Coast

7

Anchored on land:
Maritime Station entrance
building in Alicante harbour

8

New coatings
and multi filaments
Textile Roots 2004

9

Cp values for simple ridge
and valley structures

10

New Bangkok International
Airport (NBIA)
The „Inner Liner“

11

Faculty of Building Technology,
University of Eindhoven
Literature

Dear Reader,

During the last Working Group Meeting, within the frame of the EU-funded Thematic Network, it was decided to continue the TensiNet activities and to launch the TensiNet Association (see also <http://www.tensinet.com/association.php>).

The following board and regional representatives were elected:

- Mike Barnes will be the chairman for the next two years
- Heidrun Bogner and Stefania Lombardi will be the two vice-chairs
- The secretariat remains at the VUB under the supervision of Marijke Mollaert
- The editorial board of the TensiNews is enlarged: Peter Gosling, Rudi Scheuermann, Mike Dencher, Mike Barnes, Peter Pätzold, Brian Forster, John Chilton, Marc Malinowsky, Marijke Mollaert
- The regional representatives for the TensiNet Association will be:
 - Spain + Portugal: Juan Manjo (architect) + Josep Llorens (architect)
 - The Netherlands: Rogier Houtman (engineer)
 - France: Marc Malinowsky (engineer)
 - Finland + East: Matti Orpana (engineer)
 - United Kingdom: John Chilton (engineer)
 - Italy: Alessandro Zanelli (architect)
 - Germany + Austria: Rainer Blum (engineer)
 - Belgium: Marijke Mollaert (engineer)

To be able to finance future activities, members will have to pay membership fees according to the following table:

Cost per year (Euro)	Non-member	Student	School, University	Individual Member	Firm < 5 employees	Firm > 5 employees	Partner
Membership		30	150	100	250	500	2000
Mentioned in the on-line list of members	No	Free	Free	Free	Free	Free	Free
Full access to the website	No	Free	Free	Free	Free	Free	Free
Edit the database, upload documents	No	No	Yes	Yes	Yes	Yes	Yes
TensiNews	25	Free: 1	Free: 20	Free: 1	Free: 2	Free: 4	Free: 8
TensiNet Workshop (organised by a partner)			-10% for up to 2 people	-10%	-10% for up to 2 people	-10% for up to 5 staff members	-10% for up to 10 staff members
Presence in the www.tensinet.com links, itself containing the TensiNet link			Free	Free	Free	Free	Free
Advertisement in TensiNews, workshop proceedings ... depends on size & frequency					-10%	-20%	-30%
Lifetime membership				500	1250	2500	10000

TensiNews NFO

Editorial Board:

Mike Barnes, John Chilton, Mike Dencher, Brian Forster, Peter Gosling, Marc Malinowsky, Marijke Mollaert, Peter Pätzold, Rudi Scheuermann, Javier Tejera

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

Address: Vrije Universiteit Brussel (VUB),
Fac. of Applied Sciences, Dept. of Architecture,
Platinium 2, 1050 Brussels, fax: +32 2 629 28 41
<http://www.vub.ac.be/studio2/research/lightweight.htm>

European Design Guide for Surface Tensile Structures

The European Design Guide for Surface Tensile Structures has been published in August 2004. The design guide contains the following chapters:

- Introduction** John Chilton, Brian Forster
Engineered fabric architecture Brain Forster, Marijke Mollaert
Form Jürgen Bradatsch, Peter Pätzold, Cristiana Saboia de Freitas, Rudi Scheuermann, Juan Monjo, Marijke Mollaert
Internal Environment John Chilton, Rainer Blum, Thibaut Devulder, Peter Rutherford
Detailing and Connections Rogier Houtmann, Harmen Werkman
Structural design basis and safety criteria Mike Barnes, Brian Forster, Mike Dencher
Design loading conditions Markus Balz, Mike Dencher
Form-finding, load analysis and patterning Mike Barnes, Lothar Gründig, Erik Moncrieff
Material properties and testing Rainer Blum, Heidrun Bögner, Guy Némoz
Fabrication, installation and maintenance Klaus Gipperich, Roberto Canobbio, Stefania Lombardi, Marc Malinowsky

The design guide contains the following appendices:

- Cp Values for simple tensile structure shapes**, Mike Dencher, Markus Balz
Cp values for open roof stadiums, Markus Balz, Mike Barnes
Testing methods and standards, Rainer Blum, Heidrun Bögner, Guy Némoz
An Example of the application of the testing procedure described in Appendix A3 on a PTFE coated glass fabric, Rainer Blum, Heidrun Bögner, Klaus Gipperich, Sean Seery

With its different activities (website, database, Design Guide, annual workshop Textile Roofs and TensiNews) TensiNet has an impact at both the educational and professional level. Initially, specific information was scattered and retained by experts. However, the networking that has been initiated reaches beyond the partners and has an impact on knowledge and procedures in institutions as well as professional organisations and businesses. TensiNet creates a forum, an association and a reference point.

The European Design Guide for Surface Tensile Structures (2004), the Proceedings of the TensiNet Symposium (2003) and of the Design of membrane and lightweight structures Symposium (2000) can be ordered on line http://www.tensinet.com/order_designguide.php :

	Cost (Euro)
European Design Guide for Surface Tensile Structures (2004)	100
Proceedings of the TensiNet Symposium (2003)	60
Design of membrane and lightweight structures Symposium (2000)	40

The following packages can be ordered at reduced prices:

European Design Guide + Proceedings of the TensiNet Symposium (2003) + Design of membrane and lightweight structures Symposium (2000)	150
European Design Guide + Proceedings of the TensiNet Symposium (2003)	130





















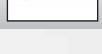

If you order any of these publications at the same time as registering as a TensiNet member the cost of the older publications is reduced by 50% and the cost of the Design Guide is reduced by 20%:

European Design Guide + Proceedings of the TensiNet Symposium (2003) + Design of membrane and lightweight structures Symposium (2000)	130
European Design Guide + Proceedings of the TensiNet Symposium (2003)	110
European Design Guide for Surface Tensile Structures (2004)	80

Marijke Mollaert

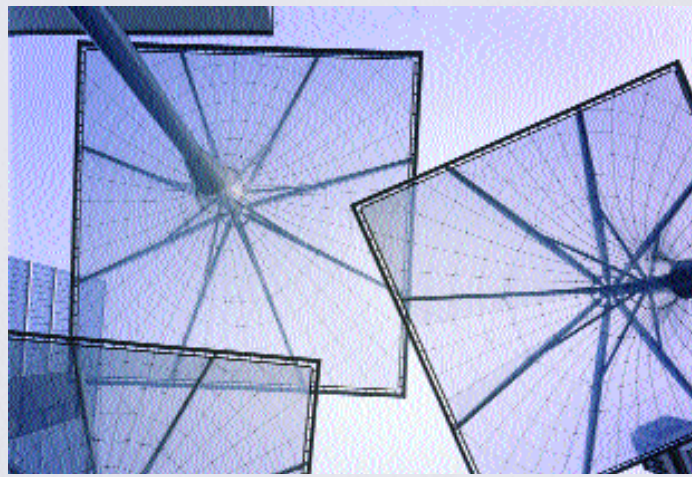


TensiNet partners

 Buro Happold Engineers www.burohappold.com	 The Arup Group www.arup.com
 Canobbio S.p.A. www.canobbio.com	 Universidad Poletécnica de Madrid www.aq.upm.es
 Ceno Tec www.ceno-tec.de	 SL-Rasch GmbH www.sl-rasch.de
 Club de la Structure Textile syndicatbaches.free.fr	 Taconic International www.taconic-afd.com
 European Council for Construction Research, Development and Innovation www.eccredi.org	 technet GmbH www.technet-gmbh.com
 Engineering Systems International S.A. www.esi.fr	 Technical University of Berlin www.survey.tu-berlin.de
 Newcastle University www.staff.ncl.ac.uk/p.d.gosling	 Tensotech Consulting www.tensotech.com
 Institut Français du Textile et de l'Habillement www.ifth.org	 Tentech www.tentech.nl
 Laboratorium Blum	 University of Bath www.bath.ac.uk/departments/arch/csemwebpage/light.htm
 Messe Frankfurt/Tehtextil www.tehtextil.de	 University of Nottingham www.nottingham.ac.uk/sbe
 Hopkins Architects www.hopkins.co.uk	 Vrije Universiteit Brussel http://www.vub.ac.be/studioZ/reZearch/lightweight.htm

Forthcoming Events

IASS 2004	Conference
Montpellier (France)	20/09/2004 > 24/09/2004
http://www.iass2004.org/	
41st Annual SES Technical Meeting	Symposium
Lincoln, Nebraska	10/10/2004 > 13/10/2004
http://www.nuengr.unl.edu/ses2004/symposia/fibrous.html	
IFAI Expo 2004	Exhibition
Pittsburgh	27/10/2004 > 29/10/2004
http://www.ifaiexpo.info/	
2nd Latin American Symposium	Symposium
Caracas (Venezuela)	04/05/2005 > 06/05/2005
http://www.arq.ucv.ve/idec/simposio/	
Tehtextil Frankfurt	Trade Fair
Frankfurt (Germany)	07/06/2005 > 09/06/2005
http://tehtextil.messefrankfurt.com/frankfurt/en/home.html	



Umbrellas for the Chamber of Commerce, Würzburg

In the inner courtyard of the Chamber of Commerce at Würzburg three extraordinary umbrellas were installed, offering an impressive sight. Each umbrella has a height of approximately 13 m and the total covered area is approximately 475 m². The biggest umbrella has an edge length of 14 m x 14 m. The funnel shape, which often is used in desert areas to collect rain, also has the advantage that it can drain the surface rain via the posts, thus avoiding costly drainage systems.

The main sub-structure of the roof consists of clamped steel posts and a fine frame fixed on the posts by horizontal and sloped struts. The extremely demanding tensioning process of the posts was carried out via the top plate into the ceiling of the underground parking space directly beneath.

Due to the use of ETFE-foil for these umbrellas their appearance is very filigree and light. A cable-net integrated in the ETFE-foils transmits the external loading to the frame and post.



Membrane structure:	Three transparent funnel-shaped umbrellas, consisting of ETFE-foils	
Primary structure:	Steel columns	
Location:	Inner courtyard of the Chamber of Commerce, Würzburg	
End of project:	October 2003	
Client:	Chamber of Commerce, Würzburg-Schweinfurt	
Architects:	Architekten BDA, Prof. Franz Göger/Georg Redelbach	
Realization of membrane Structure:	covertex GmbH, Obing	
Technical data membrane	Roof area:	approx. 475 m ²
Number of layers:	1	
Thickness of foil:	ETFE 200 µm printed with dots	
Tensile strength:	52 N/mm ²	
Fire class:	DIN 4102 - B1	

www.covertex.de

Mobile and convertible booth for election campaign

For an election campaign an innovative, expressive and mobile booth was needed for a party as an alternative for the normally used umbrellas and tables. The pneumatic booth fulfils all the requirements: it is mobile and light, expressive and convertible. On the top of an aluminium mast with an integrated round table the membrane is connected over a kind of hub. At the top of this hub the ventilator is located. Inside the mast are the electrical cables and the rainwater drainage. The foot of the booth is a standard footing for market umbrellas. The whole booth can be demounted within

5 minutes into manageable pieces, transportable in a small car or by hand.

This inflating pneumatic 'bubble' is an eye-catcher and an attraction. In less than 2 minutes the pneumatic structure is totally inflated by a solar powered ventilator.

The ventilator is regulated by a two-step switch, which reduced the air volume after the bubble is totally inflated.

The high translucency of the membrane material allows the pneumatic balloon to glow under the influence of bright sunlight. For use during the night appropriate lighting can be installed inside.



Architect:	Peter Pätzold
Manufacturer:	Peter Pätzold together with Jakob Frick Baumodeller
Dimensions:	Height: 2.6 m, Diameter 2.3 m, Covered area 4.2 m ²
Material:	Aluminium mast, galvanized steel foot, plywood, PU coated PES fabric (light spinnaker fabric)
Ventilator:	12 V, 125 m ³ /h, solar module and battery, SW

info@peterpaetzold.de

A mobile tent structure forms an elegant and charming cover for the existing grandstand of the Scherenburgfestspiele in Gemünden above the River Main. A light translucent membrane roof provides shelter from wind and rain for the spectators during the theatre summer festival without destroying the open air atmosphere that this place is well known for. And being well integrated with the historical red sandstone ruins of the old castle this white stretched textile roof creates an architecturally unique situation for the theatre play. Also, its attractive silhouette forms the new symbol for the summerfestival, that can be seen from far out in the valley.

One interesting aspect of this project is the first official application of the Tensinet Design Guide as a technical reference for the engineering and the approval procedure of this tent structure with the TÜV, which is the authorized association for technical supervision in Germany.

The membrane roof is supported by two internally located lattice masts (10.5m height), which were positioned within the existing grandstand at the edge of the upper stairways. The position and the form of the lattice mast provide a comfortable and safe situation for the movement of the public and also create the minimum disturbance for the visibility of the spectators. Each one of these main masts supports two lattice outrigger beams. This outrigger system provides the roof with structural independence regarding the adjacent historical building and allows the great span towards the stage. The lattice steel structures also provide new well-positioned supports for technical illumination equipment.

For the membrane itself a Tenera 3T20 fabric is used. This is a 100% Fluoropolymer fabric which has high tensile strength, is highly translucent (20%), dirt repellent and weather- and UV-resistant. It was chosen for its main characteristics and for the architectural quality of the white light that is shining through the Teflon fiber and for its high flexibility and friction



Grandstand Tent Cover for the open-air theatre in Scherenburg, Gemünden/Main, Germany

free surface, which is a primary requirement for keeping a good aesthetic appearance of the membrane through the successive erection processes over the years. Along its edges and ridges the fabric is reinforced with high tensile Polyester belts. At the membrane edge corners, the belts are attached to the steel frame and the peripheral suspension cables by means of demountable steel plates. After the disconnection of all steel

attachments, the pure textile membrane structure allows simple flexible handling and cleaning. The fabric is stretched by peripheral tubular masts and suspension cables, which are anchored to permanent injection anchors in the ground or in the solid stone walls.

The fabric qualities and the special structural detailing of the membrane as well as the steel structure detailing facilitate the



Client:	Theaterverein Scherenburg, Gemünden/ Main, Germany
Architect, Engineer:	Architekturbüro Rasch + Bradatsch
Contractor:	SL-Rasch GmbH
Dimensions:	Covered area 380m ² (max. width ±27m, max. depth ±17m)
Height of main masts 10.5m;	height of external masts from 5 to 6m
Weight:	25kN (6.5kg/m ² covered)
Material:	Steel works - mild steel, hot dip galvanized Cables - galvanized steel cables with swaged sockets
Membrane - Tenera 3T20 (630g/m ²);	rainwater tight fabric from 100% Fluoropolymers
Execution:	April 2004 - June 2004 (approx. 3 months)

bradatsch@sl-rasch.de • <http://www.sl-rasch.de/>

handling and the mobility of the complete tent structure without large crane equipment. This was an important aspect for the demountable tent roof that shall be installed every year at the beginning of the theatre season and shall be removed afterwards by the team of the theatre technicians. The precise geometry and prestress of the tensile structure is guaranteed during the erection by the permanent anchorage points and by the adjusted and fixed system length of the tent structure single members.

A great challenge of this project was to develop the design, to manufacture and to finish the erection of the tent structure within 12 weeks. Also, this tight schedule had to include an official approval procedure by the TÜV, which is the authorized association for technical supervision in Germany. So there was no time for any major changes of the architectural and structural design concept and the TÜV had to agree from the first design stage with the load assumptions and with the safety concept for this project. But neither the German DIN codes include standards for the windload distribution on typical tent shapes, nor was the time or the budget available to evaluate the windpressure distribution for this particular tent shape by a physical wind tunnel testing. In this critical situation the TÜV accepted the Preliminary TensiNet Design Guide for tensioned membrane structures as a reference. This state-of-the-art compendium for tensioned structures that is written by the well recommended European designers and manufacturers of tensioned structures also includes in Chapter A1 a recommendation for the windpressure cp value distribution of free-standing tent roofs and the TÜV agreed to apply this reference as basis for the structural calculation of the Scherenburg tent structure.

This application of the Tensinet Design Guide that is developed with the support of the European Community and aims at defining European Building Standards for tensile membrane structures was in fact a further step towards this common goal.

Lightweight with large span: Tensairity®

The Swiss company Airlight has developed, with the Tensairity® concept, a new pneumatic beam which enables spectacular applications especially in civil engineering. The synergetic combination of an air filled flexible tube, cables and rods gives with low pressure a very light but strong structure element.

What is the difference between Tensairity® and existing pneumatic structures? The innovative Tensairity® concept is based on the fact that air pressure is totally independent of the span and slenderness of the constituting elements. In other words: Tensairity® allows the construction of very light roof structures with extremely large span. The load bearing capacity of Tensairity® is so high that with a pressure of 200 mbar it is already possible to build temporary bridges even suitable for heavy transports. Compared to traditional airbeams, Tensairity® needs just 1% of air pressure. With such low pressure, air losses are easily compensated. Apart from civil engineering many other fields of application are possible: floating structures, sport equipment, airships and even aerospace applications.

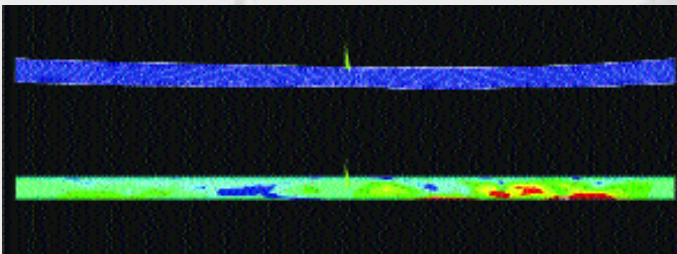


Figure 1. FEM Analysis of Tensairity® beams

Basic principles

The basic idea of Tensairity® is to use low pressure air to stabilize compression elements against buckling. The basic Tensairity® structure consists of a cylindrical airbeam (a low pressure fabric tube), a compression strut tightly connected to the membrane along the whole length of the airbeam and at least one pair of cables spiraled around the airbeam that are firmly connected to the compression element at both ends of the beam.

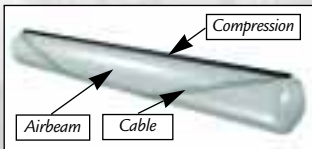


Figure 2. The Tensairity® girder: compression element on top, airbeam and cables

The compression element is connected to the membrane and thus can be considered as a beam on an elastic foundation. The buckling load of such a beam is then independent of the span.



Figure 3. Temporary bridge spanning 8 m (First prototype)

Airlight Ltd.

The Tensairity® technology has been developed and patented worldwide by Airlight Ltd. Switzerland. The company markets this technology and offers with licensing many other services such as training and support by direct applications. The main mission is to help engineers in applying the technology and to further develop the Tensairity® concept.

The main target of Airlight are civil engineers who, in a four-day introductory course, learn the theory behind the design and numerical simulation of Tensairity® structures. The access to a vast amount of related information and details speeds up the task of the engineer in the proposal and design phase.

TENSAIRITY® PROJECT: Breitling, Baselworld jewellery exhibition

The Tensairity® beam elements with 10 m span having a diameter of just 30 cm (resulting in a slenderness ratio of 33) and an internal pressure of only 0.50 bar have a load bearing capacity of more than 25kN. Four Tensairity® beam elements can carry the Bentley Continental GT sports car and more than 20 people.



Figure 4. a, b, c Breitling, Baselworld jewellery exhibition.

The beams, made of a silicon coated fiberglass fabric, are also illuminated through a glass window at one end giving a particular lighting effect.

Building owner/customer:	Breitling SA, Grenchen, Switzerland
Engineering:	Airlight Ltd., Biasca, Switzerland
Architect:	Alain Porta, Lausanne, Switzerland
Manufacturer:	Canobbio SpA, Castelnovo Scrivia (Al), Italy
Completion:	april, 2004
Fabric:	Silicone coated Fibreglas, Atex 5000, Interglas Technologies

Stefania.Lombardi@canobbio.com

<http://www.canobbio.com> • <http://www.airlight.biz>



Figure 1 A two-storey snow hotel covered with the snow (reception in the centre, 8 rooms around)



Figure 2a, 2b Internal views of the snow hotel



Figure 3 Airhall of 100m x 60m x 18m

Bubbles in the snow

In northern Finland we usually have a lot of snow. Not in an excessive way that we are forced to use it for our buildings like Inuits make their igloos, but more in a playful way that we can have fun with it. In the early days of the air halls some people were testing pneumatic structures as a mould for concrete and different resin-based materials. In Finland, in a northern city called Kemi (www.snow-castle.net), some people got the idea to build the biggest snow castle in the world.

In Sweden they already had built structures from ice but not from snow.

The first moulds were made by combining plywood with timber or steel, but off course double curved forms were difficult to accomplish.

Our long-time client (www.mailari.fi), renting big tents for all kind of summer festivals, asked us to build moulds for making small igloos. The biggest problem with moulds using air pressure has always been how to fix them to

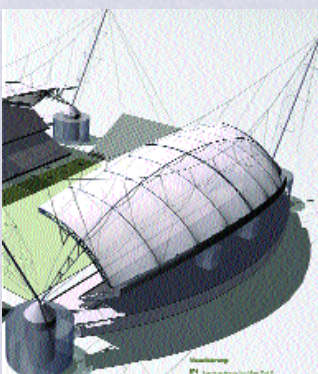
the ground, because of the size the inner pressure has to be up to 4-5 kPa to resist the weight of the packed snow against the walls. On the other hand the moulds should be easy to move and handle to meet commercial demands. Some experiments seemed promising, showing that the structure could be built in 10 minutes and was a closed volume with a demountable bottom. The smallest ones can be carried by two men having the full pressure inside. The pressure stiffens the whole structure with its bottom.

The first prototype measured 6m x 4m (diameter x height), later adding 8 smaller ones of size 3.5m x 2.3m. The biggest one we made was 12m x 8.5m and next winter we have planned to build one of size 16m x 11m. The most difficult thing is how to make snow that is structurally stable enough, not how to make the mould itself.

Anyway, those are small in size compared to the sport halls we have made in Finland: there are two halls for football training, size 120m x 68m x 21m and for the next winter we have planned one of size 180m x 72m x 22m. Because of the Finnish weather conditions these membranes are

Textile Grandstand Roofing for the New “Estádio Intermunicipal Faro-Loulé” on the Algarve Coast

One of the most interesting applications for Textile Architecture is the field of stadium roof construction. Generous, airy, and translucent roof designs which can also be shaped in varied form can be seen worldwide in many stadiums in the meantime. The operators of smaller stadiums also make



more and more use of the benefits of this design. The new “Estádio Intermunicipal Faro-Loulé” which was opened officially in a ceremonial opening on 23rd November 2003 is one of these examples. In accordance with a layout designed by the architects HOK Sportsevent and the AARQ, Atelier de Arquitectura in Lisbon, the south and east tribunes were each arched over by a roof design suspended from rope binders, using an additional steel arch concept to support this construction.

A total of 32 membrane fields each with a width of 14.40 metres and lengths varying from 31.00 to 45.00 metres is roofed. The covered base surface is a total of 10168m² in size. Highly-resistant polyester fabric with double-sided PVC coating was selected as membrane material. Due to the use of a final paint coat with fluorine polymer paint, the material additionally features a dirt-resistant surface finish.

The membrane building specialist CENO TEC GmbH carried out the work with the engineering specialist office IPL-Ingenieurplanung Leichtbau GmbH who were already involved in the project implementation at a very early stage to make the architects' design feasible for the construction of the membrane, i.e. to harmonise the material-specific and design-construction-type requirements which characterise the construction of the membrane such as sufficient curvature in opposite directions to avoid water or snow pockets, suitable steel elongations and fixing details appropriate for membranes. In particular, it was important to dissolve the relatively flat discontinuous course of the membrane and to transform it into a stable structure.



Practicable details conforming with the supporting framework structure to be provided externally had to be developed for production and mounting which made it possible to deviate loads burdening the membrane structure in a clean and, as far as possible, linear manner to the supporting framework. The membrane surfaces and the individual cutting strips were determined based on the externally specified geometry. Here the exact material behaviour under load had to be determined by a load-controlled biaxial test which in the end served to determine the compensation values for the cut. The individual fields - approx. 550 m² in size including the edge designs - were manufactured completely at the CENO TEC plant and shipped to the building site.

There, the elements were mounted to the supporting framework within a short period. In this respect, Textile Design can be compared with “Prefabricated House Operations”, meaning



Figure 4 Airhall of 95m x 55m x 16m

always manufactured in one single piece: this is the traditional Finnish way not found in any other country.

The Finnish climate has always been suitable for air halls and the number of built structures has risen to more than 500 in forty years which is a lot for a small country.

Finland is also exporting a lot of steel framed PVC-covered structures all around the world. (www.besthall.com).

<http://www.tensotech.com>
info@tensotech.com



that the mounting time compared to the project term is relatively short. The mounting work was implemented within a period of 5-6 weeks.

Architect	AARQ Atelier de Arquitectura, Lissabon + W.S. Atkins, UK
Engineering	IPL - Ingenieur- planung Leichtbau GmbH (D)
Contractor	CENO TEC GmbH
Fabric	PVC/PES fabric with a dirt-repelling final PVDF coating
Covered Area	10168 m ²
Year of Construction	2003

info@ceno-tec.de
www.ceno-tec.de

ANCHORED ON LAND

Maritime Station entrance building in Alicante harbour

The original Maritime Station was built in the sixties with a very impressive structure made of concrete shells. In 2003 it was completely renovated, and as part of this renovation, a new entrance building was planned. Finally, the option of a light structure as a hall for a heavy building was decided.

The situation of the roof, on a breakwater, almost surrounded by the sea as part of the harbour, conditioned it in two different ways:

On one side, the design should simulate the masts and yards of a Tall Ship. In order to get this, the whole structure is hanged on a mainmast (35m height, Ø619mm) in the middle and small masts (Ø219mm) on the border. The geometry of the tent, one half-cone as a mainsail and one irregular paraboloid as a gaff-topsail, and the details of the structure are constant references to ships (top basket in the mainmast, six small masts: some of them as a kind of jib-boom, stainless clews of the sails, and so).

On the other side, the structural analysis should face expected wind loads of almost 180 km/h, making the structure to be light but much more resistant than others. For this reason, the membrane used was Ferrari 1302 Fluotop T2, strong enough for this load and good for dirt-resistance and saline environment. The steel used for masts and arches is high resistant A52b/S355 JR.

The half-cone is attached under the top basket to the main mast, and it has two fixed borders –curved steel tubes - and three more fixed points on masts with four free borders - cables or bolt-ropes.

The paraboloid is anchored to the mainmast in a fixed border with plates, and five more points to each mast with bolt-ropes between them.

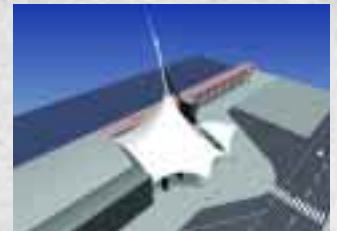
The mainmast is stabilised by cables in order to reduce flexion due to eccentric forces transmitted from the membranes. These cables (grouped in two families, one on top of the mainmast and the other on the second membrane fixation) are fixed to the masts and finally to foundations (which were designed for seismic loads).

The bottom of the mainmast is a spherical articulation designed to fix the position of the mast with the upper family of cables. On a lower position the mast is fixed to the concrete slab with a steel crown: where the mast passes through the concrete slab. This way, it does not work as an articulated mast.

The finishing of the main floor is a wooden deck, being an other reference to the nautical origin of this Tall ship anchored on land.



tejera@batspain.com
<http://www.arquitectil.net>
lzmadrid@telefonica.net



Client:	Alicante harbour authority
Location:	Alicante harbour(Spain)
Main contractor:	VIAS y CONSTRUCCIONES (Javier Vidal)
Contractor:	COMERCIAL MARÍTIMA L&Z, S.L. (José M. Lastra, Javier Tejera)
Engineering:	COMERCIAL MARÍTIMA L&Z (José M. Lastra, Javier Tejera), THEMA (Guillermo Capellán)
Fabric/Structure material suppliers:	FERRARI / FAMECA, COTNSA
Year of construction:	2003
Covered surface:	600 m ²

New coatings and multi filaments

Material compounds have a long tradition in the textile technology and a growing perspective.

The company Polymade ITT has made new products on the base of innovative textile components.

SOLAFLON coatings

With SOLAFLON a new coating system for innovative technical textiles has been developed which leads to a whole product family for textile structures. SOLAFLON is a PTFE based coating system with all well-known fluoropolymers in constructional physics. The novelty consists in the fact that a glass clear PTFE derivate can be used in any thickness of coating. Because the coating appears as a transparent and flexible film on both sides of the glass fabric, the coating is even not visible at the first glance. technology allows coatings from

some μm 's up to some $100\mu\text{m}$, whereas the polymer shows a high flexibility even at bigger layers.



Solaflon is nearly 100% transparent from 200nm up to 2500nm. This means that it is not only UVC stable but it also shows no optical change after strong radiation with high energy quanta like gamma radiation, where normal PTFE disintegrates. Within the range of the solar radiation from 300nm up to

2500nm Solaflon shows no absorption. This means that also the UVB and UVA are passing Solaflon. If glass fabrics are coated with Solaflon without additives and such a material would be chosen for a football / soccer stadium the growth of the grass would not be hindered.

That all together allows products in a very big range of transmission, which generally is only limited by the glass fabric. In this respect a transparency of 50% is nothing special. With the variable thickness of the coating light and flexible textiles can be created. Even with the worst cross creases the Solaflon film on the glass fabric remains unaffected. Because the bonding

between the polymer and the glass fibres is just a physical one as mechanical anchor into the middle of the multifilaments of the glass, this connection can be disturbed when sharp creases occur. Due to this effect a darker line could be observed, but despite this visual effect the surface remains absolutely tight. That concerns also only transparent Solaflon coatings which don't contain any additive. That can be made invisible by heating up the coating with a hot air stream, when the fabric is installed and is under tension.

Due to the high transparency of Solaflon any colouring is possible. Each RAL colour can be added and the result is a brilliant,

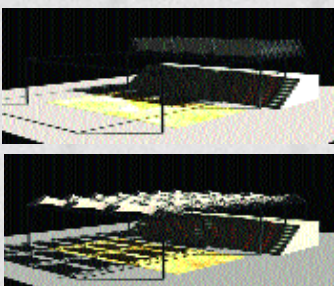
Last June the Ninth International Workshop on the Design and Practical Realisation of Architectural Membrane Structures was held at the Technical University Berlin and was co-financed by Ferrari, technet GmbH and TensiNet. The main objectives of this workshop were to provide fundamental information, as well as presenting the state-of-the-art in textile roof engineering. Ever since its conception nine years ago, the event has been growing in number of participants, bringing together the expertise of successful engineers and architects as well as the enthusiasm of newcomers to the topic. This year's event brought together about 90 people from over 25 countries worldwide. In addition to a comprehensive programme of lectures presented in English by key figures from the membrane structure industry and academia, opportunities for the study and hands-on development of practical case-studies in an informal tutorial environment were provided, touching subjects such as computational modelling, design process, detailing, environmental and economical factors, physical modelling and materials.

The general structure of the Workshop and the 'key-note' topics and lectures were the same as last year, but new for this year's event was that some presentations focussed on the Project Studies.

Ms. Stefania Lombardi (Canobbio Spa) gave a general introductory lecture on tensile structures and how an idea can be transformed into a real-life membrane structure, providing us with an insight on the process involved.

Dr. Dieter Ströbel of technet GmbH explained the working of EASY software for the computational modelling of lightweight structures, dealing with formfinding, load analysis and cutting pattern generation.

The Vrije Universiteit Brussel (VUB) was represented by newcomers Tom Van Mele, Niels De Temmerman and Caroline Henrotay, all architectural engineers, two of which gave their first ever presentation for an international audience. They presented their research topic 'Interactive Kinetic Architecture' and '4-dimensional Design', both dealing with adaptability, but within a different timeframe.



Textile Roofs 2004

Mr. Hubert Reiter from Covertex GmbH gave a presentation on the use of ETFE foil, which can mainly

be used in architecture in two ways: mechanically prestressed forms and pneumatic cushion structures. He described the design and erection process of The football Globe, a 670 m² transportable structure, made out of inflatable ETFE hexagons and pentagons, patched together to form a giant football.

Textile manufacturer Ferrari S.A. was represented by Mr. P. Burnat, Mr. F. Reitsma and Mr. J. Tejera who gave a lecture on SKY@300, a newly developed silicone coated fabric material for interior applications which has high flame retardancy. The benefits of silicone are a good resistance to UV, humidity and chemical aggressions.



Mr. Ingo Lishke from Textil Bau GmbH considered the impact of climbing for textile projects. As an illustration, the cladding of the TUB's main building was climbed with the help of Gewerbekletterern Erfurt.

Prof. Josep Llorens stated that detailing for fabric structures is not yet thoroughly documented or widespread practice, even though designing and evaluating connections and joints is critical to the overall concept and the resulting structure.

Ms. Prof. Dr.-Ing. Rosemarie Wagner shared some ideas on a recent development in tension structures concerning a system for modelling and simulation of membrane structures. It allows describing the design process in all its aspects and allows interfering of the user at each step. A non-linear optimization algorithm is used, based on a FEM-formulation.

In sessions, parallel to the lectures, a Computational Modelling Workshop was led by Dieter Ströbel and in an exhibition on Temporary Architecture some projects by students from the Technical University Berlin were presented.

The event was concluded by an interactive discussion, led by Jürgen Hennicke and Josep Llorens, on the physical aspects and construction details of membrane structures.

We're looking forward to the '10th anniversary' edition of this event next year which will be held from 26th till the 28th of May 2005.

colourful and glossy material. With the incorporation of Irodin particles the full range of metallic colours is available, but also the shine of colourful interference phenomena's can be realized. Due to the optical neutrality of the Solaflon matrix also functional particles can be built in. Out of this reason a "heat stop" effect can be generated. Special pigments which are transparent in the visible, especially for green light and which are reflecting the total infrared allowing transparent structures with cold light. The membranes will remain cold because the IR is reflected and not absorbed.

Another feature is the possibility to create a low emissivity at the surface of the membrane. That will be done by aluminising the glass fabric by PVD (physical vapour deposition) and then sheltering the metallic aluminium

coating with a thin layer of Solaflon (about 10µm). Due to the slight absorption of the far IR by Solaflon the effect of aluminium remains nearly the same, but it is secured against corrosion by the Solaflon coating.

One of the main properties is the polarity of Solaflon. That allows simple seams to be made with RF welding systems like those for welding PVC. All membranes qualities can be treated like Polyester/PVC, what means that many companies are able to tailor this material.

Solaflon can be used for technical fabrics which have to fulfil the A2 fire prevention standards.

TECHNOFIL filaments

TECHNOFIL filaments are yarns, which consist of various technical multi filaments as core media like

- Glass (yarns / plied yarns / rovings)
- Polyester yarns
- Aramide fibers / fibres of high tensile strength
- Other textile filaments in combination with coating materials like
 - PVC
 - PU / PE
 - SOLAFLON
 - PVDF / FEP / PFA

The TECHNOFIL filaments coating is performed in an extrusion process. This technology allows the use of nearly all modern thermoplastic materials as coating, whereas the customized plastic can be modified in all directions (flame retardant, UV protection, gloss, colour, polymer softening agents etc.)

Besides the wide field of PTFE coated glassfibers and PVC coated PET fibres, the importance of other coatings especially of fluoropolymer coatings is growing.



TECHNOFIL filaments are used for various products like screens, blinds, shading fabrics, filter materials, insect screens, conveyor belts, belt systems and supporting fabrics

www.polymade-itt.de

Michael Blum
[mb@polymade-itt.de]

C_p values for simple ridge and valley structures

The following paper is an extract from the European Design Guide for Tensile Surface Structures.

Appendix A1 of the European Design Guide for Tensile Surface Structures has been prepared so as to give general guidance on the C_p factors that may be expected for typical tensile structure shapes. The term C_p refers to the wind pressure coefficient that multiplies the site wind pressure to give the wind loading pressure.

Archive wind-tunnel tests of tensile structures, as well as literature covering both rigid and tensile structures have been investigated for information giving typical external C_p values for four types of simple membrane structure. The types considered are:

- a) Cone
- b) Ridge and Valley
- c) Hypar/Saddle
- d) Hybrid cantilevered canopy

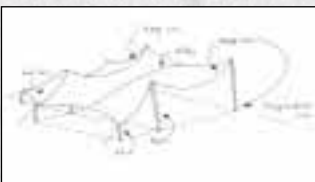


Figure 1 Typical "Ridge and Valley" Type of Membrane Structure.

From this investigation diagrams and tables giving average C_p values have been obtained. The C_p values given are on the same basis as those given in the Eurocode for conventional structures and are intended for use with the Eurocode. The external C_p values can be used in the following equation:

$$\text{External Wind Pressure (load)} = \text{Site Wind pressure} \times \text{External Mean } C_p$$

The site wind pressure can be found using the Eurocode procedure for terms q_{ref} (reference mean wind velocity pressure) and c_e(z_e) (exposure coefficient - this includes for the terrain and gust factors pertaining to the site). The Eurocode includes windspeed maps for the whole of Europe and from which the basic site reference mean wind velocity pressure can be determined. Internal/undersurface C_p values for the ridge/valley forms should

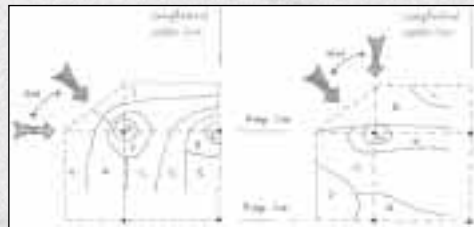


Figure 2 Ridge and Valley C_p Zone Definition

be determined using the Eurocode approach based on the distribution and size of any openings in the building envelope. The mean C_p values are given below as an average value for a zone defined as shown in the diagrams. They are suitable for the design of the membrane and its supporting structure but not for cladding panels and individual purlins, which will be subject to higher local loading as described in the Code. The behaviour of the wind and hence the C_p values will not vary greatly with small changes in overall structure size. The C_p values given here can be assumed to be valid for structures with bay dimensions of 10-100m.

Shape parameters:

The defining shape parameters for this type of structure are

$$C_p \text{ Ratio} = \frac{\text{valley width}}{\text{valley depth}}$$

b) Open or closed sides.

External C_p Values

Sides	Open	
Ratio of Valley Width to Valley Depth	2.5	4
Approximate slope of membrane (deg)	39	26

C_p Zones

A	+0.6	+0.3
	-0.39	
B	+0.23	+0.25
	-0.33	
C	-0.41	-0.2
D	-0.2	-0.3
E	-0.11	-0.45
F	-0.38	-0.35
G	-0.38	-0.8
H	-0.33	-0.5
I	-0.33	-0.9
J	+0.14	+0.35
	-0.3	-0.3
K	+0.58	0.3
	-0.29	
L	+0.38	+0.3
	-0.42	-0.2
M	-0.38	-1.2
N	-0.38	-0.6
O	+0.38	-0.4
	-0.37	
P	+0.45	+0.2
	-0.46	-0.2
Q	+0.12	+0.3
	-0.27	-0.3

Table External C_p Values for "Ridge and Valley" Type Structures

Abstract: As the New Bangkok International Airport Projects required the implementation of a new material concept, it was a very special task to develop the inner membrane, which is also called "Inner Liner". The following article should give a comprehensive overview and also describe some special issues of this project.

1. General features of the membrane materials

The Werner Sobek Engineers, the company Transsolar and the Laboratory for Dynamics and Acoustics in Stuttgart have commonly created the concept of the 3-layers membranes, which should guarantee, that (besides the static requirements of the construction) the air-traffic noise emission close to taxiways and runways should be reduced as much as possible. Additionally it was required to support the energetic concept of the construction with new composites and coating technologies of the membranes.

Besides it was also obligatory, that the „Inner Membrane“ had to be certified in accordance to the flame retardancy classification DIN 4102 A2. The outer membrane was chosen as the classical and reliable Glass-PTFE composite with high transparency, which has been proofed long term in textile architecture.

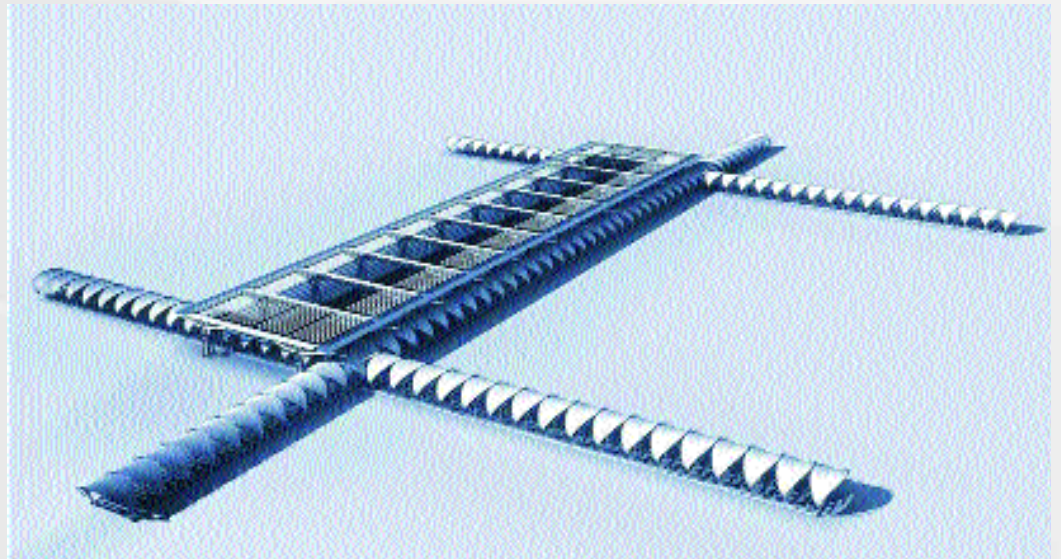
The medial layer is fabricated as highly transparent polycarbonate, which is mounted in a steel-grid construction.

The third and from inside visual "Inner Liner" of this membrane construction was asked to fulfil a composition of new requirements of flame retardancy, acoustic and energetic properties, light transmittance and light reflectance and last but not least with the general appearance of the material.



Micro perforations

New Bangkok International Airport (NBIA) The „Inner Liner“



Model of the New Bangkok International Airport

2. Special features of the INNER LINER

There were no materials in the market available, which could fulfil the complete set up of the requirements. Especially the required low emissivity and the sound absorption established created a too high obstacle for the conventional materials. The company PD Interglas AG took the first task to develop the basic glass-grid – a fabric which would allow an aluminium-coating and could perform a sound absorption and a light transmission by the correct grid-hole-opening-ratio. It was suggested that aluminium-coatings on glass fabrics would perform physically similar effects like aluminium foils, the so called "Low Emissivity" or heat reflection.

Other than polyester based fabrics, glass weaves as coating and composite bases are able to support the flame retardancy requirement A2. Although aluminium coatings on glass weaves seem not to be too complicated in general, but it's a special problem, to make sure that the aluminisation is embedded and does not lead to an oxidation, what would destroy the reflective property of the aluminium layer in the far Infra-Red.

Because all well known coating composites like PTFE, PVC or any other plastic materials are not suitable for the task, a brand new coating polymer became the key element of the product development.

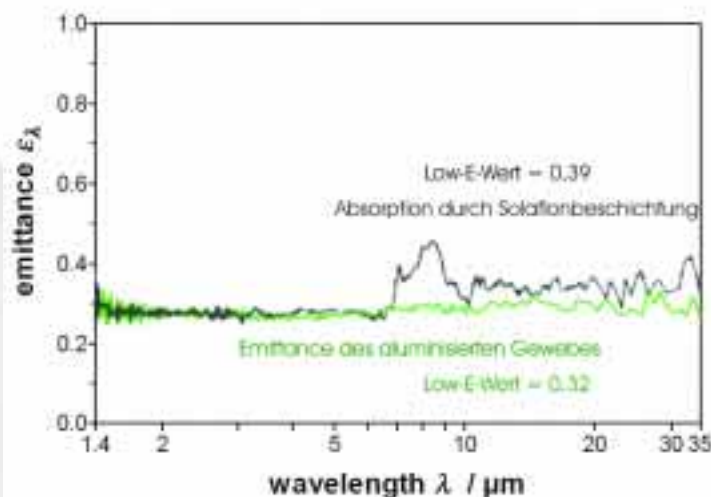
It was a high transparent, non combustibile and film-forming

polymer, which had been developed out of the group of fluoropolymers. This film-forming ability should allow to reopen the grid-holes of the weave after the coating of the membrane was completed, and therewith to enable a high sound absorption.

The weave design and coating composition allowed exceeding the fulfilment of the required noise reduction coefficient of > 0.7 to a new textile achievement value of 0.89.

Interglas AG asked Polymade to demonstrate the feasibility of the task in between 6 weeks after November 2002, because Polymade had developed a coating composite which had become known to the market under the company's brand "SOLAFLO".

After having demonstrated the general feasibility and pre-serial product testing, the complex production logistics of this composite had to be planned and coordinated, especially because a width of 2.20 m had to be aluminised in an industrial available vapour deposition process. Other than in conventional slow coating processing for industrial fabrics, the aluminisation is processed on a high speed level of 300 m/minute. This is a very difficult process to a relatively sensitive glass-grid weave, which requires unusual quality securing steps. Before receiving the order from

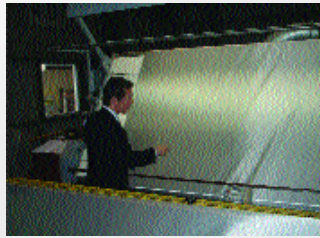


Emissivity of the aluminised membrane

the general contractor of NBIA Company ITO, numerous tests had to be performed, mainly aiming to the long term mechanical strength of the composite. This qualification program was coordinated under the product name A-Tex 2500 Low E and was coordinated between the manufacturer of the glass fabric, the coating company, B&O Hightex and the Laboratory Dr. Blum in Stuttgart. The material logistics for the roofing material such as purchase, appearance control, documentation etc. is executed by OGAWATEC, Tokyo to support the general contractor ITO, Bangkok and the fabricating company B&O Hightex, Riemsting, Germany. Pure glass based fabrics without a sufficient polymer coating cannot be used in tailoring and fabrication, because the material is too sensitive.

The process of coating should be carried out asymmetrically, that no oxidation can occur on the aluminium side, without overruling the "LOW E" effect by the fluoropolymer coating with an absorption in the far Infra-Red. A stronger coating on the back side should allow an easier handling of the membrane in tailoring, welding and assembly. The required solar reflection of the white side with more than 60% could be guaranteed due to the transparent coating of SOLAFLO.

To fulfil the required optical features of the fabrication in 104 "Typical Bays", a suitable technical "connection" or seam, had to be qualified. The demand of a weld strength, which corresponds to the material strength with 3250N/5cm, could be achieved by the availability of a transparent and compatible welding-aid. The coating material does not lead to losses of the tensile strength of the fabric, but improves the glass filament protective embedding. Consequently it was possible to keep the tensile strength after the micro-perforation of the membrane. As aluminium coating is an energy barrier for the economical RF welding-method -what generally is possible with SOLAFLO- the seams had to be made with a so called heating bar welding.



Material inspection

3. Fabrication process of the INNER LINER

The required glass-grid-fabric was woven at the PD Interglas weaving factory in Malmerspach/ France. Before the fabric roles could be sent to get aluminised, they had to get a SOLAFLO-base coating. Without this base coating it is not possible, to get the required reflection values of the aluminium. The aluminium deposition is processed in three steps up to a thickness of 120nm. After returning the charges of about 20000m² to 30000m², the further fluoropolymer-coating and micro-perforation is processed in four different fabrication steps. The appearance inspection and role recording took place at the weaving factory in Malmerspach/ France. Only there, Interglas AG had an accurate sleeve construction which allows a fold free winding and inspecting of the approximately 600kg heavy roles. Precise protocols allow economical cutting patterns and the optimisation of the tailoring.

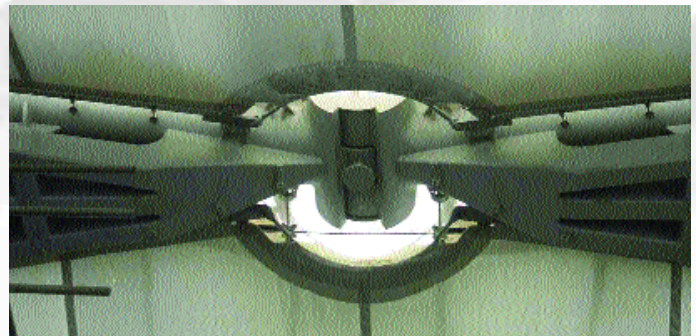
4. Demands on the appearance of the INNER LINER

As glass weaving without any defects is not possible, it was a special challenge to reduce the number and the allocation of the defects under the norm of allowed defects for solar-protective screens, falling short from a maximum of 10m per 100 ongoing-meter and mostly to offer 25m middle pieces of the typical Bays for zero defect "cutting patterns".

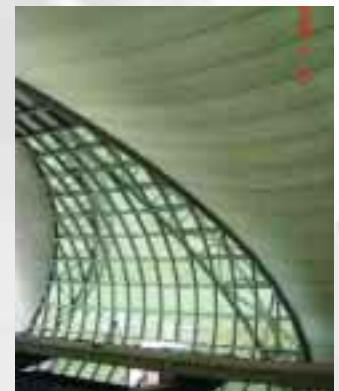
A quality improvement program implemented by the participants could guarantee that the defect number could be reduced to approximately 30% of the specified standard. For this reason it was possible to assemble more than the specified cutting patterns. Aluminium coated glass-weaves are functioning as a reflector or

a mirror and are also sensitive like a mirror. All kind of creases in the weaves appear as dark or bright marks. This caused a special demand to the fabrication, the transportation and the assembly, where each approximately 1100m² pre-fabricated membrane has to be installed at the construction side in one piece. Furthermore glass-weaves don't have any elasticity, therefore a highly specific cutting pattern, a faultless fabrication and frictionless assembly has to be secured. Each avoidable contact towards the optically sensible material could influence the appearance of the membrane. Keeping that in mind and observing the handling instructions, the technical requirements as

mechanical strength, LOW E, transmission and sound absorption will remain unchanged. When some years ago the designers of the membrane construction specified the Inner Liner, there was no material composite available, which could fulfil the bunch of demands. This challenge, to introduce a sound absorbing and open aluminised glass fabric with LOW E and other optical properties was the task which had to be matched. Without these nearly impossible challenges and the coincidence of visionary demands on the one side and the new SOLAFLO technology on the other side, the break through of this innovative material wouldn't have happened.



The Inner Liner at the New Bangkok International Airport



www.polymade-itt.de

Michael Blum [mb@polymade-itt.de]

Walter Duerbaum [wd@polymade-itt.de]

Prof. G.K.Brueck [gkb@polymade-itt.de]

FACULTY OF BUILDING TECHNOLOGY, UNIVERSITY OF EINDHOVEN
Double curved pre-stressed net - Project Lightweight Structures 2004

For many years now, the Structural Design Department of the Building Technology Faculty at the University Eindhoven, has been active in the field of lightweight structures. Research, education and projects give students the opportunity to study this subject. Each year we will organise a project in which the students design, calculate, produce and assemble a particular lightweight structure. These projects will increase the understanding of the structural behavior, the architectural freedom, and the important issues of its production. This year the assignment was to design a sculpture of a double curved, pre-stressed net with an equal mesh, to hang in the atrium of the Building Technology Faculty. Four groups of three or four students started to make several designs by sketching, using nylon stockings and the formfinding module of the computer program GSA 8.0. GSA is an internal developed program by Arup. For the formfinding it uses Dynamic

Relaxation with the element forces based on their force density and length. The TU-Eindhoven has developed a program called Convers to convert the cable layout of the GSA model into an equal mesh and its cutting pattern. The mesh generated was 110mmx110mm instead of the 100mmx100mm mesh we assembled. This was done to incorporate a 10% stretch due to the required pre-stress in the net. This equal mesh replaced the model in GSA, and was used to calculate the prestress forces in the edge ropes. With the forces and the pre-stressed lengths of the edge ropes, the unstressed length between the connections with the net could be calculated knowing the elasticity modulus of the rope. For this, the properties of the materials were tested, including their ultimate force. The firm Huck Torimex BV in Katwijk aan Zee, producing among other things nets of ropes and steel cables, showed interest in using their product for double curved pre-stressed structures,

and donated all the materials for this project. A polypropylene mesh of 100mmx100mm Ø3mm, and polypropylene edge ropes Ø5mm were used. After finishing the calculations and producing the working drawings, the students were divided into two groups, one producing the net and the other producing the edge ropes. The edge ropes and support points were given a unique code to co-ordinate the production. The connection between the edge ropes and the net was made with steel wires of about 70mm long, pinned through the ropes and twisted for fixation. To assemble the structure, we used the railing of the atrium as support points. The structure was calculated with a force of 50N/100mm in the net (15% of its ultimate load), which gave a maximum force of 1200N in the edge ropes (30% of its ultimate load) and 1700N on the support points. During assembly the locations of the corners of the net were measured to justify the length of the span ropes and the

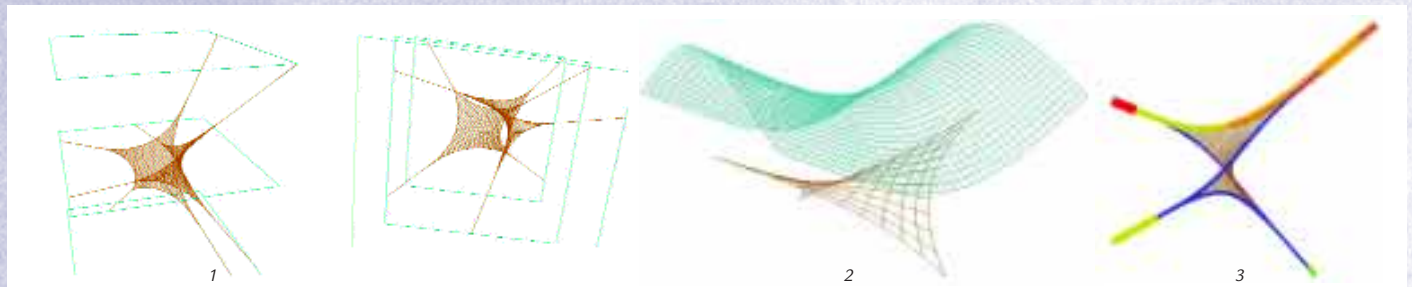


pre-stress in the structure. With the intension of developing this yearly project into an international event, we would like to welcome all students and people interested in participating next year.



<http://www.tue.nl>
 Arjan.Habraken@arup.com

- 1 · Formfinding model in GSA
- 2 · Net with equal mesh (blue) following the shape of the formfinding model (brown)
- 3 · Axial forces in the ropes
- 4 · Connecting edge ropes and the net with knots
- 5 · Assembled net in the atrium of the Building Technology Faculty, TUE



The European Design Guide for Tensile Surface Structures is a product of over three years work by the members of TensiNet - A Thematic Network for Upgrading the Built Environment in Europe through Tensile Structures, which was initiated on 1 March 2001. This guide and the other activities of TensiNet were funded by the European Commission, under the Competitive and Sustainable Growth (Growth) Programme of Framework Programme 5. The tensile surface structure business has grown considerably in the last 15 years and is predicted to grow further. Such structures are becoming bigger and more sophisticated. More clients are interested in using them but they are still considered to be special - a new technology. If tensile surface structures do not figure widely in the design vocabulary of European architects, engineers, urban planners, building owners and national authorities, their application will continue to be constrained. Therefore,

L I T E R A T U R E
European Design Guide for Tensile Surface Structures
 Brian Forster, Marijke Mollaert
 ISBN: 9 789080 868717 · Pages: 354, Soft Cover · Published: 2004 · 100,00

there is a need for people to be better informed about the general behaviour and the advantages and disadvantages of using tensile surface structures in relation to more conventional buildings. For instance, the internal environment is seen as a key issue - how do such enclosures behave and to what functions are they suited? There is also the question of maintenance. How do these structures differ from 'normal' buildings? These issues are covered in the design guide. It is a generally held view that Europe needs a code for Tensile Surface structures and this design guide is a valuable and necessary step to a pan-European Normative document. Once an EN is available the industry becomes respectable and clients' confidence should increase. In turn, that should lead to more business for constructors and designers. Nevertheless, this European Design Guide for Tensile Surface Structures is not intended to be a European standard. However, as a 'state-of-the-art' report it is a step in that direction.

