RESEARCH

LIFE CYCLE ASSESSMENT
ENVIRONMENTAL IMPACT
OF MEMBRANE MATERIALS
AND STRUCTURES

PROJECTS

Up at The O2!
GROUND BREAKING ROOF WALK PROJECT
GREENWICH, LONDON, UK

A unique PTFE coated fiberglass
TURIN UNIVERSITY, ITALY
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RESEARCH

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    Membrane Materials and Structures

   LCA  THE NEW TENSINET WORKING
   GROUP ON LIFE CYCLE ASSESSMENT FOR MEMBRANES

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20  WEBSITE TO DISCOVER
Edited

One of the main TensiNet events in the near future is the **TensiNet Symposium 2013** (Istanbul, May 8–10). As during the previous Symposia, the TensiNet Association brings together researchers, practicing architects, engineers, membrane or foil producers, manufacturers and installers of tensile surface structures. The multidisciplinary approach, considering the process from concept to set-up, from material design to architectural realization gives this event an inspiring and enriching character. Abstracts can be uploaded at the website www.tensinet.com until the 8th of October.

Another important TensiNet event will be the kick-off workshop of the new TensiNet Working Group on **Life Cycle Assessment for Membranes** (Stuttgart, October 11–12). An ambitious project will be launched, which is crucial for the whole sector as we want to contribute to a ‘sustainable’ future.

Within our association we are confident that ‘structural textile’ is a fifth building material. The design and analysis of Membrane Structures should be performed by an integrated model and hence, consistent with the respective Eurocodes for constructions in steel, aluminium and wood. To strengthen this opinion, we repeat the invitation launched in the last TensiNews FLASH: ‘Three years ago CENTC 250 has identified the need for a new EN Eurocode for Membrane Structures. From a recent discussion however we understood that the Commission is not considering Membrane Structures as a priority to support the establishment of a specific Eurocode. So we ask our members to write a letter to Mr. Vicente Leoz, Head of Unit Construction, DG Enterprise, European Commission in which the importance of a Eurocode for Membrane Structures is argued... We will collect all letters and send them as a package to Mr. Vicente Leoz.’ We thank in advance all members for helping us in this action.

Looking to the broader list of upcoming events, we see a growing interest in Textile Architecture, Transformable Structures, Membrane structures and/or Structural Membranes. We are happy to be able to contribute to several events. A special issue of the International Association for Shell and Spatial Structures-journal will be devoted to Structural Membranes and will contain the best papers of TensiNet 2013, IASS 2013 and Structural Membranes 2013. With this concertated action we hope to exchange valuable research results, to stimulate young engineers to apply for a research grant and to trigger new research initiatives.

**Forthcoming Meetings**

**WGs Workshop** in Stuttgart, Germany
WORKSHOP “Goal & Scope” WG LCA
Thursday 11 & Friday 12/10/2012
Location: PE INTERNATIONAC, Stuttgart, Germ.

**TensiNet Meetings** in Vienna, Austria
Thursday 22/11/2012
13:00 Working Group Meetings
17:00 Partner Meeting
18:00 Annual General Meeting
19:00 Lecture
in collaboration with Vienna University of Technology - Master Membrane Lightweight Structures
Location: OIAV, Vienna, Austria

**WG Meeting** in Paris, France
Core group meeting CEN/TC250 WG5
Wednesday 5/12/2012 10:00 - 16:00
Location: Groupe AFNOR,
11 Rue Francis de Pressensé,
La Plaine Saint-Denis cedex, France

**Forthcoming Events**

**Essener Membranbau Symposium 2012**
Universität Duisburg-Essen, Germany
www.uni-due.de/imi
28/09/2012

**International Textile Conference**
Dresden, Germany
www.aachen-dresden-itc.de
29-30/11/2012

**TensiNet Symposium 2013**
Mimar Sinan Fine-Art University, Istanbul, Turkey
www.tensinet2013.org
8-10/05/2013

**Techtextil 2013**
Messe Frankfurt, Germany
11-13/06/2013

**2nd International Conference on Structures and Architecture**
ICSA 2013
Guimarães, Portugal
www.icsa2013.com
24-26/07/2013

**Transformables 2013**
Seville, Spain
www.transformables2013.com
18-20/09/2013

**2013 IASS**
Annual Symposium: Beyond the Limit of Man
Wrocław, Poland
http://www.iass-structures.org
23-27/09/2013

**Structural Membranes 2013**
VI Int. Conference on Textile Composites and Inflatable structures Munich, Germany
9-11/10/2013
http://congress.cimne.com/membranes2013

**TensiNet SYMPOSIUM 2013, Istanbul**
Wednesday 8, Thursday 9 and Friday 10 May

**[RE]THINKING lightweight structures**

**MIMAR SINAN FINE-ART UNIVERSITY, ISTANBUL, TURKEY**

A three-day symposium where the Plenary sessions will refer on the one hand to the Tensinet Working groups with [RE]THINKING Analysis & Materials (Peter Gosling); ETFE (Rogier Houtman); PNEUMATIC STRUCTURES (Matthew Birchall) and [CLOSING THE LOOP] Life Cycle Assessment for Membrane Materials and Structures (Jan Cremers). On the other hand interesting projects will be presented. Prominent experts in the membrane architecture and engineering world will introduce each plenary session. The keynote speakers Horst Berger, Markus Balz & Christoph Paech (sbp), Matthew Birchall (Buro Happold), Shajay Bhooshan (Zaha Hadid Office), Jan Cremers (Hightex), Ken’ichi Kawaguchi, Alar Ruutopold (Saint-Gobain) and Werner Sobek (Werner Sobek Stuttgart GmbH & Co. KG) have already confirmed. More information and updates on the keynote lectures & program, venue, hotels, social event, sponsoring, etc. on www.tensinet2013.org

**Call for ABSTRACT** Abstracts should not be longer than 300 words and should indicate the topic(s). Papers should not be longer than 2500 words and 10 pages figures included.

Upload your abstract on www.tensinet.com

**Timing - deadlines updated**
- abstract submission - 8th October 2012
- abstract acceptance - 12th November 2012
- paper submission - 21st December 2012
- paper acceptance - 4th February 2013

**TENSINEWS NR. 23 – SEPTEMBER 2012**
**Kadzielnia Amphitheatre**

**Context**
In the historic place called Kadzielnia, located in the Polish city Kielce, the new amphitheatre with a membrane roof over the audience and the stage has been erected. The structure consist of a permanent roof over the scene and a retractable roof over the audience (Fig. 1 to 4).

**Project**
The area of the retractable membrane roof is about 2700m² and of the permanent membrane roof 1500m². The membrane roof over the audience is used only in the summer. The permanent roof over the scene must withstand a 1.8kN/m² snow load. The span of the main cable over the scene is 35m and over the audience 55m. The rigid structure consists of two sets of columns (one behind the stage and one behind the audience), and a pendulum frame in the middle. The pendulum frame, with a span of 35m is stabilized by main cables.

The pendulum frame is foreseen as a garage for the folded membrane, which is stored during the winter. The technical solutions of the retractable roof were inspired by the retractable roofs at Fortress Kufstein designed by Alfred Rein Ingenieure and by these of the Frankfurt Stadium and Warsaw National Stadium designed by Schlaich Bergermann und Partner. Unique in the Kadzielnia amphitheatre structure is that the retractable roof is not built on a closed system. The edge cable of the retractable membrane deflects inwards during the process of folding and tensioning of the membrane. In order to enable large horizontal deflections of the edge cable, a special double hinge rotary head, connecting the cable to the column, was introduced (Fig. 5).

**Technical aspects - driving system**
The mechanism of the roof tensioning consists of three main assemblies:
- cable winches
- hydraulic system
- automatic and calibration systems

The cable winch is installed on a column, where the main roof cables are installed as well. The winch frame is mounted on the rotary head of the column, therefore the position of the winch is adjusted to the changing direction (during tensioning of the roof) of the main cable.

The unit of the servomotors is located on the winch frame and is responsible for: tensioning the cable unfolding the membrane (1), gripping the first membrane pulling trolley (2), final membrane tensioning (3) and locking the membrane in a final position.
position (4). After the final locking of the membrane, all mechanical, hydraulic and controlling devices may be set off. In this stage the membrane is finally locked and preserved.

The whole structure was erected in a very short period of ten months. The design process started in August 2009 and the structure was completed in June 2010. One month later the first concerts took place.

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Context
In time with the start of EM 2012 the city of Warsaw was implementing the visitor infrastructures. The bus loop “Dworzec Wschodni (Lubelska)” is located in the immediate vicinity of the Warszawa Wschodnia railway station facing Lubelska street, nearly by the new National Stadium. It enables convenient transfers from buses into long-distance trains and commuter trains operating to Warsaw city centre and Chopin Airport.

Project
The bus loop has five platforms with 12 stops, the whole area is covered with a tensile roof structure. Under the canopy there is also a monitored parking space for bicycles.

The idea of the architects was to create a roofing structure similar to the National Stadium in Warsaw and Stadium Miejski in Poznań, looking at innovative and multi-functional materials.

Due to the given straight design lines given by the initial concept design, the engineer had to provide the correct mechanical solution taking in account upward wind and huge covered surface. The five membrane bays are been therefore designed on the valley cable principle, integrated with a smart water collection system to avoid to the visitors any inconvenience in winter time.

The fabric panels are clamped all around to the supporting steel structure and to the front and back cables by the means of double clamping plates and connected to the steel with steel straps, all covered by closing flaps. The valley cables are disposed in a Y-form on the membrane surface, connected at the field top area over a circular fabric opening.

Paolo Giugliano
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Warsaw, Poland

<table>
<thead>
<tr>
<th>Name of the project:</th>
<th>Bus Station “Warszawa Wschodnia”</th>
</tr>
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<tbody>
<tr>
<td>Location address:</td>
<td>Lubelska street, Warsaw</td>
</tr>
<tr>
<td>Client (investor):</td>
<td>City of Warsaw, ZTM Warsaw</td>
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<tr>
<td>Function of building:</td>
<td>Bus Station</td>
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<td>Year of construction:</td>
<td>2012</td>
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<tr>
<td>Architects - Tensile Architecture concept:</td>
<td>Massimo Maffeis Engineering and Consulting, Italy</td>
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<tr>
<td>Architects - Complete Design:</td>
<td>Mott MacDonald Polska Sp.z o.o., k2 engineering Andrzej Kowal</td>
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<td>Structural engineers:</td>
<td>k2 engineering Andrzej Kowal</td>
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<td>Consulting engineer for the membrane:</td>
<td>k2 engineering Andrzej Kowal</td>
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<tr>
<td>Main contractor:</td>
<td>Strabag Sp. z o.o.</td>
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<td>Contractor for the membrane:</td>
<td>KONTENT Ryszard Koniewicz</td>
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<td>Supplier of the membrane material:</td>
<td>Mehler Technologies, Germany</td>
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<td>Manufacture and installation:</td>
<td>KONTENT Ryszard Koniewicz</td>
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<tr>
<td>Material: VALMEX® FR 1400 MEHATOP F type IV</td>
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<td>Covered surface (roofed area):</td>
<td>approx. 3400m²</td>
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<tr>
<td>Length of the membrane roof:</td>
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<td>Span between girders:</td>
<td>14.20m</td>
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<tr>
<td>Length of main girder:</td>
<td>49.50m</td>
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MEHLER TEXNOLOGIES
COVERING FOR THE
Bus Station
WARSZAWA WSCHODNIA
Warsaw, Poland

Figure 1. Rendering and general view of the Bus Station
Figure 2. Connection details
Figure 3. Permanent membrane roof over the stage
Figure 4. Retractable membrane roof over the audience
Figure 5. Detail of the double hinge rotary head
Figure 6. Von Mises stresses in the structure
Context

The Millennium Dome, designed by Rogers Stirk Harbour + Partners with Buro Happold, was completed in 1999 on the Greenwich Peninsula in London. Originally commissioned to mark the beginning of the new Millennium, the landmark structure also formed a key element in the redevelopment of the entire Greenwich Peninsula. It boasts an impressive scale with a 2.2 million cubic metre enclosed space, a circumference of one kilometre and a maximum height of 50m. Intended to be an iconic and celebratory structure offering an enormous and flexible space, it has since been redeveloped and operated by AEG, one of the leading entertainment and sports presenters in the world. Now rebranded as The O2, the structure is the world’s most popular music and entertainment venue. In July 2011 planning permission was granted for the construction of a roof walkway across the top of the structure, designed by Rogers Stirk Harbour + Partners with Buro Happold. As Matthew Birchall, Director for Structures at Buro Happold explains “As the original consulting engineers and co-designers for The O2 we were delighted to be invited to design this latest addition to the London skyline. The roof walk is a combination of architecture, engineering and extreme visitor experience and represents the only installation of its kind anywhere in the world”. Up at The O2 is a partnership between AEG and O2, the UK’s leading communication company.

Proposal

The climbing experience begins on the south side of The O2 where a staircase and glass lift connect to a platform 7.5m high. From here the fabric walkway suspends above the existing fabric structure to its apex with a lanyard cable and handrail running the full length of the walkway. Climbers will be provided with ‘climb suits’ and harnesses enabling them to be attached directly to the cable as they climb to the top. At The O2’s apex a 12m diameter viewing platform with a panorama plate directs climbers to key London landmarks. The roof walk then extends to the north side where climbers descend to ground level (Fig. 1).

Brief

Main contractor ISG was formally appointed to deliver the project in October 2011 when, working closely with the client, they were instrumental in bringing together the specialist team to deliver the unprecedented and complex project. With Buro Happold already acting as lead consultant, Base Structures were next to be appointed by ISG to ensure the successful and timely delivery of the scheme. Responsible for delivering the detail design, fabrication and construction of the unique cable tensioned walkway and central viewing platform, Base immediately began extensive surveying of the site and prototyping of the proposed design principals.

Challenges

The overall challenges of delivering this project were extensive – the integrity of the existing structure could not be affected; no hot works could be used on the fabric roof; and no crane in existence could reach far enough to fully access the site. As if the daunting challenge of realising the architect’s vision was not enough, there was also a very tight and immovable deadline to contend with - The O2 arena was due to be handed over for the London 2012 Games within a matter of months.

Solution

The technical challenges this project presented were considerable. The first problem to overcome was to ensure it was actually physically possible to walk up the fabric surface – no small feat given 30° inclines and the inclemency of the English weather. To help increase traction, fabric manufacturer Mehler created a bespoke PVC fabric for this project with a non-standard textured surface. Whilst this improved grip it soon became clear that more radical surface modifications would be needed on the steepest slopes, especially in the rain – the roof walk needed to be challenging but not impossible.

Slipping and sliding

A wide range of surface...
Project highlights

- Ground breaking roof walk project over The O2 in Greenwich, London
- Survey of entire structure carried out to ensure it conformed to original design
- Unique installation systems to overcome challenging logistical problems
- All materials and tools manually transported to the apex of The O2
- Bespoke fabric solution created
- Extremely tight and immovable deadline of the London 2012 Games

modifications on the PVC fabric were manufactured and set up on a bespoke test rig, replicating a full size panel of the walkway set at the precise angle of the steepest section. With key people present from all parties involved in the project, testing ensued with volunteer climbers suitably harnessed and roped up, with a hosepipe to simulate the worst rain imaginable. After much slipping, sliding and the occasional tumble the results were clear; the only successful solution emerged to be thick ribbing, applied perpendicularly to the length of the walkway (Fig. 3).

Crane conundrum

Although the design team were confident that it was now possible to actually climb up and down the walkway come rain or shine, a key logistical challenge remained; no crane existed with enough reach to access the centre of The O2. With over 6000m² of fabric and over 7km of steel cable to transport into place, this left Base with a significant problem. All possibilities were considered, from cutting a hole in the roof to pass materials through to even using a helicopter. Eventually a completely unique system was designed to manually convey the 30 tonnes of tools and materials over the roof - pulling custom built sledges over a protective pvc runway laid on the surface of the existing fabric roof, preventing any damage to the fragile surface. Duncan Baird, Installations Manager at Base explains “We manufactured two different types of sledge, one to transport the viewing platform steelwork and another for the walkway fabric with the size, shape and configuration carefully calculated to safely spread the largest loads. As far as we are aware no one else has used this type of system before.”

Crank and slide

Weight restrictions on the roof meant that instead of using a powered winch, each sledge needed to be manually pulled up the roof using a tirfor, a manual, mechanical cable-pull with a long crank arm. With each crank of the lever pulling the sledge only 50mm at a time, it took over 2800 cranks to pull a single sledge to the top of The O2 – and with over 200 sledge trips needed for the whole project it is safe to say we had the fittest rigging team around!

Once at the apex the materials were hoisted into place using another innovation – a skyhook. Suspending a cable and hook system from the yellow masts allowed the team to easily lift everything into place without causing any strain or loading on the existing roof (Fig. 2 and 4).

Viewing platform

With the sledge and skyhook systems in place the first phase of installation involved assembling the steelwork for the central viewing platform at the apex of The O2, a key milestone since this was the first visible part of the structure to go up. With no hot works allowed on the fabric roof the steelwork was fabricated to simply bolt together like a huge Meccano kit. Support cables attached to the yellow masts take the weight of the steelwork, again ensuring no loads are applied to the existing roof surface. Only with the viewing platform completed could the fabric walkway installation now begin, from the centre of the structure down to the ground (Fig. 5).

Walkway manufacture

Back at Base HQ manufacture of the fabric continued in earnest with 75 panels making up the whole walkway, including the side wing panels. The panels for the steepest sections of the walkway required every single piece of additional ribbing to be positioned and welded by hand, an enormous task with over 3km of ribbing in total to attach.

Before going to site every panel was fitted with cables and clamps and pre-tensioned in the factory on a special rig for quality control tests. A total of 3 kilometres of cable runs through the edges of the walkway fabric and nearly 4000 clamps are used to attach the panels to the supporting cables on
The O2. The mammoth task of fitting all this hardware in the factory meant that the rigging team on site could simply lift each section into place and secure it to the previous panel and support cables (Fig. 6).

Best of British weather
As a continual supply of the fabric panels ready for install reached site, one of the biggest problems that was to face the rigging team soon became apparent – the weather. High winds make working on such an exposed site with huge pieces of fabric unsafe and this cost the team a significant number of days. Whilst it is generally only wind that causes delays for tensile fabric installations, Mark Smith, Head of Projects at Base, explains how things got even trickier “It was always going to be a challenge but not one that we weren’t used to. However, we weren’t expecting the wettest ever April on record, which meant we had to work most weekends throughout the project in order to recover the lost time.”

Increasing the tension
After pulling out all the stops the walkway panels were all finally in place and the entire structure could be carefully tensioned out - a delicate procedure that must be coordinated perfectly to prevent uneven loads being applied to the masts. It is at this stage that the side wing panels are also unfurled along the length of the walkway. Whilst these provide an extra safety precaution, being made of white mesh means they blend into the surface of The O2 below, so as not to lessen the sense of adventure. As the walkway revealed itself in its final completed form, and with all hands on deck to complete the finishing touches in time for the grand opening, it became clear that the race had been won – just.

Results
On 23rd May 2012 Up at The O2 was officially announced to the world, with the first paying climbers making the journey over The O2 on 21st June. With the works completed on time the venue could now be safely handed over for the London 2012 games, to the great relief of all involved.

Ben Luger: benl@basestructures.com
www.basestructures.com/projects/up-at-the-o2.html

Team
Alistair Wood,
Senior Vice President of Real Estate & Development, AEG
Eamonn Wall,
Project Director, ISG
Jon Clayden,
Senior Construction Manager, ISG
Tim Finlay,
Senior Structural Engineer, Buro Happold
Mark Smith,
Director/Head of Projects, Base Structures

Name of the project:  Up at The O2
Location:  The O2, Peninsula Square, London, SE10 0DX
Client (investor):  AEG
Function of building:  Extreme roof walk experience
Type of application of the membrane:  Fabric walkway
Year of construction:  2012
Architects:  Rogers Stirk Harbour + Partners
Multi disciplinary engineering:  Buro Happold
Structural engineers:  Buro Happold
Consulting engineer for the membrane:  Buro Happold
Engineering of the controlling mechanism:  Buro Happold
Main contractor:  ISG
Contractor for the membrane (Tensile membrane contractor):  Base Structures Ltd
Supplier of the membrane material:  Mehler Technologies, Germany
Manufacture and installation:  Base Structures Ltd
Material:  Embossed PVC and PVC mesh
Covered surface (roofed area):  4200m²
Span:  350m
Maximum height above ground:  53m

Verona, Italy

Context
The new multifunctional Verona Forum Center is developed on the “Ex Foro Boario” site. The project consists of 2 building complexes. One is an office building, while the other contains a hotel and wellness areas. The Wintergarden project developed with an ellipsoidal shape is part of the hotel complex sitting aside of the main building.

Project
The winter garden structure has been designed by architect Mario Bellini. It is a multipurpose covering for the Crowne Plaza Hotel in Verona. The structure consists of 7 transversal timber arches, which are connected to concrete foundations. The arches have a different shape to generate the volume of a soft curved structure. At one side of the structure there is a cubical technical building. At the opposite side there is an entrance area, which has a vertical façade. The 7 arches are connected with 11 longitudinal ribs. These curved ribs connect all arches to the technical building. The steel profiles also act as bearing.

Figure 1. Moke up for the simulation of the transparency/opacity ratio and the pattern intensity © Carol Monticelli
Profiles for the ETFE foil cushions. Together with the Politecnico of Milano, architect Carol Monticelli, made a study on the different patterns and layers in order to reach the best results for the modulation of the shadow and the transparency of the material.

The ETFE cushions are 4 layer cushions. The upper and the lower layer have a thickness of 250μm each. The inner layers have 100μm thickness. The nominal pressure in the cushion system is 300Pa. In winter time this will be increased to 600Pa and in case of reasonable snow fall up to 800Pa.

A minimized attachment detail has been developed for the ETFE cushions. Perpendicular to the surface small steel plates are placed to which on either side the cushion is attached with a small extrusion profile. A soft gutter is integrated in this connection detail to guide condensation water towards the lower ends, where it is further guided to the drainage system.

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At the Politecnico di Milano (Cluster CLUStex ARCHITETTURA TESSILE) and in collaboration with Canobbio SpA the transparency/opacity ratio and the pattern intensity of the ETFE foil cushions was studied.

Physical technical requirements:
- average thermal transmittance of the cushions U value = 1,5W/m²K
- average diffuse solar factor G value = 0,3

In order to satisfy the requirements and to dispose of different lighting rates from the top to the bottom of the pneumatic covering system, the opacity of the cushions varies within a range 50÷70% (1-2 printed foils) over the whole envelope.

Research Carol Monticelli - Coordination Alessandra Zanelli
Context
The restoration of the historic Wroclaw Railway station was completed just before the Euro 2012 competition. The project was performed by grupa 5 architects, who won the competition organized by the city of Wroclaw in 2008. The winning project connects beautifully the Neo-Gothic and Art Nouveau architecture with modern solutions.

The Wroclaw (Breslau) railway station was built in the years 1855-1877 as a main railway station beside two other already existing stations. It was designed in English Neo-Gothic Tudor style. In years 1899 – 1904, the station was expanded and reconstructed. The Neo-Gothic architecture of the main building was preserved, but the new main hall and four platforms were designed in the Art Nouveau style. Now the main railway station needed a restoration and extension. The historic style of the existing buildings was maintained and the new elements were designed in a modern manner connecting the glorious past with contemporary architecture.

Among other new elements the membrane roof was introduced to cover the open space between the two existing roofs. The open space was originally foreseen as a locomotives berth. The area was not roofed, to allow steam to escape. Nowadays, as the steam locomotive have disappeared the area could be covered.

Project
The idea of the architects (grupa 5) was to design a light roof, which would not violate the beauty of the historic Art Nouveau architecture. The new roof was designed as a membrane structure, tensioned on steel arches, which covers the area of four platforms between two old sheds (Fig. 1). The structure of the membrane roof consists of 12 similar fields. The dimensions of a singular field are 21x11.40m. The total dimensions of the membrane roof are 84x34.2m (Fig. 2). The main bearings elements are longitudinal, perpendicular and diagonal arches made out of tubes with a diameter of 356mm. The shape of the arches refers to the original arches of the German architect Bernard Klusch, built in the years 1899-1904. In the dome surface of the roof, bracing are applied. The roof is situated in a first snow zone, thus total snow load is 1.05kN/m². According to the requirements of the Polish law concerning snow removal, in the low points of the membrane on the columns, huge openings were introduced. The membrane is attached to the main longitudinal arches on the bottom side (Fig. 3). In this way the steel structure (arches and bracings) is visible from the platform only on sunny days as a shadow on the membrane. The use of the translucent membrane (Mehler Mehatop F IV) gives a lot of light to the platforms and brings a friendly and pleasant atmosphere.

Andrzej Kowal
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NEW ROOF FOR
railway station

Wiesloch-Walldorf, Germany

Context
Autumn ’09 I was invited to present a design for a membrane roof structure at the ICE railway station at Wiesloch-Walldorf, located close to Heidelberg and well known through SAP. An existing pedestrian bridge as well as a pedestrian path along various bus stops on top of a new two storey car park building had to be covered. This hundred Meter long walkway connects bus station and car parking with train platforms as well as Wiesloch with Walldorf.

Our goal was to create as little impact as possible to the existing environment. Space for founding was limited. The pedestrian bridge was not designed to receive any additional forces. The railway platforms and the car park building had to be kept free of columns. Beside our client wished a significant sign, a strong and at the same time assortative design, in between the disorder of many structural elements like platform roofs, stairways, lifts, electrical equipment of high voltage power lines. Spring 2010 our design was accepted in all political committees. A year later all tender documents were prepared. In autumn 2011 Taiyo Europe received the contract.

Project
Two pylons located between car park building and railway station area support 24 cables to support the smoothly bended main steel tubes. 20 saddle-shaped white membrane elements generate the required appearance. Each unit is approximately 10*5m large. The supporting steel structure consists out of a three-dimensional steel framework. The bearings are limited to supporting steel struts at both ends and in the centre.

A mayor challenge had been the installation procedure, due to the strict rules of the Deutsche Bundesbahn. Some 18 months before the lift over the tracks took place, the exact date had to be agreed. It was from 1.00 AM to 4.00 AM at 1st June 2012. The high voltage power line had to be switched-off and a defined security procedure had to be followed.

Half past midnight the lift started. Around 4 o’clock 1st June ‘12 the 700tons crane could turn back. Just in time!

It was an extremely exciting exercise for everybody involved in the process.

Thanks at that point to all participating persons.

Michael Kiefer: michael.kiefer@k-ta.de
www.k-ta.de

Name of the project: New roof for railway station.
Location address: Wiesloch-Walldorf, Germany
Client (investor): MetropolPark Zweckverband Wiesloch-Walldorf
Function of building: Covering of walkway between bus station and railway platforms
Type of application of the membrane: Saddle-shaped surface structure
Year of construction: 2012
Architects: Michael Kiefer, Freier Architekt (K.TA)
Structural engineers: Tobias Lüdeke, Manfred Schieber (both K.TA)
Consulting engineer for the membrane: Tobias Lüdeke
Main contractor: Taiyo Europe
Contractor for steel structure: Zeman GmbH
Supplier of the membrane material: Verseidag
Manufacture and installation: Flontex Polen/ Montagebau Lenk
Material: Verseidag PTFE/ Glas
Covered surface (roofed area): ca. 1000m²
Membrane assembling system: Tennect (Carl Stahl)
Environmental Impact of Membrane Materials and Structures

THE NEW TENSINET WORKING GROUP ON LIFE CYCLE ASSESSMENT FOR MEMBRANES

Increasing energy efficiency in the operation of buildings is a major challenge of our time. But we also have to focus on the energy consumption ("grey energy") and environmental impact of the materials and structures used for our buildings - with regard to their full life cycle, from the production to recycling or disposal. It is important to understand that the effects of our planning decisions extend deeply into the future. Most buildings are meant to last for decades. Our industry is proud to also offer this perspective to our clients when they embark on our materials and structures. In parallel, the planet’s resources are shrinking and get more and more contested and hard-fought. Compared to other industry branches, the building sector is still lacking efficiency in the use of materials and rationalisation, the overall recycling rate is very low.

With regard to the membrane industry we see a Janus-faced discussion: On the one hand we apply polymers that use enormous amounts of energy for their production. They contain a high amount of primary energy in relation to their mass (Fig. 1), and emissions from some of the materials can represent dangers for the environment and users. On the other hand, they have an undoubted potential for generating resource and energy savings through forms of construction that utilise these materials very efficiently. Membrane material’s mass per area is very low.

Life Cycle Assessment (LCA)

Some months ago, a new working group has been founded by an initiative of the author which will focus on the subject of Life Cycle Assessment (LCA) in our industry. The aim of this group is to review the current status on membrane materials and typical membrane structures with regard to LCA issues which can be used as a key evaluation criterion in the objectification of the discussion on membrane materials that our industry is based on (Fig. 2).

The LCA approach aims for a transparent objectification of the discussion on membrane materials and rationalisation, the overall recycling rate is very low.

The LCA method which can be split into four phases: definition of goal and scope, inventory analysis, impact assessment and interpretation (Fig. 3). In a final step all results like reports and declarations have to be scrutinised by an independent group of experts which is essential if comparative statements, e.g. with respect to rival products, are to be made or the results are to be made public.

Environmental Product Declarations (EPD)

Drafting a product LCA is a time-consuming and expensive process that is generally carried out for the product manufacturer or a group of manufacturers by a specialist company. The ecological characteristics of a product are communicated in the form of environmental declarations. According to the ISO 14020 family, these environmental product declarations (EPD) are classified as so called “type III” environmental labels which are highly regulated. Here, the most important environmental impacts of products are described systematically and in detail. The starting point is a product LCA, but further indicators specific to the product (e.g. contamination of the interior air) are also included. In this form of declaration it is not the individual results of measurements that are checked by independent institutes, but rather conformity with the product category rules (PCR) drawn up to ensure an equivalent description within that product category. An EPD describes a product throughout its entire life cycle – it contains all relevant environmental information.

Environmental Product Declarations (EPD) help in early planning stage, they show environmental performance of a product or a product group, they are often used in political discussion and can be a basis for a company’s internal benchmark and improvement.
Why we? And why now?
Why it is important for our industry to pro-actively address the LCA issue now?

- Building assessment systems with country-specific priorities for indicating the building’s, like for example LEED (Leadership in Energy and Environmental Design), BREEAM (Building Research Establishment Environmental Assessment Method), DGNB (German Sustainable Building Council). The latter was one of the first methods to prescribe a certification system that looks at the entire life cycle of a building and also includes a type of building LCA based on EPDs of the individual construction products (Fig. 4). This puts the focus of planners, users and investors to environmental impact of a whole building (including the LCAs of construction products). "Green Building" is a highly growing market share;
- Competitive situation by comparing membrane materials and structures to alternatives with LCA data available;
- Defence against prejudices based on missing, insufficient, misleading or wrong LCA data;
- Customers awareness. Communication on environmental product performance gains importance for manufacturers and will strengthen customer relationship;
- LCA data will become more and more important in tendering and award procedures. This also applies to the use for Construction Product Regulation;
- Existing and future legal regulations on waste concerning the building industry.

Although the importance of the various sustainability criteria may vary, issues considered to be important include:

- Energy and carbon dioxide emissions (from building operation);
- Materials and resource use (including embodied energy);
- Waste minimisation, including recycling;
- Transport (in relation to the use of the building);
- Water conservation and use (within the building);
- Land use and ecology;
- Minimising pollution;
- Construction and building management (including security);
- Health and well-being within the building.

Material and building component selection has a direct impact on the building design and performance and hence affects the operational energy use and the health and well-being of its occupants. Therefore, the industry needs to quantify these benefits in order to maximise its sustainability credentials.

Some more background
With the advent of the European single market for construction products, the European Commission became concerned that national EPD schemes and building level assessment schemes would represent a barrier to trade across Europe. The EU therefore sought a mandate from the EU Member States to develop European standards for the assessment of the sustainability performance of construction works and of construction products. This mandate is called CEN/TC 350. From 2010 European standards began to emerge from this process and Standard BS EN15804 was published in February 2012 providing core rules for construction product EPD.

The Construction Products Directive of 1989 was one of the first Directives from the EU Commission to create a common framework for the regulations on buildings and construction products. It has been replaced by the Construction Products Regulation (CPR) and is legally binding throughout the EU. The CPR includes requirements for the sustainable use of natural resources, the reduction of greenhouse gas emissions over the life cycle and the use of EPD for assessing and reporting the impacts of construction products. If an EU Member State wishes to regulate in these areas of sustainability it must use European standards where they exist when regulating and must withdraw national standards. This means that in the case of the CPR a Member State must use the CEN/TC 350 suite of standards.

An EPD provides robust and consistent information that can be used in building level assessments and the guide elaborates on the variety of ways that this can be done. In addition a number of building level tools are emerging aimed at improving decisions at the design stage by combining embodied environmental impact data and whole life cost data (i.e. economic) and link them to BIM (Building Information Modelling) data. Across Europe, the various environmental rating schemes are seeking to harmonise the ways in which they assess products and buildings. Increasingly models are emerging to link embodied impacts with operational data thus enabling a better understanding of the trade-off between operational and embodied impacts and in time benchmarks for different types of buildings will emerge. All of which contributes greatly to the goal of a low carbon, more resource efficient, sustainable built environment. [2]

Where we are and next steps
The status reached so far is rather heterogeneous and inconsistent for the typical materials we use. There are some forerunners, for example there is a first (but only company specific) EPD on ETFE (Fig. 5). On the level of structure types, there is hardly any information...
available so far. The LCA Working Group will identify and describe steps that could be taken within the Tensinet association to achieve a coherent data base to work with. It should also be as open and transparent as possible to gain a maximum of credibility.

Kick-off workshop
As a next step we will have a kick-off workshop in Stuttgart with LCA-consultancy PE International on October 11th/12th. Aiming to define goal and scope of a common project, our topics are:

- discussion and agreement on the goals of the LCA/EPD membrane project;
- specific, average or template EPDs, value of an EPD calculator?;
- clustering of comparable products for EPDs;
- definition scope of the work;
- proposal for products to be included (PTFE/glass, ETFE, PVC/PES, PTFE fabric, PTFE glass laminate, silicone glass fabrics, others?);
- agreement on producers and sites to be included;
- agreement on contractual and financial solution.

The idea of having a common successful LCA/EPD membrane project is based on some assumptions:

- joint project of several producers and other players of the membrane sector;
- for each product group there is at least one producer of final product involved and willing to contribute;
- the project is managed by a neutral third party (PE International) to allow for confidentiality in data handling, producers will supply data in agreed time schedule.

Following the workshop we intend to structure the LCA project in the following tasks:

- Development / adaption of the PCR-Documents;
- Data collection for the production of Membranes;
- Data collection for the End-of-Life Scenarios;
- Provision and development of the upstream data (supply chain data);
- System modelling and calculation of the LCA results;
- Documentation of the LCA and development of the EPDs.

So far, there are amongst others the following manufacturers involved: Dyneon, Verseidag-Indutex, Serge Ferrari, Saint-Gobain PP, and Sefar. We hope that even more relevant and important players in the membrane world understand the chance of this project, also with regard to economical benefits compared to individual actions on the subject. Thanks to the Tensinet Board, the kick-off workshop will be free of charge to all the participants.

If you are interested to join us for the workshop or generally for the group, please contact the author via email (jan.cremers@hft-stuttgart.de).

Hightex Group is a specialist provider of large area architectural membranes for roofing and façade structures. Hightex has been involved in the construction of a number of high profile buildings including Cape Town Stadium and Soccer City Stadium in Johannesburg, the Wimbledon Centre Court retractable roof, the roof of the Suvarnabhumi International Airport in Bangkok. Recent projects include the new stadia of Warsaw, Kiev, Vancouver, and most recently Porto Alegre and Maracana in Brazil.

If you are interested to join us for the workshop or generally for the group, please contact the author via email (jan.cremers@hft-stuttgart.de).

REFERENCES

PICTURES AS FOLLOWING:
4: DGNB/ PE International
5: Institut Bauen und Umwelt e.V.
6: taken from [2], p.5
Context
There are many different methods to cover the roofs. The contribution of these coverings, which are made of conventional structural elements, diminishes since they are used very often in the beginning of the project and have the tendency to become complex. Both with the texture of the material, and different third dimension aesthetic perception, the membrane architecture add the harmony of movement and conflict to the project.

The architect, who designed a stadium in Turkmenistan, decided to use the membrane architecture as the product of such a thought. This structure is made as an idea of using it for 2017 Asian Olympic Games, covering an area of approximately 25,000m².

Project
Within the 20,000 spectator capacity Ashgabat stadium complex steel roof is covered with an interesting membrane system. The stadium roof is solved as a cantilever steel truss. The cantilever steel truss is interconnected with cross vaults which are supporting the membrane. Arch membranes are frequently installed as ring rope roofs for stadiums, with the arch being supported with a hinge on the carrier cable and the warp direction of the fabric mostly running at right angles to the arch. When several arches are arranged next to each other, the membrane is mostly pulled in along the arch from rope truss to rope truss.

The installation of the arch and the pulling in and tensioning of the membrane are mostly done field by panel from scaffold hanging under the rope trusses or by abseiling. To stabilize the arches, temporary ropes tensioned diagonally in three dimensions can be installed during the erection.

When pulling on the membrane in the arch direction, it is first anchored to the end points, in order to mount the edges to the truss. After pulling the membrane to the opposite side, it can be successively tensioned against the truss starting in the middle and fixed by mounting the edge elements. The fabric, folded longitudinally, was lifted transverse to the arch trusses and unfolded on both sides over the secondary arches.

After fixing the membrane to the corner points, the clamping plates were installed along the edges of the arch trusses. The introduction of the pretension was done at right angles to the arch truss by moving the preassembled keder rail sections. This was done with the help of lashing straps, with the force being introduced successively starting from the middle of the arch truss.

After the edge rope, which had already been pulled in, had been tensioned, the edge of the surface was finally tensioned through the webbing fabricated into the corners and fixed by bolting the ropes intended to secure against wind uplift to the crown of the arch.

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Name of the project: Ashgabat Stadium
Location address: Ashgabat / Turkmenistan
Client (investor): State of Turkmenistan
Function of building: Stadium
Type of application of the membrane: Covering
Year of construction: 2011
Architects: Design Group
Multi-disciplinary engineering: Gelişim İnşaat Proje San. ve Tic. Ltd. Şti.
Structural engineers: Tensaform Membrane Structures Industry & Trade Inc.
Consulting engineer for the membrane: Tensaform Membrane Structures Industry & Trade Inc.
Engineering of the controlling mechanism: Gelişim İnşaat Proje San. ve Tic. Ltd. Şti.
Main contractor: Polimeks İnşaat A.Ş.
Contractor for the membrane (Tensile membrane contractor): Tensaform Membrane Structures Industry & Trade Inc.
Supplier of the membrane material: NAIZIL
Manufacture and installation: Tensaform Membrane Structures Industry & Trade Inc.
Material: NAIZIL PLUS COVER-TYPE III
Covered surface (roofed area): 25,000m²
Roof Cantilever Height: 30m / Cantilever Range: 9,5m / Total Steel Tonnage: 1268 tons
A MODERN LIGHT-ROOF FOR
the Rütlihaus restaurant
Rütli, the birthplace of Switzerland

Context
Rütli is definitely much more than a meadow - it is the birthplace of Switzerland and a cultural monument of national importance. In the last few years rebuilding and new construction projects were carried out to improve the infrastructure. At the conclusion of this work, the terrace of the Rütlihaus restaurant was slightly modernized by adding a modern light-roof. This legendary 5-acre meadow on the shores of Lake Uri, a small lake connected to Lake Lucerne, can still only be reached by boat or by foot using the "Swiss Way", a hiking trail established in 1991 that starts at the village of Seelisberg. On this meadow was, according to legend, in 1291 the oath of Rütli sworn, which made the three original cantons of Uri, Schwyz and Unterwalden eternal allies. This meadow now contains the Rütlihaus restaurant, a picnic area, the "Dreiländerbrunnen" and a small exhibition showing its history. Around 1 million people per year, including numerous high-ranking personalities from home and abroad, visit and enjoy the facilities at Rütli.

Historic value and appeal preserved
The aim of the announcement of a competition by the Federal office for buildings and logistics BBL in Bern in 2007 was for the acquisition of additional utility and storage areas for the many public events held at Rütli, such as the traditional "Rütlischießen". The highest priority was placed on ensuring that the new buildings would complement and blend in perfectly with the existing infrastructure of Rütli, which was designed in 1865 as a landscape park. This stipulation was convincingly adhered to by the winning design from the architectural firm Aschwanden Schürer AG. The central concept of this design was a decentralized organization of buildings each having their diverse functions. As part of this infrastructural improvement, the roof of the Rütlihaus restaurant terrace was to be replaced.

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Figure 1. Views from underneath the light-roof structure

Figure 2. Aerial views on the light-roof structure

Figure 3. Façade and roof plan

Project - Unique roof structure
In close collaboration with the Office for Historical Monuments, the new terrace roof of the Rütlihaus restaurant was constructed as a delicate and elegant low-height membrane structure, blending in perfectly with the landscape: the slightly inclined roofs and the spruce wood make a pleasant and refined combination (Fig. 1 & 2). The canopy consists of five linked gables (Fig. 3). Weather and UV protection is provided by a translucent membrane SEFAR® Architecture TENARA® Fabric 4T40HF, which has a light transmission of approximately 40% and allows the transmission of a mild and pleasant fraction of the sunlight. This makes the roof function like an airy pergola.

The project has been selected for the "Prix Lignum 2012". The Prix Lignum 2012 distinguishes high-quality and innovative use of wood in buildings, in interior design, furniture and works of art. (National Prize award, Zürich 27 September 2012).
Project
A golden painted carpentry support the textile membrane built to close the roof of a mall in an original way. The cap of this textile structure is a disk made of transparent plexiglass making sunrays and light passing through. The tent covers a Ø 20m circular area. The central part is supported by a ring located at the top of a pusher pole. The base of the pusher is supported by nine rod bars connected to the top of concrete columns. The covering membrane is a single layer type with a total negative curvature, stabilised through prestress. Under the membrane layer cables are located to avoid snow pounding and safety cables guarantee stability of the pusher column. The structure has been calculated according to the following standards:

a) C.N.R.-UNI 10011/88 “Steel constructions. Instructions for design, realisation, verification, use and maintenance.”

b) Draft prEN13782 European Standard “Tents-safety”.

c) UNI U50.00.299.0 “Tents, tensile structures, air-supported structures. Instructions for design, realisation, verification, use and maintenance.”

The admissible tension method is used for verifications. The covering is calculated with an elastic membrane material but with geometric non-linearity (big displacements).

Accidental loads taken into consideration were the following:
- snow: qs = 80 kN/m²
- wind: qw = 80 kN/m²

The structures are designed with the hypothesis that the lateral sides are all closed. It will be the tent manager’s responsibility to avoid that partial openings increase wind action creating inside overpressure. The loss of pre-tension can involve vibrations and flapping under the wind action, but even create pockets in which rain or snow are collected. Generally, the more sensible areas to these phenomena coincide with the areas of lower curvature. The cables used are made of galvanised steel, protected from corrosion. In spite of that, the phenomenon of corrosion cannot be fully avoided in time, above all in presence of aggressive environments, like in areas with high humidity rate, pollution and saltiness. In case of lining of cables by means of PVC or other kinds of lining, a better protection is guaranteed till lining is integral. If some cracking in the lining occurs, the corrosive phenomenon can be dangerous as it cannot be seen so clearly. So, it is very important that during the inspections the liners’ integrity condition is verified. Besides corrosion, cables can also be damaged by mechanical phenomena, especially where they come in contact with other elements, such as plates, saddles, clamp terminals, etc. in correspondence of which the inspection must be particularly careful. By this architectural application also another customer’s requirement has been satisfied, that is air conditioning of the whole premises, keeping anyway a natural light passing through this roof.

<table>
<thead>
<tr>
<th>Name of the project:</th>
<th>COSMOS MALL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location address:</td>
<td>THESSALONIKI GREECE</td>
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<tr>
<td>Client (investor):</td>
<td>COSMOS MALL</td>
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<tr>
<td>Function of building:</td>
<td>ATRIUM COVERAGE</td>
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<tr>
<td>Year of construction:</td>
<td>2006</td>
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<tr>
<td>Architects:</td>
<td>ARCH NIKOKAVOURAS, Athens Greece</td>
</tr>
<tr>
<td>Consulting engineer for the membrane:</td>
<td>Eng. Dario Ravasi, Varese, Italy</td>
</tr>
<tr>
<td>Engineering for the controlling mechanism:</td>
<td>Eng. Dario Ravasi, Varese, Italy</td>
</tr>
<tr>
<td>Main contractor:</td>
<td>ARKA SYNTHESIS LTD Athens Greece</td>
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<td>Supplier of the membrane material:</td>
<td>PM ENGINEERING SRL Senago Italy</td>
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<td>Material:</td>
<td>PRECONTRAINT 1302T</td>
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<tr>
<td>Covered surface (roofed area):</td>
<td>315m²</td>
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</tbody>
</table>
A unique PTFE coated fiberglass

Context
The new headquarters of the Faculty of Law of the Turin University is located along the river Dora on the site of the ex-Italgas area. A synergy among firms and design studios has been able to reinterpret the distribution of the pavilions: connections and passages have been added with the use of highly characterizing elements as the unique PTFE roof and the wavy façade.

Concept
The general concept of the architectural design has been developed by Architect Sir Norman Foster together with a team of architects and engineers. Simete has taken care of the structural design: the arches are connected in a system assuring the correct tension of the membrane. The roof structure is sitting on top of the concrete building covering the individual building parts below. The roof is placed with a distance above the roof slab and has only secondary sealing requirements. Between the building parts the steel structure is made with expansion joints to allow a movement, as caused by an eventual earthquake, up to 20cm in horizontal direction. The membrane cladding is not interrupted in these joints and needs to compensate the

ROOF AND FAÇADE

Turin University, Italy

Context
In Paddington on the West Side of Brisbane is the Caxton Street Precinct, famous for its entertainment venues and bustling nightlife. A new addition to the area is the Halo Lounge Bar. The structure designed to look like a halo - sitting above the nightclub. The fabric structure was built to provide for better nightclub functionality by allowing for image projection onto the internal membrane.

Project
The structure is free from above with the bracing struts designed to be no higher than the top of the columns and all within the depth of the perimeter skirt which created the architectural look required, a seamless and floating halo effect. The 498m² ‘halo’ is made from Ferrari 702 Alu Black Blockout fabric with a internal floating gutter suspended from the steel framework above. The perimeter skirt is clad with fabric on both the outside and inside. Not only does this hide all the framing but on the inside acts as a projection screen so images can be viewed by the four projectors suspended from the internal structural gutter.

The external hidden structural framing pushes the internal exposed gutter down creating an oval shape inverted cone style design. The structure required a complex design to achieve the illusion of simplicity. The solution offered is striking and stands out from other buildings in the area. The aesthetic appeal of the venue is further enhanced by the floating fabric roof which gives the Halo Nightclub its ‘halo’.

The unique, yet simple exterior of the structure required a complex design;
In essence the design is an oval shaped inverted cone. All steelwork was designed to be hidden within the depth of the perimeter skirt so no steel was visible from above the top line of the skirt or below. Only the 4 columns can be seen which are also painted black to be disguised or are hidden within internal walls. The internal structural steel gutter also acts as the support of the audio and projection equipment which disguises the actual main use to control water catchment of the membrane above. The project presented some challenges due to the irregular shape of the structure but came together to the exact specifications of both the client and the architect.

The completed “halo” has created a prominent additional feature of not only the club, but also the iconic location of Caxton Street in Brisbane.

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Components

The unusual project title „cut.enoid.tower“ represents the main components that are merged into an overall architectural structure. The distorted appearance of the two wooden plates is generated by the impact and interaction of pin-joint compression-only members and different versions of prestressed, tension-only catenoids. The unity of all elements and forces can be read as deflections which were simulated, found and analyzed by means of a series of physical and digital models. A modification of only one of the elements of the system will therefore cause a new equilibrium and variation of the whole tower-structure. 1,5km of 4mm high-performance yachting elements of the system will therefore cause a new equilibrium and variation of a series of physical and digital models. A modification of only one of the elements and forces can be understood as a first prototype and creative sculpture with complex geometrical and structural background.

Overall Geometry and Architectural Appearance

The workflow from design to reality was only possible by applying latest results of basic research in this field in combination with efficient software to solve the complex overall geometry and to convert and process the huge amount of 3d-data. The close collaboration with an excellent and courageous engineer – in this case ArtEngineering, Dr.-Ing. Switbert Greiner, Stuttgart – is another essential factor for the success of a challenging experimental structure like the „cut.enoid.tower“, which can be understood as a first prototype and creative sculpture with complex geometrical and structural background.

Context

The experimental structure „cut.enoid.tower“ was realized on the basis of the research on minimal surfaces as elements in architecture by Günther H. Filz at the Institute of Structure and Design, University of Innsbruck. At the same time this case study was part of research based teaching involving students of architecture into the process of generation. The „cut.enoid.-tower“ was erected in Austria on 1650m above sea level considering architectural and functional issues like climbing, relaxing and enjoying the stunning scenery as well as maximum wind speed of about 140km/h. The unusual project title „cut.enoid.tower“ represents the main components that are merged into an overall architectural structure. The distorted appearance of the two wooden plates is generated by the interaction of pin-joint compression-only members and different versions of prestressed, tension-only catenoids. The unity of all elements and forces can be read as deflections which were simulated, found and analyzed by means of a series of physical and digital models. A modification of only one of the elements of the system will therefore cause a new equilibrium and variation of the whole tower-structure. 1.5km of 4mm high-performance yachting robes meeting in 5697 knots were tied by students in order to produce the unique shapes of the minimal surface of a “spinning” and a “branching” catenoid, which are spanning freely shaped cut-outs. Especially the “branching” - catenoid turned out to be a challenging task in terms of finding the right boundary conditions that generate a minimal surface having minimal surface area content and equal forces in all directions at the same time (soapfilm-analogy) as well as in terms of assembly. An innovative

WEBSITE TO DISCOVER

Serge Ferrari’s flexible composite materials are installed in sport venues around the world: from the most iconic structures to the everyday practice fields for the next generation athletes.

An interesting overview:

http://architecture.sergeferrari.fr/sport-venues?langue=EN

One of the smaller sport facilities are the Royal Artillery Barracks.

Magma Studio designed three, temporary, movable, and recyclable barrack buildings made of Serge Ferrari NPP* composite material which offers unique advantages:

- being lightweight, they are as quick and easy to install as to remove and re-install;
- manufactured based on Précointrait Serge Ferrari patented technology, they are flexible, very strong, extremely stable dimensionally: characteristics that remain durable, even after several installation removal operations;
- finally, the membranes natural translucency provides the natural light contribution and recreates the variations in the sun’s strength or the clouds’ conveyed shadows, conditions to be met to ensure official approval of the performance characteristics of these sporting events, which are usually held in the open air.

Inside, 14,000m² of white microaerated Soltis 92 NPP composite were tensioned to respond to a triple concern: enhancement of thermal comfort, absorption of sound reverberation and contribution to aesthetics by concealing the building frame members, while maintaining maximum light transmission.

Finally, 10,000m² of Stamisol FT 381 NPP open-work composite material were installed to support structurally the ballistic protection screens.

Architect: MAGMA Architecture SARL
Fabrication/Installation: Base Structures
Serge Ferrari flexible composite materials:
- External envelope Précointrait 1002 S2 NPP
  Material area: 22.500m²
- Internal lining: Soltis 92 NPP
  Material area: 14.000m²
- Structural support: Stamisol FT 381 NPP
  Material area: 10.000m²