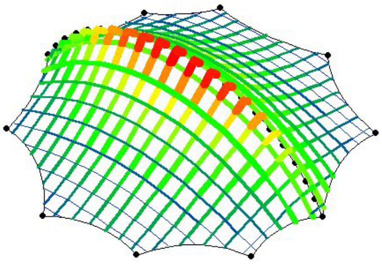

Textile Roofs 2024

April 28th - 30th, 2024

Prof. Rosemarie Wagner, KIT

Dr.-Ing. Bernd Stary, academus GmbH

Orca ten Broke seminar ship, Berlin

Report. **Prof.Dr.-Architect Josep Llorens.**
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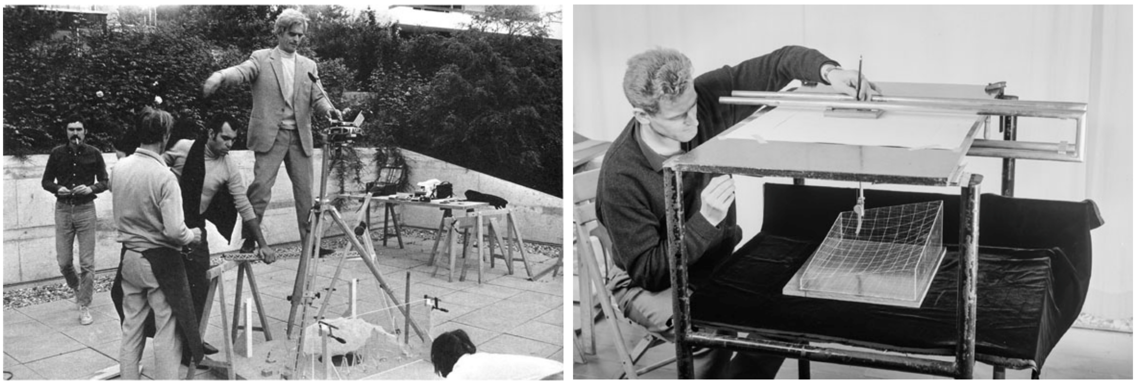
Introduction

Textile Roofs 2024, the twenty-sixth International Workshop on the Design and Practical Realisation of Architectural Membranes, took place on 28–30 April, 2024 at the Orca ten Broke Seminar ship, Berlin, and was chaired by Prof. Rosemarie Wagner (Karlsruhe Institute of Technology) and Dr.-Ing. Bernd Stary (Academus GmbH). It was attended by 93 participants from 22 countries covering three continents. Once again, the attendance demonstrated the success of the event, which has become firmly established since it was first held in 1995.

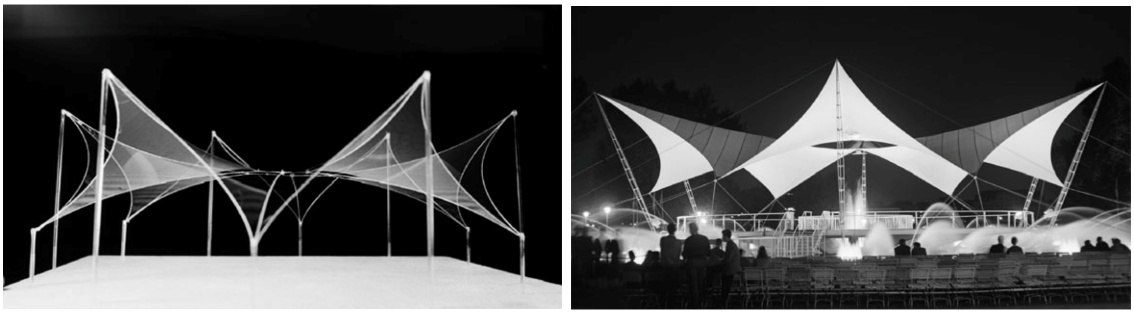
1 History

Frei Otto - The cradle of the modern tent construction - Dipl.Ing Martin Kunz.

The special guest lecture reviewed the work of Frei Otto and his team from his archive at the "saai/KIT" (Archive for Architecture and Civil Engineering, Karlsruhe Institute of Technology) that contains 420 models, 20.000 plans and sketches and 90.000 pictures. A significant selection was presented and commented on, showing the model-based design method (figs. 1 to 8).

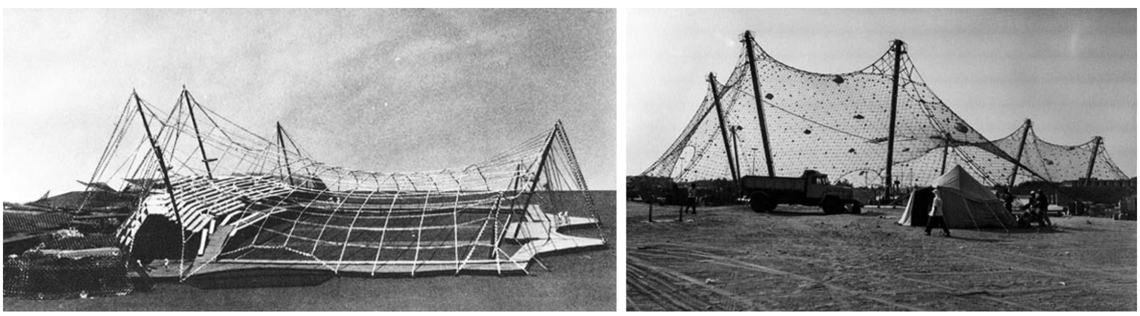


Figures 1,2: Taking photographs and measuring models.



Figures 3,4:"Tanzbrunnen, Cologne, 1957: soap film model and as built.

Figures 5,6: IL, Stuttgart, 1967: soap film model, cable net and as built.



Figures 7,8: Sports hall, Jeddah 1981: suspended chain model and cable net.

Brief history of ETFE design and technology in architecture - Torsten Balster

After introducing the new lightweight architecture with the dome over Manhattan (1960), the Biosphere and the German Pavilion (both in Montréal, 1967), the main characteristics of ETFE were listed: high transparency, UV stable, extremely flexible, low weight, long lifetime, self cleaning, outstanding fire performance, 100% recyclable, high chemical resistant and acoustic comfort.

While the first applications in architecture were ephemeral, a permanent structure was built for the Burger's Zoo in Arnhem, 1982, which is an evidence of the durability of the material, confirmed by weathering tests (fig.09).



Fig.09: Mangrove Hall

Fig.10: Schlumberger Institute

Fig.11: Cycle Bowl

Successive developments have been:
• the printing with high reflectivity for solar control introduced in the Schlumberger Research Institute, Cambridge 1992 (fig.10).
• the variable shading system controlled by pressure difference of the Hannover Cycle Bowl, 2000 (fig.11).
• the breakthrough of the Eden Project, Cornwall, in 2001 for its size, frames and nodes.
• the incorporation of photovoltaic cells initiated in the classroom for the future, at the Royal Borough of Kensington and Chelsea, London 2003, revealing the need for avoiding overheating and condensation
• the 1st permanent cable supported curtain wall structure of the Unilever Building in Hamburg, where re-adjustment of pre-tension was needed to recover losses due to the high temperature
• the Thermocap joint, to reduce heat losses for the Graft Therme, Delmenhorst, 2011 (fig.12).
• the 2011 Environmental Product Declaration EPD-VND-2011111-D (ISO 14025)
• Design issues related to the ultimate and serviceability limit states according to PD CEN TS 19102 were also discussed.
• the coupled movement joints of the Allegiant Stadium, (Las Vegas 2020) to allow for movements between the supporting cable net and the ETFE cushions (fig.13).
• the sliding bearings of the "The Leaf", Assiniboine Park, Winnipeg, Canada 2022, (fig.14).

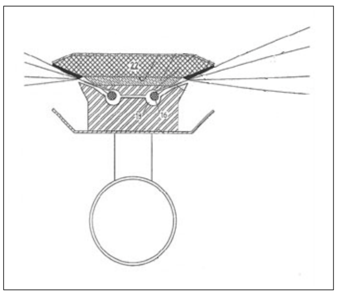


Fig.12: Thermocap

Fig.13: Allegiant Stadium

Fig.14: The Leaf

The lecturer ended by making an optimistic claim regarding an alleged decline in PFAS contamination.

2 Design

The paradox of heavy lightweight structures - Josep Llorens

The growing concern for the environment and sustainability favours tensile architecture because it saves material, energy, emissions and waste. However, some designs do not take advantage of these benefits because they apply conventional methods suitable for concrete and steel, which are not appropriate for structural membranes. This leads to the paradox that supposed lightweight membrane structures end up being oversized cladded imposing steel structures. The way to take advantage of the benefits of membrane structures is to design and build them according to their basic principles: only tension, funicularity, curvature and pre-tension. In addition to the basic principles, some design steps that also contribute significantly on efficiency are:

- the supporting structure impact. It is convenient to design it so that it does not contradict lightness and sustainability, better avoiding bending and optimizing the masts.
- the shape cannot be arbitrarily determined. Geometry and forces interact. They have to be in equilibrium at any point. The form results from the boundary conditions and supports, applied loading, material mechanical properties, curvatures and distribution of pre-tension. Free forms require a steel framework.
- the structural analysis with special mention to wind loads and hybrid structures. Codes are unfavourable and lead to over sizing and cost increase and the membrane has to be analyzed together with the supporting structure.
- the cutting pattern generation and layout are significant. As well as contributing to the spatial configuration, the orientation of the fabric, its shear deformation, the stiffness of the seams and the process of pretension influence the result.
- the life cycle analysis helps to optimize energy and material consumption, waste production and gas emissions.

The presentation was completed with best practices, innovations and improvements to favour efficiency (figures 15 to 24).

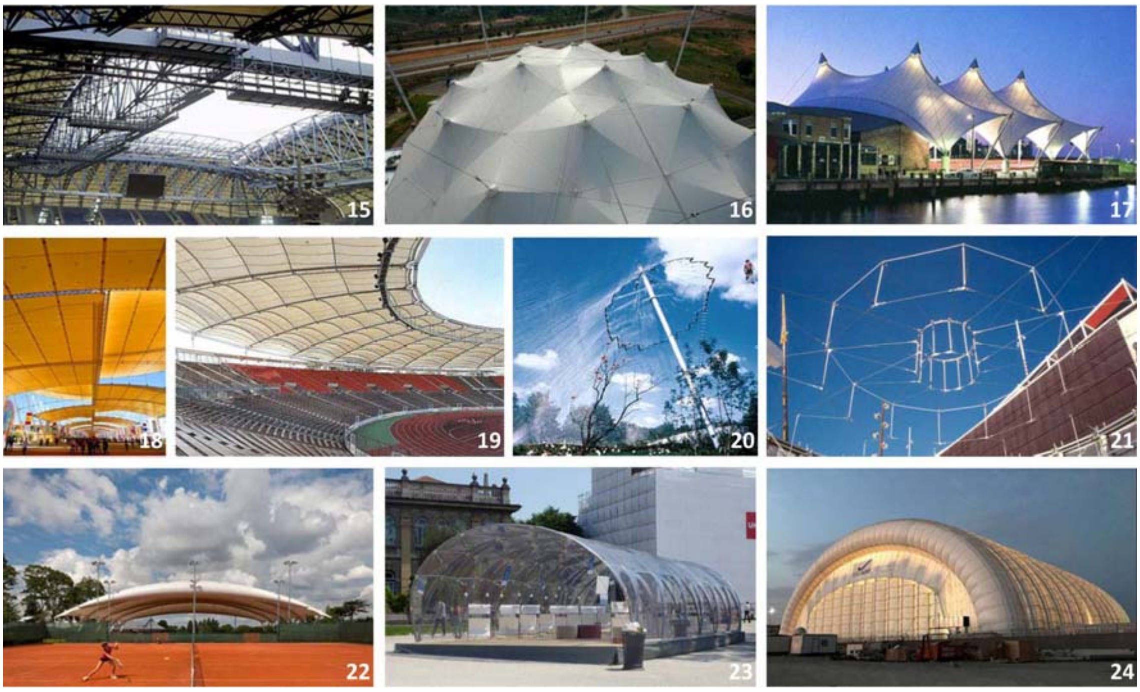


Fig.15: What can be improved/avoided. Figs.16 to 24: Best practices and improvements: 16 Suspended, 17 Ridges and Valleys. 18 Cable beams. 19 Spoke wheel. 20 Only masts. 21 Cable dome. 22 Tensairity. 23 Active bending. 24 Inflatable hangar.

Lightweight footprint. The pathways towards Zero Carbon for Tensioned Membrane Architecture: ongoing actions and next steps - Bruce Danziger

Bruce Danziger exposed a major concern for reducing the embodied and operational carbon of lightweight structures. He started with the 2 year plan of the Nohmura Foundation for Membrane Structures Technology based on the development of a website to collect, capturing collective efforts, manage and track data and comparison studies.

A central idea is to proof that lightweight structures have less environmental impact than normal weight materials of construction. Several plans, declarations, strategies and propositions have been formulated aimed to the carbon reduction for tensioned membrane structures with the contribution of architects, engineers, manufacturers, suppliers, builders, clients, owners, and stakeholders.

Several data and approaches were mentioned, such as the PFAS restrictions, EPDs (Environmental product declarations) and methods for calculating the impacts, including the Buro Happold's in house embodied carbon assessment tool. According to the EPDs from different manufacturers, values of the CO_{2eq}/kg were provided for PES/PVC (5,09), Fibreglass/PTFE (241,55) and the ETFE System (51,68).

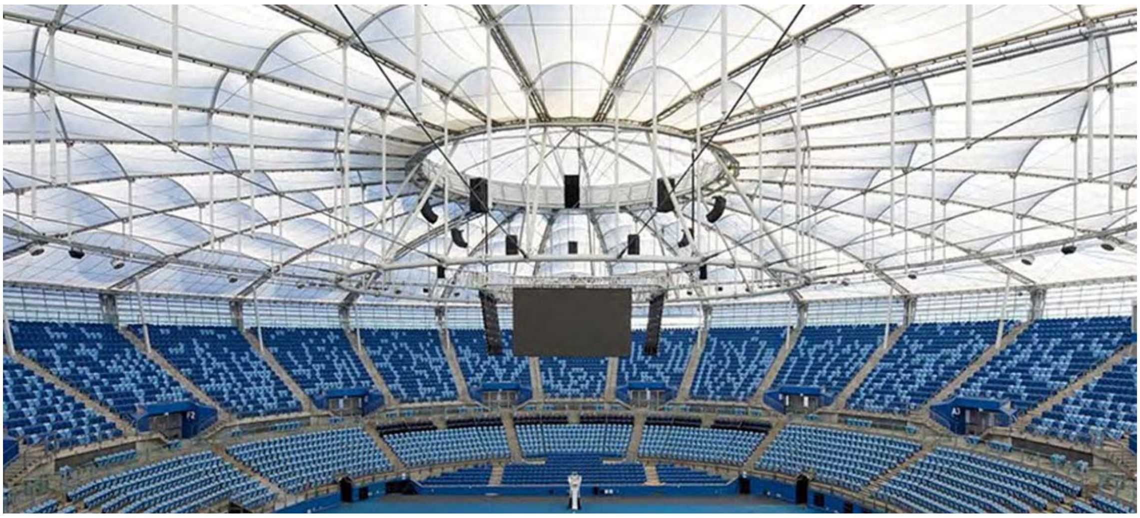


Figure 25: Ken Rosewall Arena, Sydney 2019.

The Ken Rosewall Arena was presented as a case study erected in Sydney with 10.500 m^2 of fabric (including wastage) and 429 T of steel (41 kg/m^2). The fabric was produced in Philippines and manufactured in Japan, the cables were supplied from Italy and the steel fabricated in China. It is rated A (137 $kgCO_{2eq}/m^2$) with the Structural Carbon Rating Scheme of the Institution of Structural Engineers (fig.25).

He mentioned the Denmark's leadership in limiting the value of CO_{2eq}/m^2/year up to 12 from January 1st, 2023. It means for 50 years: ≤ 600 CO_{2eq}/m^2 in total; 300 CO_{2eq}/m^2 for building (not operational) and 150 CO_{2eq}/m^2 for the structure and substructure. He also commented on the "Embodied Carbon Action Plan" to reduce embodied carbon of the buildings and the "ECOM - Embodied Carbon Estimator" to quickly find the embodied carbon order of magnitude.

He finally recalled the sustainable development goals, that are: no poverty, zero hunger, good health and well-being, quality education, gender equality, clean water and sanitation, affordable and clean energy, decent work and economic growth, industry, innovation and infrastructure, reduced inequalities, sustainable cities and communities, responsible consumption and production, climate action, life below water, life on land, peace, justice and strong institutions and partnerships for the goals.

Efficient computer models for use in textile architecture - Jürgen Holl

Jürgen Holl, from technet gmbh, addressed various aspects of computer modelling considering observations made over the last few years regarding the projects becoming increasingly complex and the costumers in pursuit of minimal efforts and resource consumption. As a result, models need to be more efficient, complete, fast and accurate, but simple enough to be practically applicable including relevant physical laws and principles.

Additional boundary conditions must be fulfilled for pneumatic structures if a given internal pressure or volume must be maintained, with consideration that internal pressure loads are non-conservative and, for certain load cases, the Gas Law must be applied

Other improvements of the software were exposed:

• in water bags the deformations change the loads and the contact in such a way that they cannot be kept constant (figure 26).

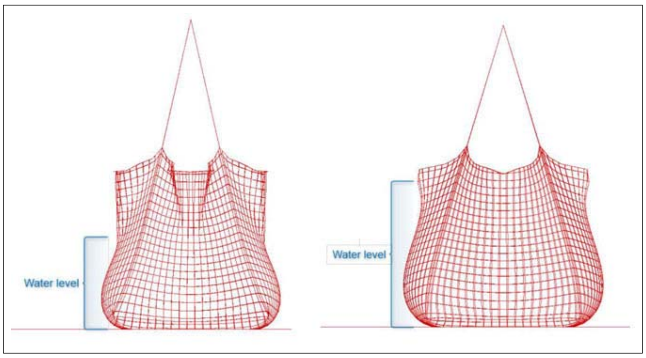


Figure 26: buoyancy loads.

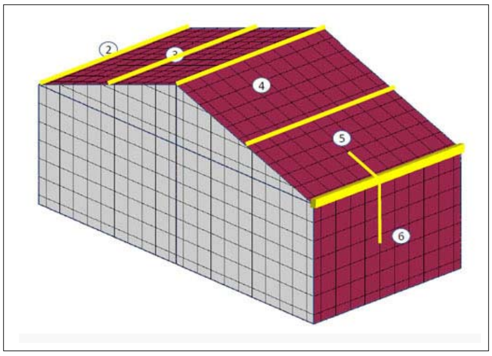


Figure 27: textile hall with sliding supports.

• if the membrane slides on the beams or cables, the panels involved act as one piece, and the membrane may be detached in case of wind. It is the case of the intermediate sections of textile halls and free cables used as reinforcement (figure 27).

• the need for a digital wind tunnel due to the inaccuracy of the codes with respect of the wind loads.

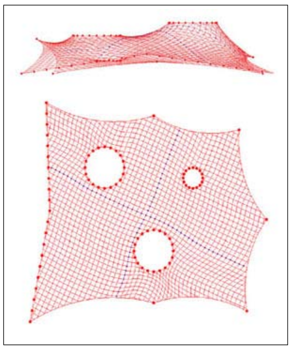


Figure 28: equidistant mesh.

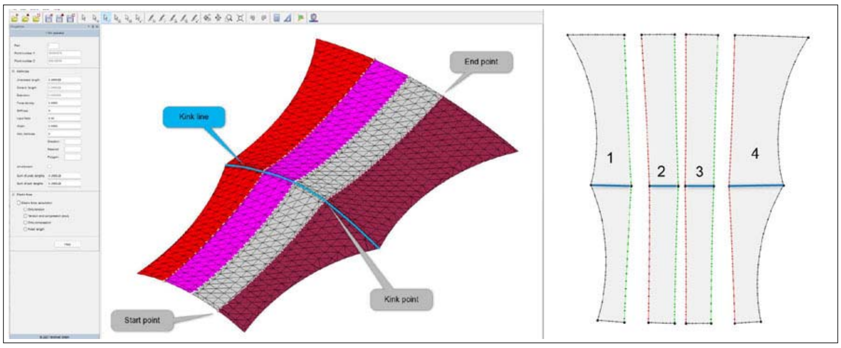


Figure 29: pattern generation with kink points.

• for meshes it is interesting to build them equidistant for easiness of manufacturing. In addition, by changing the mesh angle, they adapt easily to curved surfaces without tension (figure 28).

• in ridge and valley structures it can be useful to run the seam lines through kink points to reduce the number of panels (figure 29).

Formfinding & environmental aspects - Robert Roithmayr

Robert Roithmayr introduced his talk with a live demonstration of scanning the seminar room as a background for the design (fig.30). He recalled the principles of curvature and proportion and noted that sustainability is linked to efficiency that can now be considerably increased by harvesting energy with solar cells attached to the membrane (fig.31). He also recalled the "Formfinder" software, available online, to assist architects and project planners in designing, planning and implementing membrane and foil structures generating a productive dialogue between the client, the architect, the structural planner and the material manufacturer.

Figure 30: scanning the seminar room

Figure 31: solar cells attached to the membrane

The second part of the presentation was dedicated to the software "Strategyfinder", specifically designed to enable members of a group to appreciate differing perspectives and generate constructive dialogue and debate. It is about overcoming situations in which clients can be disappointed with the final outcome, often because what they regarded as key features of the design have not been adequately addressed. For their part, architects sometimes are disappointed with clients because they didn't make the goals clear at the outset. The initial meetings between client and architect can be critical to success, and project management that keeps track of client needs can often get lost in the tracking of technical and engineering aspects of the project. That is why an approach to develop an effective client/architect collaboration was presented. It uses a new and original software platform designed for enhancing collaboration leading to an outcome that neither could have created on the own and both parties are pleased with. The methodology designed into the software platform has been developed and used extensively over 30 years of research and application. Now it is enhanced by its use in the field of architecture. It was schematically summarized by "GOAL: <u>why</u> are we doing this? + STRATEGY: <u>what</u> do we want to do? + ACTION: <u>how</u> are we going to do this?".

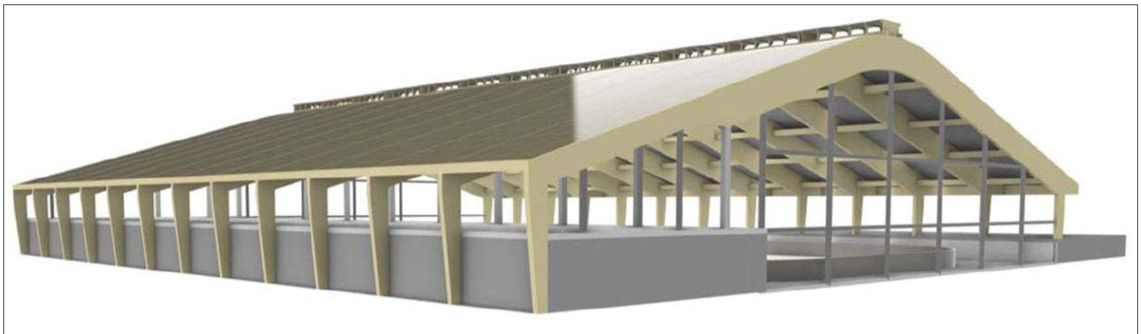


Figure 32: skating ring in Switzerland

It was illustrated with some decisions concerning the project of a skating rink in Switzerland (figure 32).

3 Projects

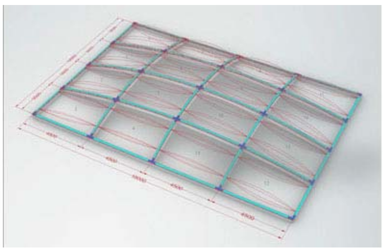
ETFE constructions. Workflow and iconic projectes - Stephan Brückner

Stephan Brückner began his lecture by listing a succession of milestones in ETFE construction:
2004 Engineering design for Allianz Arena in Munich and first ETFE single skin stadium in Hannover.
2010 First ETFE roof with integrated flexible PV elements.
2012 First ETFE four later project.
2015 First ETFE single layer digital print project.
2021 First ETFE five layer project.

Fig.33 Al Jamea Tus Saifyah Fig.34 Arc River Culture Pavilion Fig.35 Marriot West End

It was followed by a no less impressive cascade of iconic projects:
2010 Replacement of the Canopy Car Park - Munich (with flexible PV elements integrated in ETFE cushions)
2010 Marriot West End Gate Canopy - Frankfurt (figure 35).
2011 Yonkers Raceway Entrance Canopy - New York (no tubes seen)
2012 The Arc River Culture Pavilion - Daegu (four layer ETFE cushion, figure 34)
2015 Lodz Tram Station (first coloured digital print on ETFE)
2016 Mitoseum Dinosaur Park Entrance Building - Bautzen
2017 Munich Tram Station (ETFE single skin without cable pockets)
2017 SACMI Auditorium - Office Building - Imola
2018 Place Rogier Canopy Public Area - Brussels
2020 Azebaijan Pavilion EXPO 2020 - Dubai (grand cushions with digital printing)
2022 EDGE Suedkreuz - Headquarter Vattenfall AG - Berlin (four layer cushions)
2023 Al Jamea Tus Saifyah - Nairobi (figure 33).
2023 Mind Innovation District Facade - Milano (single skin without cable pockets)

The third part of the lecture was devoted to parametric design beginning with the design of an hexagonal ETFE roof structure (fig.36) and a case of optimization of water drainage (fig.37). Finally, the detailed workflow for the design of the Greenhouse Didattica Serra in Sicily (fig.38) with Rhino/Grasshopper and Easy software was presented, including:
1 Data based pre-definition of all form finding & patterning parameters
2 Generation of 3d-membrane systemlines & 3d-positions for cushion applications
3 Generation of folders for each cushion (up to 5-layers)
4 Form finding of each cushion including all layers
5 Patterning of each cushion, including all layers, printing lines and additions
6 Arrangement of all cutting pattern to one single cad-file
7 Re-importing of 3d-seamlayout, including 3d-cushion applications.



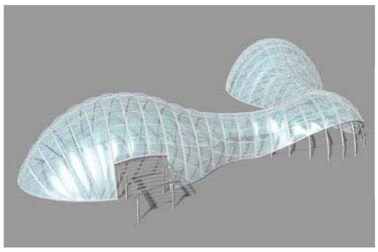


Fig.36 Hexagonal ETFE structure Fig.37 Drainage optimization Fig.38 Didattica Serra Greenhouse

The first ETFE foil structure in Japan - Yoshinaka Iizuka

Yoshinaka Iizuka began with a brief overview of his personal biography, the history of design criteria in Japan and that of the Membrane Structures Association of Japan.

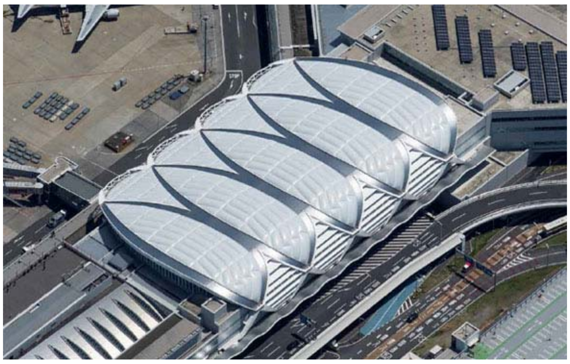


Figure 39: External view

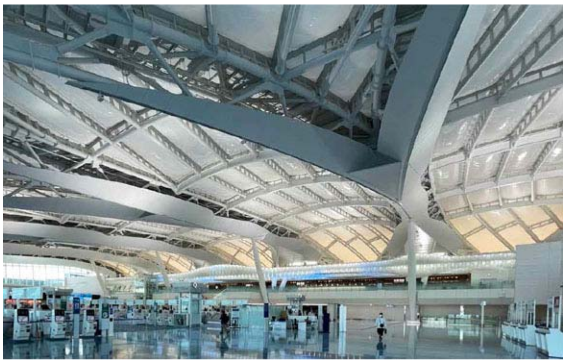


Figure 40: Internal view

The main part of the presentation was devoted to the 6.474 m^2 roof of the T2 Tokyo International Airport (figures 39 to 43). Its structural system is based on a main steel trussed frame as a base to clamp the 3 layer 318 cushions consisting of printed ETFE (500 μm) + non flammable PTFE (600 μM) + printed ETFE (500 μm), with a heat transmission coefficient of 1,7 $W/m^{2o}K$ and a light transmission of 2,4%.

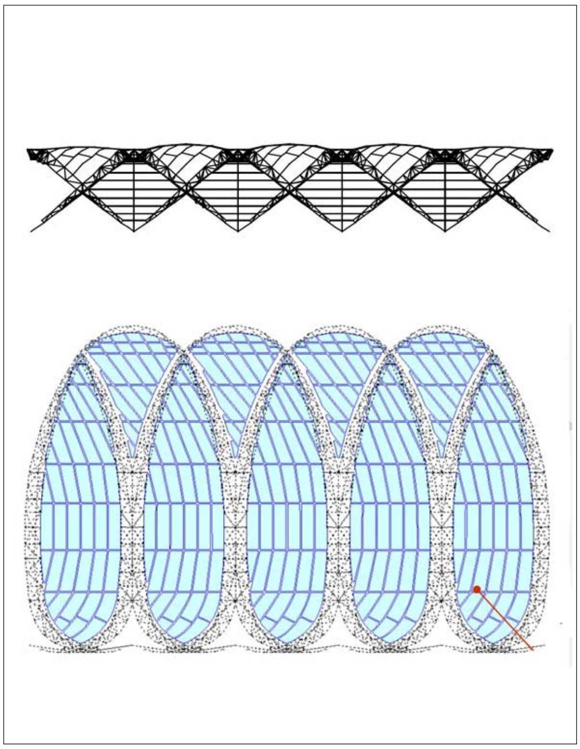
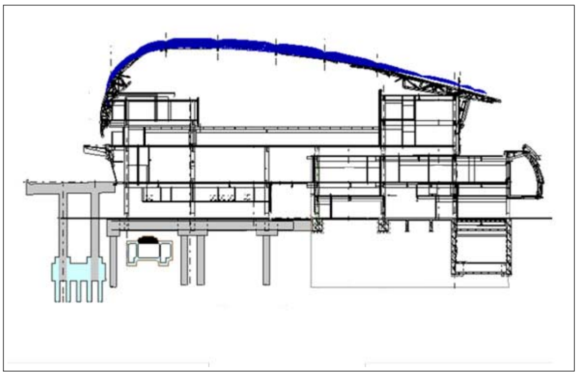


Figure 41: Elevation and plan



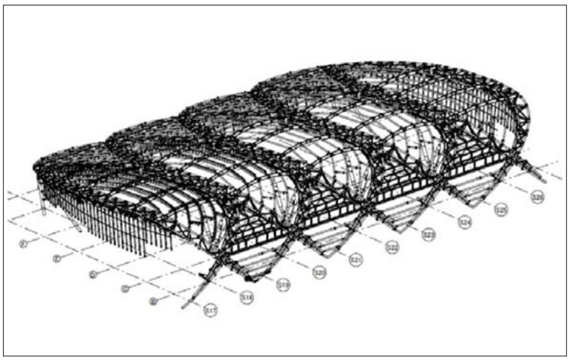


Fig.42 (top): Section - Fig.43 (bottom): Frame

The maximum stress of the external ETFE layer under wind load (3,2 kN/m^2) and internal pressure (600 Pa) is 5,47 kN/m, lower than the allowable 8,4 kN/m. The maximum displacement under snow load (1,075 kN/m^2) and internal pressure (1.100 Pa) is 0,173 m for a 3.391 m span, meaning a displacement ratio of 1/19,6 lower than 1/10. The safety of the PTFE middle and ETFE inner layers were also checked in case of ponding due to pressurization interruption or ETFE failure.

The workability of the installation was checked with a mock-up.

Characteristic identity for iconic projects - Martin Glass

Martin Glass presented stadiums built in China designed by gmp Architects.

Figure 44: Kunshan Football Stadium

Figure 45: Wuxi Olympic Sport Centre

The city of Kunshan, near Shanghai, commissioned them a new football stadium to accommodate 45,000 spectators (figure 44) and the city of Wuxi the Olympic Sport Centre, including a stadium for 60.000 spectators (figure 45).

Figure 46: Sanya Sport Centre

Figure 47: Chengdu Future City

Gmp also won the competition to design the stadium of the Sanya International Sport Centre, that has been built without their participation (figure 46). Another competition in which they participated and won was the Chengdu Future City with Ø32m umbrellas of which mock-ups have been built so far (figure 47).

Figure 48: Suzhou Olympic Sport Centre

Figure 49: Wuyuanhe Stadium, Haikou

Two more gmp designs were shown: the Suzhou Olympic Sport Centre (including a 45,000-seat stadium, an indoor pool with 3,000 seats, and a sports hall with 15,000 seats, figure 48) and the Wuyuanhe Stadium in Haikou with 41,400 seats designed asymmetric with a higher west tier facing to the sea so that visitors can enjoy the view.

Development in tensile architecture. What's next? - Sergio Leiva

Sergio Leiva started with the presentation of "form TL" as a consulting engineering from design to production for supporting and lightweight structures, events, exhibitions and architectural art work. After reviewing the typology of membrane, cable-net structures and the design parameters he focused on what he considered to be the four mayor building types.

Figure 50: Saarbrücken Stadium

Figure 51: Nouvelle Destination

1) Mechanically tension membranes: Forum Kirchberg, Luxemburg 1998; Kurlinik Masserberg 1994; Velodrome Abuja 2006; Zénith Strasbourg 2007; Nuvola Roma, 2016; Textile Akademie Möchengladbach 2018; Batumi Stadium 2020; Saarbrücken Stadium 2021 (figure 50).

2) Pneumatically tension membranes: Nouvelle Destination 2001 (figure 51); Raumwelten Pavilion 2015; BMW fair hall IAA Frankfurt; Modern Teahouse 2007.

Figure 52: Botanic Garden Árhus

Figure 53: Copragi Pavilion

3) ETFE cushions: Dresden castle 2008; Meilenwerk Düsseldorf 2006; Botanic Garden Árhus 2013 (figure 52); Tropical Islands 2004; Rheinhallen Köln 2005; Bushof Aarau 2013; Lilienthalhaus Braunschweig 2017.

4) Single layer ETFE: Unilever 2009; Bundestagarena Berlin 2006; Copragi Pavilion (figure 53); TemporActive Pavilion 2019.

Figure 54: Tuballonn

Figure 55: Art Installation

Figure 56: Zayed National Museum

He answered the question posed in the title "What's next?" mentioning the software tools available on the market that offer new possibilities to designers for the design of so called free form shapes leading to a wide range of structures such as the Tuballonn stage for the Konsberg Jazz Festival 2006 (figure 54), the Janet Echelman Art Installation for the IAA Mobility Munich 2021 (figure 55) and the Foster + Partners Zayed National Museum in Abu Dhabi (figure 56).

New trend "Glamping Tents" - Meltem Sahin

Meltem Sahin presented the holiday bungalows that Asma-Germe designed for the southern coast of Turkey, provided with a double layer textile roof and façade.

Figure 57: Glamping tent on a hillside

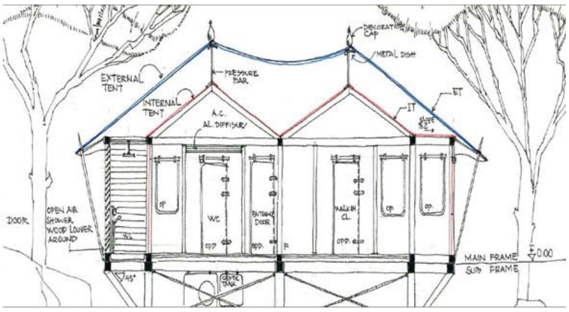


Figure 58: Section

Figure 59: Wood structure for the enclosure

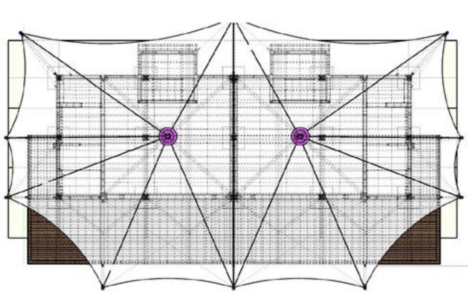


Figure 60: Plan

Figure 61: Interior roof

Figure 62: Structure of the outer layer

Figure 63: External roof

They are located on a hillside, hidden behind the trees, raised off the ground and overlooking the sea (figures 57,58, 60). They are based on the superposition of two structures: the enclosure (made of wood, figures 59 and 61) and the structure of the upper layer of the roof (made of steel, figures 62 and 63).

Figure 64: Almost completed project

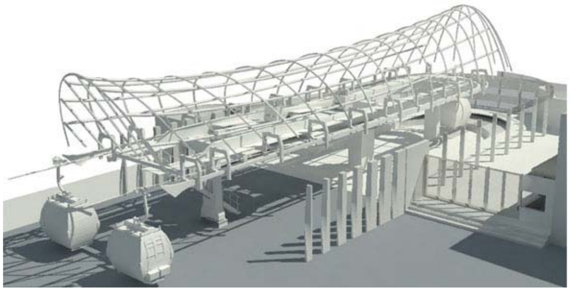
The result is a lightweight dry construction that could be dismantled without leaving a trace (fig.64). Note that it lacks cement and concrete (except for the footings).

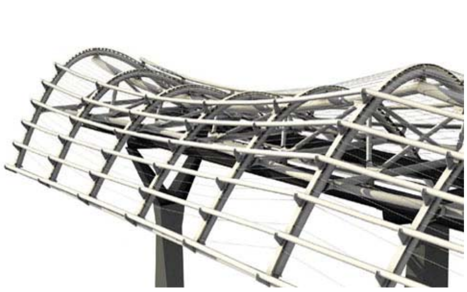
Double curved ETFE Foil Structure in the Mountains - Cornelius Schlotthauer

In 2017 the old Olang cable car stations (figure 65) were considered out of date technically, aesthetically and in terms of comfort, so they were replaced by new ones. Their design was presented by Cornelius Schlotthauer.

Figure 65: old Olang cable car station. Figure 66: competition proposal

The presentation included the parametric design of complex forms, the engineering of the ETFE foil and the steel structure, the digital fabrication and the speed-up building process (5/6 months).





Figures 67 and 68: evolution of the model

The process began with a competition (October 2017, figure 66) and ended with the opening of the stations in June 2020. Constraints and challenges were considerable including building quickly (5-6 months) on the mountain under difficult climate conditions. Moreover, dynamics and fluent movements associated with cable car and skiing were difficult to express adequately.

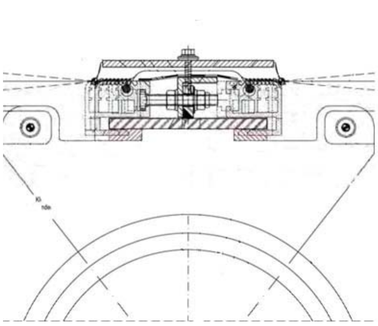


Figure 69 and 70: ETFE clamping and section Figure 71: New Olang cable car station

The initial design started from the idea of a transparent envelope showing the machinery and following the movement of the cabins. This idea led to develop the whole design in 3D and needed the use of parametric tools (Rhino-Grasshopper) to adjust the geometry to variable angles..

4 Research

Biogas storages and wind - Sergej Ryklin

Three approaches for the static analysis of biogas storages (figure 72) were presented. The first one was based on the German DIN 4134: "Air supported structures; structural design, construction and operation" with a formula for calculating stresses in warp and weft directions. The second approach was based on the European DIN EN 1991-2. "Eurocode 1: Actions on structures. Part 1-4 General actions, wind actions" and the application of a FEM program with the wind loads applied on a 3D model. The third approach also used a FEM program but measuring different wind loads obtained with wind tunnel tests (figure 73) at the Laboratory of Building and Environmental Aerodynamics of the Karlsruhe Institute of Technology.

Figure 72: biogas storages

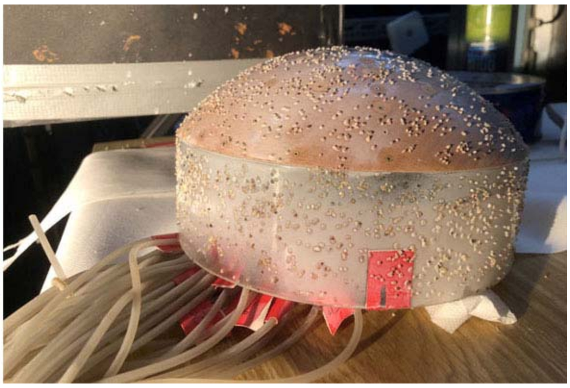
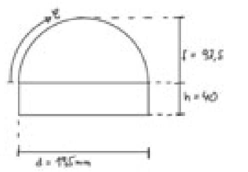
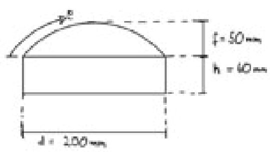


Figure 73: wind tunnel test model

Two models have been analysed:
- hemisphere: Ø20 m; h=4 m; f=10 m
- 1/4 calotte: Ø20 m; h=6 m; f=5 m

Dimensions	Model			DIN 4134	EN 1991	Tunnel
Hemisphere Ø=20 m h=4 m f=10 m			warp	13,9	48,8	32,3
			weft	11,4	9,1	9,5
			top	-	43,6	25,8
1/4 calotte Ø=20 m h=6 m f=5 m			warp	15,2	14,5	24,2
			weft	12,1	3,3	5
			top	-	14,5	22,1

Conclusions drawn from the results:
• DIN 4134 is outdated because the stress is lower and the top is not taken into account.
• DIN EN 1991 is precise for the hemisphere but questionable for the 1/4 calotte.
• Wind tunnel values are higher for the 1/4 calotte.

Some questions remain, such as the influence of the deformations or the reliability the wind tunnel scaled down to 1/100.
More issues for the future are the double layer gas storages, digital wind tunnel, calculation of anchors, structural supports, account for imperfections, effect of the cylinder height, cp calues for different f/Ø ratios, cone shaped gas storages and different wind profiles.

Flying whales LCA60T airship envelope development - Rogier Houtman

Rogier Houtman presented the development of the Flying Whales LCA60T airship, a solution for air cargo transport, which does not need heavy transport infrastructure on the ground that degrade the environment, in a way that opens up new horizons for the development of remote areas (figure 74, 75). It will carry 60 tonnes with almost no environmental impact, loading and unloading in hover flight, with 7 propulsion points that ensure perfect control, a speed of 100 km/h and vertical takeoff and landing.

Figures 74, 75: the airship is a transport system for remote areas which do not have infrastructures.

It measures 200 m long and 50 m in diameter with a cargo bay dimensions of 96m long x 8m high x 7 m wide and "under slings" outside to hold packs of larger dimensions. It is supported by a rigid structure of composite materials for maximum operational security. Its lift is ensured by 180.000 m^3 of 14 cells containing non-pressurized inert helium. Floating on helium means less energy to fly and less CO_2 emissions.

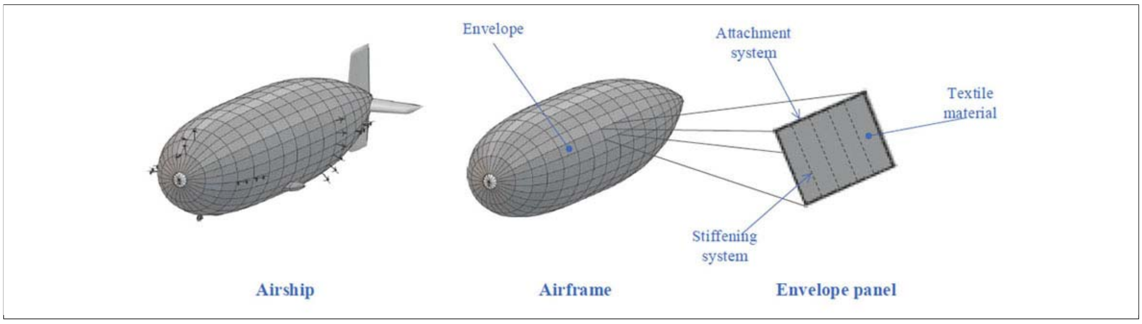


Figure 76: the panels enclose the structure of the Flying Whales LCA60T

The airship is wrapped with 23.600 m^2 of fabric subdivided into 438 panels reinforced with belts, which have a maximum length of 13,5 m and a maximum width of 5 m and a total length of attachment of 5.500 m.

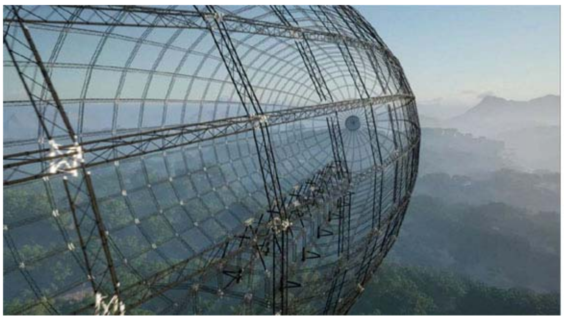


Figure 77: rigid structure of the airship

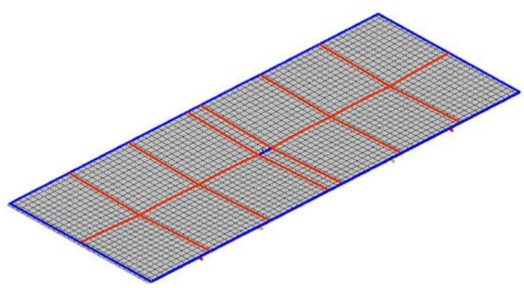


Figure 78: envelope panel reinforced with belts

Finally, the main challenges to be considered were mentioned, such as the antecedents, lightness, interfaces between different parts, water tightness, ventilation, internal pressure, tolerances, pre-tension, eigenfrequency, ageing, lightning, costs and fire retardancy behaviour.

5 Products

Steel wire ropes and end fitting equipment usage principles in lightweight structures - Bahadir Senol

Bahadir Semiol showed the products and equipment of SNL Tensi for lightweight structures such as cables, end fittings and assemblies (figures 79, 80). He also included in his presentation the tests carried out as well as comments on the safety factors, calculations, length, elongation, construction, end fittings and coatings.

Figure 79: steel wire ropes, end fittings and tests.

He underlined the importance of calculating the lengths taking into account the creeping (after loading behaviour), the cutting temperature and the design temperature, the additional elongation due to the end fittings, the climate and tolerances. He presented also some test results on cables to which the elasticity formula cannot be applied as if they were rods or profiles.

Figure 80: end fitting options and applications

He strongly recommended the close cooperation between architects, structural engineers and qualified manufacturers to discuss and specify all the details.

Figure 81: Firüzkoÿ Stadium, Istanbul.

Figure 82: Crocodile Arena, Bursa

He summarized the manufacturing of cable systems process including receiving orders, measuring, swaging, socketing, testing, pre-stretching , packing and transporting. He finally mentioned the retractable structures as a special field of application and showed some of its most outstanding achievements (figures 81, 82).

Cable mesh as structural substitute for lightweight footbridges - Fabian Graber

Figure 83: Himmelhausmattesteg slow traffic suspension bridge, Trubschachen, 2020

Interesting applications of cable meshes were presented by Fabian Graber such as zoo enclosures, green structures, suicide prevention and bridges. He showed in detail the Himmelhausmattesteg pedestrian and cycle bridge suspended from a wire rope mesh instead of the usual suspension ropes (figure 83). It connects the Trubschacher Himmelhausmatte with the train station creating a safe way to school for the local children and closes a gap in the national hiking and cycling network. With a slight incline as it crosses the river, the bridge spans a total of 25.8 metres, with the suspended section of the bridge stretching 21.5 metres between the supporting pylons. The bridge joins the road to the neighbouring district, with its 2.2 metre width enabling the municipality’s 5 tonne snow-clearing tractor to cross in the winter. The bridge is designed for a payload of 4.0 kN/m^2.

Construction process: after completion of the foundations, the articulated pylons were positioned in place together with the temporary suspension cables which had already been attached. The girder had been manufactured off-site and transported to Trubschachen in one-piece, where it was lifted into position by pneumatic crane and secured to temporary cables. The cost was: steel structure including installation 72.000 € (29%) + construction works 120.000 € (49%) + ropes and nets including installation 55.000 € (22%) = 247.000 € meaning 4.300 €/m^2 or 9.500 €/m. The bridge is a joint project of the companies Jakob AG, Thuner Bau AG and Kambly SA as well as the municipality of Trubschachen. More information at: *https://www.jakob.com/ch/en/references/himmelhausmattesteg-suspension-bridge-on-a-wire-rope-mesh*

Figure 84: Webnet bridge in Lugano - Parco via Pico, 2022. Span: 15 m.

Looking to the future, the talk ended by answering the question ‘What's next?’ with the webnet bridge in Lugano - Parco via Pico, 2022. Span: 15 m (figure 84).

Patterns for parasols. Technical textile between tension and decoration - Katja Bernert.

Katja Bernert presented colourful parasols that will cover one of the resorts of a Red Sea Development on Shura Island, created by the architectural firm Foster & Partners. The material of the parasols is VALMEX® Concept Coral, innovative for its diamond-shaped patterning within the mesh (figure 86) with a wide range of colours (figure 85). The initial engineering for the canopies was done by Tensys UK and the workshop engineering is done by Tensys Australia, commissioned by the manufacturing company OTS (Obeikan Tensioned Structures).

Figure 85: partial Valmex colour chart

Figure 86: diamond shaped patterning

Figures 87, 88, 89: *Welcome to Red Sea Global (RSG), where luxury, sustainability, and innovation converge*

"The design concept for Shura Island is known as Coral Bloom because of how it carefully blends in with the pristine natural beauty of the surrounding landscapes (figures 86,87,88). With their nature-inspired designs, the Shura hotels will give guests a unique barefoot luxury experience like no other place on earth. While having a shared master design, the resorts will offer distinct villas and experiences, and will be enjoyed by a range of guests, from honeymooners and families to adventure seekers and wellness lovers. The buildings have been designed to provide natural defenses from erosion, while new habitats have been created through landscaping that enhances the island's natural state". More astonishing information at: *https://www.redseaglobal.com/en/our-destinations/the-red-sea/shura-island*

Experimental project - Stev Bringmann

During the afternoons, as usual at 'Textile Roofs', various workshops, constructions and experiments took place.

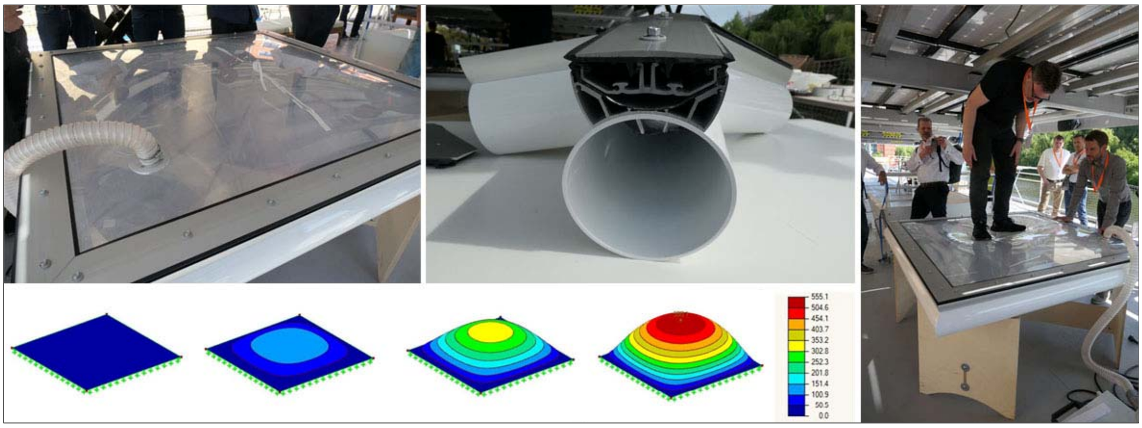


Figure 90: experimental project.

Stev Bringmann was in charge of inflating an ETFE cushion (figure 90).

Practical project: from 3D scan to installation of a tensile structure on the seminar ship - Janek Jeschke

Figure 91: installation of the practical project.

Work steps of the practical project realised during the workshop (figure 91): **1** Capturing environment via 3D scan. **2** Static laser scanning in a nutshell - Remarks on data acquisition, registration and other pitfalls -Registering the raw data (merging the individual point clouds into one large point cloud) - Cutting and alignment of the point cloud. **3** Conversion of the point cloud into. **4** Easy Modelling. Import solid data into EASY -Form-finding -Static analysis -Cutting patterning. **5** Fabrication of the membrane and the tensioning straps. **6** Assembly and tensioning of the tensile structure.

Airvillon

Figure 92: Airvillon, the pavilion that builds itself.

During the workshop, the Airvillon was demonstrated. It is an inflatable pavilion measuring 4x4 m that sets itself up automatically with a fan, so light that it has to be hold down when the wind blows. More information at: https://airvillon.org/

AMA Awards

AMA (Architectural Membrane Association) presented its AMA Awards to reward and honour outstanding contributions to sustainability and conservation of natural resources by awarding particularly good examples of products, projects, design and ideas in the field of lightweight and membrane structures.

Some of the points that will be taken into account are:
• Improvement of environmental conditions for humans, animals and/or plants.
• Reduction of non renewable energy consumption, emissions or waste
• Exploitation of renewable energies (solar, thermal, wind or water energy)
• Improvement of recycling processes.
• Advancement of durability or service life (measurable).
• Improvement of working conditions or working processes.
• Extraordinary (structural) design regarding to utilization, location, appearance etc.
More information at: *https://www.amaforum.com/ama-awards*



Figures 93,94,95: AMA Awards 2022. Left: Merck Transformer Station, Darmstadt. Middle: Luxembourg Pavilion, EXPO Dubai. Right: Retractable membrane ceiling for public buildings, Shanghai.

VIII Simposio Latinoamericano de Tensoestructuras

The "VIII Simposio Latinoamericano de Tensoestructuras" was anounced by Paula Moya.

TOPICS: The symposium will cover topics related to design, planning, calculation, engineering, manufacturing, and specific installation methods of the technology, as well as its relationship with technical and environmental aspects relevant to current architectural concerns.

ACTIVITIES: Lectures and presentations, product showcases, workshops, student competition and visits.

VENUE: Faculty of Architecture Design and Urbanism, Ciudad Universitaria, Autonomous City of Buenos Aires.

ATTENDEES: Open to professionals, researchers ,students, educators, companies, or anyone interested in the proposed theme.

More information at: *https://www.latensored.org/slte-viii-buenos-aires-argentina-2024/*

Figure 96: Skyline of Buenos Aires from Puerto Madero

TR 2024 Cruise

Figure 97:

TR 2024 Cruise route

J: Jetty

98: Lessingbrücke

99 Siemenssteg

100: Kraftwerk, Charlottenburg

101: Westhafen

The TR 2024 cruise explored a new route unknown to cruise fans and regular TR attendees (figure 97). It went north-west to what was once the western harbour of Berlin. Some points of interest where the Lessingbrücke (figure 98), the Siemenssteg (figure 99) with the Kraftwerk Charlottenburg (figure 100) and the Westhafen (figure 101), apart from industrial installations and buildings, some of them refurbished as housing.

Figure 98 (left): The current Lessing (2007) bridge substitutes an earlier bridge which was itself a post-war repair (1950) of the original wooden bridge (1878) replaced in 1903 by a stone bridge.
Figure 99 (right): The Siemenssteg is a pedestrian bridge that was built in connection with the station between 1899 and 1900, in order to not only serve as a pedestrian bridge but also to carry the electrical cables to Charlottenburg. It was not destroyed in the Second World War because it had no strategic importance for the street fighting. Today it is one of the well-preserved historic footbridges over the Spree. It was extensively renovated in 1960.

Figure 100 (left): The Kraftwerk Charlottenburg went into operation on 1900 and restored in 2007.
Figure 101 (right): The administration building dominates the Westhafen, the inland port connected to the Oder and Elbe rivers opened in 1923. Its slender, tapering tower with a viewing gallery, lantern and pyramid roof is reminiscent of a town hall tower or lighthouse and is the landmark of the Westhafen for arriving ships.