REPORT

TEXTILE ROOFS 2019

Textile Roofs 2019, the twenty-fourth International Workshop on the Design and Practical Realisation of Architectural Membranes, took place on 20–22 May, 2019 at the Archenhold Observatory, Berlin, and was chaired by Prof. Rosemarie Wagner (Karlsruhe Institute of Technology) and Dr.-Ing. Bernd Stary (Academus GmbH). It was attended by 75 participants from 14 countries covering four continents. Once again, the attendance demonstrated the success of the event, which has become firmly established since it was first held in 1995.

Lightweight design with Maffeis Engineering

M.Sc. Antonio Diaferia, Maffeis Engineering SpA, Solagna.

Antonio Diaferia presented three recent works of Maffeis Engineering, an international specialty design and structural engineering consultancy, based in northern Italy. The Volgograd Stadium, designed by the Arena Project Institute is one of the FIFA World Cup Russia 2018 stadiums. Its roof consists of a tensile bicycle wheel supporting PVC and ETFE membrane claddings. A summary description can be found in the TensiNews 34, p.5. Especially significant is the replacement of the planned polycarbonate panels by polyester and ETFE membranes, which resulted in a saving of 15 kp/m^2 of steel. *"With membranes, less steel"*, pointed out Mr. Diaferia.

Rising to a height of 246m the Thyssen Krupp test tower (TKT) in Rottweil is used to test and certify high-speed elevators. with a visitors' viewing platform at a height of 232m. The structure of the test tower consists of a thin reinforced concrete hollow tube with a diameter of 20.80m tapering in thickness from 40cm at the bottom to 30cm at the top. The envelope consists of a long-lasting PFTE coated, glass-fibre fabric that increases in transparency as it ascends the tower and reduces the solar radiation improving the durability of the concrete.

And the third work was the Khalifa International Stadium for the 2022 World Cup characterized by the compression ring formed by two inclined arches (Fig. 1).

Powerful tools for formfinding, statics and patterning of textile structures

Dipl.-Ing. Dieter Ströbel, technet GmbH.

The computer-aided design of membrane structures was summarized by Dr. Dieter Ströbel. He stated that computer models have to be correct, precise and complete for a realistic approach. They also have to be generated in a fast way, using information from many experts and applicable for mass production illustrated by the Mecca Tent City, Allianz Arena (Munich) and the Khan Shatyr Entertainment Centre (Adana).

The design process was exposed starting from the mixed form finding, based on the force density method combining stiff elements with the membrane. The operations involved and the results were reviewed, mentioning the definition of boundaries and nets, support forces, force distribution, stress distribution, contour lines and drainage, including the automatic generation of the primary structure, different net types and enslaved points or lines. As the second step of the design process, the non-linear structural analysis was presented, starting from initial values and based on a precise description of the material behaviour including the consideration of the shear and creep stiffness which steers the interaction between warp and weft. Special comments were devoted to the importance of the material directions, the gas law (for pneumatic structures), sliding/reinforcing cables (Fig. 2) and hybrid systems such as textile halls, cable meshes and cable nets.

The third main step is the patterning procedure based on the flattening of surfaces reducing distortions, keeping the cutting out waste as low as possible and minimizing the amount of work. Additional requirements are the compensation of the geometrically developed surface in order to establish the pretension, the correspondence of seam lines and the translation to cutting drawings provided with welding marks, cutting and system lines. Automatic patterning, mass production, attachments and printing are also possible.

Finally, the free Pre-Designer module was presented for the pre-design of textile membrane surfaces or cable nets, available at: https://www.technet-gmbh.com/en/support/downloads/downloads-easy/

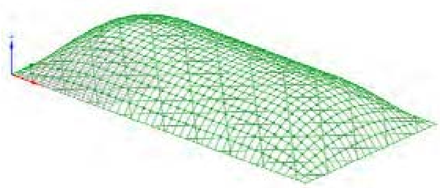


Figure 1: Dar Al-Handasah Consultants with Maffeis Engineering SpA, Taiyo Middle East and Pfeifer, 2014: Khalifa International Stadium, Doha.
Figure 2: The form-finding calculation finds the position of sliding/reinforcing cables (technet).
Figure 3: FLOPEC Building, Esmeraldas.

Smart wraps - Textile Façades

Katja Bernert, Mehler Texnologies, Low & Bonar.

Wrapping buildings was an interesting contribution of Katja Bernert. She illustrated this current application of textile membranes with several examples. Textile façades are a good choice because depending on the mesh size, the open mesh fabric allows the desired amount of light to come through. At the same time the penetration of rain can be minimized. In addition, the mesh density can be varied as desired to create a more or less intense visual barrier. With textile façades, buildings can appear in creative shapes and colours that cannot be achieved so easily and quickly with solid materials. For the aforementioned Volgograd Arena, Low & Bonar GmbH developed a specific type of blue and white coloured translucent membranes which feature the colours of the club which is to overtake the stadium after the FIFA world cup.

In the city of Esmeraldas on Ecuador's west coast, Flopec, the national oil company, decided to build a new head office building contributing to the urban landscape development (Fig. 3).

A steel construction has been enveloped with a 4.000m^2 textile seamless wrap that blends into the colour of the sky. It avoids mechanical and individual sun shading devices and reduces the wind loads. A huge opening on the building's ground floor frames the view of the ocean and opens the way to the beach huts situated directly behind the paved area. And, in addition, the façade can be used as a cinema screen in the evenings. See also for a description in the TensiNews 31, p. 9.

Lightweight membrane structures

Architect, Legally Certified Engineer, Univ. Lecturer, Dipl.-Dr.techn. Robert Roithmayr, formfinder GmbH.

"You are only able to see if you have knowledge" is the lapidary sentence with which Professor Roithmayr summarised his lecture. He focused on three basic steps of the structural membranes design, which are "get inspired, be creative and make it real", assisted by the formfinder software and database together with the Postgraduate Master of Engineering Program at the Donau Universität, Krems: www.donau-uni.ac.at/dbu/membrane.
He also exposed the rapidly retractable at any time "Bionic Umbrella" unique design for sun and rain protection (Fig. 4) and invited the audience to participate in the formfinder database https://membrane.online.

Assessment of details

Dr.Architect Josep Llorens, Barcelona School of Architecture.

There are different ways of approaching the structural behaviour of membranes according to the characteristics of the materials, material consumption, efficiency and visual expression, among many others (Fig. 5). The appropriate design of membrane structures should be based on the lightness and the ability to follow the load paths, provided they have the right combination of curvature and depth. Structural membranes, if not designed as such, end up as the cladding of an imposing steel structure totally disproportionate.
Professor Jürgen Hennicke, who unfortunately could not attend the 2019 Workshop, pointed out in the previous edition the need to develop an assessment method for detailing structural membranes.
Can a method be developed to assess the appropriateness of details? The principles and requirements of textile roofs may be used as criteria for assessment of detailing. *Details may be assessed qualifying the degree of fulfilment of each principle and requirement as good, fair or bad*. These criteria can also be scored and weighted, (although scoring and weighting are not recommended).
The principles and requirements were formulated at the 2010 edition of the Textile Roofs International Workshop and summarised at: https://www.textile-roofs.com/wp-content/uploads/2018/03/TR10-Report.pdf.

To shape or to form, that is the question

Nicolas Goldsmith, FTL Studios, NY.

Nicolas Goldsmith, the 2019 special guest lecturer, dared to approach the thorny problem of the design of the form. He distinguished "shape making" inspired free-forms that materialize directly a brilliant idea, from "form finding", a process from which the building is organized and the form is optimized. Several examples of the "form-finding" method were shown. The Empire City Casino Porte Cochere at Yonkers Raceway in Yonkers, New York is a FTL project that reflects the form-finding approach. It is a newly constructed porte-cochere with a pneumatic ETFE film roofing system (Fig. 6). The design started from a partial toroid form as an initial surface. A lattice shell with the same curvature throughout was developed using both, a digital and physical model, each showing different aspects and highlights.

Figure 4: Robert Roithmayr: Bionic umbrella.
Figure 5: Two different (opposite?) approaches to design the edges of membrane structures.
Figure 6: Studio V Architecture with FTL and Birdair, 2013: Porte-cochere, Empire City Casino, Yonkers, NY.
Figure 7: FTL Design Engineering Studio, 2008: Sun Valley Music Pavilion, ID.
Figure 8: FTL Design Engineering Studio, 2009: Skysong at ASU Campus, Scottsdale, AZ.

For the Sun Valley Pavilion the natural acoustics of the hypar form was used and, to reach the volume of space required, two shells were needed: an outer shell that is both structural and acoustical and an inner shell only for acoustics tuned like a musical instrument (Fig. 7).
The Sky Song at Arizona State University was inspired by the early 20th century American dancer Loie Fuller who created an amazing array of moving forms illuminated with coloured lamps, turning herself into constantly changing flowers of light. The form of the Sky Song was created using physical models that were later translated into digital models. Four pairs of conoids of revolution combined with trussed curved beams suspended from A-frame masts were arranged with rotational symmetry (Fig. 8).
At the end of the lecture, a quick look at a historical evolution of architecture revealed an almost linear progression from solid mass constructions to diaphanous skins. New membranes point towards the incorporation of multiple functions such as information systems, acoustic and thermal conditioning, energy harvesting, that is to say the customization of the envelope relative to the climate of the site, solar orientation and building needs. More details of the presentation and its examples can be found in: N.Goldsmith, 2018: "Mass to membrane", ORO Editions, Novato CA, whose purpose is "to take my personal investigations and observations in the field of lightness and to understand how to incorporate emerging technologies and the qualities of lightweight structures into an architectural mainstream".

Development of Membrane Structure Technology

Prof. Dr. Wujun Chen, Space Structures Research Centre, Jiao Tong University, Shanghai.

A comprehensive report about the development of structural membranes (1995-2019) for architecture in China was presented by Professor Chen.
1. The application of modern architectural membranes in China, although incipient, is developing rapidly favoured by some important events such as the Olympic Games, national Championships and International Exhibitions (Fig. 9). Main fields of application have been sports, business and public buildings. Materials used are PTFE, PVDF, PVF, ETFE and ePTFE among others and the typology includes mechanically tensioned and air-supported structures, cable-domes, spoke-ring cable structures and more.
2. Recent developments encompass more than sports and exhibitions and employ air-supported membranes, reinforced concrete shells, façades and aerogel insulation blankets. Additionally, membranes built around 2000 are being replaced.

3. The Committee for Membrane Structures in China was established in 2002 as a branch of the China Association of Spatial Structures. Its main responsibilities are to regulate, promote and lead the membrane structure industry by enrolling new members, establishing qualifications, training, disseminating and exchanging knowledge, awarding, promoting innovation and issuing specifications and guidelines.
4. The membrane structures industry is divided into that of materials (steel, cables and membranes) and engineering (design, manufacture and construction). A list of 12 technical specifications was provided and average price varies from 65 to 129€/m² according to the material, engineering conditions and business negotiation.
Professor Chen concluded that, although the application of structural membranes in China has not been extensive, the industry and technical specifications have been completely established. There is a need to promote specialization of the industry together with the realization of more architectural applications and improving some technical aspects such as fire protection. He ended up expressing the desire to exchange and cooperate.
Finally, a question was raised: why the roofs built around 2000 are being replaced instead of checking their characteristics, which would probably allow them to last longer? The answer clarified that the replacement affects the roofs of the public buildings when their warranty period (10 years) ends.

Material and process developments in fibre reinforced flexible and rigid composites Dr.-Ing. Thomas Steigmaier, Deutsche Institute für Textil + Faserforschung.

The German Institute of Textile and Fibre Research is the Europe's largest textile research centre, founded under public law in 1921, for application oriented research from molecule to product. With three research centres and a production company (ITVP), it is connected to the Stuttgart and Reutlingen Universities. Most important fields of research are high performance fibres and yarns, smart textiles, functionalized textiles, finishing, medical technologies, lightweight design and fibre composites. Main applications are architecture, construction, health, care, mobility, energy, environment, production technologies, clothing and home textiles. Outstanding examples presented at the conference were sensor-yarn systems, printed-sensor systems, actuators, electronic textiles, cooling surfaces and solar thermal collectors with integrated energy storage.Through sensor-yarns, capacitance may be measured and therefore changes produced by stress, humidity, temperature, light and more can be recognized. An interesting application to the building stock, where insulation is impossible due to lack of space or monumental protection, is mildew prevention developing yarns with moisture sensitivity and heating functionalities.
To collaborate with robots, a sensor-mat has been developed. It switches the safety according to the position of the operator slowing down the machine when entering a danger area or stopping it when entering into the work area. Another visionary development is the self-cooling surface, motivated by the increase of average temperatures, megacities and energy demand, that has been inspired by the hairs of Saharan silver ants (Fig. 10), "whose silver hairs reflect sunlight at the shorter wavelengths while in the mid-infrared range they help the ant's body exchange its heat to a cooler area, the sky" (G.Bernard).

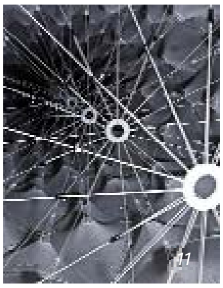


Figure 9: Guirui Theatre, 2019 Beijing International Horticultural Exhibition.
Figure 10: Saharan silver ant.

Figure 11: Tower 2, interior view: cones pulled inwards (A.Ingvartsen).

Shaping hybrids. Prototyping of new material systems Prof.Dr.-Ing. Christoph Gengnagel, CITA-KADK/KET - UdK Berlin.

Professor Gengnagel showed two research projects exploring active bending in hybrid structures. Hybrid Tower Projects 1 and 2 are a reaction against the convention of stiff, static architecture. They ask what a structure would look like if built from soft materials that give way to forces in a controlled manner, embracing the ideas of resilience and adaptation (Fig. 11). A complete description can be found in: https://issuu.com/cita_copenhagen/docs/tower2_booklet_pages__for_issuu_
At the Department of Structural Design and Engineering of the Berlin University of arts a research has been carried out to develop a novel method to install elastic grid shells reported in TensiNews 34, p.16. Elastic grid shells, like the Multihalle in Mannheim, are highly efficient structures, able to cover large spans with very little material and embedded energy. In addition, the simplicity of these structures generates beautiful double-curved shell surfaces from slender and initially straight rods.
Nevertheless, the existing methods of installation are usually associated with significant complexity, cost and time. The investigated method, which uses a pneumatic falsework, greatly increases the speed of construction for large-span shells (up to 100m in a matter of days), which will have groundbreaking implications on construction costs and efficiency (even though the structure is doubled), with promising potential for applications in rapidly deployable event-halls and shelters. An animation of the installation can be found in: https://www.youtube.com/watch?v=OKe14VF03RM

Architecture fully fashioned Prof.Dr.-Ing. Claudia Lüling, Universität Frankfurt.

At the "Building for the future" Department of the Frankfurt University of Applied Sciences, Professor Claudia Lüling develops research on alternative efficient structures with new composite materials made in the course of seminars that will soon be realized.
1 - 65 kp Lightweight pavilion (Fig. 12). Extremely light and made of a textile-foamed composite material, a four-meter-high, self-supporting, cone-shaped pavilion has being created in the form of a net mesh, inspired by the fibrous and sponge-like cattail plant Typha.
2 - Spacer Fabric Shell (Fig. 13). The lounge furniture "Spacer Fabric Shell" explores the load-bearing capacity of the foam composite in the form of an arc-shaped self-supporting grid shell. A reversed catenary of cured foam prevents bending. It is ergonomically shaped as a slightly oscillating seat with an acoustical atmosphere that invites to relax.
3 - With its insulation in hot and cold climates, the ZeltHAUS offers protection against natural disasters, in refugee camps or can serve as temporary accommodation in urban mega structures (Fig. 14).
4.- Spacer Fabric Pavilion (Fig. 15). The modular, lightweight textile pavilion shows innovative possibilities of textile construction using composite of textiles and foams. A self-supporting dome structure made of spacer textiles was designed and realized with a combination of folds and partial expansion of multi-layered textiles.
More projects supervised by Professor Claudia Lüling can be found at: https://www.frankfurt-university.de/de/hochschule/fachbereich-1-architektur-bauingenieurwesen-geomatik/kontakt/professor-innen/architektur/prof-dipl-ing-claudia-lueling/tab-designbuild/

Figure 12: 65 kp Lightweight Pavilion.
Figure 13: Spacer Fabric Shell.
Figure 14: Zelt Haus.
Figure 15: Spacer Fabric Pavilion.

Retractable Membrane Roofs

Nikolai Kugel, Architect, arch22.

A series of retractable roofs related with historical existing buildings or urban contexts were shown by its architect Nikolai Kugel. Their most relevant features are the accommodation to the pre-existences and characteristics of the retractable membranes, as well as the complexity of the driving systems.
In the Amphitheatre of Lavis (Fig. 16) the stage is covered by a permanent textile roof of 240m², spanned between a rounded concrete back board and a central arch bearing structure. This supporting arch spans 26m. It is anchored back to the hillside by cables arrayed in a fan-shaped way that guides the retractable part of the membrane roof covering 560m² of the audience area. The retractable membrane can be folded and bundled manually using ropes, winches and rack gears along the main supporting arch and protected by a transparent canopy. The roof of the stage is a membrane optically detached from the back board, offering to the spectators a great panorama of the opposite mountains. The sonically hard back board and the convex curved membrane roof are causing very good acoustics, distributing uniformly the sound through the audience.
More projects can be found at:
http://www.arch22.de/?page_id=1207 and http://www.kugel-architekten.com/ content.php?n=1

HF Welding by Forsstrom

Mikhail Wallin, Forsstrom HF AB.

The speaker presented Forsstrom as the world leading company at the HF welding arena. High frequency (HF) welding is the joining of materials by supplying HF energy in the form of an electromagnetic field (27,12MHz) and pressure to the material surfaces to be joined. PVC and PU are the materials most commonly used with HF welding. Advantages of HF welding are: repeatable, reliable, strong, durable, even welds, waterproof, multi-layer and environmentally friendly. Main accessories used by HF welding are the electrodes that can be standard, soft, lamella or supplementary. HF welding is the recommended technology by all leading PVC manufacturers of structural membranes because it is reliable and creates even welds with superior repeatability. The HF technology can also be used for a large number of other applications, such as: industrial, boat covers, military, pool liners, billboards, tarps, truck covers, oil booms, stretch ceilings, agriculture, tents and sports. The quality depends on the HF energy, % of the machine capacity related to the size of the electrode, pressure and cooling time.
Forsstrom has developed ForFlexx, a unique and patented welding method to join flexible coated PVC and PU fabrics with metal attachments using HF welding and also to join two coated metal surfaces. Together with Formfinder Software GmbH in Austria, a development project is being carried out with the aim of developing alternatives to anchoring/attaching structures based on the ForFlexx technology (Fig. 17). More information at: www.forsstrom.com

ETFE & Printing - case studies

Dipl.-Ing. Björn Beckert, Fabritecture, "where dreams take shape".

The contribution of Björn Beckert started with the presentation of the capabilities of "Fabritecture", mentioning the project and management of membranes, frames, cables and specialised cladding. He focussed mainly on the possibility of printing ETFE for solar shading, back lit applications and aesthetics.
Two outstanding case studies were shown: the Oran Park Library façade, Sydney, (TensiNews 35, p.4) and the Elizabeth Quay Ferry Terminal, Perth (Fig. 18).

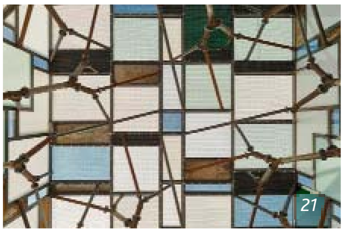
The speaker dared to predict the future pointing at: - greater variety of ink colours, water resistant inks for printing onto single skin applications, long-lasting inks for permanent application – no delamination, UV stable also for sensitive colours, stretch resistant inks – no cracking when under tension, studies on light transmission of different printing colours in different densities, custom art work printed onto ETFE and endless creative freedom!

The PCT CAN Santander Project

Ind.Eng. Feike Reitsma, IASO.

The multi-sports track of the PCT CAN (Scientific and Technological Park of Cantabria) has been covered with a textile roof supported by a steel structure to practice sports under adverse weather conditions but enjoying natural light (Fig. 19).
The total dimensions are 90x30x9m. The supporting structure is composed by 12 main trusses with a frame at each end. The roof is subdivided into 13 panels of Serge Ferrari TX30-III. Its total surface is 3.170m² (17,4% more than 90x30=2.700m²). Valley cables tension the membrane and provide double curvature.
Referring to the appropriateness of the whole structure, one wonders why there are trussed

Figure 16: Kugel Architekten, 2012: Amphitheatre Lavis.
Figure 17: ForFlexx (Forsstrom) with R.Roithmayr: one corner plate in three different positions.
Figure 18: Elizabeth Quay Ferry Terminal, Perth.
Figure 19: C.Galiano with Arenas Asociados and IASO, 2017: PCT-CAN Sport pavilion, Santander.

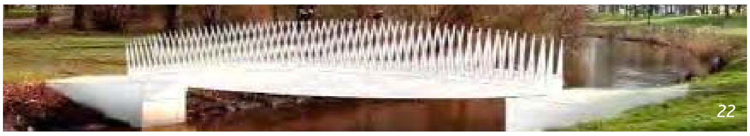



Figure 20: Technospan, 2019: Sahajmarg Spirituality Foundation Meditation Hall.
Figure 21: Karlsruher Institut für Technologie, 2019: "Mehr.WERT.Garten" Pavilion, Heilbronn.
Figure 22: Eindhoven University of Technology, 2015: Bio-based composite bridge.
Figure 23: Rottweil Test Tower: laserscan of the concrete column.
Figure 24: Installation of the joint participants' project.

	Total	SF		MEHLER		SIOEN		HIRAOKA		HEYTEX		SATTLER	
		m^2	%	m^2	%	m^2	%	m^2	%	m^2	%	m^2	%
2016	494000	235000	48	200000	40	36000	7	13000	3	10000	2	-	-
2018	414000	252000	61	92000	22	40000	10	10000	2	-	-	20000	5

Table 1: Membrane market for PVC coated fabrics in India (A.Sathar).

beams in bending instead of ridge cables in tension, and why the frames are not further apart, since the membrane allows it.

On the path to standardized membrane and tent structures: intermediate status and outlook

Dr.-Ing.Jörg Uhlemann, Universität Duisburg-Essen.

Dr.Jörg Uhlemann began his lecture with a short introduction to the Institute for Metal and Lightweight Structures-Essen Laboratory for Lightweight Structures (IML-ELLF), devoted to testing and research on material behaviour (including membranes), testing methods, measurement and simulation. He introduced existing standards for membrane and tent structures made of technical fabrics and foils in USA, China and Japan with special mention to the European standardization work led by the Committee CEN/TC 250/WG 5, predicting optimistically the issue of the "Eurocode for Membrane Structures" by 2024. He also mentioned relevant research activities such as the validation of design elastic constants through testing and analysis considering experimental measurement inaccuracies.

Acceptance of membrane architecture in India. A tour with Indian Projects

M.St.Abdul Sathar, Technospan Structures pvt ltd.

Abdul Sathar started by launching a truly compromising challenge: "We create any imaginable shape or form in any size". He provided market values for PVC coated fabrics in India (Table 1) and he showed a great variety of projects carried out in India by his company Technospan, with costs varying between 30 and 100€/m^2, dealing with cyclones and storms. The most impressive were the great meditation halls for a large number of participants (Fig. 20). He concluded that India is a huge size developing country that has a high potential for membrane structures, as long as failures due to poor design, workmanship and low quality materials are avoided. After asking how to overcome these difficulties, he formulates the needs:

- more awareness on membrane structures among architects, engineers and clients,
- workshops and training centres in India to develop an efficient network for quality projects,
- to implement standards and practices for design, engineering and working methodology and
- independent engineering companies to design and check the membrane projects.

Mehr.WERT.Garten - Form-finding of tree structures for building from waste

Rosemarie Wagner, KIT, Karlsruhe.

The Mehr.WERT.Garten (Added.VALUE.Garden) pavilion addresses the question how we can perform a paradigm shift in the way we use our resources, from the currently dominant linear economy (take, make, throw) towards a circular economy of closed and pure material cycles. Its objective is to proof that it is possible to design, detail and construct according to the principles of the circular economy. The pavilion building materials are separated into four groups:
(1) the load-bearing structure is largely made from reused steel originating from a disused coal-fired power plant in north-western Germany. It consists of four inclined supports that fan out like trees and are connected to each other by a rigid steel frame structure (Fig. 21).
(2) The façades and roof are clad in panels manufactured from recycled bottles glass and industrial glass waste.
(3) The furniture is built from recycled HDPE plastic waste, while the chairs are 3D printed from plastic household waste.
(4) The floor of the pavilion as well as the landscape design of the garden forms an assemblage of various reused and recycled materials and products made from mineral construction and demolition waste.
More at: https://nb.ieb.kit.edu/?p=6265

Bio-based composite pedestrian bridge

Patrick Teuffel, Innovative Structural Design, Eindhoven University of Technology.

The bio-based composite bridge aims to design and realize a 14m span pedestrian bridge made from fibre-reinforced polymers, that have a high percentage of bio-based content. The bridge has been installed over the river Domel, at the campus of the Eindhoven University of Technology to investigate the design potentials and structure challenges of bio-based fibre-reinforced polymers, which are relatively new materials in architectural and structural load-bearing applications (Fig. 22). Along with the design possibilities of the material, the entire design process and installation were presented together with the detailing, focusing on the evaluation of different structural typologies and the optimization of the selected geometry. Future research is expected such as adhesion fibres and resins, research on bio-based resins, environmental impact: more LCA's, cradle to cradle certificate, low cost circular composites, fire classification: now S4 ST2 SR2 (DIN 5510), M2 (NF P 92-501), moisture sensitivity and long-term behaviour and durability.

Monitoring membrane structures deploying terrestrial laser scanning

Sergey Ryklin & Son, Ryklin Engineering, Taiyo Europe & Technet.

The advantages of monitoring membrane structures were underlined: "Has your structure been built according to the specifications?". "Does your structure behave as it should?". Geometric discrepancies arise (frequently) due to: subsidence, the structure has not been built according to the design, the material does not behave as it should, failures, damages, etc.
Some notions regarding the features and influencing factors of terrestrial laser scanners were commented, remembering that they can only capture data within their field of view, so that several viewpoints are required to entirely document an object. Some examples were shown: the Veytaux energy plant in Switzerland, the Rottweil tower in Germany (Fig. 23), and the replacement of the Place Rogier roof in Belgium.