TensiNews

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

REPORT

SLTE 2018

PROJECT

KNITCANDELA COP22 VILLAGE

KNITCANDELA © PHILIPPE BLOCK

TensiNews INFO

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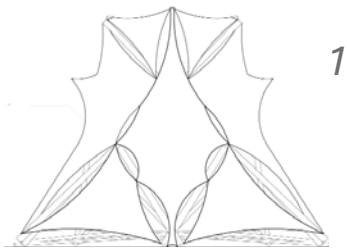


Edito

Dear Reader

Very soon, beginning of June, our next TensiNet Symposium "Softening the Habitats: Sustainable Innovations in Minimal Mass Structures and Lightweight Architectures" will take place at the Politecnico di Milano. Organizing and scientific committee have worked hard and prepared an inspiring event for you. We have received abstracts covering a wide range of interesting topics, which you should not miss. You find more details here and on the conference website.

Another important event this year is the joint symposium Structural Membranes together with IASS which will take place beginning of October. It is celebrating the 60th anniversary of the IASS, and it is the 9th Structural Membranes Symposium, this year held in Barcelona. This year is also the year of Techtextil, where many of our partners and members participate. We are glad to support again the student competition. The Textile Roofs symposium is this year back to Berlin, and hosting many interesting presentations and workshops.

This TensiNews is again full of recent projects, actual research topics, new developments in our industry and conference reports. A Candela shell made of concrete on flexible knitted formwork is presented, as well as new developments in the film industry, such as multilayer film, and Nano technology applied to film. Jörg Uhlemann was so kind to provide a summary of the 4th Leichtbau Symposium in Essen, and Joseph Llorens has written an enthusiastic report about the 7th Latin American symposium of tensile structures. Two projects in Morocco are presented and a textile façade realised last year in USA.

I am very proud that our TensiNet working group "good practice" has finalised the preparation of the code of conduct on good practice in the tensile architecture. I invite you to follow these rules and declare "We follow the approved standards of good practice rules of TensiNet", which is the first quality seal in our industry and a very important statement that you provide good quality. You find more details here and on our website.

I hope you enjoy this issue of TensiNews. I am glad to see you on one of the events this year, especially on our Symposium in Milan.

Yours sincerely, Bernd Stimpfle

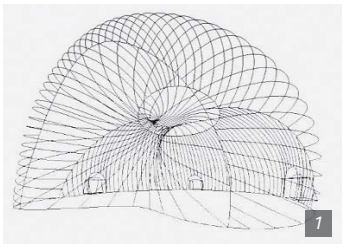


Figure 1. Visualisation Ark Nova © Anish Kapoor
Figure 2. Ark Nova © Anish Kapoor

Architect Arata Isozaki wins the Pritzker Prize 2019 and with this he continues the tradition of Japanese prize winners such as Shigeru Ban (2014), Toyo Ito (2013) and Sanaa (2010). Isozaki starts his practice in the early 60ties and his projects are spread all over the world. The architecture of Arata Isozaki has been considered visionary and futuristic.

One of his more recent realisations is "Ark Nova", a travelling concert hall. Together with the British-Indian artist Anish Kapoor he designed this expressive orb-like pneumatic structure. The membrane structure can be quick erected and later on dismantled, folded up, loaded on a truck and brought to another site. During the Lucerne Festival Ark Nova travelled through the areas in Japan affected by the tsunami. Referring to the intentions of the designers: "We named the Project Ark Nova, or 'new ark', with the hope that it will become a symbol of recovery immediately after the great earthquake disaster".

http://anishkapoor.com/961/ark-nova-2
http://anishkapoor.com/949/installing-ark-nova

Forthcoming Events

TECHTEXTIL 2019 | *"Space For Innovation"*
14–17/05/2019 | Frankfurt am Main, Germany | **https://techtextil.messefrankfurt.com/frankfurt/en.html**

TEXTILE ROOFS 2019 | *International Workshop on the Design and Practical Realisation of Architectural Membrane Structures* | Archenhold Observatory, Berlin, Germany | *20-22/05/2019* | **www.textile-roofs.de**

6th International TensiNet Symposium *"Softening the Habitats: Sustainable Innovations in Minimal Mass Structures and Lightweight Architectures"* | *3-5/06/2019* Politecnico di Milano, Milan, Italy | **www.tensinet2019.polimi.it/**

ICSA2019 | *The 4th International Conference on Structures and Architecture* | *24-26/07/2019* | Lisbon, Portugal | **www.icsa2019.com**

Joined International conference **IASS SYMPOSIUM 2019 & STRUCTURAL MEMBRANES 2019** *FORM and FORCE 2019* | *7-10/10/2019* | Barcelona, Spain | **http://congress.cimne.com/formandforce2019/frontal/default.asp**

Nonwovens Innovation Academy 2019 | *16 – 17/10/2019* | Deutsche Institute für Textil- und Faserforschung Denkendorf | **https://www.edana.org/education-events/conferences-and-symposia/event-detail/nonwovens-innovation-academy2019/**

International Conference on Advanced Building Skins | *28 – 29/10/2019* | Bern, Switzerland | **www.abs.green**

TensiNet Meetings

TensiNet Meetings | *TensiNet Partner Meeting 1/2019* | *04.06.2019 at 18.00* (during TensiNet symposium, Politecnico di Milano) |

Mexico City KnitCandela AT MUAC

KnitCandela is a thin, sinuous concrete shell built on an ultra-lightweight knitted formwork that was carried from Switzerland to Mexico in a suitcase!

Figure 1. General view on the finished structure © Mariane Popescu

Context

Built at the Museo Universitario Arte Contemporáneo (MUAC) in Mexico City as part of the first exhibition of Zaha Hadid Architects in Latin America (20.10.2018 - 03.03.2019), KnitCandela is an homage to the famous Spanish-Mexican shell builder Félix Candela (1910 - 1997). It reimagines his spectacular concrete shells through the introduction of novel computational design methods and the KnitCrete formwork technology.

The shell's dynamic geometry is inspired by the fluid forms of the traditional and colourful dress of Jalisco, Mexico. The builders' nickname for the project was 'Sarape', which is a scarf or poncho with a stripe pattern. The shape also pays homage to Candela's famous restaurant at Xochimilco, a trope he repeated in several subsequent projects.

While Candela relied on combining hyperbolic paraboloid surfaces (or "hypars") to produce reusable formworks and thus reduce construction waste, KnitCrete allows for the realisation of a much wider range of anticlastic geometries. With this cable-net and fabric formwork system, expressive, freeform concrete surfaces can now be constructed efficiently, without the need for complex moulds.

KnitCandela's thin, doubly-curved concrete shell with a surface area of almost 50m² and weighing more than 5tonnes, was applied on a KnitCrete formwork of only 55kg. The knitted fabric of the formwork system was brought to Mexico from Switzerland in a suitcase.

Collaboration

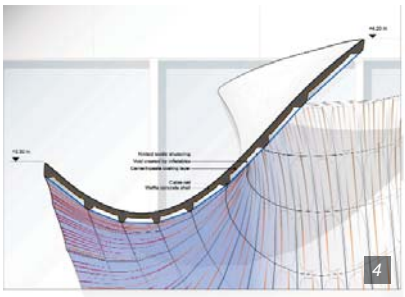
Designed and constructed by multiple teams in Europe and Mexico, the realisation of KnitCandela is the result of a collaborative effort that harnessed collective expertise in computational design, engineering and fabrication. The architectural design is the latest expression of the evolving search of the Computational Design Group of Zaha Hadid Architects (ZHCODE) for designs that utilise structural and constructional features to enhance the spatial experience of the user. For the realisation of this expression, the Block Research Group (BRG) of ETH Zurich introduced the KnitCrete formwork technology and developed the structural design and construction system. Architecture Extrapolated (R-Ex) managed the execution of the project on site in Mexico City as part of its continued engagement in the digitisation of building trades in Mexico.

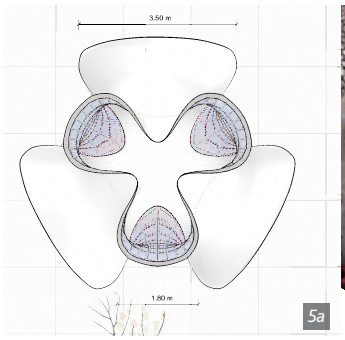
KnitCrete

KnitCrete is a novel, material-saving, labour-reducing and cost-effective formwork system for the casting of doubly curved geometries in concrete. The KnitCrete technology is being developed at ETH Zurich by the Block Research Group in collaboration with the Chair for Physical Chemistry of Building Materials, as part of the Swiss National Centre of Competence in Research (NCCR) in Digital Fabrication.

KnitCrete formworks use a custom, 3D-knitted, technical textile as a lightweight, stay-in-place shuttering, coated with a special cement paste

Figure 2a. Cable-net and knit formwork tensioned in between the external frame © Maria Verhulst
Figure 2b. Balloons being inflated and inserted into the fabric formwork pockets © Mariane Popescu
Figure 2c. Concreting of the sophisticated waffle shell with stiffening ribs in two directions © Mariane Popescu





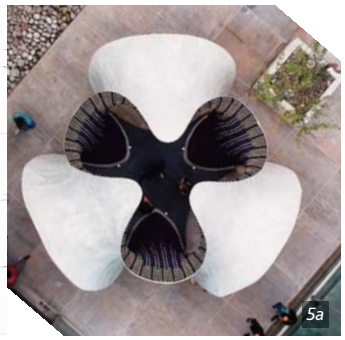


Figure 3. Interior of the finished structure referring to the colourful dress of Jalisco © Philippe Block
Figure 4. Section detail
Figure 5a-b. Top view / Drone image©Leo Bieling

to create a rigid mould, and supported by additional falsework elements such as a tensioned cable-net or bending-active splines. Compared to conventional weaving, knitting minimises the need for cutting patterns to create spatial surfaces, allows for the directional variation of material properties, and simplifies the integration of channels and openings, for example, for the insertion of additional formwork elements, insulation, reinforcements, electrical components and technical systems for heating and cooling.
The hybrid and ultra-lightweight KnitCrete formworks are thus easily transportable, reduce the need for additional supporting structure and scaffolding, and simplify the logistics on the construction site (Fig. 2).

KnitCandela

The 50m² of textile shuttering of the formwork for KnitCandela is made up of four long strips ranging from 15m to 26m in length. Each of the four pieces is a seamless, double-layered textile produced in one go. The two layers of the textile fulfil different tasks. The visible inside is an aesthetic surface that displays a colourful pattern and reveals traces of the supporting cable-net falsework system. The backside fulfils technical needs by including features for inserting, guiding and controlling the position of additional formwork elements.
The pockets created between the two layers as part of the spatial knitting process are inflated using standard modelling balloons. These inflated pockets become cavities in the cast concrete, forming a structurally efficient waffle shell without the need for a complex, wasteful formwork. On the technical side of the textile, the pockets have different knit densities to control the inflated shape and openings for the insertion of the balloons, such that differently sized cavities can be created with one standard balloon size.
The interplay between the soft, warm, colourful fabric on the inside of the shell and its hard, cold concrete exterior is visible from all viewing angles. The stripe pattern visualises the short rows typical of the knitting fabrication process and expresses the radial symmetry of the shape. The pattern along with the simultaneous visibility of the soft inside and the hard outside of the shell, enhances the spatial experience of the curvatures of the shape and the space it defines (Fig. 3).

Enjoy the making-of movie https://vimeo.com/297258002

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http://block.arch.ethz.ch/brg/project/knit-candela-muac-mexico-city

Name of the project:	KnitCandela
Location address:	Museo Universitario Arte Contemporáneo (MUAC), Mexico City, Mexico
Function of building:	pavilion
Year of construction:	2018
Design:	Zaha Hadid Architects Computation and Design Group; Block Research Group, ETH Zurich
KnitCrete technology:	Block Research Group, ETH Zurich; Chair of Physical Chemistry of Building Materials, ETH Zurich
Fabrication & construction:	Block Research Group, ETH Zurich; Architecture Extrapolated
Structural Engineering:	Block Research Group, ETH Zurich
Concrete development:	Holcim Mexico
Site construction coordination:	Architecture Extrapolated
Global dimensions shell:	5.8m x 5.8m x 4.1m
Surface area of concrete:	47.5m²
Weight concrete:	5tonnes
Weight formwork:	30kg (cable net) + 25kg (knit)
Total length yarn:	350km
Type of yarn:	Polyester (PES)
Total amount of loops:	14 660 028
Knitting time:	36hours
Modelling balloons used:	1000
Sponsors:	COMEX, ETH Zurich, NCCR Digital Fabrication, Zaha Hadid Architects, Steiger, Participations SA, Holcim Mexico, Imerys Aluminates, Boston Consulting Group
Special thanks:	Grupo Altiva, UNAM Arquitectura

FILM TECHNOLOGIES FOR ADVANCING BUILDING SKIN FEATURES

FROM FUNCTIONAL FILMS TO TAILOR MADE LAMINATES

Fluoropolymers are well known materials in the architectural industry. Films made from these materials can be made into aesthetically pleasing building skins. Multilayer Optical Film technology can be used to manage building features while maintaining architectural aesthetics. The technology has been applied, for example, to the creation of visibly transparent IR mirror films, visible mirrors and decorative films.
3M's proprietary nanostructuring process allows for almost universal bonding of fluoropolymers to any substrate.

Fluoropolymer Film Technology

Films based on fluoropolymers are known in the industry for a long time. Still they have numerous features that make them unique in comparison to other resins.
They show for instance extremely high UV and weathering resistance paired with high mechanical stability over a wide temperature range from -200 up to +260°C as well as superior chemical resistance. Excellent barrier properties and high transparency comes along with low adhesion and susceptibility to dirt. They are non-flammable (LOI ranging from 35 up to 95%), weldable and can be easily recycled. Films made of ETFE are used in famous projects all over the world, e. g. the Eden Project Cornwall UK, the Unilever Building Hamburg Germany and the Minnesota Viking Stadium US.

Multilayer Optical Film Technology

At every interface between two different refractive indices (RIs), some light is reflected and some transmitted (neglecting absorption). When layers of differing RIs alternate, there is constructive interference for some wavelengths. Nature has numerous examples of interference colors (rainbow trout scales, beetles, morpho butterflies, etc.).

Multilayer Optical Films are based on a variety of polymers. Using this principle, they can provide functionality from heat rejection to mirror properties to decorative effects (Fig. 1). Their sharp-edged wave length reflection bands can be selectively tailored (e.g. IR, visible light). They feature up to more than 1000 alternating layers of bi-refringent and isotropic polymer pair layers. They can be used for highly reflective mirrors with up to 98% reflectivity, e.g. visible mirrors (400-800 nm), near IR mirrors (800-1600 nm), and broadband mirrors (400-1600 nm).

Nanostructuring Technology

3M's nanostructuring process offers a primerless, solventless, environmentaly durable modification of all polymeric substrates. Used on fluoropolymers, this creates a high wettability surface, outperforming sodium naphthalate chemical priming and corona treatment, while maintaining fluoropolymer features. It allows e.g. for nearly universal adhesive bonding of fluoropolymers and printing on fluoropolymeric films.

Conclusion

The combination of durable and universally resistant fluoropolymers with taylor made multilayer optical films, using the above described nanostructuring technology will allow for the creation of new and advanced film and laminate products for the architectural industry and beyond that have not been possible before.

REFERENCES

1. T.J. Alfrey and W.J. Schrenk, „Physical Optics of Iridescent Multilayered Plastic Films", Polymer Eng. Sci., Vol. 9, p. 400-404 (1969)
2. M.M. David, 3M Corporate Research Process Laboratory, Maplewood, MN; personal communication

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Sebastian Zehentmaier is Application Engineering Specialist with 3M Dyneon in Germany for over 12 years. In this role, he is responsible for global application and product development of ETFE and FEP and for the development of forward integrated fluoropolymer films and film applications.

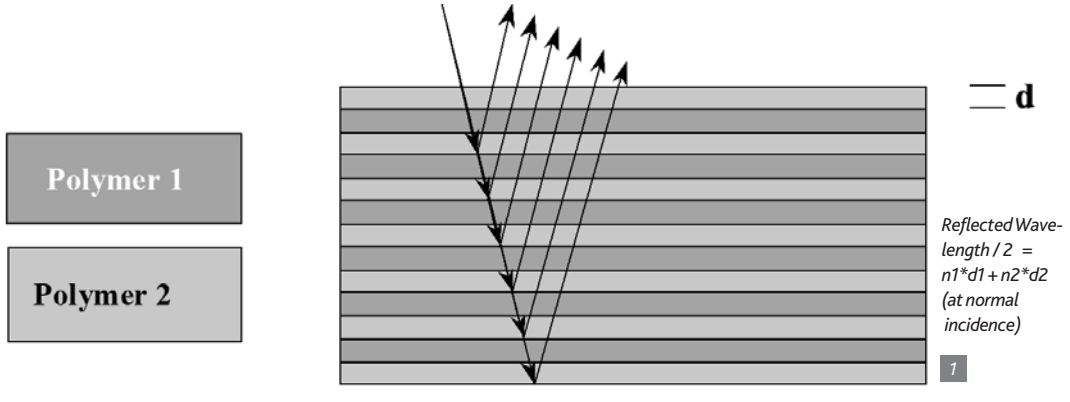

Figure 1. Quarterwave Interference Stacks (1)

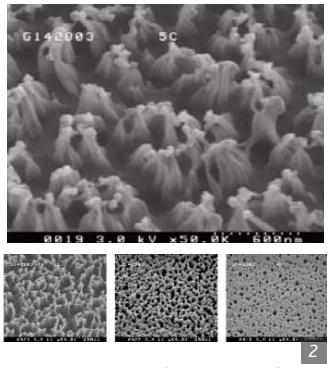

Figure 2. SEM images of nanostructured surfaces (2)

4. Essener Membranbau Symposium 2018

At 28 September 2018 the 4. Essener Membranbau Symposium 2018 was arranged by the Institute for Metal and Lightweight Structures of the University of Duisburg-Essen – now for the fourth time. This year, also tent structures have been considered and analogies between membrane and tent structures have been emphasized. 110 participants from practise and science found their way to a lively exchange in Essen. The organizers would like to thank the external speakers Dipl.-Ing. Stefan Regenfuß (Röder Zelt- und Veranstaltungsservice), Dr.-Ing. Thomas Misiek (Breinlinger Ingenieure), Dr. rer. nat Carl Maywald (Vector Foiltec), Prof. Dr.-Ing. Kai-Uwe Bletzinger (Technical University Munich), Dipl.-Ing. Christoph Paech (schlaich bergermann partner) and Dipl.-Ing. Jürgen Bradatsch (SL Rasch), who have contributed to an exciting day with their well worth seeing presentations.

Presentations

Prof. Dr.-Ing. Natalie Stranghöner (University of Duisburg-Essen, Institute for Metal and Lightweight Structures) gave a lecture on the current state in the standardization work for membrane structures on European and national level and tent structures on national level. This year, a second focus was laid on new design rules for stainless steel, which is oftentimes used together with membrane and tent structures. Her presentation can be downloaded for free from the website of the institute: www.uni-due.de/iml.

Dr.-Ing. Jörg Uhlemann (University of Duisburg-Essen, Institute for Metal and Lightweight Structures) presented intermediate results of the running research project „Characterisation and modelling of structural fabrics", funded by the German Research Foundation DFG (Deutsche Forschungsgemeinschaft). A new membrane component test stand has been planned and built, enabling the in-situ measurement of prestressed plane membranes under orthogonal surface loads. First test results revealed strengths and weaknesses of existing material models in detail. On this basis, material models are now going to be enhanced.

Tent structures as the central theme have been picked out by Dipl.-Ing. Stefan Regenfuß (Röder Zelt- und Veranstaltungsservice). He showed the development on this sector in the last two decades. Partly, tent structures have become so complex that the changeover to permanent and solid buildings is hardly to recognize. The disciplines of membrane and tent structures – since ever having obvious analogies regarding used materials, load bearing behaviour etc. – are thus coming even closer. In conjunction with membrane and tent structures, cables are used frequently, e. g. at field edges or for strutting.

Dr.-Ing. Thomas Misiek (Breinlinger Ingenieure) presented innovation in the ongoing revision of the design and product standards for cable structures. Thanks to analogies in the load bearing behaviour of cables and structural membranes it will be possible to adopt some rules in the standardization work for membrane structures.

Constructions with ETFE foils came up in the 80's of the last century. Vector Foiltec recently exchanged foils in two of the first structures. Thus, naturally aged material was at disposal for technical analyses. Dr. rer. nat. Carl Maywald (Vector Foiltec) could demonstrate that UV-rays have no negative impact on the foil's mechanical properties even after almost 30 years of service. Cyclic mechanical stresses even lead to stiffening and strengthening of the material.

The integration of mechanical analyses in CAD environments is currently one research focus at the Chair of Statics at the Technical University Munich headed by Prof. Dr.-Ing. Kai-Uwe Bletzinger. This is enabled by the „Isogeometric analysis (IGA)". One challenge is e. g. the mechanical coupling of subareas. Huge progress was made in the last years. With numerous examples, Prof. Bletzinger depicted the potential of this new method, provided by Kiwi3d. Kiwi3d is a PlugIn for Rhino3D, combining Grashopper with the IGA implementation „TeDA" developed at the Chair of Statics.

For a major stadium project in Qatar, a new woven fabric has been developed by schlaich bergermann partner sbp together with architects and material suppliers. The main goal was a textile optic of the fabric combined with traditional patterns of the Bedouins. But beside optics, this innovative uncoated fabric had to fulfil manifold technical requirements like e. g. tensile strength, fire safety, noise insulation, durability. Dipl.-Ing. Christoph Paech (schlaich bergermann partner) traced very vividly the development from the first approaches to the final product which is woven from polyester yarns surrounded by coloured PVC on a Jacquard weaving loom.

Dipl.-Ing. Jürgen Bradatsch (SL Rasch) presented convertible huge umbrellas. Impressive in form, colours and size they are the unique trade mark of SL Rasch. Moveable mechanisms enable the umbrellas with spans up to 53m to open and close automatically. PTFE fabrics, which are partially developed specifically for these structures, show enduring strength even in daily folding processes. The umbrellas withstand extreme UV irradiation and desert climate. They can be combined to huge climate roofs by smart arrangements of single umbrellas.

Traditionally, at the end of the day the Essen Laboratory for Lightweight Structures (ELLF) of the Institute for Metal and Lightweight Structures of the University of Duisburg-Essen and the various test stands could be visited. This occasion was lively used for active exchange.

The proceedings are available under: Natalie Stranghöner, Jörg Uhlemann (Eds.), 4. Essener Membranbau Symposium, Shaker Verlag, Aachen, 2018.

In the light of the good feedback, the organisers look forward to the next 5. Essener Membranbau Symposium 2020 to be held at 25 September 2020.

Dr.-Ing. Jörg Uhlemann
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Speakers at Symposium (from left to right): Christoph Paech, Dr. Jörg Uhlemann, Dr. Carl Maywald, Dr. Thomas Misiek, Prof. Natalie Stranghöner, Prof. Kai-Uwe Bletzinger, Stefan Regenfuß, Jürgen Bradatsch

Cincinnati has been at the forefront of neurologic care for more than 30 years. Physicians at the University of Cincinatti Health Department helped discover a couple of major neuroscience treatments — saving countless lives around the world. More than 125 physicians and researchers work together in the UC Gardner Neuroscience Institute aiming at being among the worldwide leading institutes in neuroscience research.

Figure 1. General view of the protecting skin made of tensile fabric © Mehler Texnologies - Figure 2 a/b/c. Detailing the three-dimensional structure © Structurflex (a); Mehler Texnologies (b-c)

UC GARDNER NEUROSCIENCE INSTITUTE

TRANSFORMING COMPLEX CARE WITH TECHNICAL TEXTILES

Being successful not only in research but also in treatment resulted in the need for a new house: in November 2016, the UC Health Board of Trustees approved the planning for a new building.
The institute was designed by Perkins + Will, the American interdisciplinary architecture and design firm. Together with the façade experts from Structureflex they developed the design for the undulating tensioned façade. It is made of Mehler Texnologies TF400 vinylcoated polyester mesh. The tensile façade was installed end of 2018, the whole building opened for patients in spring 2019.

FlexFaçades by Structurflex is a globally operating specialist in tensile fabric façades and fabric cladding. The distinguished façade of the Neuroscience Institute provides protection from wind, heat, and solar glare, creating opportunities for reducing heating and cooling costs and even eliminating artificial heating and cooling systems. The homogenous façade wraps the main visual parts of the building. At the same time people working within the building can still easily look out of their windows – through the glass and equally through the mesh fabric (Figs. 1-2).

The façade's 3D structure softens the environment in many ways: on the one hand its acoustical effect adds to the surrounding streets' sound absorption. On the other hand the fabric's mesh structure has a filtering effect within the street's micro climate. Both functions are similar to those of the surrounding trees.

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Katja.Bernert@lowandbonar.com
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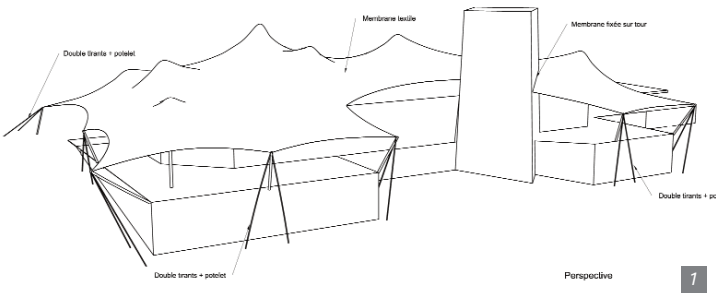
www.structurflex.com/

Name of the project:	UC Gardner Neuroscience Institute
Location address:	234 Goodman St, Cincinnati, OH 45219, USA
Year of construction:	2018
Architects:	Perkins + Will
Client (investor):	Messer Construction
Function of building:	University Building
Type of application of the membrane:	undulated sunshade façade structure over glass curtain wall
Contractor for the membrane (Tensile membrane contractor):	Structurflex
Supplier of the membrane material:	Low & Bonar GmbH
Manufacture and installation:	Flexfaçade by Structurflex
Material:	Mehler Texnologies Valmex TF400, white

Chrifia Golf Club House

Marrakech, Morocco



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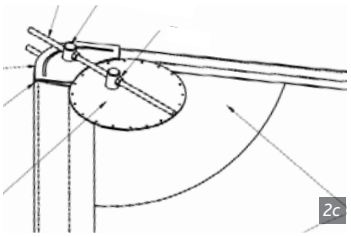
You wouldn't expect it but Morocco is well known for its fabulous located golf sites and so it became in the last 10 years one of the world's exciting destinations. The Chrifia Golf club house is built in a unique and massive "Marrakech" style and is enlarged with an attractive tensile structure. This large tent has two purposes: It should cover and shade the perimeter of the large terraces and secondly it should federate the building and its terraces under a cover designed like the snowy peaks of the Atlas (Fig. 1) The architect Youssef Melehi develops an architecture that takes tradition into account, but at the same time lends itself to innovation. The engineering office Prat SA was responsible for the calculations and execution details of the membrane (Fig. 2) and it was Ametema SARL who took care of the execution phase.

The use of the fabric Precontraint known for its low shrinking and primordial creep was essential here, as the structure measures 50mx30m and was made from one piece of membrane. The light under the textile roof is very pleasant. The canopy protects well the heat of the sun of Marrakech while remaining faithful to the allegory of snow-capped peaks (Fig. 2 – 3).

Interesting to know is that the same team of architect, structural engineer and contractor-manufacturer were involved in the realisation of the tensile canopies for the station of Marrakech, located only a few km away from this site.
See http://www.ametema.ma/realisations/gare-de-marrakech-maroc/


2a


2b

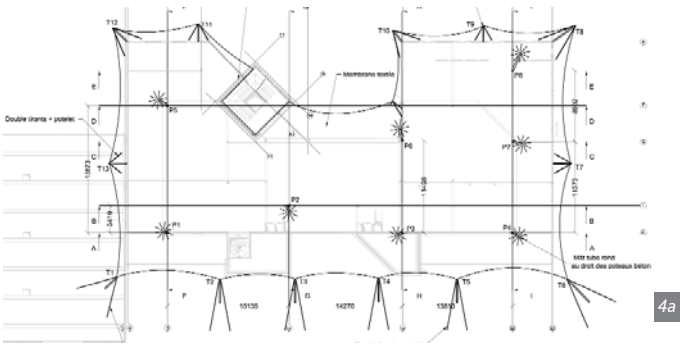

2c


2c


2d


3a


3b



4a

4b

Elalem Youness
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Figure 1. Tent structure referring to the snowy peaks of the Atlas mountains © Youssef MELEHI
Figure 2a - b. Under the canopy © Ametema.
Figure 2c. Construction detail edges © Prat SA
Figure 2d. Construction detail upper part post © Prat SA
Figure 3a-b General view © Ametema.
Figure 4a-b. Top and side view © Prat SA

Name of the project:	Chrifia Golf Club House
Location address:	Marrakech, Morocco
Client (investor):	Compagnie Générale Immobilière (C.G.I.)
Function of building:	Club House Building and Maintenance Facilities
Type of application of the membrane:	solar protection
Year of construction:	2014-2015
Architects:	Youssef MELEHI
Structural engineers:	Prat SA – Toulouse
Consulting engineer for the membrane:	Prat SA – Toulouse
Engineering of the controlling mechanism:	Save Project
Main contractor:	Ametema SARL
Contractor for the membrane (Tensile membrane contractor):	Ametema SARL
Supplier of the membrane material:	Serge Ferrari
Manufacture and installation:	Ametema SARL
Material :	Précontraint 1202S
Covered surface (roofed area):	1600m²

SLTE 2018 Seventh Latin American Symposium of Tensile Structures

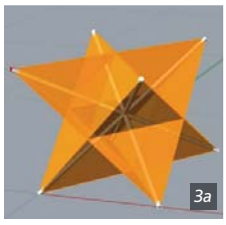
The Seventh Latin American Symposium of Tensile Structures was held in the Ccori Wasi Cultural Centre, Lima, in September 2018. It was organized by the Ricardo Palma University of Lima and chaired by Roxana Garrido and Jesús Peña. It was the seventh in a series of symposiums that began in São Paulo in 2002, followed by one in Caracas in 2005, in Acapulco in 2008, in Montevideo in 2011, in Santiago de Chile in 2012 and Brasilia in 2014.
The main topics focused on recently-executed projects, as well as applications, design, current research, and education.

OVERVIEWS

In his "Introduction to lightweight structures" Pedro Alva, from the Technical University of Perú, summarized their main characteristics and applications. Simplicity, efficiency and sustainability were mentioned together with a varied typology. He started from the antecedents of Joseph Plateau, Frederick Lanchester and remembered Buckminster Fuller, Felix Candela, Pier L.Nervi, Eduardo Torroja and Frei Otto. Nature as a model was also illustrated with several examples highlighting the variable radius geodesic domes (Fig. 1).

Alfredo Mujica, from the Ricardo Palma University presented alternatives to conventional reinforced concrete structures such as:
a) folded plates, based generally on laminar triangles that make up three-dimensional systems. The union of their edges are dihedral angles and the rigidity of the whole is given by the shape of the components and their connections. The folds can be parallel, radial or mixed.
b) hyperbolic paraboloids, that are usually combined and provide curved profiles.
c) tensile surfaces, the most efficient structures that provide more span with less material.
d) polyhedral structures. Considering that "the polyhedra are the bricks of the universe", professor Mujica showed several experiences made by his students (Fig. 2).

In "Learning by making. Academic experiences", Ruy Pauletti from the Technical University of Sao Paulo, reviewed the basic ideas concerning tensile ("taut") structures beginning with meaningful examples such as the windmills, the Golden Gate Bridge and the umbrellas (that are stiff because they are tensioned). He pointed out that they are light because they weigh less than what they support. He also clarified distinctive features by appropriated comparisons between rigid and flexible structures. Flexible structures change drastically the shape when the load pattern varies because they are funicular, meaning that the form has to follow the loads, paradoxically unlike the rigid structures that admit so called "free" forms. The design process was also summarised with special mentions to the equilibrium conditions and patterning. The talk was illustrated with several examples highlighting membrane tensegrity sculptures developed in the context of a graduate course on light structures at the University of São Paulo (Fig. 3).



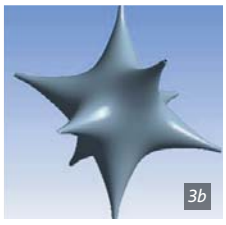


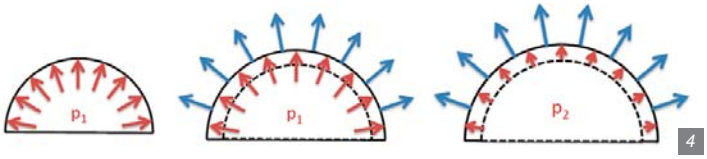
Figure 1: K.Tejlgaard & B.Jepsen, 2012: "Deconstructed" geodesic dome, Allinge.
Figure 2: A.Mujica, 2014: Students made a geodesic dome in Barranco.
Figure 3a/b: R.Pauleti, 2017: Cusped octahedral sculpture.

DESIGN

Jürgen Holl, (technet GmbH), presented the mean features of the software Easy for the integrated planning and calculation of lightweight surface structures accredited by 400 licenses in 40 countries. He began referring to modelling as an abstraction to approach the reality with the purpose of understanding and predicting. To get enough accuracy and savings, he preached the need for modelling hybrid structures instead of calculating each part separately. He illustrated it with the chambered pneumatic structures of the Expo in Switzerland. The separation of the substructure on two subsystems (pneumatic membrane plus steel ring, struts and cables) would imply increases of 67% and 100% in the computed values of the maximum bending moment and deformation respectively. Comparably, when it comes to pneumatic structures, satisfying the gas-law means a reduction of 67% and 52% in the computed values of the inner pressure and maximum stress respectively (Fig. 4). He also showed the advantages of using accurate models for textile halls considering sliding supports, shear stiffness and crimp. He finally presented the PreDesigner free tool addressed to all people who are interested in the predesign of textile membrane surfaces or cable nets. It helps to find a pre-design for 3D surfaces.

In "Architectural design of lightweight membrane structures", F.Alvarado presented on behalf of R.Roithmayr, the software "formfinder" as easy to operate as a sheet of paper and a pencil. It assists architects and project planners in the design, planning and cost-effectiveness assessment for the implementation of form-active structures (Fig. 5). Form-active structures are made of flexible non-rigid materials ranging from, for instance, a simple awning to "textile façades" and the roofing over sports stadiums. He also mentioned the capability of simulating different options according to the shape, size, curvature, sag/span ratio, proportions, loads, drainage, sun and shading in connection with an extensive database of typology and projects as a reference.

J. Llorens summarized the Joint Research Centre Science and Policy Report of the European Commission: "Prospect for European Guidance for the Structural Design of Tensile membrane Structures" to support the implementation of the future "Tensioned Membrane Structures" Eurocode. Although the geographical coverage of legal application of the Eurocodes is limited to that of the countries of the European Union, its content could be used as a reference for the standards of the Latin American region. The most relevant aspects of the document were discussed such as material properties, bases of design, durability, structural analysis, ultimate and serviceability limit states, details and execution. The annexes were also mentioned.



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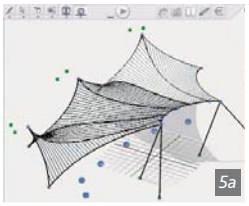
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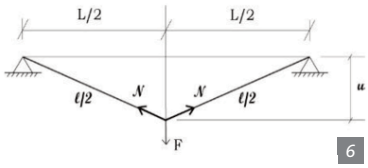
Figure 4: Pneumatic structure. Left: No external loads. Volume V1. Inner pressure p1. Middle: External load (wind suction). Gas low not satisfied. The inner pressure and the volume remain the same. Right: Gas law satisfied. Volume V2 > V1. Inner pressure p2 < p1.
Figure 5a/b: Velden Gemonaplatz sail, designed with Formfinder.
Figure 6: Tensioned rope subdivided into two elements.
Figure 7a: final geometry of the net.
Figure 7b: displacements of the conoid in the z direction.



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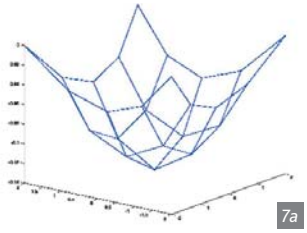
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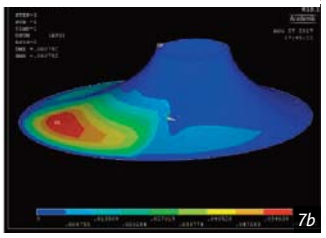
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Non-linearity was the topic of K.Rocha (Technical University of Sao Paulo) and R.Sastre (Technical University of Catalunya). Assuming that the magnitude of the deformations significantly affects the results, both speakers addressed the issue. Professor Sastre focused on the basics such as the justification of its necessity, the procedure of approaching it, its advantages and disadvantages. K.Rocha went into three models: a tensioned rope subdivided into two elements (Fig. 6), a net and a conoid (Fig. 7). The tensioned cord showed the significance of the geometric non-linearity. With the net, a routine developed with MATLAB was validated with the results obtained with ANSYS. And with the conoid, the search for the shape was explored aiming to a minimal surface. It was concluded that to discretise it as a net, radial and circumferential cables should be used and, as expected, the more refined the cable net, the greater the accuracy.

CURRENT RESEARCH

"Morflex", presented by R.Garrido from the Ricardo Palma University, is a morphostructural laminar system based on the tensegrity principle. This structural feature is manifested in the spatial order of the components, which are complemented through tense–compressive efforts. The main property of the Morflex system is to optimize the entire configuration through its flexible elements. These elements are arranged so that they allow release the potential energy generated by themselves. The application of Morflex system for this contribution is the design of a lightweight thematic pavilion (Fig. 8). The proposed lightweight structural innovation inspires its configuration in the jungle, as it seeks to sensitize the preservation of the Amazon, mainly affected by informal mining.

"Suitability of structural membranes to the refurbishment of historic buildings and protection of archaeological remains" was the presentation of J.Llorens from the technical University of Catalunya. The characteristics that make structural membranes suitable for the refurbishment of existing buildings have been investigated by analysing 80 interventions in 24 countries. The cases have been classified chronologically, distinguishing them by fields of application, by countries, and by the type of installations, whether they are mobile or fixed. Several design strategies have been identified and contrasted with the principles set by the International Council on Monuments and Sites. The results were illustrated with examples chosen from the cases investigated, with the aim of highlighting how membrane structures can fulfil the most important principles of the preservation of architectural heritage (Fig. 9).

"Hybrid shell structure in Colombia using wild cane and cementitious materials" by E.Cortés (University of Cambridge) explores the suitability of wild cane as an active bending material, corroborated graphically and mathematically with data obtained from previous research. Elastic deformation used as a self-forming process can be approached by three ways: behaviour-based, a geometry based and an integral approach. A behaviour-based approach describes vernacular methods of construction with wild cane. This research is focused on a geometry-based approach where geometry is defined by analytical and experimental form-finding methods. Currently experimental work with wild cane arches searches for a feasible spatial configuration with optimal behaviour under compression stresses (Fig. 10).

In "Air chain of bamboo" J.Simón (Technical University of Perú) showed a full-scale prototype of a dome based on the implementation of the "Bambú-Flex" mechanism seeking lightweight construction alternatives and searching for the efficiency of the structural design. Its flexibility, adaptability and modular design allows the achievement of the project with prefabricated parts post-formed during installation. (Fig. 11). This evolution of the "Bambu-Flex" mechanism is the result of the experiences and reflections conducted at "Bambú-Lab" since its formation in 2012. (https://www.facebook.com/bambulab.peru/). Lightweight bamboo structural systems have been investigated taking advantage of its qualities as a rapidly recovering renewable resource, non-polluting, low-cost and feasible


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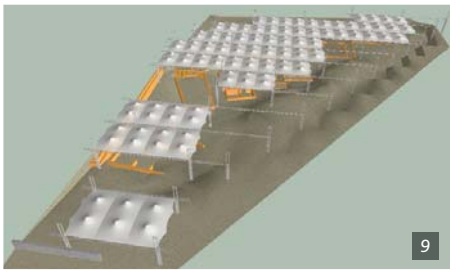
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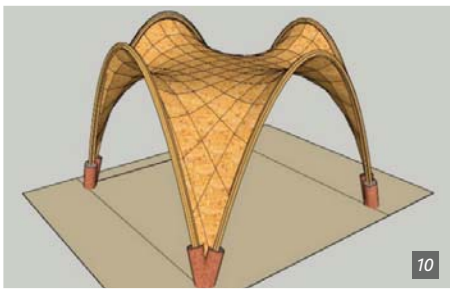
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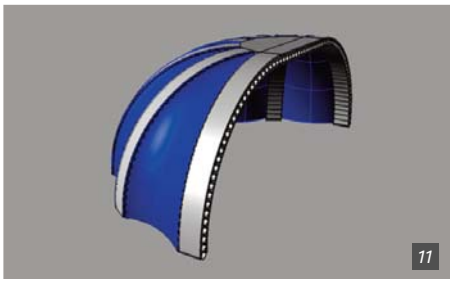
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Figure 8: Morflex Amazon Pavilion (IASS 2015 Amsterdam Symposium).
Figure 9: Modulated, lightweight and translucent textile roof for the "Amphitheatre Roman House" in Mérida (J.Llorens with Arqintegral, 2002).
Figure 10: Anticlastic wild cane structure.
Figure 11: Air-chain of bamboo prototype.

both as an industrial and handcrafted construction; which gives it high adaptability by integrating its lightweight and flexible nature with its morph-structural potential.

J.Espinoza (Ricardo Palma University) addressed the possibility of obtaining variable geometries through funicular tensegrities. He started from a previous idea of a super elastic tensegrity model (Fig. 12). Introducing bows and pulleys mechanisms, he hinted at the possibility of covering large surfaces with retractable roofs mounted on mobile rails supported by funicular systems. He considered the syncretic fusion of the concepts "tensegrity" and "funicular" a simple idea full of innovation and options for unsuspected structural uses.
M.Rodríguez (Ricardo Palma University) reported on an "Application of a post-tensioned reticular system made of guadua angustifolia". It is a system developed from a modular grid of bamboo easily assembled and adaptable to places with limited possibilities of anchoring (Fig. 13). The sections are hinged with pins forming an adaptable grid stabilized by embedded post-tensioned cables (Ø1/4") that run between the fixing points and the pinned joints.

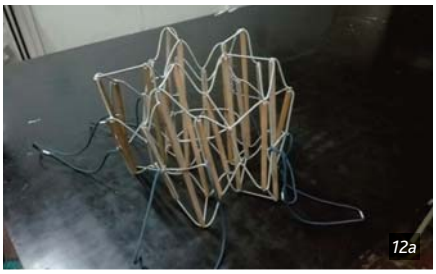
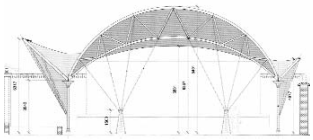


Figure 12 a/b: Loose (a) and stretched (b) variable geometry obtained through a funicular tensegrity.
Figure 13a/b: Post-tensioned grid of bamboo for "Safari Kids", Jockey Plaza, Lima.



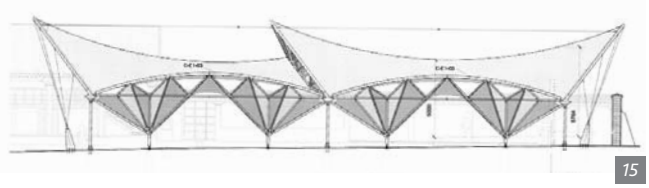


Figure 14: J.León, Architect with Grupo ESTRAN, 2016: Central arch. Coffee drying patio, La Estancia, La Floresta.
Figure 15: J.León, Architect with Grupo ESTRAN, 2016: Lateral arch. Coffee drying patio, La Estancia, La Floresta.
Figure 16a/b: Grupo ESTRAN, 2017: Roof-top terrace. Waldorf Hotel, Caracas.

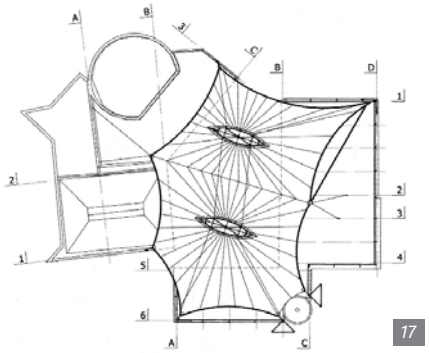
The system could be accommodated to prisms and polyhedra and the fixing points at the ends of the bars could be aligned or not for complex arrangements.

RECENT PROJECTS

Professor C.Hernández (Central University of Venezuela) reviewed 30 years of his professional activity dedicated to transformable architecture and membranes highlighting two recent works. The 615m² roof of the coffee drying patio at La Estancia (La Floresta) was distinguished because it was designed totally independent of the existing historical and protected colonial building. It is subdivided into two structural modules framed between 3 central arches (ℓ =14m, Fig. 14) and 4 lateral arches (ℓ =15m, Figs.14-15) complemented by micro perforated fabric shading panels. The roof-top terrace of the Waldorf Hotel in Caracas was also presented. It consists of a series of modules tensioned between the cornice, high points suspended from booms and low points attached to the parapet, the whole not interfering with the panoramic views of the city (Fig. 16).

Dr.Juan Gerardo Oliva Salinas (UNAM) described five of his works on existing buildings in Mexico. They are the "Artists Promenade" of the Azteca TV, the "Danzantes" restaurant in Oaxaca, the UNAM University Cultural Centre and the courtyards of the Oaxaca Government Palace and Mexico D.F. "Palacio de Minería". For the Cultural Centre of the UNAM, he designed, together with the Architect M.J.Ontiveros, a textile roof over the square left between two buildings so that it can be used as a forum for performances. It is a translucent membrane anchored in the existing buildings and supported by two central flying masts provided with quasi-transparent polycarbonate skylights on top (Figs. 17 to 19).

Professor R.Sastre (Technical University of Catalunya) on behalf of O.Avellaneda (Monterrey Technical Institute) showed the 90m² Vertex prototype of a retractable pavilion made of 378 articulated straight bars supposedly intended for hosting student events. It has been designed by the research group as part of a PhD (Fig. 20).



J.G.Oliva & M.J.Ontiveros, 2012: Cultural Centre of the UNAM, México.
Figure 17: Plan.
Figure 18: View.
Figure 19: Detail.

W.Runza, from WAGG Arquitectura Textil, de-

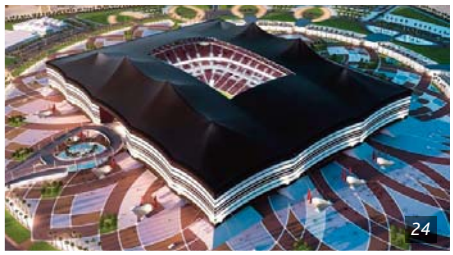
Figure 20: O.Avellaneda & J.Talamas, 2017: Vertex pavilion, Monterrey.

scribed the Bus Station of Puerto Madero, Buenos Aires (Fig. 21). It consists of four conoids supported by pairs of central masts finished with skylights. Three inverted conoids are interspersed between them for drainage purposes avoiding flat surfaces and reversing the curvature. Regarding the installation, although the manufacture of the 2.500m^2 was divided into three pieces, they were assembled onsite before lifting in order to hoist everything at once, including masts (Fig. 22). As a result, the 2.000m^2 of the bus station were covered providing visual identity to the project and the place (Fig. 23).

The most astonishing spectacular recent realization was shown by S.Taberner, from gmp Architekten, Berlin. She began by recalling their general philosophy summarized by simplicity, clear solutions, variety, uniformity, distinctiveness and structural order avoiding monotony. She tried to illustrate some of them with an outstanding example: the 770 millions of euros Al Bayt Stadium in Al Khor City, Qatar (Fig. 24). Its design is based on the Bayt Al Sha'ar, a black and white tent used traditionally by nomadic people in Qatar as a welcome symbol of hospitality for desert travellers. Especially surprising were the dimensions (311x 273m), the change of scale with respect to the original model (Fig. 25), the trussed steel structure above the reinforced concrete (Fig. 26), the retractable roof, the 6 different kinds of membrane (Fig. 27) including the one specially customized, and the services, comprising conventional energy-consumer air conditioning. The perimeter ties along with their anchors, which are not necessary at all, will remain as witnesses of the lack of adequacy of the original model.

A.Paredes from Paredes & Alemán, Architects, Guatemala was concerned with complex geometries and digital design. He illustrated them profusely with diverse experiences and realizations such as the textile formwork to obtain different textures or the sculptural decorations to characterize interior spaces (Fig. 28).

WAGG Arquitectura Textil, 2015: Bus station at Puerto Madero, Buenos Aires.
Figure 21: General view.
Figure 22: Installation.
Figure 23: Interior view.



Al Bayt Stadium, Al Khor City, Qatar.
Figure 24: gmp Architekten (optimization):
Figure 25: Bedouin black tent.
Figure 26: trussed steel structure above the reinfor ced concrete.
Figure 27: installation of different kinds of membrane.

Figure 28: Paredes & Alemán, Architects: Recycled bottles at "Zona Pradera", Guatemala.

EDUCATION

Professor Jesús Peña, form the Ricardo Palma University, Lima, presented his experience of teaching tensile structures carried out at the University. The academic environment emphasizes the research of tensile structures such as membranes, cables and tensegrities among others in order to encourage innovations based on lightness, which brings a lower energy impact, making a valuable contribution to sustainable development, unlike other conventional building systems. A group of students and teachers including Morflex and Bambulab have been theorizing and systematizing the information of these systems, recently incorporating biomimicry, active bending, and the use of digital manufacturing as a complementary tool to analogical modelling.

C.Huanambal, from the Chiclayo University showed his experiences in teaching and learning with geodesic domes that help to handle new digital techniques achieving constructive and structural efficiency. F.Martínez from the Southern Scientific University showed that geodesic domes can also be designed from other regular polyhedrons besides the icosahedron, which is the usual one (Fig. 29).

Figure 29: F.Martínez Cendra: Regular polyhedral dome.

ROBERTO MACHICAO TRIBUTE

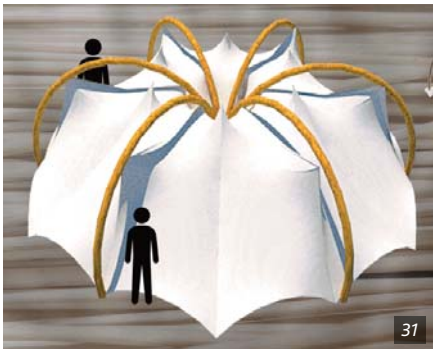
A special tribute was paid to Professor Roberto Machicao Relis (1934, Fig. 30), civil engineer graduated from the National University of Engineering (UNI) and honorary architect by the Private Antenor Orrego University (UPAO). After studying at the IL Institute he became a precursor of teaching lightweight structures in Peru leading the study of innovative structural systems such as textile roofs, tensile structures, hyperbolic paraboloids, laminated wood structures, funicular structures, geodesic domes, spatial structures and wave vaults among many others. During his long career, he has been coordinator and professor of the first Master of Architecture and the Diploma in Design for Tensile Structures. He has been also in charge of the UNI materials testing laboratory.

Figure 30: Professor Roberto Machicao Peris

He is currently professor at the Universidad Ricardo Palma (UPRP), and advisor of the company CIDELSA that provides comprehensive solutions for textile architecture and engineering.
Former students in the tribute panel emphasized that Professor Machicao managed to awaken the interest in exploring efficient forms because his knowledge focused on the introduction and understanding of structural criteria. He envisioned the pedagogical future and developed a multidisciplinary methodology unifying mathematics, physics, mechanics and structural morphology from natural methods instilling in the audience a taste for exploration and application of contemporary light structures.

STUDENT COMPETITION

The competition for design projects that make use of textile, cable, or tensegrity structures was open to architecture, engineering, and design students. The jury was made up by Roxana Garrido (Ricardo Palma University, Perú), Carlos Hernández (Central University, Venezuela) and Josep Llorens (Technical University of Catalunya, Spain). They gave the main award to S.Marañón, V.Cáceres and K.Valenzuela (Ricardo Palma University)
for the shelter "Khili Wayka" (Fig. 31)
and a second prize was awarded to R.Cabanillas, A.Valenzuela and V.Romero (Technical University) for their bamboo modular emergency shelter (Fig. 32).



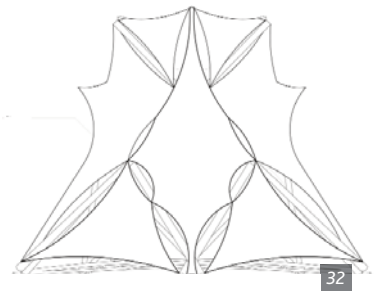


Figure 31: S.Marañón, V.Cáceres and K.Valenzuela, 2018: "Khili Wayka" shelter. Winning entry to the VII SLTE student's contest.
Figure 32: R.Cabanillas, A.Valenzuela and V.Romero, 2018: Bamboo modular emergency shelter, second prize of the VII SLTE student's contest.

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LA TENSORED.

The Latin American Network of Tensile Structures

The Seventh Symposium was also an occasion to meet the members of the Latin American Network of Tensile Structures. They updated the management team and decided to held the VIII Symposium in Buenos Aires in 2020. The participant A.Paredes from the Francisco Marroquín University showed his interest in organizing the IX edition in Guatemala, 2022. More information and the full text of the proceedings are available at: http://www.latensored.org

LEADER HEIDRUN BÖGNER-BALZ SET UP A CODE OF CONDUCT TO IMPROVE QUALITY

Within the TensiNet working group Good Practice a series of Good Practice rules were elaborated. The TensiNet Association wants to ensure, that members committing to the code of conduct offer exclusively products and services on the market which fulfil the quality ordered by the client and which meet the applicable norms, standards and laws. In addition, they agree to take into account the state of the art (technology).

GENERAL ASPECTS

- The specification of the client is fulfilled in all issues.
- Relevant standards, directives and laws are considered. Particularly, legal requirements for employed persons and for workplaces are achieved and considered. Employees and persons commissioned receive at least the mandatory minimum wage. The state of the art is applied.
- Consumption of natural resources and any burdening of the environment has to be considered.
- Offers shall be made according to legal requirements.
- The member shall be ISO 9001 certified or follow comparable standards. The involved party has sufficient capacity (personnel and material) as well as sufficient professional knowledge to manufacture or deliver the ordered services and products in the ordered quality. The party may use appropriate subcontractors.
- Subcontractors shall also follow all formulated rules in here.
- The company shall have an adequate quality assurance system ensuring the quality of the ordered services, the products manufactured and the intermediate products used.
- The company shall ensure the traceability of all products from the place of use back to the origin of the single components. An end of life treatment shall be taken into account.
- Involved Parties in tensile architecture for which individual rules have been formulated in this document are:
  - Raw material suppliers,
  - Membrane material producers,
  - Membrane manufacturers
  - Architects
  - Designers / Engineers

SUBSCRIBE THE TENSINET GOOD PRACTICE CODE OF CONDUCT

TensiNet members who want to subscribe the TensiNet Good Practice Code of Conduct should send an email to info@tensinet.com mentioning:

- Individual party is a Raw material supplier, Membrane Material producer, Membrane Manufacturer, Architect or Designer/ Engineer (select)
- Company name; First name; Last name; email & address
- "We follow the approved standards of good practice rules of TensiNet"
- "We agree to terms of publishing to above information"

Please notice that all **TensiNet members subscribing the TensiNet Good Practice Code** of Conduct will be mentioned in the online **TensiNet Good Practice Code of Conduct List** (see https://tensinet.com/index.php/about/good-practice-database).

TENSINET WORKING GROUP
GOOD PRACTICE

Every member should be aware of his individual responsibility for the quality of the own work. The delivery of quality serves to avoid errors and deficiencies, to ensure the satisfaction of the customer and finally the trust in structures with membrane materials. This does not only serve the respective company, but also the sustained growth and well-being of the membrane construction market. This is a major goal of The TensiNet Association formulated in the Memorandum of Understanding.

Everyone stating to follow the "Good practice" rules has to consider all general aspects as well as the rules formulated for the individual party her or his company is belonging to.

INDIVIDUAL RULES FOR INVOLVED PARTIES

Raw material suppliers

Raw material suppliers (producers of thermoplastic materials) shall fulfil the following aspects:

- The company possesses a certification system according to ISO 9001 or comparable.
- Environmental aspects are considered in production. Thus rules for sustainable production have been formulated. Recycling systems have been installed.

Membrane Material producers

- The company is certified according to ISO 9001 or comparable.
- The company offers "structural membranes" for architectural application with the needed performances like e-g- durability and recyclability.
- Transparency about the performance of the material should be given; REACH (Registration, Evaluation, Authorization and restriction of Chemicals) conformity of the material has to be considered.
- The company demonstrates the material properties needed for the design of textile architecture.
- Innovation in structural membranes is provided.
- Reference projects are available.
- Qualified sales people with experience and who are able to give recommendations on the right use should be available.
- Traceability of product quality has to be given.
- Experience of reachable values for the used materials, details and techniques is given i.e. recommendations on joining techniques according to specific requirements can be provided.
- Personnel should therefore be provided the needed skills, experience and internal qualifying procedures.
- General rules and relevant standards are followed.

Membrane Manufacturers

- QA-System like e. g. Certification according to ISO 9001 or comparable has been established (covering all procedures (like e.g. joining methods, correct handling, dimension control…)), traceability of products, regular training of staff.
- Experience of reachable values for the used materials, details and techniques is available (i.e. defining the joining/ seam performances by dividing them into classes according to specific requirements).
- Personnel should be qualified according to personnel skills, work experience and internal qualifying procedures.
- In house testing and / or regular checks with third party testing shall be provided.
- Quality manual for each project is created.
- General rules are followed e. g. Design Guide, SaP-Report (https://tensinet.com/files/Inspiring/JRC100166_Guidance%20for%20design%20of%20membrane%20structures%20-%20final.pdf) etc.
- Only companies who are controlling themselves can deliver good and consistent quality.

Architects

- Registered Architect.
- Accounts for the unique nature of tensile structures.
- Has own experience of tensile architecture or involves an experienced designer or engineer.
- Development of the project and management of works with right expertise, or involving partners who have these skills.
- All conditions should be known before drafting the project: functional conditions, climatic conditions, structural conditions and construction conditions.
- Functional and technical issues should be known that may arise during the life of the cover, and design in the manner for being able to deal with them, reducing maintenance efforts and costs.
- Efforts should be made towards sustainable design, which means: the use of materials with low CO_2 production and recyclability; reduce maintenance to the minimum; bioclimatic behaviour of the roof (taking into account the internal comfort).
- Plan of proper maintenance must be prepared, with minimum expenditure, and ensuring that the integrity and quality of the elements and materials remain throughout the life of the building.
- Local codes and restrictions should be taken into account.

Designers/ Engineers

- Registered Engineer, with knowledge and experience in building codes.
- Accounts for the unique nature of tensile structures.
- Should have experience of tensile architecture or involves an experienced colleague engineer, development of the project and management of works with the right expertise, or involving partners who have these skills.
- Efforts should be made towards sustainable design, which means: the use of materials with low CO_2 production and recyclability.
- Functional and technical issues should be known that may arise during the life of the cover, and design it to be able to deal with them.
- Plan of proper maintenance must be prepared, with minimum expenditure, and ensuring that the integrity and quality of the elements and materials remains throughout the life of the Building.

OUALALOU+CHOI/GROUPE ALTO/IASO

Marrakech, Morocco

COP22 VILLAGE

THINKING SUSTAINABLE FOR A TEMPORARY SPINE MADE OF CANOPIES

Figure 1. Installation of the canopies © IASO

Every year thousands of delegates from 195 countries meet for the United Nations conference on climate change in order to address questions concerning the future of the planet.
For the 2016 edition the office OUALALOU+CHOI was chosen to design the exhibition spaces for the COP22 which took place in Marrakech. This project, which addresses questions of architecture's role in creating temporary urbanism, continues the office's research, evident in such projects as the Pavilion of Morocco at the world exposition EXPO 2015 in Milan and the installation of a temporary tensile structure on the plaza of the Institut du Monde Arabe in Paris in 2014 (see TensiNews 28).

Context

The design of the exhibition grounds is based upon a temporary urbanism created by the installation of a village of canopies, entirely demountable and reusable. The exhibitions grounds were constructed within a span of five months on an empty piece of land, facing both the historical wall of the city and the Atlas Mountains. The main axis of the site connects to two of the principal roads of the city. The central spine, 680m long and 18m wide, unites all the elements of the program and is covered by a gigantic canopy along its entire length.

Canopy

The tent is a primitive and universal form of architecture that speaks to the common needs of man on this planet. The enormous tented structure over the central space covers 12.000m² and arises from a collaboration between OUALALOU+CHOI and the manufacturer Serge Ferrari. The first series of design sketches were made by Group Alto, consulting engineer for the concept design of this spine of canopies (Fig. 2).
The prestressed membrane is of an openwork design to create an effect of transparency while still remaining completely waterproof. The COP22 provided the opportunity to create an innovative tensile project, both in terms of its structure and its materiality.

Figure 2 a/b/c. design sketches of the spine © Group Alto

SAINT-GOBAIN

Allianz Field stadium

CHOOSING THE PERFECT FIT

St. Paul, Minnesota, USA

Context

When Minnesota United FC of Major League Soccer (MLS) decided to build a new soccer specific stadium in St. Paul, they wanted to not only create an iconic new stadium, but one that would also break new ground in design and materials. Of course, the stadium had to be practical in design, too. Minnesota winters are notoriously harsh, and the MLS season begins just as winter in the area comes to a close.

Objectives

The owner challenged their design team to create a façade unlike any other – one that would allow light in, as well as a view out from inside the stadium, yet still protect fans from the harsh weather. Using a material that is transparent, combined with an ingenious design and state of the art LED lighting technology, the owner's vision was achieved.

Figure 1. Night view © MNUFC

Name of the project:	COP 22 village
Location address:	Marrakech, Morocco
Client (investor):	Comité de pilotage de la COP22
Function of building:	event
Type of application of the membrane:	Canopies
Year of construction:	November 2016
Architects:	Oualalou+Choi
Consulting engineer concept design for the membrane:	Group Alto
Main contractor:	GL EVENTS
Contractor for the membrane (Tensile membrane contractor):	IASO,SA
Supplier of the membrane material:	Serge Ferrari
Engineering, manufacturing and installation:	IASO,SA
Material:	Précontraint WP392 – Anthracite 2047
Covered surface (roofed area):	12.400m²

Figure 4. A spine made of temporary canopies © Luc Boegly

Textile

The office IASO was chosen for the engineering, manufacturing and installation of the canopies. The major task was to define a system that could enable the canopy, both membrane and structure, to be easily installed and be reused. .

A total of 12.000m² was obtained by joining 19 modules of 18mx36m using defining only four different types. The first one (A), the last one (C), the central (B) and its symmetric (B'), the difference between the modules consists in the position and height of the posts creating high and low points apparently random with cables between posts in the center and in the perimeter (Figs 5-6).

The modules are formed by 3 independent membranes of 6mx36m, one at both sides and one in the middle fixed by carabiner clips to a cable in the center leaving a space of 8cm in between the membranes. Each post has oriented plates for the cables, a curved hoop for the membrane and a threaded rod system to regulate the height and the tension. The solution for absorbing the membrane's stress black ribbons reinforcements are used at all the edges and the center rope in order to avoid any clamped solutions (Fig. 7).

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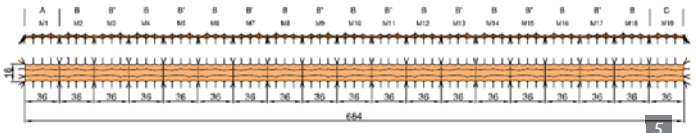


Figure 5. Plan and section mentioning the different modules (A, B, B' and C) © IASO

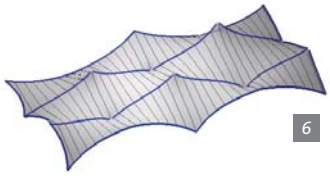
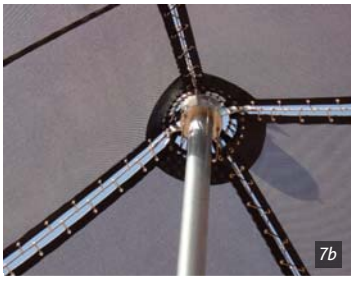
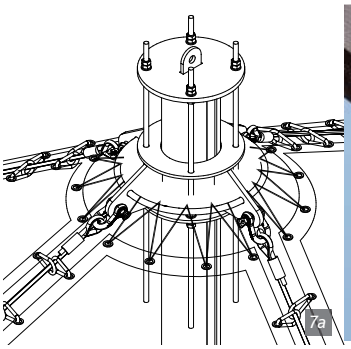


Figure 6. Module A pattern layout © IASO





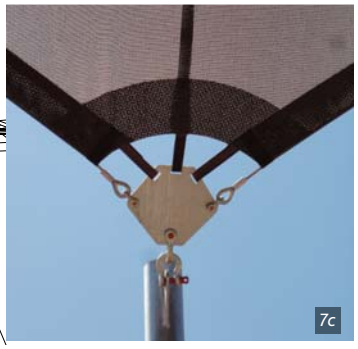


Figure 7 a-b. Construction detail upper part of the post © IASO
Figure 7c. Construction detail edges © IASO

Material

The material selected for the façade – SHEERFILL® Illuminate 28 Silver from Saint-Gobain – was the perfect fit to meet the design objectives. The dramatic design uses "driver" tubes to provide the undulating shape of the stadium and takes advantage of the properties of the Illuminate 28 Silver. The material is very light - less than 1kg/m² – with excellent tensile and tear strength. The high strength allows for less structure and support, especially compared with alternative materials that do not have reinforcement. Additionally, Illuminate 28 Silver is deployed like most other reinforced architectural membranes. Design, welding and fabrication are similar to standard SHEERFILL membranes, and Illuminate materials are used in single layers – no need for cushions or complex control systems.
Since Illuminate is made of the same basic materials as traditional SHEERFILL membranes – PTFE and fiberglass – they exhibit the same outstanding properties relative to fire performance (Class A) and an easily cleaned/rinsed surface.

Project:	Allianz Field
Location:	St. Paul, Minnesota, USA
Function of building:	Major League Soccer Stadium
Completion:	2019
Owner:	MN United FC
Architect:	Populous
Engineer:	Walter P. Moore
General Contractor:	Mortenson Construction
Contractor for membrane:	FabriTec Structures
Material:	SHEERFILL Illuminate 28 Silver
Surface Area:	Approximately 10.000m²

Allianz Field is the first major project realized with SHEERFILL Illuminate. The result is a stadium unlike any other; one which will likely inspire others to create similar dramatic structures in the future.

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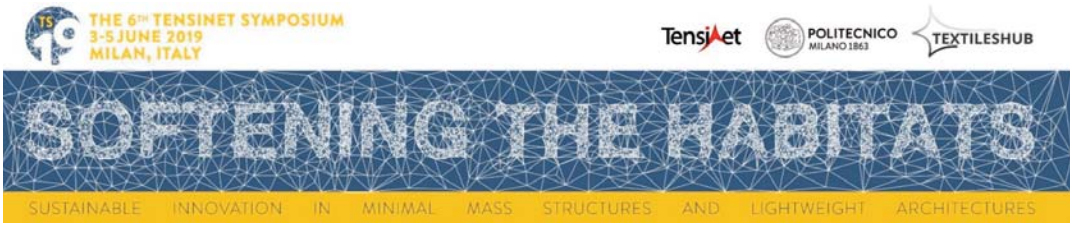

*The upcoming TensiNet 2019 is approaching! The symposium will take place at Politecnico di Milano, from the 3rd to the 5th of June 2019 and its main theme is Softening the Habitats. Sustainable innovation in Minimal Mass Structures and Lightweight Architectures. We propose a twofold reflection by means of the conference and its counterbalance, the **IN TENSION** exhibition that will be held from the 3rd to 15th of June 2019.*

About the conference, more than 60 contributions so far cover a wide spectrum of the three main topics of the 6th TensiNet edition: ***Soft Structures*** (June the 3rd), ***Softening the Environment*** (June the 4th) and ***Soft Skin*** (June the 5th) that are introduced by an inspiring mix of keynote lectures. In the first day sessions, lightweight structures are explored mostly in terms of structural performances of membranes (demountable, kinetic and kinematic, foldable, complex and hybrid) and pneumatics, and innovation in the production and installation processes. The **IN TENSION** exhibition is presented at the end of the morning session. Keynote lectures are given by **Christoph Paech** (Schlaich Bergemann Partner, Germany) whose lecture explores retractable membrane structures highlighting requirements such as flexibility, sustainability and adaptability of these structures to different venues, and **Julian Lienhard** (str.ucture GmbH, Germany) whose research focuses on form-finding process of hybrid structures. To conclude the conference's first day, a field trip in the historical centre of the city of Milan is planned.

The second day sessions are devoted to deepen the *Softening the Environment* topic: several contributions address on one hand the theme of lightness in architecture towards environmental sustainability, on the other advancements on regulatory framework, with a focus on material analysis and performance assessment. We are honoured to announce that **Neven Sidor** (Grimshaw, UK) has recently joined the conference as a keynote speaker! Senior partner of the internationally awarded Grimshaw Architects, architect Never Sidor introduces the different range of projects of the practice, with a particular attention to the design process of the Dubai Expo 2020 Sustainability Pavillion (Fig. 1). Furthermore, as Softening the Environment keynote speakers, **Maibritt Pedersen Zari** (Victoria University of Wellington, New Zealand) explores the concept of regenerative design and cross-semination between ecology, biology and architecture. Professor **Norihide Imagawa** (TIS&Partner, Japan) instead presents a collection of projects realized during his career, particularly focusing on the link between structural design and "Nature of Structure" as he himself defines. In the afternoon, there is a joined panel session with IASS (International Association for Shell and Spatial structures) on the advancements of the Environmental Compatible Structures (WG 18) seminar. Then, an Open Talk is expected to share with a wider community the pivotal themes of the TensiNet Working Groups. To conclude the second day of the conference, the Castello Sforzesco is the impressive location for the planned social dinner event.

Figure 1. Visualisation of the Dubai Expo 2020 Sustainability Pavilion, Grimshaw Partners

On the third day session, contributions concentrate on the Soft Skins topic: building physics performances of membrane and foil-based skins are investigated, as well as how lighter skins can potentially generate novel ideas on habitats. The session is opened by the lectures of **Jan Knippers** (Institute for Building Structures and Structural Design, Germany), who specialises in the field of innovative and resource-efficient constructions, and **Mette Ramsgaard Thomsen** (Centre for IT and Architecture, KADK, Denmark) whose lecture focuses on knitted fabrics and the intersection between architecture and computer science (Fig. 2 – 4).

Looking forward to seeing you all in Milan, we gladly inform you that TensiNet members receive a 20% discount on the registration fee. For the details, please visit the official TS19 website or contact us by email.

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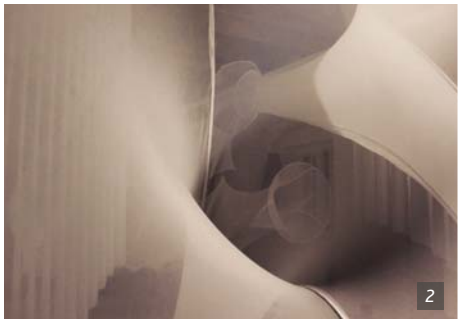

Figure 2-4. Installation made during the workshop Textile logics for a soft space, CITAstudio, KADK

IN.TENSION exhibition

In parallel with the conference, the TensiNet 2019 Symposium will collect a series of tangible results of the ongoing change in the field of tensile architecture in a dedicated exhibition, entitled IN.TENSION. The exhibition will be held at the Politecnico di Milano from the 3rd to the 15th of June 2019, containing two exhibiting modes, one for posters showing built projects and one for prototypes.

The poster exhibition aims at presenting cutting-edge projects, techniques and materials that have been implemented in the field of tensile architecture in the last 5 years and that have the potential of changing the construction and the lifespan of membrane structures for a more sustainable built environment. In a way, these projects still remain an intention, not yet disseminated and not yet common, but focusing on the future.

The posters will be on display in the Guido Nardi Exhibiting Space at Politecnico di Milano, amidst a tensile installation made of recycled leftover membrane pieces coming from different projects or manufacturers, as a symbol of the discourse on sustainability that the 6th TensiNet Symposium aims to open. The poster exhibition will also include an extended dynamic map, which will analyse the role of lightweight structures in the context of rising environmental concerns by doing a complete mapping of all the processes behind the exhibited projects, the materials they use and their lifecycles. This map will give a picture of the status quo and thus aims at becoming a reference for reflection in the near future.

The prototype exhibition gives the opportunity to more experimental projects to be shown, in contrast with the built projects in the poster exhibition. A selection of mock-ups will be scattered all around the campus of Politecnico and will highlight the latest research advances in the field of lightweight construction systems and materials. Green areas of Politecnico will host prototypes reaching dimensions of up to 3x3x3 meters and withstanding outdoor conditions, while covered vaulted areas of several courtyards will collect smaller scaled prototypes, reaching a maximum of 1x1x1 meters.

The exhibition will also extend to the TemporActive pavilion, which will enclose the entrance and starting point for the conference, in addition to a dedicated space for sponsors. TemporActive is the flagship project of the TensiNet 2019 Symposium, a temporary research pavilion with special focus on structural and environmental performance monitoring, that uses the combination of a bending-active structure and a translucent flexible envelope with the aim of facilitating the assembly and disassembly process. The structure will be installed in a central position, in front of Politecnico di Milano, Leonardo Campus: a space for innovation to show to students, the scientific community and citizens the most innovative ongoing advances in research (Fig. 5).

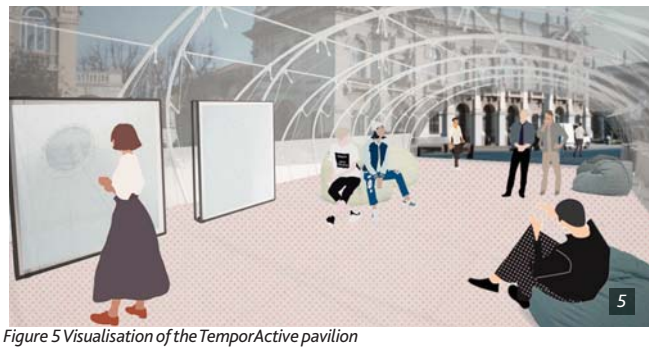

Figure 5 Visualisation of the TemporActive pavilion

We take the chance to remind you that sponsors of the TensiNet 2019 Symposium are granted a spot within the IN.TENSION exhibition and do not have to go through the selection process of the call for exhibiting. If you are interested in becoming a sponsor or an exhibitor, please consult our website for the full guidelines: www.tensinet2019.polimi.it

INFLATABLE ART INTERVENTIONS

Sea Monsters HERE

A TEMPORARY INSTALLATION

former navy Yard, Philadelphia, USA

Figure 1. Huge inflatable tentacles coming out of the desolate warehouse © JennfierTran, Group X
Figure 2. © Andrew Weiss Photography

Filthy Luker and Pedro Estrellas are driven by their passion for innovative design, public art and mischievous intervention. The duo have time again proven to be pioneers in the inflatable medium as well as carving themselves a unique niche in the international Street Art movement with their larger than life sculptures and anarchic humor. Their pop-up installations never fail to turn heads, raise smiles and create epic scenes that shifts the mundane towards the surreal, the sublime and often the downright ridiculous.

End of 2018 artists Filthy Luker and Pedro Estrellas in partnership with Group X, an anonymous collective of local artists and curators made a scaring installation of a huge sea monster trying to escape out of the windows from a warehouse at the former Philadelphia's navy Yard.

The sea monster consists of a series of 20 huge purple tentacles, up to 12m long, which are bursting out of windows and from the rooftop of the desolated building, moving as the breeze captures them.

These sculptures are sewn together and are inflated on location using a constantly powered fan. The fans are small and quiet and fitted discretely inside the sculpture. Once dismantled the pieces are packed down and compressed into small, carriable bags for economic transport and storage.

Designs in Air had a varied selection of these inflatables structurally assessed and certified and can therefore apply these safety standards to inflatable objects of similar size and shape.

Pneumatic structures with a twist!

More info on their website https://www.designsinair.com/inflatable-sculptures/inflatable-tentacles/ and https://www.filthyluker.org.

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SOFTENING THE HABITATS

MOVEABLE STRUCTURES

schlaich bergermann partner has been working on innovative movable structures for more than 20 years. This includes several fields of engineering and construction like retractable bridges, CSP-technology and movable roofs for concert halls, court yards and sport facilities.

The demand for smart buildings with adaptive components is growing from year to year, since they increase the possible usage options and functionality of a building significantly. Retractable roof or façade elements are often implemented in projects of all sizes, to, for example, flexibly protect a space from environmental conditions, enhance a certain user comfort or react on different utilizations. A deployable roof for example can transform an outdoor stadium into a mega multipurpose indoor arena within minutes. From an operational view, this creates valuable possibilities and helps to successfully run the venue. However, there are of cause numerous technical and coordinative challenges that come with designing these structures. Its integration within a building or a fixed structure requires detailed planning and coordination between the involved collaborators. From an aesthetical point of view, it is important that the structural design for the retractable elements is developed in close consideration of the overall architecture and appearance of the respective building or space. Therefore innovative engineering solutions are required using appropriate materials. A smart structural system in combination with the use of lightweight materials, such as high-strength steel cables and textile membranes, simplify the driving technology significantly and reduce the overall energy consumption during operation. The geometry of the supporting structural system must be carefully developed and designed for different configurations, so that beside the structural integrity the movability of the retractable elements is given under all relevant loading conditions.

Figure 1 and 2: Barahat Al-Nouq Square in Doha © schlaich bergermann partner, transsolar
Figure 3: Deployable roof at the National Stadium in Warsaw © Marcus Bredt
Figure 4 and 5: Deployable roof and pneumatic cushion at the BC Place Stadium, Vancouver © schlaich bergermann partner

Different moving principles are possible for deployable structures: They are either based on linear movement, radial movement or swinging movements. Furthermore, using flexible textile membranes or cables allows for the application of folding patterns that reduce the size of the overall system from fully deployed to the storage position. Typical reduction factors are seen in a range from 1/20 until 1/100.

Linear movements

The shade canopy structure for the Barahat Al-Nouq Square in Doha is approx. 35m wide and 90m long. In each of the 30 axes two cables are spanning between two building structures on either side of the square. From the fully locked cables 36 membrane covered panels per axis are suspended creating 18 V-shaped folds. At the upper end of the V-shaped fold the panel is fixed to the cable with sliding trolleys that move during operation. In retracted configuration the panels are stored at the perimeter while the folds are nearly vertical. In hot weather conditions, when the square needs to be shaded, the system is pulled to the other side of the square, opening the V-shaped folds and creating a zig-zag arrangement of the panels. The panels themselves are 2,70m x 1,40m in size and consist of an aluminum frame with a PVC coated Polyester membrane cover. Various arrangements of folding – also different in adjacent bays – are possible and provide on the one hand adequate shading of the square but also a unique visual appearance. The result is a puristic movable structure, which on demand can move within a few minutes (Figs. 1-2).

Radial movements

In the last years, we developed several large-scale convertible roofs, such as for the National Stadium in Warsaw and the BC Place Stadium in Vancouver. The moving procedure of the membrane roof of the National Stadium in Warsaw shows poetic engineering. Approximately 11,000m² of PVC coated polyester membrane are supported by 60 single radial cables. The roof can be automatically deployed from the central parking garage along these cables. Electric winches move the driving carriage actively into the reach of the hydraulic stressing cylinders. The membrane itself is connected to the driving carriages and certain sliding carriages, which are all running on the primary steel cables (Fig. 3). The specific weather conditions in Vancouver can potentially lead to very high accumulated snow drifts and loads. To assure the all-year use of the 8,500m² retractable roof, which transforms the stadium within 10 minutes into a fully closed multipurpose arena, inflated and pressure-controlled cushions were integrated instead of a single layer membrane. 36 cushions with a max volume of 105m³ are attached by sliding carriages to the lower cable of the cable girder. Radial Polyester belts between the cushions transfer the forces into the surrounding structure. They are mechanically stressed before the inflation of the cushion commences. A fluorpolymer coated PTFE fabric with extremely high translucency and excellent performance characteristics, especially in relation to the folding requirements, was chosen. The air pressure in the cushions is variable and responds to the respective environmental conditions. The standard pressure of 500pa can be adjusted to max 2000pa, based on load measurements of magnetic sensors at the primary steel cables and local climatic data input (Figs. 4-5).

Future prospects

Various further movable roofs structures using textile membranes are currently under development and construction. For these retractable roofs the very different and oftentimes extreme conditions like wind, snow, sun and earthquake need to be taken in account. Every roof concept and every planning process is unique and needs to be designed and addressed differently to respond to the local situation. In this regard, different movement concepts and geometrical principles are applied, creating outstanding systems with unique appearances. As stated above, the demand for individual roof structures is yet to increase in the future.

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