REPORT

STRUCTURAL MEMBRANES 2015

VII INTERNATIONAL CONFERENCE ON TEXTILE COMPOSITES AND INFLATABLE STRUCTURES

The "Seventh International Conference on Textile Composites and Inflatable Structures" was held in Barcelona in October 2015. It was organized by the International Centre for Numerical Methods in Engineering (CIMNE) and was chaired by E. Oñate (UPC) and K. U. Bletzinger (TUM). It was the seventh of a series of symposiums that originated in Barcelona in 2003. The next session will be held in Munich in 2017.
At the three-day conference, 9 plenary lectures and 81 presentations in 13 sessions were given to 118 participants from 25 countries and 4 continents. The main topics that were covered included: building physics, materials, testing, and advanced methods for analysis and simulation. Ongoing research, applications and recent projects were also shown.
http://congress.cimne.com/membranes2015/frontal/default.asp

Main lectures

R. M. Pauletti from the University of Sao Paulo began the plenary lectures exposing some basic ideas on the behaviour and analysis of cable and membrane structures. These structures require their elements to be taut rather than slack or wrinkled, in order to work properly. They are characterized by being lightweight, funicular, and flexible. Dr. Pauletti highlighted the paradox between the formal stiffness required by flexible structures and the wide range of shapes permitted by stiff structures (Fig. 1 and 2).

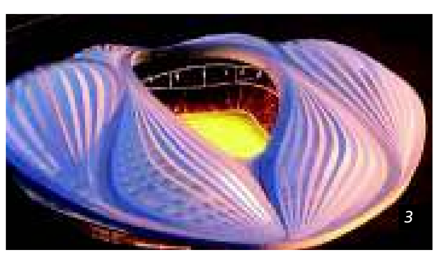
K. Göppert entertained the audience as he usually does with an impressive collection of works of Schlaich, Bergermann und Partner. He stressed the efficiency of the solutions developed illustrated with the Mercedes Benz (Stuttgart) and Amazonia (Manaus) Arenas, the BC Place (Vancouver), and the stadiums of Kiev, Krasnodar, Caracas, Cape Town, Warsaw, Baku and Abu Dhabi. However, disproportionate investments, whimsical shapes, and abandonment do not meet in some cases, the principles of efficiency and sustainability (Fig. 3).

R. Wüchner, from the Technical University of Munich, considered the computational wind-structure interaction for the analysis and design of flexible, lightweight, and complex-shaped structures. He focused on the ultra-lightweight and flexible Buildair pneumatic arches and evaluated the wind-induced phenomena, local wrinkling, the required consideration of increased air pressure under heavy storms, anchoring forces, and deformations. He explained the difficulties of simulating wrinkles, vibrations, proper wind modelling, dynamic properties, coupling, damping, stiffness, boundary conditions and scaling that require systematic stepwise validation of the results for the simulations be reliable (Fig. 4).

"70 years in 30 minutes" was the presentation of J. Hennicke from the ILEK (Stuttgart). He recalled the principal contributions of Frei Otto to the knowledge and dissemination of structural membranes and looked over his career, including his collaboration with P. Stromeyer, the largest manufacturer of tents in Germany, and the founding of the Institute for Lightweight Structures in Stuttgart in 1964.


1


2


3


4

Figure 1. The form of flexible structures is neither arbitrary nor free. It is funicular. (National Library, Riyadh).
Figure 2. The shapes of rigid structures can be arbitrary. (Louis Vuitton Foundation, Paris).
Figure 3. Al-Wakrah Stadium, Qatar.
Figure 4. Geometrical, non-linear structural simulation of a single tube. Wrinkling is highlighted.

Frei Otto based his method of design on the observation of natural processes to obtain the form as it was illustrated by his most significant work. In order to continue Dr. Otto's legacy, J. Hennicke recommended the issue of number 20 of the journal of the Institute, where 400 problems and issues related to the development of lightweight structures that remain unanswered are listed.

M. Majowiecki from the University of Bologna in "Wide membrane enclosures: personal experiences" discussed the particularities of wide span structures. He focused especially on the effects of scaling, mentioning particularly the Montreal Olympic Stadium, where the 1.800m^2 solution of the Boulevard Carnot swimming pool was scaled up to 20.000m^2. He noted that the Roma Olympic Stadium was the first of the current generation of large membrane roofs based on stretched radial cables that connect the inner tension and outer compression rings (Fig. 5).

J. Marcipar from Buildair explained his experience in the design of inflatable structures. He showed some images of what they have done in the past in order to detect weak points that led to improvements in making very large inflatable and portable structures based on single pressurized tubes. According to this technology, a 45m indoor span hangar for the Lufthansa Service has been erected at the Budapest airport (Fig. 6). Other applications, such as industrial, off-shore activities, remote locations, humanitarian aids, aeronautical applications, and disaster relief were envisaged.

A. Pronk, from the Technical University of Eindhoven, surprised the audience with ice architecture. Specializing in formwork techniques, he recovered the fibre-reinforced ice called "pykrete" and shared various experiences. His version of Antonio Gaudi's "Sagrada Familia" in ice stands out among his works and projects (Fig. 7). He announced upcoming designs based on Felix Candela and Leonardo da Vinci ideas (Fig. 8).

R. Wagner, from the Karlsruhe Institute of Technology, also surprised the audience by showing nets that are accessible to the public, that which recall the trapeze artists of the circus shows. The installation "In Orbit," by Tomas Saraceno in Düsseldorf, is a superposition of three cable networks, separated and stretched

Figure 5. The Roma Olympic Stadium, 1990, was the first of the current generation of large membrane roofs.
Figure 6. Buildair hangar, Budapest airport.
Figure 7. The "Sagrada Familia" in ice.

Figure 8. Ice bridge inspired by Leonardo da Vinci.
Figure 9. Tomás Saraceno, "In Orbit" installation, Düsseldorf.
Figure 10. Brazil pavilion, Expo Milano, 2015.

by six inflated spheres that produce the sensation of floating in the air to those who dare to move in them (Fig. 9). In the pavilion of Brazil at the Milan Expo 2015, the use of the network provided a combination of architecture and scenery as a metaphorical expression of flexibility and fluidity, offering to the visitors un-expected scenarios for leisure and rest (Fig. 10).

Technical sessions

17 Technical sessions included 81 papers devoted to topics of greatest interest for structural membranes, such as folding and adaptable structures, design procedures, advanced methods of analysis, ETFE, wind action, active flexion and flexible forms, pneumatic structures, aerospace applications, materials, essays, case studies, details, and installation processes.

Accomplishments, recent projects

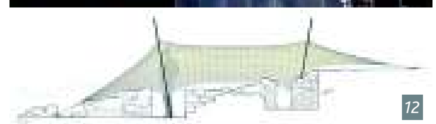
R. Houtman from Tentech showed the "Inno-wave-tion" portable pavilion based on the "tensairity" principle of combining inflated air beams with compression elements and cables (Fig. 11). In this case, a roof is pushed up by a central sphere and stretched against a compression ring made of CHS, stabilized by an inflated meandering torus around the perimeter. The structural analysis was performed integrating membrane and steel sections, and respecting the gas law, using the Easy-Beam and Easy-Vol modules of the Easy software by Technet GmbH.

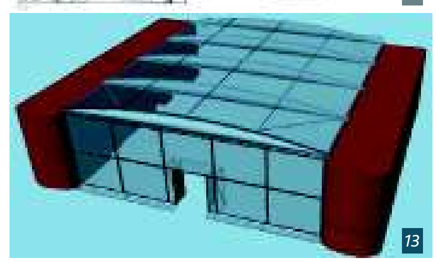
M. Barozzi from the Technical University of Milano proposed a solution to cover archaeological excavations that require climate protection, ease of installation, lightweight construction, minimal impact, and flexibility to match the different configurations of the archaeological sites. He developed a prototype for the ruins of Nora in Sardinia, based on the principle of active bending, in which the tension of the membrane is coupled with the bending of the supporting arches (Fig. 12).

Another accomplishment was presented by P. Becarelli, from the University of Nottingham, namely the itinerant Ducati Superbike Pavilion. The main requirements were to represent the commitment of the company to innovation and to the optimization of the transportation and assembly process of the structure. It was therefore decided to use five tensairity pneumatic beams resting on the trucks used for the transport of motorcycles and their equipment (Fig. 13).

C. Armendariz, from Crearquitectura, showed his achievements in Latin America. He highlighted the Mix Mall membrane structure in Guatemala. It is a ridge and valley membrane over a courtyard protecting a restaurant (Fig. 14). He announced the "VII Simposio Latinoamericano de Tensoestructuras" to be held at the Rafael Landívar University of Guatemala from 7 to 9 September 2016: https://sites.google.com/site/slteviisimposio-guatemala/home/slte-vii

N. Pauli described the insulated, ventilated, multiple-layer membrane of the CIRC Auditorium in the town of Auch, in southern France (Fig. 15). It has an elliptic ground plan of 48x32m, and a height of 19m. The structure is composed of 22 trussed arches made of laminated timber. The envelope is multi-layered. The internal skin is opaque, impermeable, and manufactured in one 2.200m^2 piece. The external skin is translucent and the 160mm Rock-wool insulation layer is fastened upon a 400g/m^2 PES/PVC 402 standard, white membrane. All membranes are PVC-coated polyester provided by Ferrari. A ventilated air cavity and water collector complete the design of the roof envelope.





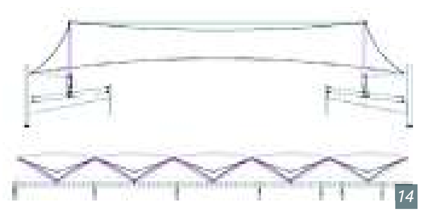


Figure 11. "Inno-wave-tion" pavilion by Silvain Dubuisson, for BNP.
Figure 12. Bending active shelter for the ruins of Nora (Sardinia).
Figure 13. The Ducati Superbike Pavilion.
Figure 14. Mix Mall, Guatemala, made by Crearquitectura.
Figure 15. CIRC Auditorium, Auch.

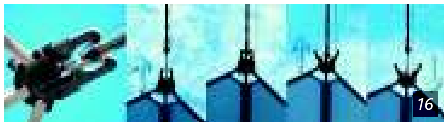


Figure 16. Autonomous mechanical clamping system.
Figure 17. Corner detail. Dornerplatz structure, Vienna.

Detailing

A. Hub, from Alfred Rein Ingenieure GmbH, discussed technical solutions for the construction of retractable roofs. The main points he focussed on were minimizing friction on the slide bearings, using central motor units, anchoring, locking, clamping (Fig. 16), pretensioning, and protecting the parking position. These points were illustrated by three case studies: the courtyard roof for the Künstlerhaus München, the Dome roof for the Tree Top Path in Bad Harzburg, and the auditory roof of the Natur Theatre in Bad Elster.

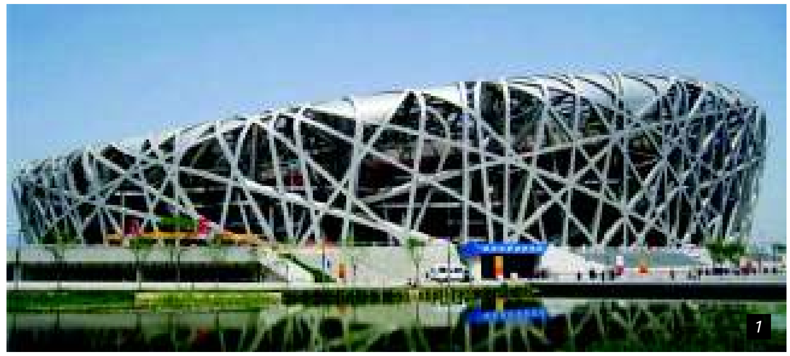
S. Chiu, from the University of Southern California, referred to corner details for tensile membrane structures in order to improve their design. The detailing of the connections and joints is particularly critical, because they essentially affect the entire structure's stability, durability, installation, maintenance, aesthetics, and cost. Firstly, corners involve material property changes among different structural elements. Secondly, through corner details forces are transferred from a large surface area to a supporting structure. And lastly, all these considerations must be resolved in the most concentrated area of the structure. Consequently, research has been initiated on this subject through interviews and case studies (Fig. 17).

Proceedings, plenary lectures and next conference

The Proceedings of the Conference are available at: http://congress.cimne.com/membranes2015/frontal/doc/Ebook2015.pdf
and the plenary lectures at YouTube:
https://www.youtube.com/playlist?list=PLiyl-VE6-1ou1-0pa8KV456yEtZU6stcU
The next international Structural Membranes conference will be held in Munich from 9 to 11/10/2017 at the Technical University. Further information will be made available at:
http://congress.cimne.com/membranes2017/frontal/default.asp

Josep I. de Llorens,
Dr. Architect, ETSAB/UPC
ignasi.llorens@upc.edu

Covertex joins Pfeifer group



Covertex membranes (Shanghai) Co., Ltd. provides advanced design, engineering, manufacturing and construction services in the field of membrane structures. Using materials such as ETFE, PTFE, PVDF/PVC and others, Covertex designs, produces and installs iconic membrane structures for government and private-sector in a wide array of industries, including infrastructure, commercial, sports and entertainment markets.

Since July 2015 it is a German owned business entity, held by PFEIFER Seil- und Hebetechnik GmbH, one of the world's leading company for complex structures. PFEIFERs well known expertise in steel, cable, glass and movable structures is now completed by the integration of Covertex. Thus, this global portfolio starting from design, engineering, fabrication, installation up to maintenance is now provided from a single source – a unique service to the construction business worldwide!

Together with Pfeifer, Covertex will continue to actively improve and develop new membrane technologies in close cooperation with innovative architects, high performance material suppliers and certified research institutes. With its design-, engineering- and manufacturing capacity, they will be a leading company in the field of membrane structures.
Covertex is completing Pfeifer expertise by supplementing membrane know-how. It is a competitive alternative to other building materials and best fitting to Pfeifer's cable structures, able to span large distances, flexible to complex shapes.

Examples of these iconic projects erected in China are the National Stadium, Macao Oceanus, Suzhou SIP and Guangzhou South Railway Station (Fig. 1 - 4).

Dr. Gregor Grunwald,
Pfeifer Covertex
ggrunwald@pfeifer.de
Thomas Hermeking,
Pfeifer Seil- und Hebetechnik
thermeking@pfeifer.de
www.pfeifer.info

Figure 1. National Stadium (2007)
Area: 36.500m² Single layer ETFE
Figure 2. Macao Oceanus (2009)
Area: 6.460m² ETFE Cushion
Figure 3. Suzhou SIP (2009)
Area: 9.500m² ETFE cushion + 8.500m² PTFE
Figure 4. Guangzhou South Railway Station (2010)
Area: 15.2200m² ETFE cushion