SLTE 2014

SIXTH LATIN AMERICAN SYMPOSIUM OF TENSILE STRUCTURES

The Sixth Latin American Symposium of Tensile Structures was held in Brasilia in September 2014. It was organized by the Polytechnic School of the University of Sao Paulo and chaired by Ruy Marcelo de Oliveira Pauletti. It was the sixth 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 and in Santiago de Chile in 2012. This edition has been held in conjunction with the annual Symposium of the International Association for Shell and Spatial Structures, which provided the opportunity to enlarge the scope of the conference. The main topics focused on recently-executed projects, as well as typology, design, materials, testing, current research, and education.

OVERVIEW

In his presentation, A. Capasso summarised his book: "Atopic architecture and membrane structures" (ISBN 978-88-8497-242-2), which focused on the use of tensile membrane structures in construction. The book aims to illustrate the contemporary place of these structures in architecture as a new structural archetype of the twentieth century. This approach involves textiles and fabrics, which define a contemporary architecture of lightness, brightness, and versatility, amounting to a new language with its own repertoire. Invited contributors to the book enrich the volume, and the blue sketches made by the author are delightful (Fig. 1).

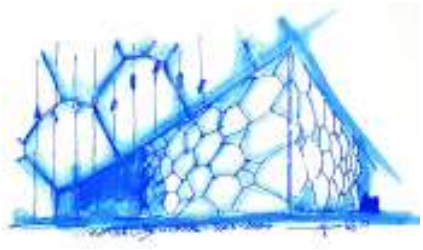

Figure 1. A. Capasso: Water Cube, Beijing 2008.

TYPOLOGY

K. Morishita introduced a classification of tension structures made of cables based on the tensile force level and on prestress application methods. According to this classification, recent designs and interesting installation examples were shown, with the pergola in the Marunochi Park Building standing out: an oval bicycle wheel around a column (Fig. 2 and 3).

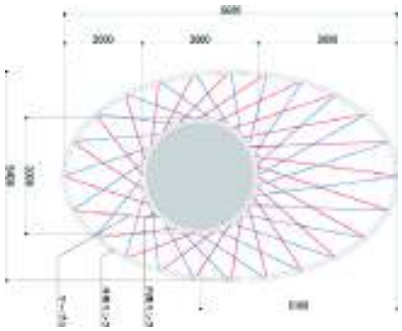

Figure 2. Pergola in the Marunouchi Park Building. Plan. M. Miyashita, I. Ogawa, T. Yoshihara, A. Okada & N. Miyasato, 2009. (Courtesy of K. Morishita).

Figure 3. Pergola in the Marunouchi Park Building. Elevation. (Courtesy of K.Morishita).

J. Jimenez presented the "String Tens" system to stabilize regular and semi-regular polyhedral frames, with emphasis on formal and functional optimization through the use of tensile structures. An application was submitted to the student competition (Fig. 4).

Figure 4. A playground in a cube stabilized with halyards. Universidad Privada del Norte, Perú.

Figure 5. The form of the Wuhan Greenland Centre optimizes the wind effect.

DESIGN

According to N. Goldsmith, shape finding and form finding are different approaches to design. By shape, he meant an arbitrary formal geometry or algorithm that suits aesthetic requirements, whereas form implies organization and purpose, such as efficiency and appropriateness (Fig. 5).

J. Llorens referred to several types of recoverable lightweight foundations in tension for structural membranes with different materials, geometries, manufacturing, installations, efficiencies, and depths. A better understanding of their uplift behaviour and mode of failure allows for the pull-out capacity of anchors to be estimated confidently, encompassing the complex relationship between various modes of failure, anchor geometry, and soil properties.

MATERIALS - TESTING - MONITORING

F. Sahnoune presented the Serge Ferrari Group's new product Précontraint TX30, which focuses on innovation, durability, and recycling based on its new top coat technology and PVC formulation. Recycling has been a concern that has led to the Texyloop procedure, because

80% of the material output is generated by raw materials. Prominent examples of recycling PVC-coated polyester fabric are the Mound Stand Lord's Cricket Ground, the German Pavilion at the 2010 Shanghai Exhibition, and the 2012 London Olympic Aquatic Centre (Fig. 6): http://en.sergeferrari.com/lightweight-architecture/recycling-a-promise-is-kept

Figure 6. The London Olympic Aquatic Centre has been partly dismantled and the PVC-coated polyester has been recycled.

H. Li monitored a 1.5x1.5m monolayer cable net that supports a 60.05x21m glass curtain of the Shanghai Lujiazui Diamond Tower (Fig. 7) to investigate the wind environment and the wind-induced vibration characteristics. He showed that the spectrum of measured fluctuation of wind velocity was basically in agreement with the Davenport wind spectrum, and the probability distribution characteristics of wind-induced response did not correspond to a Gaussian distribution due to the structure's nonlinear stiffness.

Figure 7. Glass curtain wall, supported by a monitored cable net.

J. Chilton presented on-site monitoring results of the thermal behaviour of an atrium enclosed by an ETFE foil-cushion roof, including the distribution of air, mean radiant and foil surface temperatures, and incident solar radiation. The study showed heat gain on the upper level under warm sunny conditions, and convection heat transfer during the absence of solar radiation on overcast days (Fig. 8).

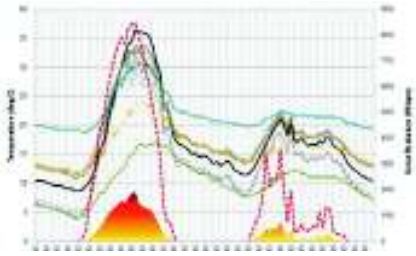

Figure 8. Typical thermal behaviour of the ETFE cushion during consecutive warm sunny and cloudy days in April 2014 (Nottingham).

ETFE

A novel form-finding method called the visco-plastic-forming process has been studied by M. Wu, using the unrecoverable deformation of ETFE foil to form the designed structural shape. This process makes the form-finding process of the ETFE cushion simpler. He performed uniaxial viscoplastic-forming tests, and found that strain contributes more to the creep process leading to the final unrecoverable deformation than does time.

Y. Li focused on biaxial creep tests of cruciform and bubble specimens of ETFE foil and their numerical simulation. He established coefficients of relation with uniaxial tests and simulated the bubble test by FEM with good agreement (Fig. 9 and 10).

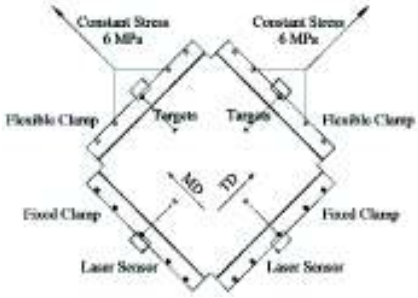

Figure 9. Cruciform creep test.

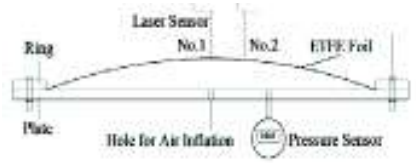

Figure 10. Bubble creep test.

E. Jeong reviewed the applicability of stretch fabrication using ETFE film. By manufacturing a study model (Fig. 11) and by performing tests, he was able to verify that stretch fabrication can be applied to films with various shapes and that it is an effective method for using the film under high stress.

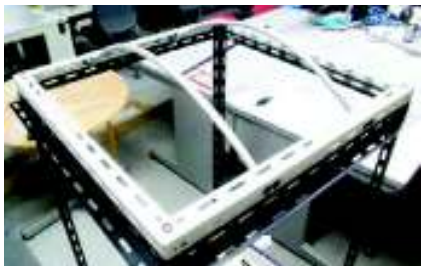

Figure 11. Parallel arch model to verify stretch fabrication.

W. Chen insisted on the flat-patterning way to determine the form of ETFE cushions. He developed an experimental set-up system of 2.5m triangular cushions, including photogrammetry and laser displacement measurements. Three phases were observed: form developing, creep, and creep-recovery (Fig. 12). The results demonstrated the applicability of the flat-patterning method and they unveiled more ETFE properties.

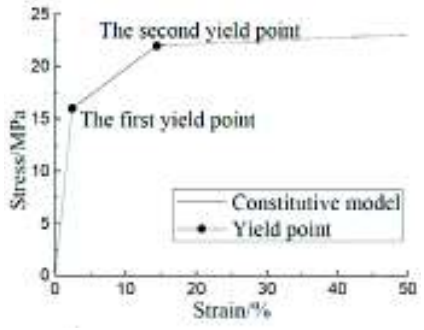

Figure 12. Simplified nonlinear constitutive model of ETFE foil.

CURRENT RESEARCH

The research of G. Filz & S. Schiefer provides a general framework for the creation of structurally-efficient forms composed of one or more intersecting anticlastic shapes assembled from planar modules, which can consist of planar elements. Due to planarity and material cuts, little data is necessary for the fabrication of the modules, which are easy to store, transport, and quickly assemble. In addition, changes of the sidewall angles generate architecturally-interesting patterns that can be rotated in space, while maintaining their structural performance and interlocking qualities (Fig. 13).

Figure 13. One full catenoid rotated in space. A compression-only form and a self-interlocking produce a simple joining through stacking.

Following the steps of E. Pérez Piñero and F. Escrig, C. Morales from the Universidad Veracruzana showed a lightweight, deployable, and flexible structure, based on the scissors mechanism. The design of the nodes was specially highlighted, because they need to be simultaneously adaptable to the different positions during the installation and dismantling processes, adjustable, and hinged. This allows for convergence of the bars in order to avoid additional eccentricities (Fig. 14).

Figure 14. Deployable structure developed experimentally by C. Morales, Facultad de Arquitectura de Poza Rica, Universidad Veracruzana.

A. Bloch proposed a new analytical formulation to predict the collapse of an inflatable beam, which agrees with experimental results. He applied the Virtual Image Correlation (VIC) method, which finds an analytical contour that best fits the physical boundary. This contour allows the identification of the mechanical properties of the inflatable beam, and it validates the model.

EDUCATION

Professor E. Cortés of the Faculty of Architecture and Design at the "Pontificia Universidad Javeriana" in Bogotá, reported on the module "Architecture in Concrete," that includes the application of fabric flexible formwork with the aim of obtaining different textures, complex curves, and geometric forms (Fig. 15).

Figure 15. Different textures obtained with fabric formwork.

J. G. Oliva demonstrated teaching procedures practiced for several years at the Faculty of Architecture at the "Universidad Nacional Autónoma de México" applied in the teaching of design and construction of tensile structures to architecture and civil engineering students. The results obtained were demonstrated with projects carried out by the students (Fig. 16). From the fusion of mechanics and geometry, a new term emerged called MECHAMETRY, which could be defined as the application of Mechanics and Geometry to the architectural and structural design of lightweight structures.

Figure 16. The "Trajinera" designed by a student of the UNAM won the IFAI International Achievement Award competition in 2007.

O. F. Avellaneda in turn exposed his experience with the "Deployable and tree-like structures workshop" of the School of Architecture in Sant Cugat del Vallès, Spain. Its practical and theoretical approaches are aimed at learning the design of non-conventional structures in architecture, using physical and digital tools (Fig. 17). The students submitted the winner entry to the IASS-SLTE 2014 competition.

Figure 17. Itinerant book house for outdoor reading: http://smia-experimental.com/2014/03/06/itinerant-book-house/

RECENT PROJECTS

In addition to the Brazil 2014 World Cup Arenas, which are well-documented in the literature, some interesting works were presented at the Symposium. A selection is shown below.

N. Fiedler, who is a pioneer on the use of structural membranes in Brazil, - exposed some of his works. After manufacturing tents in his garage, developing software, and meeting Frei Otto, he produced more than 18.000 projects-, 1.760 of which have been built (Fig. 18). A selection of them is available at: http://www.fiedler.eng.br

Figure 18. Nelson Fiedler: 14.000m² temporary roof for Petrobras, 30m high in Itaborai.

F. Alvarado, from "Espacio Cubierto, SA" Chile, presented three cases of design optimization: the Leonardo da Vinci School, the Frontera University Amphitheatre and the Navidad Municipal Amphitheatre. Three criteria were adopted in the comparison: sections, unit weight, and reactions. Differences between starting designs and final solutions were considerable (Fig. 19).

Ch. Garcia-Diego & H. Pöppinghaus, from IF Group, described the envelope of the National Gymnastics Arena in Baku. It is a lightweight textile ribbon structure that wraps around the curved perimeter of the building on three different levels, suspended from the roof-top, and supported on an undulating steel structure made of circular, hollow sections (Fig. 20).

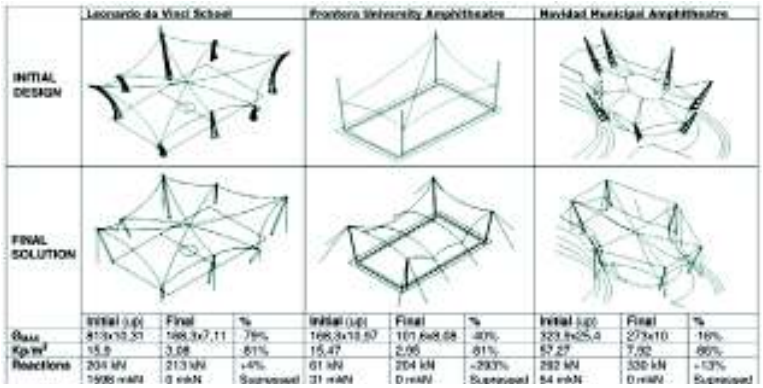

Figure 19. Comparative values of three initial and final optimized designs by "Espacio Cubierto," Chile.

Figure 20. Baku National Gymnastics Arena, IF Group.

R. Santomauro presented some relevant examples of membranes developed in Uruguay during the last 15 years. He discussed the interaction between technological and constructive learning, market requirements, architectural programs, specific uses, collaborative teamwork, resolution problems, and choice of appropriate materials. He emphasized what can be accomplished with light-weight non-traditional methods, highlighting the new expressions that are attained (Fig. 21). He finally referred to the current teaching practices at the Faculty of Architecture of the "Universidad de la República," Montevideo.

Figure 21. Olimar River Amphitheatre, P. Pinto & R. Santomauro, Uruguay.

G. Carella, Senior Architect of CIDELSA, Peru, introduced his personal opinion about membrane architectural design, and how it has evolved over time. He mentioned four basic concepts to be considered and managed properly in order to develop a good project:

- geometrize the idea into a shape that can be drawn, measured and built,
- configure the structure for stability
- modulate, vary, and repeat
- relate the environment, structure, and membrane

All concepts were illustrated with a wealth of examples built by CIDELSA, Perú (Fig. 22).

Figure 22. CIDELSA: Central Square, Paseo Quilín Mall, La Florida, Santiago de Chile.

The projects presented at the Symposium that were best adapted to the environment, most sustainable, and most ecological were the "Ecogalpoes," (ecopavilions) developed by Bambutec, a company formed by researchers and former students of the Catholic University of Rio de Janeiro (Fig. 23). The "Ecogalpoes" employ a prefabricated structural system of spatial trusses made of bamboo treated with raw clay, natural fibres, and castor oil polymers that ensure durability and protection from weathering. The connections employ ropes and textile craft moorings, and the roof is covered and stabilized by tensioned, textile canvas. The lightness and mobility of structural components, manufacturing techniques, and materials employed favour the design of new forms for construction, the clean application of local installation, and the formation of a new profile of skilled builders, resulting in agile execution, little waste & noise, low power consumption and low environmental impact.

Figure 23. "Ecogalpoe" Bambutec: http://www.bambutec.com.br

From the same University, a low-tech prototype was presented to reconcile tensile structures technology with tradition. It is a prestressed frame and cable net supporting the membrane (Fig. 24). Since the prototype is still under development, we hope to see the results in the next Latin American Symposium.

Fig. 24. Low-tech prototype. Universidad Pontificia Católica de Sao Paulo

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 Débora Frazatto, Architect IAB SP, Brazil, professor Reyolando M.L.R.F. Brasil, Universidade Federal do ABC, Brazil, professor Juan Gerardo Oliva Salinas, UNAM, México, and professor Roxana Garrido Sánchez, Universidad Ricardo Palma, Perú. The jury gave the award to Omar Avellaneda and Natalia Torres (Fig. 25) supervised by professor Ramón Sastre, Sant Cugat School of Architecture, Universitat Politècnica de Catalunya.

Fig. 25. O. Avellaneda & N. Torres, 2014: Temporary deployable school. Winning entry to the SLTE student's contest.

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The Latin American Network of Tensile Structures

The Sixth Symposium was also an occasion to meet the members of the Latin American Network of Tensile Structures. This group consolidated their association, approving the statutes and defining the registration. The VII Symposium 2016 in Guatemala was announced, and representatives of Peru and Argentina showed an interest in organizing the VIII and IX editions in 2018 and 2020, respectively. More information and the full text of the proceedings are available at: http://www.latensored.org