

by **Dr. J.I. de LLORENS. Architect**
School of Architecture, Barcelona, Spain

e-mail: ignasi.llorens@ca1.upc.es

The "TR 2001" Sixth International Workshop on the Design and Practical Realisation of Architectural Membrane Structures , took place last June at the "Technische Universität" of Berlin and was headed by Prof. Dr.-Ing. Lothar Gründig.

It attracted 57 participants from 18 countries, consolidating the 1995 initiative to promote the design of architectural membrane roof structures.

Main lectures, specialist and participant presentations, together with hands-on physical and computational modelling workshops were held over three days including general overviews, specialist points of view, valuable data, up-to-date information and advice.

1. "Introduction and subject overview" was presented by Michael Kiefer, Dipl. Ing. of Birdair Europe Stromeyer GmbH. He summarized the main phases and characteristics from theory to reality, illustrated by a series of examples divided into two types, depending on whether the membrane is not part of an integrated system or contributes to the primary structure.

He concluded by calling for future tasks concerning computer programs, material development, manufacturing, the approval process and education.



Cargo Hangar. The textile not forming part of an integrated system



Entrance Roof, Lisbon Trade Fair. Textile as part of an integrated system

"Physical Modelling" was presented by Lothar Grundig, owing to the unexpected illness of Erik Moncrieff. He focussed on the principle stages of the design process: form finding, load analysis and cutting pattern generation. Physical modelling was revealed to be useful for early form finding and visualization in order to obtain force equilibrant surfaces quickly and for train and conceptual design training.

Types and building procedures were presented as an introduction to the afternoons hands-on workshop.



TR 2001 Physical modelling workshop



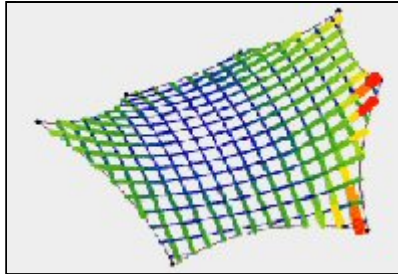
Soap film modelling

"Computational Modelling Concepts" by Dr. Dieter Ströbel provided a comprehensive explanation of the Easy system. This consists of a set of

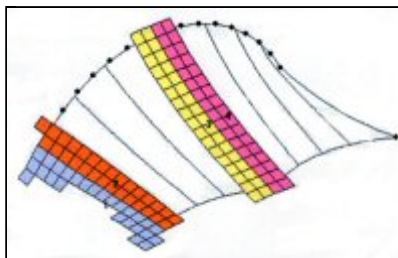
software modules for the design of geometrically non-linear lightweight structures. Basic concepts, principle stages, results and applications were presented, including force equilibrant form finding, load analysis, cutting pattern generation and visualization as an introduction to the afternoon hands-on workshop. Joachim Bahndorf physically demonstrated some of the principles during the Participant Presentations.



J. Bahndorf demonstrating the force density method.



"EasySan" structural analysis



"EasyCut" cutting pattern generation

More information can be found at <http://www.technet-gmbh.com> "Manufacturing Small Membrane Structures", by Ingo Lishke offered an insight into the manufacturer's point of view, including project planning for production, cutting plans, cutting, seam preparation, welding, sewing and gluing of seams and reinforcements, setting-up, reinforcement of corner details and high points, edge rope pockets, quality control, packaging of finished membrane structures, and costs.

SUMMARY OF COSTS (DM 2001) Small project (85 m²)		
MATERIALS	PVC	2241
	Corner plates, cables, straps, fittings, etc	772
MANUFACTURING	Data processing	91
	Cutting	684
	Abrasion	274
	Welding	1733
	Sewing	1459
	Orders	182
	Packaging	182
TOTAL COST		7618
COST/m²		90

"Detailing" by Josep Llorens included a list of principles such as: structural requirements, geometry, erection process, climate, environment and visual expression.

A typology of joints and connections was presented, including seams, edges, ridges, valleys, corners, mast tops, held up high points, pulled down low points, funnels and base plates. These are extensively illustrated in "Joints, Connections, Fittings and Anchors Data Bank", available on the internet website: "<http://www.upc.es/ca1/cat/recerca/tensilestruc/inicio.html>" which was presented by the author during the Participant Presentations



The distance between the hinge and the clamp bends the cable



The corner does not have sufficient width and stiffness



The shackle looks small

Designing textile structures requires careful attention to details, particularly to joints and connections. The main requirements are shape, strength, flexibility and waterproofing. Behaviour can be analysed by following the path of loads running from the membrane to the supports and by checking all of the elements involved. Detailing mis-consideration may lead to poor solutions, local failures or general collapses.

6. "Environmental aspects" in textile architecture was introduced for the first time at the Berlin workshops by Marijke Mollaert. She focussed on climate, rain-proofing, thermal performance, lighting, acoustic aspects and recycling. A wealth of examples, data and illustrations compensated for the lack of literature on such an important topic.

Mrs. Mollaert's contribution was an essential one in a field where environmental aspects are becoming increasingly important.



Pitched roofs of tents are open eastward to catch the first warming rays



Convertible roofs adapt to climatic conditions



The use of multiple layers and insulation material reduce sound transmission



Portable structures leave no traces

7. "Materials" was presented by Rainer Blum. He commented on "How can a curved surface be made out of a flat material?" mentioning the geometric problem, the structural properties of the fabric and the cutting pattern generation. The influence of coating, loading behaviour and crack propagation were analysed together with the presentation of a biaxial testing machine, the mechanical behaviour of seams, measurement tools and tests on details.

He concluded by calling for future tasks concerning general admission adopting EU regulations, setting standards, energy, conditioning and acoustic.



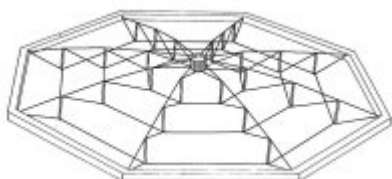
Dr. Trompette biaxial tension rig, Lyon



Biaxial test at S.L. Rasch & Bradatsch, Leinfelden

8. "The virtual world of tensional integrity" was introduced by Rosemarie Wagner. Defining these fascinating tensegrity structures as "islands of compression in a sea of tension" and stating their principles, formed the basis of the last main lecture. Introduced by Kenneth Snelson and Buckminster Fuller, tensegrity structures are an ensemble of disconnected, prestressed, selfanchored and non bending compression elements. Their geometry is defined by the equilibrium of tension and compression forces, influenced by the process of tensioning, manufacturing errors and stiffness.

The David Geiger cable dome was presented as the main application of the tensegrity concept with a span of up to 2 km





Cable dome

Venezuela Pavilion. Cafeteria (Hanover 2000).

9. Other events at TR 2001 included the Panel Discussion on Economic Factors and the Participant Presentations.

Jürgen Hasse introduced the TensiNet network for tensile structures: <http://www.tensinet.com>, an initiative of 22 partners from 9 European countries under the "Share and Exchange" scheme, which has been funded by the EU and developed at the Vrije Universiteit Brussel.

The Venezuela Pavilion in Hannover 2000 and its cafeteria were presented by Josep Llorens focussing on new building solutions aimed at adaptability and lightness.

Silke Hoffmann highlighted the suitability of membranes structures for greenhouses and encouraged their inclusion in new designs.

Rogier Houtmann summarized the full range of materials for membrane structures, together with their main properties, characteristics and applications.

10. Daily afternoon hands on physical and computational modelling workshop completed the practical activities promoting the development of case studies within an informal tutorial environment.

Recent textile structures constructed in Berlin provided more opportunities to explore and discuss current solutions. The Bundeskanzleramt the Scandinavian Embassy and the Sony Centre Forum Roof were recommended.



Scandinavian Embassy. Berlin



Sony Centre Forum Roof. Berlin

Following the increased knowledge gained from the TR 2001 and the expectations arising from the TensiNet start up, the 2002 edition of the Workshop will take place from May 30 to June 1. Up to dated information, inside views, expert lectures and practical training are expected, brought together by the expertise of successful engineers and architects as well as the enthusiasm of newcomers and repeating participants.

Dr. Josep Llorens, Architect, Professor of Building Technology at the School of Architecture, Technical University of Catalonia (UPC), Barcelona, Spain