

3.1 THE MINIMAL ART OF TENSILE MEMBRANE STRUCTURES

Membrane structures have forms generated by tensile equilibrium and as such can be considered a type of natural structure. Shell structures follow lines of compression largely avoiding bending forces. Tree-like branched structures, generated by a system of linear tension or compression forces, also follow structural principles found in nature. Within this family tensioned membrane structures are the most commonly used, and exist in a wide variety of forms.

How do we design membrane structures which are minimal and in a state of pure tensile equilibrium?

In designing orthodox buildings the essential task of the architect is to define the general layout, the geometry and materials, in order to reach a functional and pleasing design meeting the client's needs. The first sketches, which capture and express the idea and spirit of the building, are followed by design drawings which organise the essential ideas according to particular rules and are often based on orthogonal planning grids. Following this route the architect selects conventional materials and structural forms, concluding with the selection of a rigid cladding system to form a weather enclosure.

The process is different for structures obeying the natural flow of forces and for many traditional building methods where the main structural elements and their synergism feature the objects and the buildings.

Whilst mainstream architecture is more concerned with realizing rational clusters and sequences of orthogonal space, membrane structures are buildings where structure and form are intimately linked. Minimally shaped surfaces create interesting spaces and environments through the counterpoint of light and shade. Well designed membranes can provide a wide range of weather protection

from sun, rain, snow and wind. They can be designed to be translucent and in some instances transparent, allowing as much or as little daylight as required into the spaces that they cover, while being the primary structural component coping with a wide range of spans. The expression of all these qualities taken together are embodied in the unique shape of tensioned membrane structures – less is more and there is no better way of achieving more with less than with lightweight tensioned membrane structures.



Fig. 1 Fountain Tent Starwaves, Cologne, Germany, rebuilt 2000, Architekturbüro Rasch + Gradtsch with Frei Otto.

European Design Guide For Tensile Surface Structures

C. A. Brebbia



European Design Guide For Tensile Surface Structures:

The European Design Guide for Tensile Surface Structures Brian Forster, Marijke Mollaert, 2004 **European Design Guide for Surface Tensile Structures**, 2004 **Fabric Structures in Architecture** J Llorens, 2015-03-28 Fabric Structures in Architecture covers the varying ways textiles and their properties are used in building construction with particular focus given to tensile structures The text begins with the fundamental principles of textiles including the origins of fabric architecture then progressing to a discussion of the modern textiles of today It covers relevant textile materials and their properties including coatings and membranes In addition a range of design considerations are discussed with detailed information on installation and failure modes A series of case studies from around the world accompany the discussion illustrating the applications of textiles in architecture Offers key coverage of the fundamental principles from the origins of fabric architecture to modern textile Provides analysis of relevant textile materials and their properties including coatings and membranes Contains expert insights in to the applications of textiles in architecture presenting a series of relevant case studies from around the world *Construction Manual for Polymers + Membranes* Jan Knippers, Jan Cremers, Markus Gabler, Julian Lienhard, 2012-12-17 Whether it be as translucent sheets broadly stretched membranes and inflated foil cushions or in graceful organic curves architecture today is utilizing plastics in the most disparate forms and for a wide variety of purposes Innovative technical developments are constantly improving its material properties at the same time there is a growing new awareness of its potential as a construction material While plastics used to be employed primarily as an inexpensive variant on traditional building materials they are increasingly regarded in the construction world today as a serious and viable alternative be it as supporting structures roofs facades or elements of interior design and decoration Thanks in large part to this inherent self sufficiency plastics are currently enjoying an unprecedented surge in popularity even among the international architectural avant garde as multiwall sheets or corrugated fiber reinforced panels or as filling between glass panes And the new generation of ecological bioplastics also pays tribute to the debate on sustainability ridding plastics of their lingering reputation as environmental offenders From the history of plastics and membranes in architecture to their material properties and requirements in construction and design the *Plastics and Membranes Construction Manual* cuts to the chase providing the kind of solid and comprehensive overview of the subject that readers have come to expect from the Im DETAIL series Selected project examples round off the reference work and make it indispensable for the day to day life of the professional planner and for every architecture library **Textiles, Polymers and Composites for Buildings** G Pohl, 2010-09-27 Textiles polymers and composites are increasingly being utilised within the building industry This pioneering text provides a concise and representative overview of the opportunities available for textile polymer and composite fibres to be used in construction and architecture The first set of chapters examine the main types and properties of textiles polymers and composites used in buildings Key topics include the types and production of textiles the use of

polymer foils and fibre reinforced polymer composites as well as textiles and coatings for tensioned membrane structures. The second part of the book presents a selection of applications within the building industry. Chapters range from the use of textiles in tensile structures, sustainable building concepts with textile materials, innovative composite fibre applications for architecture to smart textile and polymer fibres for structural health monitoring. With its distinguished editor and team of international contributors, *Textiles, polymers and composites for buildings* is an important reference for architects, fabric manufacturers, fibre composite experts, civil engineers, building designers, academics and students. Provides a concise and representative overview of the opportunities available for textile, polymer and composite fibres to be used in construction. Provides an insight into how high tech textiles already influence our daily lives as well as potential applications in modern buildings. Features a thorough discussion of technical characteristics and requirements of textiles used for buildings and construction.

Fibrous and Composite Materials for Civil Engineering Applications R Figueiro, 2011-04-19. The use of fibrous materials in civil engineering both as structural reinforcement and in non structural applications such as geotextiles is an important and interesting development. *Fibrous and composite materials for civil engineering applications* analyses the types and properties of fibrous textile and structures and their applications in reinforcement and civil engineering. Part one introduces different types of fibrous textiles and structures. Chapters cover the properties of natural and man made fibres and of yarns as well as an overview of textile structures. Part two focuses on fibrous material use in concrete reinforcement with chapters on the properties and applications of steel fibre reinforced concrete, natural fibre reinforced concrete and the role of fibre reinforcement in mitigating shrinkage cracks. In part three the applications of fibrous material based composites in civil engineering are covered. Chapters concentrate on production techniques and applications such as reinforcement of internal structures, structural health monitoring and textile materials in architectural membranes. With its distinguished editor and international team of contributors, *Fibrous and composite materials for civil engineering applications* is a standard reference for fabric and composite manufacturers, civil engineers and professionals as well as academics with a research interest in this field. Explores the development of fibrous materials in civil engineering both as structural reinforcement and in non structural applications such as geotextiles. Key topics include short fibre reinforced concrete, natural fibre reinforced concrete and high performance fibre reinforced cementitious composites. A standard reference for fabric and composite manufacturers, civil engineers and professionals as well as academics with a research interest in this field.

Biaxial Testing for Fabrics and Foils Paolo Beccarelli, 2015-01-30. This book offers a well structured critical review of current design practice for tensioned membrane structures including a detailed analysis of the experimental data required and critical issues relating to the lack of a set of design codes and testing procedures. The technical requirements for biaxial testing equipment are analyzed in detail and aspects that need to be considered when developing biaxial testing procedures are emphasized. The analysis is supported by the results of a round robin exercise.

comparing biaxial testing machines that involved four of the main research laboratories in the field The biaxial testing devices and procedures presently used in Europe are extensively discussed and information is provided on the design and implementation of a biaxial testing rig for architectural fabrics at Politecnico di Milano which represents a benchmark in the field The significance of the most recent developments in biaxial testing is also explored *Tensinet Symposium 2007* Alessandra Zanelli,2007 Lightweight Energy Alessandra Zanelli,Carol Monticelli,Nebojsa Jakica,Zhengyu Fan,2022-11-30 This book explores membrane materials as a means of translating natural and renewable resources into a more flexible dynamic and reactive architectural skin It represents the first time that energy saving design has been addressed systematically in relation to lightweight building systems and tensile membranes Understanding of the energetic behavior of membranes and foils used as a building envelope is a fundamental theme as it is the integration of flexible photovoltaics in membranes as well as the exploitation of water and wind resources A theoretical methodological framework for consciously designing the membrane life cycle is presented The authors cross cut and combine exploration of climate based design methodology and life cycle thinking strategies Both active and passive systems are investigated referring to alternative productive resources like sun wind and water Case studies are brought forward in the book s second half highlighting energy lightness for an increasingly dematerialized architecture and addressing inherent issues Four main research and development paths are presented the first two focusing on advancements in facade materials and Photovoltaic systems applicable to membrane architecture the third referring to fog and dew harvesting and the fourth dealing with the future frontier of flexible transparency and designs for well being through a passive solar system **High Performance Structures and Materials Engineering** Mark Zhou,2011-03-30 Selected peer reviewed paper from 2011 First International Conference on High Performance Structures and Materials Engineering ICHPSM 2011 in May 5 6 Beijing China 2011 High Performance Structures and Materials III C. A. Brebbia,2006 Including the latest developments in design optimisation manufacturing and experimentation this text presents a wide range of topics relating to advanced types of structures particularly those based on new concepts and new types of materials *IABSE Symposium Budapest 2006* ,2006 Design Recommendations for ETFE Foil Structures ,2013 The Design Recommendations for ETFE foil Structures are a product of over 4 years work by TensiNet ETFE Working group TensiNet is an association or platform for all parties interested in tensioned membrane structures It is a multi disciplinary association conforming to the initial objectives of the EU funded thematic network 2001 2004 The Design recommendations for ETFE foil structures have been established as a separate Annex of the European Design Guide for Tensile Surface Structures published by the TensiNet Association in 2004 Although ETFE is a widely used material it is still a young material compared to other materials as steel wood and concrete A European standard is not available nor is extensive research on mechanical properties These design recommendations present current knowledge and compare different design concepts Therewith it is a state of the art report not intending to be

comprehensive However as TensiNet is involved in the preparation of a Eurocode on Membrane Structures CEN TC250 WG5 these recommendations will be used as input for the Eurocode on Membrane Structures This Guide recommends safety requirements which need to be considered for the design calculation manufacture installation maintenance operation examination and testing of ETFE foil structures This can be applied to double and multi layer ETFE cushion structures or single layer tensioned ETFE membrane structures The field of application of this Guide includes all kinds of ETFE covered structures The content of this Guide brings together the different existing concepts as far as possible TensiNet com

Prospect for European Guidance for the Structural Design of Tensile Membrane Structures Marijke Mollaert, Silvia Dimova, Artur Pinto, Steve Denton, 2016 Within CEN TC 250 WG 5 CEN TC 248 WG 4 the TensiNet Association and COST Action TU1303 an international team of researchers engineers architects material producers and manufacturers has been working on this report which provides background information in support of the implementation and development of a future Eurocode for the Structural Design of Tensile Membrane Structures Tensioned Membrane Structures have unique properties compared to the more conventional built environment Besides their low self weight and high flexibility these structures are known to be optimally constructed as they are only loaded in tension It results in shapes adapted to the flow of forces and a minimum of material needed to realise the span Despite a considerable amount of scientific knowledge exists only few design codes are available A common standardised approach as well as a comprehensive European design standard is needed in order to provide verification techniques a common pool of design approaches and to achieve a harmonized safety level This background document consists of three major parts a general explanations giving scientific and technical background for the design of membrane structures b state of the art overview on existing national and European rules and recommendations on the design of membrane structures and c proposals for European harmonized design rules which could be part of the future Eurocode for Tensile Membrane Structures The final aim is to develop a Eurocode for the Structural Design of Tensile Membrane Structures which will help to design and implement these lightweight structures The Eurocode will not only assist and support the industry and engineering offices but will also encourage potential clients to choose these sustainable applications

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