Business Concept for Desert Light Structures, LLC

John Middendorf
POB 3580
Pagosa Springs, CO 81147

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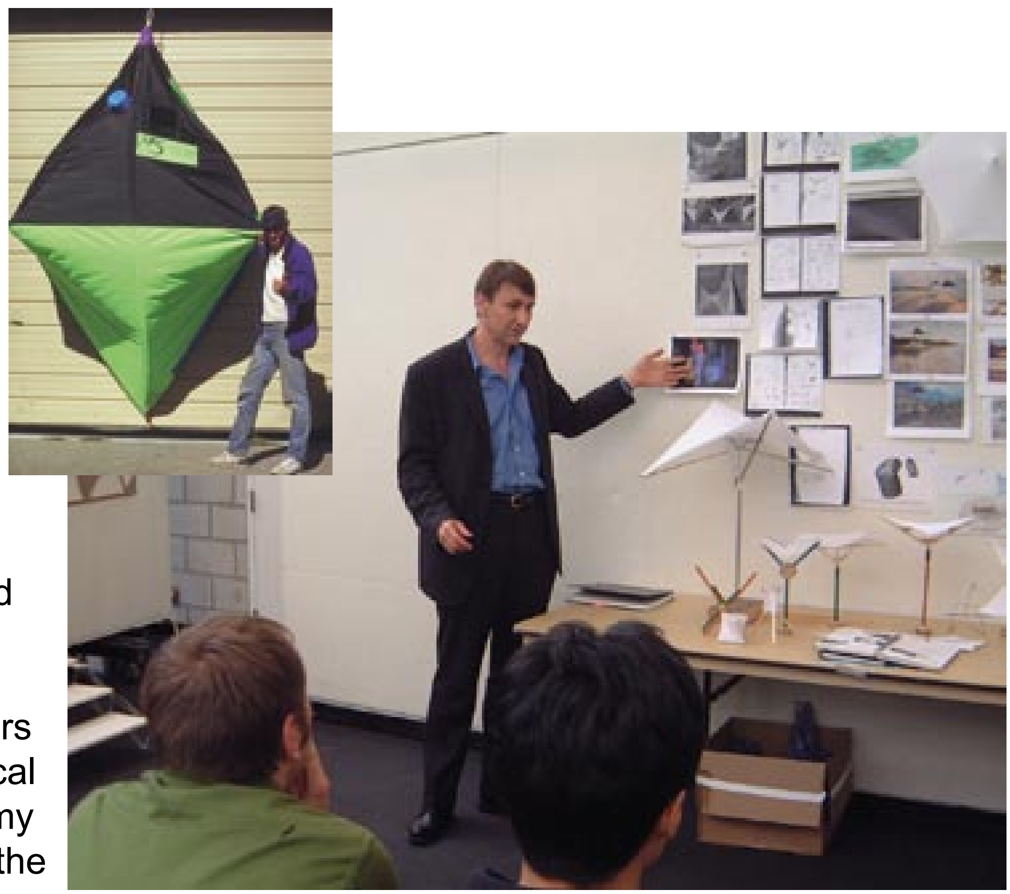
The Nutshell *"Commodity, Firmness, and Delight"--Vitruvius*

The science of tensioned minimal surfaces has inspired an exciting new fabric technology for architectural applications. Until recently, the field of tensioned fabric structures has been the exclusive realm of a tight circle of major firms with a focus on civic scale projects. Two factors offer a market opportunity for the rising demand in urban scale projects:

1. Recently developed engineered woven fiberglass fabrics are strong and have a 35 year life span in desert conditions.
2. Software analysis programs are now commercially available (previously, the complex computer-aided-design algorithms were proprietary).

Desert Light Structures, LLC plans to begin with custom, smaller scale projects, involving the design, analysis, manufacture, and installation of fabric membrane structures in the Colorado Plateau area.

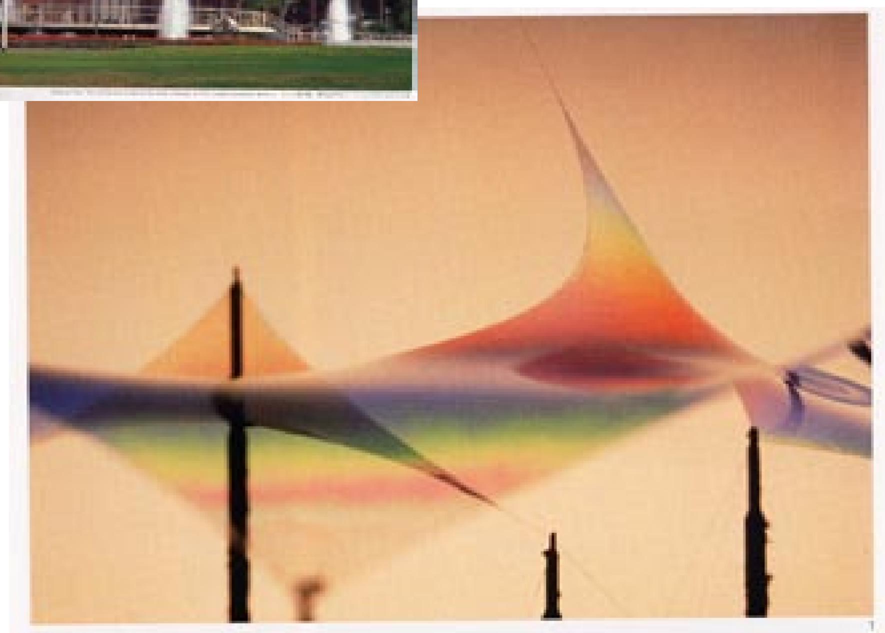


People

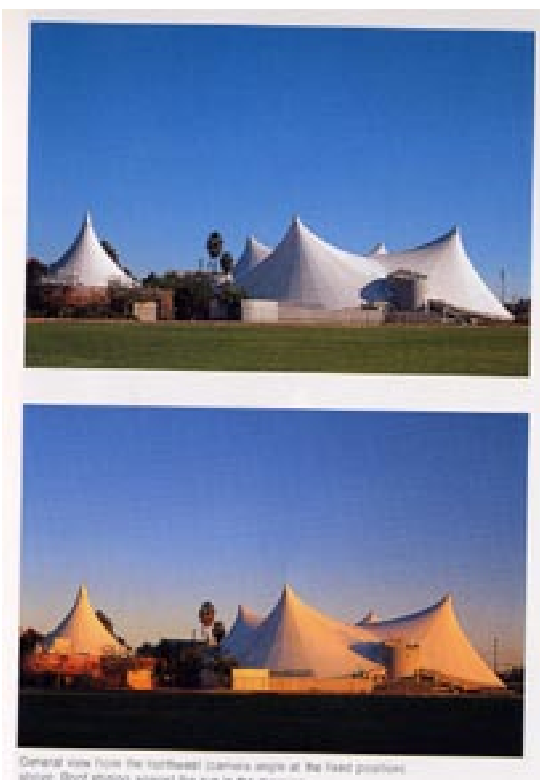
John Middendorf is a designer and mechanical engineer with over 10 years of experience in fabric and structure projects. In 1987 John began A5 Adventures, Inc. which produced world renown suspended camping tents that revolutionized climbers ability to live on vertical walls in remote, stormy places. After selling the successful design company, John completed a Master's of Design from Harvard Design School, where he learned architectural skills.

As projects are contracted, John plans to hire a range of employees, including specialists in manufacturing, sales, installation, and office management. Engineering, accounting, and legal consultants will also be employed.

Background

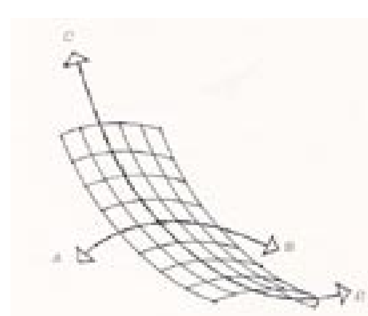


In 1957, Frei Otto designed and built the fabric dance hall, the Federal Garden Pavilion, in Germany. The design of this structure was based on photometric studies of soap bubbles and marked the dawn of modern fabric architecture. Frei Otto's "Design, Structure, and Calculation of Buildings of Cables, Nets, and Membranes", published by the MIT Press in 1966, offered the information engineers needed to program the complex non-linear algorithms needed for the first architectural CAD (computer-aided-design) software.



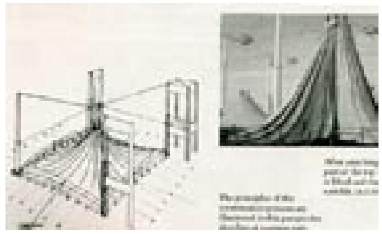
Beginning in 1967, Klaus Linkwitz and others developed CAD software, which enabled Frei Otto to design the 1972 Olympic roofs in Munich, structures involving computer generated minimal surfaces. In 1973, the La Verne Student center in California was built, marking the first use of long life flexible fiberglass fabrics in architecture. These fabrics have retained over 80 % of their original strength since their inception.

Right: tension fabric architecture always has the anti-clastic form (double opposing curvature of a surface). The opposing force vectors hold each point on the fabric in stable equilibrium. This allows a pre-tensioned surface to resist deflection from external loads.



Civic Projects 1973-1998

By 1981, large scale projects such as the Haj Terminal in Saudi Arabia, were accomplished. Designed by membrane structures pioneer Horst Berger and built by SOM architects and engineers, this structure required advanced analysis with proprietary software and opened the doors to more complex structures.

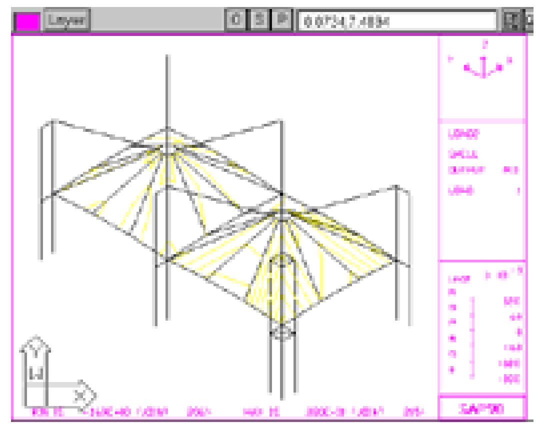


Photos:
Top right: Haj Terminal, Saudi Arabia

Above: Assembly Drawings

Right: Proprietary 1981 CAD software used to design the Haj Terminal.

Left: meeting with Horst Berger, 2001



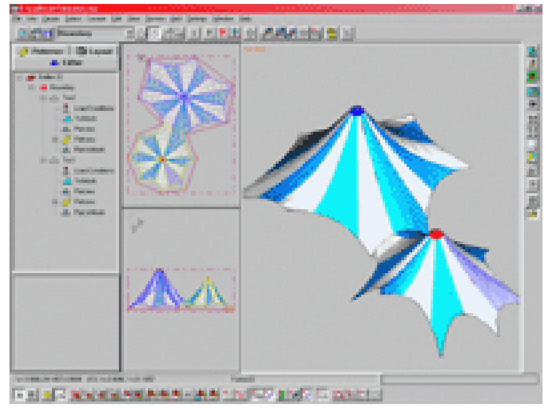
Until around 1998, the economies of scale and the cost of developing proprietary CAD software kept the realm of tension fabric structures to a few large companies including Birdair, Geiger Engineers, FTL Happold, SOM, Skyspan (Europe), and Taiyo Kogyo (Japan). Although a few companies, like Moss Tents, Tentnology, and Fabric Structures, Inc. produced smaller hyperbolic paraboloid structures, these companies were limited by the lack of advanced analysis programs and the lack of commercial availability of engineered architectural fabrics.

Above: Graphical Computer Analysis of the Denver airport.

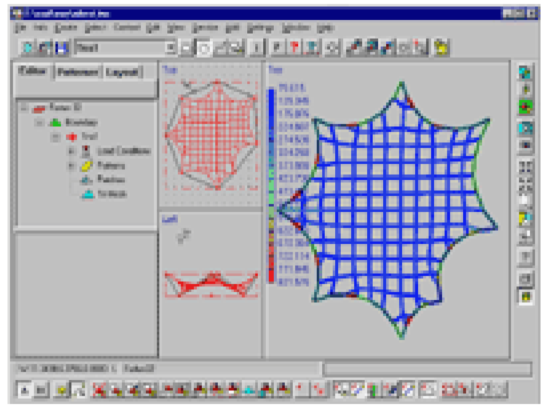
Above: Interior of the Denver Airport, a building whose appeal includes the diffuse internal natural light.

Modern Tension Fabric CAD Software

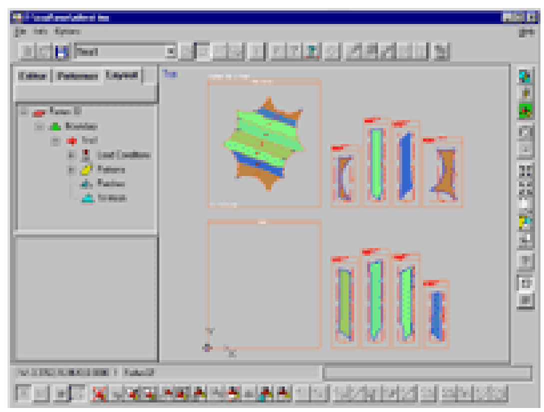
Since 1998, several modern software packages, ranging in cost from $6000 to $26000 per workstation, have become commercially available. These packages offer graphically interfaced design and analysis, and produce workable patterns which can then be used for manufacture. The recent availability of these complex programs offers an opportunity for entrepreneurial designers to gain a foothold in the exciting and developing field of membrane architecture. *(note: all of these programs are from other countries--Germany, Italy, Canada, and the UK, where membrane architecture is more prevalent).*



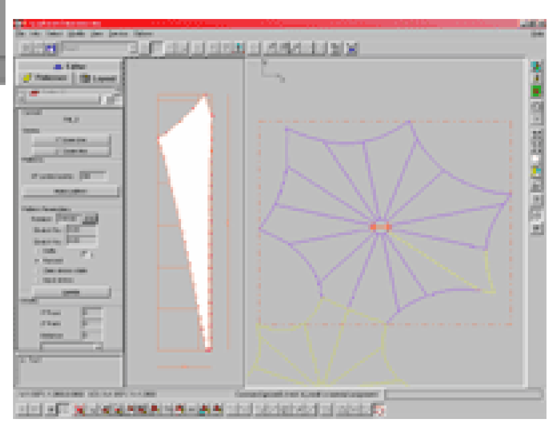
Step 1: Create shape in Forten32 software.



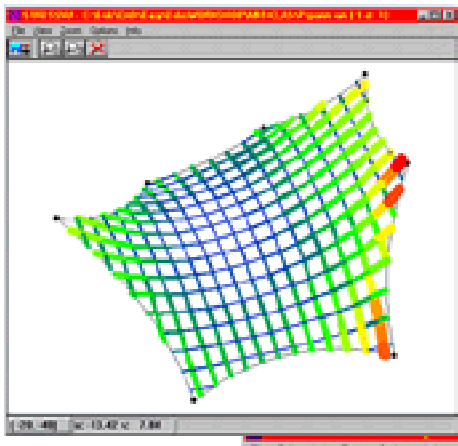
Step 2: Analyze shape

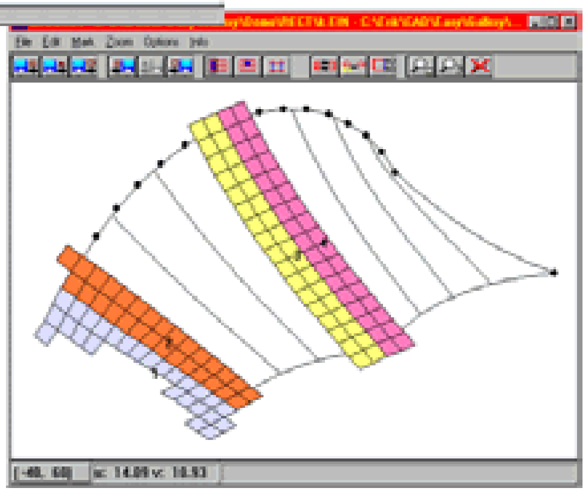


Step 3: Optimize patterning

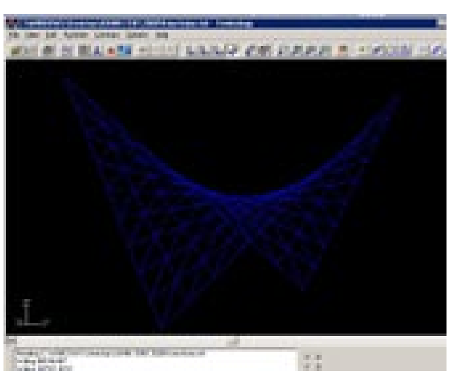


Step 4: Create individual pattern specs.





Above and right: EASY tension fabric membrane analysis and design software ($26000 from Technet)

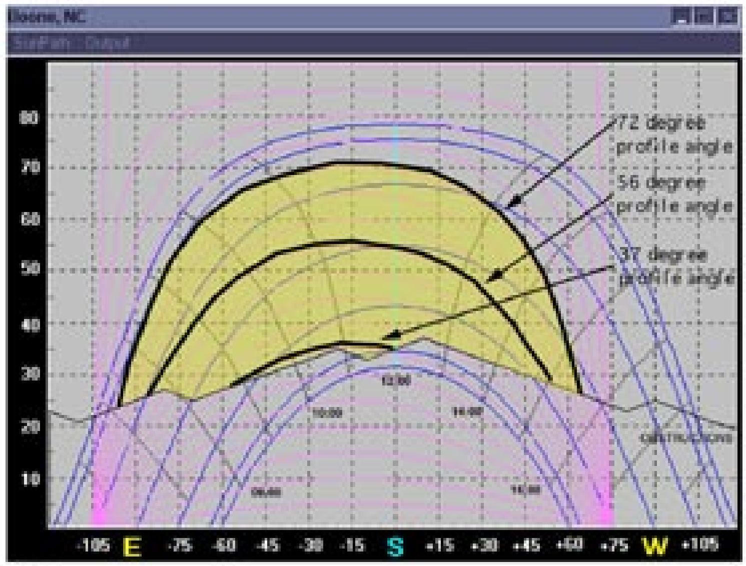


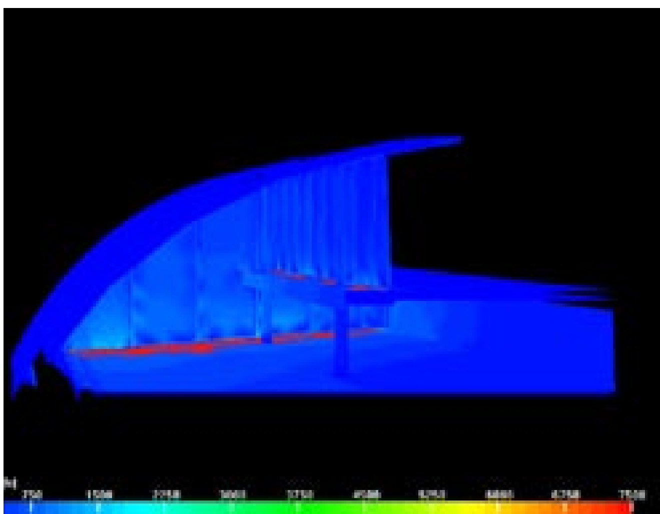
Left: Tentnology Software

Other Computer Software Tools

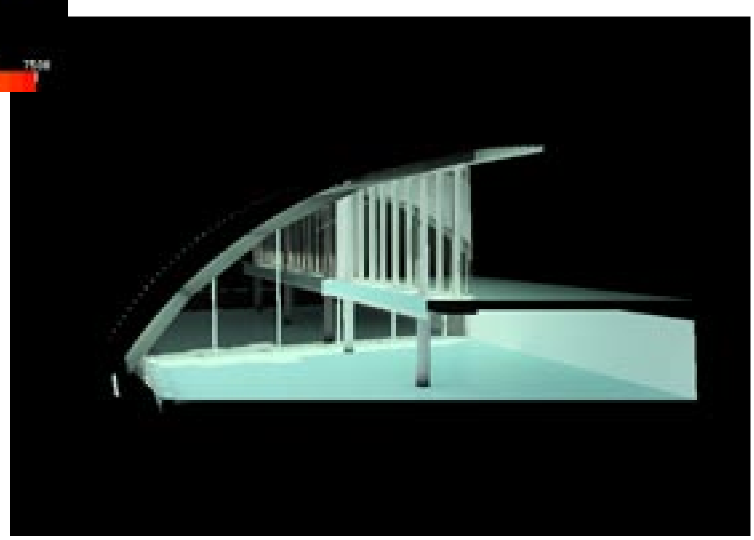
Additional CAD tools can be used to offer professional design services to clients. Site analysis mapping available solar radiation can be merged with shading representational tools culminating in final CAD models which can predict accurately aesthetic and economic performance of designs.

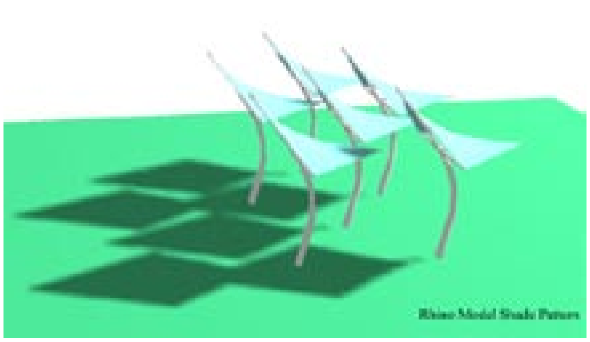
Right: SunPath analysis of existing building to determine required shading angles for different times of the year.





Left and Below: Lightscape analysis of CAD models allow for rapid experimental design variations to optimize a myriad of light, energy, and aesthetic factor. (John Middendorf GSD project: energy simulation of a Richard Rogers building).





Left: Rhino conceptual CAD models indicating shading patterns.

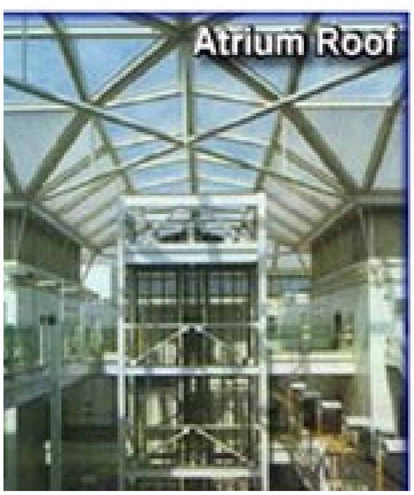
Opportunity

Using the new technology in fabrics and computer software, there are many markets to explore. These include:

Commercial Projects: Interfacing with architects, owners, and landscape designers to create architectural membrane projects to enhance public areas.

Custom Residential Solutions: Tensile fabric structures are sculptural and can offer a variety of residential shading, aesthetic, and privacy needs.

Interior Design: Custom fabric installations for retail and service industries.



Atriums and Greenhouses: Using new clear fluorocarbon membranes, greenhouse roofs and courtyards can be designed with interesting double curvature surfaces.

Ultimately, larger structural, aesthetic, and functional projects like this transportable music stage will be within the realm of the new business.

Appendix 1: Resources

Competitors
Shade Concepts (Irvine, CA) http://www.shadeconcepts.com/
Duvall Design (West Rockport, ME): http://www.midcoast.com/duvall
Advanced Tensile Structures (ASI, Las Angeles, CA): http://www.asidesign.com/
Sullivan and Brampton (San Leandro, CA): http://www.sullivanandbrampton.com/
Transformit (Maine): http://www.transformitdesign.com/
Tensile Designs International (Kansas)

Large Fabric Structure Building Companies
Birdair: http://www.birdair.com
Skidmore, Owings, Merrill: http://www.som.com
Ove Arup: http://www.arup.com/
Buro Happold: http://www.burohappold.com/
Geiger Engineers: http://www.geigerengineers.com/
Schlaich Bergermann: http://www.sbp.de/
Nicholas Grimshaw & Partner: http://www.ngrimshaw.co.uk/
Skyspan: http://www.skyspan.com/home.html

Membrane Contractors
EIDE Industries: http://www.eideindustries.com/

Fabric Manufacturers
Archifab: http://www.fabrimax.com/archifab2.htm
Taconic: http://www.taconic-afd.com/documents/links.html
Seaman: http://www.architecturalfabrics.com/whitepaper.html
Chemfab: http://www.chemfab.com/chemglas.htm

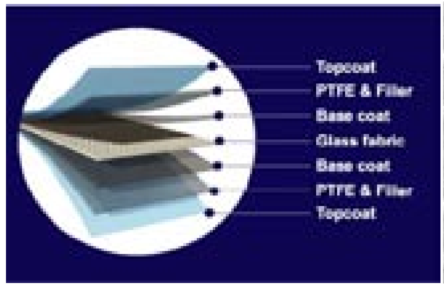
Software
Technet GmbH: http://www.technet-gmbh.com/
Forten: http://www.forten32.com/
Tentnology: http://www.tentnology.com
Surface: http://www.surface.co.nz
Patterner: http:/www.specialstructures.com

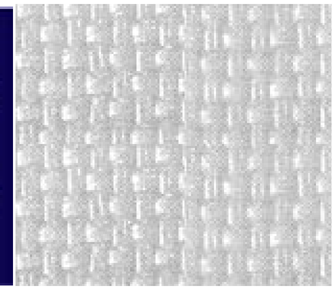
Organizations
American Society of Civil Engineers: http://www.asce.org/
International Fabrics Association: http://www.ifai.com/

General
Introduction to Fabric Structures: http://www-ec.njit.edu/civil/gateway.html
Curvilinear Surfaces: http://www.curvedsurfaces.com/
Great Buildings: http://www.greatbuildings.com/
International Database of Structures: http://www.structurae.de/
Tensile Structures Yellow Pages: http://members.tripod.com/forten32/tsyp.html
The Eden Project: http://www.edenproject.com/

Appendix 2: Fabric Properties

Modern engineered architectural fabrics offer cost effective membranes with good longevity. Reliable elongation for proper design and analysis is a unique requirement of tensioned architectural fabrics.





Properties	**Archi-fab Silicone Coated Fiberglass**	**Taconic PTFE Coated Fiberglass**	**Generic PVC Coated Polyester**
Tensile Strength	High	High	Medium
Tear Strength	Very high	High	Medium
Elongation	Low	Low	High Need to re-tension
Dimensional Stability	High	High	Low
Flexibility	High Easy to fabricate, transport and install	Low Difficult to fabricate, transport, and install	High Easy to fabricate, transport, and install
Color	All colors	White	All colors
Self-cleaning	Very good With topcoat	Best	Satisfactory With topcoat
Flammability	Low	Low	High (requires fireproofing)
Toxicity	Pure Burned to clean ashes	PTFE flame Toxic fume	Toxic Toxic fume
Temperature Range	-100 F - 500 F Flexible at –100 F	-80 F - 500 F Stiff at -80 F	-80 F - 300 F Stiff at -80
UV Resistance	Excellent	Excellent	Fair
Seaming Method	Gluing or Sewing Silicone adhesive tape	Sintering Fusing PTFE	Welding Hot air welding
Weights	30 oz/sq. yd	13.4 to 50 oz/sq.yd.	varies
Widths Available	60”	96.5”	60” typical
Life Span	>25 years	> 25 years	7 –15 years

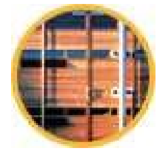
Building Materials: Membranes

Called the "fifth building material", membranes have been used successfully for many architectural applications.

glass

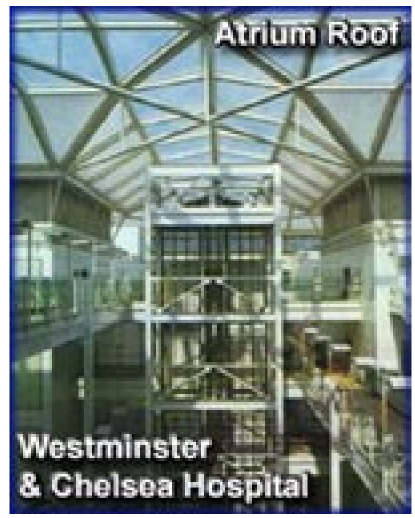
metal

stone



wood

membrane



Fluoropolymer Films

Strength: High (385 lbs/in for 0.14" film)
Translucency: High
Lifespan: High (30-50 years)
Fire Resistance: High
Environmental Impacts*: Moderate
*(for production and recycling)

PTFE Coated Fibreglass (composite)

Strength: Very High (900 lbs/in)
Translucency: Moderate/ High
Lifespan: High (30 years)
Fire Resistance: Moderate/High
Environmental Impacts: Moderate

PVC Coated Polyester or Nylon

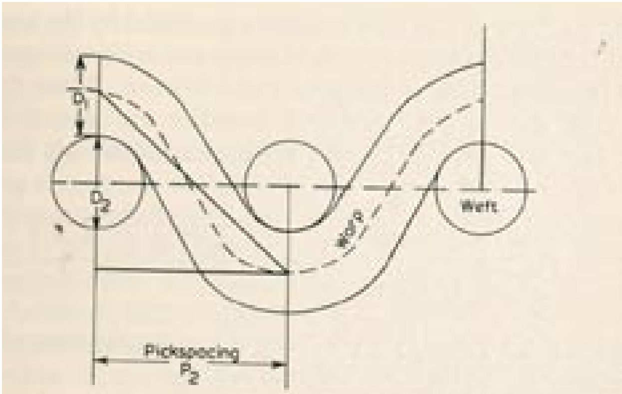
Strength: Medium
Translucency: Medium
Lifespan: Medium (10-15 years)
Fire Resistance: Moderate w/ coatings
Environmental Impacts: High

Organic Fabrics

Strength: Low
Translucency: Low
Lifespan: Low
Fire Resistance: Low
Environmental Impacts: Low

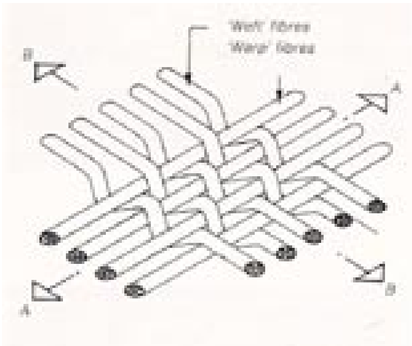
Effects of Weave on Properties

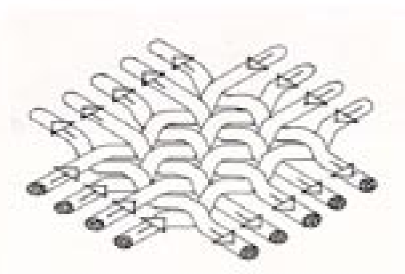
The main variables in a given weave are the density of yarns in each direction (warp and weft) and the radius of bends of the yarns in the weave. Higher density of fibers generally relates to higher overall strength, but the sharp radius of the fibers will decrease the strength of the individual fibers. The radius is dependent on the diameter and the spacing of the yarns in each direction.

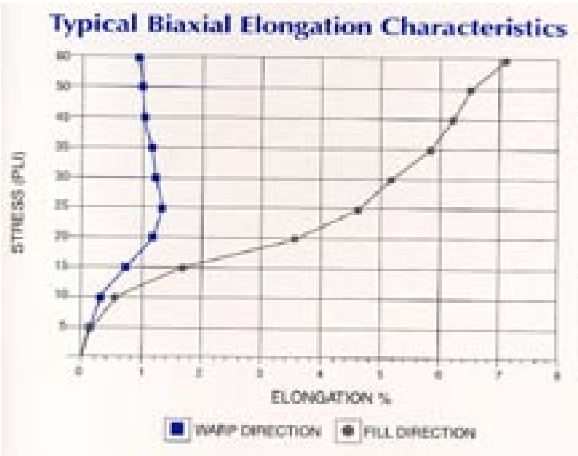


Biaxial Nature of Weave

The biaxial nature of a weave gives different properties in the warp and weft direction. An important structural aspect to consider is the different elongation in the two directions. The diagram on the right illustrates how the material reacts to a force in the warp and weft directions. In the case of forces across the bias, the Poisson's ratios in each direction determines the overall elongation.







Important Bi-axial Properties

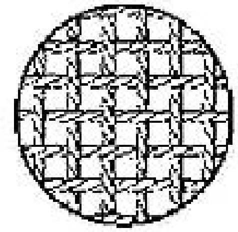
•Strength
(38.5 ounce per square yard PTFE coated Fibreglass Fabric)
Warp: 785 lb/in.
Fill: 560 lb/in.

•Modulus of Elasticity (E)
E=stress/strain
(stress=force/area,strain=dL/L)

•Poisson's Ratio: ratio of strain in x and y directions

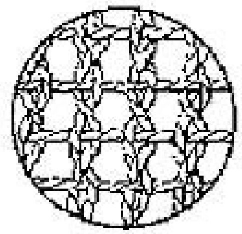
Weave Patterns and Properties

Plain



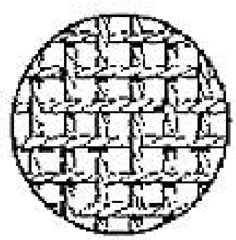
A plain weave is the most simple and most commonly used weave pattern. In this type of weave, the warp and filling threads cross alternately. Plain woven fabrics are generally the least pliable, but they are also the most stable.

Leno



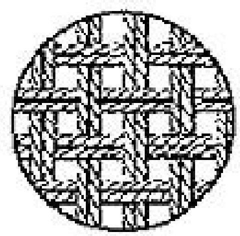
The leno weave is a locking type weave in which two or more warp threads cross over each other and interlace with one or more filling threads. It is used primarily to prevent shifting of fibers in open weave fabrics.

Twill



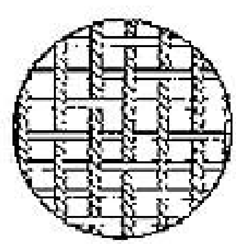
A twill weave is a basic weave characterized by a diagonal rib, or twill line. Each end floats over at least two or more consecutive picks enabling a greater number of yarns per unit area than a plain weave, while not losing a great deal of fabric stability. This type of fabric looks different on one side than on the other.

Basket Weave



The basket weave is a variation of the plain weave in which two or more warp yarns cross alternately with two or more filling yarns, resembling a plaited basket. This weave is more pliable and stronger than a plain weave, but is looser and therefore, not as stable. The basket weave is typically used in the composites industry.

Satin Weave



In a satin weave, the face of the fabric consists almost completely of warp or filling floats produced in the repeat of the weave, which causes one side of the fabric to look different than the other side. There is one filling thread which floats over three or more warp threads, then under one. This is the most drapeable of weave patterns and conforms very easily around most contoured surfaces. Most satin weaves are either four, five, eight, or twelve harness satins and are typically utilized in the composites industry.

High Strength Woven Fabrics

Fibers

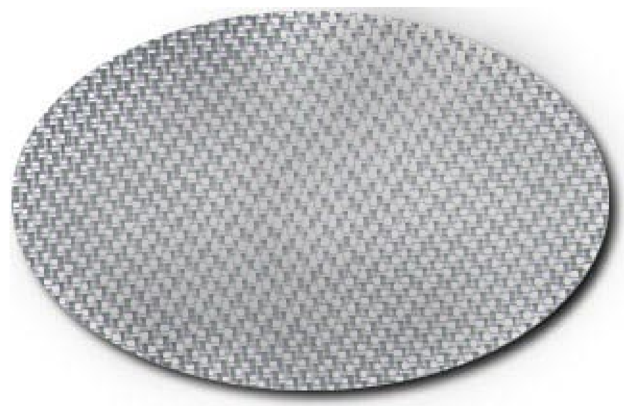
Common fibers used in woven composite membranes are Aramids, Glass, and Carbon. Woven fabrics can also combine fibers of each material.

Aramids (Kevlar®)

High strength to weight ratio at moderate cost. Excellent thermal and dimensional stability and moderate strength loss with temperature. Sensitive to UV light and brittle when bent over sharp radii. Moderate moisture retention, but with no loss of strength. Long fibers. Typically composited with thermoset resins. Color: Yellow.

Fiberglass

High tensile strength, but low relative strength to weight ratio. High dimensional stability, and low moisture absorption. High heat, fire, and chemical resistance. Typically composited with coatings or laminations in architectural applications.
Color: White.



Carbon Fiber

Highest strength to weight ratio, and highest cost. High melting point. High dimensional stability.Short fibers. Typically composited with thermoset resins. Color: Black.

Comparison of Fibers

Material	Tensile Strength (GPa)	Tensile Modulus (GPa)	Density (g/ccm)	Specific Strength (GPa)
Carbon	3.5	230.0	1.75	2.00
Kevlar	3.6	60.0	1.44	2.50
E Glass	3.4	22.0	2.60	1.31