ETFE

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DIBA TENSILE ARCHITECTURE

WHAT IS ETFE?

ETFE foil paneling consist of pneumatic cushions comprising of between 2 and 5 layers of a modified copolymer Ethylene Tetra Flouro Ethylene. The ETFE Foil is extruded into thin films and supported in an aluminum perimeter extrusion, which is supported on the building frame. These wafer-thin, transparent membranes are tension-stressed only, and reduce the weight of the outer skin and load-bearing system to a minimum.

The cushions are inflated by a small inflation unit to approx. 220 Pa which gives the foil a structural stability and gives the roof high insulation properties.

Eden Project, Cornwall, England

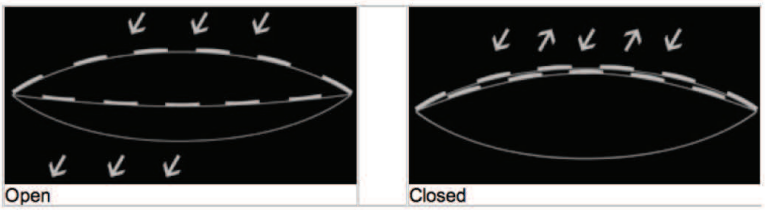
Additional advantages:

- extremely low dead weight
  (305 g/m2 at a thickness of 200µm)
- high light and UV transmittance
- high chemical resistance to acids and alkalis
- active solar shading
- outstanding insulation
- catalyst for natural ventilation
- ecologically friendly / energy efficient
- long-span / any shape capabilities
- fire self-venting
- extreme durability
- unaffected by atmospheric pollution
- life expectancy - greater then 30 years

COLOR, TRANSPARENCY, AND SOLAR CONTROL

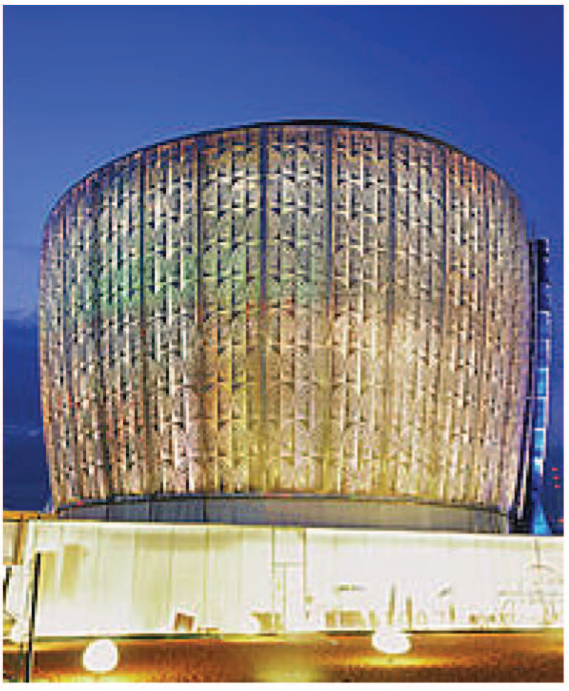
Due to the good transmission characteristic color rendering under an ETFE Foil roof is extremely good, being as daylight across the visible light range. Alternatively colored foil may be specified. ETFE Foil is very transparent across the visible light region (380-780 nm) having a light transparency of approx. 94-97% of total light. Transmission across the ultraviolet range (320- 380nm) is also very good (83-88%). It is also important to note that the film has high absorption in the infrared range, a property that can be exploited to reduce the building's energy consumption.

Whilst the base material is very transparent, ETFE foil can be treated in a number of different ways to manipulate its transparency and radiation transmission characteristics. The foil can be printed with a variety of surfaces to affect transmission, or printed with graphic patterns to reduce solar gain whilst retaining transparency, or can incorporate a white body tint to render the foil translucent. The degree of translucency can then be manipulated by adding additional layers of foil into the system. Alternatively, cushions can be constructed with variable shading and reflectance by differentially pressurizing air chambers in cushions to cause opaque graphics on intermediate layers to alternately cover or uncover each other.



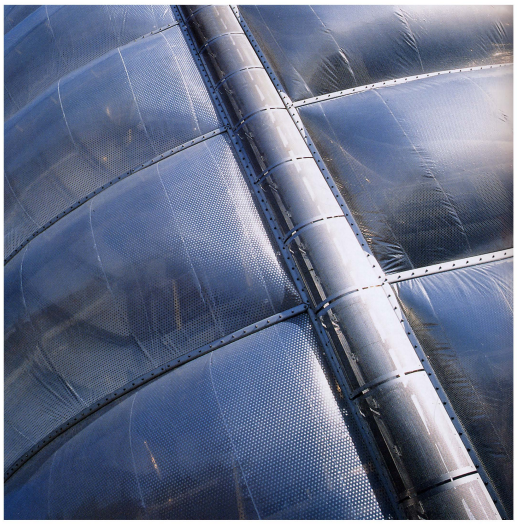
Allianz Arena, Munich

Cycle Bowl, Expo 2000



Cycle Bowl, Expo 2000

Single-layer ETFE



Cushion ETFE

Allanz Arena, Munich

Allianz Arena, Munich

PANEL/CUSHION SIZE

The limited loadability of the sheeting means that the maximum inflatable span, according to the inflatable and the roof geometry, is approximately 4.5m for longitudinal and 7.5m for round or square inflatables. Larger spans usually need additional support from cables or cable nets.
Mechanically pre-tensioned structures, unlike multi-layered, pneumatically supported structures, pre-tensioned by air pressure differences, here the smaller-cut, single layer membranes are pulled to the edges and fastened. Thus, they are mechanically pre-tensioned. Because of sheeting's load-bearing capacity in comparison with fabric membranes, uses have been restricted so far to relatively small elements or to large areas with frequent supports (up to approx. 1.5m).

ERECTION/ASSEMBLY

Thin sheathing has to be pre-tensioned if it is to be able to disperse external loads in various directions through tension forces alone, without forming folds. Two construction methods are distinguished here: pneumatically pre-stressed or supported structures, and mechanically pre-stressed structures.
Specific to pneumatically pre-stressed structures, blowing creates a slight excess of pressure in the gap, which makes the sheeting into a cushion, so it is pre-stressed and stabilized. The pressure needed for stabilization is generally only approx. 200 to 1000Pa, which corresponds to a surface load of 0.2 to 1.0 kN/m2.
As a rule, manufacturers assemble the sheeting themselves or are present in a supervisory capacity. Sheeting is assembled using special assembly tools which enable the pouch and its beading to be pulled into the groove of an edging element running around the structure. Each manufacturer carries a range of their own edging elements, usually multipartite, consisting of extrudded aluminum profiles. The individual parts are screwed together so that the pouch and its beading cannot slip out. This creates a positive joint. The bolt holes in the edging elements are usually so arranged that screws cannot penetrate or damage the sheeting. As an alternative to straight edging elements with restricted flexibility, it is possible to use garland cable pouches or polygonal or curved flat elements as edging devices.

MANUFACTURE AND PROCESSING

The process of making ETFE and processing it as a membrane can be broken down into 4 essential production steps: polymerization, granulation, extrusion, and preparation. Polymerization (multiplication) means arranging the small molecules (monomers) to form a large molecule. A polymer is made up of the same monomers, different monomers produce a copolymer. The ETFE polymer consists of about 25% ethylene and 75% tetra-fluoroethylene monomer units. After polymerization, the ETFE is in powder form, and then heated (melting temp approximately 265C – 285C) to produce granules. The granulate is then calendared or extruded to make a semi-finished material, in other words, rolled sheeting. A distinction is made between blown sheeting and flat or cast sheeting, according to the extruder tool used. At present, flat sheeting produced by the broad-slit extrusion process at a density of 1.75 g/cm3 is used exclusively in the building industry, because of its better material qualities. Sheeting can currently be made up to 250 µm thick, with a roll width of 1.55m.

So far, only a few companies are able to preweld the rolled material to form curved membrane to tailored specifications, in other words, to prepare it. In welding, a distinction is made between partial surface joining and joining edge to edge. The latter, usually involve beaded pouches made of ETFE sheeting. A so-called beading, usually a flexible PVC or EPDM round cord, or sometimes around an aluminum bar, is drawn in. The pieces of sheeting are placed one on top of the other at the welding seams and thermally welded together. This produces a seam about 10mm wide, also translucent that is certainly thicker than the basic material, but only visible from close to.

INFLATING

The energy consumption used by the inflation units is minimal because the blower units only maintain pressure, they do not need to create air flow. A roof or panel is generally powered by one or several inflation units with each inflation unit maintaining pressure to approx. 1000 m2 of roof. An inflation unit comprises two backward airfoil blowers powered by electric motors.
The inflation unit operates approximately 50% of the time on an average roof and uses a similar amount of power to a light bulb

MAINTENANCE

Unlike fabric structures ETFE Foil is an extruded material. This means that the surface is extremely smooth. This smoothness coupled with ETFE Foils anti adhesive properties means that the surface does not attract dirt, and any dirt, such as bird droppings, is washed off whenever it rains. ETFE Foil roofs never need to be cleaned externally. Internally foil roofs are usually cleaned on a 5-10 year cycle depending on the dirt in the internal atmosphere. This usually means that expensive internal access equipment is not required as the long cleaning cycles make rope access a cost effective solution.

Although ETFE foils are very robust, damage may of course occur. Minor damage can be repaired in situ should an ETFE Foil cushion become damaged; the panel can be easily replaced from outside with no internal access being required. Any major damage can be repaired temporarily, and the damaged elements will be replaced at a convenient time to the owner.

TEST STANDARD	TEST DESCRIPTION	RESULTANT
ASTM D-882 ASTM D-882 PA 201/SSTD 12-99 PA 203/SSTD 12-99	tensile strength at break elongation at break small missile impact test cyclic load test	34,000/7000psi 45/650% Pass Pass at 60psf
Xenotest 150/Hanau ASTM D-570 ASTM D-495	weathering resistance water absorption 24hrs air resistance	no change .007% 122 seconds
ASTM D-1003	transparency	95%
UL 94 NFPA 101 ASTM D-1929 ASTM D-635-98	flammability rating surface burning charact. flash-ignition temp. rate of burning	V-0 Class A 878 degrees F HB - no visible combustion

ENVIRONMENTAL CONCERNS

ETFE foils have an extremely low energy consumption during their manufacturing process and the complete system weighs between 50-90 percent less than systems made from other materials with comparable properties- further conserving on the structural system needed to support the cladding. Part of the system is manufactured from recycled materials and the entire system can ultimately be returned to the manufacturer's facility to be recycled at the end of the project's life. The longevity and low life-cycle costs make ETFE foils effective solutions for sustainable in achieving long life and low maintenance.
The architect can explore green or sustainable design solutions for responsive, intelligent day lighting and dynamic thermal properties that can alter spatial characteristics and building performance. These opportunities and capabilities put ETFE foil in a category to themselves.

AIR DRYERS

The inflation units can easily be fitted with dehumidifiers to dry air being fed to the cushions. It is recommended that this be considered for high humidity environments.

FIRE

ETFE Foil has low flammability and is self-extinguishing. The cushions self vent in the event of fire as the hot plume causes the foil to shrink back from the source of the fire allowing the fire to vent to atmosphere. The quantity of material in the roof is insignificant in fire terms and one does not experience molten drips of Foil from the roof.

ACOUSTICS

A foil roof is acoustically relatively transparent. This means that the foil acts as an acoustic absorber for room acoustics, enhancing the internal perceived environment.

INSULATION

A standard three layer cushion has a U value of 1.96 w/m2°K. This is better than triple glazing when used horizontally (glazing manufacturers figures are for vertical glazing which considerably enhances the figures). The cushions insulative qualities can be further enhanced by the addition of further layers of foil, which can in turn be treated with coatings.

DURABILITY

ETFE Foil is unaffected by UV light, atmospheric pollution and other forms of environmental weathering. The material has been extensively tested both in the laboratory and out in the field and no degradation or loss of strength is observed. The material does not become brittle or discolor over time. It is anticipated that the material has a life in excess of 40 years.

ECONOMIC CONSIDERATIONS

Cost of ETFE compared with other structural membrane materials:

BASIC MATERIAL	PRICE (RAW MATERIAL € PER M2)	PRODUCTION. INSTALLATION, CLAMPING, CABLES AND AIR SUPPLY (€ PER M2)	STEEL (€ PER M2)
ETFE 200 µ inflated cushions	14 - 15	200 - 400	350 - 800
PTFE-GLASS Type IV, 1 layer	35 - 65	150 - 400	200 - 600
PVC-POLYESTER Type II - IV	4 - 12	80 - 250	150 - 350

* cost of support materials (clamping, cables, etc) fluctuate

STRUCTURE

ETFE is structurally supported by a steel frame; no back-up structural supports are required. Additional membrane support can be provided by cables to achieve larger spans.

WATER, AIR, VAPOR BARRIERS

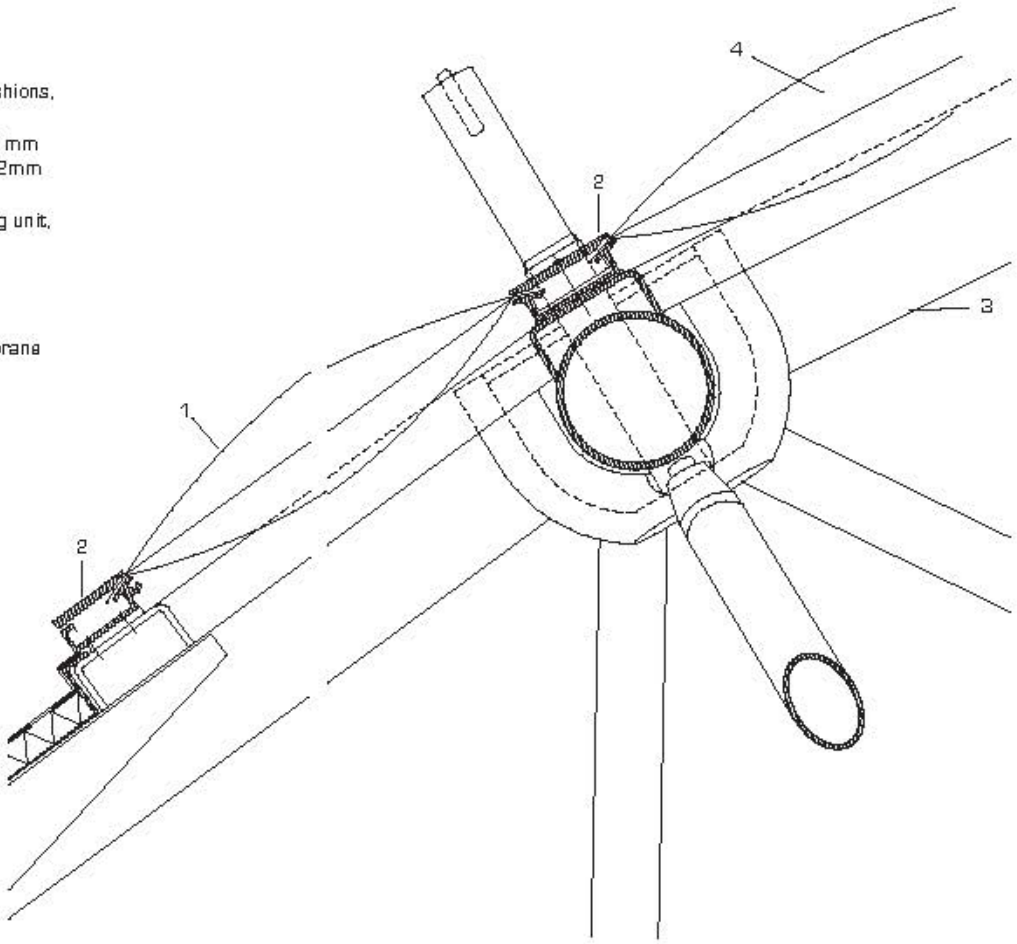
The cushion material (fluoropolymer sheets) act as water, air, and vapor barrier all in one.

1. ETFE sheeting cushions, triple-layer:
internal sheeting 0.1mm
external sheeting 0.2mm

2. Aperture clamping unit, extruded aluminum

3. Steel support

4. Triple-layer membrane



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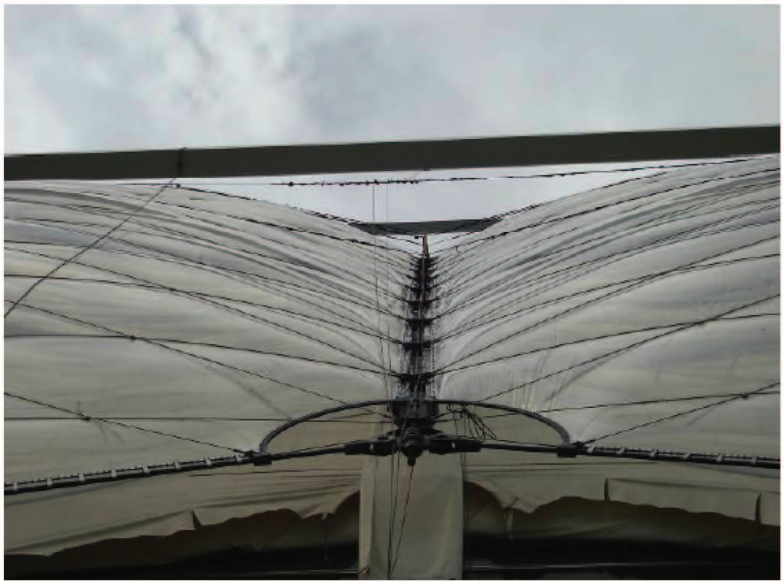
Tropical Islands, Berlin



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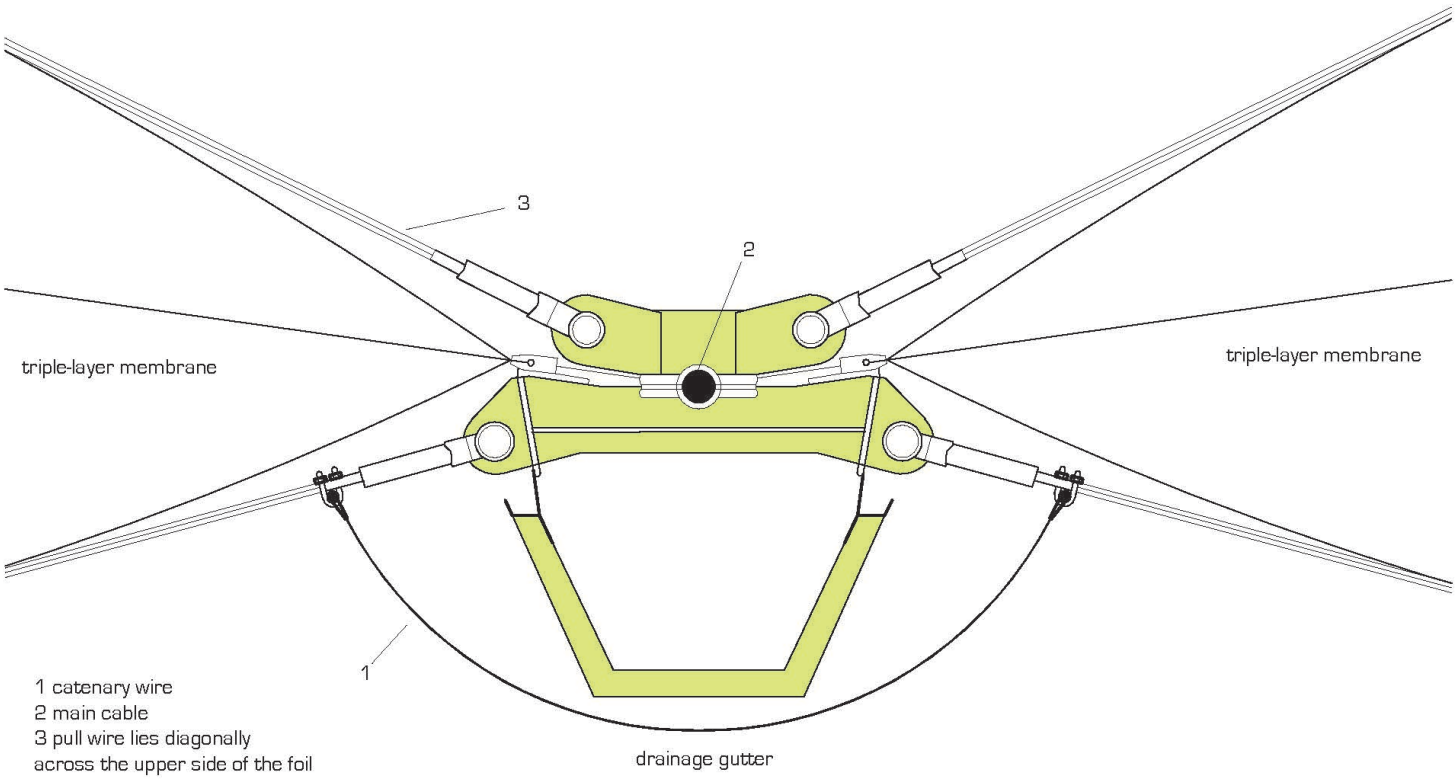

16mm cable lying on the lower foil. The cable is made of stalum, coated in aluminum, with no additional protectants needed.