ETFE; The New Fabric Roof

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Introduction

Ethylene Tetra Fluoro Ethylene - not the sexiest of names, however ETFE foil is fast becoming one of the most exciting materials in today's design industry and has set the construction world alight with the potential it offers.

Originally invented by DuPont as an insulation material for the aeronautics industry, ETFE was not initially considered as a main-stream building material, its principle use being as an upgrade for the polythene sheet commonly used for green house polytunnels. The advantages of its extraordinary tear resistance, long life and transparency to ultra-violet light off-set the higher initial costs and 20 years later it is still working well. It wasn't until the early 1980s, when German mechanical engineering student, Stefan Lehnert, investigated it in his quest for new and exciting sail materials, that its use was reconsidered. Although discounted for Stefan's original purpose, he saw its strength, high light transmission and structural properties as an advantage to the construction industry and started to develop the systems we see today.

Over the past twenty years, Lehnert has increased awareness of the material and its uses and it is rapidly bursting into the consciousness of architects and designers worldwide. Most recently, the Eden Project in the UK and the Beijing Olympic Aquatics Centre, nicknamed the "Watercube", have brought the material into discussion. ETFE is increasingly being specified on a wide range of projects – from schools and offices, to government buildings and sports facilities. ETFE is under the architectural spotlight and intends to shine.

The Principles of ETFE

ETFE foil is essentially a plastic polymer related to Teflon and is created by taking the polymer resin and extruding it into a thin film. It is largely used as a replacement for glazing due to its high light transmission properties. Transparent windows are created either by inflating two or more layers of foil to form cushions or tensioning into a single skin membrane.

Weighing approximately 1% the weight of glass, single ply ETFE membranes and ETFE cushions are both extremely light weight. This in turn enables a reduction of structural frame work and imposes significantly less dead load on the supporting structure. This reduced requirement for steelwork provides a big cost benefit for clients and is a key benefit when replacing glazing in old structures to meet current building codes e.g. railways station roofs.

Alongside its low weight, the major benefit of ETFE is its high translucency. Transmitting up to 95% of light, it is easy to see why it was chosen to construct the Eden Project Biomes in 2000 and more recently the Biota Aquarium in London (due to be completed in 2011) where the full spectrum of natural light and UV is essential to plant health.

When high levels of light and UV transmission are not required, ETFE also has the ability to be printed, or fritted, with a range of patterns. This fritting can be used to reduce solar gain while retaining transparency or alternatively can incorporate a white body tint to render the foil translucent. ETFE cushions can be lit internally with LED lighting to make them glow or projected onto externally like a giant cinema screen, creating dramatic results.

While fritting provides good solar control, modern technology now allows project designers to go one step further. When manufacturing multi-layer cushion systems, one outer and one inner layer of ETFE foil can be printed to allow the light transmission to be varied thereby adjusting the shading coefficient. In these type of cushions, the top and middle layers are printed in a corresponding ('intelligent') pattern which when pressed together covers 100% of the surface with fritting. The middle layer is programmed to rise and fall (using air pressure) to increase and decrease the percentage of printed area and therefore control solar gain.

Unaffected by UV light, atmospheric pollution and other forms of environmental weathering, ETFE foil is an extremely durable material. While no ETFE structure has been in place for longer than twenty five years, extensive laboratory and field research has suggested that the material has a life span in excess of 40 years.

ETFE scores well on the eco-friendly front as well. Being 100% recyclable and requiring minimal energy for transportation and installation means that it makes a significant contribution to the move towards green construction and sustainability.

The benefits of this material are extensive and in some areas yet to be put to use. With an impressive portfolio of both ETFE and tensile fabric structures world wide, Architen Landrell look at two of their recent applications of ETFE in the UK market.

Case Study 1 - Single ply ETFE: Radclyffe School

In recent years, the use of ETFE has been particularly popular in the construction of new build schools. Hailed as environmentally friendly, architecturally aesthetic and cost effective it is not surprising that it has been included in both single ply and cushion form.

The covered street at Radclyffe School is a good example of the use of single ply ETFE. The atrium area, which forms the intersection of five school buildings, needed to be covered for one simple reason – to provide an open but dry space for students and staff to gather, socialize and learn. Without a requirement for insulation, with a need to keep costs down and with a desire to maintain natural light, single ply ETFE provided a good solution.

Although Architen Landrell was not involved in the original design of the scheme, the design team worked extremely hard on the detailing of the structure. We carefully analysed the ETFE membrane and made some improvements to the form to address some initial design issues. We worked hard to improve the perimeter detailing in the areas of the cable connections and ensure that the ETFE would fit onto the steelwork accurately.

The ETFE was supported by a cable net to accommodate the larger spans. These were inserted through pockets on the underside of the fabric and the intertwining of the lateral and longitudinal cable mesh helps the fabric resist snow loads and wind uplift. Additionally, a study was carried out on the support cable locations which found that additional cables were needed in certain locations again to avoid problems with ponding.

The perimeter of the ETFE is fixed to the steelwork using aluminium and silicon rubber extrusions attached with stainless steel fixings developed by Architen Landrell specifically for ETFE. As a high level structure, the ETFE was installed over working nets to ensure safety at all times during the construction phase.

Single ply ETFE has massive, and somewhat untapped potential for creating interesting and dynamic structures in a range of settings and with a variety of effects. The installed structure at Radclyffe School is proof that it is possible to create an ETFE roof using the simplest of shapes, even with minimal curvature, but without losing any of the architectural impact.

Case Study 2: NW Bus Station – ETFE Cushion System

ETFE cushions are finally being recognized as a striking piece of architecture in themselves, not just being chosen to form roof structures and rooflights they can be used to create striking canopies. Blurring the division between the inside and the outside somewhat, they are as much a feature in themselves as a method of construction.

At the brand new Westfield White City Shopping development in East London, it was important to the client to achieve eye catching design as well as practicality. The North West Bus Interchange forms one of the main entrances to the shopping complex and is a valuable location for boosting general awareness of the use of ETFE cushions.

The two layer ETFE cushions form the main canopy and span approximately 60m by 18m and the two layers are continually inflated using high-tech inflation system to create the bubble-like cushion form. The translucency of the membrane proves the feeling of a traditional bus shelter is a long way from this reality, however the practicalities of weather protection are not lost.

The double skinned cushions include drainage to a central gutter and are supported by safety cables in case the power supply fails during storm conditions. Each individual cushion was specifically designed in order to be easily removable for replacement if necessary. As is standard with all our ETFE projects, the cushions also include bird wires fitted to the perimeter of all ETFE panels to deter perching birds.

The even bubble-like look of the ETFE cushions is largely down to the detailed patterning of the separate skins. By increasing the diagonal length of the fabric, the curve of cushions at maximum inflation can be predicted and controlled and any creases can be avoided.

At North West Bus Interchange, the inflation unit is the system's crowning feature. An intelligent system designed to provide maximum information and flexibility for us and for the client, it is simply not in the same league as the more traditional ETFE inflation systems. Previously, a crude pressure switch would detect low pressure in the cushions and turn on all fans at maximum speed until optimum pressure was achieved. Naturally, the pressure would decrease over time and the fans would constantly repeat this process, draining energy and putting unnecessary strain on the equipment.

Our cutting edge approach uses the fans constantly to minimize the energy required and to continually monitor the cushion conditions. Multiple sensors, located throughout the structure, monitor the external environment and adjust the pressure of the cushions accordingly. For example, in high wind speed, pressure will be increased to compensate by making the cushions more rigid. With an inbuilt dehumidifier, the unit can anticipate snow by monitoring the surrounding temperature and humidity levels, increasing the internal air pressure and drying the air only when needed to prevent condensation within the pillows themselves.

As well as being pre-emptive, the inflation control system is more energy efficient than traditional methods. The fans themselves take energy to start/stop and where before, fans were turned on at maximum speed, the brushless duty fan now runs constantly; a duplicate system alternates taking turns to run allowing time to replace a faulty fan when required. The environment sensors now allow the system to run at lower pressures for most of the time with the increased pressure required for extreme weather conditions only called upon occasionally.

The whole system has the ability for remote diagnostics which can be accessed from anywhere in the world. We also have key alarm states that will automatically email the office and alert staff to potential problems on site, such as mass air leaking due to vandalism, and therefore guarantee quick reactions to possible problems. All this is installed in a very small control box with a footprint of only 3’ by 1’.

ETFE cushion structures, such as North West Bus Interchange, are increasingly being design led by architects as the principles of ETFE are becoming more widely understood. As it becomes a more main stream product, the demands made on design, inflation systems and control will become more ambitious. So where do we go next?

The Future …

Much has happened very quickly in the development of ETFE. In thirty years it has gone from creation to one of the industry’s most sought after building materials.

But there is plenty more development to be done. The makings of ETFE as a long term construction material will lie in the development of various high-tech coatings and methods of printing which will modify not just the translucency but also the thermal and acoustic properties of the fabric itself.

By increasing the number of layers and by incorporating ‘nanogels’ is it possible to increase the thermal properties of ETFE foil. Its use in an internal setting has yet to be fully discovered partly due to its current lack of acoustic absorbtion properties. The latter is a major selling point for foil for traditionally noisy areas like indoor sports halls and swimming pools – the echoing noise now simply escapes through the roof - However when noise exclusion is required eg airports, external traffic noise and heavy rain and hail, ETFE currently struggles. However, noise and rain suppression systems are now being incorporated into external structures with successful results and there is much potential for this to be developed further to improve acoustics.

Architen Landrell are running an active test programme to develop IR reflective coatings that will allow multilayer ETFE systems to transmit visible light yet block (insulate) infrared transmission. Current systems have similar insulation levels to conventional glazing products so the search is on for products that will dramatically improve on these values

All these developments will move ETFE into wider product areas.

What is clear is that the world is not short of architects, designers and contractors who want to specify ETFE foil in their projects. Demand is high and with demand comes increasingly adventurous design briefs which constantly push the boundaries of what can be achieved.

ETFE is still in its infancy but these are exciting times and there is much more potential to tap into. It continues to open new horizons for architects and designers which will ensure that it remains in the architectural sphere for the foreseeable future.

Amy Wilson, Architen Landrell - Taken from Interface Magazine, January 2009