ETFE: The New Fabric Roof

By Amy Wilson

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 mainstream building material. Its principal use was as an upgrade for the polythene sheet commonly used for greenhouse polytunnels. The advantages of its extraordinary tear resistance, long life, and transparency to ultraviolet light offset 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 ETFE in his quest for new and exciting sail materials, that its use was reconsidered. Although discounted for Lehnert's original purpose, he saw its strength, high light transmission, and structural properties as advantages to the construction industry and started to develop the systems we see today.

Over the past 20 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 (*Figure 1*) and the Beijing Olympic Aquatics Centre, nicknamed the "Watercube," have brought the material into public 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.

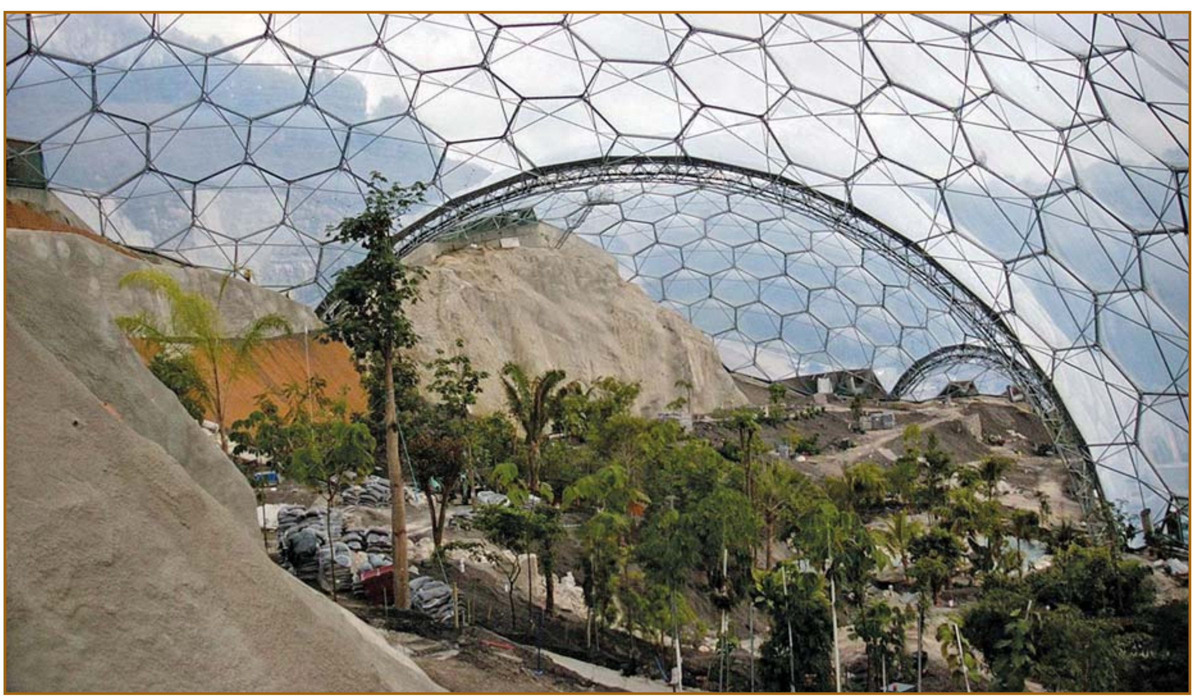

Figure 1 – Eden Project Biomes, Cornwall, UK.

The Principles of ETFE

ETFE foil is essentially a plastic polymer related to 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 green construction and sustainability.

The benefits of this material are extensive and have yet to be put to use in many areas. With an extensive worldwide portfolio of both ETFE and tensile fabric structures, Architen Landrell looks at two of its recent applications of ETFE in the UK market.

Figure 2 – Aluminum framing connects all panels together and carries the weight of the fabric cushions.

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 lightweight. This enables a reduction of structural framework and imposes significantly less dead load on the supporting structure (*Figure 2*). The reduced requirement for steelwork provides a large cost benefit for clients and is a key advantage when replacing glazing in old structures to meet current building codes (e.g., railway station roofs).

Another major benefit of ETFE is its high translucency (*Figure 3*). 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, it 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 may be projected onto externally like a giant cinema screen, creating dramatic results.

While fritting provides good solar control, technology now allows project designers to go one step further. When manufacturing multilayered 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 types of cushions, the top and middle layers are printed in a corresponding "intelligent" pattern which, when the layers are 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 25 years, extensive laboratory and field research have suggested that the material has a lifespan in

Case Study 1: Single-Ply ETFE on the Radclyffe School

In recent years, the use of ETFE has been particularly popular in the construction of new 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 (*Figures 4* and *5*). 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 insu-

Figure 3 – In Wiltshire, England, the "Swindon Dome" covers an atrium with an ETFE dome large enough to house the entire college and allows maximum light to be transmitted to the space below.

Figure 4 – ETFE side panels join the roof and walls at the Radclyffe School.

Figure 5 – ETFE roofing helps to create an inside/outside space, which is very popular for schools.

lation, with a need to keep costs down, and with a desire to maintain natural light, single-ply ETFE provided a good solution.

Architen Landrell was not involved in the original design of the scheme, but its design team detailed the structure, analyzing the ETFE membrane and addressing initial design issues. Added perimeter detailing of the cable connections ensured that the ETFE would fit onto the steelwork accurately.

A cable net accommodates the larger ETFE spans. The cables are inserted through pockets on the underside of the fabric. 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 to avoid issues of ponding.

The perimeter of the ETFE is fixed to the steelwork using aluminum and silicon rubber extrusions attached with stainless-steel fasteners 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 process.

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: ETFE Cushion System on the NW Bus Interchange

ETFE cushions are finally being recognized as striking pieces of architecture in and of themselves, not simply as roof structures and skylights, but also as aesthetically arresting canopies. Blurring the division between the inside and the outside, they are as much a feature as a method of construction.

At the 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 (*Figures 6* and *7*).

Figure 6 – NW Bus Interchange will be one of the busiest areas of the Westfield site and will see millions of visitors each year.

Figure 7 – Over 60 m (almost 200 ft) long, the canopy shelters commuters from the rain.

The two-layer ETFE cushions form the main canopy and span approximately 60 m by 18 m (197 ft x 59 ft), and the two layers are continually inflated using a 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 (*Figure 8*).

The double-skinned cushions include drainage to a central gutter and are supported by safety cables in case the power

Figure 8 – Translucency of the ETFE gives travellers maximum view of their surroundings.

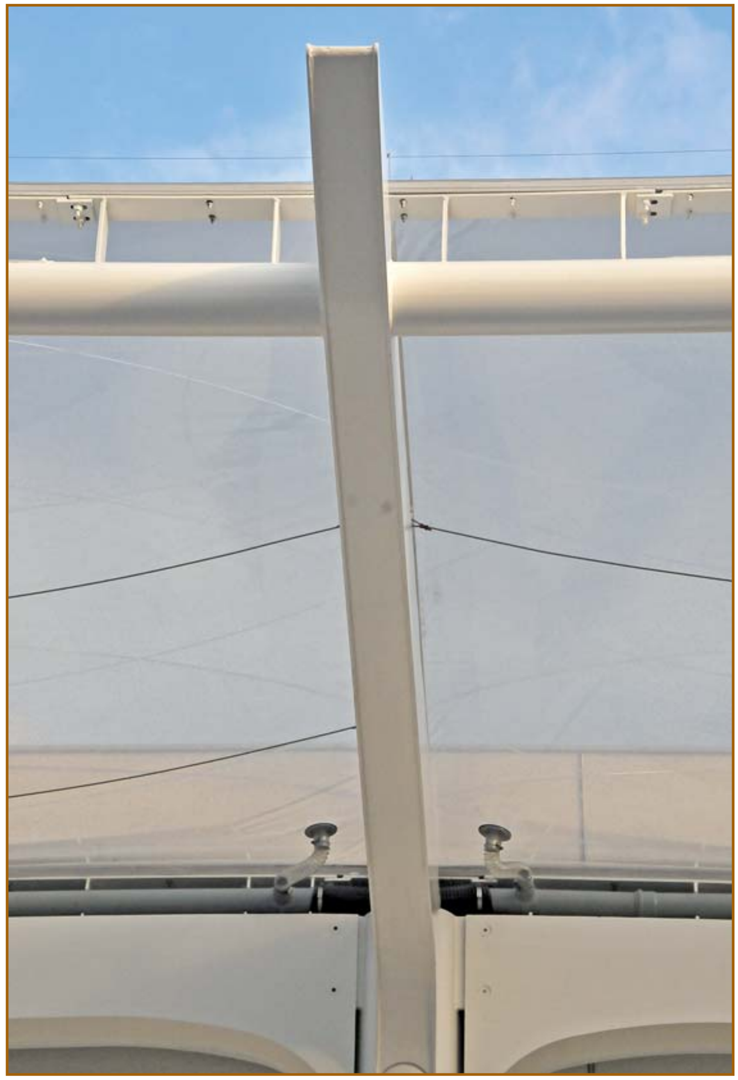

Figure 9 – The cushions are supported by safety cables in case of power failure.

supply fails during a storm (*Figure 9*). Each individual cushion was specifically designed in order to be easily removable for replacement, if necessary. The cushions also include wires fitted to the perimeter of all ETFE panels to deter perching birds.

The even, bubble-like look of the ETFE cushions is due 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 the North West Bus Interchange, the inflation unit is the system's crowning feature. An intelligent system designed to provide maximum information and flexibility for the client and the structure itself, it is a noted improvement on more traditional ETFE inflation systems. Previously, a 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.

Architen's inflation unit continually uses fans to minimize the energy required and to monitor the cushion conditions. Multiple sensors located throughout the structure constantly monitor the external environment and adjust the pressure of the cushions accordingly. For example, in high winds, pressure will be increased to make the cushions more rigid. With an inbuilt dehumidifier, the unit can anticipate snow by detecting the surrounding temperature and humidity levels, and then increase the internal air pressure and dry the air only when needed, in order to prevent condensation within the pillows themselves (*Figure 10*).

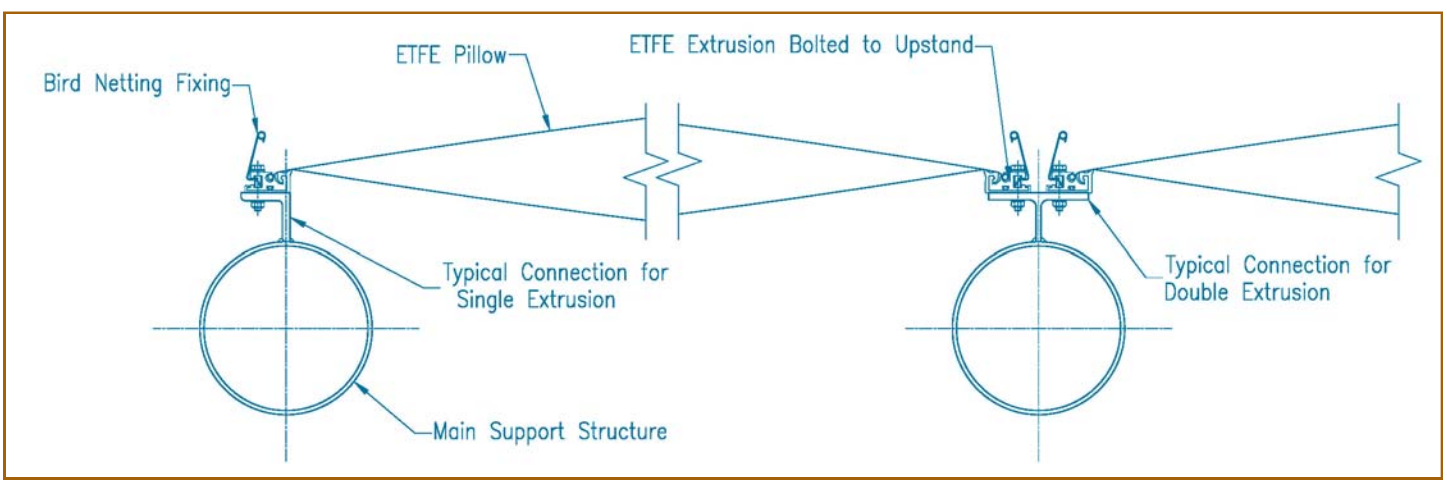

Figure 10 – Example ETFE diagram.

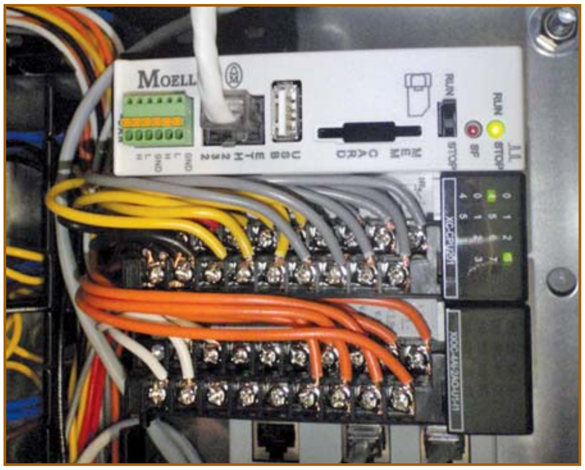

Figure 11 – The complex control system monitors and alters the pressure of the cushions as required.

As well as being preemptive, the inflation control system is more energy-efficient than traditional methods. The fans take energy to start and stop, and where, before, fans were turned on at maximum speed, the brushless duty fan now runs constantly. Duplicate systems alternate, taking turns running and allowing time in which to replace a faulty fan when necessary. The environment sensors 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 to be diagnosed remotely and accessed from anywhere in the world. Key alarm states will automatically e-mail the office and alert staff to potential problems on site, such as mass air leakage due to vandalism, guaranteeing quick reactions if problems arise. This is all installed in a very small control box with a footprint of only 3 ft x 1 ft (*Figure 11*).

ETFE cushion structures such as the North West Bus Interchange are being designed more frequently as the principles of ETFE are becoming more widely understood. As ETFE becomes more mainstream, 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 30 years, it has gone from creation to one of the industry's most sought-after building materials.

But there is plenty more advancement to come. 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," it is 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 absorption properties. The latter is a major selling point for foil for traditionally noisy areas such as indoor sports halls and swimming pools; the echoing noise now simply escapes through the roof. Still, when noise exclusion is required (e.g., external traffic noise and heavy rain and hail in airports), 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 is running an active test program to develop IR reflective coatings that will allow multilayer ETFE systems to transmit visible light yet block (insulate) infrared transmission. Current systems have insulation levels similar to conventional glazing products, so the search is on for products that will dramatically improve on these values. All of these developments will move ETFE into a wider product arena.

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. ETFE continues to open new horizons for architects and designers, and it is sure to remain in the architectural sphere for the foreseeable future.

Amy Wilson

Amy Wilson is sales and marketing manager for Architen Landrell Associates Ltd. She has been with the company for over six years, starting as a student and working her way up. She has been involved in both tensile fabric and ETFE projects and in internal and external work, and has experience with of a wide variety of projects.

NNSA Wins Property Innovation Award for Roof Management

The General Services Administration (GSA) has chosen the Department of Energy's (DOE) National Nuclear Security Administration (NNSA) as the winner of its "Achievement Award for Real Property Innovation" in the Asset Management category for its Roof Asset Management Program (RAMP). The awards were established to motivate federal agencies to improve real property management. RAMP is DOE's innovative and unique process for managing roof repairs and replacement at six NNSA sites, as a single portfolio, under one contract.

Partners at the six sites include:

- Kansas City Plant (KCP) – Kansas City, MO
- Pantex Plant (PTX) – Amarillo, TX
- Y-12 National Security Complex – Oak Ridge, TN
- Los Alamos National Laboratories (LANL) – Los Alamos, NM
- Lawrence Livermore National Laboratory (LLNL) – Livermore, CA
- Nevada Test Site (NTS) – Las Vegas, NM

The contractor selected for the RAMP program was Building Technology Associates, Inc. (BTA), an experienced roof asset management firm based in Michigan that has several employees who are members of RCI.

RAMP uses a single database and centralized management for 4,700 separate roof areas totaling over 16 million sq ft for the six sites. This is the first multisite facility management program instituted for the NNSA. It has delivered outstanding results and is considered a model for other programs within NNSA.

Prior to RAMP, appropriations went to individual sites to spend as they saw fit. Roofing concerns were often only addressed when critical operations were interrupted by roof leaks. This reactive approach to roof leaks often resulted in premature replacement of the roof, the use of a limited number of roofing contractors, and a higher cost of roof replacements. Roof leaks are now viewed as opportunities for repair and life extension rather than a large capital investment in reroofing. So now, instead of funding a few select roof replacements, the monies can be used to extend the life of hundreds of roof areas.

Key RAMP accomplishments and benefits to date include:

- Additional $19.3 million value to the roofing portfolio through life-extending repairs,
- Savings of $7 million in construction costs,
- Increase of 25% in average remaining service life of roof inventory,
- 1.9 million sq ft of existing roofs replaced with more energy-efficient sustainable roofs,
- Elimination of $46 million in deferred maintenance from the 2003 Congressional baseline,
- Realized energy-cost savings exceeding 50 percent, and
- An exceptional safety record.

RAMP has allowed NNSA to more effectively manage its $370 million portfolio of roof assets. This is a mature, flexible, and very effective management process that can be applied to other agencies with limited modification.