Architen ETFE System

Guide to ETFE Cushion Design

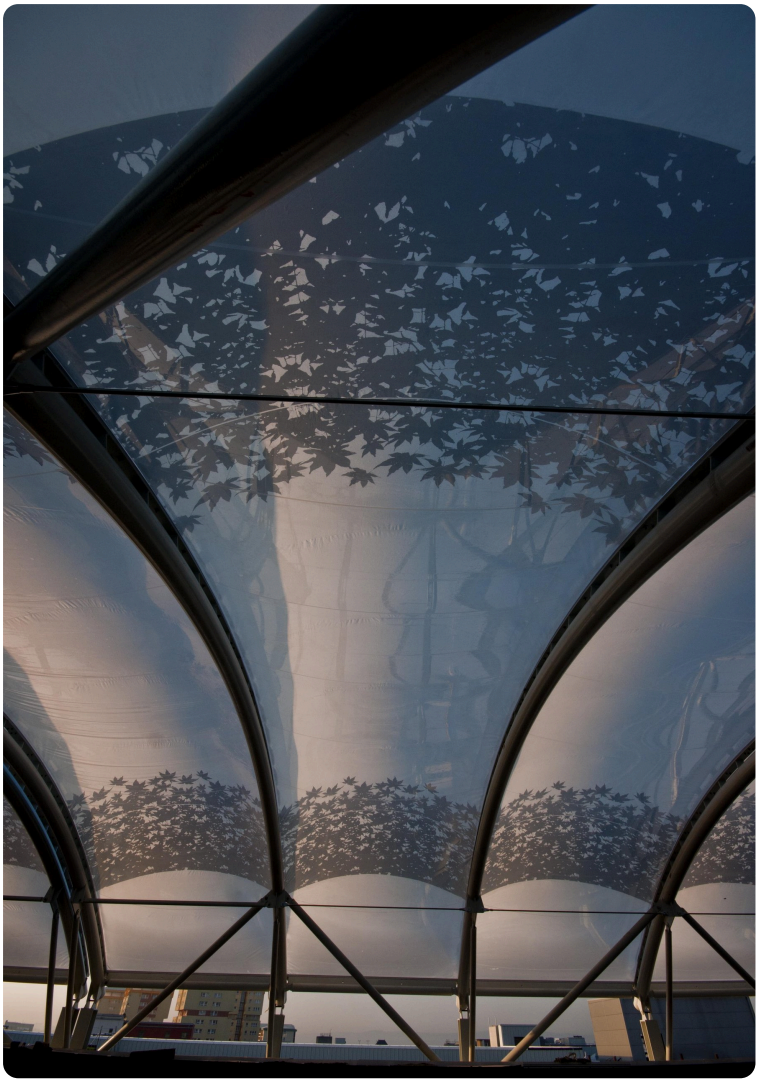
A practical guide for architects, engineers and contractors designing with ETFE foil.

Approx. 1%
Of the weight of glass

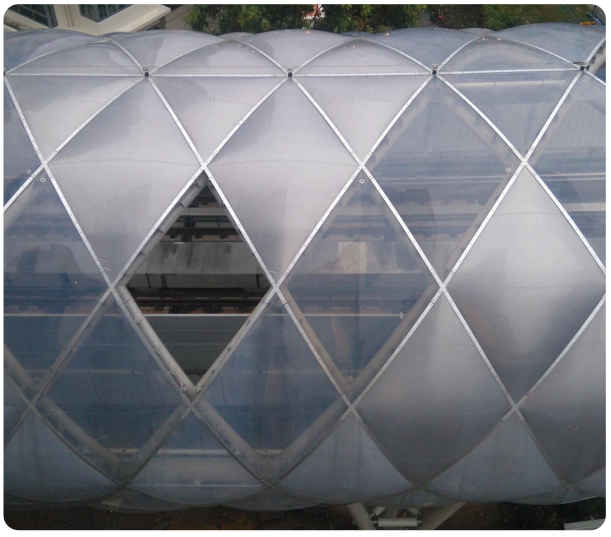
Up to 95%
Light transmission

As low as 1.4 W/m²K
U-value (4 layer cushion)

30+ years
Expected life







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TALK TO OUR TEAM

Introduction

ETFE (ethylene tetrafluoroethylene) is now established as one of the most exciting materials in today's design industry, and architects, contractors and clients are increasingly aware of the potential it offers.

Originally invented by DuPont as an insulation material for the aeronautics industry, ETFE was not initially considered a mainstream building material; its principal use was as an upgrade for the polythene sheet used on greenhouse poly tunnels. It wasn't until the early 1980s, when German mechanical engineering student Stefan Lehnert investigated it in his search for new sail materials, that its use was reconsidered. Although discounted for that 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.

ETFE is now specified by architects and designers across the world on a wide range of projects – from schools and offices to government buildings and sports facilities.

An extremely thin membrane, ETFE copolymer is extruded into thin films (or foils) which are used in two ways: as a single layer membrane supported by a cable system, or as multi-layer cushions held in an aluminium perimeter extrusion, which is in turn supported by the main building frame.

ETFE cushions are kept continually pressurised by a small inflation unit, which maintains a constant pressure and gives the foil its structural stability and insulation properties.

Key benefits

- Very lightweight
- High level of light transmission
- Transmits UVA radiation needed for effective plant growth
- Does not deteriorate
- Long lifespan (30+ years)
- Self-cleaning properties
- Fully recyclable
- High level of fire resistance
- Printable and available in a range of colours
- Structurally stable in both high and low temperatures
- Weldable
- Fabricated off-site
- Easy to maintain

Insulation (U-value)

A single layer ETFE membrane has a U-value of approximately 5.9 W/m²K and provides little more than a barrier to the outside world. A multi-layer ETFE cushion offers a good level of insulation, which is why cushions are often used as part of the architecture of mainstream spaces.

The thermal performance of ETFE cushions can be improved by adding more layers of foil to create additional pockets of air.



5.9 W/m²K
Single layer ETFE foil



2.9 W/m²K
2 layer ETFE cushion



1.9 W/m²K
3 layer ETFE cushion



1.4 W/m²K
4 layer ETFE cushion

FURTHER READING

Full U-value calculations and foil properties are in the Architen ETFE System data sheets for Single Layer, 2 Layer, 3 Layer and 4 Layer Cushions.







Light transmission

ETFE foil is naturally translucent and transmits light across the entire visible light region (380–780 nm). A single layer of medium weight ETFE has a light transmission of approximately 90–95%, with a reduction as more layers are added:

Single layer	Up to 95%
2 layer cushion	Up to 80%
3 layer cushion	Up to 75%
4 layer cushion	Up to 70%

Transmission across the ultraviolet range (320–380 nm) is also very good (approximately 83–88%), providing an environment where plants and vegetation can thrive. Clear ETFE lets through most of the sun's energy, including near-infrared, but absorbs most long-wave infrared – the heat given off by warm surfaces – so heat radiated from inside the space is not lost straight through the foil.



Solar heat gain (G-value)

As a naturally translucent material, an ETFE roof in a multi-layer cushion can contribute to natural solar gain within the space below.

G-value describes the increase in the temperature of a space due to solar radiation. Solar gain is generally desirable in winter, for its passive heating effect, and undesirable in summer, when overheating means the space needs additional cooling.

The G-value of an installation is usually expressed as a percentage or a value between 0 and 1: the higher the number, the more energy is transmitted through the ETFE foil and the more the building will heat up.

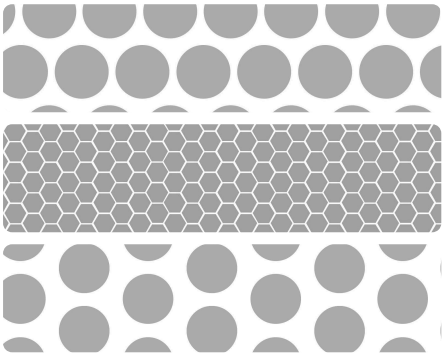
To reduce this and to control glare, ETFE foil can be treated in several ways to manipulate its light transmission and reduce solar gain: fritting the top layer, using white or matt diffused ETFE foil, or using tinted ETFE foil designed to reduce solar gain.

FURTHER READING

For more on fritting, G-values and light transmission, see the Architen ETFE System – Light & Heat Control Data document.

Fritting

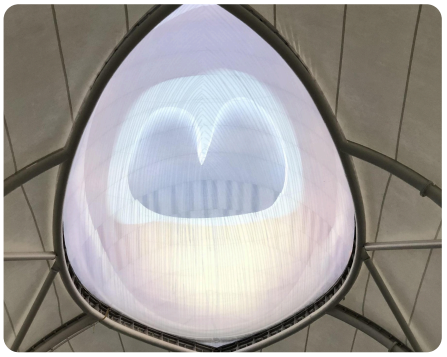
Using a specialist printing method, the surface of the ETFE foil can be covered with a silver pattern that reflects light and reduces solar gain while retaining visual translucency. By varying the coverage and density of the ink, the energy and light transmission can be tuned. We offer a standard range of fritting patterns to achieve a variety of light transmissions, and custom patterns for projects with specific performance or aesthetic requirements.



Selection of standard patterns



Custom designed printing



Custom designed full colour printing

Inflation

ETFE cushion systems get their structural stability and ability to withstand the weather from pneumatic pressure (around 250–300 Pa). Every ETFE cushion system is therefore permanently connected to an air handling unit (AHU), from which air pipes run to each individual cushion. Because the cushions only need to maintain pressure, not generate air flow, the energy used is minimal: under 60 W in normal operation and 100 W at maximum. A standard AHU handles up to 2,500 m² of cushions; larger installations use multiple AHUs networked together to share the load.

Each AHU contains two fans. They run alternately, with only one fan running at any given time. In the event of a cushion failure, adverse weather or a drop in cushion pressure, both fans run together to maintain a steady pressure.

A typical AHU has a footprint of approximately 1.5 m × 0.6 m and is located near the ETFE cushion system, internally or externally. It requires a dedicated and secure 240 V 16 A power supply.

Supplied as standard

- Industrial PLC controller with touch screen interface, data logging and full diagnostics
- LCD panel and traffic light indicators for local status
- Dual fans for load-sharing and redundancy
- Dehumidifier
- BMS interface to replicate traffic light system status
- Non-return valves to reduce air loss
- Inverter-driven fans to optimise efficiency
- Stock parts for quick replacement

Additional options

- Weather station for reactive pressure control
- Remote monitoring via the internet
- UPS battery backup for the control system
- Remote LED mimic panel
- Remote LCD control panel



FURTHER READING

Full specification, data and options are in the Architen ETFE System – Air Handling Unit data sheet.

Control system

As standard, our ETFE cushion roof systems are supplied with an advanced, active monitoring system. An LCD screen on the AHU shows real-time cushion pressure and any faults through a traffic light system:

- Green – all working normally
- Amber – minor problem that needs attention (e.g. a partially blocked air filter)
- Red – immediate attention required

The control system monitors activity automatically and adapts to avoid potential issues. If a problem occurs it will try to compensate – for example, increasing airflow to the cushions when pressure drops – and highlight the fault on the LCD display.

As an optional extra, remote monitoring allows Architen Landrell (or a designated user) to access the control system remotely, see how the system is performing, carry out off-site updates and diagnostics, and make minor pressure and performance adjustments.

FURTHER READING

See the Architen ETFE System – Remote Monitoring data sheet.

Loss of power

In the unlikely event of a power failure, the non-return valves in the AHU allow the ETFE cushion system to hold pressure for between 3 and 6 hours, depending on weather conditions, before deflating. After this, as pressure drops, the roof could be damaged by adverse weather, so we recommend providing standby power to support the cushions should this situation arise. We also recommend the roof is regularly inspected and closely monitored to avoid predictable problems.

Repair & replacement

One of the outstanding characteristics of ETFE foil is its exceptional tear resistance, lack of notch weakness and resistance to stress cracking. Cuts and scratches initially propagate, but the material quickly stretches and rounds out into a tough, low-radius area that dissipates the loads and prevents further tearing.

Minor repairs, such as a puncture, can be carried out in situ in a relatively short time. If a cushion is more significantly damaged, it can be removed and replaced individually with minimal disruption to the rest of the installation. The outside of the cushion is accessed using rope access from the main structural support, routinely carried out under IRATA/BS 7985 guidelines.

Where remote diagnostics are included, every effort is made to diagnose problems remotely. Once identified, a problem is fixed in one of two ways:

1. Remote repair (software problems)
2. On site (hardware problems) – we only need access to the building control room to resolve the problem.





Maintenance

Unlike traditional fabric structures, ETFE foil is an extruded material with a smooth surface. This reduces the amount of dirt retained on the foil and allows rain to wash away most dirt and bird droppings, so ETFE foil roofs don't need frequent cleaning – every 2–3 years is a good guideline. If a rain suppression layer has been installed, more frequent cleaning may be needed.

As an ETFE cushion roof depends on its inflation, we recommend the AHUs are serviced twice a year. A typical inspection includes checking for visible damage to the cushions; visual and physical checks on cappings, air delivery pipework, clamps, brackets and connections; operational testing of the AHU; replacing filters; fine-tuning the inflation equipment; and repairing any minor holes or tears.

Architen Landrell has a dedicated Maintenance Department handling planned and emergency works at sites across the world, with a 24/7 telephone line for call-outs and advice.

MAINTENANCE ENQUIRIES
maintenance@architen.com · +44 (0) 1291 638200
Planned maintenance, inspections and 24/7 emergency call-outs.

Cushion size

ETFE foil cushions can be manufactured to almost any size and shape. Size is limited by the wind and snow loading allowed for in the design, and by the orientation of the cushions (horizontal or vertical).

As a general design guideline, rectangular cushions typically span up to 4 m in one direction (up to 6 m for single layer ETFE) and as long as required in the other. Triangular cushions can be larger. Where the design calls for larger cushions, they can be reinforced with cable restraints to the internal and external layers, or made with thicker ETFE foil.

Life expectancy

ETFE foil has an excellent life expectancy as it is unaffected by UV light, atmospheric pollution and other forms of environmental weathering.

ETFE has been used in buildings since the early 1980s, and the material has been extensively researched and tested both in the laboratory and in the field. These tests show no degradation or loss of strength, and no sign that the material becomes brittle or discolours over time. We therefore expect an ETFE system to have a life of 30+ years.

Fire performance

ETFE foil has low flammability (melting point around 270 °C) and is considered self-extinguishing. In a fire, hot smoke causes the foil to soften, fail and shrink away from the fire source, creating natural ventilation. The foil does not form molten drips or produce fumes, so the quantity of material in the roof is not a concern.

It is not always possible to guarantee that smoke will reach the ETFE at a temperature high enough to make the cushions fail, so automatic actuators to vent smoke from the space are worth considering (see Ventilation).

Fire test results

DIN 4102	Class B1
EN 13501-1	Class B-s1, d0
NF P 92-505	M2
NFPA 701	Pass

For specific fire test reports, please contact Architen Landrell.

Birds

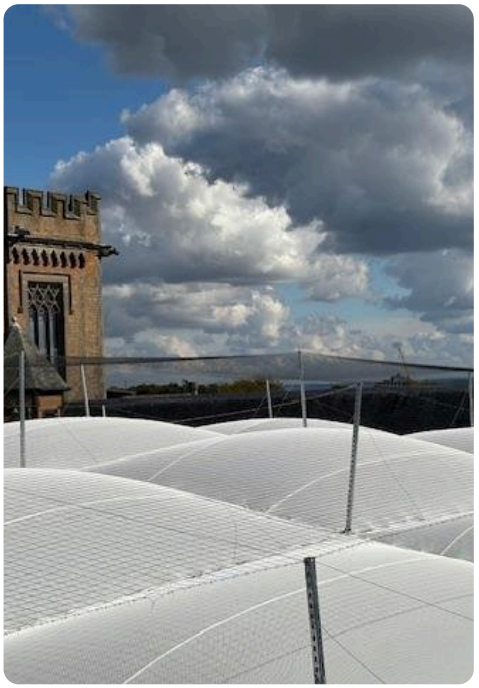
Birds are attracted to roofs as places to perch, nest and feed, and gulls in particular can peck at the foil. All Architen Landrell ETFE cushion systems are therefore supplied with a bird wire deterrent, fitted along the extrusions and steelwork so birds cannot land and perch on them.

Because the ETFE surface is smooth and non-stick, bird droppings are largely washed away by rain, and any that remain are removed during routine cleaning.

If a bird does damage a cushion, small holes can usually be repaired in situ with an ETFE patch, without affecting the look of the roof. The AHU will compensate for any minor air loss until the repair is made.

For coastal sites, waterfronts and other areas with a high risk of bird strikes, a bird netting system can also be installed. Bird wires and netting are checked as part of our routine inspections.





Fragility

ETFE foil cushion systems are certified as Class C non-fragile roof assemblies in accordance with ACR(M)001 – Test for fragility of roofing assemblies.

Class C is the lowest class of non-fragile assembly and, particularly if engineered just to pass the test criteria, may be close to the boundary between fragile and non-fragile. Its classification and use therefore require the following to be taken into account:

a. Class C assemblies should never intentionally be walked on; appropriate temporary access equipment, such as crawling boards, should always be used.

b. A Class C assembly must be treated like any other safety-critical item. Any occurrence that could affect its fitness for purpose should trigger an inspection. If an assembly has been subjected to an impact load (such as a trip or stumble), it should be treated as a fragile area, identified and protected accordingly, until it has been replaced and the adjoining panels inspected by a competent person and replaced if necessary. Procedures to ensure this happens must be in place.

c. The workforce must be aware of these limitations, as required by Regulations 3 and 8 of the Management of Health and Safety at Work Regulations (MHSWR).

d. Anyone falling on a Class C assembly may make it fragile for subsequent loads. While people may be able to recover themselves from a fall or stumble, if they cannot, the additional weight of a rescuer may cause the assembly to fail. Because all non-fragility classifications depend on the fixings, adjoining assemblies may also have become fragile; the incident panel and all adjoining panels must then be treated as fragile. This is a foreseeable risk of selecting Class C assemblies, so rescue plans must be developed before work starts and, in accordance with Regulations 5 and 8 of the MHSWR, the workforce must be aware of the rescue procedures.

Acoustic performance

ETFE foil roofing, in either single layer or cushion form, is acoustically transparent and so neither harms nor improves the acoustics of a space.

With ETFE cushions, rain noise reverberating over multiple tensioned surfaces can sometimes make a space uncomfortably noisy. For this situation we offer a rain suppression layer, tensioned over the top surface of the cushions, which acts as a damper – stopping the sound reverberating into the space below and reducing noise levels by up to 10 dB in heavy rain (Annex A of BS EN ISO 140-18:2006).

A rain suppression layer is only needed in exceptional circumstances. As it can be retrofitted to the cushion system, we recommend rain noise is assessed before deciding to install one.

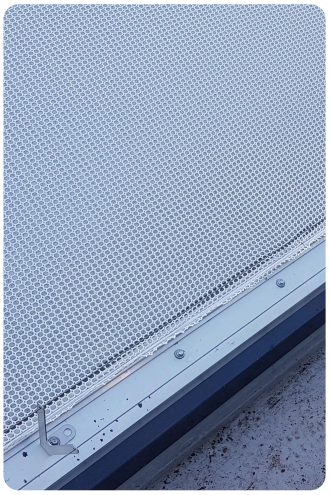
When deciding, it is worth considering how the space will be used: rain noise matters most in quiet spaces such as libraries, offices and restaurants, and least in busy or open spaces such as transport hubs and shopping centres.

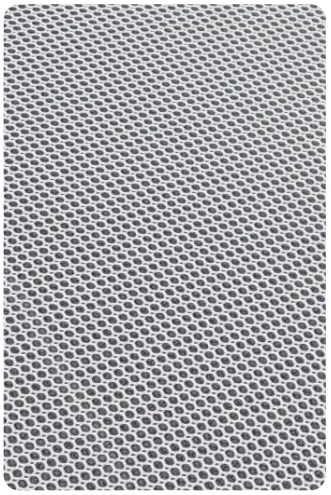
The mesh also reduces the light and solar heat transmitted into the space, which should be allowed for in the daylight and thermal design. It has a typical life of around 5 years and, as it clamps into the existing extrusions, is straightforward to replace.

FURTHER READING

See the Architen ETFE System – Rain Suppression Layer data sheet.







Rainwater & drainage

All ETFE structures are designed with curvature so that rainwater and snow do not pond on top of the membrane, which can deform the foil. Snow is encouraged to slide off, and rainwater is channelled to the perimeter of the roof where it is collected in the main gutter system.

As a general rule, we recommend ETFE roofs are designed with a slope of no less than 10 degrees at the perimeter. Shallower curvature can be achieved, but must be combined with snow sensors and/or cables to help in extreme weather.





Snow

Our ETFE systems are designed for each specific location and the local weather conditions they will be exposed to, including areas with high levels of snowfall. We reduce the risk of snow sitting on the cushions in several ways:

- Every structure is engineered to Eurocode BS EN 1991-1-3 for local snow loads.
- Where snow drift is a concern, we can adapt the ETFE foil thickness and the number of layers, and add snow support cables to the underside of the cushions.
- AHUs can be fitted with automatic snow sensors, which adjust cushion pressure at high-risk times.

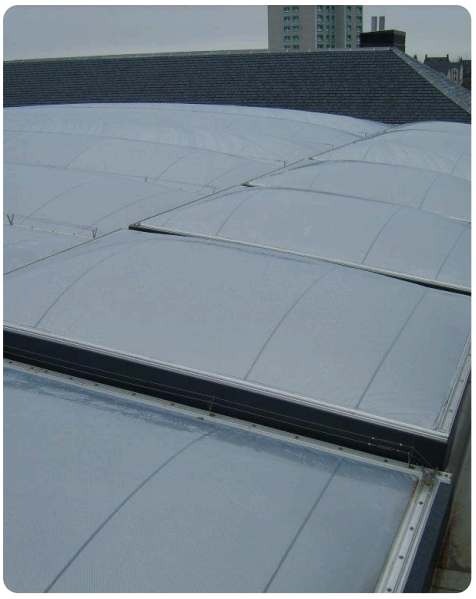
Environmental credentials

The raw material for ETFE is a Class II substance under the Montreal Protocol: it is not a petrochemical derivative and does not contribute to global warming, as is the case for all materials used in its manufacture. ETFE is made by polymerising the monomer TFE in a water-based process that uses no solvents. The material is then extruded to the required thickness – a process that uses little energy – and fabricated by welding large sheets of ETFE, which is also quick and low energy.

ETFE can be recycled easily, but because it does not degrade under UV light, sunlight, weather or pollution, it has a long life (30+ years), which reduces the need for recycling. Excess material from cushion manufacture can be recycled effectively by all ETFE suppliers. The aluminium frames need a lot of energy to produce, but they also have a long life and are readily recycled at the end of it.

ETFE cushion systems offer both good insulation and translucency. Their low weight makes them much more energy efficient than materials giving the same architectural effect – for example, ETFE is rolled for transport, taking up less space and needing less transport.

Cleaning and maintenance needs are also small: most of the time rain washes off any dirt, thanks to the smooth, non-stick surface of the material. Where cleaning is needed, only mild pH-neutral detergents are used, keeping the environmental impact to a minimum.



Ventilation cushions, Greenhill Drumpark School

Ventilation

Because ETFE systems offer a high level of light transmission, heat build-up can be a problem. Louvres are often installed around the vertical perimeter of the roof, but where this is not possible, automated opening vents can be built into the ETFE cushion system itself.

Actuated panels can be opened manually, or sensors can be connected to the Building Management System to open them automatically when heat levels get too high.

As well as providing air ventilation, opening panels can contribute to the building's fire strategy. In this case the system is triggered by the fire alarm or temperature setting, opening the hinged panels for smoke ventilation.

FURTHER READING

See the Architen ETFE System – Ventilation data sheet.

Safety & explosion risk

As a flexible material, ETFE foil can take very high loads for a short time, making it ideal where there is a risk of explosion. Where vandalism is a threat, ETFE is also an advantage, as damaged cushions will not shatter or fall from the extrusion frames.

System warranty

Our ETFE foil cushion systems are supplied with a standard 5 year warranty. An extended 10 year warranty can be provided at additional cost on request.

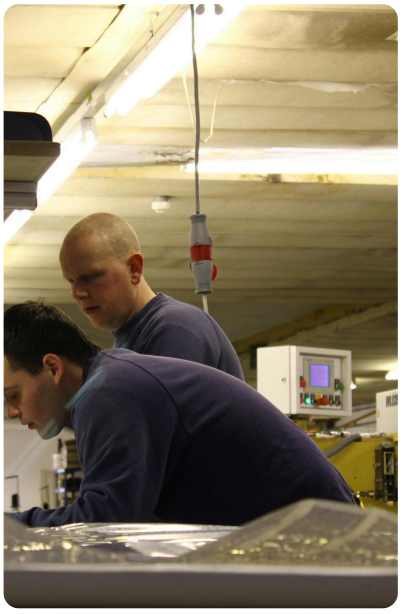
Manufacture

All of our ETFE cushion and single layer ETFE systems are manufactured in our purpose-built factory in Chepstow, UK. With two independent ETFE production lines, we can fabricate up to 100,000 m² of ETFE every year.

ETFE foil on the roll is sourced from a small number of suppliers to ensure high quality material. It is cut and welded into individual panels for each project in our factory, and with full involvement in the production process we can make sure the highest quality standards are met at every stage.

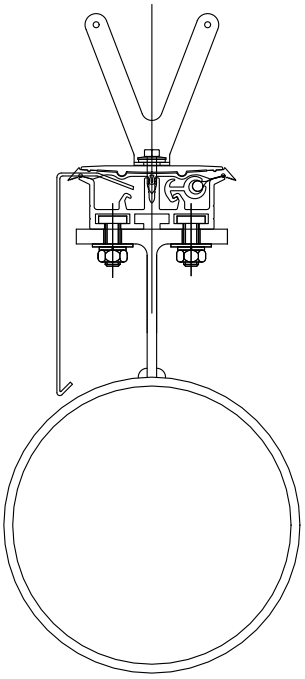




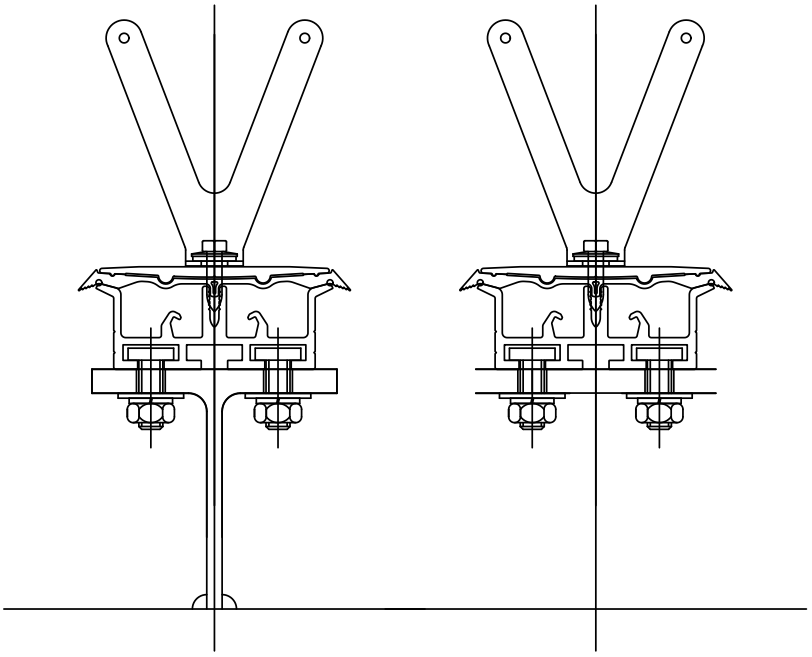


Typical connection details

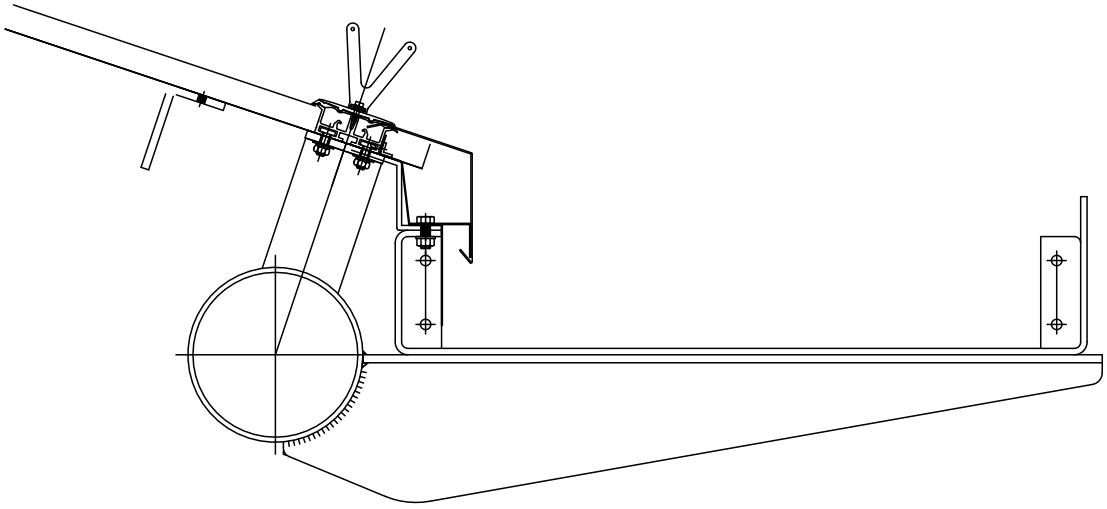
Typical details for the Architen DEX6 aluminium extrusion system, which clamps the ETFE cushions and connects them to the supporting steelwork. Every project is detailed to suit its own structure.



Perimeter: DEX6 extrusion with flashing on a circular hollow section



Intermediate: DEX6 extrusion on a single cleat (left) or twin cleat plates (right)



Perimeter gutter detail: DEX6 extrusion with flashing on a circular hollow section, discharging to a fabricated gutter

TALK TO US EARLY

To discuss the specifics of your project and how best to integrate ETFE cushions, speak to our technical sales team, who are always on hand to offer advice.

Further information

Talk to our team

Tensile fabric and ETFE structures, designed and made in Chepstow since 1983.

SALES & TECHNICAL ENQUIRIES

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ARCHITEN ETFE SYSTEM DATA SHEETS

- Single Layer ETFE System
- Two Layer ETFE Cushions
- Three Layer ETFE Cushions
- Four Layer ETFE Cushions
- Air Handling Unit
- Remote Monitoring
- Rain Suppression Layer
- ETFE Ventilation

CONTACT US