

Opportunities for composite profiles in the residential housing market

An EPTA industry briefing



25 years ago pultruded glass fibre composite was widely unknown in the building and construction market. Today, more architects, engineers and builders are discovering its benefits and finding ways to incorporate it around the home. The properties of pultruded profiles make them well suited to numerous applications in the residential housing market, where they provide strong, durable solutions, outperforming traditional materials for many years. This has led to their successful adoption in energy efficient window and door systems, and now in a further range of applications such as exterior trim, decking, pergolas, columns and fencing. Composite profiles also present excellent potential for the building of affordable housing, a growing demand worldwide. Offering a combination of properties not available with traditional building materials, and attractive attributes for green builders, the prospects for pultruded profiles are bright.

What is pultrusion?

Pultrusion is a continuous process for producing linear fibre reinforced plastic (FRP) (composite) profiles with a uniform cross-section. In the pultrusion machine the reinforcing fibres are impregnated with resin and pulled through a heated die where curing takes place. The finished profiles are cut to length at the end of the line and can then be stored and used as structural units when required. The pultrusion operation can be readily automated,

allowing for low labour involvement, and is therefore a fast, efficient way of producing high performance composite parts.

Pultrusion offers the designer major freedom regarding the geometry, properties and design of the finished profile.

Both solid and hollow profiles can be manufactured, in simple and complex cross-sectional shapes, including tubes, rods, I-beams, T-, U- and Z-profiles.



An immense variety of profile shapes is possible.

Since pultrusion allows for extremely high fibre loading and accurately-controlled resin content, pultruded parts have excellent structural properties and are produced at a consistently high quality. A range of reinforcing fibres, and formats, can be used, including glass and carbon fibre, and a variety of thermoset matrix resins, including polyester, epoxy and vinyl ester, as well as thermoplastic resins. Reinforcement, resin and additives can be combined in innumerable ways to ensure that the finished profile provides the optimum combination of properties required for a specific application. In the residential housing market glass fibre reinforced polyester resin (GRP) is the preferred choice.

Almost any profile cross-section can be manufactured within the following parameters:

- maximum length: 12 m (determined by transportation limits);
- maximum width: 1350 mm/900 mm (depending on the flammability rating);
- wall thickness: at least 1.5 mm, to a maximum of 60 mm, and typically 3-3.5 mm;
- undercuts and different wall thicknesses are possible;
- radii between 0.5 mm and 2 mm are required.

Pultruded profiles are pigmented throughout the thickness of the part and can be made to virtually any colour. Surfacing veils may be employed to create special appearances such as wood grain, marble and granite. Profiles can also be painted, cut and drilled using conventional hardened tools, and connected using bolts, screws, rivets or adhesives. A durable UV-resistant coating is typically applied to profiles intended for outdoor use.

A number of standards have been developed covering the design, fabrication and installation of pultruded profiles. These include the Pre-Standard for Load & Resistance

Factor Design (LRFD) of Pultruded Fibre Reinforced Polymer (FRP) Structures developed by the American Composites Manufacturers Association (ACMA) and the American Society of Civil Engineers (ASCE), and European Standard EN 13 706, which specifies minimum requirements for the quality, tolerances, strength, stiffness and surface of structural profiles. Other codes currently in use are the Eurocomp Design Guide and the CUR96 in the Netherlands. Work towards new European technical specifications for the design and verification of composite structures used in buildings, bridges and construction works is currently being conducted by Working Group WG4 'Fibre Reinforced Polymers' under the European Committee for Standardisation (CEN) Technical Committee 250 (CEN/TC250).

At the end of their service life pultruded profiles can be recycled. A grinding process results in a by-product that can be used as a filler in building materials such as concrete and asphalt, or reused in the pultrusion process as a filler in the matrix resin. An important advance in Europe involves the recycling of glass fibre-based composite regrind through co-processing in cement kilns. This route is becoming increasingly popular since it is highly cost effective, helps to improve the ecological footprint of cement manufacturing, and is compliant with the European Waste Framework Directive (WFD) 2008/98/EC. The composite regrind used for co-processing in cement kilns is both an alternative fuel and raw material (AFR). When combined with other feedstock materials into an input stream with consistent composition and caloric value, the inorganic fraction acts as valuable raw material, while the organic fraction acts as efficient fuel for the calcination process.

The composites advantage

Pultruded glass fibre composites offer a combination of properties not available with the traditional building materials of wood, steel, aluminium and polyvinyl chloride (PVC).

Material	Specific weight (g/m ³)	Tensile strength (MPa)	Elastic modulus (GPa)	Thermal expansion coefficient (K ⁻¹)	Thermal conductivity (W/mK)
Wood	0.7	80	12	14 x 10 ⁻⁶	0.1
PVC	1.4	70	3	85 x 10 ⁻⁶	0.1
Pultruded glass fibre composite*	1.8	240 (axial) 50 (transverse)	23 (axial) 7 (transverse)	11 x 10 ⁻⁶	0.3
Aluminium	2.7	250	70	23 x 10 ⁻⁶	170
Steel	7.8	400	210	12 x 10 ⁻⁶	40

*A comparison of the properties of pultruded composite with alternative building materials.
(*According to EN 13 706.)*

Lightweight: Pultruded profiles are 80% lighter than steel and approximately 30% the weight of aluminium. They are therefore easily transported, handled and installed, resulting in lower costs. Complete structures can often be pre-assembled and shipped to the job site ready for installation.

High strength: Glass fibre composites have excellent mechanical properties, delivering higher strength than steel and aluminium on a kg-for-kg basis. Composites are anisotropic materials and pultruded profiles deliver their highest strength values in the lengthwise (axial) direction. By varying the orientation and format of the reinforcements it is possible to optimise the required strength or stiffness in the direction in which these properties are required. Considerable design freedom can be gained by the capability of adding extra strength in highly stressed areas.

Parts consolidation: With composite materials a designer is able to integrate various separate parts and functions into one profile and to create complicated shapes which are not possible with other materials. This reduces the number of fabricated parts and, as there are less parts to join together, installation is easier. Single composite parts can replace complex assemblies of multiple parts that are produced with traditional materials such as wood, steel or aluminium.

Corrosion resistance: Glass fibre composite is stable, inert, and impervious to moisture and a broad range of chemical elements. Pultruded products will not rot or rust and require minimal maintenance compared with traditional building materials. Composites are the material of choice for outdoor exposure – in coastal areas, for example, where homes are exposed to airborne and waterborne salt agents.

Durability: Composite structures have a long life span. Many well-designed composite structures are still in use after 50 years of service. Coupled with their low maintenance requirements, this longevity is a key benefit.

Thermal insulation: Glass fibre composite has a low thermal conductivity. This is a significant advantage for applications where energy loss must be minimised, such as window and door systems, thermal breaks and cladding.

Dimensional stability: Glass fibre composite has a low coefficient of thermal expansion and pultruded profiles will not expand, shrink or warp.

High and low temperature capabilities: Glass fibre profiles maintain excellent mechanical properties at elevated and very low temperatures (even down to -50°C).

Electrical insulator: Glass fibre profiles are electrically non-conductive and ideal for components in current carrying applications.

Applications in the residential housing market

Pultruded glass fibre composite is viewed as a new material option that can meet the most stringent demands and offers manufacturers, dealers and distributors the ability to differentiate themselves in a highly competitive marketplace. The low maintenance, durability and high strength characteristics of pultruded composites are attractive to both home owners, who want to reduce maintenance time and expense, and contractors wanting to reduce service recalls. Pultruded profiles in window systems have earned a maintenance-free reputation over the last 20 years and are recognised for superior performance in dimensional stability and thermal performance. This has led to opportunities for pultruded composite to replace wood, PVC and aluminium in a variety of other applications including exterior trim, decking, columns, pergolas and arbours, as well as railings, fencing and decking. Projects have also demonstrated the application of pultruded profiles to low cost modular housing systems.

Energy efficient windows and doors

Pultruded glass fibre composite was introduced to the window market in the 1980s. Initially employed in individual components, all-composite framing systems were gradually developed. The benefits of composite profiles include better overall strength, durability and thermal performance, combined with excellent flexibility in design.

Today pultruded composite is widely accepted by window producers as a premium material that must be considered when designing top of the range, energy efficient systems. Composite frames enable the production of window systems with very low U factors, delivering significant energy savings for the home owner. Composites also answer the needs of designers and builders wishing to go beyond the limitations inherent with wood, PVC or metal frames.



Pultruded profiles offer design flexibility in the construction of highly energy efficient window systems.

The thermal performance of glass fibre composite makes it a natural choice for energy efficient windows. As an excellent thermal insulator it limits thermal bridging, reducing condensation and subsequent issues with mould. Pultruded frames exhibit superior dimensional stability in hot and cold environments and will not warp, expand or shrink. The low coefficient of thermal expansion of glass fibre composite is very similar to that of glass, and so the frames expand and contract at the same rate as the glass. This results in less stress on the window seals and lower incidents of seal failure, limiting air leaks and moisture infiltration.

Given their inherent corrosion resistant properties pultruded frames are also extremely durable. They will not rot or rust and can be used in harsh coastal environments. Frames are typically painted or coated to provide a finish that provides UV resistance against fading and cracking and enhanced abrasion resistance. These factors combine to give composite frames a longer life expectancy than PVC, wood and aluminium alternatives, with minimal maintenance requirements.

The high mechanical strength of pultruded composite means slimmer frames are possible, which enables a larger viewing area and lets more light into the home. Composite systems can be designed to withstand high levels of wind load, and they provide increased security through greater resistance to forced entry.

Pultruded profiles also offer great design flexibility. Taking advantage of the mechanical properties of pultruded composite architects are able to create bigger units, holding larger expanses of glass, and different shapes, to meet unique customer specifications. Frames can be produced to closely resemble painted wood or other finishes, and the customer is able to change the colour of the frames by painting if desired.

There are numerous applications for pultruded profiles in the window and door sector, such as: window sashes, frames and mullions; door and sliding door sills and frames; door internal stiffener profiles; insulating cores for metal windows and doors; internal profiles for fire safety doors; thermally insulating stiffeners for PVC; thermal breaks; and brise-soleil (solar shading) systems and shutters.

Green building codes and standards driving the design and construction of more energy-efficient buildings will favour the increased use of pultruded window and door components. Glass fibre composite systems are also becoming more competitive on price, and this, together with considerations of life cycle costs and return on investment, will make pultruded products more attractive to buyers.

Thermal breaks

Thermal bridging through steel and concrete framing can have a significant impact on a building's energy performance. Reducing thermal bridging reduces conduction of heat and energy consumption, and prevents surface condensation from forming inside the building.

Because of its superior thermal performance, glass fibre composite is a good option to provide thermal breaks between the home's interior and exterior steelwork or concrete to prevent thermal bridging. Various projects and applications are being developed in this area.

Exterior trim

The corrosion resistant properties of composite materials make them ideal for products exposed to the weather. Pultruded roof trim, fascia and soffit are extremely tough and durable and provide a low maintenance solution whilst maintaining the appearance of wood. The lightweight profiles are easy to transport, handle and install.

Pultruded profiles are also being used in roof rain gutters. In some cases the gutter system and fascia are combined in a single pultruded piece, reducing the labour required for installation. Pultruded gutters have a smooth inner finish to prevent deposits.

Cladding

Pultruded glass fibre composite offers a stronger, more durable cladding (siding) system than wood, metal, PVC or fibre cement cladding. The installed product is almost maintenance-free, providing the look of painted wood without the need for regular staining, treatment or painting. Composite cladding is impervious to moisture, withstands extreme temperatures and will not buckle like PVC alternatives. It is resistant to chipping, breaking and splintering, and unlike many types of wood siding is not affected by ants and termites. Lightweight composite products are easier to install than heavy fibre cement boards. Available in a range of widths and colours, pultruded cladding provides a hard-wearing, protective layer against the elements and is an excellent insulator.

Pergolas and arbours

Pergola systems based on glass fibre composite beams offer advantages over wood, PVC and aluminium. Corrosion resistant pultruded beams can deliver the look of painted wood without the maintenance requirements or risk of rot. They are stronger than PVC, with less expansion and contraction in extreme temperatures, and will not dent like aluminium. The composite will not rust, chip, fade or crack.

Because of the strength of composite profiles, rafters can span longer lengths than wood or PVC versions, with minimal deflection, and fewer columns are needed. These strength and spanning capabilities also enable accessories such as lattice and canvas to be supported.

A pultruded structural pergola system allows for designs ranging from simple to highly elaborate, and ease of assembly makes installation quick and simple.

Columns

Another growing trend for pultrusion is columns to support porticos, porches and other roof assemblies. Pultruded exterior decorative and structural columns are strong, easy to install, and maintenance free. They can achieve higher structural/load bearing ratings than roto cast glass fibre columns and are lighter in weight, making them easier to ship, handle and install. Unlike wooden columns, pultruded columns are not prone to rot, fading, attack by insects, warping and moisture.

Fencing and decking systems

Pultruded glass fibre composite handrails and fencing systems are strong, attractive and offer a longer lifespan than wood, metal and PVC products. Wood splinters, stains, warps and requires regular repainting. Aluminium, steel and wrought iron oxidise, discolour and rust, increasing maintenance costs and risking safety. PVC offers no comparable strength or durability to composite and degrades rapidly in coastal environments. Composite fencing enables longer spans than PVC, reducing the number of vertical posts required. Composite is the clear material of choice for a coastal environment, since it can survive corrosive salt water environments without rot, rust or corrosion. Glass fibre composite handrail and fencing can be made in a variety of colours, and pickets and rails can be combined to create a unique system.

Pultruded decking is an attractive, low-maintenance alternative to traditional decking materials such as wood and is particularly suited to applications where stronger decking is required. The panels will not rot, rust, chip or mildew, and are ideal for high-moisture environments, including saltwater.

Affordable housing systems

Demand for affordable housing is growing throughout the world. Pultruded profiles open up opportunities for low maintenance, highly energy efficient homes that are fast to build and easy to alter and reuse. The lightweight pultruded components result in reduced shipping costs, and lightweight houses are easier to build and require less energy to heat. Modular buildings can be designed in which all the parts are prefabricated to fit neatly together without cutting, reducing labour and waste on site.

The Startlink system is one example of a modular construction system for low-cost thermally efficient homes based on a small number of pultruded profiles that bolt and 'snap-fit' together enabling rapid assembly. House builder Larkfleet Homes opened a Startlink test house alongside its UK headquarters in 2012; this weighs just 18 tonnes compared with a conventional 40 tonne house.

Because of the snap-fit assembly it is easy to alter or extend Startlink buildings, and they can be dismantled for reuse elsewhere if desired. The composite is stable, inert and impervious to moisture, requiring only the addition of insulation to build houses. Thermal bridging is eliminated and the inherent dimensional stability of pultruded profiles means that air tightness is easily achieved.

By avoiding steel and concrete, Startlink houses are quick to build and up to 25% cheaper than traditional buildings. Because pultruded profiles are so light, concrete foundations would not be needed. Instead, a Startlink building would be best supported on pultruded piles driven into the ground and the quantities of raw materials and energy required to construct the foundation would be a tiny fraction of those required in a conventional building.

With appropriate insulation, the Startlink house has embodied energy only 20% greater than that of a conventional timber framed building (containing kiln-dried, double vacuum treated timber and raised from mass concrete footings) of the same floor plan area and built to the same Passivhaus compliant standard. However, the Startlink house needs no maintenance and is rot and termite proof.



Startlink is a pultruded component kit which can be rapidly assembled into a variety of low-rise building forms without metal fastenings.

It may also be possible to construct such homes in areas where flood risks mean that the construction of conventional buildings is not viable. If built and furnished with suitable flooring material and decorative finishes on the ground floor, Startlink homes are highly 'flood resistant' since the absence of extensive foundations and the nature of the pultruded materials means that the structure is unaffected by water.

Lightweight flat-pack houses also have a role in disaster relief. Easy to transport and simple and fast to construct, pultruded buildings could be employed as temporary accommodation

for people displaced during natural disasters such as hurricanes. When no longer required the buildings could be dismantled and transported to another site, or stored until needed again.

Future potential

Although still relatively new to the residential housing market, the properties of pultruded composite profiles have earned them a position of awareness and respect among architects, engineers and building owners. The potential for further growth is great.

Design flexibility and the ability to customise the mechanical performance of pultruded profiles according to the application are recognised advantages. The development of further standards covering the design, fabrication and installation of pultruded profiles will continue to make it easier for designers and builders to specify pultruded products.



A heightened focus on green building practices and energy efficient homes will lead to more opportunities for pultruded profiles.

Many of the properties that make composites the preferred material of choice for performance reasons also result in it being a more sustainable material than metals or wood. Its durability and resistance to corrosion results in a longer service life, lower maintenance requirements and less frequent replacement. Lightweight composite products are often easily handled and installed without heavy lifting equipment and shipment weights are lower. Direct contributions to environmental impact can be seen in applications that reduce energy requirements, such as composite window and door profiles that result in fewer air leaks and better seals than wood and steel products.

Pultruded glass fibre composites offer a high performance, cost-effective alternative to more familiar building materials, and are suited to a large number of applications in the residential construction market. A heightened global emphasis on green building and

sustainable building practices will only bring increased interest in the potential for pultruded profiles to create energy efficient and sustainable solutions for the future.

About EPTA

The European Pultrusion Technology Association was created in 1989 by a group of leading European pultruders with the mission of supporting the growth of the pultrusion industry by maximising external communication efforts and encouraging knowledge sharing between members. Since 2006, the association has existed under the umbrella of the AVK – Industrievereinigung Verstärkte Kunststoffe e.V., in Frankfurt, Germany. Membership of EPTA is open to all companies and individuals worldwide wishing to further the application of pultruded profiles.

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