Above board
Wood-plastic composites

Wood-plastic composites (WPCs) are a group of materials that have been around in various forms for some time, but are now generating interest both in the UK and overseas because of the breadth of new applications. The term WPC covers an extremely wide range of composite materials using plastics ranging from polypropylene to PVC, and binders or fillers such as wood flour and flax. These materials extend the current concept of wood composites from the traditional compressed materials such as particle-board and medium density fibreboard (MDF) into new areas, and more importantly include a new generation of high performance products.

The first generation of WPCs were formed from a combination of recycled wood flour or chips and binders and were ideal for relatively undemanding applications. Conversely, the new generation of WPCs have good mechanical properties, high dimensional stability, and can be used to produce complex shapes since they are tough, stable, and can be extruded. These new materials are high-tech products for the most demanding applications.

The most common types of WPCs are produced by mixing wood flour and plastics to produce a material that can be processed just like a plastic but has the best features of wood and plastics. The wood used to form this 'alloy' can be garnered from recycled sawdust and scrap wood products, meaning that no additional wood resources are depleted in producing WPCs. Plastic sourced from recycled plastic bags and recycled battery case materials are suitable, although in demanding applications new plastics materials are used. This means that waste products that currently cost money to dispose of can be transformed into a valuable resource, and recycling can be both profitable and ethical with materials recovered from short lifecycle applications used for long-term products.

Ecodek decking manufactured by Vannplastic Ltd, one of the few UK companies to work with wood-plastic composites (WPCs) (title image). Ramps (left) and underwater walkways (right) show the versatility of the wood-plastic 'alloy'. (Images: Wood Composite Technologies Inc)

Benefits of WPCs

WPCs can be extruded or injection moulded, which maximises resource efficiency and allows design flexibility for improved fastening, stiffening, reinforcement, finishing and joining. These are wood products that need no further processing and are weather, water and mould resistant, which makes them ideal for outdoor applications where untreated timber products are unsuitable.

Because they are a hybrid of wood and plastic, WPCs have a wide range of applications and can cost-effectively replace both wood and plastic products in items such as furniture, door frames, decorative profiles, window frames, cable trunking, roofline products and cladding. They are true hybrid materials and combine the best properties of both wood and plastics. They are competitively priced and are competitive with traditional materials such as timber, MDF and PVC-U, while being available in a wide range of finishes

The construction sector is the second highest user of plastics after the packaging industry, and timber is obviously ubiquitous in buildings – yet a fusion of wood and plastics is having a tough time finding a foothold in the UK market. Dr Robin Kent reports

and appearances. As a rule WPCs have a fire behaviour very similar to, or better than that of comparable timber products.

WPC properties

As true composites, WPCs contain the properties of both of their constituent materials. They have stiffness and strength values of between those for plastic or wood, but their density is generally greater than either of these. As an intimate mix of wood particles and plastic, the plastic effectively coats the wood particle as a thin layer and further processing of the outer layer exposes another layer of wood encapsulated in plastic.

The high moisture resistance of WPCs (they have a water absorption of 0.7%, compared to 17.2% for pine) is a direct result of the material's structure. Moisture can only be absorbed into the exposed sections of the wood and is not transmitted across the plastic boundaries. The result is that WPCs are extremely moisture resistant, have little thickness swell in water, do not suffer from fungal or insect attack, and can be easily protected by including microbial agents in the material.

Material properties can be tailored to meet the application requirements by varying the type of wood or plastic used during processing. PE-based products are cheaper and have a higher heat distortion temperature than PVC-based products, while PVC ensures a final product that is easier to paint and post-treat. Pigments, UV stabilisers and fire retardants can all be added to the WPC raw material before extrusion to improve specific properties.

WPCs and the environment

The environmental pressures on industry in terms of recycling and sustainability are growing daily and there is a clear need to extend the lifecycle of traditional building materials such as wood. For users of plastics products there is a need to reduce the dependence on petrochemicals with their rising and cyclical raw materials costs. For users of wood products there is a need to improve the resource efficiency and to recycle the raw materials waste that inevitably occurs. WPCs increase the efficiency of wood usage by up to 40% compared to traditional wood processing and can themselves be easily recycled. WPCs are considered non-hazardous waste and can be disposed of by standard methods. Their basic material structure also means that leaching from WPCs is minimal to non-existent.

Processing WPCs

The basic wood and plastic mix must be modified with process and property additives to improve processing of the final properties of the WPC. One of the major concerns with WPCs in the past has been the difficulty in combining plastics intimately with the wood flour. The general technique is to use a compatibiliser or coupling agent to improve the blending of the two materials. A typical compatibiliser is MAP (maleic anhydride polypropylene), which is used to treat the basic wood and plastic mix to improve the processing and mechanical strength of the final product.

The basic wood product is a fine sawdust in the 40 to 60-mesh range which is dry blended with the various plastics and modifiers. The mix is extruded to a dough-like consistency through a simple die with none of the die swell or calibration problems of conventional extrusion. The flow properties and thermal characteristics of the WPC blend means that simple dies can be used, even for the most complex profile. The die design and construction and the lack of calibration tooling means that tooling manufacture lead times are short (six to eight weeks from design to production).

A standard simple water bath is used for cooling and the haul-off also uses standard parts. After haul-off, the engineered net shape is complete and ready for use. Low processing temperatures (less than 150°C) give high processing rates, low energy consumption and improved safety around the extruders.

Product design for WPCs

A major benefit of extruded WPCs is that the final product form can be produced in a single step. For the first time accurate net shapes are available for wood products allowing timber use without the waste. The fine control on profile dimensions also means improved product performance and reduced material usage.

Exterior profile walls can range in thickness from 4mm to 6mm, interior walls can range from 2.5mm to 3.5mm, and it is also possible to extrude intricate internal details to tolerances of less than ±0.2mm.

Microstructure of a typical WPC showing outer layer removed and inner material still encapsulated in plastic (x100).The microstructure of a typical WPC (x50) (Images: Tangram Technology Ltd)

Net shape profile production allows products to be designed with stiffening legs, internal hooks, internal dividers, snap fittings and internal strengthening walls – all the features of plastic profile design but in wood. This means that profile weight (and cost) can be reduced, and the reduced material content also helps profile cooling to increase production speeds. Profiles can be designed with connectors to allow product systems to be developed – a concept previously not possible with wood products, and designers can add previously unobtainable value to wood products by using precisely formed products with internal hollows, strengthening ribs and re-entrant angles.

The future for WPCs

Current applications for WPCs are largely in finished products such as decking, cladding and window frames. In the USA, the market for WPC products has grown at a rate of 100% per year for the last five years, and this is increasing as new applications are found for the materials. One particular area of growth is in structural engineering applications that push the physical properties of WPC to the limit.

WPCs represent a new era of materials development that combines the old with the new to provide innovative options for the end user. The range of materials being developed is wide and progress is rapid over a huge range of polymer matrix types, fillers and stiffeners.

But these new materials are only slowly gaining acceptance in the UK. Despite huge commercial success in the USA, the UK materials processing industry has largely ignored the development of WPCs and there are very few companies operating in this area. The US construction industry has a much less regulatory 'suck it and see' approach to its building materials, and is also ahead of the UK in that it has some standards for testing WPCs.

According to Richard Zammitt from BRE Certification, the UK barrier is mainly due to a lack of existing standards in order to certify the performance of these materials to the conservative and heavily regulated UK construction industry. 'The durability [of the material] is dependent on each manufacturer's and each factory's secret recipe. So when builders are looking for an assurance that a material will last say 10 to 30 years, there's no precedent.' This does not matter for less demanding applications such as a skirting board, but for load-bearing applications, such as walkways or decking, it is more of an issue – though testing has proved the materials to be more than up to the job.

Though certification is voluntary it has a cost attached, and manufacturers are unwilling to be the first to apply. BRE is one of five organisations in the UK who can provide accreditaiton.

'An important point to note,' says Zammitt,' is that most of the existing UK companies are quality conscious, but it only takes one cheap and cheerful company – from the Far East for example – to damage the industry's reputation. So it's in the industry's own interests to look for certification to prove the quality and consistency of the materials.'

Fastening	Machining	Finishing	Sealing & filling
Nail	Turn	Prime	Silicone seal
Screw	Mill	Paint	Acrylic seal
Glue	Drill	Integral colour	Wood fillers
Staple	Sand	Emboss	
Dowel	Saw	Veneer Wrap	
Welding[1]	Mitre	Laminate	
	Rout	Varnish	
	Plane	Lacquer	

[1]The effectiveness of welding with WPCs varies with the exact WPC used. If the wood content is low then radio frequency welding can give good results.

Working and finishing – WPCs can be processed using conventional woodworking tools and have similar machining properties to wood or MDF. The uniform density of the products even makes processing easier than with traditional wood products and the net shape extrusion means that many normal processes are not needed. The table shows some of the finishing and treating options currently available

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