Review of FRP Composites for the Housing Market

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Executive Summary

Housing in the UK has been constructed from the same small selection of materials for the last several hundred years – generally masonry, timber, steel and concrete. Fibre reinforced polymer (FRP) composites have been used in the construction industry for over 50 years and offer considerable potential for greater use in the construction of buildings. Initial applications have been with small components, such as dormer windows, canopies, doors and other decorative features, but more recently FRP modular pods and complete buildings are being designed.

FRP technology offers many advantages over traditional materials and lends itself to prefabricated off-site construction. This methodology has great potential for the housing market where there is an acute shortage of affordable dwellings and increased pressure to develop sites for residential purposes. Such projects often look to low cost building programmes and therefore to off-site solutions, which may in turn mean greater use of modular schemes and or the use of prefabricated FRP components.

This report reviews the current state of the UK housing market and identifies some of the challenges it faces. FRP composites are then introduced and a review of their current application in housing discussed. Developments overseas, particularly in the US, are illustrated and the potential impact these could have on the UK industry.
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**FRP Composites for the Housing Market**

**Introduction**

The need for change in the UK construction industry is clear if we hope to meet the targets set by Government. The UK house construction market in particular faces a severe challenge to meet conflicting demands. On the one hand, housing shortages and rising prices put pressure on the availability of affordable homes. On the other hand, a changing environmental climate puts pressure on reducing carbon emissions and energy consumption as well as dealing with the consequences of changing weather conditions such as flooding.

**Challenges facing the Housing Market**

**Housing demand**

Demand for housing continues to rise in the UK and as a result, house prices have tripled over the last ten years. The Government response has been to commission reviews from Kate Barker in 2004, The Affordable Rural Housing Commission in 2006 and John Callcutt in 2007 while in 2005 the Office of the deputy Prime Minister set up a competition to build houses for £60,000. Kate Barker recommended that the 140,000 starts in 2002-3 be increased by a further 120,000 to limit price increases to the European average. She also recommended increasing social housing by 17,000 a year with a further 9,000 to cover the backlog. The ARHC recommended building 11,000 affordable homes every year in rural areas while John Callcutt made recommendations to ease housing delivery. Problems have been compounded by energy saving measures to combat global warming.

**Energy considerations**

The construction, occupation and maintenance of buildings accounts for around half of the UK’s emissions of CO2, half the water consumption, one third of the landfill waste and one eighth of all materials used in the UK economy. Energy usage is influenced in three ways:

- energy embodied in construction materials and products
- energy used during the construction process
- energy used by occupiers of the building.

It is estimated that 46% of global warming emissions are generated by buildings in use and 6-7% from the construction process. Of this, domestic households are responsible for around 30% of UK energy use, 27% of UK carbon dioxide emissions and around 24% of greenhouse gas emissions.

In late 2006 the CLG launched a ‘Code for Sustainable Homes’ to drive a step-change in sustainable home building practice. The code considers the following design categories: energy, CO2, water, materials, surface water run-off, waste, pollution, health and well-being, management and ecology. An overall rating for the house is determined by summing the points scored in each of these areas. The code uses a sustainability rating system and is applicable to new homes only:

- Level 1 is just above the current building regulations
- Levels 3 and 4 are likely to be linked to Building Regulation changes in 2010 and 2013 and require 25% and 44% improvement in carbon from energy compared to current Building Regulations.
• Level 5 requires that the energy used for elements covered by Building Regulations (heating, lighting, ventilation and hot water) has zero net carbon emissions.
• Level 6 extends this to all energy use in the home, including appliances.

The two most demanding Levels described in the Code are stretch targets to reduce net carbon from energy usage to extremely low levels.

However, tightening Building Regulations in increasing steps up to code level 6 or ‘zero carbon’ by 2016 is setting standards above German PassivHaus levels which themselves have only been achieved outside the UK. These changes are expected to increase building costs by up to 45% (as well as increase emissions from construction). The consequences of global warming are also being felt in changing weather patterns, exemplified by recent flooding. This has underlined the damage done to traditional materials by floods and the considerable cost and length of time needed to undertake repairs. Nonetheless, Government plans to build 3 million new homes by 2020 are concentrated along the Thames Gateway which is a flood plain. Add this to a shortage of skilled labour to carry out flood repairs in addition to constructing new dwellings and the scale of the challenge facing the UK house construction industry becomes apparent.

Nature of the industry

The UK house building industry is extremely disparate, with only a small number of large companies. In 2005 there were 182,644 private contractors on the DBERR register, more than 90% of which had employees or less, with no one firm having more than a 10% market share. This has major implications for the development and exploitation of new methods and products.

Waste issues

Building construction is a complicated and often wasteful process. Waste and off-cuts from materials used on site are seldom recycled. On-site practices need to be of the highest standard which poses a challenge when jobbing building work is often the norm. Building waste contributes up to 33% of all UK waste. Furthermore, 13 million tonnes of construction materials are delivered to site and thrown away unused every year. Moving the construction process away from site to the more controlled conditions of a factory would improve immeasurably the standards of supervision and quality control which would have the effect of greatly reducing waste.

Another means of reducing waste is to construct modular buildings in which all the parts are pre-designed and fabricated to fit neatly together without cutting. Modular construction is far more suited to factory production, because the standard, modular kit of parts can be mass-produced, thus saving time, materials and a great deal of money.

Customer demands

Another major issue is customer preference and to what extent this matters. Whilst many believe that the public are concerned about environmental issues, this is not generally translated into action; consumer lifestyles and behaviour remain far from sustainable. People usually make decisions based on short term personal gains and, as a buying reference, environmental aspects rank well behind price, size and location. Environmental concerns do not seem to be sufficient to motivate house builders or, through them, the rest of the market. Government intervention can substitute for direct demand from home buyers, but effectiveness is not guaranteed. Government intervention must be credible, clear and sustained and where regulation is involved, it must be enforced.

In addition, consumer preferences are complex and not often realistic. Consumer choice is limited not only by affordability, but by regulation and geography. Choice is often influenced as much by the surroundings as by the house itself. Surveys suggest that for potential buyers, the first
concern in choosing a new home is the quality of the area, notably in terms of access to facilities and services, a sense of community, safety and security. As such, the concept of sustainable communities will be very important especially as zero carbon renewable energy generation is likely to be organised on a community basis.

It is likely that factors such as cost and performance targets will drive an increase in high density living. Government figures show that, while over the last decade the number of flats being built has increased from 10% to 24% of all new dwellings, flats with 3 bedrooms have remained at only 1%. This suggests that the delivery of flats which are too small and often in the wrong places could be biasing people against a type of living which is acceptable in many other countries.

Negative perceptions of high density living include privacy and noise, but this could largely be a question of detailed design and construction methods rather than house type. On a more positive note, terraces and flats have proven themselves more secure, which is another key concern for house buyers. Additionally, people require locally available services and facilities, which is only possible with the critical mass that higher densities bring.

External appearance is rated very low on the list of new home buyer’s priorities. It is also suggested that the appearance of an individual dwelling is less significant than the overall appearance of an area.

**Traditional house design**

The basic design of the house has other implications. The design needs to take account of the future de-construction and re-use, but we need to consider how long we want a house to last for – 35 years, 100 years, longer? This poses the question whether we should be designing houses with some materials having a 500 year life whereas others last only 20 years? And introduces the idea of ‘fit for purpose’ rather than designing to specifications which become ever more exact and onerous. In the future, to have a chance of meeting the challenging performance, volume and cost targets, our designs and material choices need to concentrate on actual function and purpose rather than more optional aspects such as aesthetic appearance.

**Off-site Construction**

Government attempts to accelerate the pace of building and provide more quality control have focused on off-site construction as a better method to traditional building materials. Proponents claim it offers fewer defects, greater safety and savings in vehicle movements to deliver labour and material to site. So far it has proved to be 7-10% more expensive.

**UK examples**

Several types of modular building systems are currently in use in the UK.

- SIPS (structurally insulated panels) – these are not versatile and cannot easily be extended or modified later should change of use require it.
- Timber and steel frame – there remain interstitial condensation problems.
- Mild steel ‘Module Boxes’ – these also have condensation problems, and require heavy lorries to ship them to site where they are craned into position and bolted together to form a building.

**Overseas examples**

In Japan, two distinct types of factory built houses have been developed; Panellised and Modular, using steel or timber frames. Average site times in Japan for different construction methods are
still considerable:

- Traditional carpenter built house: 120 days
- 50% prefabricated houses: 90 days
- Modular units: 40 days

The latter have the advantage of speed, but still require concrete foundations, internal finishing and final inspection on site.

Panellised construction is popular in the US where it builds 45% of the shells of single and two storey homes. Panels are usually constructed on jigs in factories using timber frames which are clad in sheathing and boards. These are delivered to site on big trucks and assembled on prepared concrete slabs. In Florida, Composite Building Structures Inc, is constructing panels using pultruded GRP profiles instead of timber. This gives their panels improved strength and they claim this is sufficient to resist hurricanes.

**FRP composites in house building**

Fibre reinforced polymer (FRP) composites comprise a resin or polymer matrix reinforced with a fibrous material. The reinforcement has high strength and stiffness whilst the matrix binds the fibres together, allowing stress to be transferred from one fibre to another and producing a consolidated structure. FRP composites offer the designer a combination of properties not available in traditional materials. It is possible to introduce the fibres in the polymer matrix at highly stressed regions in a certain position, direction and volume to obtain the maximum efficiency for reinforcement; then, within the same member, to reduce the reinforcement to a minimal amount at regions of low stress.

The resins used in external applications are typically from the thermoset family of polymers. Fibres are usually made from glass or carbon, although there is considerable interest in the use of natural fibres for some applications.

FRP composites have numerous potential advantages in house building construction including the following:

**Off site fabrication and modular construction**

- better quality control
- improved health and safety
- faster build times
- manufacture can take place concurrently with ground works on site
- services can be factory fitted into the structure
- ability to automate and mechanise production.

**Reduced mass**

- easier, faster and more economic installation – smaller cranes required
- ability to bring larger sections to site, reducing assembly times and cost
- less disruption during installation
- reduction in size and cost of supporting structure, foundations etc
- reduced energy in transportation to site.

**Superior durability**

- resistant to atmospheric degradation
- reduction in maintenance requirements
- reduction in through-life costs and disruption.
Ability to mould complex shapes
- new aesthetic possibilities
- geometrically more efficient solutions

Special surface finishes and effects
- ability to integrate special features and a very wide variety of unusual effects
- simulation of traditional materials such as stone or granite

Improved thermal insulation and lack of cold bridging
- reduction in carbon emissions and running costs
- sustainability
- low embodied energy
- possibility of recycling
- possible use of natural fibre and resins.

FRP Composites in House Building – current applications

Although FRP composites have been used in building for over 40 years, they have found limited use within the housing market at a structural level. There are many examples of the materials being used for decorative features and the volume of these applications is considerable. However, little work has been done to determine the benefits of using FRP materials for more structural applications.

In the next section of this report we shall consider the current use of FRP composites in house building and explore where the potential lies for future development of the industry to tackle some of the challenges posed in the first part of this report.

Canopies

GRP (glass reinforced polymer) canopies are very low maintenance, require no heavy structural support, and offer significant savings in cost and build programme time over traditional methods for both new construction and refurbishment.

They are available in an extensive range of permanent colours and can be manufactured in flat roof style or pitched with clay tile or slate appearance, with integrally moulded soffits. Insulation and fixing grounds can be incorporated during product manufacture.
Roofing

There are many roofing applications for FRP composites. These range from single components to complete systems.

FRP flat roofs can be manufactured with in-service performance guarantees of 30 years. The deck may be new or formed over an existing roof. GRP roofs that have been protected from UV degradation by chippings on the gel surface should remain serviceable for considerably longer. 40 year old FRP roofs are still in use (with resin technology advancements, today’s materials are far superior and have built in UV protection). After twenty five years, a new gel surface can be applied to roofs and gutter linings extending life expectancy even further (subject to specific site conditions).

Compared to traditional roofing materials (felt and bitumen based products) FRP composites are more expensive although this additional cost is offset by vastly increased life expectancy. In many cases FRP is a cheaper alternative to traditional materials due to faster installation and the reduced need to strip out existing materials, roof sheets/tiles or glazing bars etc. The price per roof or gutter lining is often dictated by site conditions.

Roof Edge Design

The roofline is often a problem area - difficult to access, making maintenance and repair time-consuming and costly. FRP offers both bespoke and standard solutions (where existing moulds can be re-used). Fascias and soffits are produced off-site, and the lightweight but highly durable fabrication is simply lifted and fixed securely in position.

FRP Coping

GRP Coping stones offer a lightweight durable alternative to traditional cast stone. GRP copings are a good choice where there is any danger of storm damage and injury to pedestrians.

Modern building legislation has put a greater emphasis on health & safety, and especially in areas where there is a potential risk of falling stone work. GRP coping is manufactured in two
parts, a tough base plate with a stone effect GRP top moulding above. These are designed to overlap the base plate and form a drip two both sides of a party (or Gable End) wall.

Where GRP coping stones are used on a pitch they can either be supplied with pre-moulded stop ends, or alternatively with a "Kicker" detail that has one section to the pitch and the base kicking out on a horizontal plain.

Using RAL and BS colour charts, copings can be produced that will match most Bath and Portland Stone colours.

**Gutter Systems**

FRP fascia/soffit/gutter systems provide improved roofline aesthetics, functionality and ease of maintenance.

Where Sustainable Urban Drainage legislation compliance is required in the building design, FRP systems can attenuate water at the roofline as a result of designing the attenuation requirement into the fascia/soffit system.

**Decorative products**

In recent years there’s been a general move away from plain facades as homeowners and developers seek to differentiate properties by recreating the classical styles of a bygone age. GRP decorative features can mimic both classical and contemporary styles including dentils, finials and cornice mouldings. GRP cornice adds distinctive style to any residential or commercial property- new build or refurbishment, whilst the lightweight property of the product removes the dangers and skills associated with installing heavy traditional masonry alternatives.

Other features include lintels, soffits and quoins, or rafter sleeves; ornately decorative corbels beneath a structural beam; boss mouldings provide infill detail; and dummy purlins are perfect for reducing maintenance in difficult to reach flats and apartments.

**FRP Chimneys**

GRP Chimneys are designed to provide the developer with a detail that meets local planning requirements, but without resorting to the cost of building a brick stack from ground floor to roof level. GRP chimneys also offer the home buyer the benefit of increased floor area, where a traditional chimney breast would usually encroach into a room.

Both ‘cosmetic’ and fully working GRP chimneys suitable for class II gas appliances can be produced. They are light enough to need no extra load-bearing work carried out, so they can be fitted to all kinds of roof and timber-framing without modification. They can be retro-fitted to existing roofs with very little effort or adaptation.
The chimneys are one piece moulded GRP units which are clad in brick, stone or render.

**GRP Shiplap Panelling System**

The panels can be produced to simulate any original shiplap cladding to a colour of the customers' choice. They are then simply cut to length, secured with capped screws and trim is applied to finish off corners and edges.

A GRP System will greatly enhance the appearance of a property, and provide significant benefits because GRP is:

- Weather resistant, resolving problems caused by water penetration
- Chemical resistant, allowing graffiti to be removed with the wipe of a solvent saturated cloth
- Very stable, eliminating the need for costly repairs caused by shrinkage, expansion, twisting, warping and rotting.
- Available in a variety of colours. Because the pigment becomes an integral part of the material, the need for costly repainting is eliminated
- Simply cut to length and secured with plastic capped screws, reducing fixing time to the minimum and eliminating the requirement for skilled labour.
- Astonishingly tough and able to withstand substantial impact and vandalism, reducing the need for expensive repairs.

**GRP Windows**

Using GRP for a window frame material is, in some cases, preferable to other window frame materials like wood, vinyl, or metal. Wood, the once ubiquitous window framing material, becomes less common as inexpensive alternatives become more common.

GRP is a durable and long lasting window framing material that can be painted. GRP is about 3 times stronger than aluminium and about 9 times stronger than vinyl. GRP window frames are produced similarly to vinyl, however where vinyl is extruded (or pushed) through a form to process, GRP is pultruded (or pulled) to create the similar form.
FRP Composites for the Housing Market

GRP frames use less mass in manufacturing, leading to a lower conductivity and thereby higher energy efficiency. The low embodied energy and long life of the windows also contributes to increased efficiency over the life of the window. GRP essentially does not conduct heat or cold, increasing efficiency. Quality GRP frames are composed of at least 60% glass, an easily recyclable material. The high glass content makes for a very tough product. It also means the expansion and contraction rates of both the window panes and the frames are similar, increasing the life of the window unit’s seals and materials.

Installation is made easier by the fact that with GRP frames, the frames do not twist or warp during installation. This ensures the frames stay square – a common problem during installation with other types. The greatest drawback is likely to be the premium pricing which is around 10-30% above a mid-grade vinyl product. As efficiencies grow in the industry this premium is expected to decrease, making it a more competitive choice. As the competition heats up, the alternatives will become more readily available.

GRP windows are practically maintenance-free. They take paint easily, in a large selection of colours, do not warp, crack, rot, or corrode, and are very strong.

FRP Columns

FRP moulded columns are lightweight and easy to handle. They can be used in many building projects, including porches and porticos. Further strength for load-bearing properties can be added by filling the centre of the columns with steel rods and concrete, creating a real-feel concrete column that will retain aesthetics with minimum maintenance.

(Courtesy MasterPlastics)

FRP doors

Low maintenance costs, thermal efficiency and security performance make GRP Composite doors a viable choice for new build and refurbishment projects in the UK. GRP doors compete with UPVC and solid timber doors. Cost-wise they are about 2/3 more expensive than UPVC doors, but can give a better aesthetic product. The doors can be finished in a wide range of colours or wood-effects. Each door typically weighs about 25kg which is of the same order as a wooden door.

GRP is used for a variety of door types – from entry doors to garage doors. GRP doors are tested to, and exceed, the same stringent impact resistance requirements as those stipulated under BS6206:1981 as it applies to Safety Glass and Safety Plastics for use in critical locations in buildings. GRP doors also pass the Secured by design criteria demonstrating that a door has passed several anti-intruder tests.

Unlike steel, GRP door panels will not rust or corrode, and are particularly suitable for areas close to the coast where steel doors are severely tested and often have a disappointingly brief life.

Unlike timber, GRP door panels will not shrink, swell, warp or twist and do not require the regular attention needed to ensure a timber door continues to look good.
The slab consists of 2 GRP skins sandwiched by a polyurethane core and damp proof edging to prevent moisture ingress. As such, another attribute of the door is its excellent thermal qualities. The door provides up to six times greater heat insulation than a comparable timber equivalent. This is significant considering the current emphasis on energy and heat conservation.

(Courtesy Doorsmart Ltd)

**Cladding**

GRP brick cladding challenges architects and designers to adopt a more modular approach to the future of building.

GRP cladding panels provide a complete, cost effective fast-track solution to a traditionally built brick wall and are available in a variety of standard brick finishes or custom matched to an existing house finish. They are supplied as a pre-fabricated wall panel which is simply lifted into position and flush mounted onto the face of the building. No skilled labour is required on site. Standard windows and doors can be installed in the usual manner. The finished exterior face is strong durable, waterproof and provides all the aesthetic appeal of traditional brick.

**FRP fascias**

GRP can be produced in a variety of surface textures and shapes as well as an unlimited colour range. This offers many design options to architects not possible within the confines of traditional materials.

GRP can also accurately simulate traditional materials reproducing the original look, feel and style and combines lightweight with its inherent strength to provide a durable weather resistant finish.

Thermal expansion and contraction in fascias is an important factor and a common problem with metals and thermoplastics where all fixing and joints needs to be compensated for quite large movements. Not for GRP, thermal stability and in most cases no special consideration is needed. Fixings and joints can be simple and inexpensive.

In addition, GRP is both non-corrosive and non-conductive and can be manufactured to achieve a fire rating which complies to BS476.

(Courtesy IJF Developments)
Decking and garden furniture

WPC (wood plastic composite) decking is a mix of wood flour (approximately 55%) and polyethylene with the addition of certain additives to improve physical and processing properties. The material is mixed and extruded to form standard profiles.

The polyethylene used can be either virgin or recycled material made up of mainly bottle and film materials. The wood flour is also a recovered material which is processed, filtered and dried before being compounded with the polyethylene.

WPC has many useful properties when used as decking, these include:

- Low moisture absorption
- No rotting, splintering or splitting
- In-built termite and UV resistance
- Excellent dimensional stability
- Anti-slip surface in the wet and dry (tested to HSE standards)
- No toxic materials to leach into the soil
- Easy as wood to work with

(Courtesy Van Plastic Ltd)

WPC profiles are well suited for use as decking, fencing, pool sides, marinas and other similar applications. They may also be used as a replacement for wood in many other areas where a non-load bearing support or structure is required.

WPC decking is estimated to have penetrated nearly 15% share of the North American decking market. The European WPC market is small but growing, with mostly small manufacturing players. The European market, excluding natural fibres other than wood, was 65,000 tonnes in 2003 with about 30,000 tonnes of this being used for construction applications (automotive accounts for the remainder).

Internal applications

Internal housing applications for GRP centre around bathroom applications; predominantly modular units fabricated off-site and delivered to the site for installation. Such pods offer a number of advantages and disadvantages which include reduced on-site construction time, reduced tradesmen coordination and supplier coordination, ventilation, plumbing and electrics are connected and certified, clean installation on site and the facilitation of just in time construction techniques.

Obviously, these advantages and disadvantages are more relevant to some market segments and end users, than others. In addition, the economic environment will have an impact as to which factors weigh most heavily in the different market segments. At the present time, pods offer most advantages to institutional residential end users, where a high volume of installations is matched by a low requirement for differentiation and where the whole life cycle cost of a building is taken into account.

There has been a significant increase in the use of pods since 2002, when a large number of public sector projects came to fruition. This partly reflects government investment policy over the
past ten years and the drive to improve public sector services and conditions. In addition to government policies on health, education, defence and housing, there have been a number of other drivers affecting the market for pods.

Changing demographic and social factors have also played a role in so far as they have created pressure for an increase in the amount of housing and social infrastructure required. Social and affordable housing are in particularly short supply and pods are capable of making a significant contribution towards improving that situation rapidly, especially in the south east of the country.

Pods are manufactured from either concrete, steel frame or GRP. Each material has its own advantages and disadvantages. Thus concrete pods are heavy, weighing 2-3 tonnes, but they offer the possibility of greater structural rigidity and high quality finishes. Steel framed pods offer light weight solutions whilst maintaining rigidity. GRP pods are very light weight and so have less structural rigidity but can offer advantages in terms of hygiene and leak resistance. Concrete and steel pods are more expensive than GRP.

FRP composites are used for single components of a bathroom through to complete bathroom pods. Virtually any finish can be achieved and can include polished porcelain, marble, granite, plasma TV's and even an integrated phone.

Overseas developments

Considerable research and development has been carried out in the USA to develop structural applications for FRP composites. Traditional house building utilises modular construction method and/or frame construction. This is less of a step-change than from brick/block construction methods.

Dome house – Florida, USA

Constructed of moulded GRP with permanent colours, the dome never needs painting and requires little or no outside maintenance, with the exception of an occasional washing to keep it like new.

Built like a giant ice cooler, the double GRP shell sandwiches a core of urethane foam and a Space Age Thermal Barrier Foil insulation for a very high energy efficient dome. Also, the dome shape has 1/3 less outside surface than a conventional building for an additional 30% energy saving.
The dome structure has withstood direct hurricane strikes on the Florida coast. Height strength, plus flexibility of the fibreglass shell greatly reduces the risk of structural damage or personal injury in earthquake regions. Snow and ice damage is reduced due to the lack of conventional shingles and roofing materials. Its dome shape provides additional structural support during heavy snow accumulations.

Certified by HUD (housing and urban development agency, USA.) & Alabama manufactured housing commission, the Dome Homes are currently being manufactured in Tishomingo, Mississippi and Ahmedabad, India facilities.

Each Dome structure is made up of curved panels, some of which have opening for doors and windows.

![Dome structures](image)

(Courtesy of Domes International Inc)

The basic panel is triangular in shape but curved rectangular expansion panels are also available for virtually limitless size and configuration possibilities. The major component panels are hand made of GRP sprayed onto a mould, this layer is followed by a 1” to 1 1/2” layer of high-density urethane foam for insulation and then a final layer of GRP is applied.

On site the panels are bolted together and anchored to a concrete foundation. The seams where the panels meet are protected with a silicone sealant with an estimated 50-75 year life span. Windows of double - insulated Lexan are installed and sealed into place, and the doors are installed to complete the outside shell. It generally takes four people 12 hours to erect a 32 foot Dome and somewhat less time for the small structures. Interior walls and finishing take additional time, depending on the configuration.

The Dome House offers the following advantages:

- Affordability
- Lower Construction Costs - the outer shell can be erected overnight and finished out within a matter of weeks
- Construction Time Reduced 50%
- Sizes from 250 sq. ft. to 3,000 sq. ft.+
- 1 or 2 Stories
- No snow or debris pile-up on roof due to dome shape
- Aero-dynamic shape makes DOME buildings virtually wind-proof
- High impact resistance (>8,000 psi)
- High structural load capacity
- Fire resistant
- Integral fire barrier incorporated in each panel
- Fire retardant added
- Flexibility of the GRP shell reduces risk of damage or personal injury due to earthquakes
Futuristic Worldwide Homes

The house utilises FRP shapes manufactured through the pultrusion process and used as individual structural members in a standard construction system. Specifically, the overall system mirrors typical wood framed house construction. This system substitutes the FRP members for the wood studs, top plate and bottom plate. The system also includes styrofoam board insulation that is inserted between each stud to enhance the insulating and structural performance of the system.

The system features the following benefits:

- Cost $ 26,000 or $ 30.09 / sq.ft. Includes Roof, Wall, and Uplift Anchors. No door/window, foundation or ancillary systems.
- Erection Time 8 workers for 16 hrs. 128 man hours
- Durability 35 year warrantee on panels
- System Complexity One hour of training required
- Transportability 1 unit fits in C130 Panels weigh under 80 lbs.
- Building System Flexibility - Panels may be added and size expanded without changing the design.
- Ease of Maintenance - Maintenance free materials. Class 1 fire retardant, insensitive to mildew, termite & rodent proof.

Ambiente Home – USA

The walls and roof consist of four foot wide modular panels which fit together in a system designed for ease of handling and erection while maintaining structural integrity. The panels are 6 inches thick in a sandwich design with a skin of composite material on each surface and a structural core of the patented Ambi-Core which consists of glass aggregate in a resin mixture. The result is a structure which is as strong as that of concrete and can be erected in much less time.
Ambiente housing system panels are made of materials specifically formulated to enhance the following technical properties, which far exceed the capability of materials such as concrete, steel, brick or wood as used in traditional construction.

- Will exceed 3 hour rating per standard fire tests ASTM E-119
- Will not sustain combustion
- Will not ignite at standard fire temperatures
- Zero flame spread
- No toxic fumes
- Low smoke emission
- Self sealing char effect under extreme temperatures for extended periods

The housing panels are reinforced by an interconnected network of cables, made of composite material six times stronger than steel, running through each wall and roof panel, in effect forming a net within the entire structure. This interconnected net of cables ties the structure together as a single unit and to the floor, through the structural concrete slab foundation, which creates enormous load resistance in all directions far in excess of the considerable dead load of the concrete. The result is a structure which will provide the greatest resistance possible to even hurricane winds and earthquake forces.

Ambiente production methods permit architectural features and finishes, normally only associated with higher priced houses, such as more spacious floor plans, vaulted ceilings, Spanish tiled roofs, stone corner quoins and window mouldings. The highly automated production system and attention to detail also allow Ambiente to control the quality in order to deliver a finished product of the highest quality. Ambiente’s modular panel system is designed to easily accommodate future renovations for the homeowner.

Electrical conduit and outlet boxes are built in the panels making on-site installation of pre-assembled wiring kits and fixture packages quick and easy. Bathware and kitchen packages with plumbing chases, vent stacks and fixture connections are also designed for quick and efficient installation.

High quality composite doors and operable glass windows will be weather proofed and factory finished in modular panels or cartridges for easy on-site installation.

Due to the versatility of the composite material, virtually any desired effect is possible. The wall panels are pre-finished with a stucco effect designed to accept additional painting for homeowner expression of individuality. The roof panels have a Spanish tile or other desired effect to create a roof comparable only to those of upscale houses, but which will never require maintenance.

**Wood Plastic Composite Windows**

WPC (wood plastic composite) frames claim to offer the best qualities of both vinyl and wood. The material comprises wood fibre or flour (a by-product of the saw-milling industry) encased in a thermoplastic resin system. The material is extruded. This application is being developed in Europe.

Aesthetic concerns are often the most important issue when looking for windows. WPC windows may be suitable if maintaining the look of wood is desired. While the thermal properties of composite frames are similar to those of wood, WPCs offer better moisture and decay resistance.

Many manufacturers state these materials are recyclable, like many other plastics it is not known to what degree the material degrades or is reused. As the product matures in this market application, more information will be
available about its recyclability.

The complex tri-layer WPC window lineal illustrated was developed by Krauss-Maffei and Automated Extrusion.

**Future UK developments**

Startlink Systems are developing a modular construction system for low-cost thermally efficient houses based on a small range of pultruded FRP profiles that bolt and snap together enabling rapid assembly. It is predicted that this concept could provide more economic and environmentally friendly housing and enable rapid assembly to tackle the need for increased housing in many countries. It is also expected that this could provide solutions for temporary and demountable building and shelters for both military and civilian applications.

FRP has also been considered for futuristic houses utilising the ability to mould complex forms. Classroom pods have been designed and constructed demonstrating technology that could easily be transferred to the housing market.

**Summary**

House building is a complicated, lengthy and often wasteful process. Waste and off-cuts from materials used on site are seldom recycled (at least in the UK). If building processes were to be moved away from site to the more controlled conditions of a factory, the standards of supervision and quality control would automatically improve immeasurably, which would have the effect of greatly reducing waste and reducing build-times.

FRP components enable faster, more efficient construction, whereas moving towards a lightweight modular structure requiring less onerous foundations would enable sites not currently suitably for housing to be developed.

Modular construction is suited to factory production, because the standard, modular kit of parts can be mass-produced, thus saving time, materials and a great deal of money.

If an entire building can be made as a kit of parts to fit on to one low-loading truck, there need only be one delivery to site by means of a large vehicle consuming hydrocarbon fossil fuel.

Modular buildings are also easier to recycle. The reason is that the component parts can be dismantled at the end of a building's life and taken away for re-use in another modular building. The long life-expectancy of an FRP system would enable the components to be re-used in other buildings after a first building performance life of forty or even fifty years.
FRP Composites for the Housing Market

References

Code for Sustainable Homes, Dec 2006
NGCC Industry fact sheet 01: FRP for Housebuilders
NGCC Industry fact sheet 02: FRP-Housebuilding for the 21st Century

Featured Manufacturers

Avon Fibreglass Roofing: http://www.avonfibreglassroofing.co.uk
Banbury Innovations: http://www.banbury-grp.co.uk
CFS Fibreglass: http://www.cfsnet.co.uk
Domes International Inc; http://www.domesintl.com
Door Smart Ltd: http://doorsmart.co.uk
House Martin: http://www.house-martin.com
IJF Developments Ltd: http://www.grp.co.uk
Master Plastics: http://www.masterplastics.co.uk
Torclad: http://www.torclad.com
Vanplastic Ltd: http://www.vannplastic.co.uk