Journal of Civil Engineering and Environmental Technology
p-ISSN: 2349-8404; e-ISSN: 2349-879X; Volume 5, Issue 8; October-December, 2018, pp. 533-537

http://www.krishisanskriti.org/Publication.html

Role of Advanced Composite Fiber Materials in Architecture and Construction Industry A Futuristic Approach

Prof. Radhika Pathak

Asso. Prof. Priyadarshini Institute of Architecture and Design Studies, Nagpur
E-mail: pathakradhika@yahoo.com

Abstract—*Today, PCT is revolutionizing this industry by replacing the traditional materials with advanced composite solutions or Fiber Reinforced Polymers. Whilst advanced composites have until now, most commonly been used for secondary structures or large self supporting structures such as domes for mosques, PCT is developing more complex solutions to satisfy the designer's desire to challenge the established form and shape of buildings. These solutions not only include dramatic architectural features and 3D components but also futuristic complete primary structures such as exhibition centers and single shell tower structures.[1]All of these applications are only possible using advanced composites since they utilize the lightweight materials ability to be molded into complex forms and sit geometrically.*

The choice of construction materials in the building industry is very limited. The four available options in the industry include concrete, steel, wood, and masonry. While some of these traditional construction materials exhibit composite properties, they possess limited strength, stiffness, or durability. For example, wood is a natural composite made from fibers and lignin matrix. However, it is vulnerable to water damage and decay. Similarly, concrete is a composite made from aggregate, cement, water, and chemical additives. However, it has low tensile strength, and its weight to strength ratio is relatively high.[2]

Composites One offers a wide range of products for the building and construction industry, such as core materials, reinforcements, and fire retardant resins and additives. Our large supply network means manufacturers have many options for the finest products provided by the top vendors.

Keywords*: Advanced Composites, Architecture, Construction, Application, Advantages.*

1. INTRODUCTION

Fiber reinforced polymer composites (FRPCs) were first discovered in the 1940s following the rapid development of the petrochemical manufacturing industry. The combination of the two components in the composites, i.e. the reinforcing phase and the continuous phase, offers superior properties in comparison with individual components. The continuous phase (or the matrix) helps keep the fibers in their intended positions, protecting them from environmental impact, transferring loads to the fibers, as well as providing additional strength. Fibers, on the other hand, ensure the strength and stiffness of the composite. With the advantages of high strength and stiffness, low density, and highly flexible shaping, composites become potential candidates to replace conventional materials (such as aluminium and steel) in civil applications. For example, carbon fiber reinforced polymer composites contribute to a 50–70% weight reduction as an alternative to conventional metal-based materials.[3]In addition, the manufacturing flexibility of FRPC products is well-suited with the demands of architects and engineers in designing complex building structures such as the façade systems while maintaining mechanical properties and durability.

However, early applications of FRPCs were related mostly to the high performance products used in the aerospace, defense and automobile industries due to the high manufacturing cost. The applications of FRPCs have been then extended to other civil industries through many research and development projects conducted since the early 1990s. The market share distribution of FRPCs for construction has been raised to more than 25% and it has become the second largest field of FRPC application. FRPCs are used in construction as structural components, and internal or external reinforcements for concrete structures. Besides the strengthening and rehabilitation effects of FRPCs for concrete structures, FRPC itself structurally outperforms conventional construction materials such as concrete and steel. Concrete and steel bridges require 5% of their original materials to be replaced after 50 years, whereas no maintenance is required for bridges made from glass fiber reinforced polymers (GFRPs). [3]

What is Composite

An engineered combination of materials that result in a finished material with better overall properties than the starting constituents. At a microscopic level, the constituent materials remain distinct within the finished structure.Composite Materials in Building and Construction Applications as “Traditional” Composites like Wood is a natural composite of cellulose fibers in a lignin matrix. Engineered wood is wood fibers, strands or veneers bound using adhesives. Concrete is a composite of aggregate, cement, additives and water. Disc brake pads are composites of hard ceramic particles embedded in soft metal. [7]

Recently, the use of advanced fiber reinforced polymer (FRP) matrix composites have shown promise in the building industry and they are regarded as having the potential for transforming the construction of new buildings, producing spectacular new shapes and forms, and resulting in more efficient and attractive structures. FRP composites mainly consist of reinforcing fibers embedded in a polymer matrix. The reinforcing fiber provides stiffness and strength, and they can be made from glass, carbon, or aramid. The polymer matrix protects the reinforcing fibers from environmental effects and allows proper load transfer between the reinforcing fibers. The polymer matrix can be polyester, vinylester, or epoxy resins. FRP composites are light weight, corrosion resistant, durable, and have high strength. They are also anisotropic, having different strength properties in different directions, which can be tailored to meet complex design requirements by engineers or architects.

The use of FRP composites in building construction started by implementing them in tandem with traditional construction materials. For example, FRP reinforcing bars have been used in concrete construction in lieu of traditional reinforcing steel; FRP sheets have been used to wrap concrete columns to increase strength properties or add confinement; FRP roof panels, siding panels, or decks have been used on traditional wood framed residential buildings.

The International Code Council, who is responsible for developing the International Building Code, permitted the use of FRP composites in both interior and exterior parts of building construction. Owing to that fact, the use of FRP composites has increased rapidly on a larger scale where major structural or architectural elements, and even a complete residential building is solely made out FRP composites. The examples encompass FRP composites used in structural load resisting systems, in architectural cladding materials, and in framing an entire residential building in which they are the exclusive construction material of choice.[2]

1.2. Why composite materials in Architecture and Construction….

For the last 100 years, architects have been limited to using the same small collection of materials in their designs – most commonly masonry, timber, steel and concrete – meaning designers have been constrained in their efforts to turn futuristic concepts into reality.

1.3. Advantages include:

- New aesthetic possibilities: an ability to mould complex, fluid and creative forms and produce more efficient geometric shapes.
- The ability to integrate special surface finishes and a wide variety of unusual effects including simulating traditional materials.
- Hugely significant weight savings – an advanced composite cladding model can typically weigh as little as 10% of its concrete equivalent.
- Rapid installation enabling time and cost savings on site – composite structures can cover much larger spans between support points, reducing the need for substructures dramatically. This has a positive effect on the cost and weight of the completed structure, as well as a significant reduction in installation time.
- Superior durability with reduced through life costs and less degradation.
- Improved thermal insulation and lack of cold bridging.
- Longevity. Composite structures are highly resistant to corrosion. [1]
- Composite materials are used globally in building and construction and provide significant advantages over traditional building materials. Application areas include structural components, cladding and facades, roofing, doors and windows, acoustics, rehabilitation, and the fabrication of unique structures and components.
- Composite products provide light weight, strength, durability and design flexibility that is not available with other materials. These characteristics provide architects, designers and engineers real design flexibility and freedom to create new and unique structures. Composite material’s lightweight also allows for ease of use, requiring less expensive equipment and reducing overall manufacturing costs.

2. APPLICATIONS OF COMPOSITE MATERIALS IN ARCHITECTURE:

The non-materialist aspect of built environment is known as Architecture. Every element has two qualities, one is materialistic and another is non-materialist. While calculatedly chosen for architectural project it has to be considered both the properties of the materials. The non measurable and measurable values have equal importance while choosing perfect building materials. The quality and quantity makes a major impact during selection of appropriate building material. Along with structural importance &constructional behavior, visual impact with historical value of particular materials give an essence of built environment. Site selection along with site surrounding also suggest the building types as well as help to choosing particular materials. The type of material selected deduces a form to the structure. It often induces the concept or theme of the design of the structure and hence the concept of building materials glorifies the importance of endurance and visual quality terms of a design [5]

The number of publications dealing with various aspects of the mechanics of multifunctional materials and structures has increased markedly in recent years. Multifunctional materials are necessarily composite materials, and the strong growth in the use of composites has been greatly influenced by multifunctional design requirements

Composites are materials consisting of two or more chemically distinct constituents on a macro-scale, having a distinct interface separating them, and with properties which cannot be obtained by any constituent working individually. Composite materials are divided in five principal types: polymer matrix composite (PMC), metal matrix composite (MMC), ceramic matrix composites (CMC), Carbon–Carbon (CC) and hybrid composites (HC). Polymer matrix composites and especially fibre reinforced polymer (FRP) are widely utilized in construction applications, including industrial and agricultural buildings.[4]

Among the most important structural functions that a system can provide are stiffness, strength, fracture toughness, ductility, fatigue strength, energy absorption, damping, and thermal stability. Although structural weight is not a function, it is an extremely important design consideration which has driven more designs towards lightweight composite materials in recent years. With conventional structural materials, it has been difficult to achieve simultaneous improvement in multiple structural functions, but the increasing use of composite materials has been driven in part by the potential for such improvements. Composites offer the designers a combination of properties not available in traditional materials.

2.1 . GFRPs for facades

FRPCs are used in construction as structural components, and internal or external reinforcements for concrete structures. Besides the strengthening and rehabilitation effects of FRPCs for concrete structures, FRPC itself structurally outperforms conventional construction materials such as concrete and steel. Concrete and steel bridges require 5% of their original materials to be replaced after 50 years, whereas no maintenance is required for bridges made from glass fiber reinforced polymers (GFRPs). For these reasons, the potential of FRPCs as an innovative material in modern façade systems has captured significant interest in recent years. Compared to other applications in construction, FRPCs are highly competitive in façade systems because of their light weight, flexibility, and cost effectiveness in the manufacturing process. FRPCs make it possible to design complex façade systems with low embodied energy, thus they have drawn substantial attention from façade designers worldwide. Nevertheless, there are many types of FRPCs with varying properties and manufacturing costs, resulting in some difficulty in selecting the suitable material system for the façade elements. Additionally, one of the key drawbacks of FRPCs is their relatively low fire resistance, which still requires comprehensive investigations in order to be applied in façade systems subjected to strict fire safety codes. To address these concerns, this paper will explores the potential applications of FRPCs in modern façade systems, with a special focus on their fire performance. A case study of the fire performance of glass fibre reinforced polymers will be presented. This case study is conducted numerically on a fire dynamic model established for glass fibre reinforced polyester, vinyl ester, epoxy and phenol composites without flame retardants. [5]

Composite materials, such as glass fibre reinforced polymers (GFRPs), possess the advantages of high strength and stiffness, low density, as well as manufacturing flexibility; therefore, their potential in replacing conventional materials (such as concrete, aluminium and steel) in building construction has become attractive. One of the major issues that hinder the extensive use of composite structures in high-rise building technology is related to their fire resistance performance. Significant efforts have been devoted to develop better material systems and composite manufacturing technologies to comply with various building construction safety codes, while maintaining the architectural aesthetic appeal.

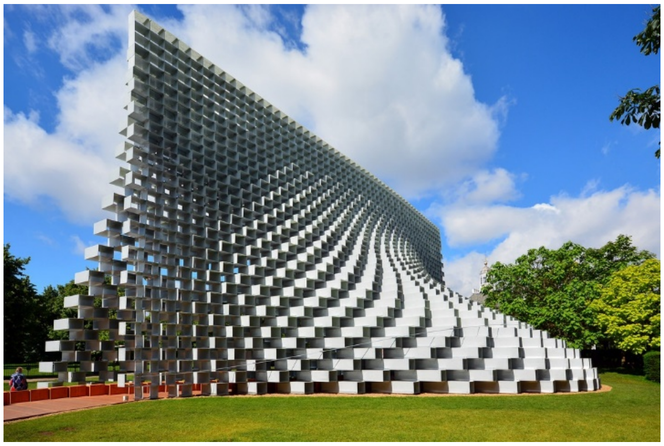


Figure 1: GFRPs Facade
http://info.bwfiberglass.com/blog/topic/gfrp

.Structural load resisting elements exclusively made from FRP composites

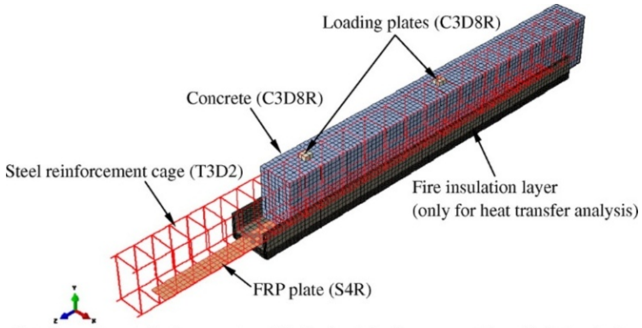
The construction of basement walls is a good example where the use of advanced composites is gaining popularity. Concrete walls have been the dominant choice for basement wall construction. However, there are many disadvantages in using concrete basement walls, including longer installation time, poor insulation properties, and the associated heavy weight. In addition, concrete cracks are often common in basement walls leading to water seepage and mold generation. Recent advances in FRP composites have made it possible to construct entire basement walls that are lighter, durable, and energy efficient with little required insulation. For example, consider the Epitome wall system developed by Composite Panel Systems LLC here in the US.

The Epitome wall, is an all-in-one system combining a vertical wall structure, continuous insulation, a double top plate, integrated stud cavities, waterproofing, and a vapor barrier. Epitome walls are factory assembled, fiberglass-faced structural insulated panels with a preformed polyurethane foam core. The panels are manufactured with 1-5/8 in. wide studs on the interior surface spaced 16 in. on center. The composite walls can be used as load bearing or non-load bearing walls. The panels can be delivered to a site in one trip and can be installed in under three hours.

The Epitome walls have passed rigorous testing, and met building code requirements and compliance for residential foundations. It was reported that the wall system can carry 25 kilopounds of downwards force per lineal foot. In addition, the panels have an insulation value 16 times more than that of the traditional concrete walls, making them attractive for energy efficiency. Advanced FRP composite structural elements, such as the Epitome wall, may cost extra upfront. However, if life-cycle cost is considered, the benefits of such systems are far superior to the traditional construction options.[5]

Figure 2: Epitome wall

http://compositesmanufacturingmagazine.com/2014/07/composite-foundations-build-stronger-infrastructures/



Note: Some elements for the concrete and the fire insulation layer are not shown for better clarity.

https://ascelibrary.org/doi/10.1061/%28ASCE%29CC.1943-5614.0000509

2.3. Architectural cladding materials exclusively made from FRP composites

The San Francisco Museum of Modern Arts underwent major expansion and renovation, and reopened its doors in 2016. This renovated building featuring a 10-story rippled, undulated, and curved facade, is the largest architectural application of FRP composites in the US. The facade consists of more than 700 FRP panels covering 54,000 ft^2 surface area. Some of the individual FRP panels measure 5.5 ft wide by 30 ft in length, while the skin thickness is only 3/16 in. The FRP composites were mechanically fastened and bonded using customized aluminum extrusion. The FRP composite system successfully passed the National Fire Protection Association (NFPA) 285 fire testing for use on high-rise building applications. There were many reasons why FRP was chosen in this particular project including its durability, very high strength-to-weight ratio compared to steel, overall shorter schedule for construction completion, and inherent form shaping capability into complex shapes as shown in Figure 2.

The FRP composites ability to offer significant energy savings when used as a thermal bridging between the exterior and the interior of a building is also praised by the architectural and engineering community. This project’s success is considered a monumental step for the use of FRP composite in future cladding designs that strive to stay ahead of the traditional curtain wall systems.

http://compositesmanufacturingmagazine.com/2015/11/frp-made-san-francisco-museum-of-modern-art-sfmoma-nears-completion/

Figure 3: Cladding made from FRP composites

2.4. Residential buildings exclusively constructed from FRP composites

Sustainability considerations, including resource limitations and cost, are increasingly demanding new solutions in residential building construction. As such, FRP composites are poised to be the most attractive solutions for replacing traditional construction materials that are used in residential building construction. For example, consider the Starlink system. This system is a modular construction for low-cost thermally efficient dwellings made entirely from FRP composites with pultruded profiles connected through bolts or snap-fitting mechanisms for rapid assembly. The parts, which are prefabricated to fit neatly together without the need for cutting, have been shown to be environmentally friendly, reduce labor cost, and eliminate waste on construction sites.

The FRP modular building does not require thermal bridging; it can be easily reconfigured for reuse on another site; it can also be altered or extended to accommodate the growth in family size in residential buildings. Figure 3 shows an example of a full-scale building made from the Starlink FRP composite system in the UK in 2012. It is striking that the all-FRP house weighs only 18 tons compared to a conventional house of the same size weighing 40 tons.

Figure 4: A full-scale house made from FRP composites (white building on the left)
https://www.pinterest.com/pin/475552041882021430/

3. CONCLUSIONS

The use of composite material in construction industry enables engineers to obtain significant achievements in the functionality of construction. This means that many interesting structural concepts not possible with traditional materials can now be realized. Composites do have a very large part to play in the construction industry. As the advantages of composite materials become appreciated their use in the construction industry will undoubtedly increase.[3]

- Composites are lightweight materials that are strong and stiff.
- Composites are much stronger and stiffer than pure polymers.
- Relative to wood, composites are stronger and stiffer.
- Relative to concrete, composites offer superior strength.
- Composites can have specific strength & specific stiffness similar to steels. [7]

In summary, FRP composites have unlimited potential for transforming the state of practice in building construction. They are shown to be more sustainable than existing construction materials; they are durable and corrosion free; they can be handled, lifted, and installed easily given their light weight; and they are energy efficient. The interest of incorporating FRP systems in building construction has accelerated due to their proven performance to pass national fire tests and their inclusion in building codes. It is anticipated that FRP composites will become the construction material of choice in the future as sustainable building construction alternatives are sought out by clients, developers, architects, and engineers alike.

REFERENCES

[1] The use of advanced composite laminates as structural reinforcement in a historic building by H N Garden and E G Shahidi

[2] Center for Real Estate Entrepreneurship on January 23, 2018. Posted in Research**Advanced composite materials are playing a major role in the building industry**by GirumUrgessa, PhD, PE

[3] Civil Engineering and Architecture 1(3): 88-95, 2013 http://www.hrpub.org DOI: 10.13189/cea.2013.010305

[4] Advanced Composite Applications in the Construction Industry, Polymers & Polymer Composites, Vol. 21, No. 3, 2013

[5] https://www.researchgate.net/publication/281198156 Building Material: Significance and Impact on ArchitectureArticle · September 2014

[6] Civil Engineering and Architecture 1(3): 88-95, 2013 http://www.hrpub.org DOI: 10.13189/cea.2013.010305 Composite Materials for Next Generation Building Façade Systems

[7] ACMA’s CORROSION, MINING, INFRASTRUCTURE & ARCHITECTURE CONFERENCE May 15, 2013 - Denver, CO