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ENHANCING THE STRUCTURAL EFFICIENCY OF BUILDINGS AND STRUCTURES THROUGH THE USE OF COMPOSITE MATERIALS: A LITERATURE REVIEW

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Annotation. *This article explores the possibilities of improving the structural efficiency of buildings and structures through the use of composite materials in modern construction. The main focus is on the resistance of carbon fiber, glass fiber, and polymer matrix composites to static loads, their lightweight nature, and corrosion resistance properties. Based on a literature review, the practical applications of these materials, along with their advantages and disadvantages, are analyzed.*

Keywords: *composite materials, carbon fiber, structural efficiency, lightweight construction, building structures.*

Introduction. In recent years, there has been a growing interest in composite materials in the construction industry. Compared to traditional construction materials, composites offer advantages such as lower weight, higher strength, and improved corrosion resistance, making them particularly effective in high-rise buildings, bridges, and industrial structures [1–3]. This article presents a literature-based analysis of the impact of composite materials on structural efficiency.

Composite materials are composed of two or more constituent components, which are combined to enhance their overall properties. In construction, the following types of composites are commonly used:

Carbon Fiber Reinforced Polymers (CFRP): Composition, Properties, and Applications in Construction.

Carbon Fiber Reinforced Polymers (CFRP) are modern composite materials that stand out due to their high strength and lightweight characteristics. CFRPs consist of carbon fibers and a polymer matrix. Carbon fibers are extremely thin yet strong filaments with a structure similar to graphite crystals. The polymer matrix—typically epoxy or polyester resin—binds the fibers together, maintains their alignment, and protects them from external influences.

CFRP materials possess high tensile strength, rigidity, and excellent resistance to corrosion. Notably, they are 4 to 5 times lighter than steel, making them highly

advantageous in both transportation and construction sectors. Their low coefficient of thermal expansion ensures stability under temperature variations. These materials are manufactured using technologies such as lay-up, pultrusion, filament winding, or resin infusion.

One of the most important applications of CFRP in the construction industry is the reinforcement of reinforced concrete structures. They are especially used to enhance the seismic resistance of bridges, buildings, tunnels, and aging infrastructures. Carbon fiber-reinforced slabs and columns can withstand heavy loads without significantly increasing the overall weight of the structure. Due to their rapid installation, effective distribution of mechanical loads, and long service life, CFRP materials are gaining increasing interest among modern construction professionals.

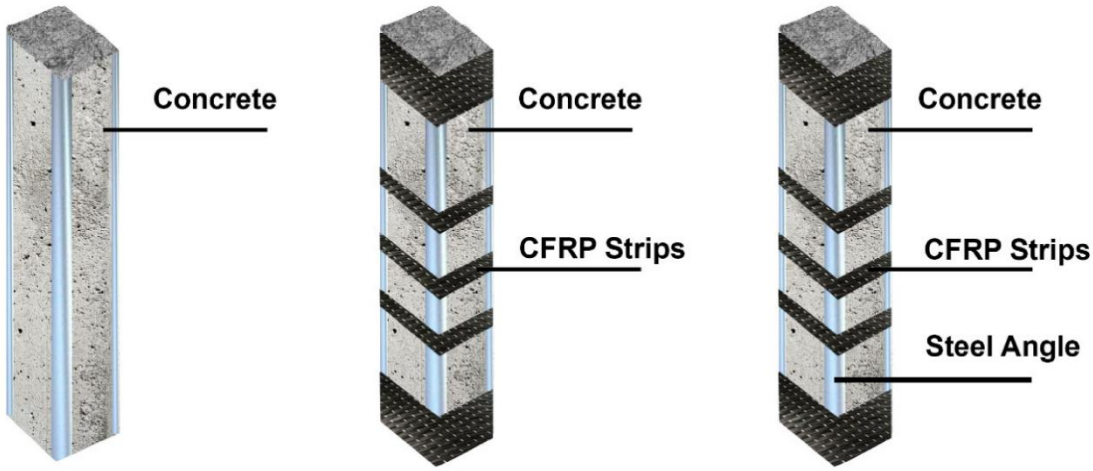


Fig 1. Application of Carbon Fiber Reinforced Polymers (CFRP) in Construction

Overall, CFRP plays a crucial role in modern construction by enhancing the efficiency of structures, extending their service life, and enabling the creation of lightweight yet strong structural systems [4].

Glass Fiber Reinforced Polymers (GFRP): Composition, Properties, and Applications in Construction.

Glass Fiber Reinforced Polymers (GFRP) are modern composite materials known for their high strength, lightweight, and excellent resistance to corrosion. GFRP is primarily composed of two main components: glass fibers and a polymer matrix. Glass fibers—produced by melting alumino-silicate or other silicate-based materials—are thin, flexible, and strong filaments that serve as the main load-bearing component. The polymer matrix, typically made from epoxy, vinyl ester, or polyester resins, binds the fibers into a cohesive system and protects them from environmental influences.

GFRP materials are particularly distinguished by their resistance to corrosion, moisture, and chemical exposure. This makes them especially suitable for use in wet

or aggressive environments. Their density is 4–5 times lower than that of steel, yet they offer high tensile strength and elastic limits, allowing them to withstand various loads. In addition, GFRP possesses excellent dielectric properties and is unaffected by magnetic fields, making it useful in electrical applications.

The use of GFRP in construction is extensive, serving as reinforcement in bridges, buildings, tunnel structures, roads, and hydraulic facilities. It is widely employed in the form of rebars, structural profiles, grating, and cladding elements. Compared to traditional steel reinforcement, GFRP rebar is more resistant to corrosion, which is especially beneficial in coastal, saline, or industrial waste-affected areas. These materials are also used to strengthen existing reinforced concrete structures, prevent deformations, and enhance seismic resistance.



Fig 2. Application of Glass Fiber Reinforced Polymers (GFRP) in Construction

However, GFRP also has some limitations. For example, unlike steel, it does not exhibit plastic deformation, meaning it can fail suddenly without warning cracks. Additionally, it has relatively low resistance to high temperatures and limited recyclability.

Overall, GFRP is an effective solution for reducing structural weight, combating corrosion, and extending service life in modern structures, making it one of the innovative directions in the construction industry [5].

Basalt Fiber Reinforced Polymers (BFRP): Composition, Properties, and Applications.

Basalt Fiber Reinforced Polymers (BFRP) are modern composite materials made from fibers derived from basalt rock, known for their high strength and heat resistance. They consist of two primary components: basalt fiber and a polymer matrix (typically epoxy, polyester, or vinyl ester resins). Basalt fibers are produced by melting volcanic rock (basalt) at temperatures of 1400–1600 °C and drawing it into fine filaments. Since this process involves no chemical additives, it is considered environmentally friendly.

Compared to steel, BFRP is lighter (density ~2.7 g/cm³) but offers comparable or even superior tensile strength (exceeding 1000 MPa). Additionally, BFRP materials

exhibit excellent resistance to high temperatures (up to 500 °C), acidic and alkaline environments, ultraviolet radiation, water, and corrosion. These properties make BFRP highly suitable for use in harsh environmental conditions.

In construction and infrastructure, BFRP is increasingly used as a reinforcement material. It serves as a modern alternative to steel reinforcement, especially in coastal areas, saline soils, industrial zones, and hydraulic structures. BFRP materials are utilized to strengthen reinforced concrete structures, enhance the durability of bridges and roads, and manufacture lightweight and durable façade panels, structural profiles, and slabs.

As a drawback, basalt fiber composites can be relatively more expensive compared to carbon or glass fiber composites, and their recycling technology is not yet fully developed. However, their high environmental safety and excellent performance characteristics position them as a promising composite material.



Fig 3. Application of Basalt Fiber Reinforced Polymers (BFRP) in Construction

In conclusion, BFRP is an advanced composite material developed from natural raw materials, offering high durability, long service life, environmental friendliness, and compliance with the requirements of sustainable development in industry and construction [6].

These materials are primarily used as reinforcing bars, surface coating layers, and in repair and strengthening applications [7].

Impact on Structural Efficiency

Carbon Fiber Reinforced Polymers (CFRP). When applied to load-bearing structural elements such as columns and bridges, CFRP significantly increases their load-carrying capacity. Due to their high modulus of elasticity, they exhibit excellent resistance to bending and help reduce deformations. Additionally, CFRPs are resistant to corrosion, moisture, and acidic environments, which extends the service life of structures. One of their greatest advantages is the ease of application—CFRP materials

can be quickly bonded to existing structures for reinforcement without the need for heavy machinery [8].

Glass Fiber Reinforced Polymers (GFRP). When used in structural elements, GFRP reduces weight and improves resistance to bending and fatigue. The non-conductive nature of GFRP fibers makes them especially suitable for use in areas with electrical hazards. Their stability against moisture and chemical exposure allows for widespread use in sewage systems, bridges, and engineering structures. Furthermore, GFRP composites are capable of absorbing heavy loads, helping maintain structural integrity under impact [9].

Basalt Fiber Reinforced Polymers (BFRP). These materials are lightweight and strong, which reduces overall structural load and significantly lessens the pressure on foundations. Structural solutions made with BFRP are durable, long-lasting, and adaptable to various climatic conditions [10].

Limitations and Challenges in Construction Applications

Carbon Fiber Reinforced Polymers (CFRP). Although CFRP is well-known for its high strength and lightweight properties, several challenges arise when using it in construction. First and foremost, CFRP materials are relatively expensive, which limits their widespread use. Secondly, CFRP is sensitive to ultraviolet (UV) radiation, high temperatures, and humidity, making it risky to use in outdoor environments without protective coatings. Additionally, CFRP is typically rigid and brittle, which complicates handling and bonding to structural elements. The processes for recycling and disposal of CFRP are also currently limited [11].

Glass Fiber Reinforced Polymers (GFRP). While GFRP is one of the most commonly used and affordable composite materials, its application in construction also faces certain limitations. One of the main drawbacks is its low modulus of elasticity, meaning it exhibits less stiffness compared to steel or CFRP. This can lead to excessive deformation in structures subjected to high loads. Furthermore, GFRP has low heat resistance, which restricts its use in areas with a high risk of fire [12].

Basalt Fiber Reinforced Polymers (BFRP). Despite being environmentally safe and possessing excellent mechanical properties, BFRP also encounters some challenges in construction. Most notably, the BFRP industry is not yet fully developed, and production technologies and standards are still emerging. This complicates the design and quality control processes in structural applications. While BFRP offers better heat resistance than GFRP, it is still not fully fire-resistant. Moreover, the surface characteristics of basalt fibers require strong adhesion with the matrix; otherwise, the bonding quality may degrade [13].

Conclusion

Carbon (CFRP), glass (GFRP), and basalt (BFRP) fiber-reinforced composite materials are proving to be effective alternatives to traditional building materials in modern construction technologies. Their high strength, corrosion resistance, lightweight nature, and ease of application make them widely applicable for strengthening existing structures, enhancing seismic performance, and constructing new buildings and infrastructure.

CFRP materials possess the highest mechanical properties and are especially important as structural reinforcements in load-bearing components and tall buildings. GFRP, due to its affordability and simplicity, is an optimal choice for lightweight structures or less heavily loaded elements. BFRP, on the other hand, stands out for its environmental friendliness and better thermal stability, making it a promising option for use in harsh environments.

Proper selection of these materials during the design process, correct determination of their bonding methods to structures, and in-depth analysis of their behavior under various climatic and loading conditions can significantly improve the overall performance of buildings and structures—such as strength, durability, seismic resilience, and long service life.

Therefore, the strategic use of CFRP, GFRP, and BFRP composites in construction, along with the rational application of their technological and economic potential, serves as a key factor in ensuring sustainable, cost-effective, and safe development in modern construction.

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