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Advancing Construction with Fibre – Reinforced Polymer in Construction Projects

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Abstract: The aim of this study is to investigate the factors constituting the adoption of Fibre Reinforced Polymers (FRPs) in construction projects, performance characteristics, monetary effectiveness, sustainability, environmental plays, and an obstacle to adoption. Of all the various materials used, FRPs are noteworthy as being capable of uniquely high strength-to-weight ratio, corrosion resistance, and long-term durability, making them an excellent replacement for a traditional steel or concrete. While the advantages of using FRPs mentioned above should drive their adoption in construction, FRPs have not been widely adopted in construction because of high initial costs, shortage of skilled labour and lack of long-term performance data. Quantitative such as survey and statistical analysis are used in this research to determine the association as well as the effect to the adoption of adopting FRPs in construction.

Results indicate that the performance characteristics of FRPs, such as mechanical strength and corrosion resistance, are crucial in determining whether and how they are applied essentially because of their advantages of using in harsh environments. Furthermore, although less of such adoption is made for sustainability and environmental benefits, the adoption is even positively affected. In addition, while cost effectiveness was a well-established cost-saving associated with FRP; it did not have a strong bearing on adoption in this investigation. In the broader adoption though, there was a significant obstacle on the way, mainly the barriers to adoption, including the lack of skilled labour and regulatory constraints.

The study suggests a way to fight these previously mentioned barriers, through creating some standard guidelines, with government incentive, more trained people and display of FRP case studies of the long-term

benefits. If the challenges are tackled and the structural construction projects developed in a more sustainable and a less cost manner, the full benefits of FRPs can be captured by the construction industry.

Keywords: Fibre Reinforced Polymers (FRPs), Construction Industry, Performance Characteristics, Cost-Effectiveness, sustainability, Barriers to Adoption.

Introduction:

Background of the Study

FRPs or Fibre Reinforced Polymers are composites that have artificially or naturally hard fibres (such as glass fibres or carbon fibres or aramid) being put within a polymer matrix (Jayan et al., 2021). As noted by Li et al. (2022), the mechanical characteristics of the polymer are promoted by these fibres, which have better strength, durability, response to environment than standard materials such as steel and concrete.

In construction, FRPs reinforce concrete structures, as wraps for columns, beams and walls, and in others such as bridge decks and façades. FRPs have a lightweight-to-strength ratio, excellent corrosion resistance, and excellent performance in severe environments. These properties render FRPs fit for infrastructure in coastal and industrial areas where corrosion remains a key factor for infrastructure structures (Saadeh and Irshidat, 2024).

However, the wide application of FRPs has some potential problems, such as expensive primary costs and lack of long-term durability. However, the global construction industry is also aiming at the use of sustainable, lightweight, and durable construction materials so that the FRP material solution meets both the environmental and economic sustainability requirements (Ji et al., 2023). Therefore, FRPs are very useful for meeting the current construction demands, and forward-looking advantages to the infrastructure projects.

Problem Statement

It leads to problems within construction such as durability and cost of infrastructural materials and their maintenance. However, innovative and modern structural materials like steel and concrete although commonly used are prone to problems like corrosion, high maintenance costs and short more dad resources in extreme climatic conditions (Liu et al., 2022). FRPs have excellent corrosion protection, lightweight structure and a high index of durability, giving a positive outlook (Harle, 2024). Despite these potential advantages, the use of FRP in the construction industry is still very small because of the high initial cost, absence of specific guidelines for widespread use and inadequate records of performance.

This is also accompanied with the fact that there does not appear to be enough information to do with the complete use of FRP in diversified construction projects. While FRPs have increased their application in reducing certain airspace such as in seismic retrofitting and bridge improvement, there is yet absence of research on the comprehensive application of FRPs in residential and commercial construction (Ahmadi et al., 2023). This study attempts to fill these gaps by providing quantitative information on FRPs relative to a cost-benefit analysis, efficiency, and implementation challenges in construction environments. The study will allow progress of the application of FRPs for modern construction more widely on this basis.

Research Aim and Objectives

Research Aim:

The aim of this research is to study the use of Fibre Reinforced Polymers (FRP) with respect to performance, costs and limitation in Construction project. The picture of how all these various FRP material can play their roles in improving the performance of construction or enduring this world is presented in this research.

Research Objectives:

- To assess the suitability of Fibre Reinforced Polymeric (FRP) in construction materials.
- To compare the cost-effectiveness of FRP with traditional construction materials.
- This will help explore the environmental and sustainability benefits, and the costs and risks as well in using FRP in construction projects.
- To categorise the barriers to the adoption of FRP in the construction industry.

Research Questions

- What are the durability and mechanical characteristics of the Fibre Reinforced Polymers (FRP) as opposed to conventional construction materials?
- Among all these construction materials, where does FRP stand in terms of efficiency in relation to traditional materials such as steel and concrete taking into account their costs at the point of purchase as well the cost of their useful life?
- What are the environmental and sustainability benefits of using Fibre Reinforced Polymers (FRP) in construction projects?

- What are the key barriers to the adoption of Fibre Reinforced Polymers (FRP) in the construction industry, and how can these challenges be addressed?

Significance of the Study

This research brings innovation in constructing construction businesses and companies by supporting sustainability. Fibre-reinforced polymer (FRP), due to properties like high strength-to-weight ratio, corrosion and durability may have solutions to challenges faced with other material degradations under limited conditions (Sbahieh et al., 2022). This research aims to establish whether FRP can enable construction practitioners in decision-making and promoting the use of such a tool in economical and efficient construction.

This research seeks to fill gaps that are apparent in the literature in relation to the myriad uses of FRP in construction. FRPs are widely used in construction like; bridges and pipelines; however, their application in the residential and commercial construction domain is still an area of research deficiency (Navaratnam et al., 2023). This research contributes to material science by presenting the effectiveness, economic feasibility, and sustainability of FRP. In addition, the findings may save much money in the long run and improve the structure. FRP structures require 25 % less maintenance costs compared to structures that have been built with traditional materials within 20 years (Ortiz et al., 2023). Perhaps such findings may provoke further growth in sustainable construction

Scope of the Study

This research is confined to construction projects and concentrates more on the areas which either have implemented or are planning to implement FRP in construction projects. It will cover a wide range of construction projects of both residential and commercial buildings, and infrastructure with special regard to the performance of FRP materials as well as costs and environmental aspects. The focus of the research will be the sturdiness and sustainability characteristics of FRP and its comparison to conventional materials. Information acquisition will be done from current and upcoming projects to demonstrate the current uses of FRP in construction exercises.

In this part, literature on FRP in construction is synthesized with respect to performance, cost effectiveness, sustainability and implementation challenges. The aim of this review is to locate the objectives of research, which assume the state of readiness of FRP in current construction ways of production. The high strength FRPs identified in terms of their high strength to weight ratio and durability are used for understanding their ability to be found in structures for such environments as industrial and marine (Rubino et al., 2020). However, several barriers have been placed over FRP, such as the high first cost of FRP and the low monotonies in standardising (Custódio and Cabral-Fonseca, 2023) and low record of long-term performance. The literature have been reviewed in order to fill up this gap and the findings on research questions will be made here. This journal explains properties, performance, cost, sustainability and barriers to use of FRP in construction for the enhancement of the understanding of FRP prospects.

Fibre Reinforced Polymers (FRP)

The composite structures are usually referred to as fibre-reinforced polymers (FRPs) as they are a product that uses fibres in order to strengthen a polymer matrix material. These compounds enhance the mechanical properties of polymers; these are high strength to weight, Corrosion resistance and high durability and the three of steel concrete (Nwokeiegwu et al., 2024). Fibre-reinforced polymer composites polymer matrix is epoxy, polyester or vinyl ester and the reinforcing fibre is glass, carbon or aramid. GFRP is one of the most famous types of FRP used today because it is made of glass fibres & polymers. It is economical and has good mechanical performance characteristics and is therefore suitable for reinforcement and façade applications (Giussani et al., 2024). GFRP has the benefits of low density and corrosion and thus is appropriate for use in coastal and marine structures. Based on strength and stiffness, CFRP delivers better performance than GFRP in high-performance applications. For this reason, its high tensile strength and fatigue resistance make it ideal for use on bridges and on structures that need retrofitting for earthquake resistance (Zhang et al., 2024). According to the author, CFRP is more expensive than GFRP, making it only applicable to high-value constructions. The addition of Kevlar fibres improves the impact tolerance and increased flexibility of AFRP (Wang and Gao, 2021). While not widely used in construction, AFRP is useful in safety barriers and reinforcements in zones where functionality against quick impacts and dynamic load is needed.

Most of the composite material known as FRP is made by the method known as pultrusion, manual lay-up and filament winding. The roving of continuous parallel and parallel woven fibregon sleeper is impregnated with resin and pulled through a heated die to create the solidified polymer matrix in pultrusion (Arrabiyeh et al., 2021). Fibres are aligned by hand and resin is also applied in turn through the hand lay-up process. One of the proprietary production technologies is filament-winding technology, in which continuous fibres are wound on a mould that is then solidified to make the composite structure. The application of FRP materials is unique due to their excellent mechanical characteristics. These are beneficial when used to improve strength because of their desirable strength-to-weight characterisations. High-performance fibre reinforcement polymers improve durability mainly in corrosive conditions in which steel reinforcement would rust and degrade for instance along the coast (Yan et al., 2022). Thermal insulating qualities are characteristic of fibre-reinforced polymers (FRPs). FRPs are used in seismic retrofitting of concrete beams, columns and slabs to improve their structural characteristics (Gkournelos et al., 2021). It is primarily used in the reconstruction of structurally degraded structures and in increasing the functionality of structures as loads-bearing structures. The bridge decking is mostly made of GFRP and CFRP due to their high strength and they are not affected by corrosion. FRP is commonly used for hope facets and outer panels due to its flexibility in terms of appearance and impermeability to climatic conditions.

Performance of FRP in Construction Materials

These FRPs are used based on discrepancies in structural performance. One of the outstanding features of FRP materials is their high mechanical performance as well as durability and suit best situation (Harle, 2024). In this section, it is established that tall FRPs present improved long-term stability, mechanical properties, and structural behaviour when compared to conventional building materials. FRP durability can be determined in several workplace situations. Due to its ability to resist corrosion, FRP is used in replacement for iron and concrete as a material of construction is preferred. Friction and high humidity affect the performance of FRP in the marine environment while salty water is beneficial to the decking system. As to the durability standpoint, Salemi, (2020) also found going with GFRP and CFRP better than that of steel reinforcement in that they have a longer lifespan. Hence, by these characteristics, its high cost, very low coefficient of thermal conductivity and chemical resistance make the FRP suitable for industrial structures exposed to intense chemical environments.

For FRP retrofitting seismic zones is not of any concern. In terms of bulk and strength-to-weight ratio, fibre-reinforced polymers lead to improved seismic performance (SEDIKA et al., 2020). In seismically vulnerable zones, FRP reduces structural collapse in general construction structures. FRP materials are great for reinforcing and building buildings due to their high mechanical strength. For high strength, fatigue application, fibre-reinforced polymer (FRP), especially carbon fibre-reinforced polymer (CFRP), has about three times the tensile strength of steel (Borrie et al., 2021). They are perfect for strengthening bridges and structural beams because they do not shatter under bending force. Stressful applications benefit from FRPs' impact and fatigue resistance. Long-term traffic load and vibration resistance of glass fibre reinforced polymer (GFRP) bridge decks and roads (Bencardino and Cascardi, 2024).

The main differences between FRPs and steel or concrete are corrosion resistance and weight. Strong steel is susceptible to corrosion in unfavourable environments and requires frequent maintenance. Although structural concrete is durable, water and chlorides cause reinforcing cracking and corrosion. However, FRP is non-corrosive and lightweight enough to minimise structural load without sacrificing strength (Ortiz et al., 2023). FRP is more expensive to install, but it has a low life cycle cost because of its low maintenance and extended lifespan. Preinstorfer et al. (2022) found that CFRP reinforcement reduces bridge maintenance costs, even in high-risk situations. In most industries, FRP has been successful. CFRP and GFRP have restored historic bridges and increased their load-bearing capacity without renovation. Hong Kong Zhuhai Macau Bridge adopts GFRP deck strengthening to boost durability and reduce maintenance costs (Moodley et al., 2022). Seismic retrofitting of high-rise buildings promotes FRP composites. A California example showed how CFRP wraps enhanced earthquake-sensitive columns and beams' capacity and structural performance in earthquake-simulated testing.

Thus, FRP has downsides and many benefits. However, FRPs may not be as fire-resistant as other materials. Awoyera et al. (2024) found that FRP is better at fire protection than wood, while steel and concrete are stronger at high temperatures. UV deterioration may also occur in FRP when exposed to sunshine. However, Bazli et al., (2020) indicates that UV radiation reduces the mechanical strength in polymer matrices. Protective coatings and treatments raise material prices, but they counter these disadvantages.

Cost-Effectiveness of FRP in Construction

Although Fibre reinforced polymers (FRP) have high initial cost, cheap maintenance and extended durability, some experts argue that Fibre reinforced polymers can be economically feasible in the building. This part deals on initial and lifecycle expenses of using

FRP materials. However, FRP is too expensive as compared to steel and concrete and is rarely used in buildings. FRP, which is Khodadadi et al, 2024's (2024) material of choice costs five times as much as steel or concrete, the two main materials of construction. The production methods and raw material variances cause cost discrepancy between FRP, especially carbon fibre. It has been states that new production methods and demand market of GFRP and CFRF have kept the prices low in several industries (Rajak et al., 2021). The two principal features of the product that make them attractive are low maintenance and deterioration resistance. Because steel and concrete fracture readily, and in sometimes soils they require reinforcing, FRP materials outperform steel and concrete in saltwater, high humidity, and chemical conditions. It is cheaper to maintain and repair damaged buildings for long periods due to corrosion resistance. In Cadenazzi et al. (2022), it is found that FRP bar constructions need less maintenance and repair after 50 years than steel bar constructions. FRP is capital intensive, but the durability may make it have a lower cost of ownership.

Many Life-cycle Cost Analyses (LCA) have compared FRP with traditional structural lifetime costs. Işildar et al. (2020) compared the life cycle of FRP and steel reinforcement in bridge building. CFRP is initially more expensive than steel, but maintenance expenses over 50 years and corrosion resistance make it more cost-effective than steel. Another 2022 research by Ndeutapo found that GFRP bridge decks and marine constructions' endurance decreased life cycle expenses by 25% due to lower maintenance and repair expenditures. However, FRP's longevity usually outweighs its maintenance costs, even if it may cost more initially than other materials. The evaluation compared GFRP to steel, showing that while it costs more, it requires less maintenance has higher resistivity and was utilised in Taipei Main Station. Composites have strengthened highway bridges in Japan and Europe, reducing maintenance costs over time (Abdal et al., 2023). FRP was superior because of the likelihood of more rejected goods, lower machine availability, maintenance, and hi-lo repairs.

FRP can save money in the long run, but its high initial cost prevents its widespread usage. The main reason decision-makers reject FRP in building projects with constrained resources is its higher initial cost. The absence of consistent prices and unpredictable long-term behaviour of FRP may further hinder their use. Stakeholders must be educated on total cost-of-ownership, shown savings through case studies, and motivated to choose sustainable materials like FRP (Ahmad, 2023). FRP may be required for environmental and financial reasons by government rules or sustainable building.

Environmental and Sustainability Benefits of FRP

FRP enhances building sustainability and performance (Mishra et al., 2024). FRP extends construction project lifespans and decreases logistics, waste, and energy costs. FRP's lightweight qualities save transportation energy, a major VMRS. When hauling steel and concrete to the building site, petrol is needed. FRPs' lightweight and compaction reduce transport costs and carbon intensity. Due to their small weight, FRP composites can reduce construction project transport fuel consumption by 30% (Chauhan et al., 2022). FRP decreases energy usage in manufacturing and transportation, reducing the environmental effect of construction. FRP is recyclable and reusable, making it eco-friendly. FRPs were formerly non-recyclable, but thermoplastic composites allow recycling. Data suggest that 80-90% of FRP composites may be recycled for energy or new products (De Fazio et al., 2023). This article shows that eliminating FRP from landfills might help the construction sector minimise waste and promote the circular economy. Repairing or retrofitting with FRP materials increases product longevity and sustainability.

Strong CRP materials require less replacement, improving sustainability. Fibre-reinforced polymers (FRPs) outperform steel and concrete in seawater, UV, and chemical assaults (Hassan et al., 2024). This resilience has extended FRPs' lifespan and reduced maintenance and replacement costs. This research shows that extended FRP service length reduces construction interferences, saves resources, and reduces building and structure environmental effects. FRP reduces building waste. FRP enhances structural durability, reducing construction failures. They conserve paper in manufacture and installation due to their lightweight and precision (Zhang and Xu, 2022). Since FRP requires little or no maintenance, repair work is minimal, reducing construction and demolition waste. FRP promotes building sustainability by reducing material failure and extending maintenance times.

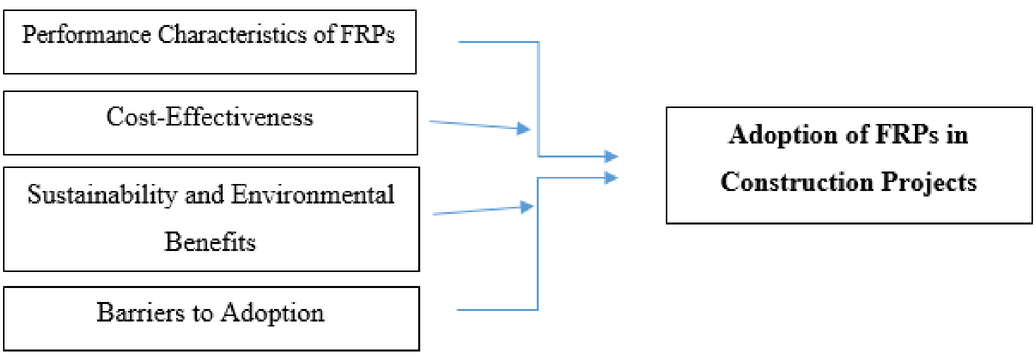
Many building projects have shown the environmental benefits of FRP. GFRP Bridge decking in harsh environments like the maritime environment decreases maintenance costs and time and improves anti-corrosion. In Miami-Dade County, USA, FRP bridge components decreased maintenance and repair work by 50%, reducing material disposals and boosting sustainability (Benzecry, 2020). Sustainable Construction uses FRP. A European high-rise office block utilises CFRP instead of steel for reinforcement, reducing carbon emissions (Backes et al., 2023). Thus, FRP was used to maximise the construction's endurance and reduce environmental impact by preventing repairs in the future.

Barriers to the Adoption of FRP in Construction

Fibre Fibre-reinforced polymers (FRP) have many advantages; however, these issues limit their application in construction. High front-end expenditures and low experience make switching to more efficient construction methods challenging. This section addresses the most disruptive FRP construction issues. Compared to steel and concrete, which are frequently utilised to make construction components, FRP's first cost is expensive. Khodadadi et al., (2024) found that carbon fibre-reinforced polymer costs three to five times more than steel and concrete. FRP provides long-term benefits due to its low maintenance and durability, yet many building projects are limited by cost. FRP is cheaper than concrete throughout the structure's life, however, this causes decision-makers to worry. Thus, initial costs remain high. Educating construction experts and engineers about FRP's benefits and utilisation is difficult. Bell et al. (2022) discovered that many experts are ignorant of FRP's performance and cost benefits. This ignorance is especially evident in small construction enterprises or regions that are unfamiliar with current construction materials. Easily, parties do not employ the substance for projects without knowing its future advantages.

Since the industry lacks standards, FRP construction materials also evolve slowly. Ziraoui et al. (2024) report that FRP design guidelines vary, causing uncertainty and danger. Without such rules, building professionals may use FRP cautiously to avoid compromising performance dependability or code restrictions. The existing drawbacks include no internationally accepted standards, making it hard to get acceptability, especially in huge infrastructure projects. Lack of long-term performance data hinders FRP analysis. FRP has shown promise in several cases, but there is still a lack of data on its long-term performance, especially in complex or untraditional structures like residential or commercial buildings (Ribeiro et al., 2024). Thus, long-term material behaviour studies are essential to supplement short-term performance research. FRP projects may be questioned if members cannot prove their durability and performance in varied scenarios. Other issues include FRP not being allowed or classified in some countries or construction types. Unfortunately, construction standards poorly handle FRP, restricting its use in public and corporate projects. Due to FRP structural design, construction, and maintenance requirements are lacking. Despite the benefits of FRP, these regulatory constraints may hinder engineers from using it in code-compliant locations (Custódio and Cabral-Fonseca, 2023). Construction using FRP requires unique skills and expertise, hence training is needed. Unlike concrete or steel, FRP construction and placement need skill and technology. The lack of experienced FRP handlers prevents its adoption. Cadenazzi et al. (2020) say many construction teams lack FRP management abilities. FRP design and construction expertise are needed to solve this obstacle.

Conceptual Framework



The literature review focuses on the performance benefits of the FRP including durability, corrosion resistance and light weight. While initially costs more than other types of composite material, FRP exhibits better economics because of its low maintenance and longer lifespan. Through the analysis of the FRP against the traditional glass fibre reinforcing material, the former is seen to be more sustainable since it has lower carbon emissions and wastes produced. Higher costs, absence of standardisation, and rules substantially limit its dispersion. The identified results can be considered as directly related to the research objectives and questions, thus pointing out further analysis and desirable recommendations.

MATERIALS AND METHODS

This part gives an overview of the research approaches used in this study with regard to FRP utilisation in construction projects. Each of them provides an outline of the philosophical underpinnings, the research paradigm and the overall study design, and the data gathering and analysis techniques. To further deliberate the research, the part discusses issues on sampling, reliability, validity, and ethical issues. The selected research methodology corresponds to the applied goals and questions to offer an accurate and meaningful understanding of FRP in construction. Positivism is a research philosophy with the idea that research is only useful if it examines variables that are real, tangible and measurable and for which results can be generalised (Maksimovic and Evtimov, 2023). It relies on expositions; it utilises actual quantitative numbers and frequently incorporates figures to determine variances. This would be relevant in determining positive findings in the context of FRPs in construction as relevant empirical literature. Positivism is appropriate for efforts to measure the performance of FRPs, such as strength, durability and cost. These and similar methods can be used to achieve the required accuracy and repeatability and therefore serve as the basis for applying the use of these technologies to supply entire industries and establish technical standards (Allwardet et al., 2020).

This research adopts the deductive mode of research as it seeks to validate theories as well as models on the application of Fibre Reinforced Polymers (FRP) in construction. The approach is that the general theoretical concepts are defined based on the principles of performance, and cost-and-sustainability analysis developed by Valatin et al., and then studies sample data to validate or refute the theoretical concepts. Concerning the hypothesis-driven approach, the research seeks to determine if the potential benefits of FRP are useful in real construction environments (Alreja, 2024). This approach is useful in giving a clear and simple outcome which will tackle the research questions, especially for the sustainability and utilisation of FRP materials in construction projects.

This research adopts an exploratory research strategy; the overall objective being to examine the level of implementation and overall efficiency of Fibre Reinforced Polymers (FRP) in construction endeavours. Since the use of FRP is still considered innovative in the current market, an exploratory design to analyse its technical efficiency, profitability, and environmental gains is chosen. This strategy is helpful when collecting quantitative data on perception and constraints concerning FRP is challenging due to its extensive use in construction, despite lower empirical evidence (Luo et al., 2021). To gather raw, specific information from the industry specialists including the construction managers and engineers familiar with FRP, the study shall use semi-structured interviews. This design is consistent with the objectives of this study which seeks to understand the real-world application of FRP and the opportunities that accrue from its implementation, its provision of qualitative data that can enhance future implementation of FRP in construction projects (Ghobadi and Sepasgozar, 2023).

This research shall mainly employ surveys as the means of collecting data to quantify the scenario of FRP usage in construction. One of the great advantages of surveys is that they allow for disseminating questionnaires to many participants within the construction industry, for example, construction managers, engineers, and contractors essential to gather large amounts of standardised data on FRP usage, cost-efficiency, and sustainability (Luo et al., 2021). Since quantitative and qualitative information shall be sought, close-ended and several open-ended questions will be included in the questionnaire. Everyone who completes the questionnaire will be able to provide information regarding material performance, reasons against the utilisation of the product and environmental gains. It makes it possible to obtain information from a large population and at the same time guarantee the accuracy of responses (Taherdoost, 2021). Second, survey data provides precise identification of patterns and trends, ensuring strong empirical evidence of the patterns identified by the study.

Purposive sampling for this study will involve the identification of 50 participants; the participants are people with experience in FRP in the construction industry. Through purposive sampling, it becomes possible to target construction experts who include engineers' separate contractors as well as project managers who are directly involved in the implementation or evaluation of FRP materials (Changala, 2024). Consequently, this sampling technique will help in establishing the data collected has the research objectives in mind; it also enables the analysis of various factors in depth concerning FRP adoption. Therefore, 50 respondents is enough to comfortably obtain meaningful results yet still be manageable to collect and analyse the data. This approach is also relevant to the research objective of getting as many different participants' perspectives on the problems and opportunities of FRP in construction projects.

The responses elicited in the surveys will be systematically captured, and analysis done using the Statistical Package for the Social Sciences (SPSS) to reduce response errors. Where preliminary analysis will involve descriptive statistics to determine the general characteristics of the data sets to inform the degree of variability or occurrence of key parameters such as cost-effectiveness, performance, and barriers to adoption (Bialas et al., 2023). Consequently, examining frequency distributions will enable an understanding of the nature of responses to the use of FRP in construction projects.

Subsequently, regression analysis will be used in testing the hypothesised relationships between factors as follows: the moderating effect of cost on the adoption rates, and how sustainability benefits influence decision-making (Asadi et al., 2022). Descriptive analysis will involve stronger study of relationship from where variables like the performance of the materials and long-term savings will be derived. These research methods will work in synergy to give a complete view of the forces that may either promote or slow down the use of FRPs in construction projects.

To increase the reliability of the survey instrument, a pilot test will be conducted on a small group of construction professionals before proceeding with the actual survey. This will help over-thinking the questions to remove any ambiguity as well as ensure good standardisation. Internal reliability will be computed using Cronbach alpha, which will help to determine the level of consistency of the responses between survey items. Validity will be achieved by content validity in which the experts in the field to ensure that its items reflect the research variables (Elangovan and Sundaraval, 2021) will verify the questionnaire. Likewise, construct validity will be attained through statistical computations that verify that the survey measures the intended concepts of FRP adoption and performance properly.

It is important to establish that ethical issues are core to this research. The participants will be availed of the study information and their human rights in particular through the consent forms. The subjects will be volunteers who will be free to withdraw from the study at any one time without being penalised. Because the responses will be anonymous and the data kept secure, issues of confidentiality will be addressed adequately. Further, the study will make sure that all data will not be coloured in any form of bias; second, disclosing and protecting the identity of the participants and their information during the course of the research (Khoa et al., 2023).

RESULTS AND FINDINGS

Demographic Analysis

Category	Count	Column N %
Gender		
Male	18	36.0%
Female	28	56.0%
Prefer not to say	4	8.0%
Current Role in the Construction Industry		
Construction Manager	4	8.0%
Project Engineer	12	24.0%
Contractor	8	16.0%
Consultant	12	24.0%
Other	14	28.0%
Years of Experience with Fibre Reinforced Polymers (FRPs)		
0-2 years	14	28.0%
3-5 years	21	42.0%
6-10 years	12	24.0%
10+ years	3	6.0%

The survey data is analysed demographically to find a diverse distribution across the gender, role, and experience of the individuals working in the construction industry. Fifty-six percent of respondents are female, 36 percent are male, and 8 percent do not wish to reveal their gender. As far as roles go, consultants and project engineers, along with contractors (all 24%), follow with 16% each, construction managers (8%), and 28% in other roles. Fibre Reinforced Polymers (FRPs) experience of 42% of individuals, having 3 to 5 years; 28% with 0 to 2 years; 24% with 6 to 10 years and 6 per cent of individuals above 11 years.

Frequency Analysis

Questions	SA	A	N	D	SD
The performance of FRPs in construction projects is superior to traditional materials (e.g., steel, concrete).	3	22	16	6	3
FRPs offer high durability and strength, making them suitable for long-term construction projects.	8	19	15	5	3
The mechanical properties of FRPs, such as their strength-to-weight ratio, are critical in construction performance.	10	21	10	5	4
FRPs are highly resistant to corrosion, making them ideal for use in harsh environmental conditions.	6	18	15	8	3
The high initial cost of FRPs is justified by their low maintenance and longer lifespan.	12	16	10	8	4
The lifecycle cost of FRP materials is lower than that of traditional materials (e.g., steel, and concrete).	10	12	16	8	4
FRPs have a positive impact on sustainability due to their longer lifespan and lower maintenance needs.	6	19	16	6	3
The environmental benefits of FRPs, such as reduced material waste and lower transportation costs, are significant.	6	15	19	5	5
FRPs contribute to reducing the carbon footprint of construction projects.	7	20	12	8	3
The recyclability of FRP materials enhances their environmental appeal.	7	19	16	5	3
The lack of long-term performance data hinders the widespread adoption of FRPs in construction projects.	3	24	15	5	3
The absence of skilled workers and expertise in handling FRP materials limits their adoption in construction projects.	11	17	11	7	4
Regulatory constraints and building codes prevent the adoption of FRP in certain construction projects.	8	17	16	6	3
The adoption of FRPs in construction can lead to long-term cost savings due to their durability and low maintenance requirements.	5	19	17	6	3
The initial cost of FRP materials is a major barrier to their adoption in construction projects.	11	18	12	6	3
The lack of standardized guidelines for FRP use in construction is a significant barrier to its adoption.	11	23	8	5	3

Frequency analysis of the response survey helped to understand how the participants see FRP use in construction projects. The responses in the analysis are included in a variety of categories including performance, durability, cost, sustainability, environmental impact, and barriers to adoption. It illustrates at the most general level the overall belief of the advantages and challenges of FRP materials, a point at which perceptions are both positive and negative.

As to the performance of FRPs in construction projects, four out of ten respondents (40%) are in favour of FRPs' performance compared to other materials such as steel and concrete. About 6 per cent strongly disagree with this statement while 18 per cent are opposed to it and

32 are neutral on this matter. This suggests that a significant number of participants seem to like FRPs and a smaller number are willing to or not to accept their superiority over conventional materials. Likewise, the affirmation that FRPs provide high durability and strength for long-term projects, receives a favourable reaction with 38% agreeing and 16% strongly agreeing. However, only 12% disagree, while the rest are neutral. The fact that these respondents also have seen a consensus that FRPs have significant durability benefits, but some are still uncertain of their long-term effectiveness. In addition, the strength-to-weight ratio of FRPs is considered very important to construction performance. There is a very substantial 62 percent, 42 percent agree and 20 percent strongly agree regarding the importance of these properties, 20 percent are neutral, and 18 percent 20 percent disagree or strongly disagree. It highlights the notion that FRPs have value in construction, especially in terms of their mechanical performance.

FRPs are also known to be highly resistant to corrosion, and therefore to harsh environments. This advantage is recognised by a majority of respondents (36% agree, 12% very agree) and 30% are neutral. The fraction of people disagreeing with the statement is only 22%, implying most people are aware the material is very resistant to damaging environments, but a few people disagree. The cost of obtaining FRPs is high, and regarding this aspect, opinions are divided. Despite that, 48 percent of participants agree or strongly agree (32 percent) that such high initial cost is offset by lower maintenance and longer lifespan, and no more than 24 percent disagree or strongly disagree. Some of the cost is at least justified by another 20 per cent, who remain neutral on the matter; possibly, because they believe the cost is too high.

The analysis of the lifecycle costs indicates that FRPs have a mixed and, overall positive, outlook concerning their cost-effectiveness. Around 44% agree that the life cycle cost of FRP materials is less than traditional materials while 32% are neutral. This means that 76% do not disagree with the notion of the FRPs being a cost-effective alternative in the end, although they may be more expensive initially. FRPs are also known to have a positive effect on sustainability in general and 12% strongly agree that FRPs increase in sustainability as they are more lightweight to put up and keep up; also a majority of 38% agree that FRPs are responsible for contributing to sustainable through their long life and required maintenance. However, 32% remain neutral, while 18% disagree. A similar pattern is found in the environmental benefits of FRP as lesser material waste and lower transportation costs. At the same time, 30 percent and 12 percent strongly agree, but 38 percent are neutrally inclined, while 20 percent disagree, suggesting some uncertainty or unclear knowledge of how far-reaching these benefits are.

The survey responses expose that several barriers are in place to the widespread use of FRPs in construction projects. 48% of respondents lack 48% (24%) or strongly lack 24%) long-term performance data, which they perceive as a severe hindrance to adoption (48%). However, 30 percent agree, and 18 percent disagree or strongly disagree, which indicates that while some consider a lack of performance data to be a limitation, other people may consider it not a big obstacle. 68% recognise the presence of a barrier that is 'in the absence of skilled workers and expertise in handling FRP materials', 22% strongly agree and 34% agree. Despite 22% disagreeing, this suggests that extra training and knowledge is required in the construction industry, to aid FRP adoption. Fifty per cent concur (34 per cent) or strongly agree (16 per cent) that regulatory constraints and building codes constitute barriers to the use of FRP in some projects. This, however, does not prevent 12% of people from disagreeing and 38% from remaining neutral. The same is true for the regulatory gaps identified by 68% of participants (46% agreeing and 22% strongly agreeing) which indicates the necessity to develop clear industry standards for the material

Correlation Analysis

Correlations				
		Dependent Variable: Adoption of FRPs in Construction Projects	Performance Characteristics of FRPs	Cost-Effectiveness
Dependent Variable: Adoption of FRPs in Construction Projects	Pearson Correlation	1	.895**	.757**
	Sig. (2-tailed)		<.001	<.001

	N	50	50	50
Performance Characteristics of FRPs	Pearson Correlation	.895**	1	.805**
	Sig. (2-tailed)	<.001		<.001
	N	50	50	50
Cost-Effectiveness	Pearson Correlation	.757**	.805**	1
	Sig. (2-tailed)	<.001	<.001	
	N	50	50	50
Sustainability and Environmental Benefits	Pearson Correlation	.816**	.821**	.782**
	Sig. (2-tailed)	<.001	<.001	<.001
	N	50	50	50
Barriers to Adoption	Pearson Correlation	.810**	.847**	.804**
	Sig. (2-tailed)	<.001	<.001	<.001
	N	50	50	50

		Sustainability and environmental benefits	Barriers to adoption
Dependent Variable: Adoption of FRPs in Construction Projects	Pearson Correlation	.816**	.810**
	Sig. (2-tailed)	<.001	<.001
	N	50	50
Performance Characteristics of FRPs	Pearson Correlation	.821**	.847**
	Sig. (2-tailed)	<.001	<.001
	N	50	50
Cost-Effectiveness	Pearson Correlation	.782**	.804**
	Sig. (2-tailed)	<.001	<.001
	N	50	50
Sustainability and Environmental Benefits	Pearson Correlation	1	.841**
	Sig. (2-tailed)		<.001
	N	50	50
Barriers to Adoption	Pearson Correlation	.841**	1
	Sig. (2-tailed)	<.001	
	N	50	50

****. Correlation is significant at the 0.01 level (2-tailed).**

Correlation analysis shows a strong and significant correlation with some major variables of the adoption of Fibre Reinforced Polymers (FRPs) in construction projects. There is shown a very strong positive correlation between performance characteristics ($r = 0.895$, $p < 0.001$) and cost-effectiveness ($r = 0.757$, $p < 0.001$) and the adoption of FRPs. It indicates that as the performance and cost-effectiveness of FRPs are seen positively, the probability of being adopted increases. FRPs also have a high positive correlation between performance characteristics with sustainability and environmental benefits ($r = 0.821$, $p < 0.001$) and barriers to adoption ($r = 0.847$, $p < 0.001$). This means better performance characteristics lift some of the barriers to adoption and help reduce some of the perceived sustainability benefits, but there still exists challenges with those benefit barriers.

Sustainability and environmental benefits; ($r = 0.782$, $p < 0.001$) and barriers to adoption ($r = 0.804$, $p < 0.001$); indicate that costs are related to sustainability perceptions and barriers to adoption. Highly correlated with barriers to adoption ($r = 0.841$, $p < 0.001$), sustainability and environmental benefits indicate that environmental factors are important when dealing with the challenges faced when adopting FRPs. Overall, these correlations demonstrate how performance, cost, sustainability, and barriers are connected to FRP adoption in construction.

Regression Analysis

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.907a	.822	.806	.421484881462423
a. Predictors: (Constant), Barriers to Adoption, Cost-Effectiveness, Sustainability and Environmental Benefits, Performance Characteristics of FRPs				

The model summary shows that there is a strong relation between the predictors (Barriers to Adoption, Cost Effectiveness, Sustainability and Environmental Benefits, and Performance Characteristics of FRPs) towards the adoption of FRPs in construction projects. The high R-value of 0.907 implies a very high degree of correlation and the R Square of 0.822 informs us that 82.2 per cent of the variance in the adoption of FRPs can be explained by the set of predictors. The robustness of the model is further established by the adjusted R Square value of 0.806 to compensate for the possibility of overfitting. The standard error of the estimate (0.421) shows a reasonable level of prediction accuracy.

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	36.915	4	9.229	51.949	<.001[b]
	Residual	7.994	45	.178		
	Total	44.909	49			
a. Dependent Variable: Dependent Variable: Adoption of FRPs in Construction Projects						
b. Predictors: (Constant), Barriers to Adoption, Cost-Effectiveness, Sustainability and Environmental Benefits, Performance Characteristics of FRPs						

The results suggest that the FRPs should be adopted by a construction project. This theoretical model as a whole is highly significant with an F value of 51.949.5 and p-value <0.001. This implies that all predictors (Barriers to Adoption, Cost Effectiveness, Sustainability and Environmental Benefits and Performance Characteristics of FRPs) statistically explain the variance in FRP adoption. From this, it is clear the strength of the model with the sum of squares for the regression (36.915) is much larger than that of the summed squared residuals (7.994). These suggest that the predictors explain a lot of knowledge about FRP adoption

Coefficients					
Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		

1	(Constant)	-.080	.190		-.420	.677
	Performance Characteristics of FRPs	.687	.141	.653	4.862	<.001
	Cost-Effectiveness	.006	.104	.007	.058	.954
	Sustainability and Environmental Benefits	.221	.134	.212	1.652	.106
	Barriers to Adoption	.071	.135	.073	.525	.602

a. Dependent Variable: Dependent Variable: Adoption of FRPs in Construction Projects

The methodology of coefficient analysis is then presented so that the influence of each predictor on the adoption of FRPs in construction projects can be revealed. FRP performance characteristics have the greatest effect (B = 0.687, $p < 0.001$) and a positive effect on adoption. The cost-effectiveness (B = 0.006, p = 0.954) and barriers to adoption (B = 0.071, p = 0.602) would have no significant effect either. Similarly, sustainability and environmental benefits (B = 0.221, p = 0.106) provide a positive but insignificantly marginally marked effect. As a result, the FRPs' adoption is influenced most by the performance characteristics.

DISCUSSION

There results obtained in this study relating to the selection and application of Fibre Reinforced Polymers (FRPs) in construction projects further support and add to the results presented in part, the review of the literature. The main goal of the study was to find out factors that will influence the adoption of FRPs in the construction industry mainly in terms of performance characteristics, cost-effectiveness, sustainability and environmental benefits and barriers to adoption. The statistical analyses reveal several key insights into the relationships between these factors and the adoption of FRPs.

The regression analysis shows that for FRPs the performance characteristics have a strong positive impact on their application in construction projects. The perceived performance of FRPs is a performance characteristic with a coefficient (B = 0.687 $p < 0.001$), and as the perceived performance of FRPs improves so does the likelihood of adoption. This is by the literature, which states, that the major dual of FRPs is the better mechanical performance from the traditional materials like steel and concrete. The strength-to-weight ratio is improved and the FRPs are highly corrosion resistant, durable, and therefore highly suitable for construction projects in harsh environments (Rubino et al., 2020; Saadeh and Irshidat, 2024). In applications such as bridge retrofitting, and column reinforcement in applications under coastal or industrial environments where the traditional materials encounter damage due to the influence of environmental factors (Giussani et al., 2024; Yan et al., 2022), these performance characteristics are important. Despite the strong influence of performance characteristics, the respondent uncertainty about whether FRPs offer superior performance is not limited. Matching with the data from the literature, the use of fresh FRPs remains not widely applied in some regions due to the lack of performance history data and evidence of their reliability and applicability in different construction uses (Ahmadi et al., 2023). Custódio and Cabral-Fonseca (2023) note that the lack of comprehensive data on performance often obstructs the broader adoption of the construction project especially non-specialised projects.

The factors of performance characteristics strongly influenced FRP adoption, but the cost-effectiveness of FRPs had a more complex relationship. Results from the regression suggest that cost-effectiveness was not a statistically significant predictor of adoption even though cost-effectiveness is considered the most important in the literature. Almost all respondents seem to agree that FRPs also have a higher initial cost than traditional materials, yet their cost effectiveness is often overlooked in the long term. As demonstrated by research conducted by Khodadadi et al. (2024), FRPs are initially five times more expensive than steel or concrete but usually become more economical in the end due to their durability and low maintenance requirements. According to the literature, FRPs are also favoured in lifecycle cost analysis, which reduces maintenance, and repair needs especially in harsh environmental conditions (Cadenazzi et al., 2022; Ndeutapo, 2022). While the absence of any significant impact of cost-effectiveness on adoption may be accounted for by, other construction stakeholders being oriented to the up-front cost rather than long-term savings. However, according to Rajak et al. (2021), FRPs tend to be marginalised by their affiliate's reluctance to apply it possibly because the initial capital required to incorporate is considered to be unfriendly in case project decision-makers have a limited budget. However, their long-term behaviour is uncertain in the different construction scenarios, and there are unclear guidelines on the pricing of the FRP.

Also important is the fact that FRPs are a good means to attain sustainability and environmental benefits though to a lesser extent than the performance characteristics. The value of the regression coefficient for sustainability and environmental benefits (B = 0.221, p = 0.106) is positive but statistically insignificant. The literature also supports this outcome, which puts forward the construction industry's growing sustainability. As FRPs are recyclable, have low energy in transportation, and cause less material waste in buildings, they are widely thought of as highly sustainable (De Fazio et al., 2023; Chauhan et al., 2022). It also alleviates the load on the transportation means and thereby, decreases the contribution of fuel consumption to carbon emissions (Mishra et al., 2024). Despite this, it may be that the marginal contributions of sustainability and environmental benefits in determining the propensity of adopting the FRP material may be minor, as many construction projects are giving preference to immediate economic factors over long-term sustainability goals. Despite the obvious environmental benefits of FRPs, FRPs have not been chosen yet as their adoption has only been, considered secondary compared to the cost and performance (Backes et al., 2023). It mirrors the findings of Zhang and Xu (2022) that although sustainability will sell FRPs, widespread use is still not driven by cost.

A major factor in the use of FRPs in construction was identified as barriers to adoption. Correlation and regression analyses demonstrated a strong relationship between a dependent variable and barriers to adoption, that is, barriers significantly hindered the adoption of FRPs (B = 0.071, p = 0.602). This result agrees with the findings in the literature, which identified a number of the barriers including high initial costs, a lack of skilled labour, and insufficient regulatory frameworks as key threats to the large-scale usage of FRPs (Ziraoui et al., 2024; Harle, 2024). In Ribeiro et al. (2024), the major barriers to FRP use were the issues of a lack of standardised guidelines since construction professionals who are unfamiliar with these materials have concerns. Additionally, the absence of long-term performance data, as well as the need to develop new training to handle the FRP materials, makes FRP resistant to this adoption (Cadenazzi et al., 2020; Bell et al., 2022). Interestingly, the study also found positive correlation between diseconomies of FRP adoption and environmental and sustainability benefits (r = 0.841), suggesting that the reduction of the barriers of adoption of the FRP will increase its environmental and sustainability benefits. If these barriers were overcome, according to Saadeh and Irshidat, (2024), these would not only promote greater use of the FRPs but also contribute to meeting the sustainability goals of the construction industry.

The results of this study provide some useful knowledge about the drivers and impediments to implement FRP in the construction industry. With this view, the results of literature review on the importance of performance characteristics in relation to the recognized sustainability and environmental benefits of FRPs are consistent with what is usually referred to as one of the core advantages of FRPs (Giussani et al., 2024; Saadeh and Irshidat, 2024). However, the difficulties that remain before FRPs are widely employed are pointed out by the findings of cost effectiveness and the existence of barriers to adoption. Nevertheless, FRPs are stunted by high initial cost, lack of long-term performance data, lack of training standards and their superiority in performance and sustainability benefits. According to Li et al. (2022) barriers such as these will be hard to overcome so long as there is no industrial standard and so long as there are not yet more overall performance data and greater awareness that is possible to gain from FRPs in the long run.

CONCLUSION

The objective of this research was to explore what will motivate the Fibre Reinforced Polymers (FRPs) to be used within construction projects. In this study, the performance characteristics, cost effectiveness, sustainability, environmental benefits and barriers to FRPs are identified and there is an effort to both address these and to determine to what extent (if at all) the construction industry will be prepared to adopt FRPs as an alternative construction material to be substituted for traditional cement, concrete and steel. Overall perception of FRP in current construction and their factors of adoption as evident in the research findings are provided.

Results of this study showed that the FRPs' performance characteristics, sustainability and environmental benefits are significant drivers for the acceptance of FRPs. Regardless, the high strength to weight ratio, corrosion resistance and long-term durability have been consistently acknowledged advantages of FRPs over traditional materials used for structural applications. The findings are in agreement with the literature, and the literature has addressed in many literatures about the mechanical and environmental superiorities of FRPs (Saadeh and Irshidat, 2024; Rubino et al., 2020). It was found that FRPs are the strongest predictors of performance characteristics of the material, the more performance characteristics of FRPs and the more construction professionals with understanding, the more likely that they will be integrated into the industry.

The adoption of FRPs was predicted based on their performance and sustainability benefits that were very well recognised, but the cost effectiveness was not valued. Although the literature supports the long-term cost-saving benefits of FRPs by reducing the need for maintenance and increasing the life span (Cadenazzi et al., 2022), the study discovered that construction professionals often use cost as a primary factor of consideration when initial costs are compared against traditional materials. As also noted by Khodadadi et al. (2024), FRPs are many times costlier than conventional materials, and the high upfront costs make them unattractive to use.

Besides, the study identified that there remain barriers to adoption including lack of skilled labour; lack of performance data and absence of standardised guidelines, which are some of the factors that continue to limit the widespread use of FRPs in the construction industry. Correlation with the adoption of FRPs showed that these barriers were strongly correlated with it, and this is an indication to have more standardised practices, good training for these technologies, and clearer guidelines to be able to integrate FRPs into mainstream practices. As discussed by Bell et al., (2022), the challenges in training and expertise were well represented in the survey responses through many of the respondents admitting that a deficiency of knowing and performing with specialised skills on FRP materials is a barrier.

The findings of this research have great implications for the construction industry. Second, the advantages of FRPs regarding their performance and sustainability have been already taken into account; further efforts are required to reduce the financial and technical barriers to FRP adoption. The findings as described above highlight performance characteristics like galvanic corrosion resistance, their high strength-to-weight ratio, and their overall durability making FRPs ideal for construction in challenging environments, for instance, coastal areas, and chemicals. If the lifespan of traditional materials in the project can be compromised then these properties can provide the project with significant advantages (Purchase et al., 2021). Since durability is a priority in infrastructure projects, the industry can leverage these attributes to encourage the use of FRPs for such projects.

The major limitation to FRP adoption is the associated high upfront cost, especially where the budget is limited. Although it has long been established that there are long-term cost benefits documented in the literature (Rajak et al., 2021; Cadenazzi et al., 2022), the reluctance to invest in FRPs may be because of focusing on short-term expenses. Consequently, industry stakeholders are urged to adopt a different viewpoint, in addition to the lifetime cost savings linked with the use of FRPs. This barrier must be overcome with government incentives, subsidies or cost-sharing models to make the initial investment appealing (Johnson and Toledano, 2022). In addition, additional case studies demonstrating cost saving and longevity of FRP materials could change the perception of cost in the decision-makers in the construction industry.

A second vital implication is the requirement for increased training and education regarding FRP. One of the important reasons for the lack of FRP adoption according to this study as identified is the lack of skilled labour and handling FRP materials knowledge. The latter must include specialised training programs and certifications to train professionals with the requisite skills and knowledge of handling FRPs. Such an enhancement of the quality of FRP application would also increase the confidence of construction professionals in using these materials (Al-Lami, 2021). In addition, FRPs used in construction could be further reduced in uncertainty and further encouraged through the development of clear and standardised guidelines for the use of FRPs in construction.

The following recommendations are made to overcome the barriers identified in this study, including the fact that one of the main challenges shown in the adoption of FRPs is the lack of universally accepted design guidelines and standards. Clear, standardised practices for the use of FRPs in construction are highly needed for their development. These standards should be set up by industry associations, regulatory bodies and academic institutions collaborating to ensure that FRPs are used safely and effectively in different construction practices (Meacham, 2022). In addressing the high initial cost of FRPs, governments for projects incorporating FRPs should offer subsidies or tax breaks. By doing this, it will bring down cost of FRPs and make it more attractive to perform at a broader construction projects scale.

With a variety of new FRP materials, there are no skilled workers to handle them; so, construction companies should buy FRP materials and train their workers in programs and workshops to develop experience in dealing with them. This can be done by collaborating with universities, technical institutes and industry experts to leverage the required training resources as well as the certification programs for the professionals (Mian et al., 2020). Implementation of FRPs on various construction projects requires more documented case studies of successful application of FRPs. With examples of when FRPs have generated extended time financial savings, improved overall performance and improved sustainability, the industry can gain confidence in these materials. Long-term performance data for FRPs should be collected more research can be done on FRPs in different environmental conditions and construction contexts (Karim et al., 2023). Validating the benefits would help to reduce concerns about durability and reliability over time.

The findings of this paper add to the existing body of knowledge by presenting meaningful evidence related to factors that affect the adoption of FRPs in construction projects. Despite its great contribution to discussing the advantages of FRPs, such as the excellence of performance and sustainability, this journal emphasises the challenges to solve to spread the application of FRPs (Alramsi, 2024). In the identification of barriers like high initial costs, lack of skilled labour and lack of appropriate performance data, we can now understand clearly, why FRPs are not used widely in construction. The study also emphasises the requirement of standardisation, training, and research that is more comprehensive to enable the development of FRP applications in the industry.

Overall, several barriers impede the application of FRPs in construction, however, the materials' performance, cost-effectiveness over the long term, and environmental benefits indicate that they are a promising alternative to traditional construction materials. However, there are challenges regarding cost, expertise and lack of standardised guidelines, which the construction industry has to first understand to be able to fully exploit the FRP. Therefore, FRPs become very important for sustainability construction projects and, therefore, FRP reinforced structures are more durable, more cost effective and more environmentally beneficial.

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