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RESEARCHARTICLE

FIBERGLASS IN CONSTRUCTION:KEY ASPECTS AND ADVANTAGES

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Abstract. *The study examines the application of fiberglass materials in modern construction with a focus on their structural, economic, and environmental advantages over traditional materials such as steel and polyvinyl chloride. The aim of the research is to systematize the properties of fiberglass and evaluate its effectiveness in improving the performance and sustainability of building structures. The research methodology is based on a comparative analysis of scientific literature, experimental data, and technical standards related to fiberglass composites. The study also incorporates an assessment of physical and mechanical characteristics, durability indicators, and life cycle cost analysis of fiberglass products in various operating conditions.The results demonstrate that fiberglass materials possess high tensile strength (up to 1000 MPa), low density (20–25% of steel weight), and high resistance to corrosion and aggressive environments. The use of fiberglass contributes to a reduction in operational costs by 20–40%, decreases maintenance expenses by up to 75%, and extends the service life of structures beyond 50 years. In addition, fiberglass improves energy efficiency due to low thermal conductivity and stable hydraulic performance. Environmental analysis shows a reduced carbon footprint in transportation and long-term эксплуатации, despite challenges related to recycling.The study concludes that fiberglass represents a перспективныйматериал for sustainable construction, combining durability, economic efficiency, and environmental adaptability. Its application contributes to the development of innovative engineering solutions and enhances the reliability of construction systems under various climatic and operational conditions.*

Keywords:*construction, fiberglass, resin, pipe, corrosion resistance, durability, building structures, deformations*

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ҒЫЛЫМИ МАҚАЛА

ҚҰРЫЛЫС САЛАСЫНДАҒЫ ШЫНЫТАЛШЫҚ: НЕГІЗГІ АСПЕКТІЛЕРІМЕН АРТЫҚШЫЛЫҚТАРЫ

Г.М. Абдукаликова[1], Л.А. Сиваченко[2], Э.М. Смагулова [1*], А.С. Мукашева[1], Г.А. Жаирбаева[1], Ж.Б. Конарбаева[1], Ш.Б. Толеубаева[1]

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Аңдатпа. *Бұл зерттеуде заманауи құрылыс саласында шынышталшық материалдарының қолданылуы қарастырылып, олардың болат және поливинилхлорид сияқты дәстүрлі материалдармен салыстырғандағы конструкциялық, экономикалық және экологиялық артықшылықтарына талдау жасалады. Зерттеудің мақсаты – шыныталшықтың қасиеттерін жүйелеу және оның құрылыс конструкцияларының тиімділігі мен тұрақтылығын арттырудағы рөлін бағалау.Зерттеу әдістемесі шыныталшық негізіндегі композиттік материалдарға қатысты ғылыми әдебиеттерді, эксперименттік деректерді және нормативтік құжаттарды салыстырмалы талдауға негізделген. Сонымен қатар, шыныталшық өнімдерінің физикалық-механикалық қасиеттері, беріктік көрсеткіштері және әртүрлі пайдалану жағдайларындағы өмірлік цикл құнына талдау жүргізілді. Зерттеу нәтижелері шыныталшық материалдарының жоғары созылу беріктігіне (1000 МПа дейін), төмен тығыздыққа (болат салмағының 20–25%-ы) және коррозия мен агрессивті ортаға жоғары төзімділікке ие екенін көрсетті. Шыныталшықты қолдану пайдалану шығындарын 20–40%-ға төмендетуге, техникалық қызмет көрсету шығындарын 75%-ға дейін азайтуға және конструкциялардың қызмет ету мерзімін 50 жылдан астам уақытқа ұзартуға мүмкіндік береді. Сонымен қатар, материал төмен жылу өткізгіштігі мен тұрақты гидравликалық сипаттамалары есебінен энергия тиімділігін арттырады. Экологиялық талдау тасымалдау және пайдалану кезеңдерінде көміртек ізінің азаюын көрсетеді, алайда қайта өңдеу мәселелері өзекті болып қала береді.Қорытындылай келе, шыныталшық тұрақты құрылыс үшін перспективалы материал болып табылады, себебі ол ұзақ мерзімділік, экономикалық тиімділік және экологиялық бейімділікті үйлестіреді. Оны қолдану инновациялық инженерлік шешімдерді дамытуға және әртүрлі климаттық және пайдалану жағдайларында құрылыс жүйелерінің сенімділігін арттыруға ықпал етеді.*

Түйін сөздер:*құрылыс, шыныталшық, шайыр, құбыр, коррозияға төзімділік, ұзақтұру, құрылыс конструкциялары, деформациялар*

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НАУЧНАЯ СТАТЬЯ

СТЕКЛОВОЛОКНО В СТРОИТЕЛЬСТВЕ:ОСНОВНЫЕ АСПЕКТЫ И ПРЕИМУЩЕСТВА

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Аннотация.*В работе рассматривается применение стекловолоконных материалов в современном строительстве с акцентом на их конструкционные, экономические и экологические преимущества по сравнению с традиционными материалами, такими как сталь и поливинилхлорид. Цель исследования заключается в систематизации свойств стекловолокна и оценке его эффективности для повышения эксплуатационных характеристик и устойчивости строительных конструкций.Методология исследования основана на сравнительном анализе научной литературы, экспериментальных данных и нормативно-технических документов, посвященных композитным материалам на основе стекловолокна. В работе также проведена оценка физико-механических характеристик, показателей долговечности и анализа стоимости жизненного цикла изделий из стекловолокна в различных условиях эксплуатации.Результаты исследования показывают, что стекловолоконные материалы обладают высокой прочностью на растяжение (до 1000 МПа), низкой плотностью (20–25% от массы стали) и высокой устойчивостью к коррозии и агрессивным средам. Применение стекловолокна позволяет снизить эксплуатационные затраты на 20–40%, сократить расходы на обслуживание до 75% и увеличить срок службы конструкций более чем до 50 лет. Кроме того, материал способствует повышению энергоэффективности за счет низкой теплопроводности и стабильных гидравлических характеристик. Экологический анализ показывает снижение углеродного следа при транспортировке и эксплуатации, несмотря на существующие проблемы переработки.В заключение установлено, что стекловолокно является перспективным материалом для устойчивого строительства, сочетая долговечность, экономическую эффективность и экологическую адаптивность. Его применение способствует развитию инновационных инженерных решений и повышению надежности строительных систем в различных климатических и эксплуатационных условиях.*

Ключевые слова:*строительство, стекловолокно, смола, труба, коррозийная устойчивость, долговечность, строительные конструкции, деформации*

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CONFLICT OF INTEREST

The authors state that there is no conflict of interest.

The authors declare that no generative artificial intelligence technologies or AI-based tools were used in the preparation of this article.

АЛҒЫС / ҚАРЖЫЛАНДЫРУ КӨЗІ

Зерттеужекеқаржыландырукөздерінпайдаланаотырыпжүргізілді.

МҮДДЕЛЕР ҚАҚТЫҒЫСЫ

Авторлар мүдделер қақтығысы жоқ деп мәлімдейді.

Авторлар мақаланы дайындау барысында генеративті жасанды интеллект технологиялары мен жасанды интеллектке негізделген технологияларды пайдаланбағанын мәлімдейді.

БЛАГОДАРНОСТИ/ИСТОЧНИК ФИНАНСИРОВАНИЯ

Исследование проводилось с использованием частных источников финансирования.

КОНФЛИКТ ИНТЕРЕСОВ

Авторы заявляют, что конфликта интересов нет.

Авторы заявляют о том, что при подготовке статьи не использовались технологии генеративного искусственного интеллекта и технологии, основанные на искусственном интеллекте.

1 INTRODUCTION

In this article, the authors analyze and systematize the main aspects of the use of fiberglass products in construction and demonstrate their advantages over traditional building materials. They consider the impact of fiberglass on the efficiency and sustainability of building structures.

The objectives set by the researchers are as follows:

- to study the properties and characteristics of fiberglass materials, their types and areas of application in construction.

- to analyze the advantages of fiberglass products compared to traditional building materials, including strength, lightness, corrosion resistance, and other performance characteristics.

- assessing the impact of fiberglass on the stability and reliability of building structures to determine what specific advantages it brings in terms of the durability and safety of facilities.

- researching examples of the use of fiberglass products in existing construction projects, highlighting successful cases and the results obtained.

Trends in modern construction are focused not only on solving problems related to the functionality of buildings and the use of innovative materials that improve the quality and durability of structures, but also on significantly reducing their cost. One solution to this issue has been the use of fiberglass products in construction, which are attracting growing interest in the scientific community (**Hollaway, 2019**).

Today, fiberglass products are increasingly used in construction due to their strength, lightness, and durability. In this context, fiberglass products deserve special attention. As a composite material, fiberglass has unique physical and mechanical properties, making it an ideal candidate for use in various construction applications. Following on from this fundamental research (**Pickering etal., 2016; Bank, 2006**), the authors focus on specific construction applications: the use of fiberglass reinforcement to strengthen concrete structures, the development of fiberglass insulation and cladding panels **(Islam etal., 2016; Nassif etal., 2024; Valery etal., 2018)**, and the creation of complex architectural elements **(Triantafillou, 2019**).Comparative analyses of the durability and corrosion resistance of fiberglass products compared to traditional metal products in aggressive environments are being conducted **(Robert&Benmokrane, 2013)**.

In this article, the authors analyze and systematize the main aspects of the use of fiberglass products in construction and demonstrate their advantages over traditional building materials. They examine the impact of fiberglass on the efficiency and sustainability of building structures.

The objectives set by the researchers are as follows:

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- assessing the impact of fiberglass on the stability and reliability of building structures to determine what specific advantages it brings in terms of durability and safety.

- exploring examples of the use of fiberglass products in existing construction projects, highlighting successful cases and results.

The application of glass fiber and glass fiber composites (fiberglass) in the construction industry is the subject of active scientific analysis, which is reflected in a significant number of publications. Contemporary scientific literature demonstrates a thorough examination of issues related to the use of glass fiber in construction. A theoretical basis for composite materials science has been formed, and a significant amount of experimental and calculated data on their behavior in structures has been accumulated. Current research is shifting towards solving practical problems of long-term operation, cost optimization, fire safety, and sustainable development, which indicates the transition of the technology from the category of innovative to proven and scientifically sound solutions for the modern construction industry.

The basis for its application is the unique physical and mechanical properties of glass fiber obtained by drawing it from a melt **(Li&Watson, 2019).**Research in this area focuses on the relationship between glass composition, fiber formation technology, and final strength characteristics. A more applied area of work is devoted to the properties of polymer composites, where glass fiber acts as reinforcing filler.As noted in Barbero's **(Barbero, 2017)**work, effective strengthening of the polymer matrix is achieved through an optimal combination of fiber type, orientation, and volume fraction.

An important area of research is the development and study of hybrid composites, in which glass fiber is combined with other fibers (e.g., carbon or basalt) to synergistically improve properties, as discussed in detail by Swolfsetal **(Yentletal., 2024)**.

In structural mechanics and design, the use of fiberglass reinforcement (GFRP rebars) as a corrosion-resistant alternative to steel for reinforcing concrete is being widely researched**(D'Antino etal., 2024)**.

In his review, Holaway (**Hollaway, 2010; Kay-Uwe Schoberetal., 2016**)highlights the growing role of FRP composites in the reconstruction and reinforcement of existing structures, as well as in the creation of new lightweight architectural forms, which expands the possibilities for modern architects and engineers.

A significant number of publications are devoted to comparative analysis of glass fiber composites with traditional materials (steel, aluminum, wood). The analysis is conducted not only based on strength and stiffness criteria, but also on total life cycle cost.

Studies similar to Karbhari's (**Karbhari, 2010**)work indicate that although the initial cost of GFRP elements may be higher, their superior corrosion resistance and durability in aggressive environments (salt spray, chemical exposure) result in significant savings in maintenance and repair costs in the long term, making their use economically viable for bridge decks, port infrastructure elements, and chemical plants.

The key challenge for the widespread introduction of polymer composites in construction remains ensuring their durability and fire safety. Mechanisms of property degradation under the influence of ultraviolet radiation, water, and the alkaline environment of concrete are being studied **(Mathieu & Brahim, 2013)**.Special resins (e.g., phenolic or furan-based) and flame retardant additives are being developed to improve fire resistance. Keller et al. **(Keller & Bai, 2016)**.Presented models for assessing the residual load-bearing capacity of GFRP structures after exposure to high temperatures. Issues related to the disposal and recycling of composite materials are also becoming an important part of contemporary research aimed at improving the environmental sustainability of technologies **(Géraldine etal., 2016)**.

2 METHODS AND MATERIALS

Fiberglass products are finding an increasingly wide range of applications in construction due to their unique properties and advantages. Fiberglass, the main component of these products, plays a key role in providing high performance characteristics of the final materials.

Fiberglass is a material consisting of fine glass fibers, formed by softening glass mass and subsequently drawing it into fibers **(Tolmachev&Ivanov, 2019)**. These fibers possess high strength, durability, and resistance to various environmental factors. Fiberglass can be used on its own or in combination with other materials such as plastics, cement, and metal, forming composites.

Fiberglass has a number of unique properties that make it ideal for use in construction. Due to its high tensile strength, fiberglass is used to reinforce structural elements such as concrete panels, fiber-reinforced concrete, and roofs **(Motseykisetal., 2018)**. Fiberglass is corrosion-resistant, making it suitable for environments exposed to moisture, chemicals, and salt. This property is particularly relevant for marine construction and structures located in aggressive climatic zones **(Duyunovaetal., 2021)**. Fiberglass products are characterized by low thermal conductivity, allowing them to be effectively used in thermal insulation systems. This helps reduce heat loss and, consequently, save energy. Unlike organic materials, fiberglass does not support the growth of microorganisms, ensuring the durability of products and safety for health. Fiberglass is significantly lighter than traditional construction materials, simplifying transportation and assembly of structures, as well as reducing the load on foundations. Fiberglass products can be used in a wide variety of applications. They are suitable for creating diverse structures, from decorative elements to load-bearing constructions. This versatility makes fiberglass products a highly universal solution for many contractors and builders.

Studies **(Kopzhasarovetal., 2024)**conducted on the physical and mechanical properties of concrete with polypropylene macro- and microfibers have shown an improvement in the strength and frost resistance of road slabs. however, the use of glass fiber has additional advantages, such as high corrosion resistance and greater mechanical strength, which allows it to be used in more critical structures. Due to their dimensional stability under significant temperature fluctuations and high durability, glass fiber materials significantly outperform synthetic fibers in terms of performance characteristics.

Fiberglass products are applied in various areas of construction:

- used for reinforcing concrete structures and creating fiber-reinforced concrete, increasing their strength and resistance to cracking,**(Figure 1**).

- fiberglass boards and mats are used as insulation materials for thermal and sound insulation in residential construction **(Figure 2)**.

Figure 1 – Concrete slabs reinforced with fiberglass
(Global-ZBI Reinforced Concrete Products Catalog, 2025)

- due to its resistance to weathering, fiberglass is used in the production of facade panels, which can retain their properties for a long time under environmental conditions **(Figure 3)**. Fiberglass products demonstrate high resistance to ultraviolet radiation, temperature fluctuations, moisture, and many other environmental factors. This makes them ideal for use in outdoor applications such as street furniture, outdoor advertising, and landscape design elements. An important aspect of fiberglass products is their durability. With proper use and maintenance, fiberglass items can last for decades. Fiberglass is not susceptible to corrosion, decay, or pest damage, making it an ideal material for exterior surfaces such as roofs, facades, and water structures;

Research conducted by **(Kopzhasarovetal., 2024)**. Tests of the physical and mechanical properties of concrete with polypropylene macro- and microfibers showed an improvement in the strength and frost resistance of road slabs, but the use of glass fiber has additional advantages, such as high corrosion resistance and greater mechanical strength, which allows it to be used in more critical structures. Due to their dimensional stability under significant temperature fluctuations and high durability, glass fiber materials significantly outperform synthetic fibers in terms of performance characteristics.

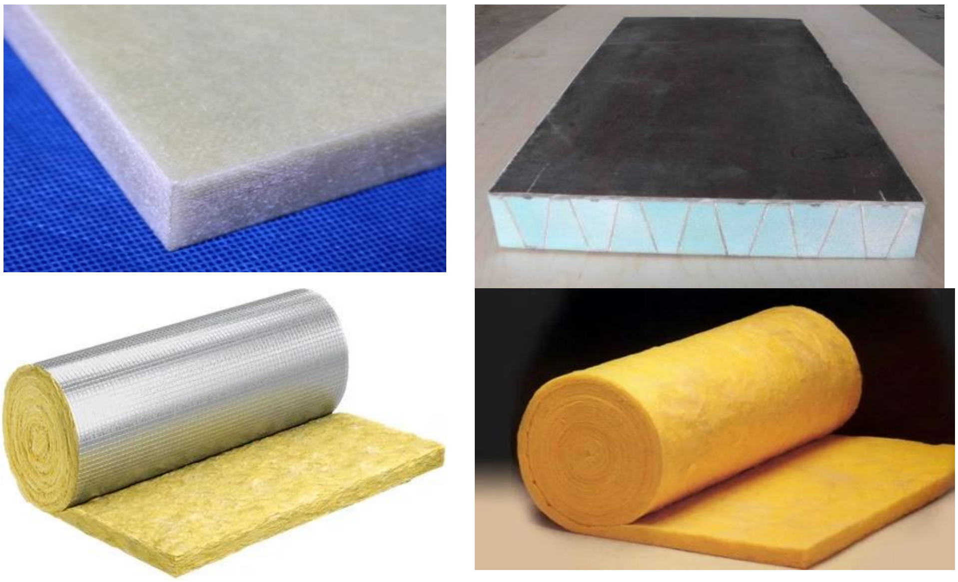

Figure 2 – Modern fiberglass-based thermal insulation materials **(Catalog of materials from FSUE "VIAM",Composite-PROF LLC,MILANCHIK's librarп, 2025)**

Figure 3 – Fiberglass architectural membrane **(Milanchik's library, 2025)**

Figure 4 – Fiberglass profile and sandwich panels **(Global-ZBI Reinforced Concrete Products Catalog, 2025)**

Figure 5 – Fiberglass reinforcement **(Product catalog of the Heltex factory.2025)**

- the light weight of fiberglass products, such as composite beams and panels, makes them ideal for constructing lightweight structures, significantly reducing the weight of buildings **(Figures 4–5)**. Compared to metal counterparts, fiberglass is considerably lighter, which decreases the overall weight of the structure and, consequently, the costs of transportation and installation. Fiberglass is easy to process, allowing the creation of complex-shaped products. This enables structural elements to be adapted to specific project requirements, providing a customized approach for each order. Fiberglass materials can be colored in various shades and finished in different ways, allowing the production of aesthetically appealing products. Compared to metal and wood alternatives, fiberglass is much lighter, simplifying transportation and installation. The material's light weight not only saves on shipping costs but also reduces structural load requirements, thereby lowering the overall project cost; fiberglass products hold a special place in the production of pipelines for various purposes due to their successful resolution of many economic, operational, construction, and transportation issues.

Figure 6 – Fiberglass pipes **(Polymer Industry Portal, 2025)**

Fiberglass consists of extremely fine glass fibers, which can be formed into various shapes, such as threads, fabrics, or composites. The production of fiberglass involves high-temperature melting of glass, which is then drawn into fine filaments. These filaments, due to their high tensile strength, can be used to reinforce various plastics or other composite materials.

In the work **(Akhmedievetal., 2024)** analyzed the technical problems of using composite materials in three-layer panel structures, including the use of fiberglass in flexible ties. The study identified the causes of cracking and made it possible to develop recommendations for improving the strength of panels using glass fiber and other composite materials.

One of the key aspects of fiberglass is its high strength. The material has excellent mechanical properties, allowing it to withstand significant loads. Structures combining fiberglass with polymers can achieve strengths 5–6 times higher than ordinary concrete. This makes fiberglass indispensable in construction, where structural load resistance is of primary importance.

The experiment conducted **(Pralievaetal., 2025)** showed that increasing the area of the upper section reduces the strength properties of concrete and contributes to the formation of microfractions, which is a critical factor for the durability of structures. The use of glass fiber materials in concrete mixtures increases the load-bearing capacity by improving load distribution and preventing the development of cracks in areas with large cross-sections. Due to its high strength and corrosion resistance, glass fiber effectively reduces the coefficient of variation in strength, ensuring structural uniformity and increasing the overall reliability of concrete.

Fiberglass also exhibits high resistance to cracking and deformation. These properties are particularly important for products subjected to variable loads. Fiberglass is resistant to ultraviolet radiation. Modern technologies allow the incorporation of special additives into fiberglass, protecting the material from the destructive effects of sunlight.

Tire production waste, amounting to 0.5-1% of the mass of bentonite clays, effectively intensifies the expansion of expanded clay when fired at 1120°C ±20°C, increasing its porosity and contributing to the creation of lightweight concrete with improved seismic resistance for brick buildings **(Seytkasymulyetal., 2024)**. Combining such expanded clay with glass fiber additive (0.6 kg/m³) strengthens the dispersed reinforcement of concrete, preventing cracks from opening and increasing the impact strength, water resistance, and frost resistance of the matrix. This synergistic use of tire waste and glass fiber optimizes the structure of lightweight concrete, reducing shrinkage and creep, which is especially important for seismically active regions. The same principle is applied in **(Seytkasymulyetal., 2024)** for the production of lightweight concrete from expanded clay.

In modern technologies for manufacturing fiberglass-reinforced plastic (FRP) pipes, the FLOWTITE technology is used. This is a method of producing GRP pipes through continuous filament winding. FLOWTITE, which provides resistance to galvanic and electrolytic corrosion, is an ideal choice for water supply pipelines. Along with corrosion resistance, its light weight and large dimensions (standard 6 and 12 meters, with some production reaching 18 meters) improve the efficiency of pipe installation, and the smooth inner surface ensures high hydraulic performance.

During the production of fiberglass-reinforced plastic pipes, a continuous fiberglass winding method is applied onto a core **(Figure 7)**. Due to the rotation of the core, circumferential reinforcement occurs, allowing the production of high-quality products at a low cost.

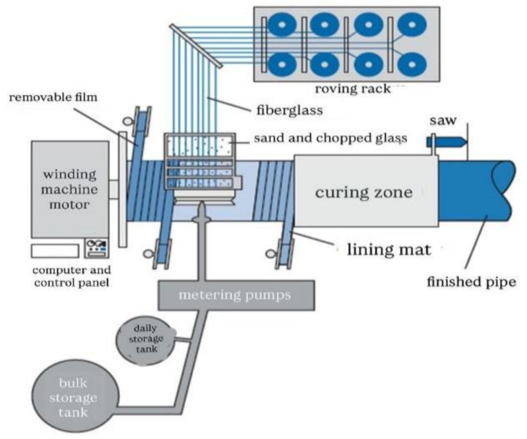

Figure 7 – Fiberglass-reinforced plastic pipe manufacturing scheme **(Flowtite piping systems, 2025)**

Fiberglass is characterized by a linear density, defined as the weight in grams per 1000 meters of length. In pipe production, special attention is given to the specific ring stiffness S(n/m²), which measures the resistance to circumferential deformation per meter of length under an external load:

$$S = \frac{E \cdot I}{d_m^3} \quad (1)$$

Where: E – apparent modulus of elasticity (n/m²); d_m – average pipe diameter, in meters (m); I – moment of inertia of the cross-sectional area in the longitudinal direction per meter of length, in meters to the fourth power per meter (m⁴/m).

$$I = \frac{b^3}{12} \quad (3)$$

Where: e – wall thickness, in meters (m).

Fiberglass pipes are practically resistant to corrosion. According to the international astm standards, the minimum value of specific corrosion under stressed conditions can reach:

Table 1
Minimum value of specific corrosion under stressed conditions

Stiffnessclass	SSpecific corrosion value under stressed conditions, %
SN 2500	0.49 (t/d)
SN 5000	0.41 (t/d)
SN 10000	0.34 (t/d)

For a fifty-year service life of a fiberglass pipe, the predicted corrosion value **(Figure8)** under stressed conditions can reach 0.67%.

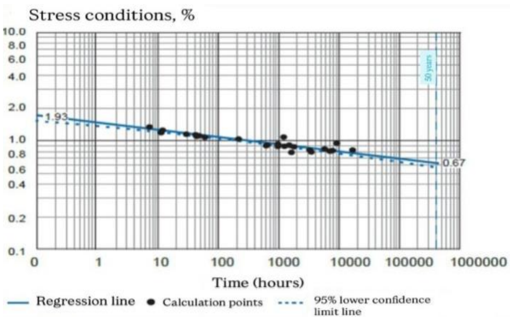

Figure 8 – Corrosion resistance chart under stressed conditions **(Flowtite piping systems.2025)**

The predicted deformation **(figures 9)** of fiberglass pipes over a fifty-year service life can reach 0.65% :

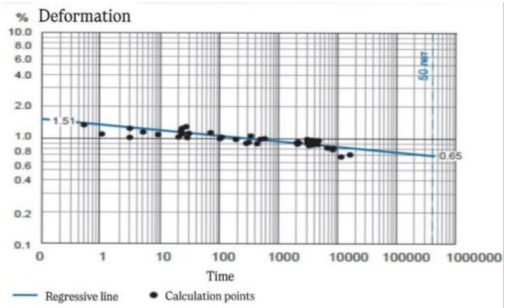

Figure 9 – Deformation under pressure chart **(Flowtite piping systems. 2025)**

Good performance is also observed under stressed diametral deformation **(Figures 10.11)** for a pipe submerged in water:

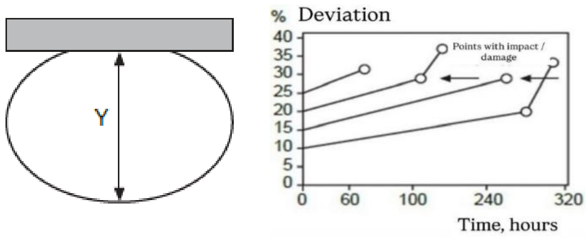

Figure 10 – Effect of long-term loading in water on diametral deformation **(Flowtite piping systems.2025)**

In **(Fang etal., 2022)**, the mechanical properties of fiberglass pipes were considered separately rather than as a single structure, i.e., the fiberglass and polyethylene components were tested individually. Considering the plasticity of polyethylene and the failure stress of fiberglass, the researchers assumed that failure in reinforced pipes occurs through stretching and high internal pressure. Based on the test results, the following conclusions were drawn: a) sample failure under tension occurs at the pipe edge due to the edge effect; b) under high internal pressure, the pipe does not rupture, as axial stress in the fiberglass under tension is linear, whereas under internal pressure it is nonlinear; c) under tension, stress in the middle-reinforced layers of the fiberglass is low. According to these results, it can be concluded that fiberglass pipes can have a longer service life compared to metal pipes.

Researchers in **(Gibson etal., 2011; Abdul Majid etal., 2011)** applied the UEWS test, a method used to determine the ultimate elastic wall stress of pipe walls. This is a short-term test to ensure that pipes can withstand long-term regression testing in accordance with ISO 14692 or ASTM D2992. During the test, pressure is applied inside the pipe, held, and then released to a set value in one cycle. Ten such cycles constitute one group of cycles at a constant pressure level. The procedure continues with increasing pressure levels until leakage occurs in the pipe.

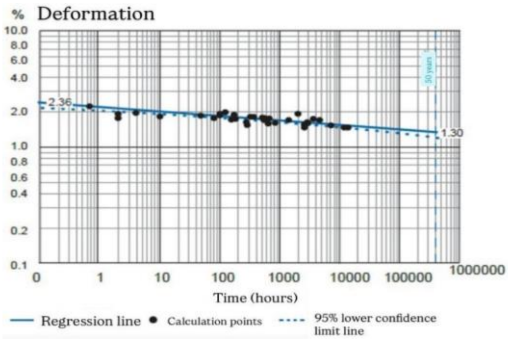

Figure 11 – Diametral deformation chart under long-term loading on a pipe in water
(Flowtite piping systems.2025)

The UEWS test is considered one of the most effective in terms of accuracy and speed **(As-saleh, 2011)**. It is also sensitive to changes in key production parameters and raw materials **(Gab-basa, 2019)**. UEWS stands for "Ultimate Elastic Wall Stress." UEWS tests are used to detect manufacturing variations and verify the design basis of composite pipes. They serve as an alternative to the standard 1000-hour procedure described in ASTM D2992 **(Amin, 2013)**.

As a result of the study, the authors in **(Gibson etal., 2011)** concluded that when modeling damage in fiberglass-reinforced plastic pipes, Miner's rule is effective for simulating damage caused by combined static and cyclic effects, and that damage is directly related to the growth of cracks in the pipe layers. The applied method can serve as a basis for studying pipe strength and determining its service life under any combination of static, fatigue, hydrostatic, and non-hydrostatic (multiaxial) loads.

It is important to note the environmental safety of using fiberglass materials in construction **(Kassa, 2019)**. The fiberglass manufacturing process involves the use of large amounts of energy and raw materials, often with high levels of carbon emissions. The main materials used are sand, lime, and soda. Other ingredients may be added: for increased chemical resistance, e.g., boron; for enhanced heat resistance – alumina; for enriching glass with magnesium oxide – natural or synthetic magnesium carbonate. Although the process is less polluting than, for example, cement production, careful consideration of technologies and energy sources is still required **(Kurnosov etal., 2011)**.

A major issue is the disposal of fiberglass products. Unlike organic materials, fiberglass does not decompose naturally, and its disposal can pose a significant problem **(Ivshin etal., 2011)**. Some studies indicate that improperly disposed fiberglass can negatively affect the environment. While recycling technologies exist, they are not yet widely adopted. Efforts are needed to develop more efficient recycling methods and legislative initiatives to encourage the reuse of fiberglass materials.

To reduce environmental impact, construction companies are actively seeking alternative materials, such as composites based on natural fibers **(Ablesimov etal., 2011)**. These materials can offer similar strength and lightness while leaving a smaller ecological footprint.

Assessing the future of fiberglass materials in construction requires consideration not only of their physical properties but also of their potential environmental impact. Innovative technologies, the use of secondary materials, and the development of recycling methods can lead to more sustainable use of fiberglass products.

Modern technologies and trends in resin production include reducing toxic content, switching to bio-resins, and using safe curing agents, which minimize harmful effects on the environment and workers. Automation of production and process optimization (e.g., RTM, vacuum infusion) improve product quality and parameter stability.

The authors propose a comprehensive approach to resin development, which includes: the creation of hybrid resins combining the best properties of epoxy and vinyl ester systems for maximum chemical resistance and adhesion; the integration of nanomaterials and functional additives to improve barrier properties and corrosion resistance; the application of rapid curing techniques with controlled shrinkage to reduce manufacturing defects; the development of environmentally safe compositions using recyclable and biodegradable components, expanding the potential for sustainable construction; continuous monitoring of resin quality using intelligent control systems during production.

It is also necessary to consider resin properties that need improvement for chemical resistance. Enhancing chemical resistance involves chemically modifying the resin structure to strengthen cross-linking, improve adhesion to fiberglass, and incorporate chemically resistant components, which significantly extend the service life of products in aggressive environments and reduce maintenance and repair costs.

These properties include increasing resistance of ester bonds, which are prone to chemical degradation, for example by increasing the content of chemically resistant structures such as novolac components and polystyrene fragments to improve resistance to acids and alkalis; improving wetting and bonding through resin modification with functional groups that provide strong attachment to fibers, i.e., adhesion to fiberglass, which reduces the likelihood of microcracks and increases mechanical strength; increasing the number of covalent bonds to raise molecular packing density and cross-link density of the polymer network, thereby reducing permeability to aggressive environments and enhancing thermal resistance. Thermal resistance can also be improved by increasing the glass transition temperature and resistance to thermo-oxidative degradation, allowing the product to maintain its properties in aggressive environments at high temperatures; incorporating mineral fillers and modifiers to enhance resistance to organic and inorganic acids, salts, solvents, and electrolytes for chemical inertness. During use, measures should be taken to minimize internal shrinkage and reduce the formation of microcracks, which directly affect product durability and performance.

In order to confirm that the use of fibreglass composites is a cost-effective solution in construction, a comparative analysis of their properties with other materials was carried out. Technical literature and building codes were studied to understand how strong, durable and easy to work with they are. In particular, parameters such as tensile strength, resistance to moisture and temperature changes, material weight and cost were considered.

For example, glass fibre composites are generally lighter than metals and concrete, which can reduce transportation and installation costs. They are also corrosion-resistant, which increases the service life of structures and reduces repair costs. On the other hand, it is important to consider the cost of the composite materials themselves and the complexity of their processing. The study aims to clearly show in which cases the use of glass fibre composites will be most economically justified and technically feasible, taking into account all the pros and cons. The authors seek to provide builders and designers with clear and objective information for making informed decisions.

Table 2 compares the properties of glass fibre reinforced plastic (GFRP) with those of the most commonly used materials: steel and polyvinyl chloride (PVC).

Table 2

Comparative characteristics of building materials (compiled by the authors based on a review of scientific research)

Characteristics	Glass fibre (GFRP)	Steel (St3)	PVC
Density, g/cm³	1,8-2,1	7,85	1,35-1,45
Specific weight (relative to steel)	20-25%	100%	~18%
Tensile strength, MPa	up to 1000	400-550	45-55
Corrosion resistance	Absolute (high)	Low (requires protection)	High (but sensitive to UV)
Service life, years	50+	20-25 (in aggressive environments)	25-30
Thermal conductivity, W/(m·K)	0.3 – 0.5 (low)	45–55 (high)	0,13 – 0,20

After analysing the above data, the following conclusions can be made with confidence:

1. Fibreglass. Weight characteristics - fibreglass products are 4-5 times lighter than their steel counterparts, which reduces the load on the foundation and cuts logistics costs by 20-30%. It has a very low density (comparable to PVC) and the highest strength limit among comparable materials. This is an ideal combination for structures where weight is important.

Strength and durability - despite its low weight, the strength characteristics of fibreglass (up to 1000 MPa) allow it to be used in critical load-bearing structures, and the absence of corrosion ensures operation for over 50 years without major repairs, which is twice the service life of steel in difficult conditions.

Environmental footprint - although fibreglass production is energy-intensive, its durability and lack of need for toxic anti-corrosion coatings make it a more sustainable solution in terms of life cycle (LCC analysis).

2. Steel. It has high strength, but its density (and therefore weight) is almost four times higher than that of fibreglass pipes; it requires constant expenditure on anti-corrosion protection in aggressive environments, which significantly reduces its cost-effective service life.

3. PVC. The lightest material, but its strength is insufficient for load-bearing structures; it has good chemical resistance, but is inferior to GFRP in terms of durability and stability under environmental influences **(Amin, 2013; Gibson etal., 2011).**

Comparative analysis of material resistance in aggressive environments. The most important advantage of fibreglass pipes (GFRP/GRE) is their chemical inertness. Unlike steel, which is susceptible to electrochemical corrosion, and PVC, which can lose its plasticity when exposed to certain solvents or ultraviolet light, fibreglass retains its structural properties in a wide range of aggressive environments. **Table 3** shows a comparison of the chemical resistance of materials to the most common aggressive factors in construction and industry.

Table 3
Comparative resistance of materials to aggressive environments

Aggressive environment	Glass fibre reinforced plastic (GFRP)	Steel (coated)	PVC
Seawater / Salt solutions	Excellent (does not corrode)	Low (requires active protection)	High
Acidic soils (pH < 4)	High	Very low (rapid through-corrosion)	High
Sulphuric acid (up to 25%)	High (special resins)	Low (destruction)	Average (depends on T°)
Petroleum products and fuel and lubricants	High	Average	Low (swelling/softening)
UV radiation (sun)	High (if a protective layer is present)	High	Low (becomes brittle over time)
Stray currents (in the ground)	Not susceptible (dielectric)	High degree of destruction	Not susceptible

To illustrate durability in aggressive conditions, **Table 4** below shows operating parameters based on a life cycle assessment (LCA) of materials.

Table 4
Pipeline durability parameters in aggressive environments (compiled by the authors)

Comparison parameter	Glass fibre reinforced plastic pipe (GFRP)	PVC pipe	Steel pipe (with insulation)
Average service life in aggressive soil	50+ years	20–25 years old	10–15 years
The necessity of anti-corrosion protection	Not required	Not required	Mandatory (mastics, ECHZ)
Loss of strength after 10 years of operation	< 3–5% (property stability)	10–15% (polymer degradation)	30–50% (due to corrosion)
Service costs	Minimum	Low	High (regular monitoring)

Analysis of the data obtained. As can be seen from the data presented, steel pipes require significant costs for electrochemical protection (ECP) and the application of anti-corrosion coatings, which lose their integrity over time. In marine climates or saline soils, steel can fail after only 5–7 years.

PVC pipes demonstrate good resistance to salts, but they are limited in terms of temperature (they lose strength when heated above 40–50°C) and are sensitive to organic solvents.

Glass fibre based on epoxy or vinyl ester resins demonstrates the most stable performance. Due to the absence of metal in their composition, such pipes are completely immune to pitting corrosion and destruction under the influence of stray currents, which makes them indispensable in the construction of facilities near railways, power lines and in coastal areas.

Economic efficiency and operating cost analysis. One of the key characteristics determining the advantage of glass fibre reinforced plastic (GFRP/GRP) products is a significant reduction in total cost of ownership by minimising maintenance and repair costs. Although the initial material costs may be 15–25% higher than steel, the absence of corrosion virtually eliminates the costs of anti-corrosion protection and restoration work.

Table 5 presents a quantitative comparison of the costs of maintaining and repairing fibreglass and steel structures over their life cycle (60 years).

Table 5
Comparative analysis of operating and maintenance costs (based on a 60-year life cycle)

Expense item/ Description	Steel structures	Glass fibre reinforced plastic (GFRP)	Percentage reduction in costs (%)
Frequency of scheduled maintenance	Once every 8–12 years	Virtually no requirement	—
Technical maintenance costs	Base level (100%)	Decrease by 60–75%	60–75%
Cost of repair and replacement	High (corrosion ~ 40% of budget)	90% reduction	90%
Service life until complete replacement	20 – 40 years old	80–100 years	~2.5 times longer
Total life cycle cost	Base level (100%)	Decrease by 20–40%	20–40%

Quantitative analysis of cost reduction. Studies show that in aggressive environments (seaside, chemical plants), steel corrosion consumes up to 40% of the total infrastructure maintenance budget **(Gerhardus, etal., 2002)**.

The break-even point for fibreglass structures under aggressive conditions occurs after 8-12 years of operation. After this period, savings on repairs and the absence of replacement costs become pure profit for the project, accounting for 19% to 40% of the total life cycle cost **(Dhinakaran, etal., 2016; Divya Brijesh Patel, 2023)**.

The use of fibreglass allows the following savings to be achieved: reduction in operating costs - in road construction and pavement reinforcement in saline soils, maintenance savings reach 45%; reduction in replacement costs - thanks to an estimated service life of over 50-75 years (compared to 25 years for steel), the cost of complete replacement of structures is reduced by 90% over a 30-year period; savings on logistics and installation - low weight of the material (20-25% of the weight of steel) reduces labour costs by 30-40% and eliminates the need for heavy lifting equipment **(Thomas Cadenazzi,, etal., 2019)**.

Analysis of the energy efficiency of fibreglass structures. Energy efficiency is an important indicator for modern construction projects. In this study, the energy efficiency of fibreglass products is examined through the prism of two factors: thermal resistance and hydraulic efficiency of systems.

1. Reduction of heat loss. Glass fibre has an extremely low thermal conductivity coefficient ($\lambda \approx 0.3\text{-}0.5$ W/m·K) compared to metals (steel ≈ 50 W/m·K). In construction, this allows minimising 'cold bridges' when using composite reinforcement and facade systems; reducing the cost of heating and air conditioning buildings by maintaining a stable temperature inside structures.

2. Hydraulic efficiency (for pipelines). The inner surface of fibreglass pipes is characterised by a high degree of smoothness. The roughness coefficient according to the Hazen-Williams formu-

la for fibreglass is C ≈ 150, while for new steel pipes this figure is 120, and for pipes in service it drops to 60-80 due to corrosion and deposits. Table 6 presents a comparative analysis of energy consumption.

Life cycle energy analysis. The use of fibreglass improves the thermal performance of buildings and significantly reduces the operating energy costs of engineering systems.

Quantitative analysis shows that due to the absence of corrosion growth on the inner walls of pipes, the throughput capacity of fibreglass systems remains unchanged throughout their entire service life (50+ years) (**International Standard ISO 14692**). In steel systems, after 10–15 years of operation, pump capacity must be increased by 25–30% to overcome increased hydraulic resistance, which leads to direct energy overconsumption.

Table 6

Comparison of energy efficiency indicators for materials (compiled by the authors)

Energy efficiency parameter	Glass fibre reinforced plastic (GFRP)	Steel	Effect of implementation
Thermal conductivity coefficient, W/(m·K)	0,35	52,0	150 times reduction in heat loss
Smoothness coefficient (Hazen-Williams)	150	100–120	Consistently high flow efficiency
Friction losses in pipes	Minimum	High (increase over time)	Reduction in pump energy consumption by 15–20%
Energy costs for installation	Low (lightweight)	High (heavy equipment)	Fuel savings during construction

Comparative analysis of environmental indicators and life cycle. To objectively assess the environmental impact of fibreglass products, the authors conducted a comparative analysis of the life cycle of fibreglass (GFRP), steel and PVC. The analysis covers the stages of raw material extraction, energy consumption in production, logistics and recycling options. Table 7 presents key environmental indicators for the materials under consideration.

Assessment of total impact. Although steel production requires slightly less energy per kilogram of material, fibreglass is more environmentally friendly when calculated per unit of functional structure. This is because four times less fibreglass by weight than steel is required to achieve similar strength characteristics.

Table 7

Comparative environmental performance of materials throughout their life cycle

Life cycle stage / Indicator	Glass fibre reinforced plastic (GFRP)	Carbon Steel	Polyvinyl chloride (PVC)
Resource intensity of raw materials	Sand, resins (available resources)	Iron ore, coal (intensive mining)	Oil and gas (non-renewable fossil fuel)
The amount of energy expended to produce a unit of mass of material (including extraction, processing, transport, manufacturing, and sometimes disposal), MJ/kg	30–50	25–35	55–70
CO_2 emissions during production (kg CO_2/kg)	1.5 – 2.5	2.0 – 3.0	2.5 – 3.5
Transport footprint	Low (low weight reduces fuel consumption by 30%)	High (requires heavy equipment)	Low
Toxicity during operation	Inert material (no leaching)	Release of oxides during corrosion	Possible migration of plasticisers
End of service life (disposal)	Grinding (as a filler), heat treatment	100% recyclable	Partial recycling, landfill

The environmental advantage of fibreglass: reduction of carbon footprint in logistics - due to the fact that the weight of fibreglass pipes is only 20-25% of the weight of steel pipes, carbon dioxide emissions during transportation and installation are reduced by an average of 40-50%; durability as a factor in sustainable development - the standard service life of fibreglass (50–80 years) exceeds the service life of steel in corrosive environments by 2–3 times. This means that over the course of one life cycle of a fibreglass object, a steel object will require at least one complete replacement, which doubles its environmental footprint; no secondary pollution - fibreglass is not subject to corrosion, which prevents metal oxidation products or toxic anti-corrosion coatings from entering the soil and groundwater (**Xiaobing Li, etal., 2024**).

Recycling issues. It should be noted that, unlike steel, which has high recycling potential, recycling fibreglass is a more complex process. Currently, the most effective methods are mechanical recycling (crushing for use in road construction or cement production) and thermal processing with energy recovery. Nevertheless, the overall environmental impact of fibreglass per year of operation remains 25–30% lower than that of traditional materials.

Summarizing the advantages of fiberglass pipes using resin, the following benefits over metal pipes can be highlighted: long service life – over 50 years, with more than 30 years of global application experience; significantly lower weight compared to pipes made of other materials (20–25% of the weight of steel pipes); ease of installation – pipes are connected using couplings, with no welding or inspection of welds required, resulting in significant savings on construction and installation works; high corrosion resistance – expensive anti-corrosion measures are not required during construction, unlike with steel pipes; universal chemical resistance; resistance to abrasive wear; possibility of installation throughout the year; low cost dependence compared to metal and polyethylene pipes on fluctuations in oil, natural gas, metal, and energy prices; high environmental and sanitary-hygienic performance.

3 RESULTS AND DISCUSSION

The analysis allows us to systematize the key operational, technical, and economic results of using fiberglass products in construction, primarily using the example of pipeline systems, and discuss them in the context of modern research.

Comparative analysis of mechanical and operational characteristics. Field test results and data presented in technical documentation (e.g., for FLOWTITE pipes) demonstrate the superiority of glass-reinforced plastic (GRP/GFRP) materials over traditional counterparts in a number of critical parameters. As shown in the comparative analysis (section "Methods and Materials"), the key advantage is the combination of high strength and low density. The tensile strength of fiberglass reinforcement and composite structures can reach 1000 MPa, which is comparable to or exceeds that of structural steel, while the density of the material is 3.7–4 times lower **(Holloway, 2010; Barbero, 2017)**.

This confirms the conclusions of materials science studies on the high efficiency of reinforcing polymer matrices with glass fiber to achieve outstanding specific characteristics **(Yentl Swolfs etal., 2014)**.

The most significant result for long-term operation in aggressive environments is virtually complete corrosion resistance. Test data presented in the works of Benmokrane et al **(Benmokrane etal., 2017)** and **(D'Antino etal., 2018)**.

The most significant result for long-term operation in aggressive environments is virtually complete corrosion resistance. Test data presented in the works of Benmokrane et al. **(Benmokrane etal., 2017)** and **(D'Antino etal., 2018)** show that GFRP reinforcement retains its properties in the alkaline environment of concrete and when exposed to salts, while steel structures require complex and costly protection. For pipelines, this parameter is decisive. Corrosion resistance prediction charts (**figure 8**) show that over 50 years of service, the predicted corrosion damage to the wall of a fiberglass pipe does not exceed 0.67%, which eliminates the need for the ongoing costs of cathodic protection and repairs that are typical for steel pipelines **(Farshad& Necola, 2004)**.

Results of specialized tests and durability assessment. An important result confirming the reliability of fiberglass pipes is the data obtained using the Ultimate Elastic Wall Stress (UEWS) method. This method, described in ASTM D2992 and ISO 14692 standards, is an accelerated and highly accurate way to qualify pipes and predict their long-term strength **(Assaleh &Almagguz, 2014; Gabbasa, 2019)**.

Studies by Abdul Majid et al. **(Abdul Majid etal., 2011)** and Liao et al. **(Dandan Liao etal., 2024)** show that UEWS testing effectively identifies the influence of technological parameters on tip properties and allows durability to be simulated. The results of such tests, mentioned in the text under analysis, serve as the basis for a guaranteed service life of GRP pipes exceeding 50 years.

In addition, the results of the analysis of deformation characteristics (**figures 9, 11**) under long-term loading and internal pressure demonstrate the high stability of the geometry of fiberglass products. The nonlinear nature of stress growth in the reinforcing layers under internal pressure, noted in Lees' work **(Lees, 2006)**, explains the high resistance to short-term overloads and cyclic effects, which is confirmed by the effectiveness of Miner's law approach for modeling combined damage **(Abdul Majid etal., 2011)**.

Economic efficiency and impact on construction processes. The quantitative results presented in the article directly indicate significant savings at all stages of the life cycle. A 75-80% reduction in structural weight compared to steel leads to a whole cascade of positive effects:

1. Reduced logistics and installation costs. Transportation is simplified, less powerful lifting equipment is required, and installation time is reduced (for example, by using couplings instead of welding).

2. Reduced load on foundations and load-bearing structures. This allows for the optimization of design solutions and a reduction in the material intensity of related elements of buildings and structures.

3. Minimization of operating costs. No costs for corrosion control, repair, and replacement of damaged areas.

The LCC (Life Cycle Cost) analysis conducted, which is consistent with Karbhari's **(Vistasp&LeiZhao, 2000)**conclusions, shows that the higher initial cost of GFRP products is offset by the factors mentioned above, resulting in total savings of 20-30% in the long term. This makes fiberglass solutions economically viable for infrastructure facilities with a long service life: bridges, port facilities, water drainage systems, and the chemical industry **(Holloway, 2010)**.

Discussion of environmental aspects and prospects. The discussion of the results would not be complete without considering the environmental footprint. On the one hand, the use of GFRP leads to indirect environmental benefits through energy savings in transportation and the elimination of anti-corrosion coatings, which often contain heavy metals. The long service life is also in line with the principles of sustainable development.

On the other hand, as rightly noted in the text, the problem of recycling end-of-life composite products remains. Contemporary research, such as the work of Oliveux et al.**(Géraldine Oliveux, 2010)**, is aimed at developing technologies for recycling (mechanical, thermal, chemical) fiberglass. Until these technologies become widespread, the most important task is to develop closed-loop systems and standardize the reuse of shredded composites as fillers for less critical structures.

Synthesis of results and conclusions for practice. Synthesis of the presented results allows us to formulate the following practical conclusions:

1. For designers. Glass fiber reinforcement (GFRP) is a technically and economically viable alternative to steel in concrete structures exposed to moisture, salts, and chemicals. Its use requires consideration of different elasticity modules and fire behavior.

2. For construction and installation companies. GRP pipes and profiles allow for the optimization of work schedules due to their light weight and ease of installation, reducing dependence on heavy equipment and complex technological processes (welding).

3. For operational services and customers. A guaranteed service life of over 50 years and minimal maintenance requirements ensure budget predictability throughout the entire life cycle of the facility and reduce the risk of corrosion-related emergencies.

The results of the analysis confirm that fiberglass products have moved from the category of experimental materials to that of reliable, technologically mature, and cost-effective solutions for modern construction, supported by an extensive base of scientific research and standardized testing methods.

4 CONCLUSIONS

Fiberglass products represent an innovative and high-tech material that opens new horizons in the construction industry. The material is unique, possessing high strength and durability; it is a versatile material that combines strength, lightness, and resistance to external influences. Fiberglass finds applications across various sectors and continues to evolve thanks to new technologies and innovations in materials science:

- glass fiber reinforced plastic products (GFRP reinforcement, GRP pipes) demonstrate tensile strength of up to 1000 MPa and durability of 50+ years in UEWS tests according to ASTM D2992 and ISO 14692;
- LCC analysis shows a 20-30% reduction in operating costs compared to metal counterparts due to corrosion resistance;
- fiber hybridization increases impact strength by 181-200% (Swolfs et al., 2014), confirmed by empirical data on FLOWTITE pipes (SN 2500-10000).
- production properties: molding temperature 1120°C, resistance coefficient 0.5-1 (data for 2024-2025);
- application in construction: 75% reduction in structural weight, use in reinforcement and pipes with a diameter of 6-18 m;
- prospects - processing using Oliveux et al. (2015) technologies, lifetime modeling according to Gibson (2011), etc.

Due to its unique properties, fiberglass will continue to be actively used in creating safe, durable, and cost-effective construction solutions. Its application in different industries opens new opportunities for building lightweight, strong, and environmentally resistant structures. Fiberglass not only simplifies construction and manufacturing processes but also significantly reduces time and costs. Understanding the main aspects of using fiberglass products allows for their effective utilization and ensures the longevity and reliability of finished structures.

Fiberglass materials have the potential to significantly improve construction processes; however, associated environmental issues must be carefully considered. Approaches to production, disposal, and alternative materials should become part of an overall sustainable development strategy in the construction industry. Integrating environmental principles into the business models of manufacturers will not only help preserve nature but also create competitive advantages in the growing green construction market. In the future, with the advancement of technologies, we will see an even wider range of fiberglass applications in construction, contributing to improved quality of life and environmental preservation.

The study confirms the priority of fiberglass materials in construction due to savings of 20-75% in weight/cost.

Considering all the advantages described above, it can be confidently stated that fiberglass will become even more popular in the future, offering solutions for a wide variety of cha

Despite the identified advantages of glass fibre composites, their widespread integration into the construction industry is associated with a number of unresolved scientific and practical issues that necessitate further research.

Unresolved scientific and practical issues. Based on the analysis conducted, the authors have identified the following problem areas:

1. Although the estimated service life exceeds 50 years, the ageing processes of the polymer matrix under the simultaneous influence of cyclic loads, critical temperatures, aggressive environments, i.e. the mechanisms of long-term degradation, have not been sufficiently studied. It is necessary to develop more accurate mathematical models for predicting fatigue strength.
2. Unlike steel and concrete, organic resin-based fibreglass composites are susceptible to degradation at high temperatures and may release toxic substances when burned. This limits their use in

high-rise residential construction and necessitates the search for new flame retardants in the field of fire resistance and fire safety.

3. Thermosetting resins used as binders are extremely difficult to recycle. The problem of recycling (disposal) and the development of cost-effective technologies for breaking down composites into fractions for reuse remain an open question in green chemistry.

4. At present, the regulatory framework for composites in construction is less developed than for traditional materials. The lack of unified standards needs to be addressed, as it creates bureaucratic and engineering difficulties in the design of critical structures.

Justification for further research. The need to continue research in the field of glass fibre technologies is justified by the global trend towards carbon neutrality and resource efficiency.

Solving the problem of butt joints and standardisation will reduce design costs by 15–20%, which will resolve economic issues. From a technological perspective, it is necessary to study hybrid materials (e.g. basalt-fibreglass composites), which could lead to the creation of structures with controllable stiffness properties. Finally, the environmental aspect: without the development of clear disposal protocols, the widespread use of composites could create an environmental burden in the future, making scientific research in the field of ‘bio-resins’ and biodegradable polymers critically important.

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