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Review

Composite as a Material of the Future in the Era of Green Deal Implementation Strategies

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Abstract: Composite materials have become synonymous with modernity, desired in nearly every aspect of our daily lives, from simple everyday objects to sanitary facilities, pipelines, the construction of modern sewer networks, their renovation, water supply, and storage reservoirs, to complex structures—automotive, planes, and space science. Composites have seen a considerable rise in attention owing to their characteristics, durability, strength, reduced energy usage during the manufacturing process, and decreased transportation costs. Composite materials consistently outperform steel, cast iron, and concrete in terms of CO_2 emissions. Additionally, these materials have a long service life of about 150 years or more and are corrosion-resistant. Today, continued sustainable development is contingent upon access to safe drinking water and the availability of its resources and modes of conveyance. As a result, composite pipes have considerable potential due to their very low flow rate, which directly affects the prices of drinking water pumping and irrigation systems. However, there are also certain disadvantages associated with fibre-reinforced composites, such as easy surface damage, low heat resistance (up to 220 °C), long product forming time, and high cost of the material. Additionally, the product's initial high durability and extended life cycle, coupled with high abrasion resistance, anisotropic strength, and stiffness in the final phase, prove to be unfavourable since composite material cannot be rapidly reintroduced into the manufacturing cycle. However, its disposal requires a negligible amount of energy. The article discusses the various composite materials available, their applications, and the potential for further developing their manufacturing technology toward nanocomposites and composites of natural origin that are readily biodegradable at the end of their service life; dubbed "green composites". The study's findings are unequivocal: this class of composite materials warrants further investigation in the future since they align perfectly with the concept of sustainable economic growth and Green Deal implementation.

Keywords: composite materials; bio-composites; nano-composites; short-life composites; CO_2 emissions; green deal implementation

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1. Introduction

The tremendous industry growth beginning in the late nineteenth century resulted in almost permanent changes to our environment, which we are still experiencing more than a century later. Our generation must make the required adjustments to end harmful human activity, which means that all efforts must be made to halt this degrading process.

Such actions have been and continue to be carried out throughout Europe. The European Commission has adopted a package of political and economic initiatives dubbed Green Deal Implementation with the overarching goal of achieving climate neutrality in Europe by 2050; it was also assumed that by 2030, gas emissions would be reduced by 50% to 55% compared to 1990 levels. Climate neutrality was planned to boost the economy via green technology, develop a sustainable industry and transportation, and offer nutritious food to people.

To accomplish this goal, all sectors of the economy must take action, including: (I) investing in environmentally friendly technologies; (II) assisting industry in innovation; (III) implementing cleaner, more affordable, and healthier modes of private and public transportation; (IV) decarbonizing the energy sector; (V) ensuring buildings are more energy efficient; and (VI) collaborating with international organizations [1].

The European Commission established the Europe 2020 plan in 2010 to achieve "smart, sustainable, and inclusive growth". The three objectives are referred to as 20-20-20, and the aim was established by the Europe 2020 plan, which required member states to:

1. 20% reduction in greenhouse gas emissions relative to 1990 levels;
2. 20% share of renewable energy in gross final energy consumption; and
3. 20% reduction in total energy consumption relative to the preliminary 2020 consumption forecast [2].

Although, several EU member states fell short of the 2020 goals. However, each member state engaged in climate change-related initiatives, which prompted the European Commission to expand its environmental protection programs. Even though it generates clean energy and saves money, one of the most critical ecological goals is to utilize contemporary building materials that can ultimately replace older ones that need much power to produce, such as steel, concrete, and cast iron. The traditional material is wood, which has been used in building for over 10,000 years. It is worth mentioning that the world's oldest wooden structure is regarded as a Buddhist temple in Japan—the Hōryū-Ji (Figure 1), the complex was constructed around 1400 years ago.

Figure 1. Oldest wooden building—A Buddhist temple Hōryū-Ji [3].

It is considered that the nineteenth century was the era of steel, while the twentieth century was the age of concrete. Still, in the twenty-first century, apart from the widespread usage of polyester-glass composites, wood is regaining popularity, in no little part because wood is the only naturally occurring and renewable material used in ordinary buildings.

The inherent limits of wood, such as length and thickness, have been addressed via the development of contemporary technologies such as cross laminated timber (CLT). It is constructed by cross-glueing consecutive layers of solid CLT hardwood boards to produce a plate with dimensions of 20 m × 4 m and a thickness of up to 0.6 m. The panels are lightweight and can be placed without heavy equipment, even significantly reducing the time required to create multi-story structures. CLT is made out of 99 percent wood and less than 1% glue and is formaldehyde-free. This technique was developed in 1947 by French engineer Pierre Gauthier and was successfully used to construct walls and roofing by architect Jean Prouvé, ten years later. It first emerged on building sites at the turn of the twentieth century and is still being used more and more freely today. The panels are also resistant to fire (solid wood buildings are very fire resistant) and earthquakes. The technique is an environmentally friendly, monolithic, quick, and straightforward method that provides enough insulation—five times that of reinforced concrete [4–6]. An evident, obvious and good solution (to the use of steel and concrete) seems to be the growing usage of composite materials, which are very light, strong, and almost impervious to corrosion, and ultimately align with the Green Deal Implementation programme.

When the energy consumption of manufacturing processes is compared to that of pipe production, it is clear that composite pipes stand out positively with a contribution of less than 2000 kg CO_2—equivalents, which is roughly half that of ductile cast iron pipe, the following lowest total assistance, and even three times that of those made from steel [7].

The career of composite materials began in the mid-twentieth century, when their durability and corrosion resistance were appreciated, the first boat hulls were built. They were then used in construction, aviation, and transport.

In the meantime, it is impossible to imagine a world without these materials, which, by the way, are continuously evolving: new and better resins, new glass and carbon fibre reinforcements (early 1960s). Numerous manufacturing methods have been developed, including winding, centrifugal casting (tubes), pultrusion, and vacuum shaping [8]. In the 1990s, composites were first utilised in infrastructure construction. An all-composite bridge was built at Aberfeldy Golf Club in Perthshire, Scotland, to increase the size of the tiny nine-hole course. Nonetheless, a pedestrian bridge was required due to the River Tay separating the region [9]. The club's administrators entrusted Prof. Bill Harvey of Dundee University to devise the optimal solution. The lecturer brought together final-year students, Maunsell Structural Plastics, a design firm, and the contractor O'Rourke.

The collaborative effort culminated in a ground-breaking project named "Linksleader" in the shape of a 113-m-long, 63-m-wide span bridge. The towers and deck are constructed of FRP, the stay cables are made of Parafil aramid parallel-lay ropes, and the parapet railings are made of FRP. Only the connections between the deck and stay cables had to be constructed with aluminium. Initially, the bridge was intended to support a pedestrian load of 5.6 kN/m. On 3 October 1992, the Aberfeldy Bridge was officially opened. It was the world's first FRP structure, winning the Saltire Award for Civil Engineering Design in 1993, explaining the high level of interest in its wear and tear technical condition. The University of Edinburgh assessed the building's technical situation twenty years after it was built. The findings revealed only modest indications of wear, mainly on the handrail and the exposed surface layer of glass fibres. All of these losses were promptly rectified, allowing for continued functioning for years to come. The main issue was that basic repairs were not done by experts and instead included screwing new components into place, resulting in damage [10–14].

Composite bridges have exploded in popularity worldwide in recent years due to their ability to combine the advantages of steel and concrete bridges. The primary benefits are lightweight construction, which reduces the stress on fasteners and supports and builds quickly utilising light construction equipment. To summarise, if the composite bridge is constructed correctly, it will be cost-competitive with concrete bridges with small and medium support spacing and steel bridges with support spacing up to 120 m [15–17].

Composite materials reinforced with glass and carbon fibre have high durability, sometimes up to 150 years [18], and are also resistant to degradation; on the other hand, there is a need for composite materials with a much shorter lifetime, e.g., 10, 15, or 25 years, for use in an internal vehicle or aeroplane equipment. It is for these purposes that the so-called "short-life composite materials" are developed. Natural fibres such as sisal, jute, linen, hemp, wood grain, ram, bamboo, cotton, or coconut fibres have been considered as reinforcement.

The cutting-edge technology of the twenty-first century is now focused on composites, namely, on so-called nanocomposites. These are materials that have a nanometre scale in at least one component. Carbon nanotubes are often utilised as reinforcement in composite materials. They enhance the product's mechanical, thermal, and electrical characteristics. [19].

2. Composite as a Material

It is difficult to find an unambiguous definition of composite material in the literature, perhaps because it originated from various science and technology fields. The term which can be found most often states that a composite is: a material composed of at least two components (phases) with different properties, connected in such a way that when joined, it has other (usually better) properties compared to the components used separately. This definition is generally supplemented with a provision concerning the nature of the connection of the composite elements, which should occur at the macroscopic level [20–22].

Another often-used definition is one proposed by Lawrence J. Broutman and Richard H. Krock in 1967, according to whom composites are materials characterized by four features:

1. made by humans,
2. consist of at least two different (in terms of chemistry) materials with clearly marked separation boundaries between the components,
3. components of the composite create it by taking part in its entire volume,
4. have properties different from its members [23].

Over 3000 years ago in Mesopotamia, the first composites were produced when strips of wood were bonded together at various angles to make the first plywood (Figure 2). Straw and mud were employed to reinforce the walls of houses (Figure 3) less than 1000 years later. In our age, the Mongols developed composite bows composed of wood, bamboo, bovine tendons, and silk lined with pine glue; these bows increased the strength of the arrow shooting by a factor of ten.

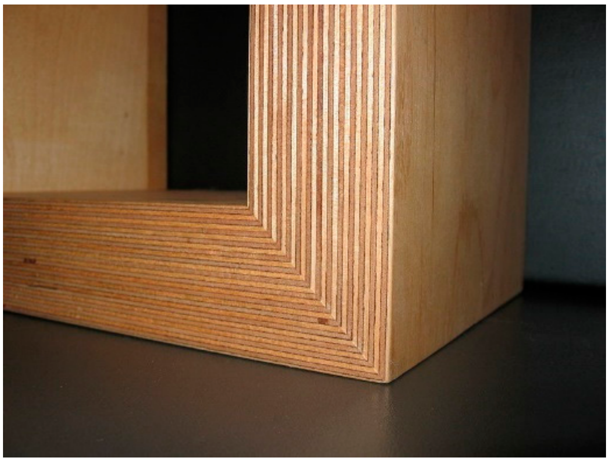

Figure 2. Plywood [24].

Figure 3. Bricks are made out of straw and mud [25].

At the turn of the twentieth century, the industrial revolution and the development of the polymerization process enabled the production of synthetic resins. When the capability of producing glass fibres was discovered in the 1930s (by the Owens Corning company), it resulted in the invention of a composite material combining these two materials, resulting in the creation of a composite that is still in use today (glass reinforced polyester).

The actual career of composites started in the second part of the twentieth century. Carbon fibres were discovered in the early 1960s, followed by the development of mats and roving fabrics made of glass and carbon fibres; later, in the 1990s, the production of so-called multi-axial carpets evolved, resulting in previously unheard-of strength parameters for composites made of polyester and epoxy resins [26].

3. Different Applications

The end of the twentieth century and the dawn of the twenty-first century saw tremendous technological advancement in creating composites, which swept into our lives and permanently altered them. Composites are utilised in almost every aspect of our life as a building material. Civil engineering, infrastructure, pipe and tank construction, offshore construction, aerospace structures (Figure 4), yachts and boats, and sanitary facilities are only a few examples.

Figure 4. Assembly line of Boeing 787 Dreamliner [27].

Composites are lighter than conventional materials and stronger; for example, carbon composites based on epoxy resins may have up to five times the strength of steel while weighing just 20% of the weight. As a result, composites are categorized as highly excellent building materials. Additionally, they exhibit resistance to material corrosion, exhibit strong chemical and thermal resistance, are effective insulators, and often exhibit characteristics not seen in other readily accessible building materials [28]. However, composites are simple to shape, robust and have a high impact strength. They also provide design freedom. Additionally, they are often less expensive than some metals.

4. The Main Challenge with Traditional Materials on the Example of Pipes

For centuries, pipes were constructed using steel, ductile iron, stoneware, bricks, and concrete. These materials react with water and sewage, resulting in corrosion and a life of 0–50 years. Micro-organisms induce decay in a variety of materials, including conventional pipe materials. In slime and sewage sludge, bacteria break down organic and inorganic sulphur compounds, creating hydrogen sulphide (H_2S). When coupled with oxygen (O_2), sulfuric acid (H_2SO_4) is formed, corrosive to the interior pipe surface (Figure 5).

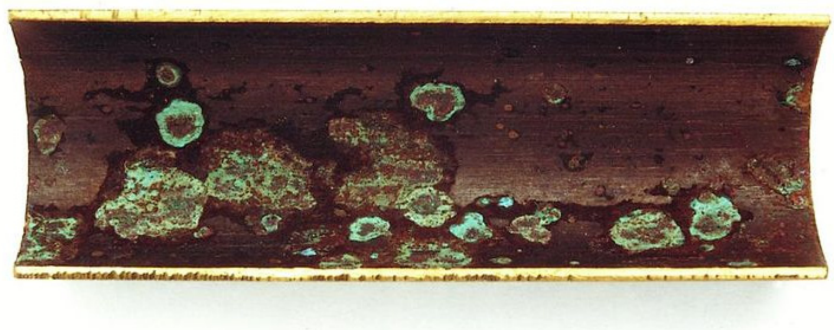

Figure 5. Section of brass tube with visible corrosion [29].

In certain instances, the conditions may be so severe that they accelerate the corrosion and degradation of certain materials. In other cases, the sewage is less aggressive and degrades more slowly.

5. Properties of Composite Pipes

In the mid-twentieth century, it was discovered that composite pipes resisted corrosion and deterioration of the pipe material very effectively. Glass-fiber reinforced plastic (GRP) pipes were introduced into the market in the late 1960s. Polyester resins, glass-fibre reinforcement (continuous or chopped), and fillers are used as raw materials in pipes (usual quartz). Continuous filament winding, centrifugal casting, and cross winding are all available manufacturing methods. Norms and standards define standardised performance criteria. GRP pipes have a very long-life cycle, which is as much as 150 years. A series of long-term tests, mostly strain corrosion, are performed to demonstrate these values, and using regression analysis, a significantly longer life cycle time may be predicted.

These tests are carried out by ISO 10952, which specifies a method for evaluating the strain corrosion characteristics of glass-reinforced thermoset plastic (GRP) pipes and fittings under deflection circumstances. To give complete test results after a defined time, an ISO 10928 regression analysis must be performed. The line must be tested using a machine that delivers a vertical force to opposing sides of a 600 mm wide and 300 mm long pipe to mimic horizontal stress over at least 10,000 h of exposure to 5% sulfuric acid (Figure 6).

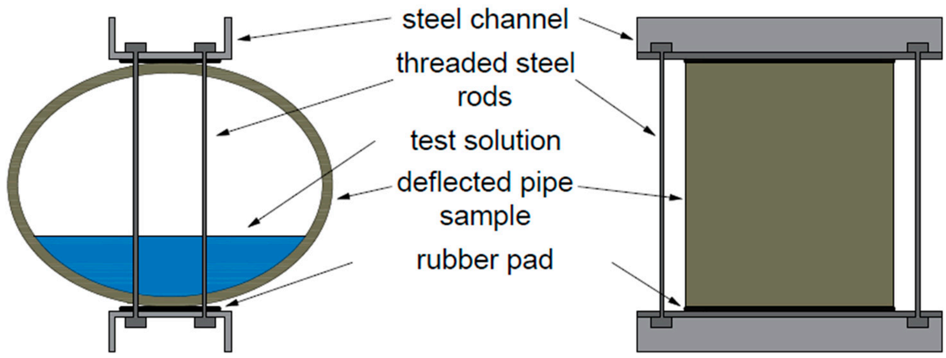

Figure 6. Typical test sample: pipe DN600 with a 5% sulfuric acid (H_2SO_4) test solution simulates the natural state in wastewater; adapted from [18].

A typical set of tests comprises 18–25 samples drawn from a single manufacturing batch and exposed to various degrees of stress. After applying the load to the sample, the stress is recorded, and the sample is treated under controlled circumstances until it is damaged, which may be recognised as pipe wall leaking. Assume that at least one data point has a length of 10,000 h and that the other data points are dispersed evenly throughout time with a sufficient correlation coefficient. We may confidently use the classical/legitimately employed statistical techniques to half a century in such a scenario (Figure 7).

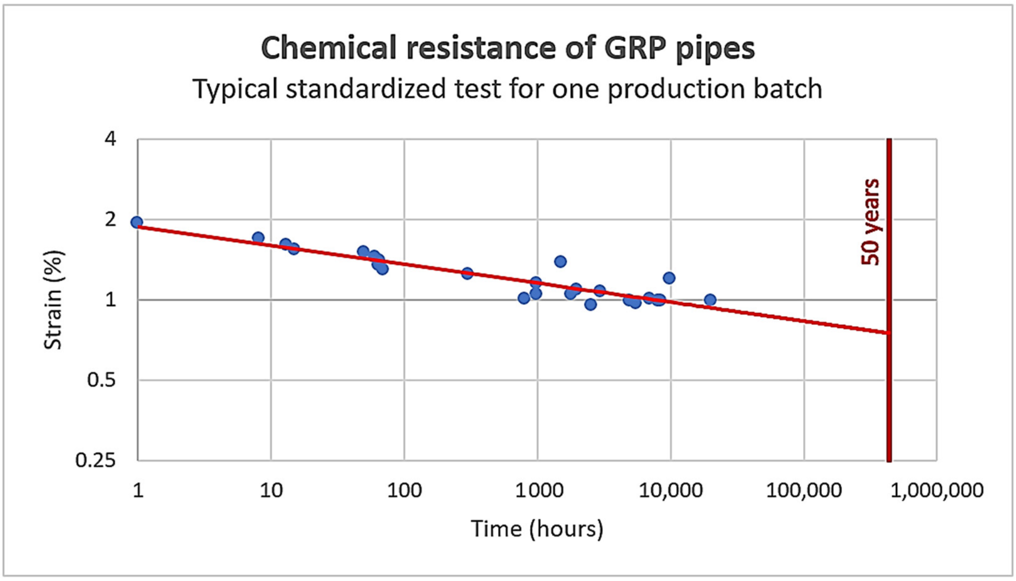

Figure 7. Typical Flowtite pipe tests: The horizontal axis is the time to failure, and the vertical scale is the strain on a logarithmic plot. Each sample on the graph represents a pipe that was put under strain until it failed. According to the statistics, a straight line that fits the data is calculated. 438,000/0.67% with typical long-term deflection of 3% (resulting in 0.27% for current designs), the calculated margin is approximately 2.5%; adapted from [30].

With test data gathered over a more extended period and considerably bigger sample size, regression analysis for a 150-year service life may be given. It turns out that GRP pipes will easily survive this service life. When comparing various pipes made of different materials, the pipe's service life is often the deciding factor. It should not be less than 50 years for all accessible materials; nevertheless, the service life criterion is not apparent when considering environmental sustainability.

Since the late 1990s, researchers have analysed the products' life cycle assessment, such as water transmission pipes. A life cycle assessment is required to ascertain the extent and distribution of a product's environmental burdens [31].

However, these investigations could not provide conclusive evidence about whether pipe materials are superior or inferior. It is essential to use similar boundary conditions to split the life cycle into distinct stages, such as raw materials, energy consumption, transportation, installation, and usage. This split enables the identification of environmental stressors and their distribution throughout distinct stages. We may then construct an environmental indicator known as the "global warming potential" (GWP) or the "climate change" indicator, where the measurable number (kg) represents the CO_2 equivalent emission for each phase.

It is critical to offer research-based comparisons of specific pipe materials, including diameters, pressure ratings, and stiffness classes. Pipes must be capable of withstanding specific external loads—both dynamic and static. Additionally, they must exhibit specific long-term characteristics like strain corrosion, bending in moist circumstances, and so on. Additionally, the unit pipe weight, the installation technique, and the ground conditions all play a role for particular installations.

If we take into consideration only two pipe materials, this means GRP and PVC; first of all, we will have to define the contribution to selected environmental indicators for both materials (Tables 1 and 2).

Table 1. Contributions to selected environmental indicators—GRP, adapted from [7].

Category	Raw Material	Energy	Transportation
Climate change (kg $CO_{2\ EQ}$)	1278	61	274
Mineral depletion (kg FE $_{EQ}$)	50	0.4	12
Fossil fuel consumption (kg Oil $_{EQ}$)	570	18	100

Table 2. Contributions to selected environmental indicators—PVC, adapted from [7].

Category	Raw Material	Energy	Transportation
Climate change (kg $CO_{2\ EQ}$)	5576	318	212
Mineral depletion (kg FE $_{EQ}$)	14	2	9
Fossil fuel consumption (kg Oil $_{EQ}$)	1726	93	77

This analysis (Figures 8 and 9) shows how different environmental sustainability is for both materials; PVC accounts for the most significant proportion of CO_2 equivalents, while GRP is much lower, about four times PVC [7].

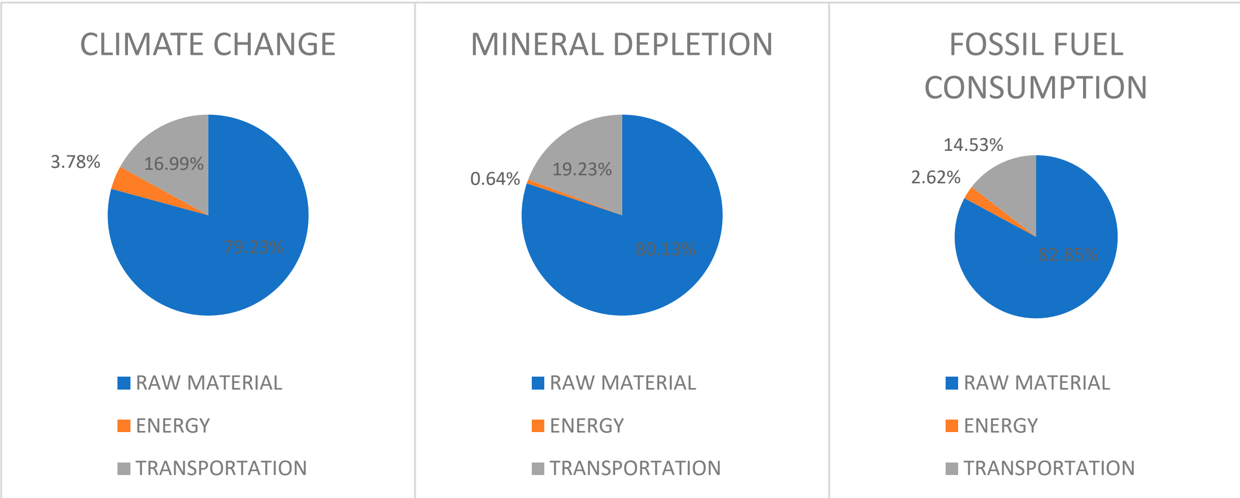

Figure 8. Distribution of the impact of the various life cycle phases—GRP, adapted from [7].

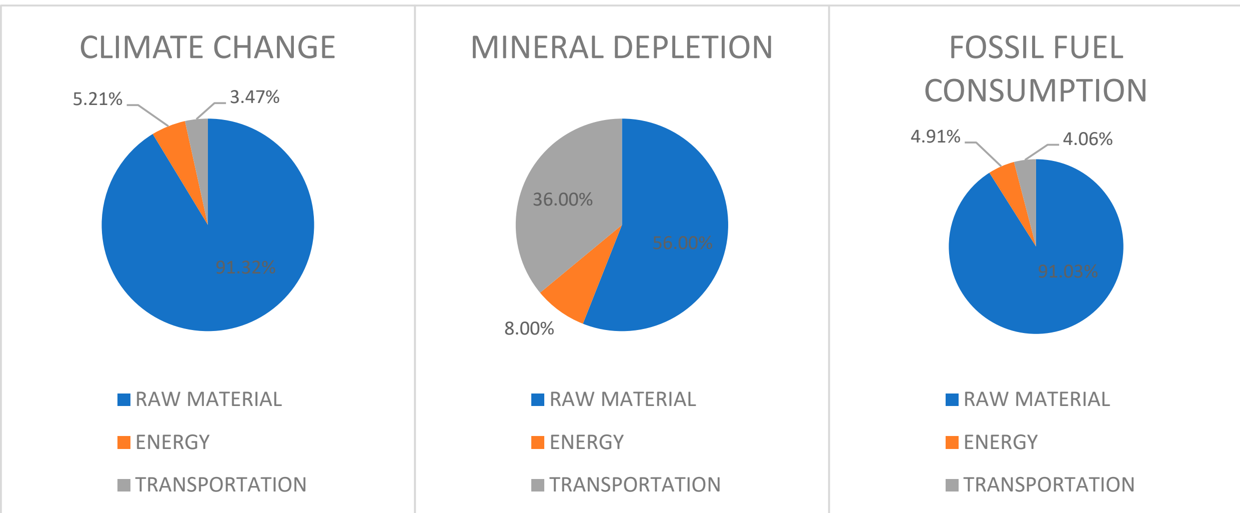

Figure 9. Distribution of the impact of the various life cycle phases—PVC, adapted from [7].

More interesting is a further comparison between ductile iron, PE, PVC, and GRP (Figure 10) regarding climate change's environmental indicators. The impacts associated with plastic-based materials are disproportionately concentrated in the raw materials life cycle phase. PE and PVC are the most significant contributors, both in terms of raw materials and total contribution. The raw materials life cycle process is where ductile cast iron contributes the least. Still, its impacts on the energy and transportation life cycle processes are more significant than the combined contributions of the other three pipe materials. The emissions share of GRP pipe is less than 2000 kg CO_2 equivalents, which is approximately half that of ductile cast iron pipe, which has the second-lowest overall contribution [7].

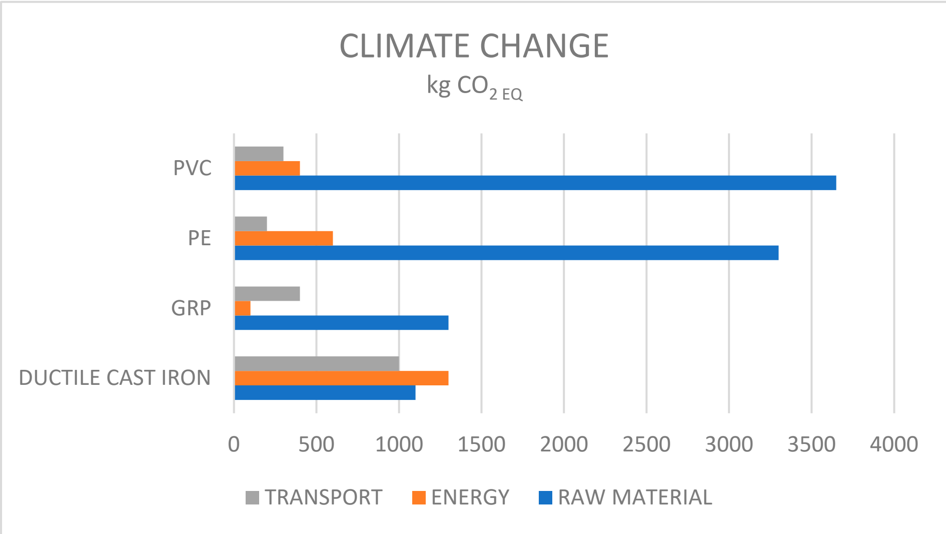

Figure 10. Impact of the pipe materials on the environmental indicator climate change, adapted from [7].

6. Hydropower—The Source of Renewable Energy in Norway

Norway is regarded as one of the most environmentally-friendly nations in Europe. Over 95% of energy is generated from renewable sources, primarily hydroelectric power plants. The water supply pipeline—so-called penstock—plays a critical role in addition to the turbine. Since the 1970s, Norway has utilised composite material pipelines, which are inexpensive to manufacture using the minimal amount of energy required in the manufacturing process and are very light, robust, and have low hydraulic resistance.

Pipelines built at the time continue to operate to this day, and after 45 years of repeated durability testing, they show no indications of age, retaining all mechanical parameters. Norway's inland waterways are home to a total of 31 GW of installed capacity, producing 144 TWh of renewable energy, while the country's hydropower and dam infrastructure is on average 46 years old.

They will necessitate upgrading both the central turbine systems and penstocks, and the natural choice for replacement is, if necessary, composite pipes. To minimise disruption to the natural landscape, composite lines are typically coloured as invisible as possible—a sample of this approach is the Safa Kraftverk project (Figure 11). The great advantage of composite pipes is their relatively low weight, which enables transport (Figures 12 and 13) and installation (Figure 14) of the line in an unconventional way. Additionally, the Nordic system is linked to several other nations through high-voltage direct current transmission lines. Sweden has direct existing connections to Germany and Poland [32].

Polish net imports hit a record high of 13.1 TWh in 2020. Poland imported 14.7 TWh, the majority of which came from Sweden (3.9 TWh). For the first time in history, the quantity of energy purchased from two other neighbours—Germany (3.5 TWh) and the Czech Republic (3.1 TWh)—was comparable to cable imports under the Baltic Sea last year. Poland purchased 2.3 terawatt-hours from Lithuania, 1.5 terawatt-hours from Ukraine, and 0.4 terawatt-hours from Slovakia. Poland purchased approximately PLN 3 billion worth of energy from overseas in total. By contrast, Poland's surplus of goods exports in the first 11 months of the previous year surpassed PLN 50 billion [33].

Figure 11. Safa Kraftverk project [18].

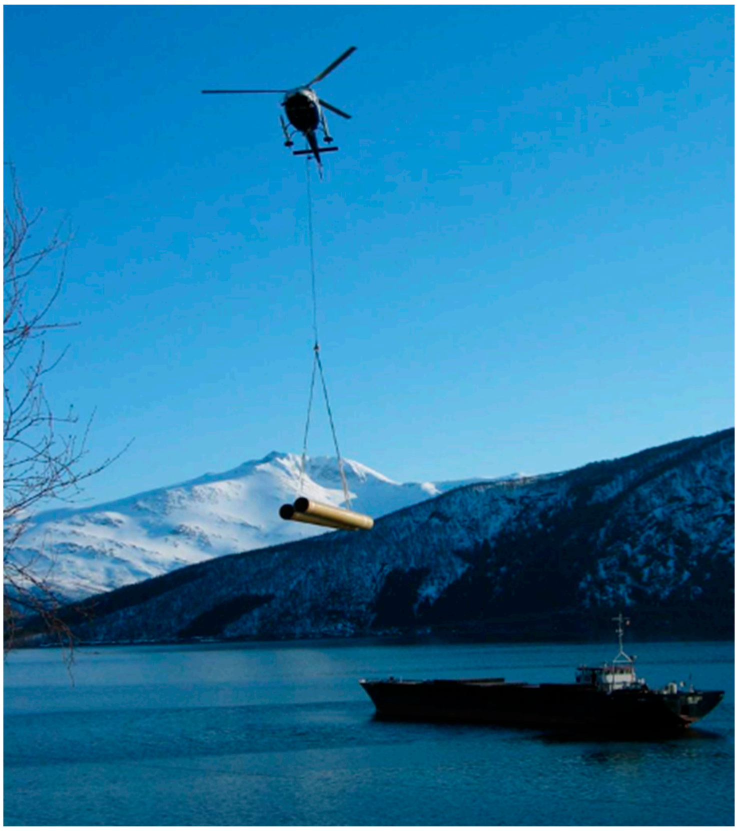

Figure 12. Unloading of pipes by helicopter [18].

Figure 13. Pipe supply during winter time [18].

Figure 14. Installation of pipes from barge [18].

7. Renovation of Old Channels in the City of Los Angeles

Another sample of ecological and environmental-friendly approaches is the use of composite materials to redevelop old sanitary sewers. Los Angeles currently manages and operates one of the world's most extensive wastewater collection and treatment facilities, with over 6500 miles of canals and four wastewater treatment plants capable of treating 550 million gallons of wastewater each day. A sanitary sewer system in Los Angeles started in the 1870s and continued till the 1950s.

Many of these older sewer networks are nearing the end of their service life and will need to be repaired or replaced to serve Los Angeles residents. Recent work on "non-circular canals" includes projects in the section of Central Outfall Sewer (C.O.S.) and North Outfall Sewer (N.O.S.) at a length of approximately 100 km (Figures 15–19). The efficiency of pipe relining reaches up to 600 m per day.

Los Angeles and the state of California have the strictest requirements concerning the qualification of these types of installations, not only in the U.S.A., but also abroad, and the choice of this modern technology of composite structures as a promising material for channel renovations with the use of advanced static calculation methods is very significant.

Figure 15. Unloading and transportation of segments of pipe on-site [34].

Figure 16. Installation access pit with stored segments of non-circular pipeline [34].

Figure 17. Lowering the segment into the pit [34].

Figure 18. Aligning the segment with the host pipe [34].

Figure 19. Installation of the segment into the host pipe [34].

8. Green Composites

While composite materials are still considered novel, they have been extensively used for more than 70 years. They are often composed of polymeric materials that have been reinforced with glass or carbon fibres.

Over this lengthy period, it has been observed that the life cycle of these goods is often longer than their usefulness, which is sometimes seen as a negative rather than a benefit since ecological integrity requires effective recycling. There are limited options for disposing of non-biodegradable glass fibre-based composites. They may be recycled into lower-grade goods, burned for energy recovery, or disposed of in a landfill. Regrettably, the most cost-effective method of disposal at the moment, and therefore the chosen method, is landfill storage. This, coupled with the material's remarkable resilience, exacerbates landfills' already significant adverse effects on the environment. Reprocessing is only applicable to thermoplastic composites that can be granulated and then reprocessed through injection moulding. Finally, incineration is the most sustainable form of disposal, but it is also the most expensive, and the burning of petrochemical-based composites emits extra CO_2, making the process environmentally harmful. It is worth mentioning that the burning of biocomposites that do not include petrochemicals does not result in any additional CO_2 emissions but results in almost three times fewer net energy benefits at 8.3 MJ per kg, compared to 21.5 MJ per kg for polypropylene composites [35]. One of the primary benefits biocomposites offer over conventional composites is their biodegradability. This is the most environmentally beneficial way of disposal by a long shot.

Additionally, it has also been noticed that the waste of polymeric materials reinforced with glass fibres has accumulated, hence the idea of replacing the classic reinforcement of composites with materials of natural origin called green fillers, which are widely available and easily degradable. The resulting thermoplastic polypropylene or polyethene composites reinforced with, for example, hemp, flax, or sisal fibres, have weaker mechanical properties but also lower specific weight—to be exact, their density equals 0.9 kg/m^3 compared to 1.8 kg/m^3 in case of polymer composites with glass fibres. They are also fully recyclable, with much lower energy consumption than glass composites [36].

Because biocomposites are not as durable as their glass or carbon fibre counterparts, they cannot be used as a construction material for structural elements. Instead, they are used as interior parts for cars (Figure 20) and aeroplanes. They are cheaper to produce than regular composites and lightweight and scratch-resistant, which are beneficial for interiors.

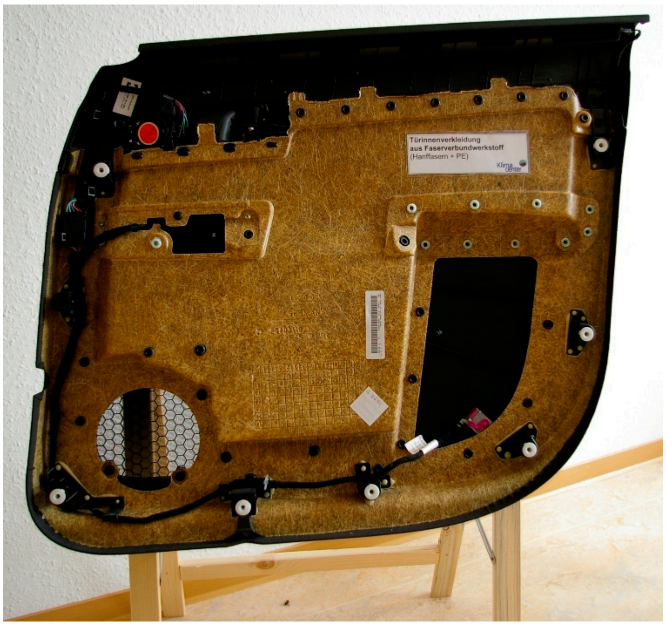

Figure 20. Biocomposites in the automotive industry [37].

Lately, some biocomposites are also used instead of wood to produce musical instruments. In particular, biocomposites with flax fibres are used to replace tropical wood such as ebony. The main advantage here is that the composites can be indistinguishable from the wood, both in wood's pleasant "feel" and the resonating qualities wood provides to instruments. It is easy to see a positive impact on the environment with such a solution because bio-composites are considered eco-friendly and contribute to lower wood usage.

In addition to vehicle interiors and music instruments, biocomposites found application in aerospace in the form of "aerospace cork", whose primary purpose is to prevent parts of the shuttle from overheating during launch [38]. This kind of high-tech application proves that biocomposites are as viable a material as traditional composites. It is important to remember that green alternatives of common materials are sometimes disregarded as inferior to be easily recyclable.

It is worth noting that biocomposites may also be used to construct boats. Although it is not a widely adopted option, the German firm "GREENBOATS" has brought biocomposites-based boats to the market. Typically, composite boats are constructed from glass or carbon fibre composites. The business makes use of a biocomposite made of flax fibres. Flax fibres are the most tear-resistant natural fibres and exhibit comparable stress and buckling properties as glass fibres. Additionally, linseed oil can be obtained from dried seeds of the flax plant. It is essential because the harvested oil can replace the oil base in epoxy resins, contributing to the sustainability of flax fibre-based composites. Another essential element of the boat's construction is cork harvested from trees cultivated for that purpose without cutting them (the cork is peeled every 9 to 12 years which does not damage the trees). Cork is a crucial part of the boat's exterior because its water-repellent properties provide a significant advantage in the event of a leak. Currently, boats built by "GREENBOATS" company are made of 80% renewable materials, but as stated on the company's webpage, the goal is to get as close to 100% as possible [39].

Last but not least is the matter of volatile organic chemicals (VOCs). Traditional composites release them and, in closed spaces where their concentration can get high, contribute to lower air quality and, in consequence, may negatively impact human health [40]. This issue now is more important than ever with the current pandemic and people who isolate themselves in their households. Many biocomposites do not release any VOCs; that is why they should be more commonly considered interior parts of cars, aeroplanes, and home interiors.

Apart from their sustainability benefits, the primary reason biocomposites are used in vehicle interiors is their lighter weight than conventional composites, which provides several benefits such as reduced fuel consumption and improved power efficiency, with the absence of VOCs considered a bonus. However, in civil engineering, the weight of the structure is irrelevant, and in this case, the improved interior air quality that biocomposites offer over conventional ones becomes a significant benefit.

9. New Areas of Research

At the moment, successful research is being conducted on another kind of composite—polymer nanocomposites. These are materials in which at least one component has a nanometric size of 10^{-9} m. They are constructed of polyethene, polystyrene, polypropylene, epoxy resins, or polycarbonate, depending on the material. The reason nanocomposites are so appealing is their molecular level controllability.

It is also important to mention some new technologies like wavy composites, variable angle tow composites, the possibility of 3D printing, and topological optimization. A wavy composite is an emerging form of constrained layer damping that uses standard fibres, resins, and viscoelastic materials in a new configuration to provide both high damping and stiffness. The FEA modelling and prediction, testing, and material selection provided several vital discoveries related to the properties of this new material. Using damped wavy composites, it is possible to produce structures with the stiffness of steel, graphite composite weight, and damping properties (30% was measured, and as much as 50% is expected for high modulus fibres). Corrugated composites exhibit exceptional damping properties when excited by thrust, shear, and bending loads [41].

Variable angle tow (VAT) composite laminates with continuously varying fibre orientations across each ply plane provide variable stiffness qualities. Fibre orientation distributions are used to adjust the stiffness of VAT plates. Because of the mild, non-uniform, in-plane load redistribution, it can significantly enhance buckling resistance. Variable angle tow placement permits fibre orientations to alter with position across a ply's whole plane, resulting in varied in-plane stiffness qualities [42].

Currently, shape optimization is a vital tool in modern industrial design. Simply put, it is a method used to optimize the layout of material in a design space. This is particularly evident in the aviation industry, which has made significant progress, e.g., in optimizing the shape of aircraft, both in terms of achieving lower and lower air resistance and decreasing weight while increasing strength properties. In the case of composites, topological optimization (mainly due to lack of predefined configurations as opposed to conventional products) is more popular, which is a mathematical method that describes and optimizes the material arrangement in a given design space for a given set of boundary conditions, loads, and constraints to maximize system performance. Topology optimization has a wide range of applications in the automotive, aerospace, biochemical, and civil engineering industries and is generally applied at the concept level of the design process [43].

More and more companies have been using 3D printing technology to manufacture composite parts in recent years. The main advantage of this approach is a fully automated process which significantly cuts down the time needed to produce each part. In addition, this method is very efficient in manufacturing complex designs based on computer 3D geometries.

An important aspect to consider while focusing on composite 3D printing is reinforcement materials because composites manufactured using this method are often used for lightweight and robust parts. The reinforcement is made out of fibres which increase the strength of the product without increasing its weight. There are two types of support, short fibre or continuous fibre. The cut, short fibres consist of segments less than a millimetre long, mixed with a resin to increase the stiffness, slightly reducing the strength of the elements. The print quality is influenced by the proportion of chopped fibres to the matrix material. However, the highest efficiency is guaranteed by continuous fibre reinforcement, which makes the product's mechanical properties comparable to steel with a significantly lower weight.

In the industry, carbon fibres, glass fibres, and Kevlar are widely used as materials to strengthen composites. Glass fibres are the cheapest option. At the same time, Kevlar has the highest resistance to vibration and shock, which makes composites based on it more flexible and less brittle than those with glass fibre reinforcements. However, carbon fibres reinforced composites are the most widespread in the 3D printing industry. Among other things, they are often used as bike frames [44].

10. Perspectives

Composites are already a ubiquitous material used in various industries. Low weight, high durability to mechanical stress and environmental conditions combined with the ability to adjust specific characteristics to fit the application make them unique and valuable construction materials. As an example, Alen John et al. [45] describe composites in the automotive industry. They are already used as car bumpers, but there is also potential for use in other vehicle parts such as suspensions or even brakes. Another exciting application of composites in earthquake-resistant buildings was proposed by Md Iqbal Ahmad et al. [46]. Cement composites reinforced by fibres can be used as an alternative to the reinforced concrete frame of such facilities. It is a crucial issue in some parts of the world located in areas prone to earthquakes.

It is important to note that biocomposites are more sustainable than conventional composites in some applications since they are composed of natural fibres and oils rather than petrochemical-based components. According to M.R. Nichols et al. [40], if current fossil fuel use continues, petroleum will run out in 40 years, and coal will run out in 70 years. That is why it is critical to reduce consumption, if not eliminate it completely. Biocomposites seem to be an excellent solution to this issue. A. Balaji et al. [47] believe that the use of bagasse fibre-based biocomposites will revolutionise future generations' lifestyles. Biocomposites will become a staple of most people's lives when new, undeveloped biocomposites and more efficient manufacturing technologies become available. Gradually, due to their availability and cheap cost, biocomposites will be used in more and more areas of life.

Subash et al. [48] emphasized the application of biocomposites in interior of aircraft and automobile constructions such as cabin linings, seat cushions, and shelving. They are vital for these sectors, and biocomposites based on fibres, such as bagasse and bamboo, coir, sisal, kenaf, and jute, seem to have tremendous promise.

Although, we cannot anticipate biocomposites to completely replace conventional composites (where appropriate) during the next several years. However, many companies are already working to bring eco-friendly and sustainable goods to market. Consider the distinct material advantages that bio-composites have over traditional materials, namely, their lightweight, lack of volatile organic compounds, and, of course, biodegradability. There is no doubt that bio-composites will see a significant increase in production in the coming years, particularly in the construction and manufacturing sectors of the market. M.R. Nichols also predicts in her paper that the biocomposite business will be valued at more than USD 40 million by 2025.

11. Conclusions

In today's world, it is clear that we must take the most excellent possible care of our environment, and the Green Deal Implementation program offers an opportunity for future generations to enjoy a clean environment, fresh air, pure water, and the beauty of nature as well. The conclusion drawn from the available analyses is that one of the best materials that fit directly into the Green Deal philosophy, enabling the development of green technologies, the creation of a sustainable industry, transportation, and thus a clean environment, are various types of composites, both those with the highest durability—used for example in pipe sewage systems—and those that are easily degradable. Comparative analyses of the production of comparable sewage pipes made of various materials, including cast iron, PE, PVC, and GRP, using the so-called Global Warming Potential (GWP) index, reveal that composite pipes emit the least CO_2 equivalent—twice as little as cast iron pipes and four times as little as PVC pipes, with a service life of up to 20 years. As a result, one can safely assert that composites based on glass fibres will be the industry's future material.

On the other hand, there is a strong demand for composite materials with a relatively limited life span and that are readily biodegradable. They are resins composed of synthetic and biological components—unsaturated polyester or epoxy resins on a physical foundation (using cashew nut shell extract or soybean oil). Natural fibres, such as jute, hemp, or linen, are often utilised as reinforcement. Due to the much-reduced energy consumption and CO_2 emissions required to manufacture, these biocomposites have a considerably lower environmental effect than those produced using glass reinforcements. Additionally, research on composites has shown that resins have a significantly more significant impact on the environment. As a result, considerable emphasis is being placed on the development of biopolymers. Natural composites are extensively utilised in a variety of industries, including automotive, aviation (passenger cabin equipment), building (composite boards, garden furniture, doors, and shelves, among others), and the broader sports and leisure sector (camping, sports equipment). Due to the increasing demand for ecologically friendly materials from consumers and designers, the continued fast development of new technologies and materials of this kind should be considered.

In the long run, given the global community's rising awareness of the need for sustainable development, we will see an increase in demand for composite materials of different kinds, as they are the most ecologically benign and align precisely with the Green Deal's implementation concepts.

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References

1. Available online: ec.Europa.eu/info/strategy/priorities-2019-2024/European-green-deal_en (accessed on 30 April 2021).
2. European Commission. *Europe 2020: A Strategy for Smart, Sustainable and Inclusive Growth*; European Commission: Brussels, Belgium, 2010.
3. Available online: commons.wikimedia.org/wiki/File:Horyuji_temple_,_%E6%B3%95%E9%9A%86%E5%AF%BA_-_panoramio_(16).jpg (accessed on 15 September 2021).
4. Brol, J. *Rozwiązania Konstrukcji z Drewna i Materiałów Drewnopodobnych*; Builder: Wasrsaw, Poland, May 2016.
5. Available online: zawod-architekt.pl/pokaz/nie_bojmy_sie_drewna,733 (accessed on 19 October 2021).
6. Available online: budujzdrewna.pl/aktualnosci/clt-cross-laminated-timber-material-xxi-wieku (accessed on 19 October 2021).
7. Fjeldhus, K.S. Selecting Materials for Potable Water Pipes from an Environmental Perspective. Master's Thesis, Universitetet for Miljø- og Biovitenskap, Ås, Norway, 2012.
8. Knight, M.; Curliss, D. *Encyclopedia of Physical Science and Technology*, 3rd ed.; Academic Press: Cambridge, MA, USA, 2003; Volume 3, pp. 455–468.
9. Kitane, Y.; Aref, A.J. *Developments in Fiber-Reinforced Polymer (FRP) Composites for Civil Engineering*; Woodhead Publishing: Cambridge, UK, 15 May 2013.

10. Stratford, T. The Condition of the Aberfeldy Footbridge after 20 Years in Service, Structural Faults and Repair. In Proceedings of the Structural Faults and Repair 2012, Edinburgh, UK, 3 July 2012.
11. Cadei, J.; Stratford, T. The design, construction and in-service performance of the all-composite Aberfeldy footbridge. In Proceedings of the 1st International Conference on Advanced Polymer Composites for Structural Applications in Construction, Southampton, London, UK, 15–17 April 2002; pp. 445–453.
12. Harvey, W.J. *A Reinforced Plastic Footbridge, Structural Engineering International*; Structural Engineering International: Aberfeldy, UK, 1993; Volume 3, pp. 229–232.
13. Pimentel, R.L.; Waldron, P.; Harvey, W.J. *Assessment of the Dynamic Behaviour of Aberfeldy GRP Plastic Cable-Stayed Footbridge, Seminar on Analysis and Testing of Bridges*; Institution of Structural Engineers: London, UK, 1995; pp. 38–40.
14. Lee, D.J. *Project Linksleader: The First Major Cable-Stayed GRP Bridge*; FIP Symposium on Modern Prestressing Techniques and their Applications: Kyoto, Japan, 1993; pp. 671–678.
15. Pipinato, A.; De Miranda, M. *Steel and composite bridges. Innovative Bridge Design Handbook*; Butterworth-Heinemann: Oxford, UK, 11 November 2015.
16. Hollaway, L.C. A review of the present and future utilisation of FRP composites in the civil infrastructure with reference to their important in-service properties. *Constr. Build. Mater.* **2010**, *21*, 2419–2445.
17. Pavic, A.; Reynolds, P.; Cooper, P.; Harvey, W.J. *Dynamic Testing and Analysis of Aberfeldy Footbridge, Final Report Ref. CCC/00/79A*; The University of Sheffield, Edinburgh Research Explorer: Sheffield, UK, 31 July 2000.
18. Amiblu, Flowtite Norway, Flowtite Produkt Guide, Sandefjord. Available online: https://www.amiblu.com/wp-content/uploads/Amiblu-Product-Guide.pdf (accessed on 24 April 2021).
19. Available online: compositeslab.com/composites-101/history-of-composites (accessed on 30 April 2021).
20. Braszczyńska-Malik, K.N.; Pędzich, Z.; Pietrzak, K.; Rosłaniec, Z.; Sterzyński, T.; Szweycer, M. Problemy Terminologii w Kompozytach i Wyrobach Kompozytowych. *Res. J. Pol. Soc. Compos. Mater.* **2005**, *1*, 19–24.
21. Boczkowska, A.; Kapuściński, J.; Lindemann, Z.; Witemberg-Perzyk, D.; Wojciechowski, S. *Kompozyty Wydanie II Zmienione*; Oficyna Wydawnicza Politechniki Warszawskiej: Warszaw, Poland, 2005.
22. German, J. *Podstawy Mechaniki Kompozytów Włóknistych*; Wydawnictwo Politechniki Krakowskiej: Kraków, Poland, 2001.
23. Brautman, L.J.; Krock, R.H. *Composite Materials*; Academic Press: New York, NY, USA, 1975.
24. Available online: commons.wikimedia.org/wiki/File:Birke_Multiplex.JPG (accessed on 29 August 2021).
25. Available online: flickr.com/photos/randall_niles/5075375173 (accessed on 27 August 2021).
26. Available online: twi-global.com/technical-knowledge/faqs/what-is-a-composite-material (accessed on 17 July 2021).
27. Available online: commons.wikimedia.org/wiki/File:Jetstar%27s_first_787_on_the_production_line_(9132370198).jpg (accessed on 29 August 2021).
28. Ogin, S.L.; Brønsted, P.; Zangenberg, J. *Modeling Damage, Fatigue and Failure of Composite Materials*; Woodhead Publishing: Cambridge, UK, 2016.
29. Available online: commons.wikimedia.org/wiki/File:Korrosion_Rohr01.jpg (accessed on 16 November 2021).
30. Jonsson, H. *Amiblu Stream Magazine*; Flowtite Norway: Sandefjord, Norway, 2019.
31. Friedrich, E.; Pillay, S.; Buckley, C.A. *The Use of LCA in the Water Industry and the Case for an Environmental Performance Indicator*; University of KwaZulu-Natal: Durban, South Africa, August 2007.
32. Available online: hydropower.org (accessed on 10 August 2021).
33. Available online: wysokienapiecie.pl/35185-importujemy-coraz-wiecej-pradu-ratujemy-sasiadow-eksportem/ (accessed on 10 August 2021).
34. Czapla, A. Collection of author's own photo materials. 2019; (Unpublished Material).
35. Van Dam, J.E.G.; Bos, H.L. *Consultation on Natural Fibers: The Environmental Impact of Hard Fibers and Jute in NON-textile Industrial Applications*; ESC-Fibres Consultation: Rome, Italy, 2004.
36. Quarshie, R.; Carruthers, J. *Technology Overview Biocomposites*; NetComposites Ltd.: Chesterfield, UK, March 2014.
37. Available online: commons.wikimedia.org/wiki/File:T%C3%BCrinnenverkleidung_Hanf-PP_nova.jpg (accessed on 30 August 2021).
38. Partanen, A.; Carus, M. *Biocomposites, Find the Real Alternative to Plastic—An Examination of Biocomposites in the Market*; Reinforced Plastics; Nova-Institut GmbH: Stuttgart, Germany, December 2019; Volume 63.
39. Available online: green-boats.de (accessed on 20 July 2021).
40. Nichols, M.R. What Are the Benefits of Biocomposites? *Reinf. Plast.* **2020**, *64*, 326–327. [CrossRef]
41. Pratt, W.F.; Allen, M.S. *Designing with Wavy Composites*; Patterned Fiber Composites, Inc.: London, UK, 2000.
42. Wua, Z.; Weaverb, P.M.; Rajua, G.; Kima, B.C. *Buckling Analysis and Optimisation of Variable Angle Tow Composite Plates*; Thin-Walled Structures; University of Strathclyde: Glasgow, UK, November 2012; Volume 60, pp. 163–172.
43. Delgado, G. Optimization of Composite Structures: A Shape and Topology Sensitivity Analysis, Optimization and Control. Ph.D. Thesis, Ecole Polytechnique, Palaiseau, France, 2014.
44. Carlota, V. *The Complete Guide to 3D Printing Composites*; 3Dnatives: Paris, France, 2020.
45. Alen, J.; Sanu, A. A Review on the Composite Materials Used for Automotive Bumper in Passenger Vehicles. *Int. J. Eng. Manag. Res.* **2014**, *4*, 98–101.
46. Ahmad, M.I.; Mallick, R.; Chakraborty, S.; Guin, A.; Chakraborti, A. Composite Materials: The present scenario, future trends & its applications focusing on earthquake resistant building constructions. *J. Civil Eng. Environ. Technol.* **2015**, *2*, 65–69.

47. Balaji, A.; Karthikeyan, B.; Raj, C.S. Bagasse Fiber–The Future Biocomposite Material: A Review. *Int. J. ChemTech Res.* **2014**, *7*, 223–233.
48. Subash, T.; Pillai, S.N. Bast fibers reinforced green composites for aircraft indoor structures applications: Review, National Conference on Recent Trends and Developments in Sustainable Green Technologies. *J. Chem. Pharm. Sci.* **2015**, *7*, 305–307.