Mechanical recycling of single-component powdered epoxy prepreg waste for applications in polymer concretes

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ABSTRACT

Pre-impregnated fibers (prepregs) are one of the greatest challenges for material recycling. In this study, production-derived prepreg waste in amounts ranging from 0.1 vol% to 5.0 vol% was incorporated as reinforcement in an epoxy-based polymer concrete. The effects of prepreg content and aggregate ratio (sand-to-gravel) on the mechanical (flexural and compressive strength), structural and physical properties of the polymer concrete were evaluated. The thermal properties of the resin within the prepreg waste were investigated, alongside its bonding capability with the epoxy resin employed in polymer concrete production. A prepreg content of 3.0 vol% resulted in an approximate 50% increase in both flexural and compressive strength, attributed to structural reinforcement by short fibers. However, higher prepreg contents led to a marked increase in open porosity (from 0.17% to 6.22%) and, consequently, in water absorption at 5.0 vol% prepreg, which is undesirable. Statistical analysis identified the optimal prepreg content and aggregate ratio as 3.0 vol% and a 35:35 sand-to-gravel ratio, respectively.

Keywords: composites, prepreg, wastes, polymer concrete, materials.

INTRODUCTION

In recent decades, a dynamic increase has been observed in the production and use of polymer-fiber composites across numerous advanced and demanding industrial sectors, such as aerospace, space industry, automotive, railway, energy, construction, as well as sports and medical industries, among others. As composite production continues to grow, the amount of composite waste is also increasing. Such waste represents one of the most challenging materials to recycle due to its multi-material composition. Among the significant types of composite waste are prepreg wastes, which are semi-finished products in the composite industry composed of a fibrous fabric or mat (e.g., carbon, glass, or aramid fibers) impregnated with a thermosetting resin. The term "prepreg" originates from "pre-impregnated", reflecting their partially processed nature [1]. A characteristic feature is that the polymer matrix is only partially cured, and further curing takes place at later stages of production, e.g. using autoclave techniques [2] or the increasingly popular out-of-autoclave techniques [3–6].

Among the most commonly applied methods for the management of prepreg waste are long-term landfilling, incineration, and pyrolysis, each presenting environmental, economic, and technological limitations [7]. The landfilling of waste without a specific recovery purpose leads to environmental burdens and is economically unjustified [8,9]. Thermal processes such as incineration or pyrolysis involve high financial expenditures

associated with the construction and operation of the facilities [10–12]. Moreover, they are burdened with the issues related to the emission of toxic substances into the environment, either directly or indirectly, for example through the accumulation of harmful compounds in filtration systems [13–16]. Consequently, increasing attention is being directed toward simple material recycling methods that enable the reuse of waste as secondary raw materials, without the need for complex and costly processing operations.

One of the promising future-oriented approaches involves the use of prepreg waste as an additive in construction materials to enhance their properties. An especially interesting direction of development is polymer concrete, in which the traditional cement binder is replaced with synthetic resins. The substitution of cement with a resin binder allows for obtaining significantly improved properties, including higher mechanical and chemical resistance, as well as considerably lower water absorption, which directly translates into enhanced frost resistance [17,18].

In its basic form, polymer concrete is a composite material composed of aggregates bound together with a resin matrix, such as epoxy or unsaturated polyester resin. The incorporation of reinforcing fibers into the structure of polymer concretes has been shown to beneficially enhance their mechanical performance [19]. The use of prepreg waste in such composites may not only contribute to reducing the amount of composite waste in the environment, but also lead to improvements in certain functional properties of polymer concretes.

In the literature, various approaches to the management of prepreg waste can be found. Researchers primarily focus on prepreg scraps, which represent a typical by-product of composite manufacturing. Tomioka et al. [20] conducted studies on the pelletization of carbon fiber-reinforced polypropylene prepregs. The obtained pellets were subsequently used for injection molding, providing a simple, effective, and economical method for managing this type of waste. Such an approach is feasible for thermoplastic matrix; however, it is not applicable to thermosetting matrix, such as epoxy and unsaturated polyester resins. In the case of thermoset-based prepregs, researchers usually limit their efforts to pressing prepreg scraps or performing recycling using chemical methods. Material recycling carried out by cutting prepreg scraps and subsequently

pressing them into plate form was described by Zogg et al. [21]. The resulting plates exhibit a flexural modulus of approximately 17 GPa and a flexural strength of about 250 MPa, which, for commercial glass-fiber-reinforced composites, is sufficient to meet the performance requirements of commercial products. A similar methodology for processing uncured prepreg scraps into a consolidated composite was proposed by Nilakantan et al. [22]. They observed that, despite the high void content (above 2%), it did not adversely affect the mechanical strength of the laminate. One of the benefits they identified in recycling prepreg scraps was the shorter production time compared to virgin materials, as forming the waste material does not require lengthy vacuum cycles or debulking steps. Bianchi et al. [23], in turn, focused on the environmental impact of managing prepreg scraps, identifying the avoidance of landfilling and incineration as the most significant benefits. Smith and Hubert [24] reported a major challenge associated with prepreg waste in the aerospace sector, where, according to the authors, 30–50% of uncured prepregs become waste after cutting. They attributed this situation to inefficient cutting processes, fixed prepreg roll widths, and the limited shelf life of the material. The authors utilized prepreg waste to manufacture composites via compression molding, employing a flow-compaction method. Their process does not require the use of new resins or fillers. There are many similar solutions in the literature in which prepreg scraps are formed into functional products. Their common feature is that the product life cycle becomes closed, but only once, since further processing of the resulting waste into an equivalent product is no longer possible. An alternative to simple mechanical recycling processes is chemical recycling. An example of chemical recycling of prepreg waste is the study by Hanaoka et al. [25], in which carbon fibers were recovered using nitric acid. The analyses carried out demonstrated that, when properly conducted, the process makes it possible to obtain fibers in an almost undamaged form. Similarly, in the article by Ali and Asmatulu [26], chemical recycling of prepreg was described for the recovery of glass fibers using sulfuric acid, nitric acid, acetone, and distilled water. A potential limitation of chemical recycling is its negative environmental impact, as well as the fact that it often focuses solely on recovering the reinforcing fibers while neglecting the recovery of the composite matrix.

The aim of this study was to analyze the feasibility of utilizing glass-fiber-reinforced prepreg waste in the modification of polymer concretes and to describe the applied methodology, which includes waste preparation, the fabrication of polymer concretes with diverse formulations, and subsequent testing of the resulting materials. The study sought to demonstrate the economic and environmental potential of this approach, as well as to examine how the addition of such waste affects the functional properties of polymer concretes. In this way, the research contributes to achieving more sustainable production of composites and construction materials as well as supports the implementation of circular-economy principles within the polymer concrete sector.

MATERIALS AND METHODS

For the preparation of the polymer concretes, a typical LH288 epoxy resin (Havel Composites, Czech Republic) based on Bisphenol A was used, together with an LH636 hardener (MGS) (Havel Composites, Czech Republic) based on cycloaliphatic amines. The resin-to-hardener weight ratio was 100:35, and the resin crosslinking process was carried out at room temperature of approximately 20 °C for 24 h. Subsequently, the cured samples were post-cured in a laboratory oven at 70 °C for 12 h in accordance with the manufacturer's recommendations to ensure complete crosslinking of the resin.

Filler materials in the form of quartz sand (Kreisel, Poland) with a particle size range of 0.5–1.4 mm was used as the fine fraction, quartz gravel (Polskie Składy Kamienia S.C., Poland) with a particle size range of 2–8 mm served as the coarse fraction, and production waste from prepreg manufacturing in the form of 10 × 10 mm squares was added in a volumetric amount ranging from 0 to 5.0%. The prepreg production waste used in the study is a composite consisting of glass fiber and a one-component powdered epoxy resin. The compositions of the tested polymer concretes are presented in Table 1.

The polymer concretes were prepared using the casting method. The components were homogenized in predetermined proportions and then poured into silicone molds with dimensions of 160 × 40 × 40 mm. The density, open porosity, and water absorption of the tested materials were characterized using the water displacement method (Archimedes' method). Differential scanning calorimetry (DSC) was performed on the prepreg waste added to the material in order to determine the curing temperature in the prepreg and its glass transition temperature (Tg). The analysis was carried out using a DSC Q20 apparatus (TA Instruments, New Castle, USA). Mechanical strength tests were also performed. Flexural strength was determined using a support span of 150 mm and a loading rate of 10 mm/min. Compressive strength tests were conducted on cubes with dimensions of 40 × 40 × 40 mm at a compression rate of 5 mm/min. Both tests were performed in accordance with the EN 196-1 standard using an MTS-810 testing machine.

Thermal-derivative analysis (ATD) was performed on the tested material to determine the curing temperature of the resin. This made it possible to determine the temperature range in which the curing process occurs and to identify the peak temperature corresponding to the highest reaction rate.

To determine the fracture characteristics, the amount of voids, and their influence on the failure behavior of the material, fracture surfaces were examined using a stereoscopic microscope (Nikon, Tokyo, Japan), model Nikon SMZ 745T.

On the basis of the results, statistical tests were carried out to determine the influence of the selected groups of factors and their significance on open porosity, flexural strength, and compressive strength. A Tukey post-hoc test was applied, preceded by an ANOVA (Analysis of Variance) test.

RESULTS AND DISCUSSION

The DSC analysis was carried out on a sample with a mass of 6.20 mg. The heating rate in both cycles was 10 °C/min, while the cooling rate was 5 °C/min. On the basis of the DSC curve shown in Figure 1, it was determined that the exothermic peak appearing during the first heating – corresponding to the curing process of the resin in the prepreg – occurs at approximately 55 °C. The second-heating curve indicates that the glass transition temperature of the resin lies within the range from the onset of the curve inflection (approx. 107°C) to its endpoint (approx. 117 °C), which allows the Tg value to be estimated at about 113 °C.

Differential thermal analysis was performed on the tested polymer concrete samples, from which it was found that with a volumetric content of 35% fine aggregate, 35% coarse aggregate,

Table 1. Compositions of the tested polymer concretes

Sample	Fine aggregate (sand), [vol%]	Coarse aggregate (gravel), [vol%]	Pregreg waste, [vol%]	Epoxy resin, [vol%]
PC_0_55/15	55	15	0	30
PC_0_45/25	45	25	0	30
PC_0_35/35	35	35	0	30
PC_0_25/45	25	45	0	30
PC_0_15/55	15	55	0	30
PC_0.1_55/15	55	15	0.1	29.9
PC_0.1_45/25	45	25	0.1	29.9
PC_0.1_35/35	35	35	0.1	29.9
PC_0.1_25/45	25	45	0.1	29.9
PC_0.1_15/55	15	55	0.1	29.9
PC_0.5_55/15	55	15	0.5	29.5
PC_0.5_45/25	45	25	0.5	29.5
PC_0.5_35/35	35	35	0.5	29.5
PC_0.5_25/45	25	45	0.5	29.5
PC_0.5_15/55	15	55	0.5	29.5
PC_1.0_55/15	55	15	1.0	29.0
PC_1.0_45/25	45	25	1.0	29.0
PC_1.0_35/35	35	35	1.0	29.0
PC_1.0_25/45	25	45	1.0	29.0
PC_1.0_15/55	15	55	1.0	29.0
PC_3.0_55/15	55	15	3.0	27.0
PC_3.0_45/25	45	25	3.0	27.0
PC_3.0_35/35	35	35	3.0	27.0
PC_3.0_25/45	25	45	3.0	27.0
PC_3.0_15/55	15	55	3.0	27.0
PC_5.0_55/15	55	15	5.0	25.0
PC_5.0_45/25	45	25	5.0	25.0
PC_5.0_35/35	35	35	5.0	25.0
PC_5.0_25/45	25	45	5.0	25.0
PC_5.0_15/55	15	55	5.0	25.0

and 30% resin, the peak curing temperature of the LH288 epoxy resin is approximately 30.4 °C. The test results indicate that during the resin curing process the temperature does not reach a level high enough (approximately 55 °C) for the resin present on the surface of the prepreg to initiate post-curing. However, the tested polymer concretes were post-cured at 70 °C for 12 hours, which was sufficient to complete the post-curing of the resin in the prepreg waste. At the same time, the temperature was not high enough to exceed the glass transition temperature.

Table 2 shows the results obtained from testing the material using the Archimedes method. The apparent density of the tested materials ranged from 1.75 g/cm³ to 2.06 g/cm³. By comparing the obtained density values with the BS EN 206:2013 standard [27], it can be stated that the tested samples fall within the category of lightweight concrete (density < 2000 kg/m³) as well as normal-weight concrete (2000 kg/m³ < density ≤ 2600 kg/m³).

For the open porosity and water absorption, a statistical ANOVA analysis was conducted, with the results shown in Tables 3 and 4, which indicates that both prepreg content (hence resin volume ratio) and ratio of sand to gravel significantly impact open porosity and water absorption of polymer concrete. Further analysis using Tukey post-hoc test showed that usage of 5% prepreg content significantly increase both parameters. The observed sharp increase in open porosity in
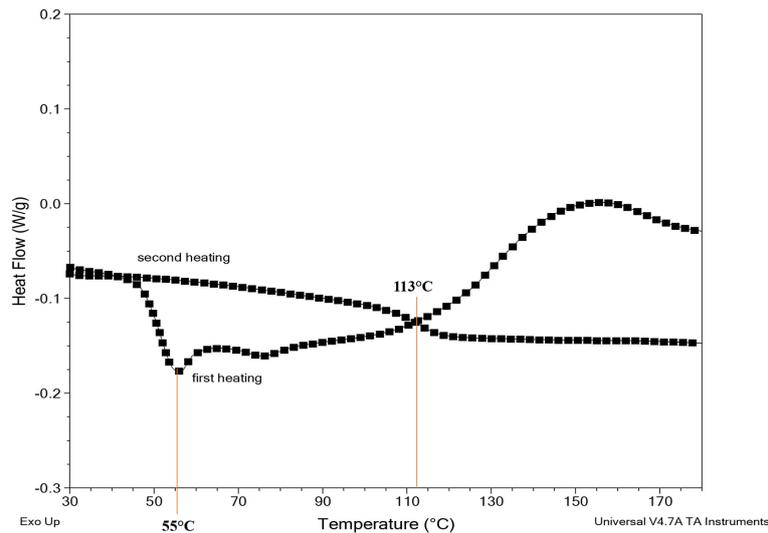
Figure 1. DSC curve of the resin in the prepreg waste

Table 2. Archimedes method results for polymer concrete

Sample	Water absorption, [%]	Apparent density, [g/cm³]	Open porosity, [%]
PC_0_55/15	0.25 (0.03)	1.86 (0.00)	0.47 (0.06)
PC_0_45/25	0.28 (0.05)	1.90 (0.02)	0.52 (0.10)
PC_0_35/35	0.30 (0.08)	1.94 (0.03)	0.58 (0.14)
PC_0_25/45	0.20 (0.04)	2.06 (0.01)	0.40 (0.08)
PC_0_15/55	0.12 (0.01)	2.04 (0.02)	0.25 (0.02)
PC_0.1_55/15	0.28 (0.03)	1.75 (0.01)	0.49 (0.06)
PC_0.1_45/25	0.14 (0.01)	1.97 (0.01)	0.28 (0.03)
PC_0.1_35/35	0.12 (0.02)	2.01 (0.01)	0.24 (0.04)
PC_0.1_25/45	0.13 (0.04)	1.98 (0.01)	0.26 (0.08)
PC_0.1_15/55	0.08 (0.03)	2.03 (0.04)	0.17 (0.05)
PC_0.5_55/15	0.18 (0.02)	1.85 (0.02)	0.33 (0.03)
PC_0.5_45/25	0.19 (0.04)	1.87 (0.02)	0.36 (0.08)
PC_0.5_35/35	0.17 (0.02)	1.93 (0.02)	0.33 (0.03)
PC_0.5_25/45	0.21 (0.06)	1.97 (0.03)	0.42 (0.11)
PC_0.5_15/55	0.13 (0.01)	2.01 (0.03)	0.27 (0.02)
PC_1.0_55/15	0.17 (0.04)	1.89 (0.01)	0.32 (0.09)
PC_1.0_45/25	0.15 (0.06)	1.92 (0.03)	0.29 (0.11)
PC_1.0_35/35	0.21 (0.07)	1.97 (0.02)	0.40 (0.12)
PC_1.0_25/45	0.22 (0.05)	2.00 (0.02)	0.43 (0.09)
PC_1.0_15/55	0.11 (0.04)	2.01 (0.01)	0.22 (0.07)
PC_3.0_55/15	0.10 (0.02)	1.96 (0.02)	0.19 (0.04)
PC_3.0_45/25	0.17 (0.08)	1.97 (0.01)	0.34 (0.15)
PC_3.0_35/35	0.17 (0.04)	2.00 (0.01)	0.34 (0.07)
PC_3.0_25/45	0.13 (0.02)	2.00 (0.02)	0.25 (0.03)
PC_3.0_15/55	0.52 (0.18)	1.99 (0.00)	1.04 (0.36)
PC_5.0_55/15	0.88 (0.22)	1.95 (0.02)	1.71 (0.42)
PC_5.0_45/25	0.87 (0.37)	1.99 (0.01)	1.73 (0.73)
PC_5.0_35/35	0.54 (0.21)	1.99 (0.01)	1.08 (0.43)
PC_5.0_25/45	1.48 (0.48)	1.96 (0.02)	2.91 (0.92)
PC_5.0_15/55	3.35 (0.36)	1.86 (0.03)	6.22 (0.58)

Table 3. Results of ANOVA analysis for open porosity

Parameter	DF	Sum of squares	Mean square	F value	P value
Prepreg content	5	70.07554	14.01511	22.98291	< 0.0001
Sand/Gravel ratio	4	8.82157	2.20539	3.61655	0.00923
Error	80	48.78445	0.60981	--	--
Corrected total	89	127.6816	--	--	--

Table 4. Results of ANOVA analysis for water absorption

Parameter	DF	Sum of squares	Mean square	F value	P value
Prepreg content	5	19.16412	3.83282	20.99687	<0.0001
Sand/Gravel ratio	4	2,55853	0.63963	3.50402	0.01092
Error	80	14.60341	0.18254	--	--
Corrected total	89	36.32606	--	--	--

the polymer concretes containing 5 vol% prepreg waste results from an insufficient amount of resin to ensure structural continuity of the material. The reduced resin content leads to the formation of voids, which is further intensified by the increased resin absorption by the glass fibers. The plot of open porosity as a function of prepreg content and the gravel-to-sand ratio is shown in Figure 2.

The materials were tested with respect to their mechanical properties. The flexural strength test showed that the strength varied widely, ranging from 20.1 MPa to 43.41 MPa. The results of all samples are presented in Figure 3.The lowest result was obtained for the mixture without any prepreg addition and with aggregate composed of 15% fine fraction and 55% coarse fraction by volume. The highest result was achieved when a 3% volumetric addition of prepreg waste was used together with 35% fine aggregate and 35% coarse
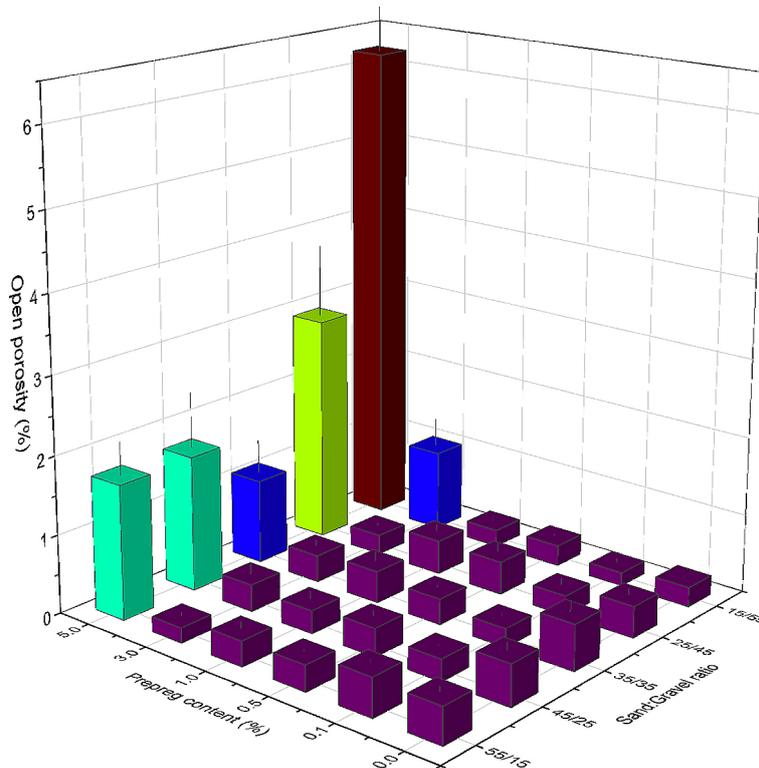
Figure 2. Open porosity results for different prepreg content and sand-to-gravel ratio

aggregate; these samples also reached the highest compressive strength values. Compared to the sample with the same aggregate ratio but without the prepreg addition, this represents an increase in flexural strength of approximately 80%. In the article by Vipulanandan et al. [28], it is also shown that the addition of glass fibers increases the flexural strength of polymer concrete, in this case based on polyester resin. In the article [29], where Babaie and others investigated the effect of steel and polymer fibers on the strength of concrete, the authors likewise concluded that fiber content increases the flexural strength of the material (Table 5).

The statistical analysis showed that both prepreg content and sand/gravel ratio have a significant impact on flexural strength. By using Tukey post-hock test it was determined that at least 3% of prepreg is necessary to observe a significant change. Also, sand/gravel ratio 15/55 has significantly lower values of flexural strength. The highest value was obtained for sample PC_3.0_35/35. Table 6 shows the ANOVA test results for flexural strength.

In the case of compressive strength, the statistical analysis, the results of which are presented in Table 7, showed that only the prepreg content has a significant impact. The results shows that in most cases the compression strength increase with prepreg content. By using Tukey post-hock test it was determined that the overall desirable amount of prepreg is between 0.5–3.0%. The compressive strength tests results are shown in Figure 4. The increase in compressive strength of

Table 5. Results of mechanical strength tests

Sample	Flexural strength (dev), [MPa]	Compressive strength (dev), [MPa]
PC_0_55/15	25.47 (1.13)	73.30 (16.10)
PC_0_45/25	24.29 (1.62)	65.83 (3.51)
PC_0_35/35	24.26 (1.83)	64.27 (7.42)
PC_0_25/45	24.23 (1.80)	75.05 (7.71)
PC_0_15/55	20.10 (1.96)	81.25 (17.33)
PC_0.1_55/15	24.25 (2.05)	80.97 (17.05)
PC_0.1_45/25	26.85 (4.19)	96.01 (1.72)
PC_0.1_35/35	27.03 (1.65)	96.01 (1.72)
PC_0.1_25/45	21.40 (3.42)	85.61 (5.94)
PC_0.1_15/55	24.17 (1.33)	95.58 (4.24)
PC_0.5_55/15	28.47 (0.77)	92.07 (2.27)
PC_0.5_45/25	26.94 (3.00)	93.43 (1.78)
PC_0.5_35/35	26.23 (0.38)	95.07 (2.40)
PC_0.5_25/45	26.88 (4.03)	101.87 (3.54)
PC_0.5_15/55	24.49 (0.92)	105.70 (1.46)
PC_1.0_55/15	28.01 (2.76)	96.87 (3.03)
PC_1.0_45/25	30.64 (0.18)	99.77 (2.62)
PC_1.0_35/35	26.36 (3.73)	101.12 (3.56)
PC_1.0_25/45	25.11 (3.37)	104.18 (3.58)
PC_1.0_15/55	23.32 (0.25)	105.40 (0.37)
PC_3.0_55/15	29.51 (2.79)	105.89 (4.59)
PC_3.0_45/25	31.52 (2.40)	104.49 (3.98)
PC_3.0_35/35	43.41 (8.51)	110.59 (0.45)
PC_3.0_25/45	32.68 (3.50)	109.41 (1.65)
PC_3.0_15/55	26.83 (5.24)	100.25 (7.42)
PC_5.0_55/15	40.18 (3.10)	94.86 (6.58)
PC_5.0_45/25	39.54 (4.50)	98.09 (15.15)
PC_5.0_35/35	37.02 (3.15)	109.40 (6.63)
PC_5.0_25/45	31.71 (1.90)	90.18 (12.31)
PC_5.0_15/55	27.75 (9.79)	65.73 (7.44)

Table 6. Result of ANOVA for Flexural strength

Parameter	DF	Sum of squares	Mean square	F value	P value
Prepreg content	5	1618.44804	323.68961	19.30278	<0.0001
Sand/Gravel ratio	4	471.93243	117.98311	7.03576	<0.0001
Error	80	1341.52533	16.76907	–	–
Corrected total	89	3431.9058	–	–	–
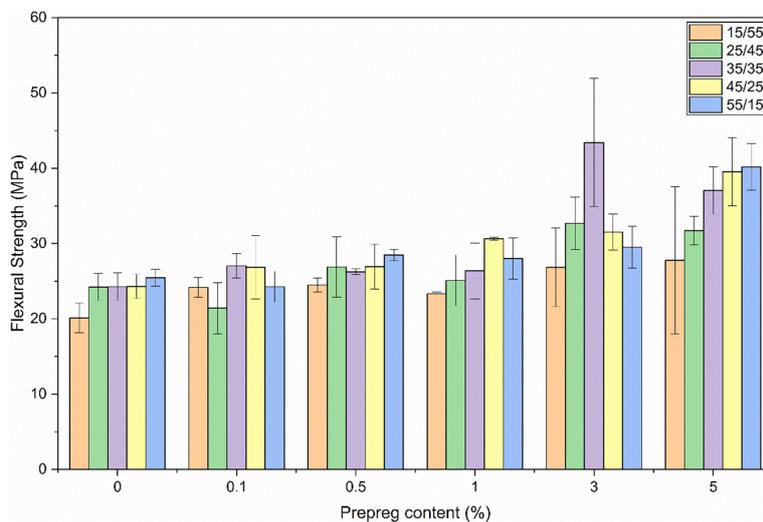
Figure 3. Flexural strength results for different prepreg content and sand-to-gravel ratio

Table 7. Result of ANOVA for compressive strength

Parameter	DF	Sum of squares	Mean square	F value	P value
Prepreg content	5	10723.64	2144.729	20.8915	<0.0001
Sand/Gravel ratio	4	304.9756	76.24391	0.74268	0.56572
Error	80	8212.829	102.6604	–	–
Corrected total	89	19241.45	–	–	–

polymer concretes was documented in the article by Laredo Dos Reis [30], where an improvement in compressive strength ranging from 27.5% to 45.4% was obtained for the addition of glass fibers, and from 36.1% to 55.1% for carbon fibers. The author also noted that the addition of fibers changes the failure behavior of polymer concrete – from brittle fracture in the absence of reinforcement to a more ductile cracking pattern when fibers are used.

During the mechanical tests, it was observed that the samples containing prepreg did not fracture completely or suddenly; instead, a scratch formed on their surface, which was not observed in the samples without prepreg. Owing to the presence of glass fibers originating from the prepreg, the polymer concrete partially retained its structural integrity, and at the fracture site the glass-fabric fibers held the material together. Figure 5 shows the fracture cross-sections of polymer concrete samples with different prepreg contents and a volumetric aggregate ratio of 35% fine aggregate and 35% coarse aggregate. The analysis of the fracture characteristics indicates a high degree of integrity of the entire composite, as evidenced by the fact that the cracking did not occur along the boundary between the aggregate grains and the matrix, but directly through the coarse aggregate particles. The images also reveal the influence of the prepreg waste content on the cohesion of the composite, with visible protruding glass fibers that held the material together after fracture. Similar results were obtained in another study,
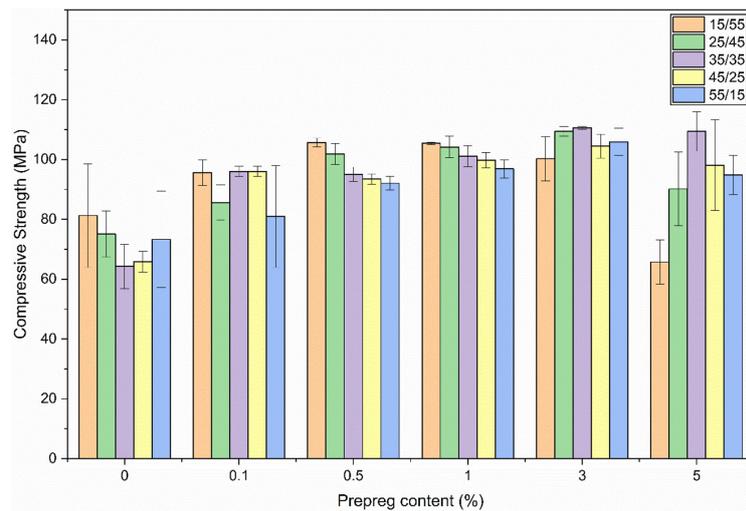
Figure 4. Compressive strength results for different prepreg content and sand-to-gravel ratio
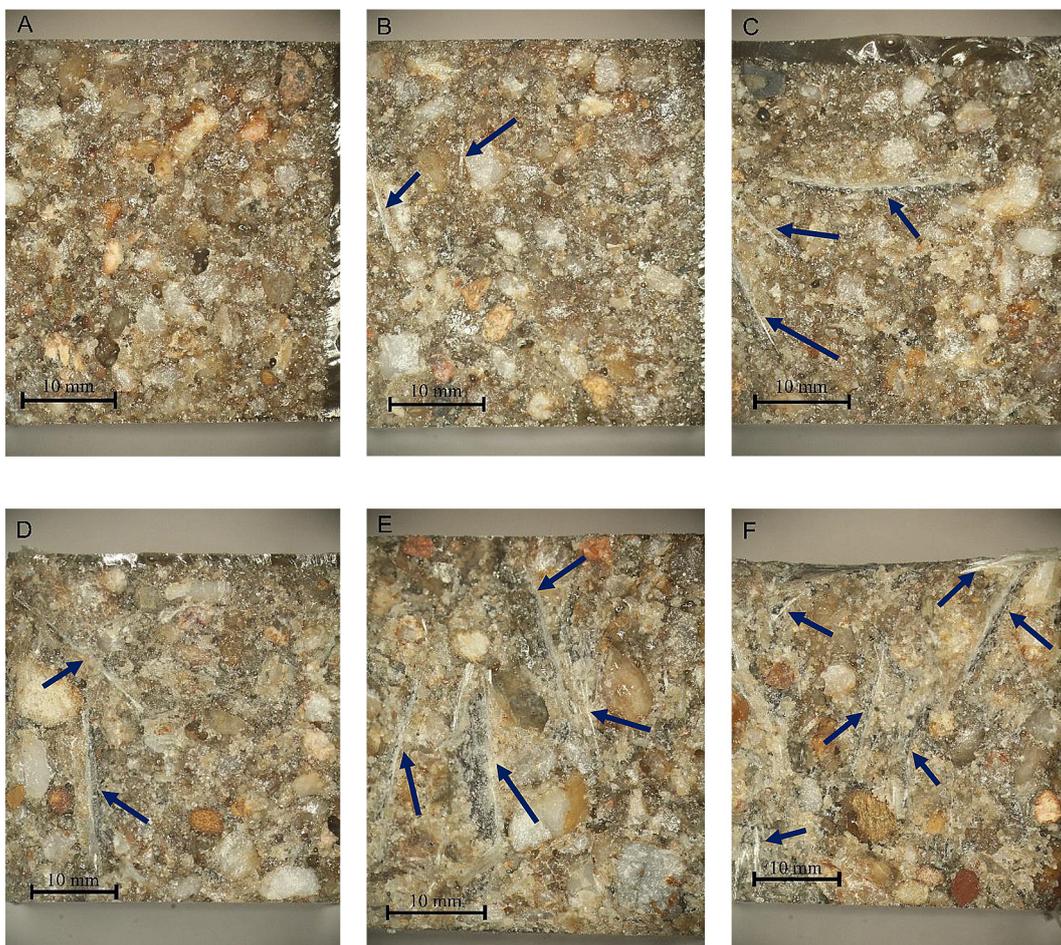

Figure 5. A-F. Fracture cross-sections of the samples with 35% fine aggregate and 35% coarse aggregate, with prepreg waste marked by arrows

where Smoleń et al. [31] added ground GFRP waste to polymer concretes. As in the present research, the glass fibers contained in this waste prevented the complete separation of the material after failure. In the article by Blazy et al. [32], a similar mechanism was described, in which the material, after cracking, was still able to carry part of the loads.

CONCLUSIONS

The conducted investigations confirm that the use of prepreg waste is justified in the production of polymer concretes and has a positive effect on the mechanical properties of the tested material.

The heat generated during the curing process of the epoxy resin with the aggregate is not sufficient to initiate the post-curing of the resin present on the surface of the glass fabric. Therefore, to achieve full cohesion of the material, it must be subjected to a post-curing process at temperatures above 55 °C.

The open porosity and water absorption of the material are influenced by both the prepreg content and the fine-to-coarse aggregate ratio, as confirmed by statistical tests; however, the highest increase in these parameters was recorded for a 5% volumetric content of prepreg.

The flexural strength tests showed that in order to obtain a statistically significant effect on this parameter, at least 3% by volume of prepreg must be incorporated into the polymer concrete. It was also observed that the volumetric proportion of 15% fine aggregate to 55% coarse aggregate should be avoided.

The applied statistical analyses demonstrated that the prepreg content has a significant effect on compressive strength. The optimal volumetric content for achieving improved compressive strength is in the range of 0.5% to 3% prepreg.

Considering the properties of the tested polymer concretes and the results of statistical tests, the most optimal solution is the incorporation of 3% by volume of prepreg.

The presence of prepreg in the composite increases its cohesion after failure. Instead of complete separation of the material, a crack forms, and the glass fibers hold the fractured parts together.

The use of waste prepreg in polymer concretes increases their mechanical strength, making it a justified and effective method for managing this problematic waste material.

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