Using Additives To Enhance The Compressive Strength Of Particulate Composites

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The primary aim of this study is to improve the compressive strength (CS) of the particulate composites. This is accomplished by mixing a polymer base with various additives, such as sawdust (SD), aluminium (Al), and iron (Fe) particles. The necessary composites are produced by adding varying weight percentages (wt%), i.e., 5, 10, and 15% weight-by-weight (w/w) of the additive compounds. In this study, the researchers employed a hand-moulding approach to produce a compressed composite. The experimental findings indicated improved CS value of some of the composites. These findings were influenced by factors such as the type of additives, density, wt% of the additive, and the properties of particle dispersion within the polymer. It was noted that when 15% (w/w) of Fe particles were added to the compound, the CS value improved by 23%. Despite an excellent dispersion of particles within the polymer, a minimum improvement in CS of 12% was observed after the addition of 10 wt% of SD particles.

Keywords: compressive strength; particulate composites; mixing a polymer; sawdust; aluminum; iron

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1. Introduction

In its most basic form, a composite material is made up of a minimum of two components that are combined to generate material qualities that differ from those displayed by the individual components. Most composites consist of a bulk substance known as the matrix and a reinforcement compound, which makes the matrix stiff and strong [1]. Particulate-filled polymer composites are widely used in different industries owing to their low manufacturing costs and ease of manufacture. Polymer matrices use particle fillers for several reasons, such as cost reduction and enhanced stiffness, in addition to other properties. The most common filler materials used in polymer matrix composites include calcium carbonate, alumina, and silicon carbide. However, several researchers have investigated the application of natural filler materials. Natural fillers are popularly used for composite reinforcement owing to their low cost, renewable nature, and biodegradability. This has led to a decrease in the use of costly, non-biodegradable traditional reinforcement techniques like synthetic fibres and ceramic fillers [2–4]. The researchers investigated the compressive strength (CS) of composite materials in this study and also determined the effects of different additives and specific environmental factors on the CS value. In an earlier study, Hassan et al. [5] examined the effect of carbonised and uncarbonised eggshell particles on the development of composites that combined eggshell and polyester particles. They noted a steady increase in the CS values, wherein uncarbonised particles showed a maximal CS value of 103.6 MPa when 50 % weight-by-weight (w/w) of eggshell particles were added to the composites, while the addition of the same concentration of carbonised eggshell particles led to a maximum CS value of 116.5 MPa [5]. Eren and Subaşı [6] also investigated the effect of utilising additives with different commencement rates, in addition to fillers with varying types and grain distributions, on the resin consumption and CS values of polyester matrix composites. The maximal CS values for the filled composites were noted at a 1.0 % initiator ratio. The three resin mixtures that showed the maximal CS values were seen to be: a basalt-filled resin mixture in AFS 40-45 grain distribution, the quartz-filled resin mixture in AFS 40-45 grain distribution, and the basalt-filled resin mixture in F1.0 grain distribution, which showed CS values of 130.43, 129.91, and 129.19 MPa , respectively [6]. To reinforce the epoxy matrix-based composites that were fabricated using the hand lay-up technique, Chlob and Fenjan [7] investigated the effects of using different weight percentages (wt %) of natural additives on the thermal and mechanical properties of epoxy resins. These additives included short fibres and particles derived from both plant and animal sources, such as sheep wool, wood dust, and cow bones. To characterise these composites, the researchers conducted mechanical tests such as CS and thermal tests like heat conductivity in accordance to the ASTM standards. Their results indicated that the kind, source, and wt % of the material additives might increase or decrease the thermal and mechanical properties of the composites [7]. Ateş et al. [8] observed that although PB polyester resin exhibits a lower density value, it showed a higher CS than that shown by the PA polyester resin. The samples exhibited structural degradation when significantly low or high hardener and catalyst ratios were used in comparison to the standard recommended quantities [8]. Nhoo et al. [9] showed that an increase in the volume percentage led to an increase in the CS values of the Pyrex and Al values. Aluminium (Al) showed a maximal increase of 60 % with a significant loss of 40 %, while charcoal and TiC showed a steady decreasing rate of 30 % [9]. Lastly, Bhagyashekar and Rao [10] discovered that the positive deformation processes enabled by the filler's presence in the matrix helped in improving the CS values of the matrix with higher percentages of the filler material [10].

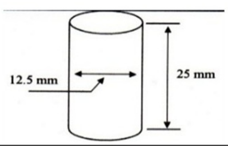

Figure 1: The standard specimen according to ASTM-D790.

Fig. 1. The standard specimen according to ASTM-D790

2. Experimental setup

2.1. Raw materials

A polymer matrix composite consists of two components: the base material, which is present in the matrix phase, and the additives, which constitute the reinforced phase. The properties of the composite are greatly influenced by the selection of the matrix and reinforced phases. Hence, in this study, the researchers conducted substantial research to select the best components for designing the polymer matrix composite.

2.2. Matrix materials

Epoxy resin (LFBM) from KOSTER was used to make the matrix. LFBM is an epoxy resin with a low-viscosity component and a specially designed amine hardener. This type of epoxy material shows the following qualities: Mixing volume ratio (A/B): 1/1 (where A = epoxy resin; B = hardener). At higher temperatures, this resin cures faster, which allows it to transition from a liquid state to a hard solid state at room temperature.

2.3. Reinforcement materials

Three distinct additives were used to improve the performance of epoxy: sawdust (SD) particles with a size of 355 μm, aluminium (Al) particles with a size of 100 μm, and iron (Fe) filing particles with a mesh size ranging between 48-500 μm. The different concentrations of the additive used in this study were 5, 10, and 15 %w/w. Fe filings are regarded as an important metallic element that are produced by filing and grinding. They show hardness, strength, and density of 7.8 g/cm^3. Al is a ductile metallic element that is used for designing a composite. It is easy to produce and displays the following properties: it is lightweight, non-magnetic, ductile, and has a density of 2.7 g/cm^3 (which is one-third of the density value of iron). The Al powder is produced using techniques such as milling and turning. Lastly, SD particles are seen to be a cheap by-product of the furniture manufacturing process. It shows many advantages such as low weight, insulation against heat and sound, and shows a density of 0.7 g/cm^3.

2.4. Composite preparation

The composites were made using the reinforcing elements and matrix material. Composite materials are made using a variety of processes, each of which has specific application domains, benefits, and drawbacks. This study employed the hand-moulding approach since it is simple, easy to use, and generates samples of different shapes and sizes. The matrix material (epoxy resin) was combined with reinforcing materials to shape and size it appropriately for the compression test (CT). Fig. 1 exhibits the standard composites that were selected based on the ASTM-D790 standards, while Fig. 2 presents the mould that was used for their production. Several epoxy mixtures were created to generate various composite sets that could be compared to pure epoxy samples. Each kit included three epoxy mixture composites. Fig. 3 depicts the fabricated composites.

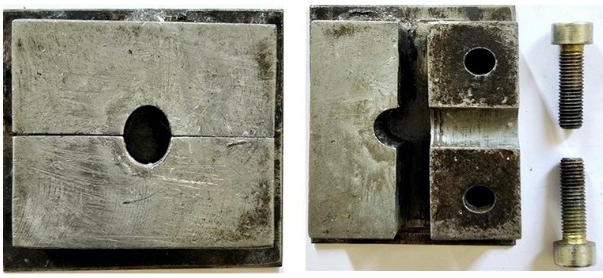

Fig. 2. The mold used to produce the standard specimens

Fig. 3. The prepared composites a: pure epoxy; b: Fe filing; c: Al; and d: saw dust

3. Experiment results

The composites are tested using a CT to determine their response to different compression loads (CL). As indicated in Fig. 4, a Wolpert-type machine with a 50 KN capacity was used for the CT, and CS was assessed using standard composites in accordance with ASTM-D790 standards (Fig. 1). Additionally, shore hardness Type D technique is used for implementing the hardness test on the composites and pure epoxy with a value of 40 (Fig. 5).

Table 1 shows the findings of composite hardness tests.

Table 1. The Shore hardness of the fabricated composites

Additive Type	5%	10%	15%
Fe	44	54	60
Al	40	48	53
SD	35	37	42

Fig. 4. The Wolpert machine

Fig. 5. The Shore hardness meter

Before analysing the findings, it is imperative to ascertain the primary factor that significantly influences the outcomes. The factor that was determined in this study was seen to be particle density, as illustrated in Fig. 6. Due to their high density, the filing particles in the Fe-containing composites were concentrated at the bottom of the container, while the remaining particles are dispersed throughout the composites. In contrast, due to the medium density of Al particles, the Al particles are spread throughout the composites while a lower concentration of particles were concentrated at the bottom. On the other hand, because of the low density of the SD particles, the SD particles are properly dispersed throughout the composites. According to earlier research, particle density played a major role in the particle dispersion throughout the composites.

Figs. 7 to 9 exhibit the experimental CT results for the composites fabricated in this study. The results indicated that the CS value of the composites vary depending on the type and density of the additive. Therefore, the findings in this study can be categorised into 3 groups based on the 3 different types of additives.

Fig. 6. The effect of particles density on particle distribution

3.1. Group A: Composites with iron (Fe) filing particles.

It was noted that when 5 %(w/w) of the pure epoxy is added to the composite, the compressive load decreased to 7.1 KN. This could be attributed to the fact that the high density of the Fe filings 7.8 g/cm^3 caused the precipitation of the additives to the base of the composites. However, when the concentration was increased to 10 %(w/w) of the Fe particles, the compression load of the composites was improved. Hence, the CL value increased from 8.6 to 10 KN for composites with 10 wt% additives and from 8.6 to 10.6 KN for the composites containing 15 wt% of the additives because of the good mechanical property of Fe particles.

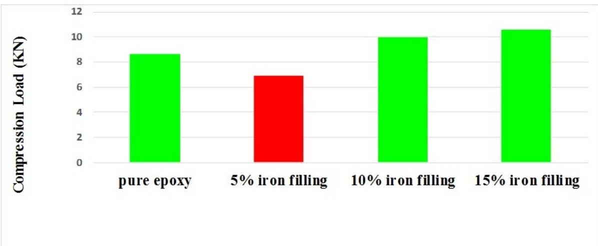

Fig. 7. A comparison of the CLs of the composites in Group A

3.2. Group B: Composites with aluminium (Al) particles

Al particles have a density of 2.7 g/cm^3. Here, the inclusion of this additive showed the opposite effect from that shown by the Fe filing additives. The results in Figure 8 indicated that the CL for composites fabricated using 5 %(w/w) of Al particles showed no effect on the CL of the pure epoxy composites. However, when 10 and 15 %(w/w) concentrations of Al particles were added to the composite it decreased the mechanical properties of the composites, in comparison to the composites included in Group A for all the weight percent values used in this study. The CT results are shown in Fig. 8.

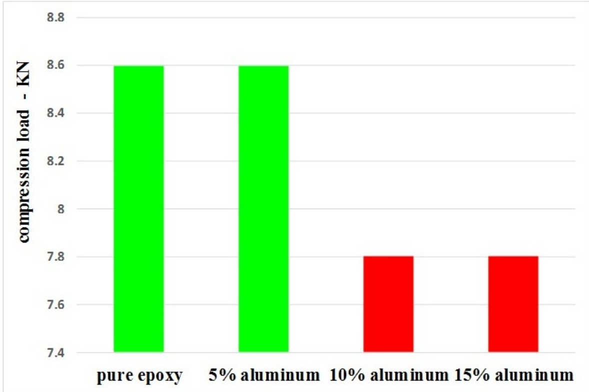

Fig. 8. A comparison of the CLs of the composites in Group B

3.3. Group C: Composites with saw dust particles.

Sawdust has a low particle density 0.7 g/cm^3 which played a vital role in their uniform distribution throughout the composites. The results indicated an increase in the CS value from 8.6 to 9.4 and 9.6 KN for the composites containing 5 and 10 wt% of SD additives, respectively. However, SD particles show poor mechanical properties compared to those presented by the Fe and Al particles. The composites with 15 %(w/w) of the additives showed poor mechanical properties that were reflected in their CL value of 8.2 KN. Fig. 9 displays the findings of the CT for composites included in Group C.

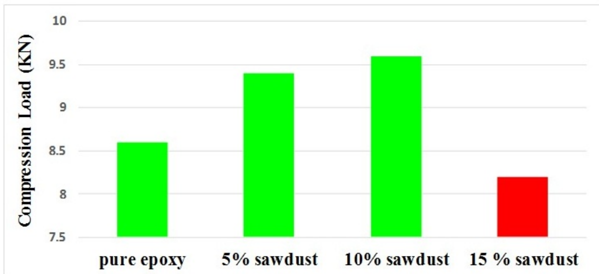

Fig. 9. A comparison of the CLs of the composites in Group C

4. Conclusions

The following conclusions were summarised using the experimental findings:

1. CS value improved in many composites
2. The improvement in the CS value was influenced by factors such as type of additives, density, and the weight concentration of the additives.

3. The composites containing 15 %(w/w) of the FE filing particles showed the maximal improved CS value of 23 %.

4. On the other hand, the composites with 10 %(w/w) SD particles showed the minimal CS improved value of 12%.

5. Not all the Al composites showed any improvement in their CS values.

6. It was also noted that an increase in the wt% of the additives led to an increase in their hardness values.

7. The composites with 15 %(w/w) of Fe filing additives showed the maximal hardness value.

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