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Retraction

Retracted: Thermogravimetric Analysis and Mechanical Properties of Pebble Natural Filler-Reinforced Polymer Composites Produced through a Hand Layup Technique

Advances in Materials Science and Engineering

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This article has been retracted by Hindawi, as publisher, following an investigation undertaken by the publisher [1]. This investigation has uncovered evidence of systematic manipulation of the publication and peer-review process. We cannot, therefore, vouch for the reliability or integrity of this article.

Please note that this notice is intended solely to alert readers that the peer-review process of this article has been compromised.

Wiley and Hindawi regret that the usual quality checks did not identify these issues before publication and have since put additional measures in place to safeguard research integrity.

We wish to credit our Research Integrity and Research Publishing teams and anonymous and named external researchers and research integrity experts for contributing to this investigation.

The corresponding author, as the representative of all authors, has been given the opportunity to register their agreement or disagreement to this retraction. We have kept a record of any response received.

References

[1] R. Kumar, S. M. Kumar, M. E. S. Kumar et al., "Thermogravimetric Analysis and Mechanical Properties of Pebble Natural Filler-Reinforced Polymer Composites Produced through a Hand Layup Technique," *Advances in Materials Science and Engineering*, vol. 2022, Article ID 1837741, 8 pages, 2022.

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Research Article

Thermogravimetric Analysis and Mechanical Properties of Pebble Natural Filler-Reinforced Polymer Composites Produced through a Hand Layup Technique

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Using pebble and fibre in an epoxy matrix, the mechanical, dynamic, and thermal characteristics of a composite were examined. Tensile, flexural, impact, and interlaminar shear strengths are experimentally determined. In this study, we compare the mechanical performance of carbon fibre composites composed entirely of conventional epoxy (NE). The results of a comparative investigation using 15 and 20% carbon fibre in an epoxy matrix are presented. Additional categories for compressive strength and damping ratio were defined based on this performance. The epoxy resin was combined with carbon fibre (15 wt% and 20 wt%) in a unidirectional arrangement and manufactured with different fillers like pebble. The goal of this research is to better understand the bonding mechanisms between damping materials and the resin matrix in order to increase interfacial bonding performance. This information is required for both selecting the appropriate material for applications and developing a composite construction using that material.

1. Introduction

When compared to metal and ceramic matrices, polymer matrices are most typically utilised due to their cost efficiency, ease of producing complex parts with reduced tooling expense, and excellent room temperature properties [1]. Since the last few decades, composite materials have emerged as a new type of material for the manufacturing machine tool structures that produce fewer vibrations [2,3]. Polymer composites have several advantages over traditional materials such as steel and concrete, including their light weight, high strength-to-weight ratio, and good fracture resistance. Under cyclic loading, all engineered materials dissipate energy. Because of their excellent stiffness-to-weight ratio, polymer matrix composites are frequently utilised in weight-sensitive structures [4–6].

Many issues have been solved in recent years as a result of the development of new materials, methodologies, and models. However, evaluating and identifying alternative combinations of parameters that will deliver the greatest results among the bonded joints is still required [7]. Carbon fibre is an important fibre reinforced in composites because of the key material properties for engineering design like the axial compressive strength [8]. The addition of micro fillers has enhanced greatly the physical and mechanical properties of composites. Compressive strength is a critical material attribute that can usually only be evaluated by experimentation [9]; compressive strengths of unidirectional fiber-reinforced composites may be predicted. Endings of stiff carbon fibres could make considerable indentations on the contact surface during compression testing using AS4/3501–6 carbon/epoxy off-axis specimens, preventing full shear deformation [10].

The interlaminar shear properties of glass fibre/carbon fibre-reinforced polymer composites based on unmodified and MWCNTs-modified epoxy resins were examined, and the results suggest that adding 0.5wt percent MWCNTs increases the ILSS by 6.4 percent [11]. The addition of micro fillers improved flexural characteristics and microhardness in the reinforcing phase DMA when micro fillers were loaded. Between the filler particles and the matrix, there was good micro-filler dispersion and adherence [12,13]. According to the abovementioned literature, there was little research done on pebbles and carbon fibre-reinforced epoxy matrix using the hand layup method. The goal of this research is to make pebble/carbon fibre and evaluate the implications of the composites. Hence, from these literature, epoxy with a pebble filler is being identified as a novel material as the viable alternative for a precision machine structure.

2. Experimental Methods

2.1. Fabrication. Araldite®, Petro Araldite Pvt. Ltd., Chennai, the carbon fibre (CF, T300) was supplied by Sakthi industries, Chennai, as a reinforcement material. To enhance the bonding strength between epoxy resins and pebble stone, river sand is used as the micro filler. The components of the epoxy resin were mixed with carbon fibres in a unidirectional manner arranged like a mat with two weight percents of 15 and 20 wt % in a mild steel mold. The pebble filler at a constant speed of 500rpm for 24 hrs particle with epoxy resin was prepared and mixed by means of continuous mechanical stirring and a clear mixture was obtained. Table 1 lists out the sample codes for all different types of epoxy composite materials.

Table 1: Sample codes for all different types of epoxy composite materials.

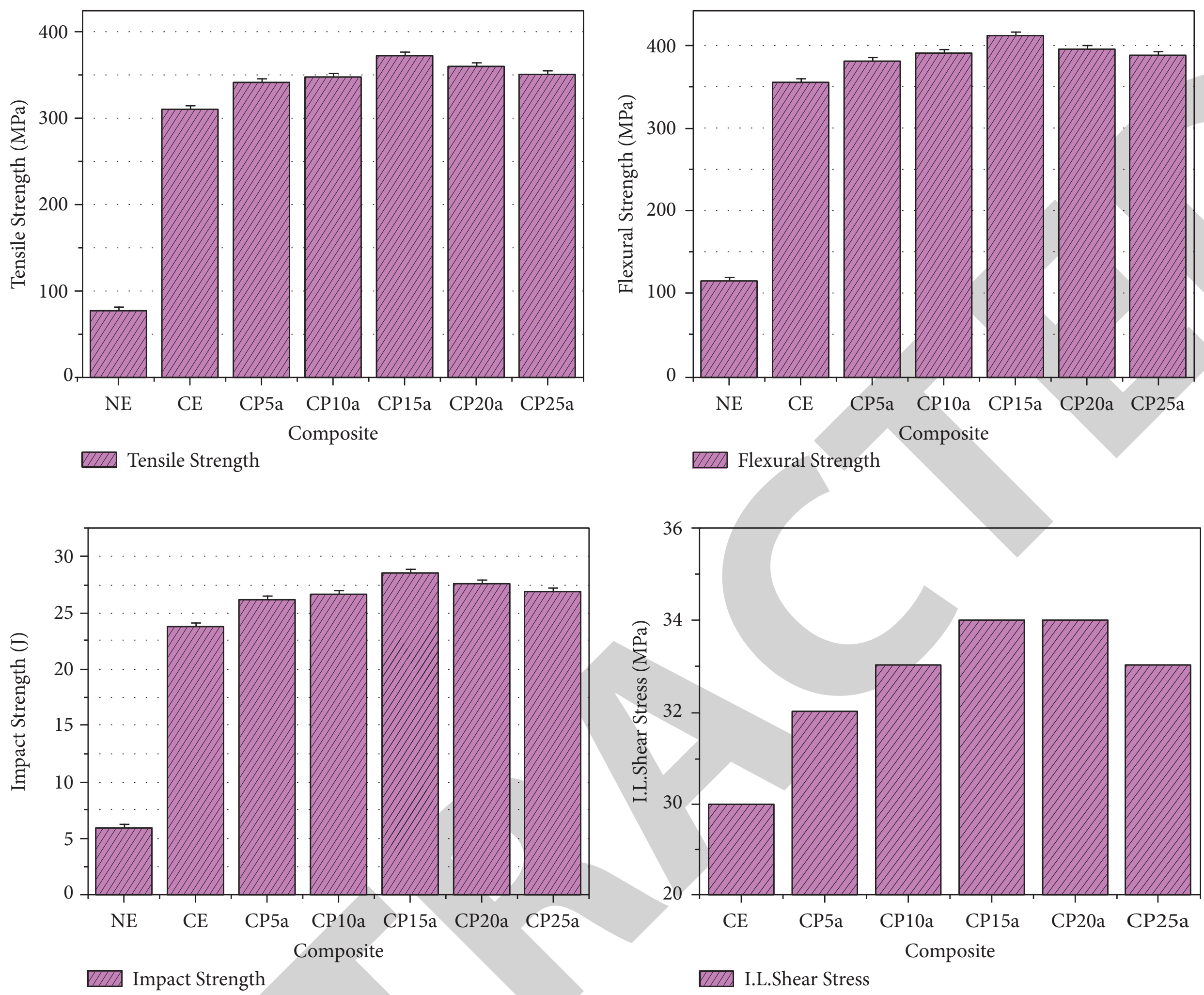
Sample code	Description
NE	Neat epoxy
CE	Epoxy resin with 15 wt% carbon fiber
CE2	Epoxy resin with 20 wt% carbon fiber
CP5a	Epoxy resin with 15 wt% carbon fiber +5 wt% pebble
CP10a	Epoxy resin with 15 wt% carbon fiber +10 wt% pebble
CP15a	Epoxy resin with 15 wt% carbon fiber +15 wt% pebble
CP20a	Epoxy resin with 15 wt% carbon fiber +20 wt% pebble
CP25a	Epoxy resin with 15 wt% carbon fiber +25 wt% pebble
CP5b	Epoxy resin with 20 wt% carbon fiber +5 wt% pebble
CP10b	Epoxy resin with 20 wt% carbon fiber +10 wt% pebble
CP15b	Epoxy resin with 20 wt% carbon fiber +15 wt% pebble
CP20b	Epoxy resin with 20 wt% carbon fiber +20 wt% pebble
CP25b	Epoxy resin with 20 wt% carbon fiber +25 wt% pebble

2.2. Testing. The specimens were $200 \times 30 \times 5$ mm and $130 \times 30 \times 5$ mm and 63.5, 12.7, and 3.2 mm, respectively. To analyse the compressive strength of the composites along the unidirectional way, an ASTM standard (ASTM C 579–01) compressive test was performed. The average value of five samples was used to calculate all of the results. Thermogravimetric analysis (TGA) is used to assess the thermal degradation of epoxy composites utilising a Perkin Elmer Pyris 7 thermogravimetric analyzer. To determine the beginning temperature of decomposition, mass loss, and highest decomposition peak, about 10 mg of the sample was heated under air at a rate of 5°C/min from room temperature to 900 °C. DMA was used to determine characteristics of a frequency of 1 Hz, a temperature range of 20 to 200°C, and a heating rate of 5°C/min. The specimen was $3\,mm \times 12\,mm\ x\ 64\,mm$ in size. Initially, the mechanical characteristics of composites (all samples) were investigated, with the best results being used for additional compression, damping, TGA and DMA experiments.

3. Results and Discussion

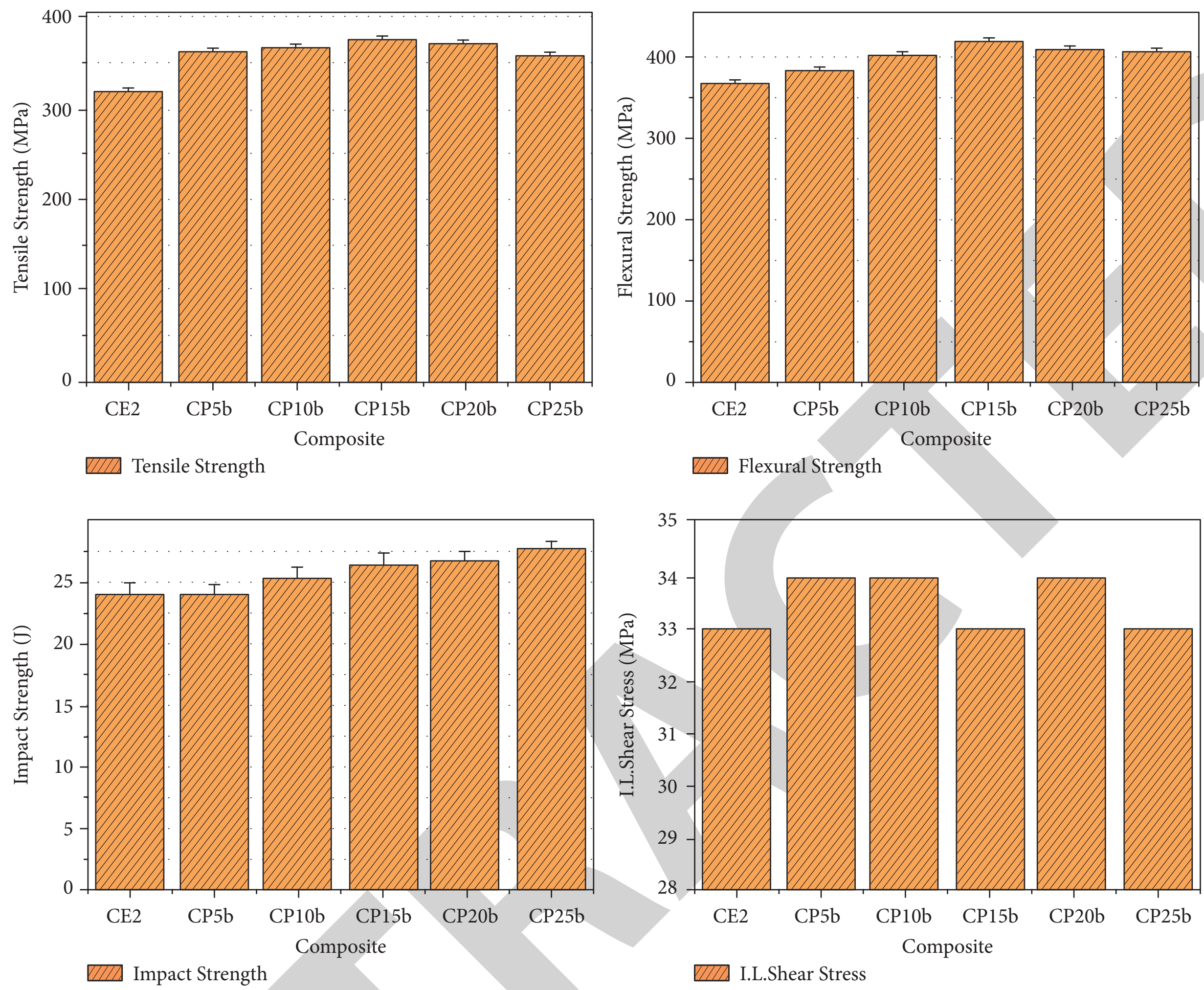
3.1. Mechanical Properties. Epoxy composites with various fibre contents were compared to plain epoxy in terms of tensile, flexural, impact, and interlaminar shear stress characteristics (NE). The mechanical characteristics of the tested materials are shown in Figure 1(a) and Figure 1(b). The addition of a pebble to the carbon fibre increases the strength of all composites in general. The tensile strength of neat epoxy resin was increased from 78 MPa (NE) to 372 MPa (CP15a) and 374 MPa (CP15b) with the addition of a filler and fibre. In the same fibre and filler ratio, flexural, impact, and interlaminar shear stress all improved. According to this study, the mechanical properties of fibre-reinforced composites are influenced not only by the fibre content but also by the pebble filler, which aids in stress transfer to the matrix [14].

The addition of filler raised the tensile strength of the epoxy composites by up to 15% in both matrixes. The filler results in increased interfacial addition and as a result, more stress transfer fibres and fillers during tensile testing. It is worth noting that the effect of pebble filler on the flexural strength of epoxy composites greatly improves the stiffness of the composites. When flexural strength of both sets of carbon fibre loading 15 wt% and 20 wt% with different



(a)

Figure 1: Continued.



(b)

Figure 1: Mechanical properties (tensile, flexural, impact, and interlaminar shear strength) of composite (a) carbon fibre 15 % wt ratio with different pebble weight ratios and (b) carbon fibre 20 % wt ratio with different pebble weight ratios.

pebble weight ratios was compared, there was no significant difference in strength enhancement when the fibre content was varied. Furthermore, because the filler improved interfacial strength in elastic qualities similar to tensile strength, all composite formulations demonstrated greater flexural strength values than the raw epoxy and carbon fibre composites.

The impact values of composite show tiny increment with filler addition. Filler addition of up to 15% in 15% carbon fibre and up to 25% in 20% carbon fibre improvement. It is noted that the interlaminar shear strength also showed similar improvement to impact strength. This is because of reinforced filler particles affecting the laminar adhesion; hence, delamination takes place easily. The following composites are taken for further studies based on the above mechanical performance and they are listed in Table 2.

3.2. Compressive Test and Damping Ratio Analysis. Figure 2 depicts representative behaviours of the four composite materials. The addition of a pebble filler to the matrix improves the properties of carbon fibre/epoxy matrix composites, albeit the degree of improvement is dependent on factors including filler particle concentration and dispersion. According to the compressive strength values of composites CP15a and CP15b, it is determined that 15 percent pebble filler provides greater strength than 20% pebble filler.

CP15a and CP15b have maximum compressive strength values of 60% and 61% higher than neat epoxy samples. For the abovementioned composites, considering the scattering and failure, describing the nonlinear behaviour and the shear strength values are not very affected. Because shear strength can induce a drop in compressive strength in the fibre composite, the pebble filler reduced compressive strength by 20%. Normally, the composite with lesser weight proportion of resin shows better compressive strength; this is due to agglomeration takes place when the resin contribution increases.

The damping ratios (ξ) were estimated using the half power band method using equation (1):

Table 2: Maximum mechanical properties of composites.

Sample code	Tensile strength (MPa)	Flexural strength (MPa)	Impact strength (J)
CP15a	372	411	27.1
CP20a	360	396	26.3
CP15b	374	420	26.4
CP20b	369	412	26.8

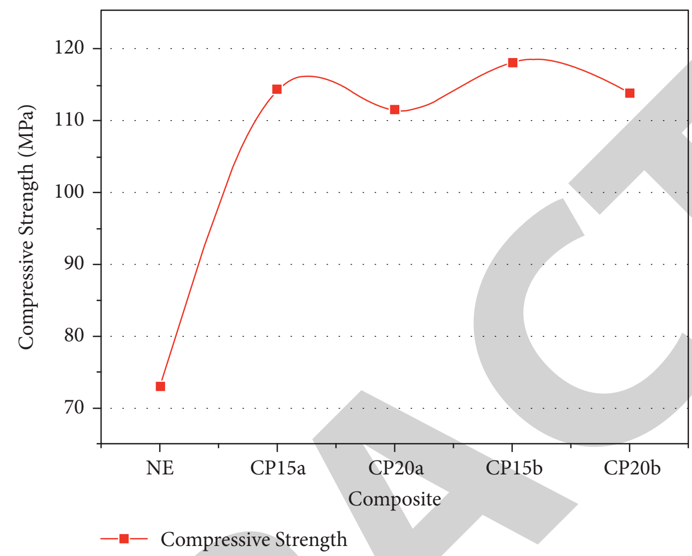


Figure 2: Compressive strength of composites.

$$\xi = \frac{(f2 - f1)}{2fn} \quad (1)$$

where ξ = damping ratio, f2-f1 = bandwidth at half power points, fn = fundamental frequency.

The variations in the damping ratio are as shown in Table 3. It reveals that the pebble 15% ratios normally produce a higher damping ratio at both set of composites. The damping ratio shows the same trend as that of compressive strength for all types of composites. Further increase in the filler ratio decreases the damping ratio due to lose of bonding properties of the composite. The damping values and compressive strength show that the 15% filler promotes higher bonding strength. So, the rate of transmission of cohesive force is better in the case of a 15% filler compared with that of a 20% filler.

Table 3: Damping ratios of the composite.

Sample code	Damping ratio (ξ)
NE	0.0311
CP15a	0.0209
CP20a	0.0234
CP15b	0.0211
CP20b	0.0245

3.3. Dynamical Mechanical Analysis. Figure 3 shows the dynamic mechanical parameters at a frequency of 1Hz. Stiffness imposed by the fillers is blamed for the increase in modulus. Fillers increase the flexibility of polymeric materials while lowering their viscosity. Tg values of the epoxy composite does not show any significant variations. The restricted mobility is caused by composites' crosslinked three-dimensional structures.

When compared to plain epoxy, the composites loaded with filler had a higher storage modulus in the first glassy stage. At 75 to 80 degrees Celsius, the storage modulus of clean epoxy and filler-loaded composites is nearly identical. This is attributed to matrix softening and loss of filler-matrix adhesion, and it was a substantial contributor to the strength loss found at high temperatures. The filler enhances the Tg of the polymer matrix by improving the contact between the matrix and the filler and restricting the mobility of the molecules.

3.4. Thermal Properties. The thermogravimetric analysis was used to determine the thermal stability of the epoxy composites as shown in Figure 4. The thermal stability of the epoxy matrix increases dramatically with the inclusion of pebble fillers and epoxy/carbon fibre composites, according to TGA thermograms. From this, the filler-matrix degrades later than the neat resin, thermogravimetric curves for the composites are similar mass loss process starting at around 400°C, because comparing the wt. loss of the composites up to 50%, there is no considerable variation in the thermal stability between the composites. The pebble filler-reinforced composite matrices have a higher char residue when

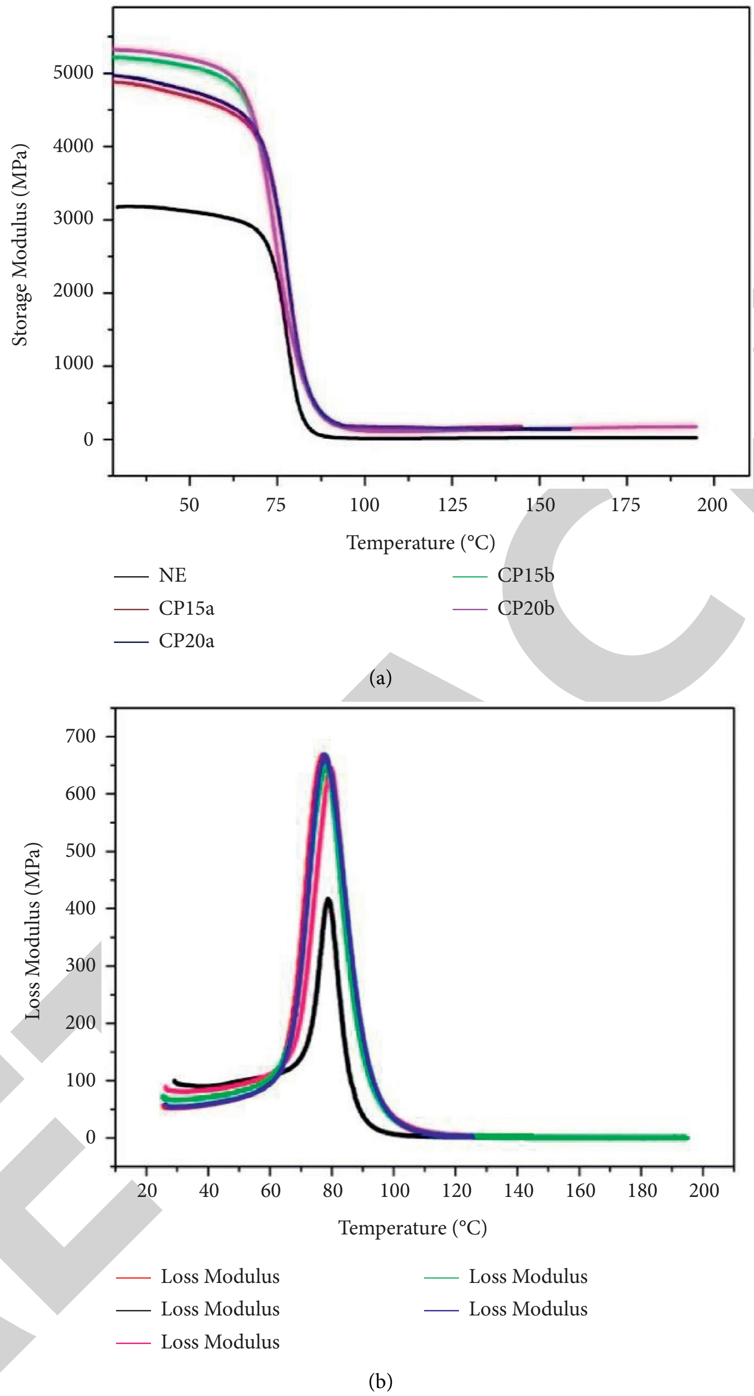


Figure 3: (a) Storage. (b) Loss modulus of different filler ratios of composites, respectively.

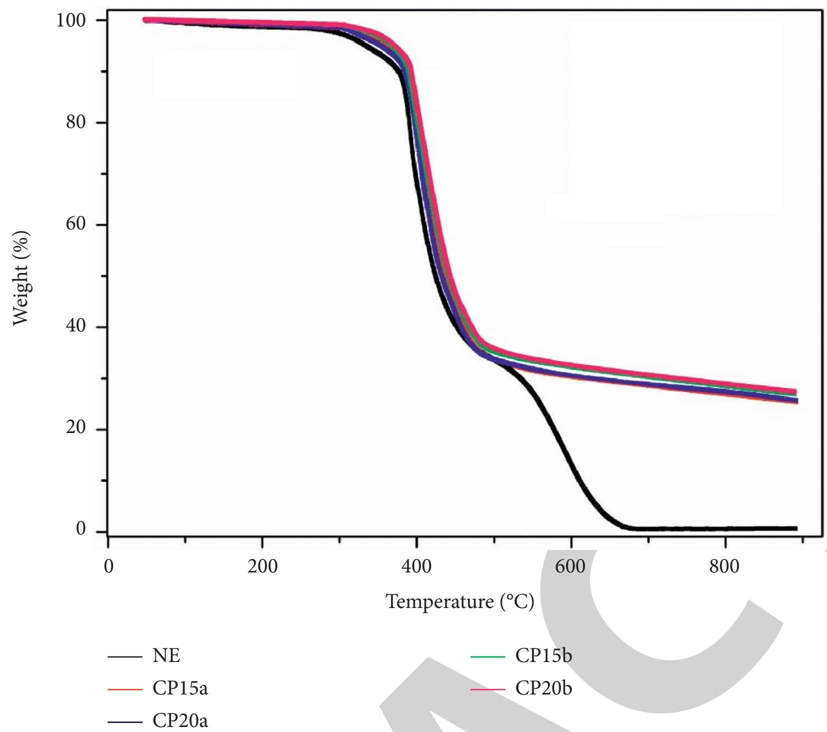


Figure 4: Thermogravimetric analysis pebble filler epoxy composites.

compared to the neat epoxy. Very little variation only can see in this final char values with addition of a 15% and 20% pebble filler. However, the presence of the pebble filler intermediary thermal stability between fillers and matrix, showing synergistic interaction.

4. Conclusions

The properties and behaviour of an engineering material under tensile, compressive, and dynamic loading conditions in both normal and adverse test situations are used to determine its performance. Synergistic effects in the form of modified mechanical properties and improved thermal qualities were produced by integrating the chosen pebble fillers into the carbon fibre-reinforced epoxy, as expected. The result from the mechanical testing showed that the addition of pebble filler and carbon fibres enhanced the tensile strength, flexural strength, and impact strength. The pebble filler-reinforced carbon fibre/epoxy matrices have a higher char residue when compared to the neat epoxy matrix which increased from 1.6 to 24.8 at 800°C.

Data Availability

The data used to support the findings of this study are included within the article. Further data or information are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

Acknowledgments

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