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Mechanical Characterization of Natural filler mixed polymer matrix Composites

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Abstract: This study focuses on the fabrication and testing of biodegradable waste powder mixed polymer matrix composites to evaluate their mechanical properties, including tensile strength, impact strength, and thermal conductivity. Additionally, the biodegradability of these composites is predicted using appropriate experimental methods. Almond shell powder and coconut shell powder, each comprising 30% by weight, are integrated into the polymer matrix. ASTM standard specimens are prepared for measuring tensile strength, tensile modulus, impact strength, and thermal conductivity. Scanning electron microscopy images are also utilized to analyze the failure behavior of the natural composites. Results indicate that the CSP/PP composite exhibits a 71.4% higher tensile strength compared to the ASP/PP composite. Furthermore, combining almond powder and coconut powder into the same matrix significantly enhances tensile strength, with an increase of 132.4% and 32.35% higher than the ASP/PP and CSP/PP composites, respectively.

Keywords: Almond shell powder, coconut shell powder, tensile modulus, impact strength, thermal conductivity

INTRODUCTION:

Composite materials were fabricated using different proportions of reinforcement materials, namely Coconut Shell Powder (CSP) and Rice Husk Powder (RHP), at 40%, 30%, and 20% volume fractions. These were combined with matrix materials Vinyl Ester (VE) and Super Vinyl Ester (SVE) at 60%, 70%, and 80% volume fractions. Subsequently, mechanical properties such as tensile strength and flexural strength were analyzed for these manufactured composites to determine their viability for engineering applications.[1]

The characteristics of polymer composites reinforced with biowaste particulates are influenced by both the shape of the particles and the structure of the particulates themselves. However, despite these variations, biowaste particulate-reinforced polymer composites present certain drawbacks, including increased susceptibility to moisture absorption, decreased impact strength, and poorer fire resistance . The properties of these composites are significantly impacted by the geometry of the particles and the structure of the particulates .[2].

Hybrid composites with biodegradable properties were created by incorporating hydrophilic organic fibers such as coconut and date seed powder into waste high-density polyethylene (WHDPE). The findings demonstrated that these hybrids are suitable for both industrial and household applications and have the ability to undergo biodegradation upon disposal, suggesting they offer a more environmentally sustainable alternative to WHDPE .[3]

The study focused on analyzing various mechanical properties, including tensile strength (TS), bending strength (BS), tensile modulus (TM), bending modulus (BM), elongation at break, and impact strength (IS). Significant enhancements were observed in TS, BS, TM, BM, and IS, with the maximum increases being 44.44%, 128.00%, 17.96%, 112.09%, and 62.50% respectively, at a 30% filler content in the composites. These results indicate that the strength properties of the composites improved as the filler content increased up to 30% by weight . [4].

The incorporation of coconut particles led to enhancements in the overall mechanical properties of the biocomposites. Surface morphology analysis was conducted to investigate the fracture and failure patterns of the biocomposites. The samples were also subjected to immersion in water, NaOH, and NaCl solutions to evaluate their water absorption and corrosion resistance properties. [5].

Another study examined the impact of incorporating coconut shell fibers into epoxy resin on its mechanical properties, aiming to assess its potential suitability for engineering purposes. Findings indicated that as the proportion of coconut shell fibers in the composite increased, both hardness and tensile strength improved. However, a reverse trend was observed concerning the impact energy of the composite, which diminished with higher fiber content. [6]

Further investigation revealed that varying amounts of coconut shell particles affected the mechanical characteristics of composites. Scanning electron microscopy showed satisfactory interfacial interaction between the coconut shell particles and the epoxy matrix. Results demonstrated that as the content of coconut shell particles increased, both tensile modulus and tensile strength of the composites improved, albeit with a slight reduction in impact strength compared to pure epoxy resin. [7].

Different biodegradable particulate composites, such as almond shell mixed composites, coconut shell mixed composites, and combinations of these particulate mixed composites, have not been characterized in terms of tensile modulus, tensile strength, thermal conductivity, and impact strength.

METHODS AND METHODOLOGY:

In this study, polyester resin serves as the matrix, into which natural, biodegradable fillers are incorporated. These fillers, sourced from coconut shells, almond shells.

Coconut shell mixed polymer matrix composite

Almond shell mixed polymer matrix composite

Coconut and Almond shell mixed polymer matrix composite

Fig.1 Tensile specimen and universal tensile testing machine for tensile strength

Fig.2 shows the tensile modulus of natural biodegradable filler mixed composites, including almond shell powder mixed polypropylene composite (ASP/PP), coconut shell powder mixed polypropylene composite (CSP/PP), and a composite containing both almond and coconut shell powders (ASP+CSP/PP), each at a 30% weight fraction of the respective filler material. In the present work, the CSP/PP composite exhibited a 71.4% higher tensile strength compared to the ASP/PP composite. Moreover, combining almond powder and coconut powder into the same matrix significantly improved the tensile strength, with an increase of 132.4% and 32.35% higher than the ASP/PP and CSP/PP composites, respectively.

This shows that the presence of both almond and coconut shell powders can promote better adhesion and interaction between the filler particles and the polypropylene matrix. This improved interfacial bonding reduces the likelihood of filler pull-out or detachment during tensile loading, thereby increasing the overall tensile modulus of the composite.

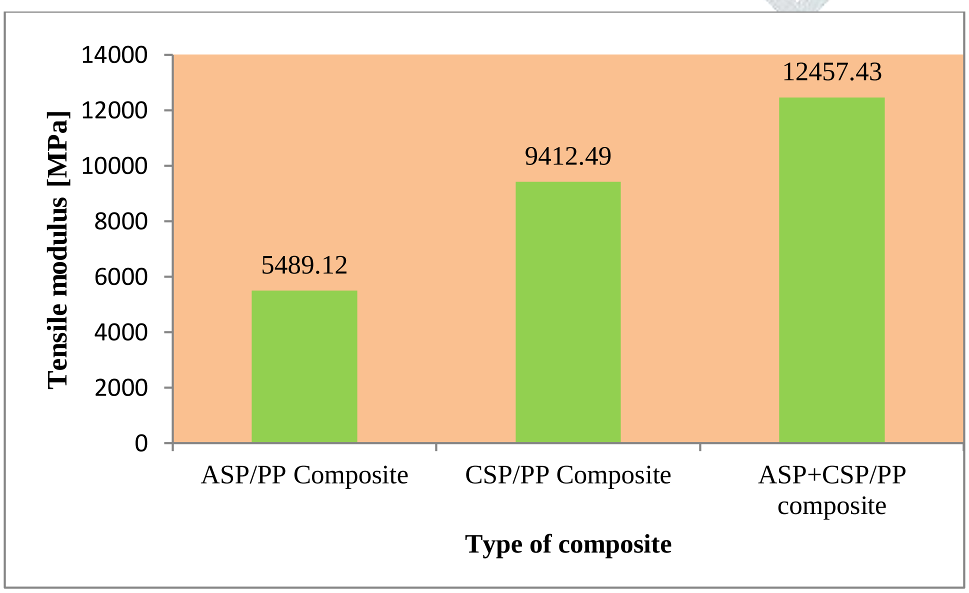

Fig.2. Tensile modulus of the particulate composite

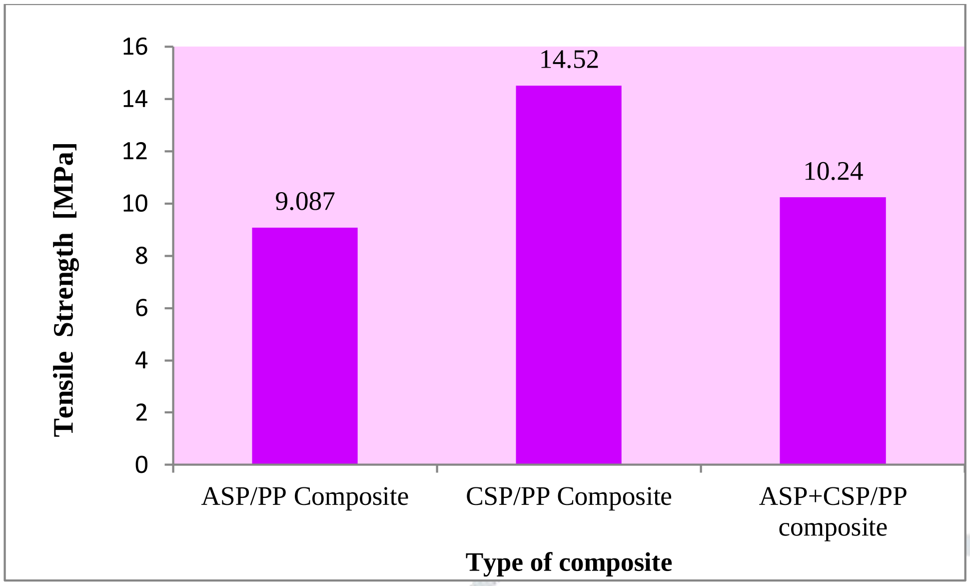

Fig.3. Tensile strength of the particulate composite

Fig.3. depicts the variation in tensile strength among ASP/PP, CSP/PP, and ASP+CSP/PP composites. Notably, the CSP/PP composite exhibited superior tensile strength compared to both ASP/PP and ASP+CSP/PP composites. Specifically, when comparing CSP/PP to ASP/PP composite alone, CSP/PP demonstrated an improvement of 59.7% in tensile strength. Interestingly, even with the addition of almond shell powder to the coconut shell powder composite (ASP+CSP/PP), the resulting tensile strength did not surpass that of the individual CSP/PP composite. This suggests that the incorporation of coconut shell powder into almond shell powder enhances tensile strength compared to the pure ASP/PP composite.

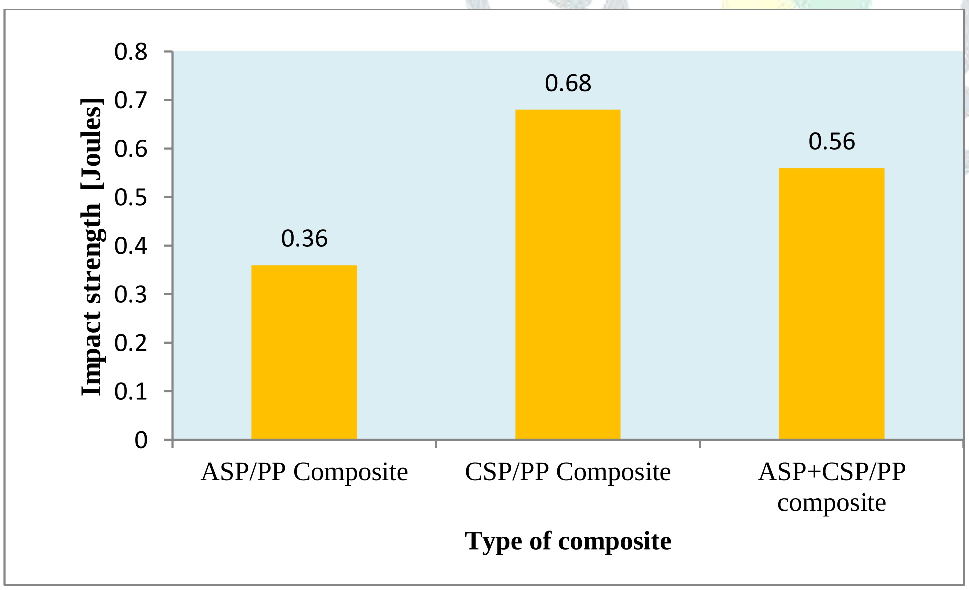

Fig.4. Impact strength of particulate composite

Fig.4. illustrates the impact strength of ASP/PP, CSP/PP, and ASP+CSP/PP composites. It is evident that the CSP/PP composite exhibited the highest impact strength compared to both ASP/PP and ASP+CSP/PP composites. A substantial improvement of approximately 88.8% in impact strength was observed in the CSP/PP composite compared to the ASP/PP composite. Conversely, the ASP+CSP/PP composite demonstrated a 55.5% improvement in impact strength compared to the individual ASP/PP composite. These findings indicate that the

CSP/PP composite offers superior resistance to suddenly applied loads, making it a promising material for impact-resistant applications.

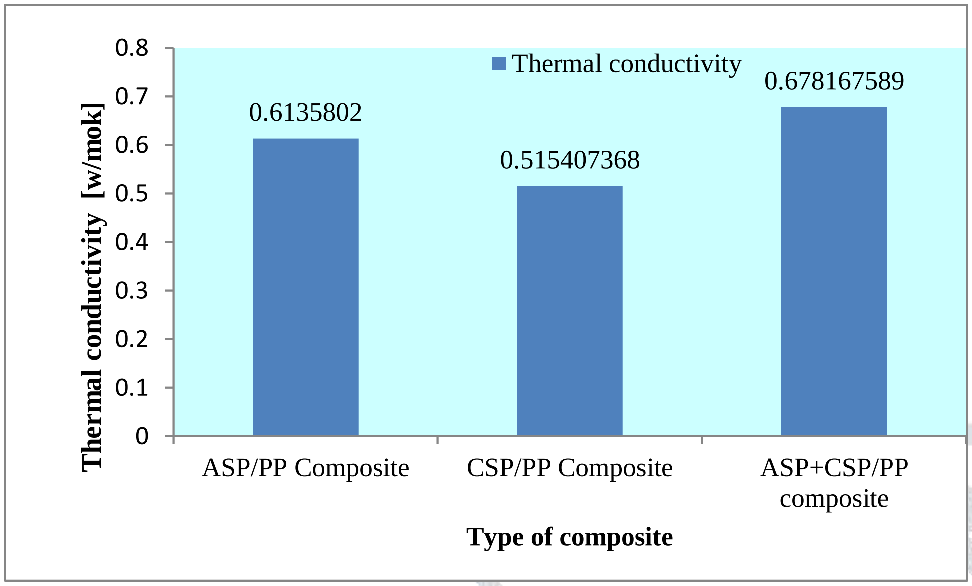

Fig.5. Thermal conductivity of the particulate composite

Thermal conductivity data for the three different filler-mixed composites is presented in Fig. In terms of this property, the almond shell particle-mixed polypropylene composite exhibited better thermal conductivity compared to the coconut shell and the combined coconut and almond shell composite. An improvement of approximately 16% in thermal conductivity was observed with almond shell powder compared to coconut shell powder mixed composite. (Fig.5)

The observed improvement in thermal conductivity with the almond shell particle-mixed polypropylene composite compared to the coconut shell and combined coconut and almond shell composite could be attributed to several factors. Almond shell particles might have inherently better thermal conductivity properties compared to coconut shell particles. Additionally, the structure and arrangement of almond shell particles within the composite matrix may facilitate more efficient heat transfer pathways compared to coconut shell particles.

Scanning electron microscopic images of the failed specimens under tensile loading are presented for ASP/PP, CSP/PP, and ASP+CSP/PP composites. These images provide different perspectives on the mechanical properties. When individual biodegradable fillers are mixed into the matrix, the particles may be unable to bear the load, resulting in particle pullouts during failure. However, in the case of combined particles, there appears to be better bonding between the particles. Consequently, in the hybrid biodegradable particle-reinforced composite, such particle pullouts are not observed in the failure zone.

In the scanning electron microscopic images, the differences in mechanical properties between the ASP/PP, CSP/PP, and ASP+CSP/PP composites are evident. When individual biodegradable fillers are mixed into the matrix, the particles may not be uniformly distributed or effectively bonded to the matrix, leading to weak interfaces. As a result, during tensile loading, these particles may fail to effectively transfer load, resulting in particle pullouts and reduced mechanical performance.

However, in the case of the combined coconut and almond shell composite, the synergistic effect of the two types of fillers may lead to improved interfacial bonding with the matrix. This improved bonding enhances load transfer between the matrix and the fillers, reducing the occurrence of particle pullouts during failure. Consequently, the hybrid biodegradable particle-reinforced composite exhibits better mechanical properties and a more uniform distribution of stress, as evidenced by the absence of particle pullouts in the failure zone observed in the scanning electron microscopic images. (Fig.6).

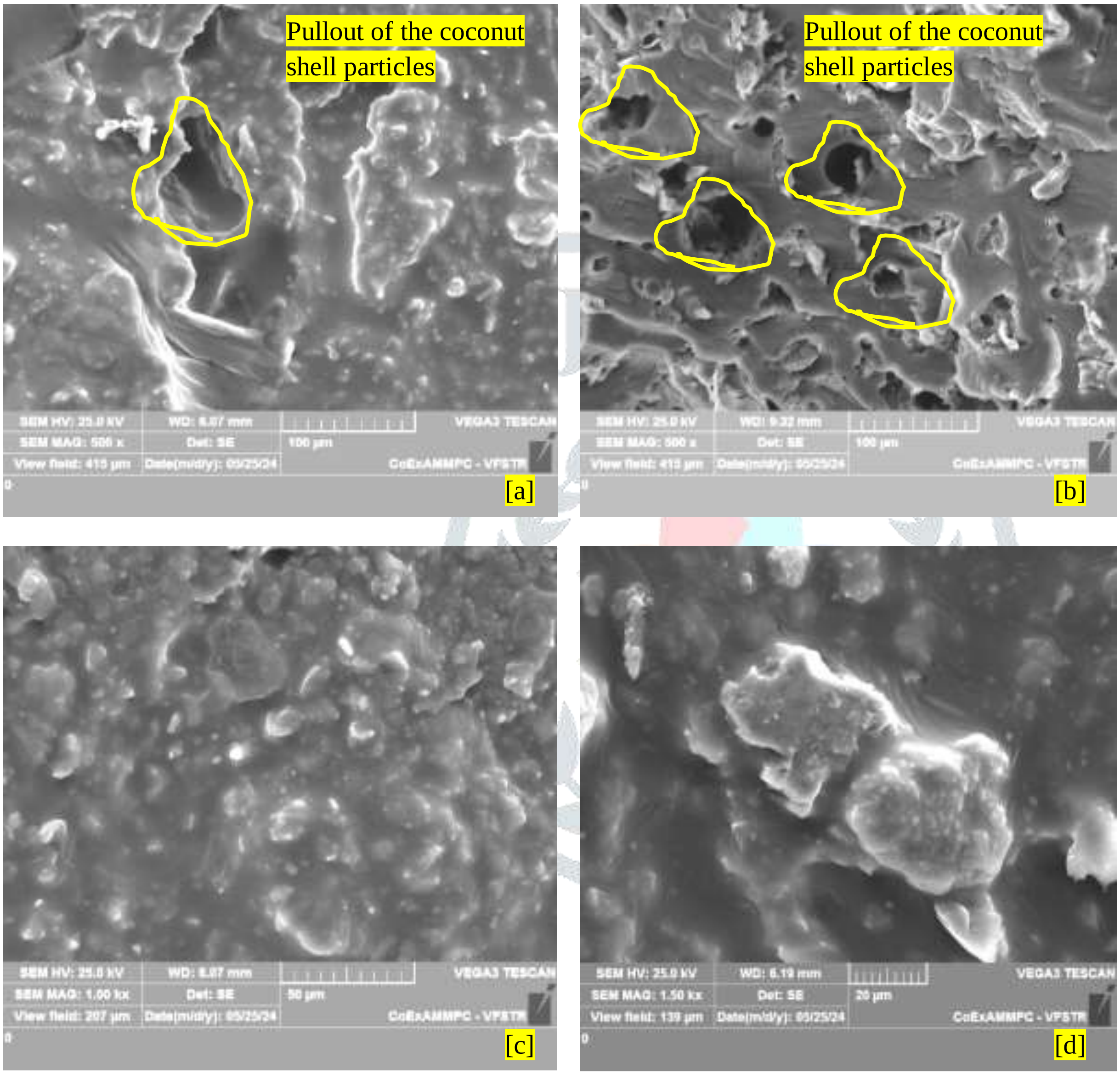

Fig.6 SEM images of [a] ASP/PP, [b] CSP/PP and [c-d] ASP+CSP/PP composite

Conclusions:

The present work addressed the effect of different particulate reinforcement on the mechanical properties of resulting composite.

The following conclusions are obtained from the present work.

- Combining almond powder and coconut powder into the polymer matrix significantly improved the tensile strength, with an increase of 132.4% and 32.35% higher than the ASP/PP and CSP/PP composites, respectively.
- The incorporation of coconut shell powder into almond shell powder enhances tensile strength compared to the pure ASP/PP composite.
- A substantial improvement of approximately 88.8% in impact strength was observed in the CSP/PP composite compared to the ASP/PP composite. Conversely, the ASP+CSP/PP composite demonstrated a 55.5% improvement in impact strength compared to the individual ASP/PP composite.
- An improvement of approximately 16% in thermal conductivity was observed with almond shell powder compared to coconut shell powder mixed composite.

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