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Tensile Properties of Green Polymer Concrete

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Abstract: This research investigates the substitution of fine aggregates with waste materials—specifically saw dust and shredded plastic bottles (PET)—to produce green polymer concrete using locally available resources. The saw dust was sourced from wood industry residues, while the chopped PET originated from recycled plastic bottles. Additional constituents included epoxy resin (from Romanian industry), fly ash, and natural aggregates. A control mix of conventional polymer concrete was prepared for comparison. Experimental mixtures were developed by replacing fine aggregates with waste materials at varying percentages, ranging from 25% to 100%. Mechanical properties were evaluated through flexural and splitting tensile strength tests. Results indicated that polymer concrete incorporating saw dust exhibited higher flexural strength than mixtures with PET waste. Furthermore, both waste-modified concretes showed improved splitting tensile strength compared to the control mixture.

Keywords: Green concrete, Polymer concrete, Saw dust, Shredded PET, Flexural strength, Sustainable construction

I. Introduction

The construction industry is undergoing a significant transformation, driven by the urgent need to address environmental degradation, resource depletion, and the increasing costs of conventional building materials. In response to these challenges, researchers and industry professionals are actively exploring sustainable alternatives that not only reduce environmental footprints but also enhance the performance and longevity of construction materials. Among such innovations, **polymer concrete** has gained attention for its superior mechanical properties, chemical resistance, and adaptability in a wide range of civil engineering applications.

Polymer concrete is a composite material made by binding aggregates with polymer resins, typically epoxy, polyester, or vinylester, instead of traditional cement. Unlike ordinary Portland cement concrete, polymer concrete offers advantages such as rapid curing, low permeability, high tensile strength, and resistance to aggressive environmental conditions. These characteristics make it suitable for applications such as bridge overlays, precast structural elements, repair mortars, wastewater infrastructure, and industrial flooring [1, 2, 3].

To further promote sustainability, researchers are investigating the use of **industrial and agricultural wastes** as substitutes for natural aggregates or as functional additives in polymer concrete. This approach aligns with the principles of circular economy and waste valorization. Fillers such as **fly ash, silica fume, ground granulated blast-furnace slag, and rice husk ash** are often incorporated to refine microstructure and reduce resin demand [4, 5, 6, 7]. Likewise, partial or full replacement of natural aggregates with materials like **shredded PET bottles,**

rubber particles, expanded polystyrene, recycled concrete aggregates, crushed glass, and saw dust offers a promising pathway to reduce landfill waste and conserve non-renewable resources [8–18].

However, the incorporation of such unconventional materials can also influence the fresh and hardened properties of concrete. While some modifications may lead to a reduction in compressive or tensile strength, others enhance ductility, reduce density, or improve resistance to thermal and chemical attacks. The mechanical behavior—especially **flexural and splitting tensile strength**—is crucial for determining the suitability of green polymer concrete in load-bearing and structural applications.

This study focuses on the mechanical performance of polymer concrete produced by **substituting fine aggregates (sand)** with **saw dust** and **shredded PET bottles**, both being abundantly available and underutilized waste materials. The substitution levels varied from **25% to 100% by volume**, allowing for a comparative evaluation of performance trends. The objective was to assess how the nature and dosage of waste aggregates influence the **flexural strength** and **splitting tensile strength** of polymer concrete. Through this investigation, the study aims to provide insights into the viability of using such waste-based composites as part of a sustainable construction strategy.

II. Experimental program

The experimental investigation involved a control mixture and two sets of green polymer concrete mixtures with fine aggregate substitutions. The control polymer concrete (CPC) was composed of the following materials by weight percentage: epoxy resin (12.4%), fly ash as filler (12.8%), and natural aggregates—sand (0–4 mm, Sort I) and gravel (4–8 mm, Sort II)—each at 37.4%. All proportions are expressed relative to the total weight of the mixture.

The epoxy resin used was Systemthree's T-88, characterized by its high tensile strength (7000 psi), excellent adhesion to a variety of materials, and high resistance to environmental exposure. The fly ash was sourced from the Raichur Thermal Power Station (RTPS), Karnataka. Its key physical and chemical properties are listed in Table 1. With a composition of approximately 57% SiO_2, 26% Al_2O_3, and 0.97% CaO, the fly ash is classified as Class F according to ASTM standards (2008). Approximately 60% of its particles were finer than 45 μm.

The waste PET used in the study was derived from recycled plastic bottles, chopped to particle sizes ranging from 0 to 4 mm. The unit weight of PET was 433 kg/m³. Saw dust, obtained as a byproduct of the wood industry, was sieved to match the particle size of the 0–4 mm sand and had a unit weight of 168 kg/m³.

In the green polymer concrete mixtures, the epoxy resin, fly ash, and 4–8 mm gravel were kept constant, while the 0–4 mm sand was substituted with either saw dust or PET in varying dosages. For the saw dust–based mixtures, sand was replaced by volume at rates of 25%, 50%, 75%, and 100%, designated as SDPC1 through SDPC4, respectively. Similarly, PET-based mixtures were designated PETPC1 to PETPC4 for corresponding replacement levels.

To prepare the polymer concrete, the aggregates, fly ash, and waste materials were first dry-mixed. The epoxy resin and hardener were then blended and added to the dry mix. The resulting mixture was cast into 70 × 70 × 210 mm prismatic molds, in accordance with European standards. Specimens were demolded after 24 hours and cured at ambient conditions. At 14 days, the samples were tested to evaluate their mechanical performance. Flexural strength (f_{ti}) and splitting tensile strength (f_{td}) were measured for each mixture using three replicate samples per test, following standard procedures.

III. Results and discussions

3.1 Flexural strength

The flexural strength values for all mixtures are presented in **Figure 1**, with the trend of variation based on substitution dosage shown in **Figure 2**.

The highest flexural strength, f_{ti}= 18.25 MPa, was recorded for the polymer concrete with 50% saw dust substitution (SDPC2), reflecting an increase of 12.6% compared to the control mixture. Overall, the incorporation of saw dust influenced the flexural strength positively, except in the case of 75% substitution (SDPC3), which showed a slight reduction of approximately 8.8% compared to the control.

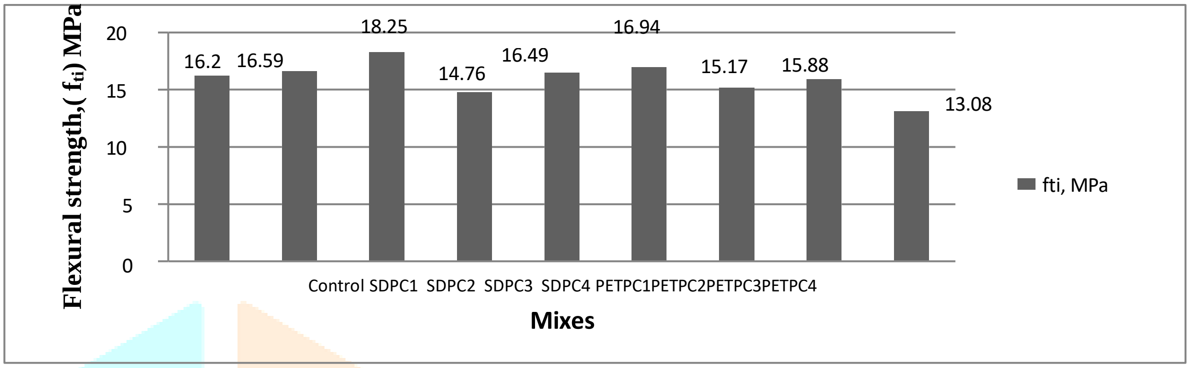

Figure 1. Flexural strength (f_{ti}) of polymer concrete mixtures with varying dosages of saw dust and PET as fine aggregate substitutions.

In the case of PET-based mixtures, the maximum flexural strength was 16.94 MPa for the 25% substitution (PETPC1), which represents a 4.6% improvement over the control. However, further increases in PET content led to a decline in performance. At substitution rates of 50%, 75%, and 100%, the flexural strength values were lower than the control by 6.3%, 1.97%, and 19.3%, respectively. This indicates a general trend: as the PET dosage increases, the flexural strength tends to decrease.

A comparative analysis of the two waste types shows that mixtures with 50% and 75% saw dust replacement (SDPC2 and SDPC3) demonstrated superior performance. In contrast, the PET-based mixtures performed better only at 25% and 100% substitution levels (PETPC1 and PETPC4). Despite the variations, the overall range of flexural strength values across both waste types remained relatively close.

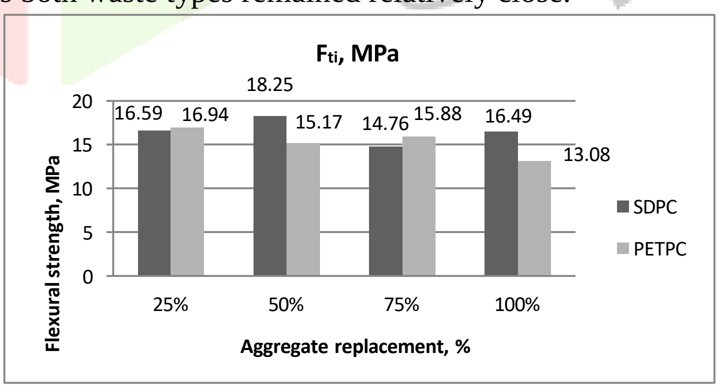

Figure 2. Variation of flexural strength with the substitution dosage.

3.2. Splitting strength

The splitting tensile strength (f_{td})alues for all polymer concrete mixtures are illustrated in **Figure 3**. All mixtures incorporating saw dust or PET as fine aggregate replacements exhibited higher splitting strength compared to the control mixture, with increases ranging from **36.8% to 53.4%**.

The highest splitting strength value, f_{td} = 7.38 MPa, was recorded for the mixture with 100% saw dust substitution (SDPC4), showing a significant enhancement over the control (Figure 3).

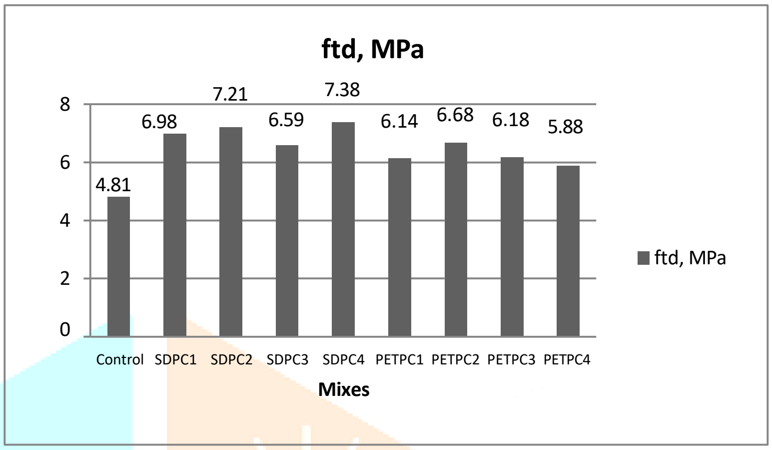

*Figure 3. Splitting tensile strength (f_{td}) of polymer concrete mixtures with saw dust and PET as fine aggregate replacements***.**

In the case of PET substitutions, the maximum splitting strength reached **6.68 MPa** for the 50% PET replacement (PETPC2), which was **4.6% higher** than the control. PET substitution improved the splitting tensile strength across all dosages, with increases ranging from **22.2% to 38.9%**, indicating a consistent enhancement in mechanical performance.

When comparing the two waste types, **saw dust substitutions outperformed PET** at all replacement levels (Figure 4). However, the difference in splitting tensile strength values between the two was relatively small, suggesting both waste materials contributed positively to the mechanical characteristics of green polymer concrete.

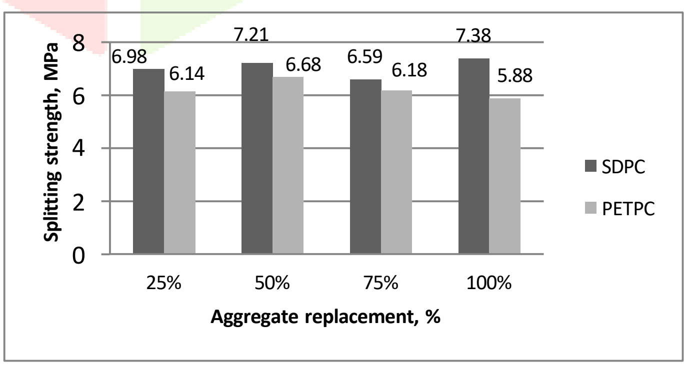

Figure 4. Variation of splitting tensile strength (f_{td}) with different substitution dosages of saw dust and PET..

IV. Conclusions

The global construction industry is increasingly focused on developing sustainable concrete by incorporating local materials and industrial wastes, aiming to reduce environmental impact and production costs.

In this experimental study, two types of waste—**saw dust** and **chopped PET**—were used to partially or fully replace fine aggregates (0–4 mm) in polymer concrete mixtures. The substitution levels ranged from 25% to 100% by volume.

The test results demonstrated that both types of waste materials influenced the tensile properties of polymer concrete. In general, increasing the substitution percentage led to a reduction in tensile strength. However, mixtures containing saw dust consistently showed better performance than those with PET.

- The **highest flexural strength** was observed in the mixture with **50% saw dust** substitution.
- For PET, the **maximum flexural strength** was achieved at **25% substitution**.
- In terms of **splitting tensile strength**, **all substitution levels** for both saw dust and PET **exceeded the control mixture**.
- The highest splitting strength was obtained with **100% saw dust** replacement, while the best result for PET was at **50% substitution**.

These results confirm that waste materials like saw dust and PET can effectively substitute fine aggregates in polymer concrete without compromising, and in some cases even enhancing, mechanical properties—particularly tensile strength.

The use of such green materials not only addresses the issue of solid waste disposal but also contributes to the conservation of natural resources. With further study and optimization, **green polymer concrete** has significant potential for use in various construction applications, provided that environmental and health standards are met.

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