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Production and characterization of cementitious mortars modified with recycled PET and rubber for application in passive ballistic protection

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Introduction

Post-consumer PET bottles and end-of-life tires are among the urban wastes generated in the largest volumes and recovered at the lowest rates. Their incorporation into cementitious matrices is a valorization route with both environmental and economic appeal. The two wastes act through distinct and complementary mechanisms: ground rubber introduces deformable phases capable of dissipating energy, while PET fibers control crack propagation through crack bridging. Combining both in a single matrix makes it possible to exploit this behavior in low-cost systems intended for impact energy absorption, such as passive ballistic protection barriers.

Objectives

To assess the combined incorporation of recycled PET fibers and ground tire rubber into cementitious mortars, aiming at an economically viable passive ballistic protection system.

- To determine the influence of rubber content (0 to 15%) on compressive and flexural tensile strength.
- To verify the contribution of PET fibers to the retention of flexural strength.
- To evaluate the dynamic modulus of elasticity as an indicator of deformability and energy absorption capacity.
- To characterize the microstructure and the rubber–paste interfacial transition zone by SEM.

Methodology

Materials

Portland cement CP II-F 32; quartz sand (fineness modulus 1.5–2.4); PET fibers from post-consumer bottles (20 × 5 mm; 1% by volume); ground tire rubber replacing 0%, 5%, 10% and 15% of the fine aggregate mass; polycarboxylate superplasticizer (≤ 2% of cement mass).

Mix design and curing

Four mixtures with a fixed water/cement ratio of 0.50. Moist curing for 28 days at 23 ± 2 °C.

Testing

Compressive and flexural tensile strength according to NBR 13279:2005; dynamic modulus of elasticity; scanning electron microscopy (SEM) for morphological and interfacial analysis.

Results and Discussion

Compressive strength decreased progressively as the rubber content increased, from approximately 18 MPa in the reference mixture to 11 MPa at 15% replacement — a reduction of 25% to 40%. This behavior stems from the weak interfacial bond between the elastomeric particles and the hydrated cement paste, observed by SEM.

Flexural tensile strength remained stable at around 4.5 MPa in all formulations, evidencing the effectiveness of the PET fibers in crack-bridging mechanisms. The dynamic modulus of elasticity decreased by 35% in the mixture with 10% rubber, indicating greater deformability — a favorable feature for energy absorption.

Table 1. Mechanical properties of the mortars at 28 days.

Mixture	Rubber (% by mass)	Compressive (MPa)	Flexural (MPa)	Dynamic modulus
REF	0	18.0	≈ 4.5	reference
B-5	5	13.5	≈ 4.5	18%
B-10	10	12.5	≈ 4.5	35%
B-15	15	11.0	≈ 4.5	48%

Overall compressive strength reduction of 25% to 40% with increasing rubber content. Tests according to NBR 13279:2005, at 28 days of moist curing.

− 39%
compression
(18 → 11 MPa)

≈ 4.5 MPa
stable flexure
at all contents

− 35%
dynamic modulus
(10% rubber)

Conclusions

- Ground rubber markedly reduces compressive strength (18 → 11 MPa), which limits the replacement level.
- PET fibers preserve flexural strength (≈ 4.5 MPa) at all contents, acting as post-cracking reinforcement.
- The 35% drop in dynamic modulus at 10% rubber indicates a gain in deformability.
- A content of 10% is the best compromise between strength and deformation capacity.
- Impact and ballistic tests are required to validate the proposed application.

References and Acknowledgments

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