TECHNICAL & ENVIRONMENTAL ASSESSMENT OF MORTARS WITH RECYCLED GLASS POWDER AS A SUPPLEMENTARY CEMENTITIOUS MATERIAL

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INTRODUCTION

Cement production has a high carbon footprint (Habert et al., 2020), and using waste materials like finely ground recycled glass can reduce emissions. While glass powder can contribute to strength, high replacement levels may weaken performance. However, the net effect depends on replacement level, fineness and curing age, and high replacement levels can lead to marked strength penalties due to clinker dilution (Jani and Hogland, 2014).

This study evaluates mortars with 10–40% cement replacement, analyzing strength over time and environmental impact, providing a clear comparison between carbon reduction and performance.

METHODS

Five mixes were produced: a reference mortar (M0) and four mortars with cement replacement by recycled glass powder as Table 1.

Table 1. Mix proportions (kg/m^3)

Material	M0	M10	M20	M30	M40
CEM I	972.41	875.17	777.93	680.69	583.45
Recycled Glass	0.00	97.24	194.48	291.72	388.96
Natural Sand	3758.59	3758.59	3758.59	3758.59	3758.59
Total Water	679.48	679.48	679.48	679.48	679.48

- Mixing followed a staged protocol: sand was pre-mixed with its saturation water for 2 min at low speed (V1; 140 rpm) and rested for 10 min (mixer off). Cement was added gradually whilst mixing continued at V1 for 30 s. Effective mixing water was then added and mixing continued for 2 min at V1. After a 1 min mixing resumed for 1 min at high speed (V2; 285 rpm).
- Mortar was cast into 40 × 40 × 160 mm prisms and cured at 20 ± 2 °C and 65 ± 5% RH until testing.
- Flexural and compressive strength were measured at 7, 14 and 28 days according to UNE-EN 1015-11.
- A simplified GWP assessment (materials only; no transport) was performed for a functional unit of 1 m^3 of mortar to enable internal comparison between mixes. Inventory data were sourced from ecoinvent 3.10 and modelling was performed in SimaPro 9.6.0.1, applying EN 15804+A2 and IPCC 2021 GTP100.

CONCLUSIONS

- ✓ Recycled bottle glass powder can function as an SCM in cement mortars to reduce materials-only embodied carbon whilst maintaining acceptable strength at moderate replacement levels.
- ✓ A 10% replacement provided the most favorable overall balance, improving compressive strength at 14 and 28 days and maintaining flexural strength equivalent to the reference at 28 days.
- ✓ A 20% replacement achieved compressive strength comparable to the reference at 28 days but reduced flexural strength.
- ✓ Higher replacements (30-40%) delivered larger GWP reductions (up to ~38%) but incurred substantial strength penalties.
- ✓ For the studied system and curing regime, 10-20% replacement appears to provide the most practical compromise between technical performance and environmental benefit.

MATERIALS

Figure 1. Crushed glass in two crushing phases

- Portland cement CEM I 42.5 R-SR.
- Limestone natural sand (S) (0/3) with density 2.447 g/cm³ and water absorption 2.6%.
- SCM: recycled bottle glass, crushed using a jaw crusher and subsequently milled with a laboratory pulverizer to obtain a powder intended to replace cement.
- Potable water was used for mixing
- No admixtures were added.

RESULTS & DISCUSSION

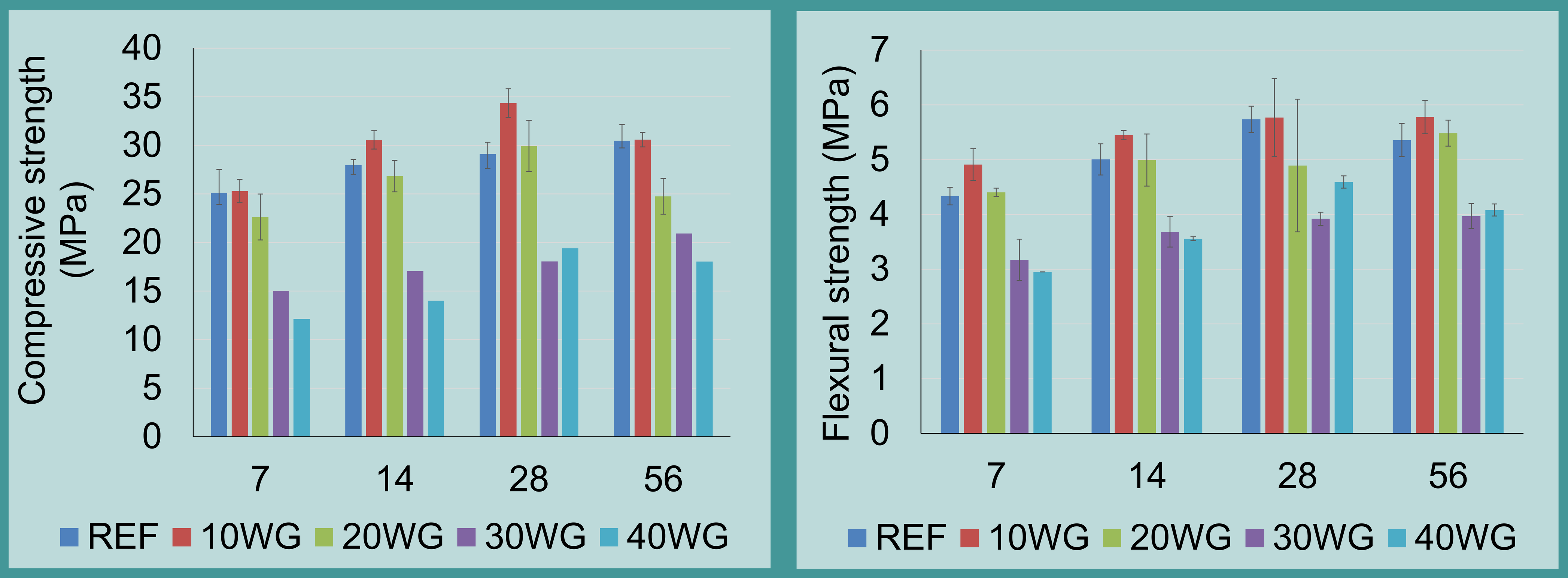

Figure 2. Mechanical Properties (Compressive and flexural strength)

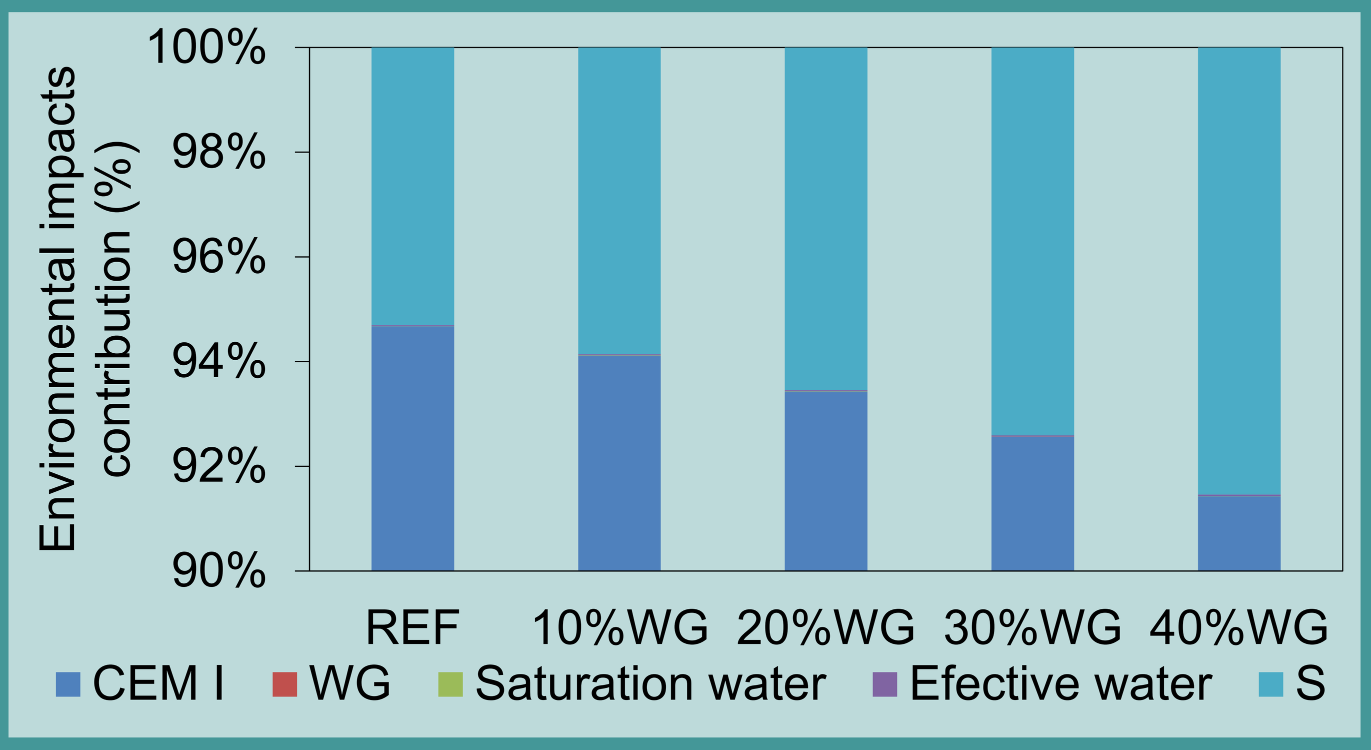

Figure 3. Material-only GWP

Regarding compressive strength at 7 days, M0 and M10 were comparable (25.12 and 25.29 MPa), whilst M20 decreased to 22.62 MPa and higher replacement levels showed pronounced reductions (15.03 MPa for M30; 12.13 MPa for M40).

At 28 days, M10 reached 34.35 MPa versus 29.11 MPa for M0 (≈+18%), and M20 achieved 29.94 MPa (comparable to M0). In contrast, M30 and M40 remained substantially lower (18.05 and 15.28 MPa). This pattern aligns with published observations that moderate glass powder contents can maintain or improve later-age strength depending on fineness and curing, whereas higher replacements tend to be dominated by dilution effects (*Matos and Sousa-Coutinho, 2012*).

Flexural strengths follow the same trends as compressive strengths.

The GWP progressively decreased with increasing waste glass content, from 497.96 kg CO_2-eq m^{-3} in M0 to 309.39 kg CO_2-eq m^{-3} in M40, representing a maximum reduction of 37.9%. According to the contribution analysis shown in Figure 3, this decrease was mainly due to the lower contribution of CEM I, which remained the dominant component, although its relative contribution decreased from 94.7% to 91.4%. Conversely, the relative contribution of S increased from 5.3% to 8.5%, owing to the reduction in total GWP rather than to a higher absolute impact. The contributions of saturation water and effective water were negligible, while WG showed no associated GWP under the assumptions considered. (*Habert et al., 2020*).

The combined results highlight a practical trade-off: carbon savings increase with replacement, but mechanical performance imposes an upper bound on feasible substitution.

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