UTILISATION OF GLASS WASTE AS A REPLACEMENT FOR NATURAL SAND IN MORTAR

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Abstract
The depletion of natural river sand and the accumulation of non-biodegradable waste glass create resource and environmental challenges for construction. This study evaluated crushed waste glass as a partial replacement for natural river sand in one to five cement to fine aggregate masonry mortar. Six glass contents from zero to fifty percent by mass of the sand fraction were tested at a constant water-cement ratio of 0.60. Aggregate grading, flow table workability, dry bulk density, seven- and twenty-eight-day compressive and flexural strengths, and brick mortar bed joint shear performance were assessed using relevant European standards. The twenty percent mix achieved 174.50 mm flow, 2277.23 kg/m³ dry density, 10.52 MPa compressive strength and 1.87 MPa flexural strength at twenty-eight days. Relative to the control, compressive and flexural strengths increased by 42.33 and 7.70 percent, respectively. Bed joint shear strength was also slightly higher at all three precompression levels, while the initial shear strength intercept remained essentially unchanged. Considering acceptable workability, the highest measured strengths, a small density reduction and one fifth sand substitution, twenty percent was identified as the optimum level within the tested range. Long-term durability, especially alkali-silica reaction, and local processing cost require further assessment before field adoption.

Keywords: Circular economy, Workability, Compressive strength, Bed joint shear

1. Introduction
Natural river sand is widely used in masonry mortar, but excessive extraction can degrade riverbeds, destabilise banks and disturb habitats. Waste glass is durable and non-biodegradable, so converting it into fine aggregate can simultaneously reduce virgin sand demand and divert glass from disposal. Previous mortar studies confirm that waste glass can function as a sand substitute when its particle size and replacement level are controlled [1], [2].

Glass differs from river sand in particle shape, surface condition and water absorption, and its amorphous silica also raises an alkali-silica reaction concern that must be considered separately from short-term strength [3]. Fine glass mortar performance is strongly dependent on grading and particle geometry [4], while broader reviews identify waste glass reuse as a circular economy route for cement-based materials [5]. Evidence remains limited for ordinary one to five masonry mortar under local material conditions, particularly when mortar properties and brick mortar bed joint behaviour are considered together. The objective was therefore to identify a practical glass replacement level using workability, density, compressive strength, flexural strength and masonry shear performance.

2. Materials and Methods
Ordinary Portland cement, natural river sand, cleaned crushed waste glass, potable water and engineering clay bricks were used. A nominal one to five cement to fine aggregate masonry proportion was selected because it is a familiar proportion for local brickwork. For laboratory batching, the proportion was converted to masses, and glass replaced the sand fraction by mass. The water-cement ratio was fixed at 0.60 for all mixes so that changes in performance could be attributed to glass replacement rather than changes in water content. Six mixes were

prepared at 0, 10, 20, 30, 40 and 50 percent replacement and are designated WG0 to WG50; the WG notation is used to avoid confusion with concrete strength grade labels.

Sieve analysis was performed on 500 g dry samples using 4.75, 2.36, 1.18, 0.60, 0.30 and 0.15 mm sieves. Figure 1 compares the measured particle size distributions. The glass had lower percentages passing than the river sand from 2.36 to 0.15 mm, indicating a somewhat coarser grading, while both materials followed the adopted fine aggregate grading envelope. Aggregate specific gravity and absorption were not independently measured, so no unverified values are reported.

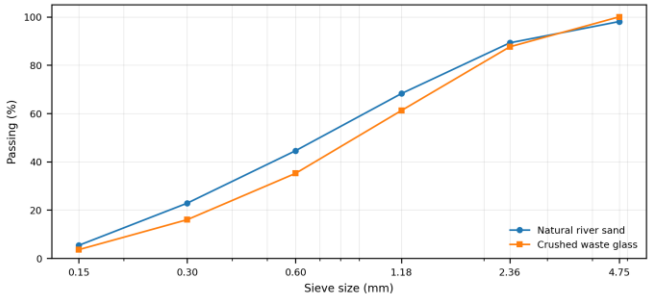

Figure 1: Particle size distribution of natural river sand and crushed waste glass.

Table 1: Test programme, standards and replication.

Property	Standard	Replication
Flow table workability	EN 1015-3	1 determination per mix (2 diameters)
Dry bulk density	EN 1015-10	3 specimens per mix
Compressive strength	EN 1015-11	3 cubes per mix at 7 and 28 days
Flexural strength	EN 1015-11	3 prisms per mix at 7 and 28 days
Bed joint initial shear	EN 1052-3	3 triplets per stress level for WG0 and WG20

3. Results and Discussion

The flow diameter remained within the adopted 165–185 mm target for every mix: 178.50, 175.00, 174.50, 170.00, 169.50 and 171.50 mm for WG0 to WG50, respectively. Dry bulk density decreased from 2335.29 kg/m³ for WG0 to 2277.23 kg/m³ for WG20 and 1993.00 kg/m³ for WG50. The density reduction at WG20 was only 2.49 percent, whereas larger reductions occurred above 30 percent replacement.

Compressive strength increased to a maximum at WG20 and then decreased. At 28 days, WG0, WG10, WG20, WG30, WG40 and WG50 achieved 7.39, 9.80, 10.52, 8.91, 7.91 and 7.74 MPa, respectively. Thus, WG20 was 42.33 percent higher than the control. The 28-day flexural strength followed the same optimum: 1.73 MPa for WG0 and 1.87 MPa for WG20, an increase of 7.70 percent, while WG40 and WG50 fell below the control. The study did not measure pore structure, interfacial transition zone characteristics or microcracking; therefore, the post-WG20 strength decline is reported as an experimental trend rather than assigned to a specific mechanism.

WG20 was selected for masonry validation only after the mortar screening stage because it combined acceptable workability, the highest 7- and 28-day compressive strengths, the highest 28-day flexural strength and only a small density reduction. This staged selection provided a

clear basis for limiting the more resource-intensive triplet testing to the control and the best-performing glass mix. Figure 2 summarises the compressive strength trend and the subsequent bed joint shear response.

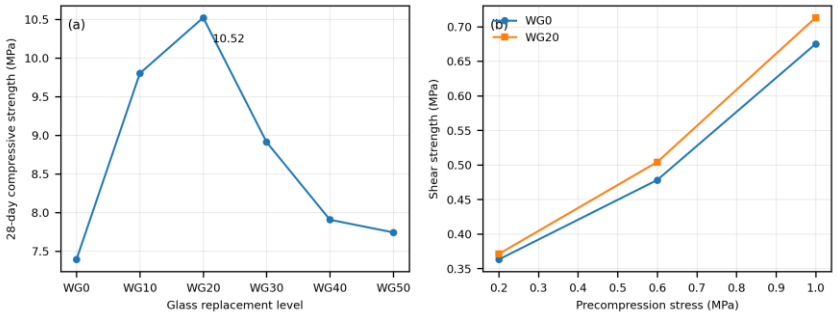

Figure 2: (a) 28-day compressive strength and (b) bed joint shear response of WG0 and WG20.

At precompression stresses of 0.20, 0.60 and 1.00 MPa, WG20 recorded shear strengths of 0.37, 0.50 and 0.71 MPa, compared with 0.36, 0.48 and 0.68 MPa for WG0. Linear regression gave initial shear strength intercepts of 0.273 MPa for WG20 and 0.272 MPa for WG0, while the friction coefficient increased from 0.390 to 0.427. The result indicates that the selected glass mortar did not reduce bed joint shear performance within the tested conditions.

Durability was not experimentally evaluated, so alkali-silica reaction resistance cannot be concluded; dedicated expansion and exposure testing is required before routine use [3]. Practical use also requires consistent glass collection, sorting, cleaning, crushing and grading. These steps add transport and processing costs; because no cost analysis was undertaken, local economic feasibility remains to be verified.

4. Conclusions and Practical Implications

Within the tested one to five-masonry mortar system, 20 percent waste glass replacement provided the most balanced performance. WG20 remained workable at 174.50 mm flow, had only a 2.49 percent reduction in dry density, and achieved the highest 28-day compressive and flexural strengths of 10.52 and 1.87 MPa. It also matched or slightly exceeded the control in bed joint shear resistance. The result supports controlled partial replacement of natural river sand with processed waste glass, but the 20 percent value should be treated as the optimum for this material set and test programme rather than as a universal replacement level. Long-term ASR-related durability, moisture exposure, field workmanship and local processing economics should be verified through further testing and pilot masonry trials before large-scale adoption.

References

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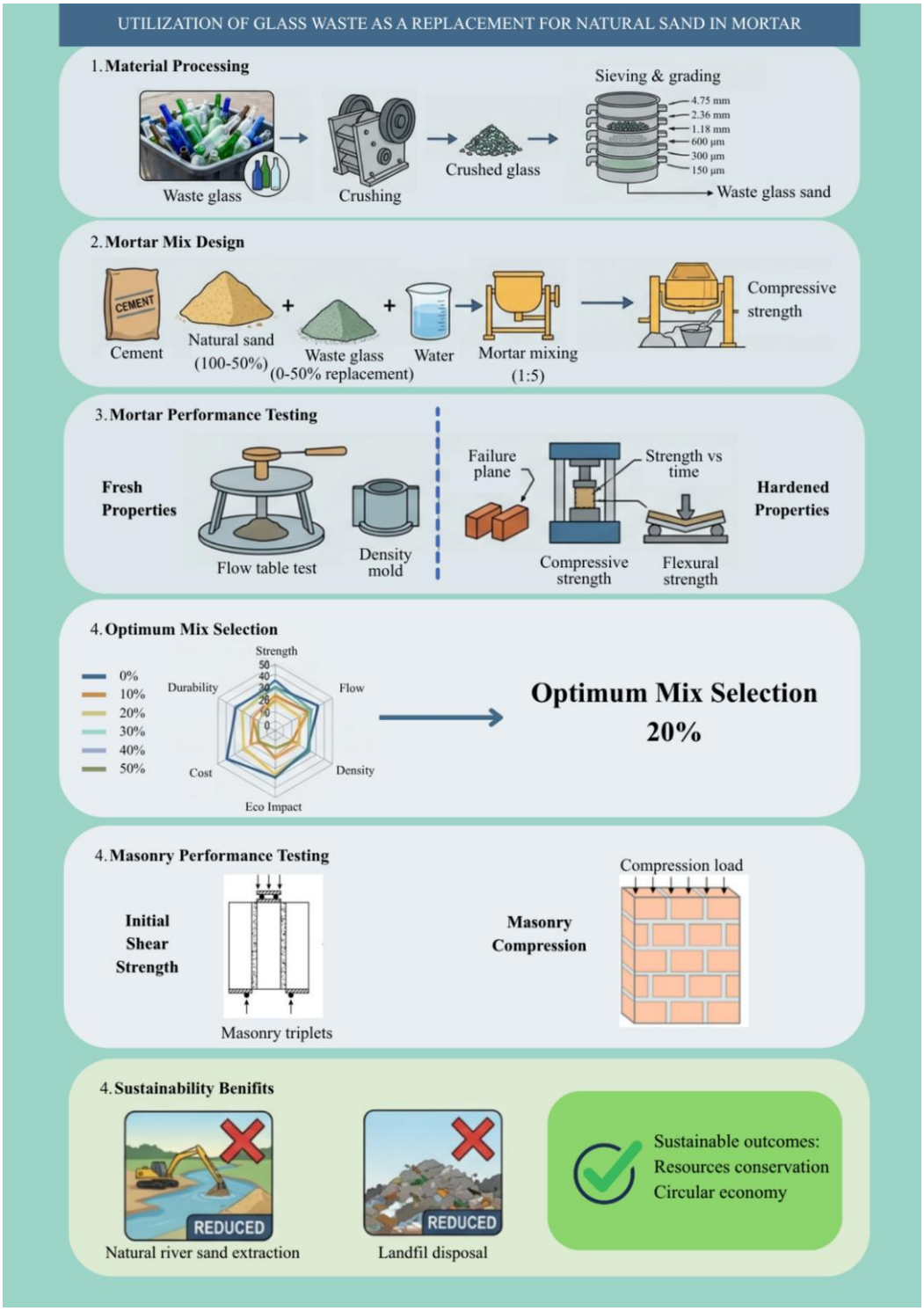
UTILIZATION OF GLASS WASTE AS A REPLACEMENT FOR NATURAL SAND IN MORTAR
1. Material Processing
Waste glass
Crushing
Crushed glass
Sieving & grading
4.75 mm
2.36 mm
1.18 mm
600 µm
300 µm
150 µm
Waste glass sand
2. Mortar Mix Design
CEMENT
Cement
Natural sand
(100-50%)
Waste glass
(0-50% replacement)
Water
Mortar mixing
(1:5)
Compressive strength
3. Mortar Performance Testing
Fresh Properties
Flow table test
Density mold
Failure plane
Strength vs time
Compressive strength
Flexural strength
Hardened Properties
4. Optimum Mix Selection
Strength
Flow
Density
Eco Impact
Cost
Durability
0%
10%
20%
30%
40%
50%
Optimum Mix Selection
20%
4. Masonry Performance Testing
Initial Shear Strength
Masonry triplets
Masonry Compression
Compression load
4. Sustainability Benifits
REDUCED
Natural river sand extraction
REDUCED
Landfil disposal
Sustainable outcomes:
Resources conservation
Circular economy