

Study On Partial Replacement Of Glass Powder As Cement And Foundry Sand As M-Sand For Sustainable Development Of Concrete

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ABSTRACT

Industrial waste utilization in concrete can reduce the consumption of conventional cementitious and fine-aggregate materials while providing a practical route for waste management. This experimental study evaluates M30 concrete containing waste glass powder as a partial cement replacement and foundry sand as a partial replacement for M-sand. Four mixtures were investigated: M0 with no replacement, M1 with 5% glass powder and 10% foundry sand, M2 with 10% glass powder and 20% foundry sand, and M3 with 15% glass powder and 30% foundry sand. The reference mix was designed with a water-cement ratio of 0.45, 405.5 kg/m³ cement, 182.47 L/m³ water, 775 kg/m³ fine aggregate, and 1161.6 kg/m³ coarse aggregate. Workability was measured by slump, and 150 mm concrete cubes were tested for compressive strength after 7 and 14 days of curing. Slump values for M0-M3 were 80, 85, 75, and 68 mm, respectively. The highest compressive strengths were obtained for M1, reaching 27.8 MPa at 7 days and 33.6 MPa at 14 days compared with 25.5 and 31.0 MPa for the control. The corresponding improvements were 9.02% and 8.39%. Higher replacement levels reduced strength. Therefore, 5% glass powder with 10% foundry sand was the optimum combination within the investigated range.

Keywords: Glass powder; Foundry sand; M-sand; M30 concrete; Sustainable concrete; Compressive strength; Workability

I. INTRODUCTION

Concrete is central to building and infrastructure construction, but its growing use increases demand for cement and natural aggregates. Cement production is energy intensive, while the extraction of conventional fine aggregates places additional pressure on natural resources. Reuse of industrial wastes in concrete can therefore support both material conservation and waste-management objectives.

Waste glass can be processed into fine glass powder and used as a supplementary cementitious material. The high silica content of glass and the pozzolanic behaviour of finely ground particles can contribute to additional calcium-silicate-hydrate formation and can also provide a micro-filler effect. In parallel, waste foundry sand offers a potential partial replacement for conventional fine aggregate.

Manufactured sand (M-sand) is widely used where river sand is scarce or restricted. The present investigation combines M-sand with foundry sand and partially replaces cement with glass powder to evaluate whether an M30 concrete mix can maintain practical workability and improve early-age compressive strength.

The study focuses on four replacement combinations ranging from the conventional control to 15% glass powder and 30% foundry sand. The resulting concrete is assessed using slump and 7- and 14-day compressive-strength tests.

II. OBJECTIVES

- To develop M30 grade concrete using glass powder as a partial cement replacement and foundry sand as a partial replacement for M-sand.
- To evaluate the workability of the investigated concrete mixtures.
- To determine the effect of increasing glass-powder and foundry-sand replacement on compressive strength.
- To identify the optimum replacement combination within the investigated range for sustainable concrete development.

III. LITERATURE SURVEY

Vandhiyan, Ramkumar, and Ramya investigated glass powder as a partial replacement for cement and reported that low replacement levels can improve mechanical properties [1]. Rukmangadhara Rao, Himali Kumari, and Vidya Sagar Lal studied alternative manufactured sand as a partial replacement for natural fine aggregate and

evaluated concrete workability and strength [2]. Srinivas Reddy similarly examined replacement of natural sand with artificial sand in specified concrete mixes [3].

Islam, Rahman, and Kazi investigated waste glass powder as a partial cement replacement for sustainable concrete and linked the response to the pozzolanic behaviour of finely ground glass [4]. Other studies reviewed in the report examined ceramic waste as a cement substitute and the use of glass powder at different replacement percentages [5]-[7]. Collectively, the literature supports combined investigation of industrial-waste binder and fine-aggregate replacements.

IV. MATERIALS AND METHODOLOGY

Materials

The experimental programme used OPC 43 grade cement, crushed coarse aggregate, M-sand, waste foundry sand, finely ground glass powder, potable water, and Fosroc SP440 superplasticizer. Glass powder was reported to have a specific gravity of 2.50 and a silica content of approximately 90-96%. The superplasticizer had a reported specific gravity of 1.15 and pH greater than 6.0.

Table 1. Selected reported material properties

Material / property	Reported value
Cement specific gravity	3.11
Cement fineness	1.8% retained on 90 μ m sieve
Cement normal consistency	34%
Coarse aggregate specific gravity	2.74
Glass powder specific gravity	2.50
Glass powder SiO ₂ content	90-96%
SP440 specific gravity	1.15
SP440 chloride ion concentration	<0.2%

M30 mix design

The control concrete was designed for M30 grade under severe exposure conditions. A water-cement ratio of 0.45 and a target slump of 100 mm were adopted. The reported final mix proportion was 1:1.91:2.86 for cement:fine aggregate:coarse aggregate.

Table 2. Reported M30 reference mix quantities

Constituent	Quantity per m ³
Cement	405.5 kg
Water	182.47 L
Fine aggregate	775 kg
Coarse aggregate	1161.6 kg
Water-cement ratio	0.45

Replacement matrix and testing

Table 3. Glass-powder and foundry-sand replacement matrix

Mix	Cement (%)	Glass powder (%)	M-sand (%)	Foundry sand (%)
M0	100	0	100	0
M1	95	5	90	10
M2	90	10	80	20
M3	85	15	70	30

Concrete was mixed, placed in 150 × 150 × 150 mm cube moulds, compacted, demoulded, and water-cured. Workability was measured using the slump test. Compressive strength was determined after 7 and 14 days of curing. The laboratory sequence of mixing, slump measurement, cube casting, curing, and testing is illustrated in Fig. 1.

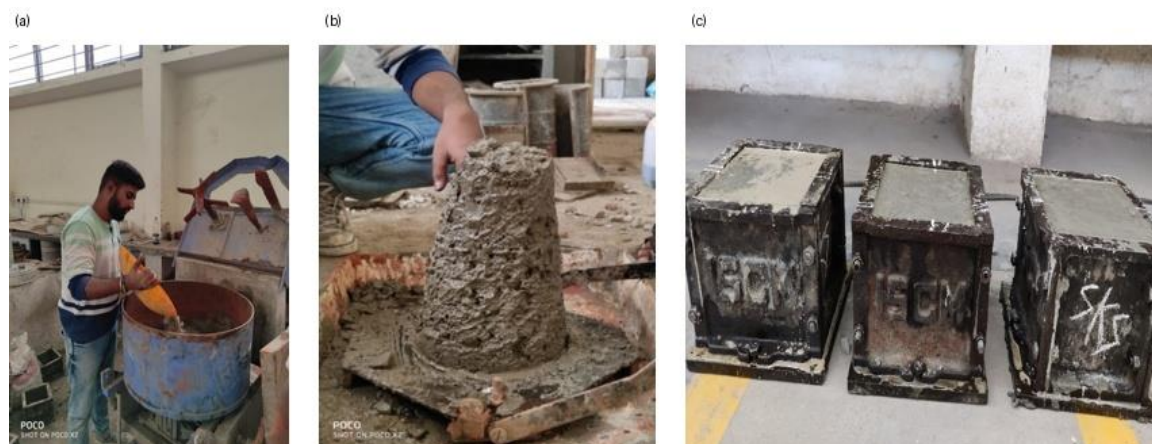


Fig. 1. Concrete preparation: (a) mixing, (b) slump testing, and (c) cube casting.

V. RESULTS AND DISCUSSION

Workability

Table 4. Slump results for the experimental mixes

Mix	Replacement combination	Slump (mm)	Reported observation
M0	0% GP + 0% FS	80	Standard
M1	5% GP + 10% FS	85	Minor increase
M2	10% GP + 20% FS	75	Reduced workability
M3	15% GP + 30% FS	68	Stiff mix

M1 recorded a slightly higher slump than the control, increasing from 80 to 85 mm. At higher replacement levels, workability declined to 75 mm for M2 and 68 mm for M3. The reduction at higher replacement levels was attributed in the report to the increasing foundry-sand content and the resulting stiffening of the mixture.

Compressive strength

Table 5. Compressive-strength results at 7 and 14 days

Mix	Replacement combination	7-day strength (MPa)	14-day strength (MPa)
M0	0% GP + 0% FS	25.5	31.0
M1	5% GP + 10% FS	27.8	33.6
M2	10% GP + 20% FS	23.2	28.5
M3	15% GP + 30% FS	20.5	25.2

The strength response showed a clear optimum at M1. Relative to M0, the 7-day strength increased from 25.5 to 27.8 MPa and the 14-day strength increased from 31.0 to 33.6 MPa. Increasing the replacement level beyond M1 reduced compressive strength, with M3 recording the lowest values at both curing ages.

Table 6. Percentage variation in compressive strength relative to M0

Mix	7-day variation	14-day variation	Performance category
M0	0.00%	0.00%	Baseline reference
M1	+9.02%	+8.39%	Optimum mix
M2	-9.02%	-8.06%	Strength reduction
M3	-19.61%	-18.71%	Maximum strength reduction

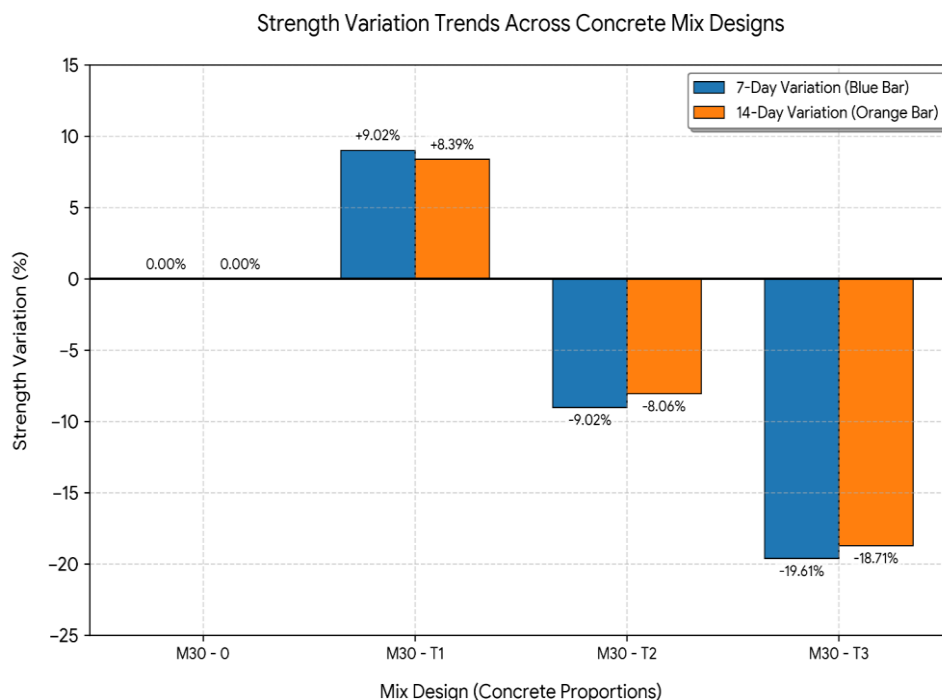


Fig. 2. Percentage variation in 7- and 14-day compressive strength for the experimental mixes.

The percentage comparison confirms the optimum response of M1, which produced gains of 9.02% at 7 days and 8.39% at 14 days. M2 and M3 produced progressively larger reductions relative to the control. Within the tested range, the beneficial effect of low-level glass-powder and foundry-sand replacement was therefore not maintained as the replacement proportions increased.

Sustainability interpretation

The M1 combination reduces the quantity of cement and M-sand used in the concrete while producing the highest measured compressive strength. The use of waste glass powder and foundry sand also provides a route for diverting industrial by-products into construction materials. The experimental programme, however, was limited to slump and compressive-strength testing up to 14 days; long-term strength and durability were not directly measured.

VI. CONCLUSION

- The workability of the concrete was affected by the combined glass-powder and foundry-sand replacement, with slump values of 80, 85, 75, and 68 mm for M0-M3.
- M1 containing 5% glass powder and 10% foundry sand produced the highest compressive strength at both test ages.
- The 7-day compressive strength increased from 25.5 MPa for M0 to 27.8 MPa for M1, corresponding to a reported gain of 9.02%.
- The 14-day compressive strength increased from 31.0 MPa for M0 to 33.6 MPa for M1, corresponding to a reported gain of 8.39%.
- Increasing the replacement beyond 5% glass powder and 10% foundry sand reduced compressive strength, with the largest reduction occurring for M3.
- Within the investigated range, 5% glass powder with 10% foundry sand was identified as the optimum combination for balancing material substitution and measured strength.

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