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Original Research Article

Experimental Investigation on Sustainable Concrete: Impact of Glass Powder as a Supplementary Cementitious Material

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Abstract

The main objective of this research is to investigate some properties of fresh and hardened concrete using glass powder as a partial replacement of cement at percentages of 15%, 25%, and 35% by weight, and to determine the optimum replacement ratio. Four concrete mixes were prepared with replacement levels of 0% (control mix), 15%, 25%, and 35% of cement by glass powder. Six cube specimens were cast for each mix. Tests were conducted on fresh concrete (slump test) and hardened concrete (compressive strength test) at curing ages of 7 and 28 days. The results showed that the workability of concrete increased with increasing percentages of cement replacement by glass powder; however, the slump values remained lower than that of the control mix. Moreover, the results indicated that replacing 15% of cement with glass powder increased the compressive strength by 7% compared to the control mix (0%). Based on the results obtained, the optimum percentage for partial replacement of cement with glass powder is 15%.

Keywords: Glass powder, slump, compressive strength, mix design, replacement.

1. INTRODUCTION

The construction industry's heavy reliance on Ordinary Portland Cement (OPC) significantly contributes to global carbon dioxide emissions, accounting for nearly 7–8% of total anthropogenic CO_2 emissions (Scrivener *et al.,* 2018; Miller *et al.,* 2020). Growing environmental concerns have accelerated the search for supplementary cementitious materials (SCMs) capable of partially replacing cement while maintaining or enhancing concrete performance. Among various industrial and municipal wastes, waste glass powder (WGP) has attracted considerable attention due to its high silica content and potential pozzolanic reactivity when finely ground (Shi & Zheng, 2007). Large quantities of waste glass are generated globally each year, and a significant portion is landfilled due to contamination and economic limitations in conventional recycling streams. When ground to particle sizes below approximately 75–90 µm, glass powder exhibits pozzolanic behavior by reacting with calcium hydroxide ($Ca(OH)_2$) released during cement hydration, producing additional calcium–silicate–hydrate (C–S–H) gel and contributing to matrix densification (Tamanna *et al.,* 2021; Fakhri *et al.,* 2025). This transformation enables waste glass to function as a value-added construction material rather than an environmental burden.

The incorporation of WGP into concrete aligns with circular economy principles by reducing landfill waste and lowering clinker consumption. Life-cycle assessment studies demonstrate that replacing 10–20% of cement with alternative SCMs can significantly reduce embodied carbon (Miller *et al.,* 2020; Islam *et al.,* 2022). Furthermore, experimental investigations confirm that glass powder integration improves sustainability performance indicators while maintaining structural viability (Aliabdo *et al.,* 2016; Al-Hellali *et al.,* 2025). Recent research also emphasizes the role of WGP in developing climate-reduced concrete mixtures with reduced environmental impact (Gomaa *et al.,* 2025).

The effect of glass powder on fresh concrete properties depends on replacement ratio, fineness, and mixture proportions. Moderate replacement levels (typically 5–15%) may enhance workability due to the filler effect and smooth particle surface, which reduce internal friction within the mix (Siddika *et al.,* 2018; Abuserriya *et al.,* 2021; Almaz *et al.,* 2025). This improvement can be beneficial for self-compacting and high-performance concrete applications.

However, increasing the glass powder content beyond optimal levels may increase water demand because of the higher specific surface area of fine particles, potentially reducing slump and altering rheological behavior (Rashad, 2015; Al-Hellali *et al.,* 2025). Therefore, careful optimization of mix design parameters is required to balance workability and mechanical performance.

The mechanical performance of WGP-modified concrete exhibits complex behavior depending on curing age and replacement level. Early-age compressive strength may decrease slightly due to slower pozzolanic reaction kinetics compared to cement hydration (Rashad, 2015). Nevertheless, long-term strength development is often enhanced as secondary C–S–H formation progresses (Tamanna *et al.,* 2021; Islam *et al.,* 2022).

Microstructural investigations confirm that the incorporation of finely ground glass powder reduces calcium hydroxide content and refines pore structure, leading to improved tensile and flexural strength performance (Shi & Zheng, 2007; Hassan *et al.,* 2025; Gomaa *et al.,* 2025). Additionally, innovative approaches combining WGP with recycled polymers such as HDPE demonstrate promising synergistic improvements in mechanical properties (Al-Mashhadani *et al.,* 2025).

Durability considerations are essential when introducing glass-based materials into concrete systems. While coarse glass aggregates may trigger alkali–silica reaction (ASR), finely ground glass powder significantly mitigates ASR expansion through its pozzolanic consumption of alkalis (Rajabipour *et al.,* 2010). Recent durability studies also report reductions in permeability, chloride penetration, and water absorption when WGP is incorporated at appropriate levels (Aliabdo *et al.,* 2016; Nature Scientific Reports, 2024).

Further experimental evidence suggests that optimal replacement levels—often between 15% and 20%—achieve a balanced improvement in both strength and durability properties (Fakhri *et al.,* 2025; Almaz *et al.,* 2025).

Although substantial research has been conducted on waste glass powder as a supplementary cementitious material, discrepancies persist due to variations in particle size distribution, glass composition, curing conditions, and mix proportions. Some studies focus primarily on mechanical performance, while others emphasize durability or sustainability aspects independently (Siddika *et al.,* 2018; Al-Mashhadani *et al.,* 2025).

Therefore, the present study aims to provide a comprehensive experimental evaluation of both fresh and hardened properties of concrete incorporating varying percentages of waste glass powder as partial cement replacement. By systematically assessing workability, compressive strength, tensile strength, and durability indicators, this research seeks to determine optimal substitution levels and contribute to the advancement of sustainable concrete technology.

2. Experimental Program

The experimental program involved a series of preliminary tests on the materials used for concrete mix design. Cement tests included standard consistency (slump), setting time, and chemical composition analysis, while fine and coarse aggregates were evaluated using sieve analysis, as well as specific gravity and water absorption tests. The chemical composition of glass powder was also analyzed to determine its pozzolanic potential. Based on these results, a control mix and several modified mixes with partial cement replacement by glass powder were proportioned, maintaining a constant water-to-binder ratio (w/b) for consistent comparison. Subsequently, a slump test was performed to assess workability, followed by casting standard concrete cubes with proper compaction. After 24 hours, the specimens were demolded and cured in water until the specified testing ages, after which compressive strength tests were conducted to evaluate the effect of glass powder on the mechanical performance of concrete.

3. TEST RESULTS AND DISCUSSION

3.1 Materials test:

3.1.1 Cement

Ordinary Portland cement produced by Atbara Cement Factory was used in all concrete mixtures. Preliminary laboratory tests indicated that the standard consistency of the cement was 29%, while the initial and final setting times were 120 minutes and 185 minutes, respectively. These values comply with standard specifications for Ordinary Portland Cement, indicating suitable workability and sufficient time for mixing, placing, and compaction. Chemical Composition of cement used in this study is presented in Table 1.

Table 1: Chemical Composition of the Cement

Oxide / Component	% by Weight
Aluminum (Al_2O_3)	7.17
Calcium (CaO)	62.50
Chloride Content (Cl)	0.004
Ferric (Fe_2O_3)	3.28
Insoluble Residue (IR)	2.12
Loss on Ignition (LOI)	0.88

Oxide / Component	**% by Weight**
Magnesium (MgO)	1.10
Silica (SiO_2)	20.16
Sulfite (SO_3)	2.75
Alkaline (Na_2O & K_2O)	0
Total	**99.964**

The high CaO content (62.5%) enhances cement hydration and contributes to early strength development. The presence of SiO_2 (20.16%) and Al_2O_3 (7.17%) supports secondary pozzolanic reactions when glass powder is incorporated, improving microstructure densification and long- term strength. Other oxides such as Fe_2O_3, MgO, and SO_3 fall within acceptable limits, indicating stable mineral composition. The very low alkali content reduces the risk of alkali–silica reaction (ASR), which is particularly important when incorporating silica-rich materials such as glass powder.

Overall, the cement characteristics confirm its suitability for producing durable and high- performance concrete mixes.

3.1.2 Coarse and Fine Aggregates

Uncrushed natural stone obtained from the Industrial Area, Extension Street, Omdurman, was used as coarse aggregate, while natural sand was used as fine aggregate. The aggregates were subjected to sieve analysis, specific gravity testing, and water absorption testing to evaluate their suitability. Sieve Analysis results for coarse and fine aggregates are shown in Table 2 and Table 3, respectively.

Table 2: Sieve Analysis Results of Coarse Aggregates

% Passing	**% Retained**	**Weight Retained**	**Sieve No.**
100	0.00	0	19
68.150	31.85	637	12.5
38.750	29.40	588	9.5
3.500	35.25	705	4.75
0.00	3.50	70	Pan

Table 3: Sieve Analysis Results of Fine Aggregates

% Passing	**% Retained**	**Weight Retained**	**Sieve**
98.8	1.20	0.012	4
93.3	5.50	0.055	8
76.3	17.00	0.17	16
48.3	28.00	0.28	30
16.1	32.20	0.32	50
2.5	13.8	0.138	100
0.0	2.5	0.025	Pan
98.80	1.20	0.012	4

The grading results indicate that both coarse and fine aggregates exhibit a well-distributed particle size range, which contributes to good packing density, reduced voids, and improved concrete strength.

3.2 Specific Gravity

The specific gravity was calculated using Equation. Table 4 and Table 5 showed the specific gravity for coarse and fine aggregates which are calculated by using Eq. 1.

$$\text{Specific Gravity} = \frac{A}{A-B} \qquad (1)$$

The specific gravity value of 2.6 falls within the normal range for natural coarse aggregates (2.5– 2.8), indicating good quality and density.

Table 4: Specific Gravity of Coarse Aggregate

Description	**Value**
A	1.983
B	1.220
Specific Gravity	2.6

Table 5: Specific Gravity of Fine Aggregate

Sample 2	Sample 1	Weight
35.70	36.30	M1
45.70	46.92	M2
142.83	141.50	M3
136.40	134.77	M4
2.80	2.73	Gs

The fine aggregate also shows acceptable specific gravity values, confirming its suitability for concrete production.

3.3 Water Absorption

Water absorption was calculated using the equation Eq. 2. Table 6 shows the water absorption for coarse and fine aggregates.

$$\text{Absorption (\%)} = \frac{C-A}{C} \times 100 \qquad (2)$$

The absorption values for both coarse (0.354%) and fine aggregates (0.6%) are relatively low, indicating low porosity and minimal water demand. This helps maintain the designed water– cement ratio and improves durability.

The coarse aggregate grading was found to comply with the requirements of BS 822-1992 for coarse aggregate classification.

Table 6: Water Absorption of Fine and coarse aggregate

Description	Fine Aggregate	Coarse Aggregate
A	500	1.983
C	497	1.976
Absorption (%)	0.6	0.354

The specific gravity of the coarse aggregate was 2.6. According to British specifications, the acceptable range for coarse aggregate specific gravity is 2.4–2.8. Therefore, the result is within the standard limits, indicating good aggregate quality and density.

The fine aggregate grading also complies with BS 822-1992 requirements for fine aggregate classification. The specific gravity of the fine aggregate was 2.8, which falls within the acceptable range of 2.5–2.8 according to British standards. This confirms the suitability of the fine aggregate for concrete production.

3.1.3 Glass Powder

Waste glass (Fig. 1) was collected, crushed, and ground into fine powder to be used as a partial cement replacement at different percentages. Chemical Composition of Glass Powder showed in Table 8.

Fig. 1: Glass waste

Table 8: Chemical Analysis of Glass Powder

Test	Sample Result (%)
Silica (SiO_2)	71.27
Aluminum (Al_2O_3)	5.23
Ferric (Fe_2O_3)	0.73
Calcium (CaO)	9.16
Magnesium (MgO)	Nil
Sulfite (SO_3)	Nil

The high silica content (71.27%) confirms the pozzolanic potential of the glass powder. When finely ground, it reacts with calcium hydroxide produced during cement hydration to form additional calcium silicate hydrate (C–S–H), which enhances strength and reduces porosity.

4. Concrete Mix Design

After completing material testing, concrete mixes were prepared with varying percentages of glass powder as partial cement replacement. The quantities percentage are presented in Table 9 and Table 10.

Table 9: Mix design percentages

Water Kg/m3	Cement Kg/m3	Coarse aggregate Kg/m3	Fine aggregate Kg/m3
195	370	1115	685

Table 10: Quantities of Materials for Different Concrete Mixes (Seven Cubes)

Water (kg)	Glass Powder (kg)	Coarse Aggregate (kg)	Fine Aggregate (kg)	Cement (kg)	Description	Mix No.
4.6	—	26.00	16.00	9.00	Control	1
4.6	1.35	26.00	16.00	7.65	15% Glass	2
4.6	2.25	26.00	16.00	6.75	25% Glass	3
4.6	3.15	26.00	16.00	5.85	35% Glass	4

4. Fresh and hardened concrete tests:

4.1 Fresh concrete

Slump test

The consistency of the concrete mix is determined by measuring its slump value after shaping the fresh concrete into a truncated cone using the standard slump cone apparatus. This test is performed either in the laboratory or at construction sites to verify the proportions of the concrete mix components, since any change in the cement content, water quantity, or aggregate amount directly affects the slump value.

The procedure involves filling the metal cone mold with fresh concrete in three equal layers, compacting each layer properly. The mold is then carefully lifted vertically upward (Fig. 2), and the vertical settlement (slump) of the concrete is measured. The measured slump indicates the workability and ease of placement and compaction of the concrete. The slump test is considered one of the simplest, fastest, and most effective quality control methods used in batching plants and construction sites, as it allows quick detection of any variation in mix proportions and ensures consistent concrete quality.

Fig. 2: Slump test

Concrete cubes with dimensions of 15 × 15 × 15 cm were prepared for the com

pressive strength test. The molds were first cleaned and properly oiled to prevent the concrete from sticking to the sides. Fresh concrete was then poured into the molds in three equal layers, and each layer was compacted using a standard tamping rod to ensure proper consolidation and eliminate air voids. Fig. 3 and Table 11 show the slump values for different glass ratios.

Table 11: presents the slump test results for the different concrete mixes

Type of Concrete Mix	Slump Value (mm)
Control Mix	160
Glass Powder 15%	85
Glass Powder 25%	115
Glass Powder 35%	135

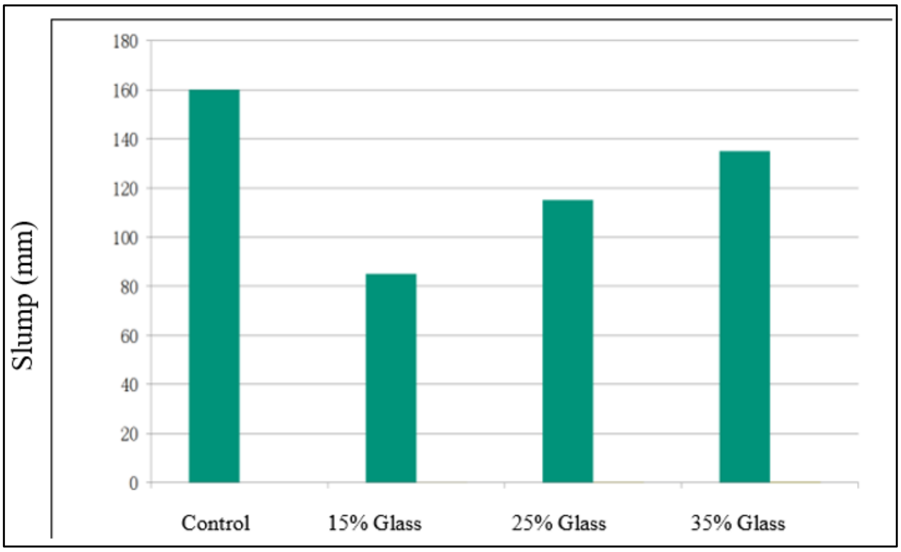

Fig. 3. Slump test result

After filling, the top surface was carefully leveled and finished. Each cube was marked for identification and left undisturbed for 24 hours to allow initial setting and hardening. After demolding, the specimens were submerged in water for curing until the designated testing age.

From the slump test results, it can be observed that the slump value of the control mix was 160 mm. When glass powder was used as a partial cement replacement at 15%, the slump decreased to 85 mm, representing a reduction of approximately 46.87% compared to the control mix.

At 25% glass powder replacement, the slump value became 130 mm, corresponding to a reduction of about 18.75% relative to the control mix.

When the replacement level increased to 35%, the slump reached 115 mm, which represents a decrease of approximately 28.18% compared to the reference mix. These results indicate that the incorporation of glass powder generally reduces the slump value compared to the control mix. However, as the percentage of glass powder increases beyond 15%, the slump value tends to increase again (from 85 mm at 15% to 130 mm at 25%), although it remains lower than the control mix.

This behavior may be attributed to the fine particle size and high surface area of glass powder, which initially increases water demand and reduces workability. At higher replacement levels, the filler effect and improved particle packing may contribute to partial recovery in slump values.

- The standard consistency of the cement was found to be 29%. According to BS 822-1992, the normal range for standard consistency is 26%–33%. Therefore, the obtained value falls within the acceptable limits.
- The initial setting time was recorded as 2:00 hours (120 minutes). According to BS 822-1992, the initial setting time should not be less than 45 minutes. The result complies with the specification.
- The final setting time was recorded as 3:08 hours (188 minutes). The same standard specifies that the final setting time should not exceed 10 hours. The obtained value is well within the permissible limit.

These results indicate that the cement used is suitable for concrete production and meets the required standard specifications.

4.2 Hardened concrete test

After concrete casting, the concrete cubes (Fig. 4) were immersed in the curing tank for 7 and 28 days. After the specified curing period, the specimens were removed from the water and allowed to surface-dry. The cured cubes are shown in Fig. 5.

Fig. 4: Casted concrete cubes

Fig. 5: Curing of concrete

Subsequently, the compressive strength test was carried out using a compression testing machine (Fig. 6) to determine the load-bearing capacity of the concrete at each curing age.

Fig. 6: Test setup for compression testing machine

As results shown from Fig. 7 and Table 12, When glass powder was used as a 15% replacement, the compressive strength increased to 22.7 N/mm², representing an increase of approximately 12% compared to the control mix. This improvement may be attributed to the pozzolanic reaction and filler effect of the finely ground glass powder, which enhances microstructure densification at early ages. At 25% replacement, the compressive strength decreased to 18.1 N/mm², corresponding to a reduction of approximately 10.14% compared to the control mix. This reduction may be due to the lower cement content and slower pozzolanic activity at higher replacement levels. When the replacement level reached 35%, the compressive strength dropped further to 15.9 N/mm², representing a decrease of approximately 21.29% relative to the control mix. Overall, the results indicate that 15% glass powder replacement improves early-age compressive strength (7 days), while higher replacement levels (25% and 35%) negatively affect strength due to dilution of cementitious material and reduced hydration products at early curing ages.

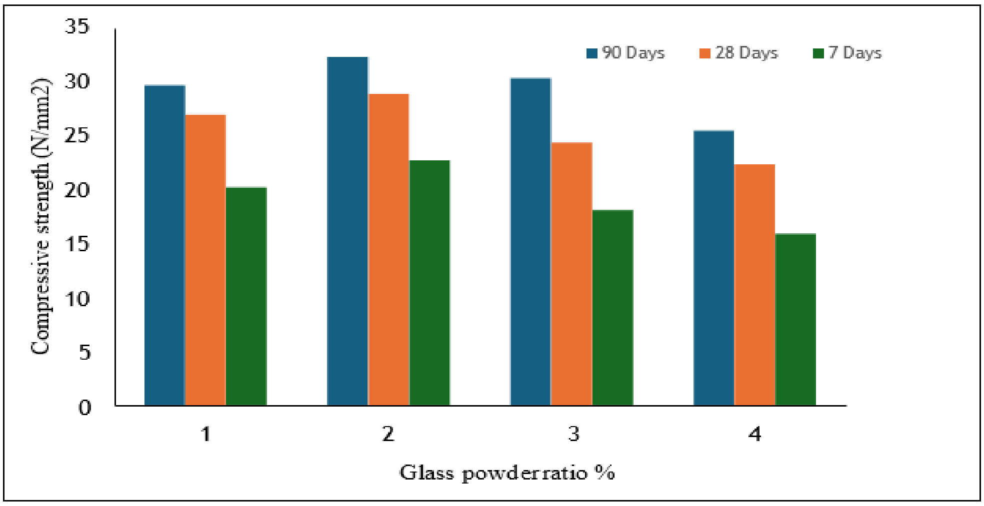

Fig. 7: Compressive strength of concrete with different glass powder ratios

When glass powder was used at a 15% replacement level, the compressive strength increased to 28.9 N/mm², representing an increase of approximately 7% compared to the control mix. This improvement can be attributed to the pozzolanic reaction of the finely ground glass powder, which contributes to additional formation of calcium silicate hydrate (C–S–H) and enhances long-term strength.

Table 12: Strength of concrete with different ratios of glass powder

Glass ratio		**0**	**15**	**25**	**35**
Compressive strength N/mm2	7 days	20.2	22.7	18.1	15.9
	28 days	27	28.9	24.4	22.4
	90 days	29.7	32.37	30.36	25.49

At 25% replacement, the compressive strength decreased slightly to 26.4 N/mm², corresponding to a reduction of about 2.3% relative to the control mix. Although the reduction is small, it indicates that increasing the replacement level begins to reduce the overall cementitious content.

When the replacement level reached 35%, the compressive strength dropped significantly to 21.6 N/mm², representing a decrease of approximately 20% compared to the control mix. This reduction is mainly due to the dilution effect caused by excessive replacement of cement, which limits the availability of hydration products necessary for strength development.

From these results, it can be concluded that the optimal replacement level of glass powder is around 15% by weight of cement, as higher replacement ratios lead to a decrease in compressive strength compared to the reference mix.

After 90 days, the result indicates that strength continues to increase beyond 28 days for all mixes due to ongoing hydration. The mixes containing glass powder are expected to gain relatively higher long-term strength because of the pozzolanic reaction between silica in the glass powder and calcium hydroxide released during cement hydration.

- The 15% glass replacement is expected to achieve the highest 90-day strength. This confirms that 15% is the optimal replacement level, as it enhances microstructure densification without significantly reducing cement content.
- The 25% replacement shows moderate long-

term improvement but remains slightly lower than the 15% mix, indicating that higher replacement levels begin to reduce the cementitious matrix effectiveness.

- The 35% replacement shows improvement compared to its 28-day strength but remains significantly lower than the control and 15% mixes due to the dilution effect.

The incorporation of glass powder as a partial cement replacement introduces both a filler effect and a pozzolanic reaction. Moderate replacement levels (15–25%) are expected to enhance long- term strength and durability due to improved microstructure densification and reduced permeability.

However, higher replacement levels (35%) may lead to a reduction in early compressive strength due to lower cement content and slower pozzolanic activity.

Overall, the results demonstrate that finely ground waste glass can be effectively used as a sustainable supplementary cementitious material, contributing to reduced cement consumption, lower environmental impact, and improved concrete performance when used at optimal replacement levels.

5. CONCLUSION

Based on the experimental investigation on the use of glass powder as a partial replacement of cement in concrete, the following conclusions can be drawn:

- The cement, fine aggregate, and coarse aggregate satisfied the requirements of BS 822-1992, confirming their suitability for concrete production. The glass powder exhibited high silica content, indicating good pozzolanic potential. The incorporation of glass powder significantly affected the slump values.
- The control mix recorded the highest slump (160 mm), at 15% replacement, slump decreased sharply due to increased surface area and water demand, at 25% and 35% replacement, slump partially increased but remained lower than the control mix. This indicates that glass powder reduces workability and may require water adjustment or admixtures in practical applications.
- At 7 days, the 15% replacement level increased compressive strength by approximately 12% compared to the control mix and a higher replacement level (25% and 35%) reduced strength due to cement dilution and slower pozzolanic reaction at early ages.
- At 28 days, the 15% glass replacement achieved the highest strength (28.9 N/mm²), exceeding the control mix by about 7% and the 25% and 35% mixes showed noticeable reductions in strength, confirming that excessive cement replacement negatively affects mechanical performance.
- At long-Term, **s**trength continued to increase at later ages due to ongoing hydration and pozzolanic reaction. Which showed that the 15% replacement remained at the optimal level, achieving the highest estimated long-term strength.

Replacement levels above 15% resulted in reduced overall strength despite some late-age gain

REFERENCES

- Abuserriya, A. A., Osman, B. B., & Mahmoud, C. S. (2021). Reusing of Construction Debris in Plain Concrete Elements. *FES J. Eng. Sci*, *9*, 81-87.
- Al-Hellali, N., et al. (2025). Glass waste as a supplementary cementitious material in climate reduced concrete – A review. *Nordic Concrete Research*. (DOI pending / not yet indexed)
- Aliabdo, A. A., Abd Elmoaty, A. E. M., & Aboshama, A. Y. (2016). Utilization of waste glass powder in the production of cement and concrete. *Construction and Building Materials*, 124, 866–877. https://doi.org/10.1016/j.conbuildmat.2016.08.016
- Al-Mashhadani, D. A. J., Wong, L. S., Midhin, A. K., & Liejy, M. C. (2025). Evaluating high performance concrete with waste glass powder and HDPE. *Indian Journal of Engineering*.
- Almaz, H., Tahirov, R., et al. (2025). Influence of replacing cement with fine glass powder on concrete properties. *International Journal of Advanced Scientific Research*.
- Fakhri, A. I., Agamy, M. H., Khattab, E. A., & Abdelkhalik, A. M. (2025). The role of glass powder in strength and durability improvement of concrete. *Engineering Research Journal*, 184(2), 150–161.
- Gomaa, A. M., Yasser, A., et al. (2025). Enhancing concrete performance and sustainability using waste glass powder. *Advanced Sciences and Technology Journal*.
- Hassan, R., Abuserriya, A., & Osman, B. H. (2025). Behavior Evaluation of Wood Ash in Concrete as Partial Replacement of Cement in Hot Arid Conditions. *Journal of Studies in Civil Engineering*, *2*(2), 54-67.
- Islam, G. M. S., Rahman, M. H., & Kazi, N. (2022). Waste glass powder as partial replacement of cement for sustainable concrete practice. *Journal of Materials in Civil Engineering*.
- Miller, S. A., Horvath, A., & Monteiro, P. J. M. (2020). Environmental impacts and decarbonization strategies in the cement and concrete industries. *Nature Reviews Earth & Environment*, 1, 559–573.
- Nature Scientific Reports. (2024). Effect of glass sand and glass powder on concrete mechanical and durability performance. *Scientific Reports*. https://doi.org/10.1038/s41598-024-76164- 9
- Rajabipour, F., Maraghechi, H., & Fischer, G.

(2010). Alkali–silica reaction mitigation using finely ground glass powder. *Cement and Concrete Research*, 40(5), 759–766.

- Rashad, A. M. (2015). Recycled waste glass as fine aggregate replacement in cementitious materials. *Construction and Building Materials*, 72, 340–357.
- Scrivener, K. L., John, V. M., & Gartner, E. M. (2018). Eco-efficient cements: Potential economically viable solutions for a low-CO_2 cement-based materials industry. *Cement and Concrete Research*, 114, 2–26.
- Shi, C., & Zheng, K. (2007). A review on the use of waste glasses in the production of cement and concrete. *Resources, Conservation and Recycling*, 52(2), 234–247.
- Siddika, A., Al Mamun, M. A., Alyousef, R., & Amran, Y. H. M. (2018). Waste glass powder as partial replacement of cement for sustainable concrete practice. *International Journal of Sustainable Built Environment*, 7(1), 37–44.
- Tamanna, N., Tuladhar, R., & Sivakugan, N. (2021). Performance of glass powder blended concrete: A review. *Construction and Building Materials*, 279, 122437.