

Experimental Investigation on Concrete Incorporating Recycled Glass Waste as Partial Replacement of Coarse Aggregate (3/8): Fresh, Mechanical and Durability Properties

Slimane MERDADI^{1, 2, 3 *}, Adda HADJ MOSTEFA^{3, 4}

¹ Department of Civil Engineering and Public Works, Faculty of Technology, University Djillali Liabes of Sidi Bel Abbés, Sidi Bel Abbés City, P.O.B.89, 22000 Sidi Bel Abbés, Algeria

² Laboratory of Structures and Advanced Materials in Civil Engineering and Public Works, University of Sidi Bel Abbés, Algeria

³ Laboratory of Innovative Materials and Renewable Energies, University of Relizane, 48000, Algeria

⁴ Department Civil Engineering, Institute of Science & Technology, University of Relizane, Relizane 48000, Algeria

<http://doi.org/10.5755/j02.ms.45757>

Received 7 August 2026; accepted 4 September 2026

This study focuses on the valorization of recycled glass waste as a partial substitute for coarse aggregates (3/8) in the manufacture of concrete, from a perspective of sustainable development and preservation of natural resources. The control concrete (CC) was produced with 100 % natural aggregates, while five experimental formulations (GC-01, GC-02, GC-03, GC-04 and GC-05) were produced by replacing 4 %, 8 %, 10 %, 12 % and 14 % of the natural gravel (3/8) with recycled glass aggregates of the same particle size. A complete experimental campaign was carried out to evaluate the performance of concretes in the fresh state, in the hardened state, and with regard to durability. The properties studied include sag, density, compressive strength, tensile strength, flexural strength, ultrasonic wave propagation speed, sclerometric index, water absorption by capillary action as well as water permeability and sulfate resistance. Experimental results show that concrete containing 4 % and 10 % recycled glass (GC-01 and GC-03) presents the best overall performance. This formulation simultaneously improves the mechanical properties, the quality of the cement matrix and the durability of the concrete while ensuring good workability. On the other hand, higher substitution rates lead to a gradual decrease in performance, mainly due to the reduction in adhesion between the cement paste and glass aggregates as well as the increase in interfacial transition zones. This research confirms that the recycling of glass waste constitutes a sustainable solution, making it possible to reduce the exploitation of natural aggregates while improving certain concrete performances when the substitution rate remains limited.

Keywords: concrete, recycled glass waste, substitution of aggregates, mechanical resistance, sustainable development.

1. INTRODUCTION

Concrete is the most widely used building material in the world due to its excellent mechanical performance, durability, and relatively low cost. However, the rapid growth of the construction sector is leading to massive consumption of natural resources, particularly aggregates, the extraction of which causes significant ecosystem degradation and an increase in greenhouse gas emissions [1, 2]. At the same time, glass waste management represents a major environmental challenge. Although glass is 100 % recyclable, a significant amount of waste is still landfilled due to sorting difficulties and recycling costs [3]. Therefore, using this waste in concrete appears to be a sustainable solution that conserves natural resources while reducing environmental impacts [4].

In recent years, numerous studies have focused on the use of recycled glass in cementitious materials, either as a mineral addition or as a partial substitute for fine or coarse aggregates [5]. The results show that concrete performance depends primarily on the glass particle size, its chemical composition, shape, surface texture, and the substitution rate [6]. Most published research focuses on replacing sand with

recycled glass. In contrast, studies on replacing coarse aggregates remain relatively limited despite their considerable environmental benefits [7].

The properties of fresh concrete are strongly influenced by the incorporation of recycled glass aggregates. The workability, density, cohesion, and stability of the mix depend on the physical characteristics of the glass particles, including their angular shape, low water absorption, and surface texture [8]. Several researchers have observed that moderate substitution rates allow for maintaining good workability of the concrete without compromising its placement [9].

In its hardened state, the mechanical performance of concrete incorporating recycled glass is primarily linked to the quality of the interfacial transition zone (ITZ) between the aggregates and the cement paste. The smooth and dense surface of glass particles, together with their angularity and packing characteristics, may affect the bond between the glass and cementitious matrix. Recent microstructural studies have shown that waste glass can modify the morphology and properties of the ITZ, with potential effects on the mechanical and durability performance of concrete [10–13]. However, these effects also depend on particle

* Corresponding author: S. Merdaci
E-mail: slimane.merdaci@univ-sba.dz

size, replacement level, packing density, and pore structure. Compressive, tensile, and flexural strengths can be preserved, or even slightly improved, for certain replacement rates, while high percentages generally lead to a decrease in mechanical performance due to weaker adhesion between the glass and the cement matrix [14, 15].

Durability is also a key criterion for assessing the feasibility of using recycled glass as coarse aggregate. Several studies have examined water absorption, porosity, permeability, chloride ion penetration, resistance to chemical attack, freeze-thaw cycles, and alkali-silica reaction [16, 17]. A critical synthesis of research on the use of glass in concrete; highlights the advantages related to durability and the limitations due to alkaline reactivity [18]. Several recent studies support the experimental findings of this work regarding the use of recycled glass as a partial replacement for natural aggregates in concrete. Premathilaka et al. (2024) emphasized that optimized substitution rates and particle sizes preserve mechanical strength while promoting eco-friendly concrete [19]. Regarding transport properties and durability, Singh & Siddique and Mansour showed that crushed glass reduces water absorption, sorptivity, and chloride penetration, thereby improving resistance to chemical attacks and freeze-thaw cycles [20, 21]. Finally, long-term testing showed that controlling glass fineness mitigates alkali-silica reaction (ASR) expansion, ensuring stable mechanical performance and enhanced resistance to sulfate attacks [22, 23].

The present study aims to experimentally investigate the influence of partially replacing natural coarse aggregate with a 3/8 mm fraction of crushed recycled glass waste on the properties of fresh concrete, its mechanical performance, and its durability. The control concrete (CC) consists exclusively of natural aggregates, while formulations GC-01, GC-02, GC-03, GC-04, and GC-05 replace (4 %, 8 %, 10 %, 12 %, and 14 %) of aggregate with a (3/8 mm), respectively, with recycled glass by mass. The main objective is to identify an optimal substitution rate that allows for the efficient valorization of glass waste while maintaining performance levels compatible with the requirements of civil engineering applications. This research thus contributes to the development of more sustainable construction materials, in line with the principles of the circular economy and the preservation of natural resources. The working hypothesis of this study assumes that a moderate replacement rate of coarse natural aggregates with recycled glass waste (fraction 3/8 mm) can maintain or improve the fresh, mechanical, and durability properties of concrete due to matrix densification, whereas high substitution rates will deteriorate performance due to a weakened ITZ.

2. MATERIALS AND METHODS

2.1. Cement

A Portland cement made with ordinary local limestone (CEM II/A-L 42.5N), produced by the GICA cement plant (Algerian Cement Industrial Group, Zahana, Mascara, West of Algeria), conforming to the Algerian standard (NA 442/2013), was used as the binder for all the mixtures. CEM II has an average compressive strength at 28 days of

52 MPa, an absolute density of 3.1 g/cm³, and a specific surface area of 4.929 g/cm². Its chemical composition is shown in Table 1.

Table 2. Chemical and mineralogical compositions of the used Portland cement

Component	CaO	SiO ₃	Al ₂ O ₃	Fe ₂ O ₃	MgO	SO ₃
%	60–65	18–22	4–7	2–4	≤ 5	≤ 3.5
C ₃ S	C ₂ S	C ₃ A	C ₄ AF	Calcaire	(SO ₃)/(SO ₃)	
45–60	15–30	5–10	8–12	6–20	3–5	

2.2. Aggregates

The gravel used in our work comes from the CHETOUANE crushing quarry, located in the wilaya of Sidi Bel Abbès of Algeria, and has two classes of 3/8 and 8/15. Table 3 presents the properties of each type of aggregate. The values presented in Fig. 1 indicate the grain size analysis curve of aggregates.

In our study, we used two types of sand (mixed sand). The first type is industrial sand from a quarry in Chetouane, located in the wilaya of Sidi Bel Abbès of Algeria, with a particle size fraction of (0/3). The second type is natural sea sand from the wilaya of Chlef, Algeria, with a particle size fraction of (0/1). This sand is called mixed sand, containing 60 % sea sand and 40 % quarry sand, as shown in Fig. 1.

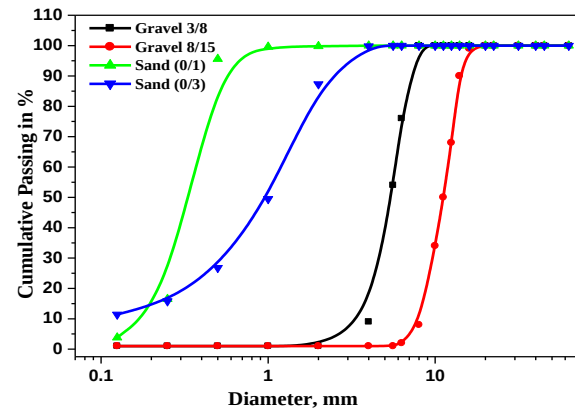


Fig. 1. Particle size analysis curve of aggregates used

2.3. Mixture proportions

In this experimental study, several materials were used to formulate different concrete compositions. To ensure the clarity and precision of our study, we chose to use a reference concrete (CC) as a comparator for our tests. We used the Fuller method, which is based on the principle of an ideal particle size distribution curve that allows for maximum aggregate compaction. The mixtures were divided into six types of concrete and are presented in Table 2 and Fig. 2. The CC concrete (Control Concrete) was composed of 100 % natural aggregates. The glass concretes: GC-01, GC-02, GC-03, GC-04, and GC-05 replaced the gravel with a mixture of 3/8 glass waste in respective proportions of 4 %, 8 %, 10 %, 12 %, and 14 % by mass.

It should be noted that the recycled glass aggregate was introduced as a mass-based replacement of the natural (3/8) gravel fraction. Because the specific gravity of recycled glass differs from that of the natural aggregate, an equal-mass replacement does not correspond to an identical aggregate volume. Consequently, increasing the recycled

glass content modifies the volumetric fraction of the 3/8 aggregate and, to some extent, the effective paste-to-aggregate ratio.

Table 2. Final compositions of the six concretes in (kg/m³)

Concrete type	Cement, kg/m ³	Sand, kg/m ³	Gravel, kg/m ³		Water, L/m ³	Admixture, L/m ³	Glass (3/8), kg/m ³
			3/8	8/15			
CC	350	792	355	729.5	175	4.2	0
GC-01	350	792	340.8	729.5	175	4.2	14.20
GC-02	350	792	326.6	729.5	175	4.2	28.40
GC-03	350	792	319.5	729.5	175	4.2	35.50
GC-04	350	792	312.4	729.5	175	4.2	42.60
GC-05	350	792	305.3	729.5	175	4.2	49.70



Fig. 2. The different quantities of materials

This volumetric effect may contribute to the observed variations in the fresh and hardened properties and should therefore be considered together with particle packing, aggregate morphology, and interfacial transition zone (ITZ) effects. Accordingly, the observed trends are not attributed exclusively to changes in the ITZ.

2.4. Experimental program

A total of 15 specimens were prepared for the mechanical characterization of the investigated concrete mixtures, including the reference concrete (CC) and concretes incorporating recycled glass waste (GC-01 to GC-05). The specimens were assigned to the different mixtures and curing ages of 2, 7, and 28 days according to the experimental testing program. For each selected mixture–age condition, one specimen was tested for the corresponding mechanical property. After demolding at 24 h, the specimens were cured by immersion in water until the designated testing age. The tests were conducted at 2, 7, and 28 days in accordance with the applicable testing procedures described in the manuscript. Since one specimen was used for each selected mixture–age condition, the reported results correspond to individual experimental measurements rather than averages of replicate specimens. Consequently, standard deviations and coefficients of variation were not calculated. This limitation is acknowledged in the present study, and the results are interpreted as measured experimental values rather than statistically averaged values.

3. RESULTS AND DISCUSSION

3.1. Testing fresh concrete

Tests on fresh concrete were carried out in accordance with current standards. The consistency of the fresh concrete was determined by the slump test to assess its fluidity and workability for an evaluation of the ease of placement of the mix are presented in Fig. 3. The density of the fresh concrete was measured to check its compactness and the accuracy of the mix proportions according to EN 12350-6, are presented in Fig. 4.

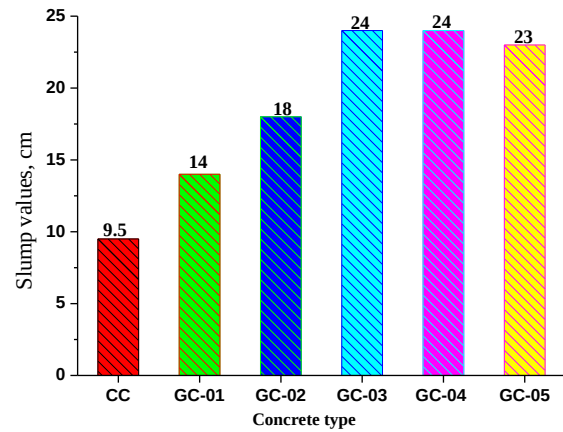


Fig. 3. Workability of different compositions (control concrete and glass concretes)

The results show that slump increases with the incorporation of recycled glass as a partial substitute for natural aggregate (3/8 mm). As expected, the slump increased with higher glass contents. This behavior is directly linked to the smooth surface morphology and near-zero water absorption of glass particles, which reduce inter-particle friction and leave more free water available for hydration paste mobility. These observations are in full agreement with the findings of Taha and Nounu [8] as well as Park et al. [9], who reported similar enhancements in concrete workability when substituting coarse aggregates with recycled glass. The high values observed for GC-03 to GC-05 indicate that a significant substitution rate greatly improves the fluidity of the mix, which can facilitate placement, but requires monitoring to avoid the risks of segregation or bleeding.

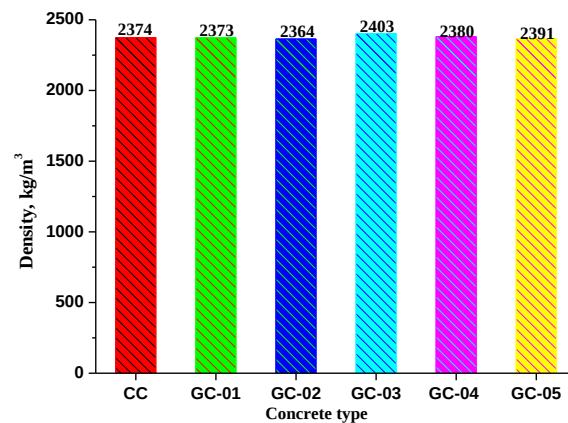


Fig. 4. Density of fresh concrete for different concrete

The results show that the fresh density of the concrete mixes varies between 2364 and 2403 kg/m³. The control concrete (CC) has a density of 2374 kg/m³, while GC-01 (2373 kg/m³), GC-02 (2364 kg/m³), GC-04 (2380 kg/m³), and GC-05 (2366 kg/m³) exhibit relatively close values. GC-03 presents the highest density (2403 kg/m³), which may be related to differences in particle packing and internal void structure. Overall, the partial replacement of natural 3/8 mm aggregate with recycled glass has only a limited effect on the density of the concrete mixes. Overall, the small differences observed compared to the control concrete (2374 kg/m³) demonstrate that incorporating recycled glass maintains a density comparable to that of conventional concrete, confirming the material's suitability for common civil engineering applications.

3.2. Tests on hardened concrete

As part of this study, several tests were carried out in accordance with applicable standards on hardened concrete samples to evaluate their mechanical properties and durability. The evolution of the density of hardened concrete was measured on cubic specimens according to EN12390-7, ultrasonic propagation velocity according to EN12504-4 and the sclerometric index was obtained using a rebound index (RI), according to EN12504-2 as a function of the rate of substitution of gravel (3/8) by recycled glass are presented in Fig. 5, Fig. 6 and Fig. 7.

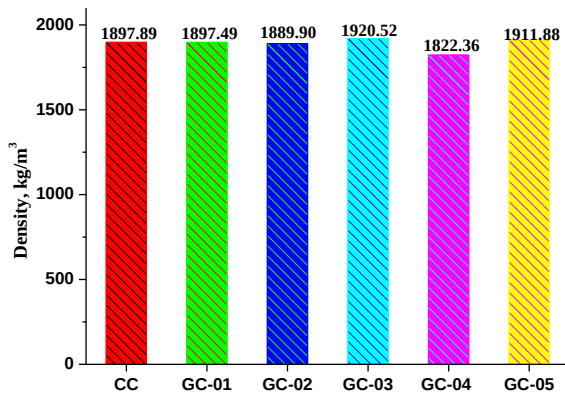


Fig. 5. Hardened density of each type of concrete

Fig. 5 shows that the hardened concrete density ranges from 1822.36 to 1920.52 kg/m³. The control concrete (CC) has a density of 1897.89 kg/m³, while GC-01 (1897.49 kg/m³), GC-02 (1889.90 kg/m³), and GC-05 (1911.88 kg/m³) show comparable values. GC-03 exhibits the highest density (1920.52 kg/m³), which may be related to differences in particle packing and internal void structure. In contrast, GC-04 presents the lowest density (1822.36 kg/m³), possibly indicating a higher volume of internal voids. Overall, recycled glass incorporation has a limited effect on hardened concrete density, except at the 12 % replacement level.

These results indicate that the incorporation of recycled glass makes it possible to maintain a density comparable to that of conventional concrete for moderate substitution rates, while higher rates may lead to a slight decrease in density due to an increase in voids in the matrix.

Fig. 6 shows that the ultrasonic pulse velocity ranges from 3712.87 to 3978.78 m/s. The control concrete (CC)

exhibits a velocity of 3957.78 m/s, while GC-01 records the highest value (3978.78 m/s). GC-02 and GC-03 show similar velocities (3896.10 m/s), relatively close to that of the control concrete. In contrast, GC-04 and GC-05 present lower values of 3712.87 and 3759.40 m/s, respectively, which may indicate differences in internal structure and void content.

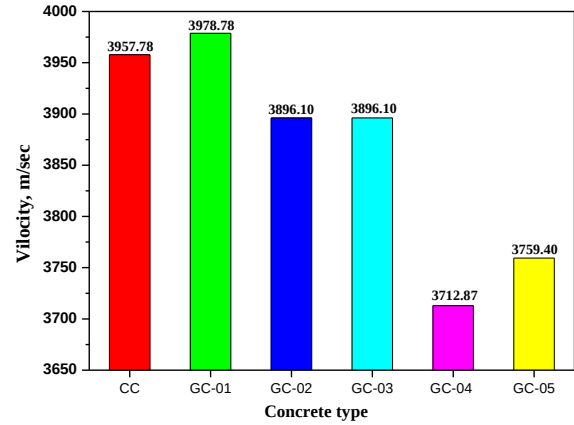


Fig. 6. Ultrasonic velocity of each concrete type rebound

Overall, the results suggest that low glass replacement levels have a limited effect on ultrasonic pulse velocity. These results indicate that a low replacement rate preserves or improves the internal matrix compactness, whereas higher substitution rates lead to an increased void fraction. This observation confirms the microstructural packing trends reported by Hussein et al. [2] and Hariharan & Punitha [5].

The sclerometer test results (see Fig. 7) show that the rebound index (RI) ranges from 18.0 MPa to 30.10 MPa at 28 days. The control concrete (CC) has an average index of 24.00 MPa.

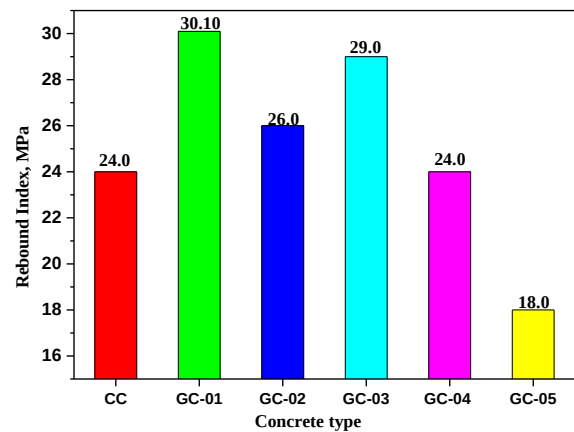


Fig. 7. Sclerometer rebound index at 28 days of each concrete

Formulations GC-01 and GC-03 recorded the highest values, indicating better surface hardness and good quality of the outer concrete layer. GC-02 also shows a slight improvement compared to the control concrete. In contrast, GC-04 maintains the same value as the reference concrete, while GC-05 displays the lowest value, indicating a decrease in surface hardness.

These results show that a low replacement rate of natural aggregate (3/8 mm) with recycled glass (4 %)

improves the quality and hardness of the concrete surface, while high replacement rates lead to a degradation of these properties. This trend is consistent with the results obtained for compressive strength and ultrasonic propagation velocity.

The compressive strength was determined on (15×15×15) cm cubic specimens at 2, 7, and 28 days, according to EN12390-3 (Fig. 8).

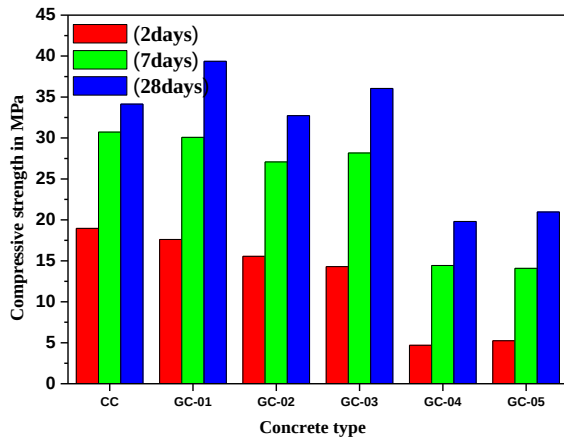


Fig. 8. Compressive strength for each concrete type at ages 2, 7 and 28 days

Tensile strength was evaluated by splitting test (Brazilian test) on 16×32 cm cylindrical specimens, according to EN12390-6 (Fig. 9). Finally, flexural strength was measured on 10×10×50 cm prisms, according to EN12390-5 (Fig. 10).

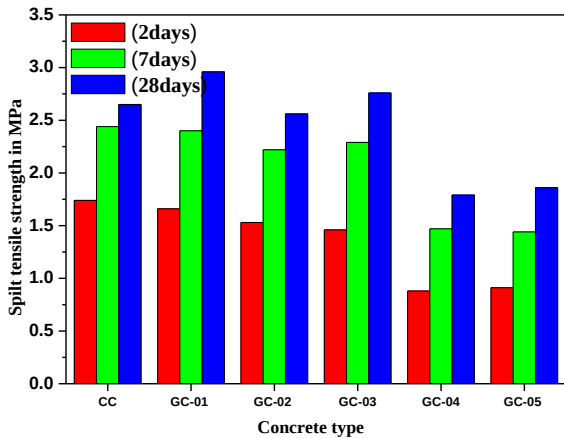


Fig. 9. Tensile strength for each type of concrete at ages 2, 7 and 28 days

The results show a progressive increase in compressive strength for all formulations between 7 and 28 days, confirming the normal development of cement hydration. The control concrete (CC) reached a strength of 34.14 MPa at 28 days. Formulation GC-01 exhibited the best performance with 39.37 MPa, representing a gain of 15.32 %, followed by GC-03 with 36.05 MPa (+5.59 %). In contrast, GC-02 registered a slight decrease (−4.16 %), while GC-04 and GC-05 showed significant losses of 41.97 % and 38.61 %, respectively. The evolution of strength between 7 and 28 days shows that all formulations continue their normal maturation. However, the gains observed for GC-04 and GC-05 remain insufficient to

compensate for the negative effects associated with the high proportions of recycled glass.

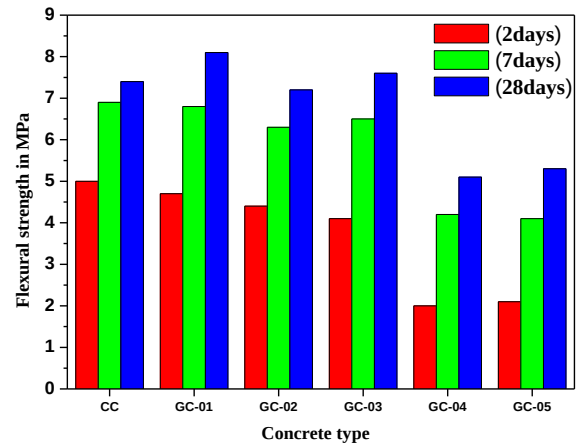


Fig. 10. Flexural strength for each type of concrete at ages 2, 7 and 28 days

Conversely, GC-01 and GC-03 maintain a steady progression in their performance, demonstrating that moderate replacement can maintain, or even improve, tensile strength. These results highlight the existence of an optimal rate of substitution of natural aggregate with recycled glass. The GC-01 and GC-03 formulations offer the best tensile performance thanks to a more compact microstructure and better stress distribution, while higher replacement rates lead to a significant decrease in mechanical performance. These observations confirm that the controlled incorporation of recycled glass into concrete is a promising solution for valorizing glass waste while preserving the essential mechanical properties of the material.

The results show a progressive increase in tensile strength for all formulations between 7 and 28 days, reflecting the normal development of cement hydration. The control concrete (CC) reached a strength of 2.65 MPa at 28 days. Formulation GC-01 exhibited the best performance with 2.96 MPa, representing an 11.85 % increase, while GC-03 also showed a slight improvement (+4.33 %). In contrast, GC-02 showed a slight decrease (−3.22 %), while GC-04 and GC-05 displayed significant losses of 32.46 % and 29.86 %, respectively. These results indicate that a low rate of replacement of natural aggregate with recycled glass can improve tensile strength through better concrete compaction, while high substitution rates reduce mechanical performance due to the poor adhesion between the glass particles and the cement paste, as well as the brittleness of the glass. Therefore, GC-01 appears to be the highest-performing formulation for tensile strength.

The results show a progressive increase in flexural strength between 7 and 28 days for all formulations, reflecting the normal development of cement hydration. At 28 days, the control concrete (CC) reached a strength of 7.40 MPa. Formulation GC-01 exhibited the best performance with 8.10 MPa, representing a gain of 9.97 %, followed by GC-03 with 7.60 MPa (+3.70 %). In contrast, GC-02 recorded a slight decrease (−2.79 %), while GC-04 and GC-05 showed significant drops of 30.43 % and 27.76 %, respectively. These results demonstrate that a low rate of replacement of natural aggregate (3/8 mm) with

recycled glass improves flexural strength through better concrete compaction and more efficient stress transmission. The non-linear variation in compressive, tensile, and flexural strengths, showing an optimum at 4 % (GC-01) and 10 % (GC-03) conforms to theoretical expectations regarding the microstructural packing and the ITZ. At low substitution levels, glass aggregates contribute to a denser matrix compaction, enhancing UPV and strength values. However, at higher substitution rates (GC-04 and GC-05), the mechanical performance drops significantly. This decline is explained by the weak physical bonding between the smooth surface of coarse glass particles and the cement paste, leading to a porous and fragile ITZ, a phenomenon widely documented by Topçu and Canbaz [6] and Ling and Poon [11]. The GC-01 formulation thus appears to be the most efficient in terms of flexural strength.

3.3. Durability tests

Durability constitutes an essential criterion for evaluating the performance of concrete in service conditions. The incorporation of recycled glass waste can modify the microstructure of the cement matrix and influence its resistance to environmental attacks. In this study, the durability properties were evaluated through water permeability according to EN 12390-8 (see Fig. 11) and sulfate resistance in terms of sulfate-induced expansion (see Fig. 12).

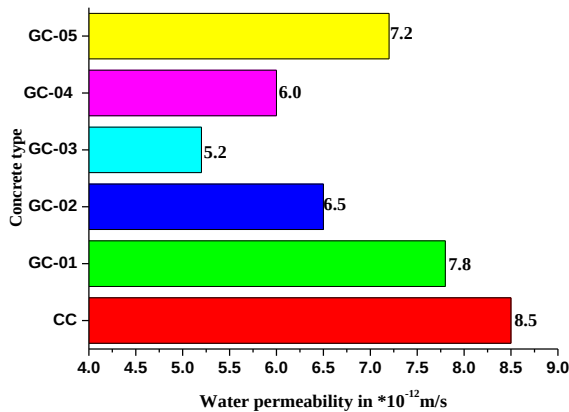


Fig. 11. Water permeability of each concrete type

According to Fig. 11, the results show that incorporating recycled glass as a partial substitute for natural aggregate (3/8 mm) reduces the water permeability of concrete compared to the control concrete (CC). The GC-03 formulation exhibits the lowest permeability (5.2×10^{-12} m/s), followed by GC-04 and GC-02. The GC-01 and GC-05 formulations also show improvement compared to the control concrete. The reduced water permeability in moderate glass replacement mixtures indicates a denser microstructure and lower capillary connectivity, which is consistent with trends reported for optimized waste glass incorporation [1, 12]. Among the formulations studied, GC-03 exhibits the best performance, confirming its potential for improving concrete durability.

According to Fig. 11, the results show that incorporating recycled glass as a partial substitute for natural aggregate (3/8 mm) reduces the water permeability of concrete compared to the control concrete (CC). The

GC-03 formulation exhibits the lowest permeability (5.2×10^{-12} m/s), followed by GC-04 and GC-02. The GC-01 and GC-05 formulations also show improvement compared to the control concrete. The reduced water permeability in moderate glass replacement mixtures indicates a denser microstructure and lower capillary connectivity, which is consistent with trends reported for optimized waste glass incorporation [1, 12]. Among the formulations studied, GC-03 exhibits the best performance, confirming its potential for improving concrete durability.

According to Fig. 12, the results show that all formulations incorporating recycled glass exhibit lower expansion than the control concrete (CC), which has a value of 0.18 %.

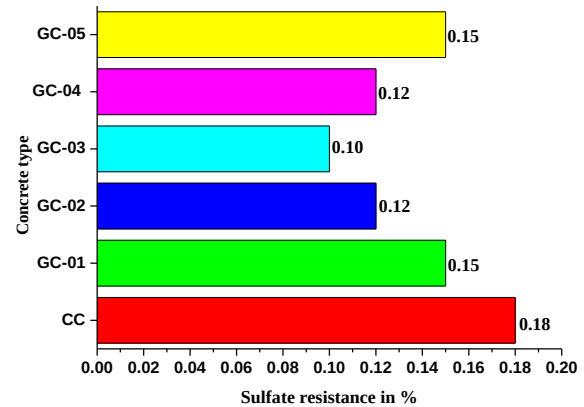


Fig. 12. Sulfate-induced expansion of the different concrete mixtures

Formulation GC-03 shows the lowest expansion (0.10 %), followed by GC-02 and GC-04 (0.12 %), while GC-01 and GC-05 show an expansion of 0.15 %, which is still lower than that of the control concrete. Regarding durability, the reduction in water permeability and sulfate expansion observed in GC-03 matches performance expectations regarding pore refinement. The smooth glass surfaces and compact packing hinder capillary continuity, thereby restricting fluid ingress and sulfate ion transport. This improved durability behavior corroborates the conclusions of Paul et al. [1] and Aliabdo et al. [13], who highlighted the positive role of controlled glass incorporation in dense cementitious systems.

The results confirm that replacing 10 % of natural aggregate (3/8 mm) with recycled glass waste (GC-03) provides the best compromise between waste valorization and improved concrete durability.

4. CONCLUSIONS

This study experimentally evaluated the effect of partially replacing natural coarse aggregate (3/8 mm) with recycled glass waste on the fresh, mechanical, and durability properties of concrete. Based on the experimental results, the following conclusions can be drawn:

1. The incorporation of recycled glass significantly improved the workability of fresh concrete, while maintaining a density comparable to that of the control concrete.
2. Moderate replacement levels enhanced the mechanical performance of concrete. The GC-01 (4 %) formulation

achieved the highest compressive, tensile, and flexural strengths, with improvements of 15.32 %, 11.85 %, and 9.97 %, respectively, compared with the control concrete.

3. The ultrasonic pulse velocity, rebound hammer index, and hardened density confirmed that low replacement rates preserved or improved the internal quality and compactness of the concrete, whereas higher replacement levels (12 % and 14 %) resulted in a deterioration of these properties.
4. Regarding durability, the incorporation of recycled glass reduced both water permeability and sulfate expansion. The GC-03 (10 %) formulation exhibited the lowest water permeability (5.2×10^{-12} m/s) and the highest resistance to sulfate attack (0.10 % expansion), demonstrating the most durable behavior among all mixtures.
5. From a practical design perspective, a 10 % replacement of natural 3/8 coarse aggregate with recycled glass aggregate (GC-03) is recommended as the most balanced replacement level for general applications within the scope of the present experimental program. While the 4 % replacement level (GC-01) resulted in the highest mechanical performance, the 10 % level provided a more favorable overall balance, particularly in terms of durability, while maintaining satisfactory mechanical properties. Therefore, GC-03 can be considered a practical compromise when both mechanical performance and durability are required. Nevertheless, for applications where mechanical strength is the primary design criterion, the lower 4 % replacement level may be more appropriate. The final selection should be based on the required mechanical performance, exposure conditions, durability requirements, and applicable concrete design standards.

The findings of this research demonstrate that recycled glass waste can be successfully valorized as a sustainable coarse aggregate in concrete, contributing to the conservation of natural resources, the reduction of landfill disposal, and the development of environmentally friendly construction materials. The present durability assessment was limited to water permeability and sulfate resistance. In particular, alkali–silica reaction (ASR) was not experimentally evaluated and therefore no conclusion regarding the ASR resistance of the investigated mixtures can be drawn from the present results. Future research should include dedicated ASR testing, together with freeze–thaw resistance, chloride penetration, and long-term exposure studies, to provide a more comprehensive assessment of the durability of concrete incorporating recycled glass coarse aggregate.

Acknowledgements

The authors sincerely appreciate the valuable time, suggestions, and comments of the editors and the reviewers, which improved the quality of the paper.

REFERENCES

1. Paul, S.C., Šavija, B., Babafemi, A.J. A Comprehensive Review on Mechanical and Durability Properties of Cement-Based Materials Containing Waste Recycled Glass *Journal of Cleaner Production* 198 2018: pp. 891–906. <https://doi.org/10.1016/j.jclepro.2018.07.095>
2. Hussein, H., Alyaa, A., Bassam, T., Fadzil, Y., Thomas, B. Effect of Recycled Waste Glass on the Properties of High-performance Concrete: A Critical Review *Case Studies in Construction Materials* 17 2022: pp. e01149. <https://doi.org/10.1016/j.cscm.2022.e01149>
3. Govardhan, N.B., Nakkeeran, G., Dipankar, R. Recycling Glass Waste Into Concrete Aggregates: Enhancing Mechanical Properties and Sustainability *Asian Journal of Civil Engineering* 26 2025: pp. 1–19. <https://doi.org/10.1007/s42107-024-01181-y>
4. Du, H., Tan, K.H. Waste Glass Powder as Cement Replacement in Concrete *Journal of Advanced Concrete Technology* 12 (11) 2014: pp. 468–477. <https://doi.org/10.3151/jact.12.468>
5. Hariharan, S., Punitha, K.A. Properties of High-Performance Concrete Incorporating Toughened Glass Waste Coarse Aggregate: An Experimental Study *Structures* 60 2024: pp. 105897. <https://doi.org/10.1016/j.istruc.2024.105897>
6. Topçu, I.B., Canbaz, M. Properties of Concrete Containing Waste Glass *Cement and Concrete Research* 34 (2) 2004: pp. 267–274. [https://doi.org/10.1016/S0008-8846\(03\)00251-5](https://doi.org/10.1016/S0008-8846(03)00251-5)
7. Ismail, Z.Z., Al-Hashmi, E.A. Recycling of Waste Glass as a Partial Replacement for Fine Aggregate in Concrete *Waste Management* 29 (2) 2009: pp. 655–659. <https://doi.org/10.1016/j.wasman.2008.08.012>
8. Taha, B., Nounu, G. Properties of Concrete Contains Mixed Colour Waste Recycled Glass as Sand and Coarse Aggregate Replacement *Construction and Building Materials* 22 (5) 2008: pp. 713–720. <https://doi.org/10.1016/j.conbuildmat.2007.01.019>
9. Park, S.B., Lee, B.C., Kim, J.H. Studies on Mechanical Properties of Concrete Containing Waste Glass Aggregate *Cement and Concrete Research* 34 (12) 2004: pp. 2181–2189. <https://doi.org/10.1016/j.cemconres.2004.02.006>
10. Zhao, H., Hu, Y., Li, Y., Wang, K., Dehn, F., Li, W. Triaxial Compressive Performance of Recycled Aggregate/Glass Sand Concrete: Experimental Study and Mechanism Analysis *Journal of Cleaner Production* 442 2024: pp. 141006. <https://doi.org/10.1016/j.jclepro.2024.141006>
11. Zhao, H., Li, W., Gan, Y., Mahmood, A.H., Zhao, X., Wang, K. Nano- and Microscopic Investigation on the Strengthening Mechanism of ITZs Using Waste Glass Powder in Modeled Aggregate Concrete *Journal of Materials in Civil Engineering* 36 (4) 2024: pp. 04024007. <https://doi.org/10.1061/JMCEE7.MTENG-16956>
12. Wang, H., Wang, A., Jiang, Y., Ling, T.C. Influences of Inert and Reactive Waste-Derived Aggregates on Mechanical, Interfacial, and Durability Performances of Mortars *Journal of Building Engineering* 111 2025: pp. 113296. <https://doi.org/10.1016/j.job.2025.113296>
13. Lu, J.X., Shen, P., Zheng, H., Zhan, B., Ali, H.A., He, P., Poon, C.S. Synergetic recycling of Waste Glass and Recycled Aggregates in Cement Mortars: Physical, Durability and Microstructure Performance *Cement and Concrete Composites* 113 2020: pp. 103632. <https://doi.org/10.1016/j.cemconcomp.2020.103632>

1. Paul, S.C., Šavija, B., Babafemi, A.J. A Comprehensive Review on Mechanical and Durability Properties of Cement-

14. **Shayan, A., Xu, A.** Performance of Glass Powder as a Pozzolanic Material in Concrete: A Field Trial on concrete Slabs *Cement and Concrete Research* 36 (3) 2006: pp. 457–468.
<https://doi.org/10.1016/j.cemconres.2005.12.012>
15. **Ling, T.C., Poon, C.S.** A comparative Study on the Feasible Use of Recycled Beverage and CRT Funnel Glass as Fine Aggregate in Cement Mortar *Journal of Cleaner Production* 29–30 2012: pp. 46–52.
<https://doi.org/10.1016/j.jclepro.2012.02.018>
16. **Adaway, M., Wang, Y.** Recycled Glass as a Partial Replacement for Fine Aggregate in Structural Concrete – Effects on Compressive Strength *Electronic Journal of Structural Engineering* 14 (1) 2015: pp. 116–122.
<https://doi.org/10.56748/ejse.141951>
17. **Aliabdo, A.A., Abd Elmoaty, A.E.M., Aboshama, A.Y.** Utilization of Waste Glass Powder in the Production of Cement and Concrete *Construction and Building Materials* 124 2016: pp. 866–877.
<https://doi.org/10.1016/j.conbuildmat.2016.08.016>
18. **Jani, Y., Hogland, W.** Waste Glass in the Production of Cement and Concrete – A Review *Journal of Environmental Chemical Engineering* 2 (3) 2014: pp. 1767–1775.
<https://doi.org/10.1016/j.jece.2014.03.016>
19. **Premathilaka, K.K.W., Liyanapathirana, D.S., Leo, C.J., Hu, P.** Application of Recycled Waste Glass to Replace Traditional Quarried Aggregates: A Comprehensive Review *Journal of Building Engineering* 86 2024: pp. 108846.
<https://doi.org/10.1016/j.job.2024.108846>
20. **Singh, H., Siddique, R.** Long term Durability Assessment of Self-Compacting Concrete Made with Crushed Recycled Glass and Metakaolin *Construction and Building Materials* 400 2023: pp. 132656.
<https://doi.org/10.1016/j.conbuildmat.2023.132656>
21. **Mansour, M.A., Bin Ismail, M.H., Imran Latif, Q.B.A., Alshalif, A.F., Milad, A., Al Bargi, W.A.** A Systematic Review of the Concrete Durability Incorporating Recycled Glass *Sustainability* 15 (4) 2023: pp. 3568.
<https://doi.org/10.3390/su15043568>
22. **Wang, T., Nicolas, R.S., Nguyen, T.N., Kashani, A., Ngo, T.** Experimental and Numerical Study of Long-Term Alkali-Silica Reaction (ASR) Expansion in Mortar with Recycled Glass *Cement and Concrete Composites* 139 2023: pp. 105043.
<https://doi.org/10.1016/j.cemconcomp.2023.105043>
23. **Zhu, X., Serati, M., Asche, H., Jackson, N., Gayler, A.** Systematic Evaluation of Crushed Waste Glass in Shotcrete: From Laboratory Batching to Field Spraying Trial *Results in Engineering* 30 2026: pp. 110146.
<https://doi.org/10.1016/j.rineng.2026.110146>



© Merdaci et al. 2027 Open Access This article is distributed under the terms of the Creative Commons Attribution 4.0 International License (<http://creativecommons.org/licenses/by/4.0/>), which permits unrestricted use, distribution, and reproduction in any medium, provided you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license, and indicate if changes were made.