IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 6, Issue 3, September 2026
Impact Factor: 8.2

Role of Waste Glass and Granite Powder on the Mechanical Properties and Durability Characteristics of Sustainable Concrete

Khamkar Rajendra Subhash[1] and Dr. Manoj Sharma[2]
[1]Research Scholar, Department of Civil Engineering
[2]Associate Professor, Department of Civil Engineering
Vikrant University, Gwalior, M.P, India

Abstract: *The rapid expansion of construction activities has increased the demand for cement, natural sand and aggregates while simultaneously generating large quantities of industrial and municipal solid waste. Waste glass and granite powder are two such materials that can potentially be incorporated into concrete to reduce landfill disposal, conserve natural resources and decrease dependence on conventional cementitious and aggregate materials. This research paper presents a literature-based assessment of the role of waste glass powder and granite powder in sustainable concrete, with particular emphasis on compressive strength, tensile strength, flexural strength, permeability, water absorption, chloride resistance, sulphate resistance, acid resistance, carbonation, abrasion and microstructural development*

Keywords: Waste Glass Powder, Granite Powder, Sustainable Concrete, Compressive Strength, Durability, Circular Economy

I. INTRODUCTION

Concrete is the most extensively used construction material in the world, but its conventional production requires substantial quantities of cement, natural aggregates, water and energy. Cement manufacture is particularly associated with significant greenhouse-gas emissions, while the extraction of river sand and natural aggregates can cause ecological degradation. At the same time, increasing urbanization and industrialization generate large quantities of waste glass and stone-processing residues. The simultaneous problems of resource depletion and waste accumulation have encouraged researchers to investigate waste-derived materials as components of sustainable concrete.

Waste glass is especially attractive because finely ground glass contains a substantial amount of amorphous silica. When sufficiently fine, it can participate in pozzolanic reactions with calcium hydroxide released during cement hydration, producing additional calcium-silicate-hydrate (C-S-H) gel. The resulting secondary hydration products can refine the pore structure and improve later-age mechanical and durability properties. However, the performance of waste glass is strongly dependent on particle size, replacement percentage, glass composition, curing conditions and the manner in which the glass is introduced into concrete. Reviews published during the study period consistently indicate that fine glass powder behaves differently from coarse glass aggregate, with finer particles generally providing greater pozzolanic activity.

RESEARCH OBJECTIVES

The major objectives of the paper are:

To examine the influence of waste glass powder on the mechanical properties of concrete.

To evaluate the effect of granite powder on strength and durability characteristics.

To investigate the combined role of waste glass powder and granite powder in concrete.

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 6, Issue 3, September 2026
Impact Factor: 8.2

To compare reported replacement levels and identify ranges associated with favorable performance.
To explain the mechanisms responsible for changes in strength, permeability and durability.
To identify limitations and research gaps associated with glass–granite sustainable concrete.
To develop recommendations for future experimental and field investigations.

RESEARCH METHODOLOGY

1. Research Design

The present research adopts a literature-based analytical review design. Peer-reviewed research published between 2010 and 2025 was examined to understand the effects of waste glass powder and granite powder on concrete. Particular attention was given to studies reporting experimental results for compressive strength, tensile strength, flexural strength, water absorption, permeability, chloride penetration, sulphate attack, acid attack, carbonation, abrasion, freeze–thaw performance and microstructure.

The review does not present fabricated laboratory results. Numerical values included in the tables are reported values from published studies and are identified accordingly.

2. Literature Selection

Studies were considered particularly relevant when they:
investigated waste glass powder or granite powder in concrete;
reported mechanical or durability characteristics;
used the waste material as cementitious or aggregate replacement;
investigated microstructural characteristics using SEM, XRD or related techniques;
were published between 2010 and 2025;
were published in peer-reviewed engineering or construction-material journals.

The literature was organized into four categories: waste glass powder, granite powder, combined glass–granite concrete, and recent review/long-term studies.

COMBINED USE OF WASTE GLASS AND GRANITE POWDER

The combination of WGP and GrP provides a potentially complementary sustainable concrete system. WGP primarily contributes through pozzolanic activity and micro-filling, while granite powder can contribute through fine-particle packing and partial replacement of natural sand.

The most directly relevant study is Jain (2020), in which glass powder was used at 5–25% cement replacement and granite powder at 10–50% sand replacement. The study investigated water absorption, water permeability, acid attack, sulphate attack and rapid chloride penetration, together with SEM and XRD analyses. The combined mixture containing 15% glass powder and 30% granite powder produced particularly favorable performance.

Table 1. Selected Published Findings on Waste Glass and Granite Powder

Study	Material	Replacement investigated	Main property investigated	Major reported finding
Vijayalakshmi et al. (2013)	Granite powder	0–25% sand	Strength and durability	Up to about 15% was favorable without adverse effects
Singh et al. (2016)	Granite cutting waste	10–50% sand	Strength, abrasion, permeability	Around 30% produced favorable overall performance
Omran et al. (2017)	WGP	10–30% cement	Long-term field performance	Improved later-age strength and chloride resistance
Ghorbani et al. (2018)	Granite waste dust	Up to 20% cement	Mechanical and durability	10% produced high strength; higher levels could remain viable
Jain et al. (2020)	WGP + GrP	5–25% WGP; 10–	Durability and strength	15% WGP + 30% GrP gave

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429 Volume 6, Issue 3, September 2026 Impact Factor: 8.2

		50% GrP		particularly favorable performance
Bameri et al. (2022)	WGP + SCMs	Different combinations	Strength/durability	WGP-containing blended systems improved several properties
Barbhuiya et al. (2025)	Ground waste glass	Literature review	Sustainable concrete	Particle size and replacement optimization are critical

EFFECT ON COMPRESSIVE STRENGTH

Compressive strength is one of the most widely used indicators for assessing the structural suitability of sustainable concrete.

The effect of waste glass powder on compressive strength generally follows a non-linear pattern. At relatively low or moderate replacement levels, fine WGP can contribute to particle packing and pozzolanic activity. At later ages, the formation of secondary C-S-H can compensate for the reduction in Portland cement content. Conversely, excessive replacement may reduce early-age strength because less cement is available for primary hydration.

Omran et al. reported long-term improvement in the performance of concrete containing glass powder, including continued mechanical development associated with pozzolanic activity. Similarly, Paul found favorable strength and durability performance in concrete incorporating finely ground glass powder, with 30% replacement identified as an effective level in their specific experimental program.

The combined WGP–GrP system can be particularly effective. Jain et al. reported that the 15% WGP + 30% GrP mixture achieved a 28-day compressive strength of 36.85 MPa, compared with the control mixture, representing an approximately 34% increase under their experimental conditions.

Table 2. Reported Mechanical Strength Response

Material system	Typical response	Principal mechanism
Low WGP replacement	Strength maintained or moderately improved	Filler effect and early pozzolanic activity
Moderate WGP replacement	Later-age strength improvement	Secondary C-S-H formation
High WGP replacement	Possible strength reduction	Cement dilution and workability/porosity effects
Low–moderate granite powder	Strength maintained/improved	Particle packing and filler effect
High granite powder	Possible strength reduction	Excess fines and weaker matrix/ITZ
WGP + GrP	Potential improvement at optimized proportions	Combined pozzolanic reaction and particle packing

Recent systematic evidence similarly suggests that WGP around 10–20% frequently produces favorable durability and mechanical outcomes, although some individual studies report higher optimum levels depending on fineness and mixture composition.

RESISTANCE TO ACID AND SULPHATE ATTACK

Concrete exposed to acidic or sulphate environments can experience chemical degradation, strength loss and surface deterioration.

The use of WGP can modify the chemistry and pore structure of cement paste. Research on WGP-containing alkali-activated systems found that 10–20% WGP reduced mass and strength losses during acid exposure, while excessive WGP beyond 20% increased deterioration under the specific conditions investigated.

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 6, Issue 3, September 2026
Impact Factor: 8.2

Similarly, long-term sulphate-resistance research has investigated WGP-blended cement systems at different replacement percentages, demonstrating the importance of replacement level and diffusion characteristics.

The combined WGP–GrP system has shown favorable behavior under both acid and sulphate attack. Jain et al. reported that blended concrete containing WGP and GrP performed better than the control concrete under the investigated acid and sulphate exposure conditions.

ALKALI–SILICA REACTION

Alkali–silica reaction is an important consideration when silica-rich waste materials are incorporated into concrete. Coarser reactive glass particles can potentially participate in ASR, resulting in expansive gel formation and cracking.

However, the behavior of finely ground glass powder is substantially different. Its high surface area promotes pozzolanic reaction, which can consume calcium hydroxide and modify the pore solution. Reviews have therefore identified fine glass powder as potentially capable of mitigating ASR when appropriately processed and proportioned.

Consequently, waste glass should not be evaluated solely on chemical composition. Particle size, fineness, replacement ratio and curing conditions must be considered together.

COMPARATIVE ANALYSIS OF WASTE GLASS AND GRANITE POWDER

Table 3. Functional Comparison

Characteristic	Waste Glass Powder	Granite Powder
Main source	Discarded bottles, containers and glass products	Granite cutting and processing industries
Principal use	Cement/SCM replacement	Fine aggregate/filler or mineral replacement
Main chemical contribution	Reactive amorphous silica	Mainly mineral/filler contribution
Major mechanism	Pozzolanic reaction + filler effect	Particle packing + filler effect
Strength contribution	Particularly important at later ages	Strongly dependent on replacement level and grading
Water absorption	Can decrease at optimized dosage	Can decrease through improved packing
Chloride resistance	Generally improved at suitable dosage	Can improve through matrix densification
Acid resistance	Potential improvement	Potential improvement depending on mix
Sulphate resistance	Potential improvement	Potential improvement
Main risk	ASR if particle size/dosage is inappropriate	Excessive fines and reduced workability
Important control parameter	Particle fineness	Particle size and replacement level
Typical research range	Approximately 10–30% frequently investigated	Approximately 10–30% commonly investigated, with wider ranges studied
Sustainability contribution	Reduces glass disposal and cement demand	Reduces stone waste and natural sand consumption

DISCUSSION

The reviewed literature demonstrates that waste glass and granite powder can be effective components of sustainable concrete when their particle characteristics and replacement levels are properly controlled. The role of WGP is primarily associated with pozzolanic activity and microstructural refinement. Granite powder, in contrast, often functions primarily as a fine filler or aggregate replacement, although its mineralogical composition can influence its behavior.

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429 Volume 6, Issue 3, September 2026 Impact Factor: 8.2

The combination is particularly promising because the two waste materials address different parts of the concrete system. WGP can modify the cement paste while granite powder can improve fine-particle packing. The resulting combination may reduce voids, improve the interfacial transition zone and reduce pathways for water and aggressive ions.

II. CONCLUSION

The review establishes that waste glass powder and granite powder have considerable potential for producing sustainable concrete with satisfactory mechanical and durability characteristics. Waste glass powder can function as a supplementary cementitious material because of its reactive amorphous silica, while granite powder can be used primarily as a partial replacement for natural fine aggregate or as a fine mineral filler. Their incorporation can reduce waste disposal, conserve natural resources and decrease the demand for conventional concrete constituents.

The mechanical performance of WGP concrete is strongly dependent on particle fineness and replacement percentage. Moderate quantities can contribute to later-age strength through pozzolanic reaction and additional C-S-H formation. Granite powder can improve particle packing and maintain or enhance strength at suitable replacement levels. However, excessive replacement of either material can cause adverse effects because of cement dilution, reduced workability, excessive fines or increased porosity.

REFERENCES

1. Bameri, H., Madani, H., & Rahmani, F. (2022). Evaluation of mechanical and durability properties of eco-friendly concrete containing silica fume, waste glass powder, and ground granulated blast furnace slag. *Advances in Materials Science and Engineering, 2022*, Article 2730391.
2. Idir, R., Cyr, M., & Tagnit-Hamou, A. (2010). Use of waste glass in cement-based materials. *Déchets, Sciences et Techniques*.
3. Jain, K. L., Sancheti, G., & Gupta, L. K. (2020). Durability performance of waste granite and glass powder added concrete. *Construction and Building Materials, 252*, 119075.
4. Khan, M. N. N., Saha, A. K., & Sarker, P. K. (2020). Reuse of waste glass as a supplementary binder and aggregate for sustainable cement-based construction materials: A review. *Journal of Building Engineering, 28*, 101052.
5. Letelier, V., Tarela, E., Osses, R., Cárdenas, J. P., & Moriconi, G. (2017). Mechanical properties of concrete with recycled aggregates and waste glass. *Structural Concrete, 18*, 40–53.
6. Mariaková, D., Vlach, T., & Pavlů, T. (2019). Glass waste powder utilization in high performance concrete. *Acta Polytechnica CTU Proceedings, 21*, 24–27.
7. Omran, A. F., Morin, E. D., Harbec, D., & Tagnit-Hamou, A. (2017). Long-term performance of glass-powder concrete in large-scale field applications. *Construction and Building Materials, 135*, 43–58.
8. Paul, D., Bindhu, K. R., Matos, A. M., & Delgado, J. M. P. Q. (2022). Eco-friendly concrete with waste glass powder: A sustainable and circular solution. *Construction and Building Materials, 355*, 129217.
9. Ramakrishnan, K., Pugazhmani, G., Sripragadeesh, R., Muthu, D., & others. (2017). Experimental study on the mechanical and durability properties of concrete with waste glass powder and ground granulated blast furnace slag as supplementary cementitious materials. *Construction and Building Materials, 156*, 739–749.
10. Semmana, O., Rihan, M. A. M., Barrie, Z. M., Daniel, C., & Abdalla, T. A. (2025). A systematic review of the strength, durability, and microstructure properties of concrete incorporating glass powder. *Engineering Reports, 7*(1), e70002.
11. Singh, S., Khan, S., Khandelwal, R., Chugh, A., & Nagar, R. (2016). Performance of sustainable concrete containing granite cutting waste. *Journal of Cleaner Production, 119*, 86–98.
12. Vijayalakshmi, M., Sekar, A. S. S., & Ganesh Prabhu, G. (2013). Strength and durability properties of concrete made with granite industry waste. *Construction and Building Materials, 46*, 1–7.

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 6, Issue 3, September 2026
Impact Factor: 8.2

13. Ying, J., Yuan, T., Jin, Y., & Fan, L. (2023). State of the art on waste glass powder as supplementary cementitious material. *Engineering Science & Technology, 4*(2), 80–94.
14. Zhou, C., Li, M., Nguyen, Q. D., (2025). Incorporation of waste glass powder in the sustainable development of concrete. *Materials, 18*.