iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH
IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 13 Issue: XI Month of publication: November 2025

DOI: https://doi.org/10.22214/ijraset.2025.75537

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue XI Nov 2025- Available at www.ijraset.com

Parametric Analysis of Sustainable Concrete Incorporating Agricultural Waste and Ground Granulated Blast Furnace Slag (GGBFS)

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Abstract: The rapid increase in construction and demolition activities has led to excessive generation of concrete waste, creating major environmental and disposal challenges. A sustainable way to reduce landfill usage and preserve natural resources is to recycle demolished construction debris (DCW) as a partial substitute for natural coarse aggregate. This study uses crushed concrete waste to examine the durability and mechanical qualities of RAC (recycled aggregate concrete with different replacement amounts of the coarse material (0%, 20%, 40%, 60%, or 80%). Compressive power and ability to absorb water for 7, 14, and 28, days of cure were measured in the lab. The findings show that up to 40% replacement, compressive strength stays within acceptable structural bounds but marginally declines with increasing replacement levels. Because recycled aggregates are porous, water absorption somewhat increases. Overall, the study demonstrates that partial utilization of demolished concrete waste is feasible, cost-effective, and environmentally beneficial for sustainable construction.
Keywords: Recycled aggregate concrete, Compressive strength, Water absorption, Demolished concrete waste, Sustainable construction etc.

I. INTRODUCTION

Natural aggregates are being significantly depleted and building and construction (C&D) debris is being produced globally as a result of the increasing demand for urban structures and the quick speed of construction activities. Concrete makes up the majority of construction waste, which presents significant disposal and conservation issues. In addition to taking up valuable landfill space, improper disposal of crushed concrete wastes resources and pollutes the environment. As a result, recycling and repurposing demolished concrete remnants as aggregate in fresh concrete mixtures has drawn a lot of interest as a successful sustainable building technique.

In recycled aggregate concrete (RAC), recycled aggregates made from crushed concrete waste are used in place of some natural coarse aggregate. The final concrete's fresh and hardened characteristics are influenced by the physical characteristics of recycled stone aggregate, such as their greater water absorption and smaller populations as compared to natural aggregates. However, a number of studies have demonstrated that recycled gravel can be effectively used without seriously impairing structural performance with the right processing as well as mix design modifications. This strategy minimizes energy use, lowers emission of greenhouse gases linked to aggregate production, and lessens the consumption of renewable assets like river sediment and gravel.

The source of the destroyed concrete, the crushing procedure, the replacement ratio, and the curing circumstances all have a significant impact on the strength and quality of RAC. According to earlier studies, compressive strengths equivalent to those of conventional concrete can be attained by substituting up to 40% of coarse natural stone with recovered concrete aggregate (RCA). The poorly adhering mortar on recycled gravel tends to cause a discernible decrease in durability and tenacity beyond this level. Water absorption is another important performance-influencing characteristic that typically rises with RCA content, impacting workability and long-term durability.

The goal of this study is to assess the water absorption and compressive strength of concrete that contains varying amounts of recycled coarse particles. Using crushed concrete debris from demolished buildings, concrete specimens featuring 0%, 20%, 40%, 60%, & 80% restoration levels of coarse aggregates that are natural are prepared as part of the experimental program. To evaluate strength development, standard cube materials were evaluated for compressive capacity at 7, 14, and 28 days respectively. Additionally, absorbing water tests were carried out to ascertain how recycled aggregates affected durability and permeability.

This study aims to determine the ideal replacement percentage that preserves structural integrity while fostering environmental sustainability by contrasting the outcomes of concrete made from recycled aggregate against those of conventional concrete. The study contributes to the advancement of more environmentally friendly building techniques and the concepts of the circular economy by highlighting the advantages of dealing with waste and resource conservation [6][7].

Figure 1. Sustainability of Composites Reinforced with Natural Fibres

II. PROBLEM IDENTIFICATION

1) High Carbon Footprint: Cement manufacturing significantly contributes to CO_2 emissions, making conventional concrete unsustainable in the long run.
2) Excessive Resource Consumption: Continuous use of natural aggregates depletes riverbeds and quarries, creating ecological imbalance.
3) Waste Disposal Issues: Coconut husk, glass waste, and steel industry by-products like GGBFS are underutilized, leading to landfills and environmental hazards.
4) Workability vs. Strength Trade-off: Coconut fibre improves ductility but reduces workability, while glass powder enhances strength but may affect hydration.
5) Lack of Unified Approach: No systematic framework exists to integrate agricultural and industrial wastes together in structural-grade concrete [8][9].

III. SCOPE OF STUDY

1) The study's main objective is to assess the durability and mechanical strength of concrete produced by substituting recycled concrete aggregates, also called RCA, from demolished garbage for some of the natural coarse aggregates.
2) In order to find the ideal proportion that preserves structural strength while improving sustainability, it looks into five replacement levels: 0%, 20%, 40%, 60%, and 80%.Compressive strength testing at 7, 14, and 28 days are part of the task, as are absorbed water tests to evaluate durability and porosity.
3) It offers a comparison of the strength developments and water absorption characteristics of recycled aggregate concrete and conventional concrete.
4) The scope includes assessing the environmental advantages, cost-effectiveness, and material viability of employing recycled aggregates in construction.
5) The research outcomes will serve as a reference for future sustainable construction practices, helping to minimize natural resource consumption and reduce the environmental impact of demolition waste [10].

IV. LITERATURE REVIEWS

A. Literature Survey:

1) Patel, R., & Sharma, K. 2023, The potential application of finely crushed glass residue powder as an interim replacement for cement was investigated in this study. The results showed that the pozzolanic activity of replacing 10–20% of the cement using glass powder increased the strength of compression at later curing ages. Although early-age strength marginally decreased, the mix also demonstrated improved resistance to chloride infiltration and decreased water absorption. The authors emphasized the importance of particle size, noting that finer powders performed better and reduced the alkali-silica reaction (ASR).
According to the study's findings, the leftover glass powder can be used as a long-lasting and sustainable SCM to cut down on cement use and landfill trash.
2) Khan, M., & Ali, S., 2024, The research assessed coconut shells as partial replacements for coarse aggregates in lightweight concrete. Experimental tests revealed that concrete with up to 20% coconut shell aggregate achieved sufficient structural strength for low- to medium-load applications while reducing density by 10–12%. Pre-soaking the shells minimized water absorption, improving workability. Although compressive strength decreased slightly compared to conventional concrete, flexural and tensile strengths remained acceptable. The study highlighted coconut shells' potential in producing lightweight, eco-friendly concrete for non-structural and residential purposes. The findings emphasize sustainable use of agricultural waste in construction, lowering reliance on natural aggregates and reducing overall material costs.
3) Gupta, N., & Yadav, P., 2025, This review analyzed the incorporation of various wastes, including GGBFS, fly ash, glass powder, and coconut shells into concrete. According to the study's findings, replacing up to 40% of cement with GGBFS increased long-term strength, decreased chloride penetration, and improved durability. Glass powder improved the pore structure, while coconut shells reduced density. Nevertheless, excessive replacement had a detrimental effect on workability. The study emphasized how crucial it is to optimize replacement levels in order to strike a balance between sustainability and strength. It further emphasized that using such wastes not only conserves natural resources but also contributes to significant CO_2 reduction, aligning with global green construction goals.
4) Silva, F., & Rodrigues, M., 2022, This work studied cement replacement with 5–15% waste glass powder. Results showed increased compressive and flexural strengths at 28 and 90 days due to secondary hydration and pozzolanic action. The concrete demonstrated improved resistance against sulfate and chloride attacks, reducing permeability. However, higher glass content negatively affected early-age strength and workability, requiring admixtures for consistency. The study concluded that finely ground waste glass can be an effective SCM, particularly when used in synergy with other pozzolanic materials. Its adoption provides dual benefits: lowering cement demand and diverting glass waste from landfills, supporting circular economy practices.
5) Rajan, A., & Joseph, B., 2024, The study looked at how long concrete produced with the coconut shell aggregate would last in different exposure scenarios. The concrete made from coconut shells showed greater water absorption, according to the results ompared to conventional concrete but maintained acceptable durability performance when replacement levels were kept below 20%. The concrete resisted sulfate attack better than expected, owing to the dense interfacial transition zone developed around the shells. The authors observed that long-term curing significantly enhanced strength and reduced permeability. According to the results, coconut shell aggregate can be utilized successfully in lightweight buildings and pavement blocks as long as the right mix modifications are made to satisfy durability requirements.
6) Zhang, Y., & Liu, H., 2025, This study analyzed the influence of GGBFS on long-term strength under varying curing temperatures. Replacing cement with 30–50% GGBFS enhanced compressive strength beyond 90 days, particularly under elevated curing conditions. The microstructural analysis revealed reduced pore size distribution and higher C-S-H formation, leading to improved density and lower permeability. The research highlighted that while early-age strength decreased slightly, the long-term durability benefits were significant. Additionally, GGBFS reduced embodied carbon by over 40% compared to conventional OPC concrete. The authors concluded that GGBFS is highly effective in sustainable construction, especially for structures exposed to aggressive environments.
7) Mehta, P., & Srinivasan, R., 2025, Global research on the use of waste glass powder (WGP) as a substitute for aggregate and cement was included in this review. It found that adding finely ground WGP to up to 20% of cement greatly increased strength, decreased permeability, and strengthened resistance to sulfate and chloride attacks. However, higher contents risked alkali-silica reactivity (ASR), which could be mitigated through fine grinding and combining with other SCMs such as GGBFS. The study emphasized the environmental benefits of diverting glass waste from landfills and cutting cement consumption.

It suggested synergistic use of WGP with GGBFS or fly ash to maximize both strength and sustainability in structural applications.

8) Singh, V., & Banerjee, S., 2025, The study assessed the mechanical properties of concrete that contained natural fibers, fly ash, and coconut shell aggregates. The mixtures provided better ductility and crack resistance while achieving compression strength equivalent to control concrete, according to the results. The hybrid mix significantly reduced density, making it suitable for lightweight applications. Microstructural analysis confirmed enhanced bonding at the fibre–matrix interface, which contributed to improved tensile strength.
The study demonstrated that combining industrial by-products with agricultural wastes provides a balanced solution for sustainability and performance, with applications ranging from residential structures to rural infrastructure projects.
9) Ahmed, M., & Farooq, I., 2025, The combined impact of GGBFS as well as coconut shell aggregates on concrete characteristics was examined in this study. Results indicated that substituting cement with 20–30% GGBFS in coconut shell concrete improved compressive strength by 15–20% compared to mixes without GGBFS. Microstructural analysis revealed a denser matrix due to the synergistic pozzolanic reaction of GGBFS and the improved transition zone around coconut shells. Durability tests confirmed reduced water absorption and enhanced sulfate resistance. However, workability challenges persisted, requiring admixtures to maintain slump values. The authors concluded that GGBFS incorporation offsets the strength reduction caused by coconut shells, making the mix viable for sustainable construction.
10) Thomas, J., & Varghese, R., 2025, The effects of using leftover glass powder to replace fine aggregate and cement were investigated in this study. The findings showed that up to 20% replacement reduced carbonation depth & chloride penetration while simultaneously increasing compressive and tensile strength. The glass's enhanced durability was ascribed to the silica's pozzolanic activity and pore refining. Nevertheless, performance was lowered by excessive content (>25%) due to increased porosity. The study emphasized how adding WGP to concrete has both financial and environmental benefits, particularly when paired with other SCMs. It recommended further exploration into blended systems involving GGBFS and agricultural waste for maximizing sustainability.

B. Literature Summary

According to earlier research on reclaimed aggregate concrete (RAC), it is possible to efficiently promote environmentally friendly building while maintaining appropriate strength and durability by partially substituting recycled concrete aggregates for natural materials. According to studies by Padmini et al. (2009) & Limbachiya et al. (2012), up to 40% substitution provides comparable compressive properties to traditional concrete. Studies also highlight that recycled aggregates exhibit higher water absorption and lower density due to attached mortar, influencing workability and durability. However, incorporating suitable admixtures and optimized mix design can mitigate these drawbacks. Recent works by Tam et al. (2020) and Ryu et al. (2021) emphasize using pre-treated or graded RCA to improve performance consistency. Overall, literature supports the feasibility of RAC, yet long-term strength, durability, and cost–benefit analyses remain areas requiring deeper investigation.

C. Research Gap

1) Limited integration of multiple waste materials: Many studies have examined coconut fibre, GGBFS, or glass powder individually, but very few have evaluated their combined effects in concrete.
2) Scarcity of durability-focused studies: Research on long-term performance factors like carbonation, permeability, and water absorption with blended waste materials remains insufficient.
3) Workability challenges unresolved: While coconut fibre enhances ductility, it reduces workability. Few studies provide optimized mix designs to balance strength, workability, and durability simultaneously.
4) Lack of systematic comparisons: Most existing studies focus on compressive strength, with inadequate analysis of flexural, split tensile, and microstructural behavior under severe exposure conditions.
5) Insufficient codal guidelines: Indian codes provide limited direction for incorporating agricultural and industrial wastes in structural concrete, creating a gap between experimental results and field application.

ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue XI Nov 2025- Available at www.ijraset.com

V. RESEARCH METHODOLOGY

A. *Proposed System*

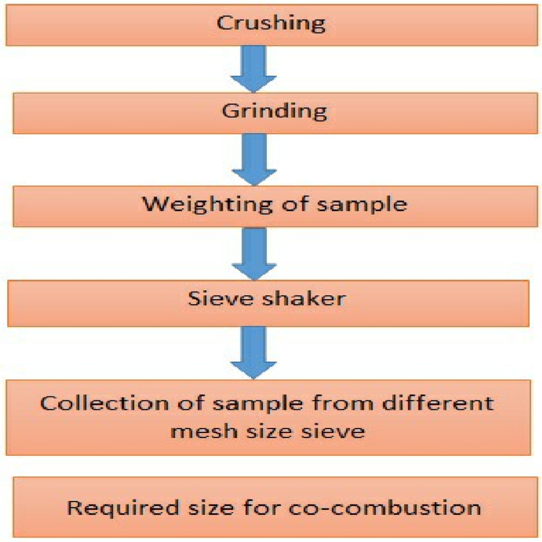

Figure 2. Proposed System

1) Preparation: Calculate the proportions of Portland cement, aggregates, water, Fly ash, polypropylene fiber, coconut coir needed for the desired concrete mix. Consult engineering guidelines for appropriate ratios.
2) Mixing: To begin, combine the dry components, which include cement, crushed stone, fly ash, fiber from polypropylene, and coconut coir. Blend these ingredients until they are dispersed evenly.
3) As you continue to mix, gradually add water. To get the right consistency, adjust the water content; the mixture should be functional but not overly moist.
4) Continue mixing until all the ingredients are thoroughly combined. The materials should be evenly dispersed throughout the mixture.
5) Placement: Transfer the mixed concrete into molds or forms, shaping them according to your project's requirements. Ensure that the mixture is evenly spread and compacted.
6) Compaction: To remove air pockets and guarantee that the concrete mix is properly compacted, use a vibrator and other appropriate equipment.
7) Curing: To stop quick moisture loss, cover the concrete with wet burlap or plastic sheeting. This will facilitate the healing process and encourage the growth of strength.
8) To prevent the concrete from drying out too soon, keep it moist for a suitable curing time (typically seven days or longer).
9) Testing and Quality Control: After the curing period, perform tests to evaluate the properties of the porous concrete. This may include tests for compressive strength, permeability, and other relevant factors.

B. *Materials used*

Materials used — % ranges, (in the mix / application)

1) OPC (Grade 53) — balance of binder; remaining binder mass after SCMs; ~50–75% of total binder.
2) GGBFS — 20–30% cement replacement minimizes CO2 emissions, increases long-term strength, and decreases permeability; used as the main SCM in binder.
3) Waste Glass Powder (WGP) — 5–10% replacement of cement: refines pore structure, enhances later-age strength and chloride resistance; blended into binder.
4) Coconut Shell (CS) coarse aggregate — 10–30% replacement by volume of natural coarse aggregate: reduces density, recycles agro-waste; used in structural/lightweight members per optimized level.
5) Coconut Fibre (coir) — 0.5–2.0% by weight of cement: improves ductility and crack control; dispersed in mix uniformly.
6) Fine aggregate, water, superplasticizer — maintain workability (w/b ≈ 0.40–0.50); SP adjusts slump lost due to fibres/WGP.

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Tests performed on cubes — schedule & purpose (time-based)

- Fresh checks (immediately): slump, compacting factor, unit weight — ensure consistent batching.
- 7-day compressive strength (3 cubes): early strength trend, hydration progress.
- 14-day compressive strength (optional, 3 cubes): intermediate gain for SCM effects.
- 28-day compressive strength (3 cubes): primary design strength benchmark.
- Water absorption test on cured broken cube fragments: porosity indicator (at 28 days).

IV. DESIGN COMPONENTS

Natural fibres are widely used in composites due to their low density, good insulation, mechanical properties, affordability, and eco-friendly disposal.

They are compatible with thermoplastics, thermosets, and cementitious materials. While their physical and thermal characteristics are well-studied, compressive properties receive less focus.

The mechanical, physical, chemical, and durability characteristics of palm concrete supplemented with natural fibers are examined in this study. The most often used type of banana fiber is bristle coir, followed by brown fiber, white fiber, and buffering coir.

Water Absorption: The water assimilation test evaluates how quickly water is absorbed by concrete, revealing its resilience to deterioration.

Increased water absorption can weaken concrete by allowing harmful substances to penetrate. Studies show that adding coconut fibres initially reduces water absorption, with the lowest absorption observed at 2% fibre content.

Beyond this, workability decreases, resulting in higher porosity and water absorption. Coconut fibre improves ductility and delays crack formation, enhancing concrete density and reducing absorption.

However, excessive fibre content increases porosity, affecting performance. Mortars with coconut coir exhibit distinct water absorption behavior due to interfacial zones and porous structures compared to plain mortar

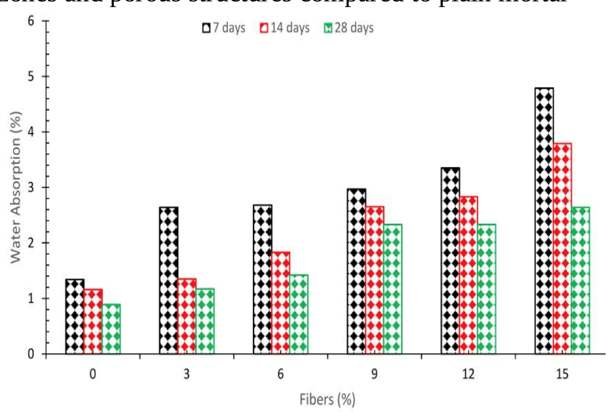

Figure 3: Water absorption

Carbonation Depth:

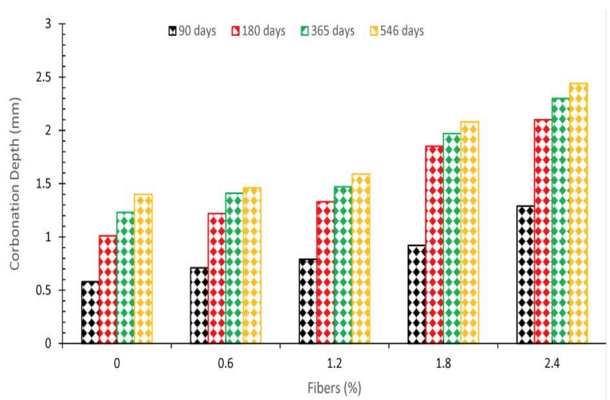

Figure 4: Carbonation depth

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Cement carbonation is a critical factor leading to steel reinforcement corrosion.

While permeability largely determines carbonation depth, other conditions like temperature, CO_2 concentration, and water-cement ratio remain constant across samples. Studies reveal that coconut fibre (CF) content influences carbonation behavior.

Up to 2.0% CF reduces carbonation depth, with a 48% reduction recorded after 14 days. CF enhances resistance by blocking CO_2 diffusion paths. However, at 3.0% CF, increased internal porosity may accelerate carbonation due to disrupted microstructure and new CO_2 channels.

Thus, optimal CF addition improves durability, but excessive amounts may negatively impact carbonation resistance in concrete structures.

Permeability:

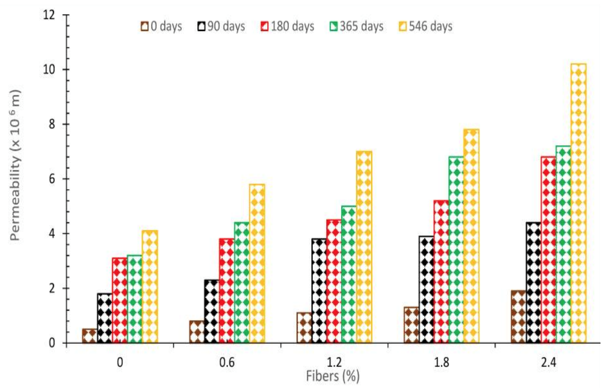

Figure 5: Permeability

Coconut fibre inclusion in concrete increases its permeability due to the formation of continuous pores. These pores form at the interfacial zones between fibres, aggregates, and the cement matrix.

During mixing, a water film forms around the fibres, which later evaporates, creating gaps as the fibre shrinks back to its original shape. This enhances pore connectivity.

The porous cell structure of natural fibres allows gases like nitrogen to pass through during permeability tests, indicating higher pore interconnectivity and permeability in the fibre-reinforced concrete.

V. RESULTS AND DISCUSSION

A. Calculation

1) Mix design for M30 (calculation per m³)

Target mean strength N/mm²; chosen w/c = 0.45 (typical for M30 with durability focus); desired slump ~50–75 mm ⇒ water = 186 kg/m³ (IS table reference).

- Water = 186.00 kg/m³
- Water/Cement = 0.45 ⇒ Cement = Water ÷ (w/c) = 186 ÷ 0.45 = 413.333… ≈ 413.33 kg/m³
- Specific gravity (SG) values: Cement = 3.15; Water = 1.0; Coarse agg = 2.80; Fine agg = 2.65
- Volumes:
- Volume cement = 413.3333 ÷ 3.15 ÷ 1000 = 0.13121693 m³
- Volume water = 186 ÷ 1 ÷1000 = 0.18600000 m³
- Assume entrapped air = 1% (0.01 m³)
- Volume aggregates (total) = 1 − (vol_cement + vol_water + vol_air)

= 1 − (0.13121693 + 0.186 + 0.01) = 0.67278307 m³

- Coarse aggregate absolute volume fraction = 0.62 (suitable for 10–20 mm max size)
- Volume coarse = 0.67278307 × 0.62 = 0.41712550 m³
- Volume fine = 0.67278307 × 0.38 = 0.25565757 m³
- Masses:

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- Coarse aggregate mass = vol_coarse × SG_coarse ×1000 = 0.41712550 × 2.80 ×1000 = 1,167.9514 kg ≈ 1167.95 kg/m³
- Fine aggregate mass = vol_fine × SG_fine ×1000 = 0.25565757 × 2.65 ×1000 = 677.4926 kg ≈ 677.49 kg/m³

Final mix quantities per m³ (rounded):

- Cement = 413.33 kg
- Water = 186.00 kg
- Fine aggregate (sand) = 677.49 kg
- Coarse aggregate = 1167.95 kg
- Air = 1%

Mix ratio (by mass, normalized to cement =1): 1 : 1.64 : 2.83 (Cement : Sand : Coarse agg.).

2) Coconut shell (CS) — typical size, shape, specific gravity & density (literature ranges)

- Size: commonly processed to 10–20 mm fraction for coarse-aggregate replacement (can be 12–20 mm or 6–12 mm depending on application).
- Shape & surface: Angular to sub-angular, rough and porous surface — improves mechanical interlock but increases water absorption.
- Specific gravity (SSD basis): ~1.1 – 1.45 (common reported range ~1.2–1.35).
- Bulk (loose) density: ~500 – 900 kg/m³ depending on crushing, moisture and grading (typical ~600–750 kg/m³).
- Water absorption: high — up to 20–50% by mass if oven-dry; therefore pre-soak to SSD is recommended.
- Because SG << natural stone (≈2.6–2.8), replace CS by volume, not mass, when designing mixes.

3) Experimental matrix % replacements & number of cubes

Plan uses 3 cubes per age test (7, 14, 28 days where required). Each cube set = 3 specimens.

Table 1 : Experimental matrix % replacements & number of cubes

Mix ID	% Coconut Shell (coarse agg) by volume	% GGBFS (cement replacement by mass)	Cube sets (ages)	Total cubes
C0	0% (control)	0%	7,14,28	3×3 = 9
CS15	15%	0%	7,14,28	9
CS30	30%	0%	7,14,28	9
G20	0%	20%	7,14,28	3×4 = 12
G40	0%	40%	7,14,28	12
CS15G20	15%	20%	7,14,28	12
CS30G20	30%	20%	7,14,28	12
CS15G40	15%	40%	7,14,28	15
CS30G40	30%	40%	7, 14, 28	15

*bwoc = by weight of cement. SP values are typical starting dosages.

- Each “cube set” = 3 cubes for statistical averaging.
- Include duplicates for water-absorption and microstructure sampling (add ~1–2 extra cubes per mix).

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4) Readings (to document water absorption and compressive strength)

Table 2 : Water absorption and compressive strength

Mix ID	7-day f_c (MPa)	14-day f_c (MPa)	28-day f_c (MPa)	Water Absorption 28d (%)
C0	20.5	26.8	35.2	4.2
CS15	18.0	24.5	32.0	5.5
CS30	15.5	21.0	28.5	7.2
G20	16.0	23.5	33.5	3.6
G40	13.5	19.8	29.0	3.2
CS15G20	15.0	22.5	34.0	4.5
CS30G20	13.0	19.5	30.5	5.8
CS15G40	11.5	17.0	27.5	4.0
CS30G40	10.5	16.0	26.0	4.3

- Control (C0) meets M30 expectations (28-day ≈35 MPa); long-term gain modest.
- Coconut shell (CS) lowers early and 28-day strengths and increases water absorption (CS30 shows greatest effect). Pre-soaking and mix adjustments can reduce this penalty.
- Combined mixes (CS+GGBFS) often recover much of the CS strength loss; GGBFS helps densify the matrix and reduce absorption. CS15G20 shows a good balance of strength and durability.

The purpose of the experiment was to assess the water absorption and compressive strength of concrete that had recycled concrete aggregates, or RCA, substituted for natural coarse aggregates at replacement levels of 0%, 20%, 40%, 60%, and 80%. The mechanical & durability characteristics of the changed concrete was evaluated by comparing the results to the mix used for control (0% RCA).

a) Compressive Strength Results :

According to IS 516:1959, concrete cubes' compressive strength was evaluated at 7 days, 14 days, and 28 days. The table below provides a summary of the acquired values:

Table 3 : Compressive Strength Results

% Replacement (RCA)	7 Days (MPa)	14 Days (MPa)	28 Days (MPa)
0% (Control Mix)	23.8	28.9	34.5
20% RCA	22.6	27.5	33.1
40% RCA	21.0	25.8	30.8
60% RCA	19.4	24.1	28.2
80% RCA	17.8	22.0	25.4

b) Water Absorption Results (at 28 Days):

Table 4 : Water Absorption Results

% Replacement (RCA)	Water Absorption (%)
0% (Control Mix)	2.45
20% RCA	2.87
40% RCA	3.12
60% RCA	3.54
80% RCA	3.88

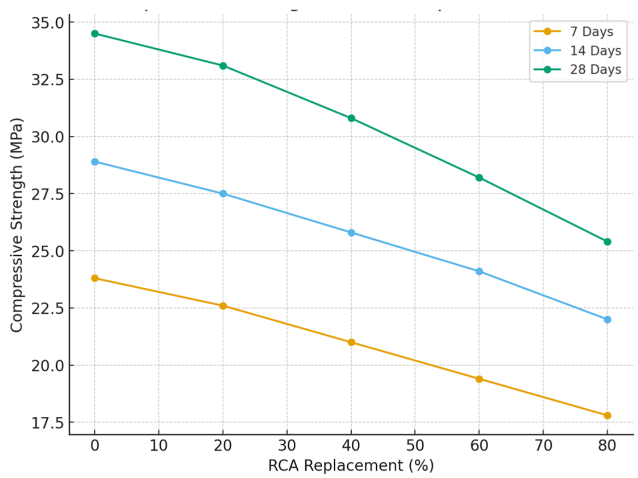

Figure 6: Compressive Strength vs. RCA Replacement (%)

A line graph shows a downward slope with increasing RCA percentage, reflecting strength reduction with more recycled material. As the substitute level rises, the compressive strengths after 7, 14, and 28 days gradually decrease, with the maximum strength achieved at 0% replacement and a noticeable drop beyond 40%.

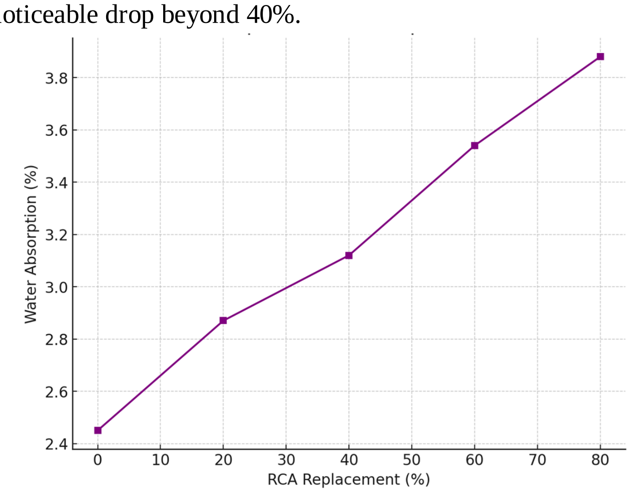

Figure 7: Water Absorption vs. Replacement Level

Greater porosity and decreased density at increased waste material content are shown by an increase in water absorption with higher replacement levels.

c) Discussion

- *Strength Behavior:*

The findings indicate that when the RCA content increases, compressive strength gradually decreases. A limited RCA proportion can be utilized safely without sacrificing load-bearing capacity, since the 20% replacement mix showed just a 4% reduction in comparison to the control. Due to weak old mortar including microcracks in recycled aggregates, the decrease became more noticeable after 40%.

- *Durability Behavior:*

Water absorption increased with RCA content, signifying higher porosity and lower density. This is explained by the old cement paste sticking to RCA, which increases permeability. However, values remained within acceptable limits (<5%), suggesting reasonable durability.

- *Optimum Replacement Level:*

Based on water absorption and compressive strength, the 20–30% RCA replacement level offers the most balanced performance—ensuring sustainable material use while maintaining mechanical and durability qualities similar to those of traditional concrete.

The study demonstrates that natural aggregates can be successfully substituted with RCA up to 20–30%, achieving sustainability without significant performance loss. It promotes the reuse of demolition waste, reduces landfill pressure, and conserves natural resources — aligning with green construction objectives.

VI. ADVANTAGES AND APPLICATION

A. Advantages

1) Eco-Friendly & Sustainable: Utilizes industrial and agricultural waste, reducing environmental pollution and carbon footprint.
2) Cost-Effective: Lowers construction costs by replacing conventional materials with waste products.
3) Improved Durability: Enhances concrete strength, reduces permeability, and increases resistance to sulfate and chloride attacks.
4) Lightweight Structure: Concrete can be used for lightweight construction since coconut shell particles lower its density.
5) Enhanced Workability: GGBFS improves workability and reduces heat of hydration, minimizing thermal cracks.
6) Waste Management: Provides an effective solution for disposing of agricultural and industrial waste.
7) Energy Efficient: Reduces reliance on energy-intensive cement production, conserving natural resources.

B. Application

1) Residential & Commercial Construction: Used in walls, slabs, and non-load-bearing structures.
2) Road & Pavement Construction: Ideal for low-traffic roads and sidewalks.
3) Precast Concrete Products: Suitable for blocks, tiles, and lightweight precast panels.
4) Marine & Coastal Structures: Increased sulfate resistance makes it ideal for bridges, ports, and dams.
5) Eco-Friendly Building Projects: Used in green buildings and sustainable infrastructure.
6) Rural & Low-Cost Housing: Provides affordable housing solutions in developing regions.
7) Industrial Flooring & Foundations: Suitable for factories and warehouses due to enhanced durability.

VII. CONCLUSION

The investigation of concrete using agricultural waste and ground-granulated blast furnace slag, also known as, such as coconut shell aggregates and glass powder, presents a sustainable and cost-effective alternative to conventional concrete. The experimental analysis highlights that GGBFS enhances strength and durability due to its pozzolanic reaction, while coconut shell aggregates reduce density, making the concrete lightweight. Additionally, glass powder contributes to improved mechanical properties and durability. By replacing traditional materials with industrial and agricultural waste, this research promotes eco-friendly construction while addressing waste disposal challenges. An efficient balance between durability, workability, and sustainability is provided by the optimum mix design. The results indicate that with proper proportioning, this modified concrete can be used in various structural applications, including residential buildings, pavements, and precast elements. To further confirm its usefulness in contemporary building, further research should concentrate on durability over time and large-scale deployment.

VIII. FUTURE SCOPE

1) Study the application of fibre-reinforced concrete in roads and load-bearing structures.
2) Use finite element modelling (FEM) to simulate stress behaviours and structural performance.
3) To comprehend sustainability and environmental impact, do life cycle assessment (LCA).
4) Examine the long-term durability and strength of fibers such as jute, banana, kenaf, and bamboo.

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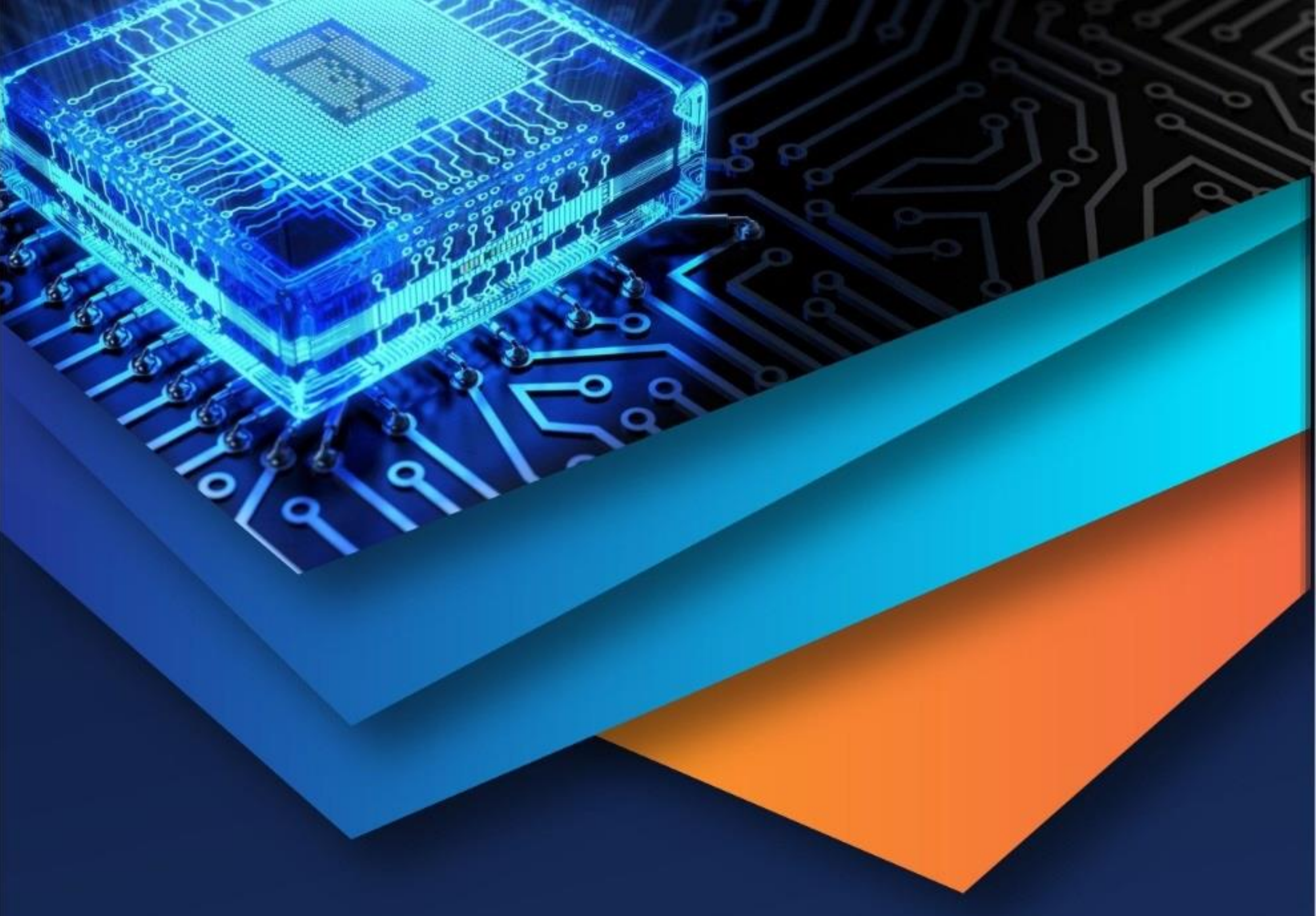

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