

Experimental Study on the Utilization of Demolished Concrete Aggregate, Eggshell Powder and Glass Powder in Building Construction

Dr. U.J Jadhav¹, Dr V S Chavhan², Dr P R Modak³, Ms. V V Rokade⁴

¹ Assistant professor, Dept. of Civil Engineering, AISSMS, Pune, India.

² Assistant professor, Dept. of Civil Engineering, AISSMS, Pune, India.

³ Assistant professor, Dept. of Civil Engineering, AISSMS, Pune, India.

⁴ Assistant professor, Dept. of Civil Engineering, AISSMS, Pune, India.

Abstract: This study investigates the use of demolished concrete aggregate (DCA), eggshell powder (ESP), and glass powder (GP) in concrete production for sustainable building construction. Rapid urbanization and increasing construction activities generate large quantities of demolition waste, waste glass, and eggshell residues. Disposal of these materials creates environmental concerns. Reusing these wastes in concrete can reduce landfill burden, conserve natural resources, and lower construction cost. Three concrete cubes of size 150 mm × 150 mm × 150 mm were prepared using combined replacement materials and tested for compressive strength using Compression Testing Machine (CTM). The test results indicate that concrete containing these waste materials can achieve satisfactory strength and can be used for practical construction applications.

Keywords: Recycled aggregate, Eggshell powder, Glass powder, Sustainable concrete, Compressive strength, Green construction.

I. INTRODUCTION

Concrete is the most widely utilized construction material globally due to its versatility, strength, and cost-effectiveness. However, the production of conventional concrete relies heavily on natural resources such as coarse aggregates, river sand, and cement. The excessive extraction of these materials has led to significant environmental concerns, including depletion of natural reserves, habitat destruction, and increased carbon emissions associated with cement manufacturing. In the context of growing sustainability challenges, the construction industry is under increasing pressure to adopt alternative materials and resource-efficient practices.

Simultaneously, the generation of construction and demolition waste, along with other industrial and domestic by-products such as waste glass and eggshells, has been rising at an alarming rate. Improper disposal of these materials contributes to environmental pollution and landfill overuse. Recycling and reusing such waste in concrete production present a promising approach to mitigating these issues while promoting sustainable development.

Demolished concrete, when processed into recycled concrete aggregate (RCA), can be effectively used as a partial replacement for natural coarse aggregates. This not only reduces the demand for virgin materials but also minimizes construction waste. Similarly, waste glass, when ground into fine glass powder, exhibits pozzolanic properties that can enhance the microstructure of concrete by improving particle packing and contributing to secondary hydration reactions. Eggshell powder, primarily composed of calcium carbonate, can serve as a filler material, improving the density and potentially influencing the strength characteristics of concrete.

Incorporating these waste materials into concrete not only addresses waste management challenges but also offers potential improvements in material performance. However, their combined effect on the mechanical properties of concrete, particularly compressive strength, requires systematic investigation. Factors such as optimal replacement levels, material compatibility, and processing techniques play a crucial role in determining the overall performance of modified concrete.

II. AIMS AND OBJECTIVES

1. To utilize demolished concrete aggregate in concrete production.
2. To use eggshell powder as partial cementitious filler.

3. To use glass powder as fine filler material.
4. To prepare concrete cubes and test compressive strength.
5. To study feasibility of sustainable building construction.
6. To reduce environmental pollution caused by waste disposal.

III. MATERIALS USED

1. Ordinary Portland Cement
2. Fine Aggregate (Sand)
3. Natural Coarse Aggregate
4. Demolished Concrete Aggregate
5. Eggshell Powder
6. Glass Powder
7. Potable Water

IV. MATERIAL PROPERTIES

The properties of materials used in the study are as follows:

1. Cement: Ordinary Portland Cement (OPC) of 53 grade was used. It conforms to relevant IS standards. Specific gravity = 3.15.
2. Fine Aggregate: (river sand) was used, conforming to Zone II as per IS standards.
3. Coarse Aggregate: Natural coarse aggregate of size 20 mm was used.
4. Recycled Concrete Aggregate (RCA): Obtained from demolished concrete, crushed and sieved. It has slightly higher water absorption compared to natural aggregate.
5. Eggshell Powder (ESP): Prepared by washing, drying, and grinding eggshells. CaCO_3 (~95%).
6. Glass Powder (GP): Waste glass crushed into fine powder to achieve pozzolanic behavior.
7. Water: Clean potable water was used for mixing and curing.

v. METHODOLOGY

1. Demolished concrete was crushed and sieved.
2. Eggshells were washed, dried, powdered and sieved.
3. Waste glass was crushed into fine powder.
4. Materials were mixed in suitable proportions.
5. Three concrete cubes of size 150 mm were cast.
6. Cubes were demolded after 24 hours.
7. Cubes were water cured.
8. Cubes were tested in Compression Testing Machine.

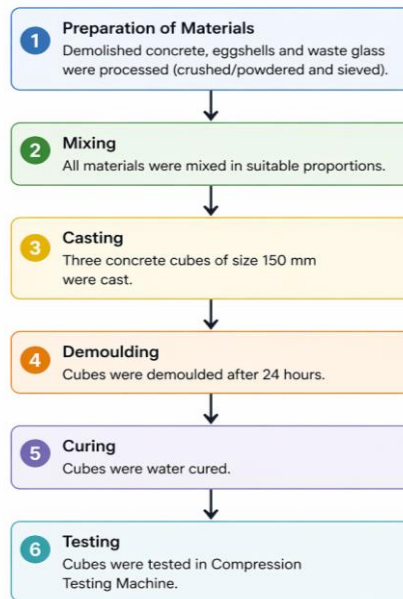


FIG1- FLOWCHART OF CONCRETE CUBE PREPARATION AND TESTING PROCEDURE

V. MIX DESIGN

Concrete mix was prepared using a nominal mix proportion suitable for M30 grade concrete. Partial replacement of conventional materials was carried out as follows:

- Replacement of coarse aggregate with RCA: 30%
- Replacement of cement with Eggshell Powder: 10%
- Replacement of fine aggregate with Glass Powder: 15%
- Water-cement ratio: 0.45

All materials were mixed thoroughly to achieve uniform consistency before casting the cubes.

VI. OBSERVATIONS AND TEST RESULTS

Cube Size = 150 mm × 150 mm × 150 mm

Loaded Area = 22500 mm²

TABLE I. CUBE TEST RESULTS

CUBE NO.	WEIGHT (kg)	FAILURE LOAD (KN)	COMPRESSIVE STRENGTH (MPa)
C1	7.13	943.8	41.95
C2	8.58	670.0	29.78
C3	8.60	812.0	36.09

Average Compressive Strength = 35.94 MPa

Formula Used:

Compressive Strength = Load / Area

(Load in Newton, Area in mm²).

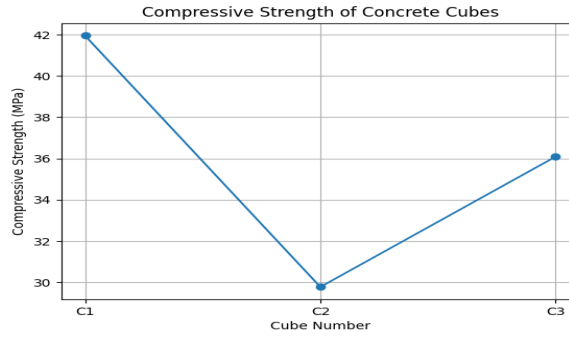


FIG2: COMPRESSIVE STRENGTH OF CONCRETE CUBES

TABLE II. COMPARISON WITH NORMAL CONCRETE

PROPERTY	NORMAL CONCRETE	MODIFIED CONCRETE
AVG STRENGTH	30 MPA	35.94 MPA
SUSTAINABILITY	LOW	HIGH
WASTE UTILIZATION	NIO	YES

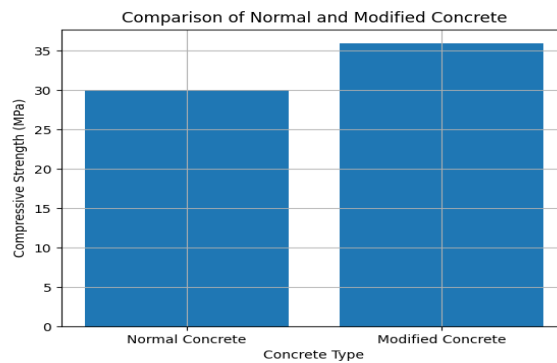


FIG 3- COMPARISON OF NORMAL AND MODIFIED CONCRETE

TABLE III. COST SAVING

MATERIAL	CONVENTIONAL COST	MODIFIED COST
AGGREGATE	HIGH	LOWER
WASTE DISPOSAL	REQUIRED	REDUCED

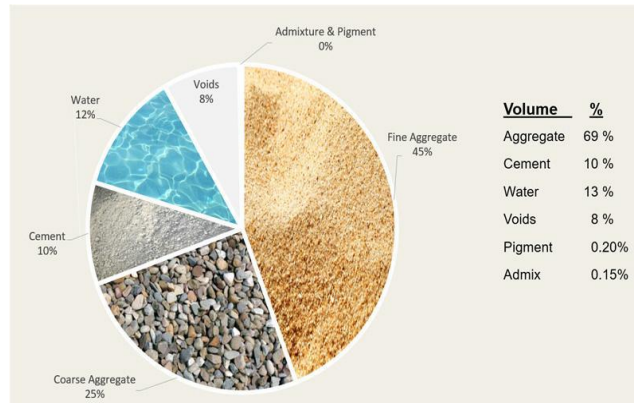


FIG4- VOLUMETRIC COMPOSITION OF CONCRETE MIX CONSTITUENTS



FIG5- COMPRESSION TESTING OF CUBE



FIG6- FAILURE OF CUBE UNDER LOAD

VII. DISCUSSION

The experimental results indicate that the incorporation of waste materials has a noticeable effect on the compressive strength of concrete.

Cube C1 exhibited the highest strength of 41.95 MPa, which may be attributed to proper compaction and uniform distribution of materials. Cube C2 showed comparatively lower strength, possibly due to the presence of voids, improper mixing, or uneven curing conditions. Cube C3 demonstrated moderate strength, indicating consistent performance.

The addition of eggshell powder improved the filler effect and reduced voids in concrete. Glass powder contributed to better particle packing and secondary hydration reactions due to its pozzolanic nature. Recycled concrete aggregate helped in reducing the use of natural aggregates, although slight variations in strength were observed.

Overall, the results confirm that the modified concrete mix provides satisfactory strength and can be used for sustainable construction applications.

VIII. ADVANTAGES OF THIS MIX

1. Reduces construction waste.
2. Reduces landfill disposal.
3. Saves natural aggregate.
4. Eco-friendly material.
5. Cost effective.
6. Promotes sustainable development.
7. Suitable for non-structural and selected structural work.

IX. LIMITATIONS

1. Only three concrete cubes were tested, which is a limited sample size.
2. Durability tests such as water absorption and permeability were not conducted.
3. Long-term strength behavior was not analyzed.
4. Variations in waste material properties may affect results.

X. CONCLUSION

The experimental investigation demonstrates that demolished concrete aggregate, eggshell powder, and glass powder can be effectively incorporated as partial replacement materials in concrete production without significantly compromising performance. The average compressive strength achieved was 35.94 MPa, indicating that the developed mix satisfies the strength requirements for a wide range of structural and non-structural building applications. The results confirm that the inclusion of these waste-derived materials contributes to adequate mechanical properties while maintaining overall material stability

In addition to structural performance, the proposed approach offers notable environmental benefits by promoting the recycling of construction and industrial waste, thereby reducing landfill disposal and minimizing environmental pollution. Furthermore, the partial replacement of conventional raw materials such as natural aggregates and cement helps conserve non-renewable resources and reduces the carbon footprint associated with concrete production. Therefore, the utilization of demolished concrete aggregate, eggshell powder, and glass powder presents a viable and sustainable alternative in modern construction practices. The findings highlight their potential for future application in eco-friendly construction, encouraging further research and large-scale implementation in sustainable infrastructure development.

XI. FUTURE SCOPE

1. Split Tensile Strength Investigation

Further research can be carried out to evaluate the split tensile strength of concrete containing eggshell powder and waste glass. This test will help in understanding the tensile resistance behavior of the modified concrete, which is critical for structural applications such as beams, pavements, and slabs where tensile stresses play a significant role.

2. Flexural Strength Performance Study

The flexural strength of concrete incorporating alternative materials can be studied in detail to assess its behavior under bending stresses. This will provide insight into the cracking resistance and load-bearing capacity of structural elements made with sustainable concrete mixes.

3. Water Absorption and Permeability Analysis

A detailed study on water absorption, sorptivity, and permeability characteristics can be conducted to evaluate the porosity and durability of the concrete. This will help determine the resistance of the modified concrete against moisture ingress, which directly affects long-term durability.

4. Durability and Long-Term Performance Evaluation

Extensive durability studies can be performed under various environmental conditions such as sulfate attack, chloride penetration, freeze-thaw cycles, and carbonation. These studies will help in assessing the long-term structural stability and service life of the developed concrete.

5. Optimization of Mix Design Parameters

Advanced optimization techniques such as response surface methodology or machine learning-based approaches can be used to determine the optimum replacement levels of eggshell powder and glass powder. This will ensure maximum strength, durability, and sustainability performance of the concrete mix.

6. Microstructural and Chemical Analysis

Future research can include microstructural studies using Scanning Electron Microscopy (SEM), X-Ray Diffraction (XRD), and Energy Dispersive X-ray (EDX) analysis to understand the bonding mechanism, pozzolanic activity, and interaction between cement hydration products and waste materials.

7. Large-Scale Field Applications

The feasibility of using this sustainable concrete in real-life construction projects such as pavements, residential buildings, precast elements, and non-structural components can be explored. Field performance studies will help validate laboratory results under practical conditions.

8. Cost and Environmental Impact Assessment

A comprehensive life cycle assessment (LCA) and cost analysis can be conducted to evaluate the economic feasibility and environmental benefits of using eggshell and glass waste in concrete production..

XII. REFERENCES

- [1] Bureau of Indian Standards (BIS): IS 516 – *Methods of Tests for Strength of Concrete*. This standard outlines procedures for determining compressive, flexural, and tensile strength of concrete specimens, forming the basis for mechanical performance evaluation.
- [2] Bureau of Indian Standards (BIS): IS 10262 – *Concrete Mix Proportioning Guidelines*. This provides the methodology for designing concrete mixes based on required strength, workability, and durability requirements.
- [3] Mehta, P. K., & Monteiro, P. J. M. – *Concrete: Microstructure, Properties, and Materials*. A widely referenced textbook covering the fundamental behavior of concrete materials and their microstructural properties.
- [4] Research Articles on Recycled Aggregate Concrete – Various studies focusing on the use of construction and demolition waste as partial replacement of natural aggregates and its effect on strength and durability.
- [5] Studies on Eggshell Powder in Concrete – Research papers investigating the use of calcium-rich eggshell waste as a partial replacement of cement, highlighting its potential pozzolanic and filler effects.
- [6] Studies on Waste Glass Powder in Concrete – Publications analyzing the use of finely ground glass powder as a supplementary cementitious material, focusing on its pozzolanic reaction and durability improvement.
- [7] Neville, A. M. – *Properties of Concrete*. This reference provides detailed insights into mechanical properties, durability aspects, and behavior of concrete under different conditions.