

Sustainable & Eco-Friendly Alternative to Concrete

Om Mahale¹, Pavan Dandge², Nilesh Ghate³, Tejas Jadhav⁴, Rohit Medhe⁵, Dr. A. A. Malokar⁶

^{1,2,3,4,5} Student, Department of Civil Engineering, Padm. Dr. V. B. Kolte College of Engineering, Malkapur

⁶ Assistant Professor, Department of Civil Engineering, Padm. Dr. V. B. Kolte College of Engineering, Malkapur

DOI: 10.5281/zenodo.19251127

ABSTRACT

Green concrete is an eco-friendly alternative to conventional concrete that focuses on reducing environmental impact throughout its lifecycle. Introduced in Denmark in 1998, it utilizes waste materials such as fly ash and silica fume as partial replacements for cement, thereby lowering energy consumption, cost, and CO₂ emissions. Since concrete production contributes significantly to global CO₂ emissions, green concrete offers a sustainable solution by minimizing resource depletion and reducing landfill waste. It maintains similar properties to conventional concrete while improving durability and environmental performance. Overall, green concrete plays an important role in sustainable development and is widely used in modern green building practices.

Keywords:- Green concrete, recycled materials, sustainability, CO₂ reduction

1. INTRODUCTION

Environmental impact of construction activities. Green concrete focuses on minimizing energy consumption, CO₂ emissions, and the use of natural resources throughout the lifecycle of concrete, including its production, construction, and maintenance.

The use of waste materials in green concrete not only helps in effective waste management but also reduces the burden on landfills. Materials like fly ash and ground glass exhibit pozzolanic properties, which improve the strength and durability of concrete by forming additional calcium silicate hydrate (C–S–H) gel. Green concrete offers several advantages such as improved durability, better thermal and fire resistance, enhanced workability, and reduced shrinkage. It also lowers the dead load of structures, making construction more efficient and economical.

In addition to environmental benefits, green concrete contributes to sustainable development by reducing maintenance requirements and extending the service life of structures. It also helps in reducing overall construction costs by utilizing low-cost waste materials. With growing concerns about climate change and resource depletion, green concrete has gained significant importance worldwide. In India, it has strong potential due to the availability of industrial waste and the increasing need for sustainable infrastructure development.

2. PROJECT OVERVIEW

This project focuses on the study and comparison of nominal concrete with concrete in which cement is partially replaced by waste glass and a combination of glass and fly ash. The objective is to evaluate the compressive strength and performance of modified concrete to promote sustainable construction practices. Waste glass, which is generated in large quantities and disposed of in landfills, is used as a cementitious material due to its high silica content. When finely ground, glass exhibits pozzolanic properties and reacts with cement hydrates to form additional calcium silicate hydrate (C–S–H), thereby improving strength and durability. Experimental studies were conducted by replacing cement with 0–25% ground glass while maintaining a constant water-to-binder ratio. Results showed a slight increase in mortar flow and improved compressive strength, especially with the use of superplasticizers. An optimum replacement of about 20% glass was found to be effective in terms of both strength and environmental benefits.

Fly ash, a byproduct of coal combustion, is also used as a cementitious material due to its pozzolanic nature. It improves workability, reduces water demand, enhances strength, and lowers heat of hydration. Fly ash is widely used in construction applications such as pavements, embankments, and structural concrete. Although it has some drawbacks like slower strength gain and sensitivity to environmental conditions, its benefits such as reduced CO₂ emissions, improved durability, and cost-effectiveness make it a valuable material in concrete production. Different types of fly ash, namely Class F and Class C, are used depending on their chemical composition and performance requirements.

The use of glass and fly ash in concrete helps in reducing environmental pollution, minimizing waste disposal

issues, and conserving natural resources. Glass is non-biodegradable and readily available, while fly ash reduces carbon emissions and enhances concrete properties. Overall, this project demonstrates that partial replacement of cement with waste materials not only improves concrete performance but also contributes to sustainable and eco-friendly construction practices.

3. PROJECT ANALYSIS AND METHODOLOGY

The project involves the analysis of M25 grade concrete by comparing nominal concrete with concrete in which cement is partially replaced by waste glass and a combination of glass and fly ash. Concrete cubes of size 150 mm × 150 mm × 150 mm were prepared with different replacement levels of 15%, 30%, and 45%. A total of four cubes were cast for each mix proportion, including nominal concrete (1:1:2 ratio), glass-replaced concrete, and glass with fly ash (1:1 ratio) replaced concrete. The required quantities of cement, fine aggregate, and coarse aggregate were calculated based on volume and unit weight, and corresponding adjustments were made for replacement materials. The results were tabulated to compare the compressive strength and material proportions for different mixes.

The methodology included selecting suitable materials such as OPC cement, fine and coarse aggregates, fly ash, and waste glass. The glass was collected, crushed into fine particles, and sieved to obtain the required size. The materials were then mixed in proper proportions, followed by placing the concrete into moulds in layers, compacting using a tamping bar, and finishing the surface. After casting, the specimens were left undisturbed, labeled, and then cured in water to ensure proper strength development. Curing was carried out under controlled moisture and temperature conditions to promote hydration and durability.

The study also explains the chemical behavior of cement and the role of pozzolanic materials like glass and fly ash. During hydration, cement compounds react with water to form calcium silicate hydrate (C–S–H) gel and calcium hydroxide, which contribute to strength development. Fly ash and finely ground glass react with calcium hydroxide to produce additional C–S–H gel, improving strength, durability, and workability of concrete. Overall, the process demonstrates that partial replacement of cement with waste materials can enhance concrete properties while reducing environmental impact and promoting sustainable construction practices.

Fly Ash in Cement Concrete

During the hydration process of cement, the principal compounds such as tricalcium silicate (C_3S), dicalcium silicate (C_2S), tricalcium aluminate (C_3A), and tetracalcium aluminoferrite (C_4AF) react with water to form calcium silicate hydrate (C–S–H) gel and calcium hydroxide (lime). While C–S–H gel contributes to strength and binding, the excess lime released during hydration remains in the pores and adversely affects the durability of concrete by increasing porosity, promoting micro-cracks, and weakening the bond between aggregates and cement paste. When fly ash is incorporated into the concrete mix, it reacts with this surplus lime through a pozzolanic reaction, forming additional C–S–H gel. This secondary reaction enhances the strength, density, and durability of concrete and continues as long as lime is available within the system.

4. ACCEPTANCE CRITERIA FOR CONCRETE

The acceptance criteria for concrete are based on the provisions of IS 456:2000. For concrete of grade M15 and above, the average strength of four non-overlapping consecutive test results should not be less than the characteristic strength plus either 0.825 times the standard deviation or 3 N/mm², whichever is greater. Additionally, the individual test result of any sample should not be less than the characteristic strength minus 3 N/mm². Each test result is considered as the average strength of three specimens, and the variation among individual specimens should remain within permissible limits. If the variation exceeds the allowable range, the test result is considered invalid.

5. COMPRESSIVE STRENGTH RESULTS

The compressive strength of concrete was evaluated for different replacement levels of cement using glass and a combination of glass and fly ash. For 15% glass replacement, the concrete showed a significant increase in strength, with average compressive strength reaching approximately 35.15 N/mm². When the replacement level was increased to 30%, the average strength was about 29.82 N/mm², which still satisfied the required criteria. However, at 45% replacement, the strength reduced to approximately 25.67 N/mm², indicating a decline in performance.

In the case of combined replacement using glass and fly ash, the results were comparatively better. At 15% replacement, the average compressive strength increased to about 37.94 N/mm², which is higher than both nominal and glass-only concrete. At 30% replacement, the strength was around 30.13 N/mm², which remained acceptable. At 45% replacement, the strength dropped to approximately 25.82 N/mm², showing that excessive replacement negatively affects the performance of concrete.

6. RESULTS AND DISCUSSION

The experimental results indicate that partial replacement of cement with glass and fly ash improves the compressive strength of concrete up to an optimum level. The increase in strength at lower replacement levels can be attributed to the pozzolanic reaction and improved particle packing, which enhances the microstructure of concrete. The combination of glass and fly ash shows better performance compared to glass alone due to the synergistic effect of both materials in consuming excess lime and forming additional binding compounds. However, at higher replacement levels such as 45%, the reduction in cement content becomes significant, leading to a decrease in strength and overall performance. The results also confirm that the optimum replacement level lies between 15% and 30% for achieving both strength and sustainability.

7. MERITS AND DEMERITS

The use of fly ash in concrete offers several advantages, including improved workability, reduced heat of hydration, enhanced durability, and lower permeability. It also contributes to environmental sustainability by reducing carbon emissions and utilizing industrial waste. However, it has certain limitations such as slower strength gain and variability in quality depending on its source. Similarly, the use of glass as a replacement material is beneficial as it utilizes non-biodegradable waste and contributes to sustainable construction. Finely ground glass exhibits good pozzolanic properties and improves strength. On the other hand, the processing of glass into fine powder requires additional effort, machinery, and safety precautions, and very fine particles may adversely affect concrete performance.

8. COST ANALYSIS

The cost analysis indicates that the use of waste glass and fly ash reduces the overall cost of concrete. The cost of cement per cube is higher compared to mixes where partial replacement is used. With 15% and 30% replacement of cement by glass, a noticeable reduction in cost is observed. The combination of glass and fly ash provides even greater cost savings due to the lower cost of fly ash compared to cement and glass. Thus, the use of these materials not only improves environmental performance but also enhances economic efficiency.

9. CONCLUSION

Based on the experimental study, it can be concluded that cement can be safely replaced by glass and by a combination of glass and fly ash up to 30% without compromising the strength of concrete. The results show that 15% replacement yields the highest strength improvement, while 30% replacement provides a balance between strength and sustainability. The combined use of glass and fly ash performs better than glass alone due to enhanced pozzolanic activity. Replacement levels beyond 45% are not recommended as they lead to a reduction in strength. Overall, the use of waste materials in concrete reduces CO₂ emissions, lowers cost, and promotes sustainable construction practices.

10. REFERENCES

- [1] G. M. Sadiqul Islam, "Waste glass powder as partial replacement of cement for sustainable concrete practice," 2016.
- [2] P. R. Wankhede, "Effect of fly ash on properties of concrete," 2014.
- [3] G. Vijaykumar, H. Vishaliny, and D. Govindarajulu, "Studies on glass powder as partial replacement of cement in concrete production," 2013.
- [4] N. Jain, M. Garg, and A. K. Minocha, "Green concrete from sustainable recycled coarse aggregates: Mechanical and durability properties," 2015.
- [5] V. A. Fulari, "Effect of fly ash," 2014.
- [6] H. Du and K. H. Tan, "Waste glass powder as cement replacement in concrete," 2014.
- [7] A. Mohajerani and J. Vajna, "Practical recycling applications of crushed waste glass in construction materials," 2017.
- [8] N. A. Soliman and A. Tagnit-Hamou, "Development of ultra-high performance concrete using glass powder," 2016.
- [9] Z. Chen and C. S. Poon, "Comparing the use of sewage sludge ash and glass powder in cement mortars," 2016.
- [10] "Concrete with recycled glass as fine aggregates," ACI Materials Journal, 2014.
- [11] F. A. Khan, M. Fahad, K. Shahazada, H. Alam, and N. Ali, "Utilization of waste glass powder as a partial replacement of cement in concrete," 2015.