STRENGTH AND DURABILITY OF CONCRETE INCORPORATING INDUSTRIAL WASTES LIKE FLY ASH, SLAG AND QUARRY DUST

R.ABINAYA R1, Department of Civil Engineering,

S.GAYATHRI N2, Department of Civil Engineering,

DR. SATHEES KUMAR P3, Department of Civil Engineering, **A.MOHAMED UWAISUL** 4, Pg Scholar, Department of Civil Engineering, Mohamed Sathak Engineering College, Tamil Nadu, India.

Abstract: This study focuses on the utilization of industrial waste materials such as fly ash, slag, and quarry dust in concrete production. The aim is to improve strength and durability while reducing environmental impact. Experimental investigations were conducted by replacing cement with fly ash and slag, and fine aggregate with quarry dust. The results show improved compressive strength, reduced permeability, and enhanced durability. The study proves that sustainable concrete can be produced effectively using industrial waste materials.

Keywords: Fly Ash, Slag, Quarry Dust, Concrete, Sustainability, Strength

INRODUCTION

Concrete has been an indispensable material in construction since ancient times, evolving significantly to meet the demands of moderninfrastructure. It is primarily a mixture of cement, coarse aggregates, fine aggregates, and water. The properties of concrete can be adjusted by modifying its components to cater to specific applications and environmental conditions. Despite its versatility, traditional concrete production is associated with significant challenges, including the depletion of natural resources, high energy consumption, and considerable carbon dioxide emissions during cement manufacturing. These emissions contribute to global warming and environmental degradation, urging researchers to develop sustainable solutions. One promising approach to mitigating these issues is incorporating industrial by-products and waste materials into concrete. By replacing conventional components with materials like fly ash, slag, and quarry dust, it is possible to enhance the performance characteristics of concrete while reducing its environmental footprint. Fly ash, a by product of coal combustion, is widely recognized for its pozzolanic properties, which contribute to improved strength, reduced permeability, and enhanced durability of concrete. Similarly, slag, a byproduct of steel production, has been successfully used to replace cement partially, leading to reduced heat of hydration and enhanced resistance to chemical attacks. Quarry dust, generated from stone crushing processes, offers an eco-friendly alternative to natural sand and helps to address the scarcity of fine aggregates.

NEED FOR THE STUDY

- Increasing environmental pollution due to cement production.
- Depletion of natural sand resources.
- Need for sustainable and eco-friendly construction materials.
- Effective utilization of industrial waste.

OBJECTIVES

- To study strength and durability of concrete using waste materials.
- To reduce cement usage by partial replacement.

- To improve mechanical properties of concrete.
- To promote sustainable construction practices.

EXPERIMENTAL PROGRAM

The study includes preparation of concrete mixes with varying percentages of fly ash, slag, and quarry dust. Tests conducted include compressive strength, tensile strength, and durability tests.

MATERIALS

CEMENT :

- Cement is mixed with water to form a paste that binds aggregates like sand or crushed rocks.

- Calcium, silicon, iron and aluminium compounds are closely ground to form a fine powdered product - cement.

- The usage of cement in various forms has been advent through the years. In the ancient times, crushed pottery, volcanic ashes, and other items were used as cement.

- In 1824, Joseph Aspdin created the precursor to modern day cement.

FINE AGGREGATES

Fine aggregates are essentially any natural sand particles won from the land through the mining process. Fine aggregates consist of natural sand or any crushed stone particles that are Fine aggregates consist of any crushed stone particles that are " smaller.

COARSE AGGREGATE

Coarse aggregate is a type of construction material that is typically larger than fine aggregate, or sand. Coarse aggregate is used in a variety of concrete

Fly ash

Fly ash reacts with calcium hydroxide in the presence of water, forming calcium silicate hydrate (C-S-H), which contributes to concrete strength. Its fine particle size enhances the packing density, reducing voids in the concrete matrix and improving durability. Concrete containing fly ash exhibits lower heat of hydration, reducing the risk of thermal cracking in large structures. Utilizing fly ash as a replacement for cement reduces the carbon footprint of concrete production by diverting waste from landfills and lowering CO_2 emissions.

SLAG

Slag, a by-product generated during the production of steel and other metals, has emerged as a sustainable and versatile material in concrete technology. It is predominantly composed of silica (SiO_2), alumina (Al_2O_3), lime (CaO), and magnesia (MgO), which contribute to its cementitious and pozzolanic properties. Ground Granulated Blast Furnace Slag (GGBFS), derived from the cooling and grinding of molten slag, is commonly used as a partial replacement for Portland cement in concrete production. The incorporation of slag in concrete not only enhances its mechanical and durability characteristics but also addresses environmental concerns by reducing greenhouse gas emissions and conserving natural resources. As an industrial by-product, slag aligns with the principles of sustainable development by promoting waste utilization and minimizing the environmental footprint of construction materials.

Quarry Dust

- Quarry dust consists of angular particles with rough surfaces, improving the interlocking and bond strength of concrete.

- Composed mainly of silica (SiO_2), with traces of alumina (Al_2O_3), iron oxides (Fe_2O_3), and lime (CaO).

- Slightly higher than natural sand, providing better packing density in concrete.

- Finer than natural sand, which improves the cohesiveness and reduces segregation in fresh concrete.

- Higher water absorption capacity due to its porous structure,

METHODOLOGY

In this chapter, the steps involved in the project are explained in order. The main research objective was to develop light weight concrete using pumice stones. The samples. of Cement grades are 33, 44, 55 depending upon the strength properties of cement and curing.

RESULT AND DISCUSSION

Compressive strength is a key mechanical property that reflects the load bearing capacity of concrete. It is essential for determining the structural suitability of a concrete mix. In this experimental study, the compressive strength test was conducted to evaluate the influence of incorporating Quarry Rock Dust (QRD), Fly Ash, and Slag into conventional concrete at different replacement levels.
Standard cube specimens measuring 150 mm × 150 mm × 150 mm were cast and cured for both 7 days and 28 days. Three sets of samples were tested: control concrete (no replacement), 10% replacement of cementitious and fine aggregate content with QRD, fly ash, and slag, and 30% replacement. The test was conducted as per IS 516:1959 standards using a compression testing machine.
The purpose of this test was to examine the variation in strength with increased substitution levels and to understand how these materials contribute to or diminish the mechanical integrity of the concrete over time.

The concrete with 10% replacement demonstrated a slight improvement in compressive strength over the control concrete at both curing ages. This is attributed to the filler effect of QRD and the pozzolanic reaction from fly ash and slag, which refine the pore structure and enhance strength.
At 30% replacement, a more significant increase in strength was observed, especially at 28 days. The compressive strength rose to 49.5 MPa, indicating that the supplementary materials continued to hydrate and contribute to strength gain over time. This improvement suggests that an optimized combination of QRD, fly ash, and slag can enhance strength while promoting sustainability.

The compressive strength results confirm that partial replacement using industrial by-products not only maintains but can even enhance the structural capacity of concrete. This aligns with sustainable construction goals by reducing reliance on traditional materials while achieving high performance.

CONCLUSION

- The study demonstrates that QRD acts as an efficient fine aggregate replacement by enhancing microstructure and reducing porosity.

- Fly ash and slag, with their pozzolanic properties, improve bonding and durability while reducing the heat of hydration.

- By utilizing QRD, fly ash, and slag, the study supports eco-friendly construction practices, significantly reducing the carbon footprint associated with cement production.

- The use of these materials also leads to a cost-effective mix, making it suitable for large-scale construction with reduced dependence on natural resources

- This mix design can be readily implemented in real-world projects, especially where sustainability and strength are both required.

- It paves the way for greener infrastructure in civil engineering without sacrificing performance.

- The work aligns with global sustainability initiatives, contributing to Goal 9 (Industry, Innovation and Infrastructure) and Goal 12 (Responsible Consumption and Production) of the UN Sustainable Development Goals (SDGs).

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