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Experimental Investigation of the Strength and Durability of Partially Replacing Cement with GGBS and Alccofine

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ABSTRACT:

Numerous research projects worldwide are focused on achieving high-strength concrete and improving its longevity to extend the material's life. In this study, cement is replaced with an ultrafine material called Alccofine at varying percentages alongside GGBS at a constant grade of M60. A consistent water content of 0.3 is maintained in the concrete mix proportions. Cryso Premia K570, a superplasticizer at 0.3 percent, is employed to enhance workability. Concrete samples are cast and cured for seven and twenty-eight days, respectively, under standard conditions. Mechanical tests such as compressive strength, flexural strength, split tensile strength, and durability tests including water permeability and the RCPT are conducted on the concrete specimens. Optimum strength is achieved at 15 percent Alccofine and 30 percent GGBS, based on mechanical properties. The investigation determines the suitable replacement percentage of cement with Alccofine and GGBS. The chloride permeability of all mixes is found to be very low, according to ASTM standards. This research aims to explore the physical characteristics and durability of M60 grade concrete with partial cement replacement using GGBS and Alccofine, and to identify the most suitable Alccofine material for concrete mixing.

Keywords: Alccofine, GGBS, Strength, Cement Replacement, Strength Tests.

I. INTRODUCTION

Concrete stands as the most commonly used human-made construction material globally, with its production and use carrying significant environmental and social implications. Cement production, closely tied to concrete demand, contributes to a substantial portion of greenhouse gas emissions, predominantly CO2, released during clinker pyro-processing from limestone. To mitigate this impact, supplementary cementitious materials like GGBS, Fly ash, Silica fume, Rice husk ash, Metakaolin, and Alccofine are being explored as cement alternatives. Numerous experiments aim to enhance high-performance concrete efficiency, known as HPC, characterized by high cement/binder content and low w/c ratio. However, HPC's workability and retention are often insufficient, necessitating the use of high-range water-reducing agents like superplasticizers. In this study, Cryso Premia K570, a superplasticizer, is utilized. Alccofine 1203, a low calcium silicate product manufactured in India, exhibits distinct properties enhancing concrete efficiency at both fresh and hardened levels. Its regulated granulation and high reactivity improve concrete properties, leading to high-performance environmental concrete with enhanced early strength and durability. Alccofine 1203 surpasses other supplementary materials due to its specific chemical structure and ultrafine particle size, finding applications in high-rise buildings, marine structures, precast elements, and bridges. Concrete durability, crucial for its ability to withstand weathering and deterioration, is evaluated through various tests including water permeability, acid and sulfate resistance, sorptivity, and RCPT. In this study, RCPT is used to assess water permeability and chloride penetration resistance, essential for determining concrete durability.

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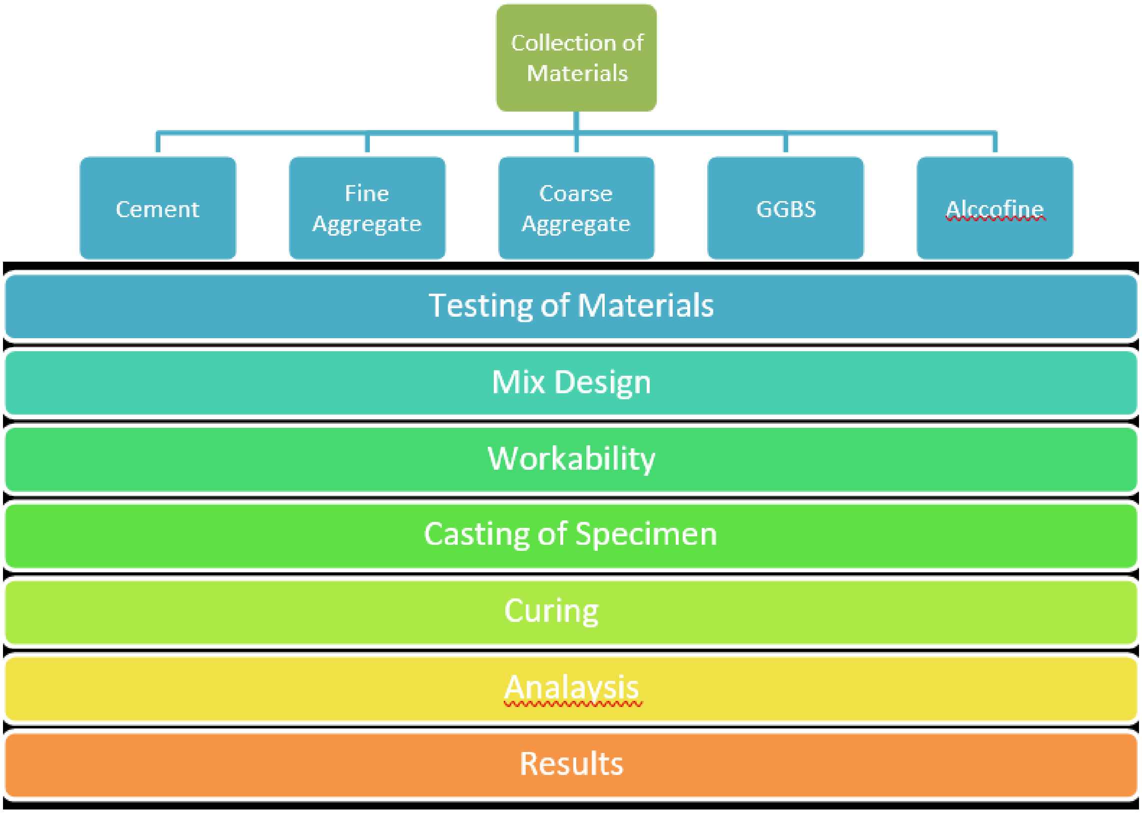
II. LITERATURE REVIEW

Siddharth et al. (2014): This research paper discusses the efficiency of concrete concerning compressive strength. With increasing demands in the construction industry, there is a growing market for high-performance concrete. Efforts to enhance concrete performance have focused on utilizing cement substitute products and mineral and chemical admixtures to improve strength and durability. Pozzolanic materials such as Alccofine (GGBS) and fly ash have been identified as effective in producing highly durable concrete composites. Concrete specimens in the study were cured using standard moist curing methods at room temperature.

Saravanan et al. (2019): This research paper explores the toughness of concrete with the addition of Alccofine and GGBS. Portland cement is a vital component of concrete, but large-scale cement production consumes significant energy and generates undesirable by-products (CO2), contributing to environmental degradation and resource depletion. To address these concerns, researchers are investigating industrial by-products as supplementary cementitious materials in concrete production. Materials such as silica fume (SF), ground granulated blast furnace slag (GGBS), rice husk ash, fly ash (FL), metakaolin, Alccofine (AL), micro-fine content, and others are being studied to partially or wholly replace cement in concrete, aiming to maintain strength while reducing greenhouse gas emissions and promoting sustainable waste management practices.

1. METHODOLOGY



Fine Aggregate: Fine aggregate refers to sand or crushed stone with a diameter of less than 9.55mm, commonly used in construction. Fine aggregates are those that have passed through a 4.75mm sieve

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and are used to fill voids in coarse aggregate and improve workability. The fine aggregates used in the project work adhere to the specifications of IS 383:1970 and are categorized as zone II. Sand sourced from the Godavari River is utilized in the construction process.

Coarse Aggregate: Coarse aggregate consists of rock quarried from field deposits, such as river gravel, crushed stone from quarries, and recycled concrete. The typical diameter range for coarse aggregates is 9.5mm to 37.5mm. In this project, aggregates with sizes of 20mm and 12.5mm are used. The properties of coarse aggregate adhere to the standards set by IS 2386-1986.

Water: Potable water, with a pH of 7 or less, is used for both mixing and curing processes. The concrete mixture contains fresh tap water conforming to IS:10500-2012 specifications.

Ground Granulated Blast Furnace Slag (GGBS): GGBS is a by-product of the blast furnace process used in iron or steel production. It is formed when molten slag, composed mainly of silicates and alumina from iron ore, is rapidly quenched and granulated into particles smaller than 5mm. The granulated slag is then dried and ground into a fine powder (GGBS) using vertical roller mills or rotating ball mills.

Alccofine: Alccofine is an ultra-fine material with specific properties that enhance concrete performance in both fresh and hardened states. Unlike other hydraulic materials like cement and fly ash, Alccofine has a smoother texture and is available in different particle sizes, such as fine, micro-fine, and ultrafine. Alccofine 1203, for example, improves the packing density of the paste portion, leading to reduced water and admixture usage and increased concrete strength and durability. Additionally, Alccofine 1203 supports both pozzolanic and hydraulic hydration reactions, resulting in a denser pore structure and significant strength gain.

IV. OBJECTIVES & USES

The primary objectives and uses of this research are outlined as follows:

1. To achieve high early strength in concrete.
2. To assess the compressive strength, tensile strength, flexural strength, and toughness properties, including water permeability and RCPT (Rapid Chloride Permeability Test), of concrete produced with various mixtures of Alccofine and a constant proportion of GGBS as a partial substitute for cement.
3. To determine the optimal percentage of Alccofine for cement substitution.
4. To enhance and prolong the lifespan of concrete structures.
5. To reduce temperature rise by mitigating hydration heat.
6. To improve workability and ease of placement and compaction in GGBS concrete.
7. To decrease the risk of thermal cracking due to reduced temperature rise during early stages.
8. To provide excellent resistance to sulphates and chemicals.
9. To reduce permeability by eliminating voids in concrete.
10. To resist the alkali-silica reaction effectively.
11. To minimize chloride penetration, thereby protecting steel from corrosion.

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V. TESTS AND RESULTS

The compressive strength test is used to measure a material or structure's ability to withstand loads on its surface without cracking or deflection. Several factors, including water-cement ratio, concrete composition, compaction, curing methods, among others, influence the compressive strength of concrete. Concrete cubes are cast and water-cured, and after 24 hours, the molds are removed, allowing the test specimens to continue curing. The specimens are then subjected to compression testing using a compression measuring machine after 7 and 28 days of curing. The load at which the specimen fails is recorded, and the compressive strength is calculated as the load divided by the cross-sectional area of the specimen.

Fig. Compressive Strength machine

Tensile Test with Split Cylinder

One of the fundamental properties of concrete is its tensile strength, which significantly affects the occurrence and extent of cracking in structures. Due to its porous nature, concrete is highly vulnerable to tension and unable to withstand direct pressure. When tensile forces exceed the concrete's tensile strength, cracks develop. Therefore, determining the tensile strength of concrete is essential to understand the load at which cracking may occur. The tensile strength test is conducted using cylindrical specimens with a diameter of 150mm and a height of 300mm. The formula for calculating split tensile strength is given by $Ld2P$, where P represents the load in kilograms of force, D is the diameter of the cylinder, and L is the length of the cylinder.

Fig. Tensile Strength Machine

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Flexural Strength Test

The flexural strength test evaluates a concrete specimen's ability to resist bending forces. Steel rollers are placed on the testing machine's bed to support the specimen, and the load is evenly distributed between two loading rollers. The flexural strength, Fb, is calculated using the formula $2BD2PL$, where P is the full load in kilograms, B is the width of the specimen, D is the depth of the specimen, and L is the length of the specimen.

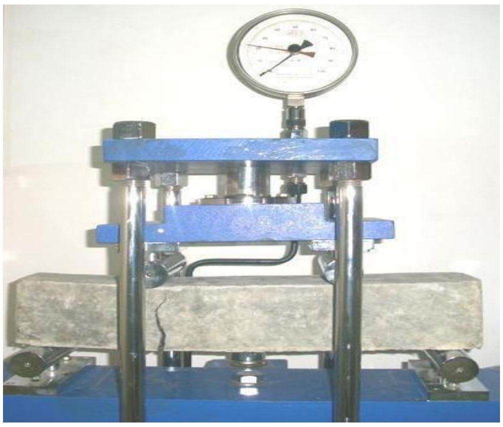

Fig. Flexural Strength machine

Rapid Chloride Permeability Test (RCPT)

The RCPT, based on ASTM C1202, assesses concrete's resistance to chloride-ion penetration by measuring its electrical conductivity. A cylindrical concrete sample is subjected to a 60V DC potential difference for 6 hours. The charge passed in coulombs is then measured. Prior to testing, the specimens are prepared by washing the surface and submerging them in distilled water. The specimens are placed in a testing mold, and chemicals are added, followed by attaching an electrode connected to a constant 23-volt DC power supply. The charge is recorded at half-hour intervals over 6 hours.

Fig. RCPT Machine

Water Permeability Test

The water permeability test evaluates the amount of water that penetrates concrete under pressure and its ability to resist water penetration. It is crucial for concrete used in water-retaining structures to be impermeable to prevent leakage. Permeability is influenced by factors such as water-cement ratio, water content, porosity, and compaction. The test determines the durability of concrete structures.

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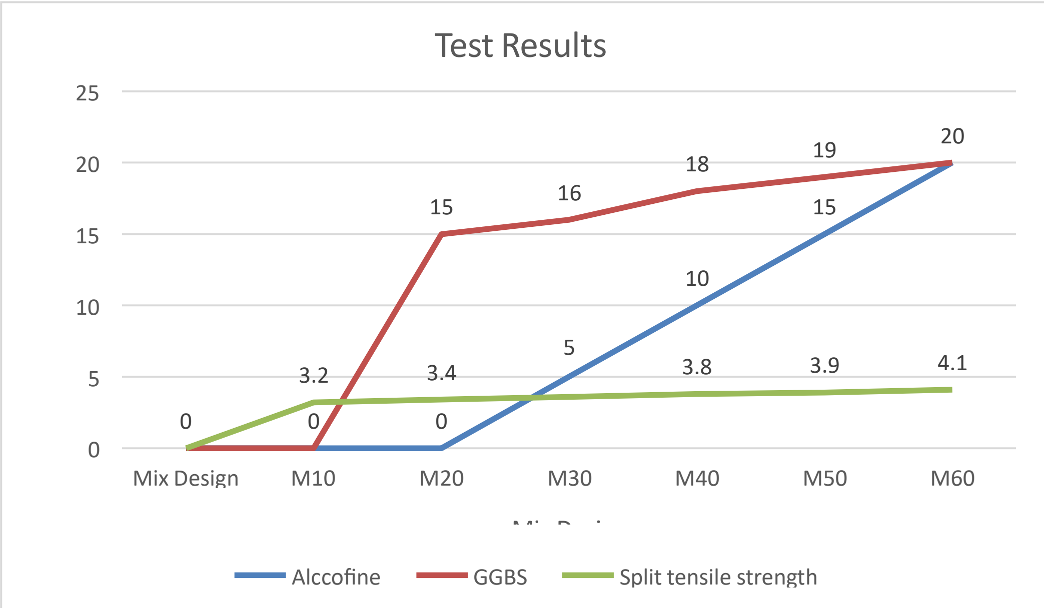

Conclusion:

- Alccofine proved to be an effective partial replacement for cement, leading to significant early strength gains.
- Concrete of M60 grade with 15% Alccofine and 30% GGBS exhibited higher compressive, split tensile, and flexural strength compared to all other mixtures.
- The inclusion of 30% GGBS and 15% Alccofine resulted in a 12% improvement in compressive strength over traditional concrete.
- The addition of 30% GGBS and 15% Alccofine increased split tensile strength by 19% compared to standard concrete.
- Flexural strength showed a 25% increase with the addition of 30% GGBS and 15% Alccofine compared to traditional concrete.
- All mixtures demonstrated very low chloride permeability according to ASTM C1202 standards.

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