RESEARCH ARTICLE OPEN ACCESS

Performance Evaluation of M30 Grade Concrete with Partial Replacement of Cement by Alccofine-1203 and Fine Aggregate by Foundry Sand

Rohit Sain*, Mohit Tiwari **

*(Department of Civil Engineering, Arya College of Engineering & Research Centre, Jaipur, Rajasthan, India, Email: rohitsain30197@gmail.com)

** (Department of Civil Engineering, Arya College of Engineering, Jaipur, Rajasthan, India)

ABSTRACT

The aim of this study is to understand how adding materials like Alccofine-1203, fly ash, and foundry sand affects the properties of concrete. In this experiment, cement is partially replaced with Alccofine-1203 at 0%, 5%, 10%, and 15%, and fine aggregate (sand) is partially replaced with foundry sand at 0%, 5%, 10%, and 15%. The concrete mix is designed for M30 grade. To evaluate the performance of the concrete, tests were carried out for Flexural Strength (FS), Compressive Strength (CS), and Split Tensile Strength (STS) after 7, 14, and 28 days of curing. The results show that using Alccofine-1203 and foundry sand improves compressive strength, durability, and reduces water absorption. The best results for compressive, tensile, and flexural strength were achieved by replacing 10% of the cement with Alccofine-1203 and 10% of the sand with foundry sand, using a fixed water-cement ratio of 0.45.The study concludes that high-performance concrete can be achieved by replacing up to 10% of fine aggregate with foundry sand and partially replacing cement with 10% Alccofine-1203.

Keywords — Alccofine 1203, Construction, Concrete, Flexural Strength (FS), Compressive Strength (CS), and Split Tensile Strength (STS).

I. INTRODUCTION

The construction industry is undergoing a paradigm shift, driven by the increasing global need for materials that are not only structurally efficient but also environmentally sustainable and economically viable. In the face of mounting challenges related to climate change, resource depletion, and environmental pollution, the sector is actively seeking alternatives to conventional construction materials.

One of the primary concerns is the widespread use of Ordinary Portland Cement (OPC). For decades, OPC has served as the cornerstone of concrete production globally, offering ease of availability, cost-effectiveness, and predictable performance characteristics. However, the environmental footprint associated with OPC production is alarming. Cement manufacturing accounts for nearly 7–8% of global CO_2 emissions, with an estimated one ton of CO_2 released per ton of cement produced. This emission is mainly due to the calcination process and the high energy demand involved in clinker production.

Moreover, concrete made with OPC often presents durability challenges, especially when exposed to aggressive environmental conditions such as chloride attack (marine structures), sulphate exposure (soil and groundwater interaction), acidic industrial environments, and freeze-thaw cycles prevalent in colder regions. These durability issues not only compromise structural integrity but also lead to increased maintenance costs and shorter service life of infrastructures.

To address these environmental and durability concerns, the industry has increasingly turned towards Supplementary Cementitious Materials (SCMs). SCMs act either as cement replacements or as cement extenders, enhancing concrete properties while reducing the clinker content in mixes. Common SCMs include fly ash, silica fume, and Ground Granulated Blast Furnace Slag (GGBS), each offering specific benefits in terms of strength, durability, and workability.

Among the newer and more advanced SCMs, Alccofine 1203 has gained special recognition. Manufactured by Ambuja Cements Ltd, Alccofine 1203 is a specially processed, ultra-fine granulated slag-based material, derived from high-quality blast furnace slag. Its unique production process involves controlled granulation followed by advanced grinding technology, resulting in a product with ultrafine particle size, high surface area, and excellent pozzolanic and latent hydraulic properties.

II. CHEMICAL AND PHYSICAL PROPERTIES OF ALCCOFINE 1203

(As per specifications supplied by manufacture "Ambuja Cement Ltd")

Table 1: Chemical Composition of Alccofine-1203

Chemical Composition	
Constituents	**Composition (%)**
SiO_2	35.30
CaO	32.20
Al_2O_3	21.40
MgO	6.20
Fe_2O_3	1.20
SO_3	0.13

(According to the manufacturer's specifications "Ambuja Cement Ltd")

Table 2: Physical Properties of Alccofine-1203

Physical Properties	
Physical Property	**Results**
Particle size distribution(micro meter)	150-600
D_{10}	1.8
D_{50}	4.4
D_{90}	8.9
Specific surface area	1200
Specific Gravity	2.70
Average particle size(microns)	4-6
Fineness(cm^2/gm)	12000
Bulk density(kg/m^3)	680 (600 to 700)

III. DESIGN SPECIFICATION

The primary objective of this study is to evaluate the strength and durability performance of concrete specimens incorporating Alccofine-1203 and foundry sand. The mix design for M30 grade concrete was prepared in accordance with the guidelines provided in IS 10262:2009. Both Alccofine-1203 and foundry sand were included in the mix proportions as per the specified standards. The entire mix design process was conducted under controlled laboratory conditions to ensure precision and reliability of the results. Key parameters and essential data relevant to the initial stage of the mix design are outlined below in mix design.

Mix Design

Table 3: Preliminary Data for Mix Design

W/C		0.45
Types of Cement		PPC
Maximum nominal size of aggregate		20mm
Type of aggregate		Crushed angular aggregate
Specific gravity of cement		3.09
Specific gravity	Fine aggregate	2.62
	Coarse aggregate	2.73
Sieve analysis	Fine aggregate	Conforming to grading Zone III Table 4 of IS 383
	Coarse aggregate	Conforming to Table 2 of IS 383
Specific gravity	Fly ash	2.19
Specific gravity	Alccofine-1203	2.70
Specific gravity	Foundry sand	2.1
Specific gravity	Marble dust	3.04

Data for Mix Proportioning

The following information is needed for designing the mix of a specific concrete grade:

- Grade designation
- Type of cement
- Maximum nominal size of aggregate
- Minimum cement content
- Maximum water-cement ratio
- Desired workability
- Exposure conditions (refer to Table 4 and Table 5 of IS 456:2000)
- Maximum temperature of concrete during placement
- Method of transporting and placing the concrete
- Early strength requirements, if applicable

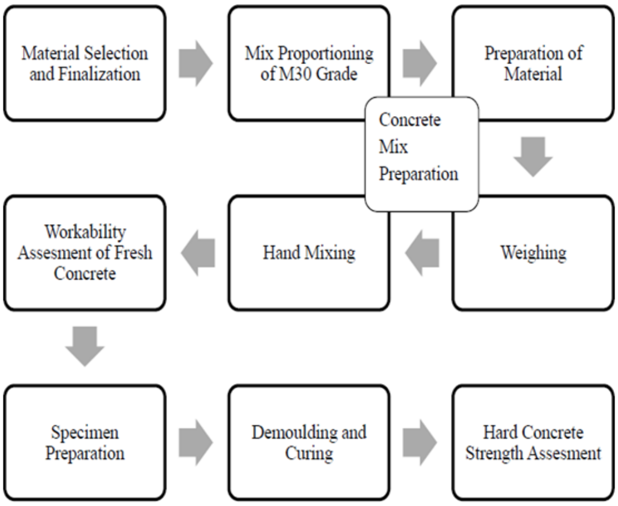

Figure 1: Experimental Methodology

IV. RESULTS AND DISCUSSION

Effect of Foundry Sand, Alccofine-1203 and Combined on Compressive Strength of Concrete (MPa): (IS: 516-1999)

The table below indicates that compressive strength increases with higher percentages of foundry sand, Alccofine-1203, and their combination. However, beyond the optimal level, the strength begins to decline due to adverse effects on the concrete's microstructure, as the C-S-H layer starts to deteriorate after the ideal dosage.

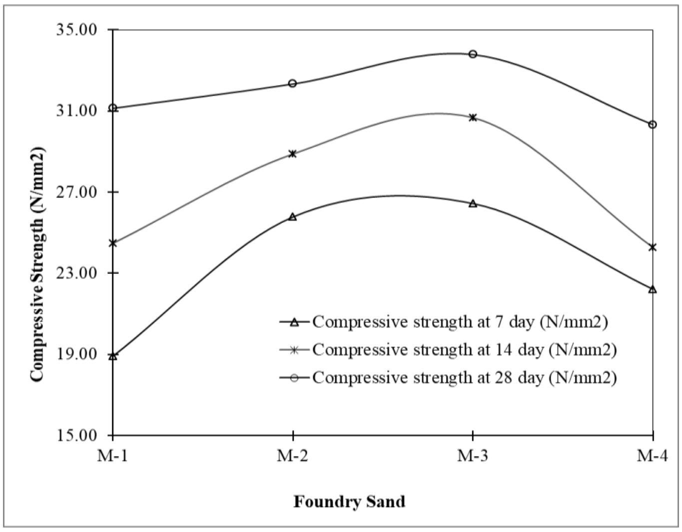

Figure 2: Effect of Foundry Sand as Fine Aggregate Replacement on Strength Over Time

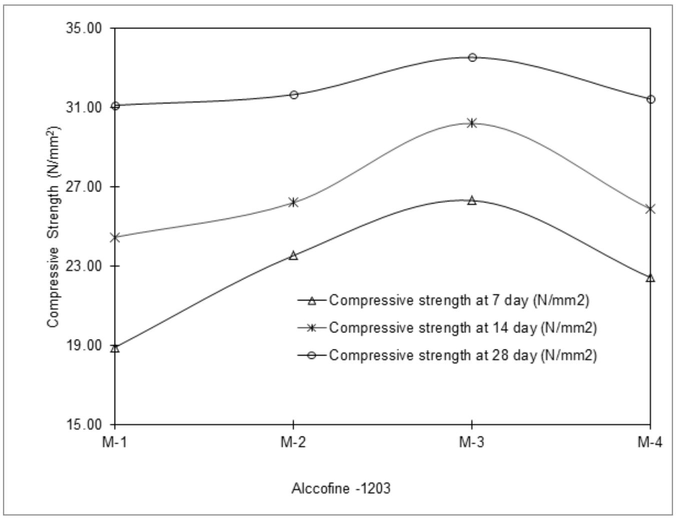

Figure 3: Graph between strength and duration for Cement Replacement of A.F

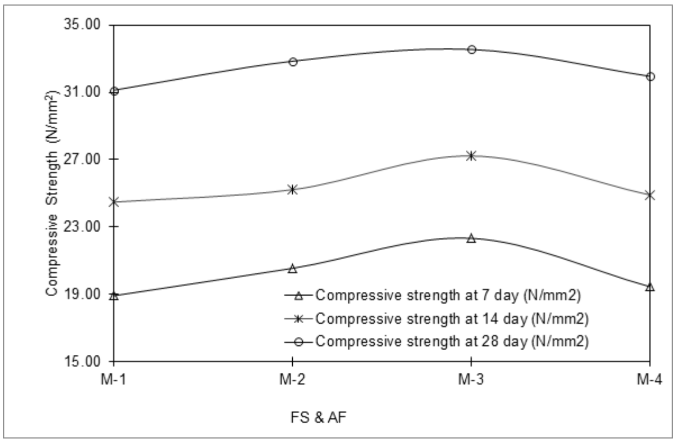

Figure 4: Effect of Alccofine-1203 and Foundry Sand Replacement on Strength Over Time

The compressive strength peaks at approximately 10% replacement, indicating this as the optimal level. Beyond this point, further addition of foundry sand, Alccofine-1203, or their combination (A.F-1203 and F.S) leads to a reduction in compressive strength. While foundry sand and Alccofine-1203 significantly enhance the concrete's resistance to compressive forces, they are less effective in resisting tensile forces.

Figure 5: Compressive Strength Test

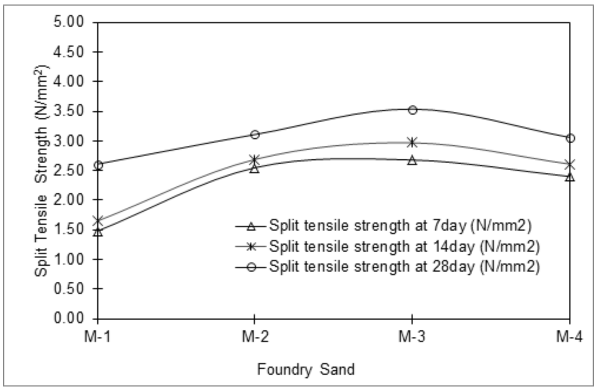

Figure 6: Effect of Foundry Sand as Fine Aggregate Replacement on Strength Over Time

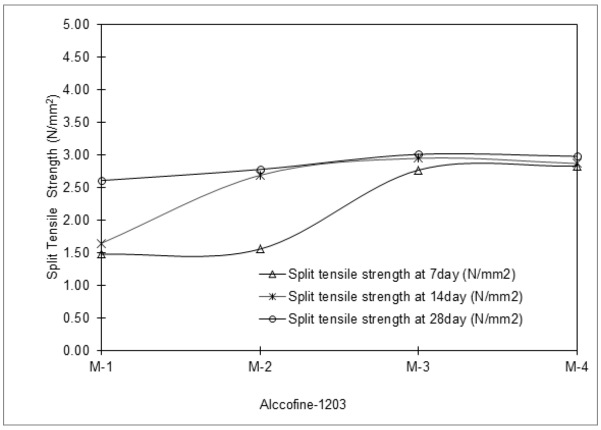

Figure 7: Strength vs. Curing Duration for Cement Replacement with Alccofine-1203

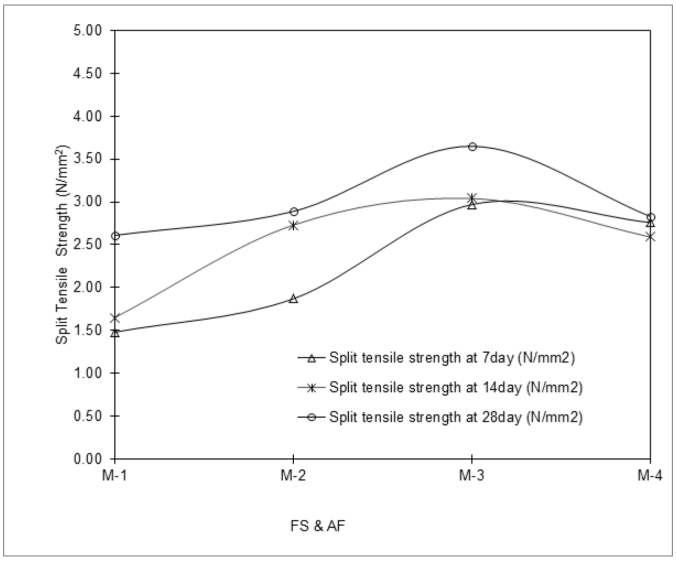

Figure 8: Strength vs. Curing Duration for Cement and Fine Aggregate Replacement with Alccofine-1203 and Foundry Sand

A similar trend to that of compressive strength was observed in the split tensile strength of concrete incorporating Alccofine-1203 and foundry sand, with optimal results achieved at 10% replacement after 7, 14, and 28 days of curing.

Figure 9: Split Tensile Strength

V. CONCLUSIONS

The This experimental investigation highlights the potential of Alccofine-1203 and foundry sand as effective partial replacements for cement and fine aggregate, respectively, in M30 grade concrete. The study demonstrates that incorporating 10% Alccofine-1203 and 10% foundry sand significantly improves the compressive strength, split tensile strength, and flexural strength of concrete compared to conventional mixes. These improvements are mainly attributed to the ultrafine particle size and high pozzolanic reactivity of Alccofine-1203, which enhance microstructural densification, reduce void content, and accelerate hydration reactions. Foundry sand, on the other hand, improves particle packing and provides filler effects, helping to reduce porosity and increase concrete density. However, the study also observed that strength properties begin to decline beyond the 10% replacement level, likely due to excessive replacement, leading to poor workability, increased water demand, and microstructural weaknesses. In addition to enhancing strength, the use of these industrial by-products supports waste utilization, reduces material costs, and promotes sustainable construction by minimizing the environmental impact of traditional concrete production. Based on the findings, an optimal replacement level of 10% Alccofine-1203 and 10% foundry sand is recommended for M30 grade concrete to achieve improved mechanical performance and durability. Further research involving long-term durability tests, such as water permeability, chloride ion penetration, and sulphate resistance, is suggested to fully validate the suitability of these materials for large-scale and critical construction applications. Overall, the study confirms that the combination of Alccofine-1203 and foundry sand offers a promising, eco-friendly solution for producing high-performance, durable, and sustainable concrete.

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