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A Performances Study on GGBS with Alccofine-Based High Strength Self-Compacting Concrete

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Abstract:- This paper conducts both experimental studies on high-strength concrete (HSC) incorporating the development of SCC mixes using industrial products such as Alccofine as an additive of 10% and GGBS as a partial replacement for cement at 0, 10, 20, 30, 40, 50, 60%, and the second phase covers the study of fresh and hardened properties of developed high strength SCC mixes in the laboratory. The study comprehensively tested properties like Rheological, compressive strength, and split tensile strength at 7, 28, and 91-day curing periods. The results highlighted enhanced workability when GGBS replaced cement, particularly in the 40% is optimum strength is satisfied. However, beyond 10% alccofine additive, adverse effects were observed across all parameters.

Keywords:- *Ground Granulated Blast Furnace Slag (GGBS), Supplementary Cementitious Material (SCM), Compressive Strength (C.S), Split Tensile Strength (S.T.S)*

I. INTRODUCTION

One of the most significant advancements in the construction sector has been the creation of self-compacting concrete (SCC). This tangible idea aims to reduce the risk brought on by the human aspect. SCC is increasingly being used because of its many appealing qualities. SCC differs significantly from traditional slump concrete in terms of its characteristics. SCC is a highly workable concrete that can flow through densely reinforced and complex structural elements under its weight and adequately fill all gaps without segregation, excessive bleeding, excessive air migration, or other material separations, as well as without the need for vibration or other mechanical consolidation. According to Okamura (1997)[21], SCC is highly designed concrete that has a significantly higher fluidity without segregation and can fill every corner of formwork while supporting itself. So, without compromising the engineering qualities of the concrete, SCC does away with the necessity for vibration, either internal or external. SCC is a fluid mixture that can be used in dense reinforcement and challenging situations without vibrating.

This concrete was initially developed in Japan in the late 1980s to combat the decline in concrete quality brought on by a lack of skilled labor, as well as issues with homogeneity and compaction at the corners of cast-in-place concrete, particularly with complex structures, to increase the durability of concrete and structures. Following the creation of SCC in 1988 in Japan, all of Europe began to work on this special noise-free revolution in the building sector. SCC research in Europe has been particularly active over the past five years, from 1991 to 2000. Because of this, Europe published self-compacting concrete requirements and guidelines before the United States (EFNARC 2002) [20]. Currently, there is a lot of research being conducted globally to improve the fluidity of concrete while maintaining its strength and durability attributes without significantly raising the cost. In November 2002, the first North American symposium on the design and application of self-consolidation concrete was held. Due to the advantages of using this concrete, various universities and government R&D firms currently employ a large number of researchers. Very limited work is reported from India, where the future for concrete is very bright due to scarcity of skilled manpower, non-mechanization of the construction industry, and abundant availability of construction materials available at very low cost. Therefore, it can be said that SCC is still quite unknown to many researchers, builders, ready-mix concrete producers, academia, etc. Self-compacting concrete (SCC) is an innovative type of fresh concrete known for its ability to flow and consolidate without the need for external vibration. This technology is particularly useful in construction scenarios where traditional concrete consolidation using vibrators is challenging. SCC is characterized by its exceptional filling and passing ability, as well as its resistance to segregation. It possesses superior flow properties in its fresh state, facilitating self-compaction and material consolidation while eliminating issues related to segregation. Alccofine is an advanced micro-fine mineral admixture derived from slag, designed for use as a supplementary cementitious material (SCM) in concrete and mortar applications. This eco-friendly material is primarily composed of low calcium silicate and boasts high glass content with remarkable reactivity. It is meticulously processed from Ground Granulated Blast Furnace Slag

(GGBS), yielding ultra-fine particles with an impressive fineness of 12000 cm^2/g, achieved through a controlled granulation process that imparts unique chemical properties.

II. LITERATURE SUMMARY

In early trials by Okamura and Ozawa (1995)[22], SCC was first described as a high-performance concrete that is capable of self-leveling and self-compaction. For self-compacting concrete, a brand-new mix design technique has been proposed. To ensure that the resulting concrete had flowability, self-compacting ability, and other necessary SCC features, the number of aggregates needed was first established. The spaces left by the aggregates were then filled with the paste of binders. The main variables affecting the qualities of SCC Nan-Su are the number of aggregates, binders, and mixing water as well as the type and dosage of superplasticizer to be utilized [21]. Evaluate carried performed an experimental test to see how much stronger concrete would be if cement were to be replaced with alumina. He conducted research and stated that a maximum of 50% GGBS could be added as a mineral admixture without having an impact on the material's capacity to self-compact. To replace a particular percentage of cement and add a certain percentage of lime, the SCC is covered in this paper. When replacing cement with GGBS, up to 40% of the self-compacting ability is retained [2]. evaluated the link between the splitting tensile and compressive strengths of self-compacting concrete. With increasing concrete compressive strength, all of the models investigated in this study appear to become less accurate [5]. According to the current investigation, GGBS and Micro Silica were used to explore the rheological and strength characteristics of High Strength Self- Compacting Concrete (HSCC) mixes [2][3][4]``.assert that the addition of cement fines strengthens combinations of ordinary and standard-grade concrete. According to the study, fly ash may be substituted for cement in concrete compositions. Crushed, granulated blast furnace slag and silica fumes. Mix design forbids the incorporation of ultra-fine substances like Alccofine[1].

The study explored the use of industrial byproducts like GGBS, SF[6], and Alcofine in concrete mixes, achieving satisfactory compressive and split tensile, strength properties. The research examined the impact of GGBS, Alccofine, and debris substitution on concrete strength, finding that certain combinations could maintain or enhance concrete strength. Studies showed that Alccofine can enhance the strength of regular and high-strength concrete when used as a partial replacement for cement.

III. METHODOLOGY

❖ *General*

An experimental program was conducted to evaluate the compressive strength and split tensile strength of self-compacting concrete (SCC). It was observed that there is no universally accepted mix design method due to the influence of material characteristics and mix proportions on SCC properties. In this study, the Nan-Su method was chosen for mixed design due to its reliability and simplicity. Self-compacting concrete using Ground Granulated Blast Furnace Slag (GGBS) and Alccofine: Alccofine was employed as an additive, while GGBS partially replaced cement at varying rates from 0% to 60%, with a 10% increment. This mixture was designated as M60 grade. The experimental output parameters strength were compressive strength and split tensile strength. The dataset collected included various materials such as cement, M-sand, coarse aggregate, GGBS, Alccofine/Micro-Silica, superplasticizer, water, and curing age in days (7, 28, 91). These materials were utilized in the experimental program to assess the properties of SCC. The research examined the impact of GGBS, Alccofine, and debris substitution on concrete strength, finding that certain combinations could maintain or enhance concrete strength.

A. Materials Used

Ordinary Portland Cement (OPC) 53 grade, complying with IS: 12269 – 2013[23] specifications, was chosen for the experiment. M-Sand, conforming to IS-383-2016 standards, served as the fine aggregate in the study, with its physical properties assessed by IS-2386-1975, and it was sourced from local suppliers. Coarse aggregates, ranging up to 20mm and occasionally 12mm for heavily reinforced concrete, were used. These well-graded aggregates with cubical or rounded shapes met the quality criteria outlined in Indian Standard Specification IS-383-2016[24]. Neutral pH water with a rating of 7 was employed for both mixing and curing the concrete specimens. Alccofine, obtained from slag with high glass content, was used as a water reducer and workability enhancer, sourced from Counto Microfine Products Pvt. Ltd., and compliant with IS: 9103-2008 standards. Micro Silica, sourced from BASF Construction Chemical Pvt. Ltd., and Ground Granulated Blast Furnace Slag (GGBS) from Astra Chemical were used as supplementary materials, along with the superplasticizer Master Glenium Sky 8233, to enhance concrete deformability and reduce water content.

B. Mix proportion:

The mix design for Self-Compacting Concrete (SCC) in this study is based on the Nan-Su method from Taiwan. It aims to determine the paste quantity needed to fill the gaps between loosely piled aggregates. The mix design process involves calculating the fine and coarse aggregate content using parameters like the S/a ratio (typically 50%), packing factor (PF), bulk densities of aggregates, concrete grade (FC), and a correction factor (CF). The calculations yield values for fine aggregate (Wfa), coarse aggregate (Wca), cement (C), and the mixing water content required by cement (Wwc). The resulting mix proportion is 1:2.36:2.12 [3], [4] with a water-to-paste ratio of 0.80. The mixes designated as M1 are conventional SCC and M2 to M7 contained GGBS (10-60%) and Additive of Alccofine 10% throughout.

C. Mechanical properties

Mechanical properties**,** including compressive strength and split tensile strength, were evaluated at different curing ages of 7, 28, and 91 days while varying percentages of GGBS were used as partial replacements for cement. These replacement percentages ranged from 0% to 60% for GGBS with 10% Alccofine. Compressive strength is a vital concrete property with direct implications for other concrete characteristics. Standard 150x150x150 mm concrete cubes were employed, and a compression testing machine applied a load at a rate of 1.40 kN/min. Compressive strength was calculated using the formula: Compressive strength = load (N) / area (mm^2). Split Tensile Strength: The tensile strength of concrete was indirectly assessed using the split tensile strength test, originally known as the "Brazilian Test." Cylindrical specimens with dimensions of 100 mm x 200 mm were subjected to this test, following IS 516-2018 [26] standards, at curing ages of 7, 28, and 91 days. The split tensile strength was determined using the formula:

Fig 1: Compressive and Splitting tensile strength

IV. RESULTS AND DISCUSSIONS

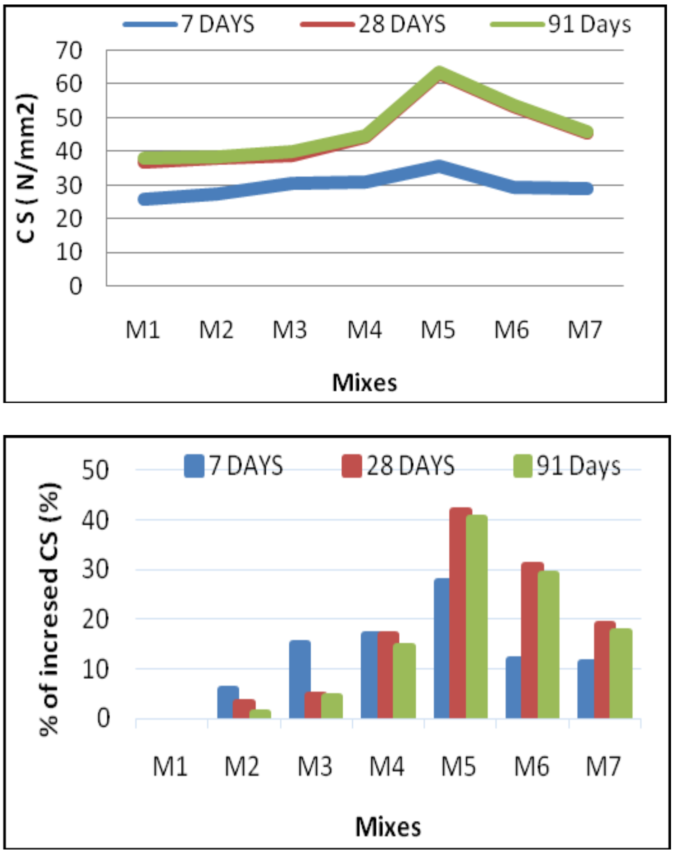
This present study Experimental and Prediction results of compressive, splitting tensile and compared those results, for various ages. Further, the results obtained are reported in the form of Tables and Graphs respectively. The workability of SCC is higher than the highest class of consistency described within EFNRC Guidelines and can be characterized by the following properties:(i) Filling ability,(ii) Passing ability, and (iii) Segregation resistance reported in Table 1.

Table 1: Fresh property of SCC.

Mixes	*Slump flow (650-800mm)*	*J-ring (0-10mm)*	*V-funnel (6-12sec)*
M1	670	7	10
M2	715	7	10
M3	715	5	9
M4	720	6	9
M5	735	7	9
M6	740	6	8
M7	745	5	8

Table 2:- Compressive Strength Results

Mixes	*Compressive Strength (Mpa)*			*% increase or decrease of Compressive Strength (%)*		
Ages	*7*	*28*	*91*	*7*	*28*	*91*
M1	25.81	36.92	38.01	0	0	0
M2	27.39	38.21	38.49	5.77	3.38	1.25
M3	30.44	38.73	39.8	15.21	4.67	4.5
M4	31.01	44.44	44.53	16.77	16.92	14.64
M5	35.58	63.2	63.5	27.46	41.58	40.14
M6	29.25	53.33	53.63	11.76	30.77	29.13
M7	29.05	45.62	45.97	11.15	19.07	17.32



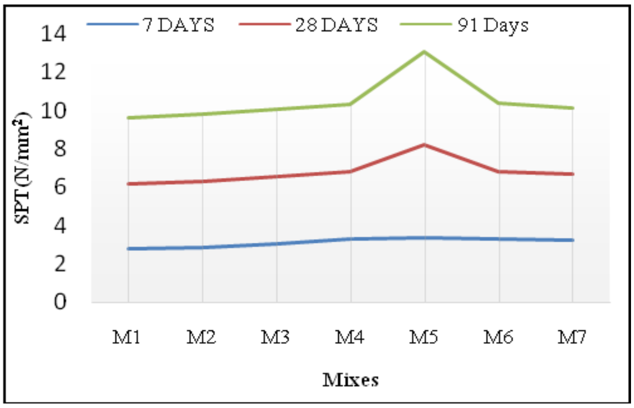
Graph 1:- Compressive Strength, mixes and % of increased CS

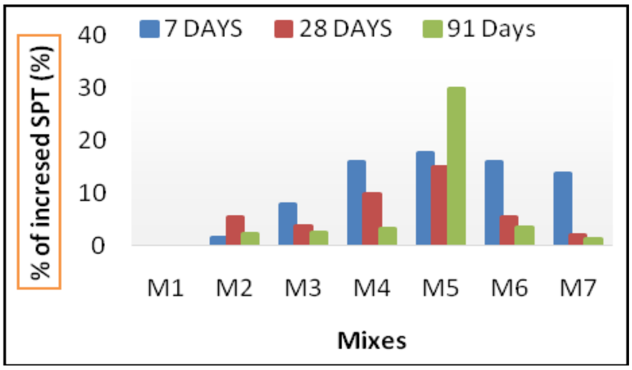
- *Observation*

Compared to the control SCC mix concrete(M1), it has been observed that the compressive strength of SCC mix of M5 maximum strength gained at various ages are 7,28& 91-days formed with admixtures 10% of Alccofine and 40% GGBS goes on increasing gradually up to **27.46%** and after which there is a reduction in compressive strength.

Table 2:-Splitting tensile Strength Results

Mixes	**Split tensile strength (Mpa)**			**increase or decrease of split tensile strength (map)**		
Days	**7**	**28**	**91**	**7**	**28**	**91**
M1	2.77	3.37	3.42	0	0	0
M2	2.81	3.56	3.5	1.42	5.34	2.29
M3	3.05	3.50	3.51	7.87	3.71	2.56
M4	3.29	3.73	3.53	15.81	9.65	3.12
M5	3.36	3.96	4.87	17.56	14.90	29.77
M6	3.29	3.56	3.54	15.81	5.34	3.39
M7	3.21	3.44	3.46	13.71	2.03	1.16





Graph 2:- Splitting Tensile Strength, mixes, and % of increased SPT

➢ *Observations*

It has been observed that the Splitting Tensile Strength of high-strength SCC mix 5 is increased at 7,28&91 days produced with the combination of admixtures such as Alccofine and GGBS goes on increasing gradually up till the 5th mix, after which there is a reduction in split tensile strength.

V. CONCLUSIONS

The laboratory investigation led to the following significant findings.

- To achieve good rheological properties of SCC, high-strength SCC mixes require high powder content and a high range of superplasticizer dosage.
- It's crucial to add the superplasticizer at the right moment, which is typically between 50 and 70 percent of the water.
- According to EFNRC guidelines, the high-strength SCC mix fulfilled the fresh qualities of passage ability, filling ability, and segregation resistances.
- SCC produces a great surface quality and fills the formwork and reinforcements without vibrating. This allows it to be compacted by its weight.
- Based on experimental experiments, it has been determined that using GGBS as an addition and replacing a portion of cement with 40% and 10% Alccofine will provide the needed strength.
- The maximum compressive strength is mix 5 enhanced by 41.58% for 28 days, while the maximum mix of 2's splitting tensile strength is improved by 29% for 91 days.
- Compressive splitting strength is seen to rise as cement replacement increases, demonstrating the sustainability and economic benefits of employing Alccofine and GGBS.

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