Structural behaviour of triple blended high-performance concrete

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Abstract. After water, concrete was the material for construction that is used on the largest scale on the planet, and as an outcome of technological development, concrete's qualities have evolved over time. A study was carried out to investigate the potential use of mineral admixture as a partial replacement in high performance concrete. Since they can significantly improve concrete strength and durability properties when compared to regular Portland cement supplemental cementations materials (SCM) like Alccofine (AF) and ground granulated blast furnace slag (GGBFS) have all been used as cement replacements on a large scale over the past three decades. As a result, HPC can be produced using lower water to powder ratios by including other cementitious materials as admixtures. In this project phase, ground granulated blast furnace slag (GGBFS) and Alccofine (AF) have been employed in varied weight ratios to substitute cement to produce high strength M40 grade concrete for 7, 14, and 28 days of compressive strength (CS) as well as split tensile strength (STS) the percentages of replacement of AF of 5%, 7.5% &10% also GGBFS percentages are 10%, 12.5 % and 15% respectively used in this project work.

1 Introduction

One of the most often used materials in civil construction is conventional concrete, a mixture of cement, required quantities of aggregates, and water. Concrete is a delicate material with radically differing tensile and compressive strengths because it has a high compressive strength but a much lower tensile strength. Criteria including quantities of cement, aggregate and , water cement ratio ,mostly determine its resistance. The focus was on the CS of concrete, however during the past 60 to 70 years, many structures have deteriorated worldwide. For use in versatile concrete applications, cement-based products, mortars, and grouts where the utilisation of fly ash is officially approved, blended cement is produced. such as improved later-age strength, increased workability, and enhanced durability. Because of its superior performance, concrete built using either slag or fly ash has gained popularity. Numerous studies have been conducted, and it was additionally determined that durability is strongly impacted by exposure conditions.

Ordinary Portland cement (OPC) combined with additives like Alccofine, GGBFS, and slag to enhance its properties for diverse uses is known as blended cement. Blended cement

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can progress the workability, durability, and chemical resistance of concrete. In a variety of applications, including residential building, precast concrete where high durability and an off-form finish are required, stabilization for road construction, including pavement recycling, mining applications, and specialized formulations including adhesives, renders, mortars, and grouts, blended cement is an excellent choice. Alccofine 1203 (Ultra-fine Slag), a low calcium silicate material, has improved workability including compressive strength because of controlled granulation and its high glass content. The alkaline solution combines the alumina silicate-based industrial by-products, fine aggregate, and coarse aggregate to form a geopolymer structure that appears to be hard rock. The alkaline solution is made a day in advance of use. Combining sodium hydroxide and sodium silicate creates an alkaline solution (Na_2SiO_3).

BFS that has been ground into granules is used to make high-strength concrete. It is made by quenching molten iron slag, a by-product of producing iron and steel, in steam or water. In conjunction with regular Portland cement and/or additional pozzolana components, Structures made of durable concrete are produced using GGBFS. Concrete constructed with GGBFS cement has a higher ultimate strength than concrete constructed with Portland cement. As a result it contains more of the strength-enhancing calcium silicate hydrates (CSH) than concrete produced only with Portland cement and less of the free lime, which is not contributing to the concrete's strength, concrete manufactured with GGBFS persists to gain strength towards time and is being shown to increase by twice its 28-day strength over time.

The polycarboxylic acid series super plasticizer products can be split into two categories based on the main chain's structure. A kind of polyether with side chains of various lengths and acrylic or meth acrylic acids as the main chain. The alternative kind is a polyether with a variety of maleic anhydride side chains of varying lengths. A variety of high-performance super plasticizer products with various properties have been developed based on these two categories There are lingo sulphate admixtures, naphthalene sulfonate formaldehyde condensates, melamine-formaldehyde sulphate formaldehyde condensates, sultanate formaldehyde condensates, and other substances before the advent of the polycarboxylic acid super plasticizer. Several of the shortcomings of conventional water reducers are resolved by a new generation of polycarboxylate super plasticizer. Last 6 to 7 decades many researchers are focused on high compressive strength of concrete bet most of structures have decorated duo to lake of required compressive strength.

2 Review of Literature

Kavitha (2022) shows that using AF is the best compaction property of cementitious material; it is best suitable for replacement of concrete with very high flexure, and extreme improvement in 28 days was observed to be 36.1 N/mm^2; hence, the adding of bamboo fibre content surges the flexural strength in replacement of GGBFS and bamboo fibres. Balamuralikrishnan R. (2021) Stated that the best compaction property when AF is used as a cementitious material is a partial replacement of cement. Surendra (2021) Stated that AF has better compaction properties when used as cementitious material and is best suited for replacing cement. The test results show that better performance in hydraulic as well as pozzolana properties GGBFS. S.Kavitha (2020) It was stated that the SSC strength of AF used as cementitious material is better suited for replacing cement. In contrast, the improvement in properties of concrete, like CS from 36.6 to 42.9 N/mm2, STS from 3.8 to 7.9 N/mm^2, and flexural strength from 4.9 to 8.3 N/mm^2 at 28 days, increased the properties of GGBFS.

Jigar Saiya(2019) It is recommended to place AF and GGBFS for better compaction properties by using HPC. Based on the test results obtained, it can be concluded that fly ash has better flow ability as compared to GGBFS. Sreejith Haridas (2018) Stated that GGBFS has better compaction properties when used as a cement material in partial replacement of cement. The test results studied the compressive strength of the mix with partial replacement of GGBFS high strength. Kiran (2018) said that using AF gives better compaction properties to river sand used in replacement of cement. The test results showed that AF material increased the strength to a large extent at the 20% replacement level of cement, and there was no reduction in strength properties by replacing river sand with m-sand or concrete with m-sand. Kavitha (2017) In his study, he evaluated the strength behaviour of self-compacting concrete (SCC) by replacing cement with AF at 5%, 10%, 15%, and 20% while keeping GGBS constant at 30%. In contrast, the improvement in properties of concrete, like CS from 36.6 to 42.9 N/mm^2 and STS from 3.8 to 7.9 N/mm^2 at 28 days, remains. GVV Satyanarayana concluded that the CS of M60-grade concrete increased when 25% of the cement was replaced with 10% lime powder and 15% GGBFS.

3 Material properties and Methodology

To develop the mechanical properties of optimum dosage of AF 5%,7.5% and10% and the experimental programme was fixated on using GGBFS of 10%, 12.5% and15%, and as a partial replacement of aggregate sand as fine combination. The cement used in the test, 53-grade OPC, was to have a chosen gravity of 3.12, a fineness of 7.5%, and primary and final setting time of 28 minimum and 570 minimum, respectively. The FA utilized was river sand. Sand has a bulk density of 1.8 g/cm^3 and a specific gravity of 0.68, respectively. The coarse aggregate used is crushed rock fines retained on a 4.75mm screen and passing through a 20mm sieve. The CA used complies with IS 383-1970 and has undergone physical property testing in accordance with IS 2386-1963. It has a specific gravity of 2.75, a bulk density of 1488 kg/m3 in the loose condition and 1559 kg/m^3 when compacted. In the investigations, drinking water was used for mixing and hardening of the specimens. Apart from having less permeability, GGBFS-based concrete is much more resistant to chloride ions entering the concrete. JSW Steel Ltd. in Karnataka provided the GGBFS, which mostly contained SiO_2 at 35.20% and Al_2O_3 at 19%.

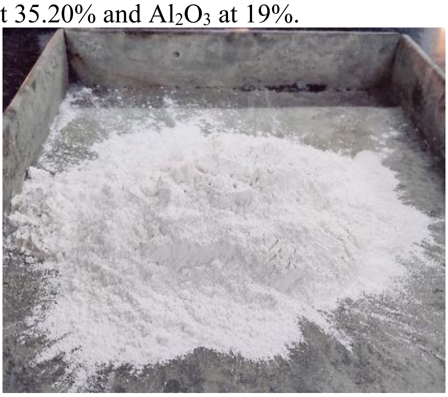

Fig. 1 : Alccofine

Fig. 2 : GGBS

Table 1: Properties of AF and GGBFS

Properties	Formula	% Composition	Properties	% Composition
Lime	CaO	30-34	Magnesia	12.0
Silicon dioxide	SiO_2	30-36	Sulfide sulfur	1.7
Aluminum oxide	Al_2O_3	18-25	Sulfite	2.5
Ferric oxide	Fe_2O_3	0.8-3.0	Manganese	1.0
Magnes. oxide	MgO	6-10	Chloride	0.05
Sulfur trioxide	SO_3	0.1-0.4	Glass content	90
Physical properties of AF			**Physical properties of GGBFS**	
Spec. gravity	2.97		Spec. gravity	3.0

The mix proportioning was carried out in accordance with the IS mix design criteria for blending concrete M40 with the replacement of GGBS and Alccofine with 0.4 water-cement ratio and 2 % of superplasticizer in various dosages, as indicated in Table 2.

Table 2 : Mix proportion for M40 grade

Mix	AF %	GGBFS %	Cement	AF	GGBFS	FA	CA	Water
			Weight in Kg/m³					
M0	0	0	350	0	0	896	1140	140
M1	5%	10%	297.5	17.5	35			
M2	7.5%	10%	280	26.25	35			
M3	10%	10%	262.5	35	35			
M4	5%	12.5%	297.5	17.5	43.75			
M5	7.5%	12.5%	280	26.25	43.75			
M6	10%	12.5%	262.5	35	43.75			
M7	5%	15%	297.5	17.5	52.5			
M8	7.5%	15%	280	26.25	52.5			
M9	10%	15%	261.5	35	52.5			

In CS, for residential construction, concrete's CS can range from 17 MPa to 28 MPa and greater in commercial constructions. Some applications employ stronger forces of more than 70 MPa with curing time period is 7, 14 and 28 days. STS is a measurement of the maximum stress at the point of bending failure on the tension face of an unreinforced concrete beam or slab. It is decided by loading concrete that is 150mm × 150 mm or 100 mm x 100 mm in size with curing is 28 days.

Fig.3 Compressive Testing machine with sample

Fig. 4 Specimen under Tensile load

4 Results

After the standard 7, 14, and 28 days of curing, the CS is assessed. The outcomes are shown in Table 5 and graphically represented in Fig.5. After 28 days of standard curing, the STS was calculated. The outcomes are shown in table 5 and graphically represented in Fig.6.

Table 3 CS and STS test results

Mix	Compressive strength (N/mm^2)			Split Tensile strength (N/mm^2)
	7 Days	14 Days	28 Days	28 Days
M0	23.4	36.1	40.22	10.11
M1	30.5	39.5	44.8	15.5
M2	31	41.3	47.5	17.3
M3	28.4	39.96	46.5	18.81
M4	29.8	41.6	47.8	16.62
M5	31	41.25	48.2	19.6
M6	27.9	38.2	46.4	16.22
M7	31	41.02	45.9	15.21
M8	30.9	41.7	43.9	13.6
M9	25	35.9	39.2	11.8

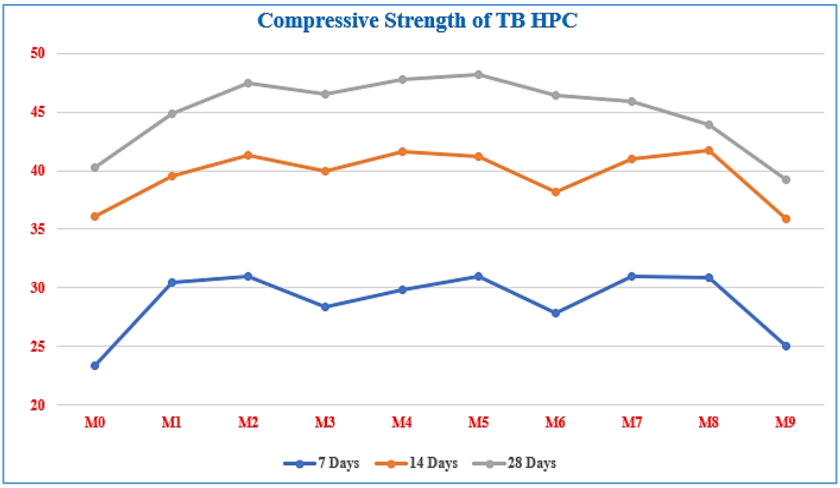

Fig. 5 Compressive strength of TBC

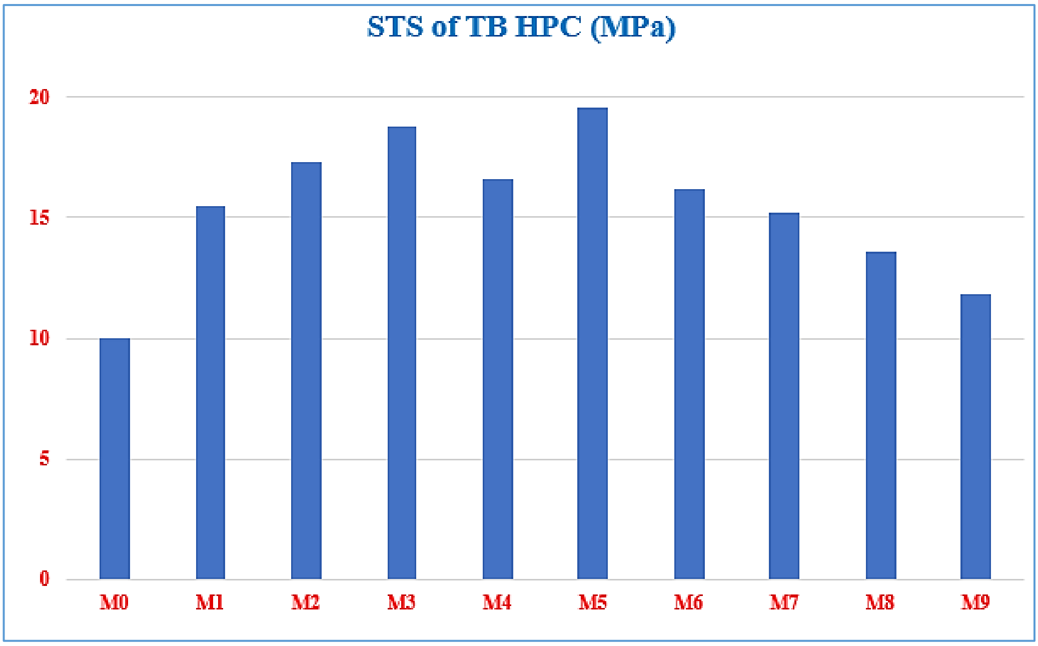

Fig. 6 STS for TBC

5 Conclusion

It can be conclude that, the compressive strength and split tensile strength increases with the replacement of cement Alccofine and GGBS by M40 grade of HPC as per Indian Standard guidelines. AF 1203 improves the particle packing and CS of concrete, and FA improves the concrete's longer term strength development. The combination of alccofine and GGBS has the effect of making HPC more durable. It has been found that cubes and cylinders both have CS and STS. The 12.5% AL mixture provides more strength, and CS is greater than STS. To test both the CS and STS of concrete constructed with GGBFS partially substituted for cement. According to the experiment, GGBFS with a 15% substitution had stronger results. It has been determined that raising the GGBFS percentage causes a decline for concrete strength.It is observed that Mix M5 having the mix proportioning of 7.5 % AL and 12.5 % GGBS having higher strength as 48.2 N/mm^2 when compared to the conventional concrete. As per the results given in Table 5, CS have been increased significantly from M1 to M5, then after it starts declining from M6 to M9 while increasing the GGBS percentages. It is noticed that 24.48 % increase in CS is noted down while comparing with conventional concrete for 28 days, whereas there is a slight changes in CS for 7 and 14 days.

Compared with traditional concrete, Mix M5 has a higher strength in STS of 19.6 N/mm^2 because of to its mix proportioning of 7.5% AL and 12.5% GGBS. According to the findings in Table 5, STS developed substantially increased from M1 to M3 and suddenly declined in M4, after which it began to improve while the GGBS percentages reached 12.5 % from M5 and due to increase in GGBS and Alccofine percentages, M6 to M9, it starts declining. The optimal mix proportion of AL and GGBS was 7.5 % + 12.5 % having a greater CS and STS, due to the particle packing and fineness of AL and GGBS concrete contains a low amount of free lime, that doesn't add to concrete strength in their early stage, and a higher proportion of the strength which was enhanced by CSH than the concrete prepared exclusively from Portland cement. Concrete produced with GGBFS also continuing to get stronger over time.

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