Mechanical Properties of Green High-Performance Concrete Using Fly Ash and Alccofine

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ABSTRACT: Concrete, a construction material utilized in infrastructure development comprising of hard, a synthetically inactive particulate substance known as aggregate, binder and water in proper mix portion. The way towards choosing appropriate elements of binder and deciding their relative sums with a goal of creating a solid of required quality, strength and properties as economical as could be expected under the circumstances. The quest for alternate sustainable and green substitution materials has been done for a considerable length of time. Research has been led on the utilization of fly ash, volcanic ash, volcanic pumice, blast furnace slag, chromite tailing, red mud, rice husk, and alccofine as concrete substitution material. As these materials improve the strength of concrete, the durability of this concrete also increases. The rate of liberation of the heat of hydration is also reduced, which is advantageous for mass concreting. The use of fly ash and alccofine also reduce environmental pollution by decreasing carbon footprints.. The different Mix Design according to Indian Standards(IS) methods were made by substitution of cement from 0% to 30% by fly ash, and again substitution of fly ash from 5% to 30% by alccofine. The superplasticizer helped for better workability with a lower water-cement ratio. The 28 days target strength of the Mix was accomplished with a substitution of 30% cement by 18% fly ash and 12% of alccofine. Mechanical properties like compressive and flexural strength of different mixes are considered mix.

KEYWORDS*: Alccofine, high-performance concrete, Compressive strength, Flexural strength*

INTRODUCTION

The quest for alternate green and sustainable binders and materials giving high performance, has been done for a considerable length of time. Research has been led on the utilization of industrial wastes like fly ash, volcanic ash, volcanic pumice, blast furnace slag, chromite tailing, red mud, rice husk and alccofine as concrete substitution material. Cements containing mineral admixtures are utilized broadly all through the world for their great execution and for natural and financial reasons like a decrease in self-weight and superimposed dead load in massive structures. It additionally diminishes structure work territory and cost with the going with decrease in shoring and stripping time because of high early strength gain in quality. The development of elevated structures with the going with investment funds in land costs in clogged regions can be accomplished. Longer ranges and fewer pillars are workable for a similar extent of loading. Reduction of interfaces in the structure of cement, limiting the flocculation of concrete particles in water and topping off of pores are significant for better properties of cement. Synthetic and mineral admixtures increase the response system to change the structure of cement in accomplishing this. Improvement of the amount of concrete and mineral admixtures and stringent portrayal of fixings likewise help right now. Initial one limits the amount of un-responded particles of mineral admixtures (in abundance of those required for filler action).Second one aides in choosing suitable fixings so the response component can happen without block. At the point when water is blended in with concrete, the concrete particles will in general flocculate. Subsequently, just a segment of the flocculated body connects with water and hydration happens in that segment keeping the greater part of the other segment un-hydrated and coming about to the higher level of voids. A high range water reducer, super plasticizer makes a conducive condition for complete hydration of concrete by deflocculating the concrete bump and making concrete water blends too scattered framework. This diminishes the danger of anhydrous concrete grain to be available in the structure of cement and to improve the pore structure during the hydration process by bringing practically all concrete particles completely in contact with water. The use of industrial by product as mineral admixtures in concrete decreases the volume of cement in concrete and hence minimizes the ozone harming substances emissions. The utilization of fly ash and alccofine makes the concrete cheaper as it decreases the expense towards binders as flyash is less expensive than cement. The present investigation may move towards the use of high strength high-performance concrete with moderate cement content and incorporating flyash and alccofine.

LITERATURE REVIEW

K.E. Hassan et.al. in 2000 studied the influence of two mineral admixtures, alccofine (SF) and fly ash (FA), along with superplasticizer [1] on the properties of high-performance concrete. Under water curing for 28 days, he revealed that the inclusion of 10% SF or 30% FA slightly improves the strength. Alccofine enhances the early strength and also the long-term properties of concrete. As per research, the permeability reduced by 71% and 87% at 1 and 365 days, respectively, when compared to OPC concrete. Wei Sun in Jan 2004 et.al studied the influence of mineral admixtures on resistance to corrosion of steel bars in green high-performance concrete and found that the addition of mineral admixtures reduced the PH values of binder pastes in GHPC, especially in double and triple-adding approaches, whereas the final pH values were still above the critical breakage pH values of passivation film on the steel bar surface. Hence there is no favorable condition for corrosion[2]. Young-jin Kwon in 2005 studied the alkali-aggregate reaction in high-strength concrete with particular respect to the ground granulated blast-furnace slag effect and concluded that in high-strength concrete, because of high alkali content, the likelihood of an alkali-aggregate reaction is far above conventional concrete[3]. The occurrence of large expansion can be prevented by using nonreactive aggregate, which has been judged according to the mortar bar and chemical method's as specified in JIS A 5308, in high-strength concrete. Using low-alkali cement and replacing the cement by 30% with blast-furnace slag can prevent the alkali-aggregate reaction which leads to a large expansion in high-strength concrete. Tahir Gonen et.al. in 2009 studied the influence of mineral admixtures on the short and long-term performance of concrete and concluded that the effect of using SF on the strength of concrete mixtures is noticeable[4]. Mineral admixtures can significantly contribute to improving the compressive strength. Eshmaiel Ganjian et.al. in 2009 [5]studied The effect of Persian Gulf tidal zone exposure on the durability of mixes containing alccofine and blast furnace slag and revealed that Alccofine specimens under cyclic wetting and drying conditions in simulated seawater exhibited higher strength loss compared to plain type II hydraulic cement where cured under potable water. Besides, the greater the alccofine amount utilized in the mixes, the more the capillary water absorption under zone exposure or/and under wetting and drying simulation. Further, the ternary blended ground granulated furnace slag (GGBS) mix was the worst performing mix altogether exposure conditions. Boukhatem, Bakhta, et al. 2011 in their paper predicting the compressive strength of ground granulated furnace slag concrete using artificial neural network described the efficiency of GGBS in concrete[6]. However, in the long term, concrete containing slag exhibits an equivalent or a greater final strength than that of control normal Portland cement concrete. Shi Hui-sheng et.al. in 2009 studied the influence of mineral admixtures on compressive strength, gas permeability and carbonation of high-performance concrete and from test results, they predicted that the effects of FA on compressive strength, gas permeability, and carbonation are greatly affected by w/b ratios[7]. At lower w/b selected, compared to the control HPC, FA with replacement up to 30% can improve compressive strength and have a marginal increase in both gas permeability and carbonation depth. Fathollah Sajedi et.al. in 2012 studied the effect of chemical activators on early strength of ordinary Portland cement-slag mortars [8] and concluded that the use of slag has many benefits, its low hydration at early stages causes the strength to be low. Hence, the uses of slag are restricted and the strength gain is more if chemical activators like NaOH and Na2SiO3 are used. Halit Yazıcı et al in 2009 studied mechanical properties of reactive powder concrete containing high volumes of ground granulated blast furnace slag and revealed that RPC can be produced with 1–3 mm coarse aggregate as well as with aggregate in powder form Compared to the conventional RPC (aggregate size <0.1 mm), this modification reduces cement and SP demand and also reduces shrinkage[9]. Ajay pathik et al. in 2011 studied micro technology for high-performance concrete and described that UFS helps gain higher strength while lowering concrete's shrinkage and creep. UFS also provides alkalinity to concrete helping it with its durability. Plastic viscosity .as well as yield stress decreased when OPC is partially replaced with blast furnace slag (BFS) and fly ash (FA)[10]. Plastic viscosity and yield stress decreases with replacing OPC with fly ash and blast furnace slag[11] . Self-compacting concretes can be made with with replacements of OPC with fly ash and blast furnace slag[12].The binder packing density of the cementitious materials increases with the addition of flyash up to 40%[13].

MATERIALS AND METHODS

Cement: Portland Slag Cement of 53 Grade (Ultra Tech Cement), which confirms the guidelines given by IS 455-1989, was used. The tests were carried out as per IS 4031 to determine the physical properties of cement. The results of the tests are shown in the Table 1.

TABLE 1: PHYSICAL PROPERTIES OF PORTLAND SLAG CEMENT

Sr. No.	Characters	Experimental Study	As per IS:12269-1987
1	Specific Gravity	3.14	3.15
2	Initial Setting Time	155 Min	>30
3	Final Setting Time	235 Min	<600
4	Fineness of cement	320m^2/Kg	> 225
5	Compressive Strength		
	3 days	41 N/mm^2	> 27
	7 days	51 N/mm^2	>37

Fly Ash: Fly ash was collected from Jindal Steel, Jajpur. The specific gravity of fly ash was found out to be 2.16. Amount of fly Ash retained in 45μm sieve was measured equal to 30%, which is within the prescribed limit. It was reported that, it is a Class-F fly ash with low calcium content. The characterization of the Fly ash and GGBS is carried out with the help of the X-ray Fluorescence test (XRF). The results of the tests are shown within the Table 2.

TABLE 2: CHEMICAL COMPOSITION OF FLYASH

	Al_2O_3	SiO_2	P_2O_5	K_2O	CaO	TiO_2	V_2O_5	Cr_2O_3	MnO	Fe_2O_3
Fly ash	28.809	59.483	0.955	1.782	1.661	2.048	429.6	259	409.5	4.78

Alccofine: Alccofine consists of particle size much finer than other cementitious materials like cement, fly ash, silica fume etc. Alccofine 1203 is a microfine mineral additive, which is a specially processed product based on slag of high glass content with high reactivity obtained through the method of controlled granulation. It is ultra fine slag has a larger total surface area for hydration and pozzolanic reaction, compared to normal GGBS. Physical Properties and chemical composition of ALCCOFINE are shown in table 3 and 4 respectively.

TABLE 3: PHYSICAL PROPERTIES OF ALCCOFINE

Fineness(cm^2/gm)	Specific Gravity	Bulk Density (Kg/m^3)	Particle Size Distribution		
			d10	d50	d90
>12000	3.11	700-900	1.5	5	9

TABLE 4: CHEMICAL COMPOSITION OF ALCCOFINE

Cao	So3	Sio2	Al2O3	Fe2O3	MgO	Cl
33	0.4	35	22.1	2.1	7.5	0.02

Fine Aggregates: Locally available Daya river sand passing through 4.75 mm sieve was used in this study. Sand was free from organic matter and silt. Properties of sand like fineness modulus, relative density etc. were determined as per IS 2386-1963 (Part I). Table 5 gives the properties of fine aggregates used. The fine aggregate is of ZONE-II confirming to IS-383-1970.

Coarse Aggregates: Locally available crushed stone coarse aggregate of 20 mm down size were used. The aggregates were a mixture of rounded and coarse aggregates. The various properties of aggregates are determined as per IS 2386 (Part III, IV): 1963 (Reaffirmed 1997) and the specifications are checked as per IS 383: 1970 (Reaffirmed 1997) requirements. Table 5 gives the properties of coarse aggregates used in this investigation.

TABLE 5: PHYSICAL PROPERTIES OF AGGREGATES

Property	Fine Aggregates	20mm Aggregate	10mm Aggregates
Specific gravity	2.65	2.82	2.78
Free moisture(%)	0.6	Nil	Nil
water absorption(%)	1.5	1.5	1.5
Fineness Modulous	2.7	5.2	6.7

Water: The amount of water used in the mix design has a direct effect on the properties of concrete. The quantity of water used was as per mix design. In this work, normal tap water was used for mixing and the pH value of used water was 7.4.

Mix Design And Curing: Designing a proper mix for a particular strength and workability is very important for assessing the properties of the materials used in concrete. Each material will influence the properties of concrete in its own way. Concrete mix was designed following the several guidelines of Indian Standard IS 456:2000 [14] and IS 10262:2009[15]. Water/binder ratio (w/b) was considered as 0.45 throughout the work. Alccofine was added to each mixes by 5% of total OPC quantity excluding control mix. Percentage of materials required for one cubic meter concrete of the various mixes tested here in for evaluation of their properties are shown in Table 6.

TABLE 6: MIX PROPORTIONS

Mix Notations	Cement(%)	Fly Ash(%)	Alccofine(%)
MA	100	0	0
MB	90	10	0
MC	80	20	0
MD	70	30	0
ME	70	25	5
MF	70	22	8
MG	70	20	10
MH	70	18	12
MI	70	15	15
MJ	70	12	18
MK	70	10	20
ML	70	5	25
MM	70	0	30

RESULTS AND DISCUSSION

Designed quantities of sand, OPC, fly ash, alccofine and coarse aggregates were added to the mixer in that order and after one minute of dry mixing, water was added to the mixer. The workability of the resulting mix was determined using a slump test. Concrete is then filled into the standard moulds and fully compacted using a table vibrator. For each type of concrete mixes, cubes (150 mm × 150 mm × 150 mm), cylinders (150 mm in diameter and 300 mm in height) and beams (100 mm × 100 mm × 500 mm) were cast to study compressive strength, splitting tensile strength and flexural strength of concrete respectively. Demoulding of specimens was done after 24 hours of casting. After careful demoulding, all specimens are kept for curing. After 3days, 7days, and 28days of curing period the specimens were allowed to dry the surface for about one to two hours. Then they were tested in appropriate testing machine for the compressive strength, Flexural Strength, Split Tensile Strength.

i. COMPRESSIVE STRENGTH TEST

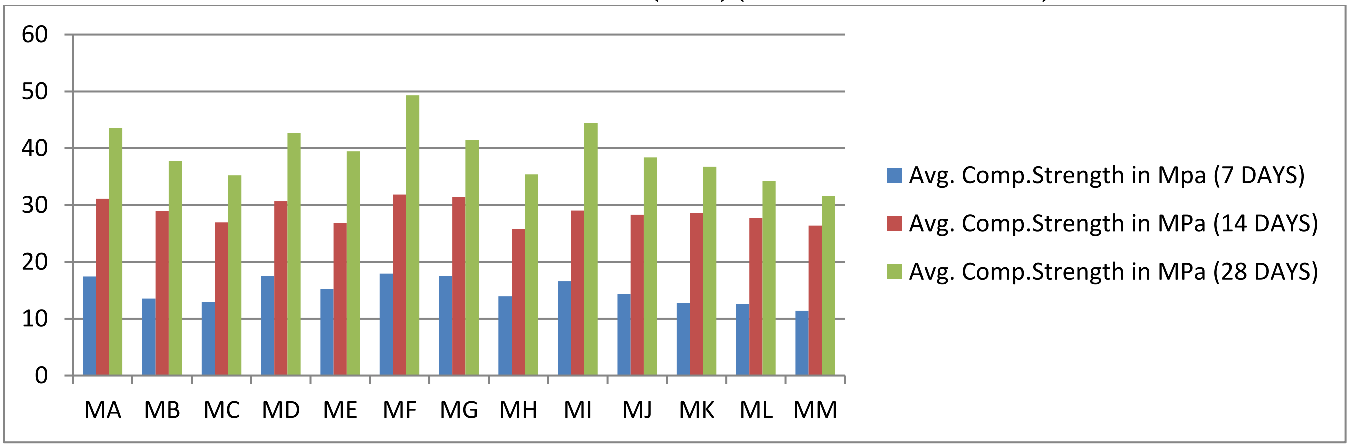
The compressive strength was studied on different ages of concrete, with different proportion of Alccofine and Fly ash in the concrete mix. The strength was studied after 7 Days, 14 Days & 28 Days of curing. The cube mould of 150mm x 150mm x 150mm size is taken as per IS: 516-1959 specification. The concrete is mixed with the help of concrete mixer machine. Coarse and fine aggregate was first taken in to the mixer machine & mixed thoroughly. Then cement, which is already mixed with Alccofine & fly ash at required proportion, was taken in to the mixer machine with 60% of water + plasticizer. Then mixer was started to revolve for the proper mixing. During this time only, the remaining 40% water + plasticizer were added in the mix. Each layer was tamped 25 times with tamping rod and then vibrated for required time.

After 24 hours of casting, the next day all the cube moulds were opened & concrete cubes were placed in the water tank for curing. The cubes were then tested on the required time period. Before testing, the set of cubes was surface dried in the air. All the cubes were tested on Digital Compression Testing Machine of capacity 2000kN compressive load. Total 117 cubes were casted for this investigation program with different Alccofine and fly ash proportions. The results are tabulated as follows:

TABLE 7: COMPRESSIVE STRENGTH AFTER 7 DAYS, 14 DAYS AND 28 DAYS OF CURING

Mix Notation	Avg. Comp.Strength in Mpa (7 DAYS)	Avg. Comp.Strength in MPa (14 DAYS)	Avg. Comp.Strength in MPa (28 DAYS)
MA	17.44	31.1	43.55
MB	13.55	28.95	37.77
MC	12.95	26.96	35.25
MD	17.47	30.66	42.66
ME	15.25	26.81	39.44
MF	17.92	31.85	49.3
MG	17.47	31.4	41.47
MH	13.92	25.75	35.4
MI	16.59	29.03	44.44
MJ	14.36	28.29	38.36
MK	12.73	28.58	36.73
ML	12.58	27.7	34.21
MM	11.4	26.36	31.55

FIG 1: 28-DAYS COMPRESSIVE STRENGTH (MPA) (WITH WATER CURING)



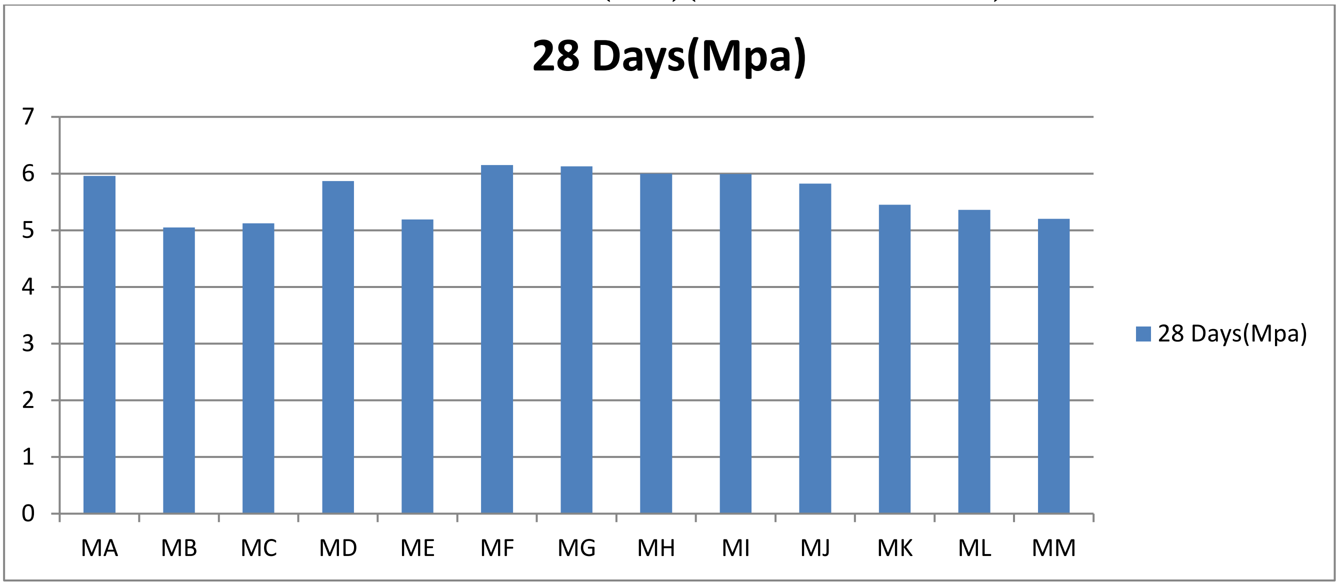
ii. FLEXURAL STRENGTH TEST

The beam flexural strength was made as per the IS: 516-1959 specification, and concrete with different Alccofine and fly ash percentage. For this study, the concrete beams of size 150mm x 150mm x 700mm were prepared. Total 39 nos. of beams were prepared with admixture. Beams were cured for 28 Days time age. The beams were tested on the Universal Testing Machine (UTM). The beams were placed normal to the casting and symmetrical two point system was adopted for the flexural tensile strength test. The results are tabulated as follows:

TABLE 8: TEST RESULTS OF FLEXURAL STRENGTH AT 28 DAYS(MPA)

Mix proportion	MA	MB	MC	MD	ME	MF	MG	MH	MI	MJ	MK	ML	MM
28 Days(Mpa)	5.96	5.05	5.12	5.87	5.19	6.15	6.13	6	5.99	5.82	5.45	5.36	5.2

FIG 2: 28-DAYS FLEXURAL STRENGTH (MPA) (WITH WATER CURING)



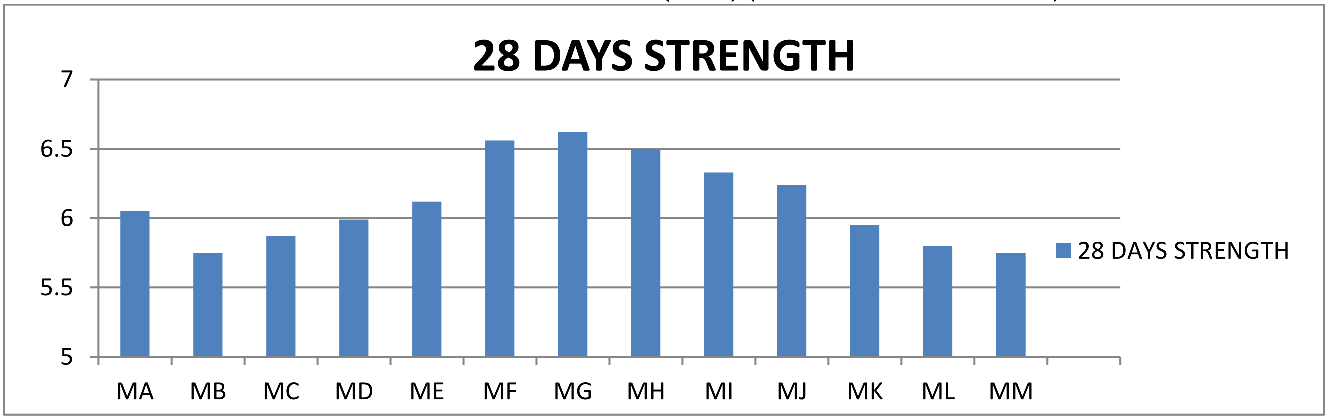
iii. SPLIT TENSILE STRENGTH TEST

The split tensile strength was made as per the IS: 5816-1999 specification, with different Alccofine and Fly ash percentage. For this study the concrete cylinders of diameter 150mm and height 300mm were prepared. Total 39 nos. of cylinders prepared for this test. Cylinders were cured for 28 Days time age. The cylinders were tested on the Compression Testing Machine of capacity 2,000kN. The cylinders were placed horizontally between loading surfaces of compression testing machine and load was applied until failure of cylinder, along the vertical diameter. The results are tabulated as follows:

TABLE 9: TEST RESULTS OF SPLIT TENSILE STRENGTH (MPA)

Mix proportion	MA	MB	MC	MD	ME	MF	MG	MH	MI	MJ	MK	ML	MM
28 days	6.05	5.75	5.87	5.99	6.12	6.56	6.62	6.5	6.33	5.24	5.95	5.8	5.75

FIG 3: 28-DAYS SPLIT TENSILE STRENGTH (MPA) (WITH WATER CURING)



CONCLUSIONS

Looking to the facts, observations and test results obtained from this investigation program, the following conclusions derived

- We concluded that initial compressive strength achieved by using Fly-Ash (22%) and alccofine (8%) is 17 MPa and 49 MPa at 7 and 28 days respectively, but after 28 days strength gain is comparatively less than other.

- After testing the split tensile strength of cylinder we concluded that we are getting tensile strength up to desired limits of 5.24 Mpa - 6.6 MPa in most of the cases, the failure was at 6.56 MPa if Fly-Ash (22%) and alccofine (8%) was taken.
- After testing the flexural strength test of the beam we concluded that we are getting maximum flexural strength of 6.15 MPa and in MF mix.
- GGBS and Fly Ash are industrial waste, harmful for environment. Reuse of these admixtures for strengthening the concrete is a blessing in disguise.

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