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Effect of mineral admixtures on durability properties of concrete

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Abstract: Concrete is an artificial material, which is made up of cement, fine aggregate, coarse aggregate and water. In this paper, an attempt has been made to replace part of cement by Ground Granulated Blast Furnace Slag (GGBS), Fly Ash (FA), Rice Husk Ash (RHA) and Silica Fume (SF) to improve the durability properties of concrete. One of the most requirements of concrete is that it should be durable under certain conditions of exposure. Deterioration can occur in various forms such as alkali- aggregate expansion, freeze-thaw expansion, salt scaling by de-icing salts, shrinkage, attack on the reinforcement due to carbonation, sulphate attack on exposure to ground water, sea water attack, and corrosion caused by salts. Addition of admixtures may control these effects. In this paper, suitable admixtures to improve the durability characteristics and the optimum percentage of replacement of cement by mineral admixtures with various proportions have been studied.

Keywords: *Fly Ash, Silica Fume, Rice Husk Ash, GGBS, Durability, Strength*

Introduction:

Of late, concrete is being used for various purposes to make it suitable for different conditions. In these conditions, ordinary concrete may fail to exhibit the required strength and durability. In such cases, admixture is used to modify the properties of concrete so as to make it more suitable for any situation. Admixtures are used as ingredients of concrete and added to the batch immediately before or during mixing. In view of the global sustainable development, it is imperative that supplementary cementing materials should be used to replace large proportions of cement in the construction industry and must be cost effective as well.

Literature review:

Aquino [1] has made an attempt to study the influence of Silica Fume (SF) and High Reactive Metakaolin (HRM) on the chemistry of Alkali Silica Reaction (ASR) products. He observed that Silica Fume and High Reactive Metakaolin reduce expansion due to ASR. Also, he observed that the calcium content of ASR products is increasing with time in all the samples without mineral admixtures and a lower level of calcium was detected in samples containing mineral admixtures.

Behera. J. P [2] has made an investigation to develop fly ash in activated form. Fly ash was mixed in the ratio of 20%, 30%, 40% and 50% by replacing Portland cement. Different physical properties of the cement thus prepared have been examined. He found that up to 40% fly ash in an activated from can be used for manufacturing blended cement as per Indian standards.

Bush T.D, Hale M.W, Russell et al [3] found that during the early hydration of the slag cement, the Portland cement releases alkali metal ions and calcium hydroxides. The glassy slag structure is broken down and dissolved by the hydroxyl ions. Initially, the reaction of the slag is with alkali hydroxide. Later, the reaction is primarily with calcium hydroxide. As hydration continues long term, the Portland cement continues to precipitate calcium hydroxide and grow rings of calcium silicate hydrate (CSH) inward from the original grain surface. Slag on the other hand, develops more CSH, contributing to strength, density and chemical resistance.

Carlos Videla and Cristian Gaedicke [4] focused on Portland blast furnace slag cement-High Performance Concrete (HPC), with specified 28-day compressive strengths between 60 and 110 MPa. Compressive and Flexural strength, elastic modulus, abrasion resistance and shrinkage properties have been studied. Laboratory test results showed that it is possible to develop a general compressive strength model combining a hyperbolic equation for strength evaluation and an exponential equation for mix design parameters. It was also concluded that the measured moduli of elasticity are lower than the ACI predicted values.

Hani H. Nassif Najim, Nakin Suksawang [5] discussed that the rate of increase of elastic modulus is less than that of compressive strength. The elastic modulus of High Performance Concrete (HPC) using ground granulated blast furnace slag (GGBS) and silica fume increase with age, and the rate of increase becomes less as the concrete approaches the age of 28 days.

Super plasticizers:

CERAPLAST 300 is used to increase the workability of concrete. It is a high range super plasticizing admixture. It complies with IS 9103:1999. It speeds up construction, increases workability and cohesion, aids pumping by reducing line friction and dry packing. Low porosity results in substantially improved water penetration resistance.

Experimental study:
Concrete mix of M30 was used for the experimental investigation. The mix design was done as per IS 10262-2009 guidelines and final mix proportion was obtained as *Cement: FA: CA: Water =1: 1.3: 2.7: 0.42*

Table I: Details of Mix proportion for concrete Mix M30

S. No	Mix Ratio	Notation	Cement (%)	Admixtures (%)			
				FA	GGBS	SF	RHA
1	Control Concrete	M30	100	-	-	-	-
2	FA 20%	FA	80	20	-	-	-
3	GGBS 20%	GGBS	80	-	20	-	-
4	SF10%	SF	90	-	-	10	-
5	RHA 10%	RHA	90	-	-	-	10
6	FA 20%+ RHA 10%	FR	70	20	-	-	10
7	FA 20%+ SF 10%	FS	70	20	-	10	-
8	FA 20%+ GGBS 20%	FG	60	20	20	-	-
9	GGBS20%+ RHA10%	GR	70	20	-	-	10
10	GGBS20%+ SF10%	GS	70	20	-	10	-
11	RHA10%+ SF10%	RS	80	-	-	10	10
12	FA20%+ RHA10% +SF10%	FRS	60	20	-	10	10
13	GGBS20%+ RHA10% SF10%	GRS	60	-	20	10	10
14	FA20%+ GGBS20%+ RHA10%+ SF10%	FGRS	40	20	20	10	10

Water absorption test:
After 28 days of curing, the specimens were taken out from the curing tank and dried for 24 hours. The dried specimens were weighed accurately and noted as dry weight. The dried specimens were immersed in water. Weight of the specimens at pre-determined intervals were taken after wiping the surface with dry cloth. This process was continued for not less than 48 hours or up to constant weight was obtained in two successive observations.

Sulphate attack test:
When concrete is exposed to environment containing aggressive chemicals, it leads to deterioration of concrete which can be assessed in terms of loss of weight of concrete. To study the acid resistance of concrete, the cubes of concrete were cured and then immersed in 3% Na_2SO_4 solution up to 28 days.
After 28 days of immersion, the specimens were taken out and visually observed for the deterioration of the concrete due to sulphate attack. The specimens were weighed once again and the weight is compared with the normal concrete in order to calculate the percentage of loss of weight and also the loss of strength. Figure 1.0 shows the cubes of sulphate attack.

Fig. 1 Cubes after sulphate attack

Chloride attack test:
A non-porous container is selected and chloride solution has been prepared by adding 3.5 % sodium chloride in distilled water. This solution is stirred well so that all the sodium chloride salts get dissolved in the solution. The initial weights of the cubes are found. They are then immersed in a chloride solution. After drying the cubes, the change in weight and also the compressive strength of concrete cubes were found. Figure 2.0 shows the cubes of chloride attack.

Fig. 2 Cubes after Chloride attack

Acid attack test:
The concrete cubes of size 100mm x100mm x100 mm are prepared for various percentages and cured in curing tank for 28 days. After 28 days, all specimens are kept in atmosphere for 2-days for constant weight. Subsequently, the specimens are weighed and immersed in 5% sulphuric acid (H_2SO_4) and 5 % hydrochloric acid (HCl) solution for 28 days. After 28 days of immersion, the specimens are taken out and kept in atmosphere for 2 days for constant weight. After drying, the changes in weight and the compressive strength of concrete cubes was found.

Fig. 3 Cubes after Acid attack

Results of water absorption test:
Table II shows the water absorption test results of average % water absorption of concrete cube specimen of control concrete and binary blended concrete with combination of FA20%+RHA10% and FA20%+SF10%.

Table II: Average Percentage of Water Absorption

S. No	Mix	Average % Water Absorption
1	M30	3.38
2	FR	2.25
3	FS	1.50

Results of Sulphate attack test:
Table III and IV show the sulphate attack test results of average % loss in weight and % loss in strength of concrete
cube specimen of control concrete and binary blended concrete with combination of FA20%+ RHA10% and FA20%+SF10%.

Table III: Average Percentage Loss in Weight of Sulphate Attack Test

S. No	Mix	Average % Loss in weight (%)
1	M30	3.38
2	FR	2.29
3	FS	1.52

Table IV: Percentage Loss in Strength of Sulphate Attack Test

S. No	Mix	Strength (N/mm^2)		% Loss in strength
		Before attack	After attack	
1	M30	33.33	30.14	9.50
2	FR	45.00	41.32	8.20
3	FS	58.50	52.40	7.40

Results of chloride attack test:
Table V and VI show the chloride attack test results of average % gain in weight and % loss in strength of concrete cube specimen of control concrete and binary blended concrete with combination of FA20% + RHA10% and FA20% + SF10%.

Table V: Average Percentage Gain in Weight of Chloride Attack Test

S. No	Mix	Average % Gain in Weight
1	M30	2.19
2	FR	0.67
3	FS	0.95

Table VI: Percentage Loss in Strength of Chloride Attack Test

S. No	Mix	Strength (N/mm^2)		% Loss in Strength
		Before attack	After attack	
1	M30	33.33	31.00	6.99
2	FR	45.00	42.91	4.64
3	FS	58.50	56.40	3.59

Results of acid attack test:
Table VII and VIII show the acid attack test results of average % loss in weight and % loss in strength of concrete cube specimen of control concrete and binary blended concrete with combination of FA20%+RHA10% and FA20%+SF10% when immersed in H_2SO_4 solution and HCl solution.

Table VII: Average Percentage Loss in Weight of Acid Attack Test

S. No	Mix	Average % Loss in Weight (%)	
		H_2SO_4 solution	HCl solution
1	M30	3.38	3.38
2	FR	3.21	3.09
3	FS	2.84	2.66

Table VIII: Percentage Loss in Strength of Acid Attack Test

S.No	Mix	Strength (N/mm^2)			% Loss in Strength	
		Before attack	After attack		H_2SO_4 solution	HCl solution
			H_2SO_4	HCl		
1	M30	33.33	30.14	30.43	9.57	8.7
2	FR	45.00	42.22	42.38	6.18	5.83
3	FS	58.50	54.55	55.74	5.90	4.72

Discussion of test results:

The blended admixture is an alternative material to cement in the production of durability concrete. The technical and economical advantages of blended concrete have been discussed with the help of test results of strength and durability.

The test results show that the early age strength of blended concrete is lower than the Ordinary Portland Cement concrete due to the slow rate of hydration.

However, the rate of hydration is influencing the strength development of blended concrete after 28 days. Among the blended concrete, the strength in binary blended combination of FA20%+RHA10% and FA20%+SF10% are found higher than other blended combinations. Therefore, binary blended combination of FA20%+RHA10% and FA20%+SF10% seem to be the optimum replacement in the investigation.

Conclusion:

An experimental study has been carried out to find out the durability properties of concrete with and without mineral and chemical admixtures. Based on the experimental study, following conclusions have been drawn.

The combination of rice husk ash and silica fume shows lower result than the control concrete due to inherent chemical reactions. The binary blended admixture concrete [with FA20%+SF10%] shows good resistance to sulphate attack, chloride attack and acid attack than the control concrete.

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