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Use of Ultrafine Slag in High Strength Concrete

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Abstract: ***This paper presents the effect of Ultrafine Slag in high strength concrete with cement replacement of 5%, 10%, 15% and 20%. Nowadays high strength concrete generally made with Ordinary Portland Cement. In this investigation Portland Pozzolana Cement (PPC) Fly ash based was used to make concrete more environmental friendly. In this experiment five mixes were prepared in which one mix was controlled with plain PPC and four mixes were prepared with 5, 10, 15 and 20% cement replacement by ultrafine slag (Alccofine 1203). Thus result shows that due to unique particle size distribution of Ultrafine slag forms dense pore structure which results in improved flowability at reduced admixture dosage, improved early strength and compressive strength at all ages in comparison to control PPC mix.***

Keywords: High Strength Concrete, Ultrafine Slag, Alccofine 1203, Flowability, Compressive Strength

1. Introduction

High Strength Concrete has gained an immense popularity nowadays due to vertical growth and rise in construction industry.In spite of the fact that highstrength or high performance concrete is many a time considered a relatively new material, its development has been gradual over many years. As the development has continued, the definition of high-strength concrete has changed. Earlier, concrete with compressive strength more than of 40 MPa was available at only a few locations. However, in recent years, the applications of high-strength concrete have increased, and high-strength concrete has now been used in many parts of the world. The growth has been practicable as a result of recent developments in construction industries, material technology and a demand for higher-strength or high performance concrete. [3]

The production of 1 Tonne of Portland Cement results in an equal amount of CO_2 emission into the atmosphere which is a major cause for greenhouse effect. So the use of mineral admixtures such as Fly ash, Ground Granulated Blast Furnace Slag, Micro Silica in concrete as a partial replacement of cement reduces the burden of greenhouse effect, save energy and conserves natural resources.Ground Granulated Blast furnace Slag is a by-product of manufacture of pig iron and non-metallic product consisting essentially of silicates and aluminates of calcium and other bases. The molten slag is rapidly chilled by quenching in water to form a glassy sand like granulated material. The various mineral admixtures affect the progress of hydration in consequence of their chemical composition, reactivity, particle size distribution, and particle shape. The actual reactivity of GGBS depends on its composition, glass content and particle size. The presence of GGBS in the mix improves workability and makes the mix more mobile but cohesive. This is the consequence of a better dispersion of the cementitious particles and of the surface characteristics of the GGBS particles, which are smooth and absorb little water during mixing. The granulated slag can be ground to a fineness of any desired value but usually greater than $3500cm^2/gm$ i.e. finer than Portland cement. Increased fineness leads to increased activity at early ages. [4]

In this experiment Ultrafine Slag (Alccofine 1203) of blain value 12000 cm^2/gm was used. It is a product based on slag of high glass content with high reactivity obtained through the process of controlled granulation.This paper presents the effect of Ultrafine Slag in high strength concrete on its rheological as well as on hardened properties of concrete with cement replacement of 5%, 10%, 15% and 20%. Nowadays high strength concrete generally made with Ordinary Portland Cement. In this investigation Portland Pozzolana Cement (PPC) Fly ash based was used to make concrete more environmental friendly.

2. Material

2.1 Cement

The Portland Pozzolona Cement (PPC) Fly ash based manufactured byAmbuja Cement was used in this experiment. The characteristics and properties of PPC as per the requirement of IS 1489 (Part I): 1991 are listed in the Table1 shown below:

Table 1: Characteristics of PPC

Characteristics	*Test Results*
Specific Gravity	2.90
Standard Consistency	31 %
Fineness :Specific Surface (m^2/kg)	391.4
Initial Setting Time (Minute)	140
Final Setting Time (Minute)	225
Percentage of Fly ash	30.57

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2.2 Ultrafine Slag (Alccofine 1203)

The Ultrafine Slag "Alccofine 1203" used in this experiment was obtained from CountoMicrofine Products Pvt. Ltd., Goa. The characteristics of Ultrafine Slag are listed in the Table No. 2 shown below:

Table 2: Characteristics of PPC

Physical Characteristics	
Test	*Result*
Bulk Density	670 Kg/m^3
Fineness (Surface Area)	12000 cm^2/gm
Particle Shape	Irregular
Particle Size, d_{10}	1.7 µm
d_{50}	4.3 µm
d_{90}	8.7 µm
Chemical Characteristics	
CaO	33.9%
Al_2O_3	22.6%
Fe_2O_3	1.4%
SO_3	0.23%
MgO	7.8%
SiO_2	32.8%

2.3 Aggregate

Locally available crushed coarse aggregate of 20 mm and 10mm with specific gravity of 2.67 was used in respective proportions. The fine aggregate was natural sand of specific gravity 2.63 confirming to Zone-II of table of IS-383-1970.

2.4 Water

The potable water used for drinking was used in the experiment. The pH value of water was 7.3 and as per standard the pH of water shall be between 6 to 8.

2.5 Chemical Admixture

The superplasticizerpolycarboxylate ether (PCE) based chemical admixture was used in the experiment. The specific gravity of the superplasticizer was 1.10.

3. Test Procedure

The drum type mixture was used for mixing of concrete. The vibrating table was used for the compaction. The surface of the concrete was levelled and the cubes were demoulded after one day of casting. After demoulding, cubes were kept in curing tank for wet curing.

A total 75 numbers of cube of size 150mm x 150mm x 150mm were investigated. The water-binder ratio was kept constant as 0.29 in all the mix. The control mix with 0% replacement was compared with different replacement percentage of 5, 10, 15 & 20% of PPC by Ultrafine Slag. The blaine value of Ultrafine Slag "Alccofine 1203" used was 12000 cm^2/gm. The compressive strength of cubes was tested at 3, 7, 28 & 90 days. The averages of 3 cubes were taken as the compressive strength. The concrete mix proportions calculated as per IS-10262 are shown in the Table 3.

Table 3: Mix Proportions in Kg/m^3

Replacement	*Cement (PPC)*	*UFS*	*Water*	*CA 20mm*	*CA 10mm*	*FA*
0%	500	0	145	645	430	714
5%	475	25	145	645	430	714
10%	450	50	145	645	430	714
15%	425	75	145	645	430	714
20%	400	100	145	645	430	714

For acid resistant test, 15 nos. of cube specimen were immersed in 5% H_2SO_4 solution after 28 days of wet curing. The solution was changed periodically and solution stirred regularly. At 90 days the weight and compressive strength was checked. The percentage reduction of weight and strength change was calculated by comparing normal curing cube with cube in H_2SO_4 solution.

4. Experiment Result & Analysis

4.1 Fresh Properties of Concrete

In the present study it is concluded that with the increase of percentage replacement of cement with ultrafine slag, the use of superplasicizer admixture dosage get reduced. The control mix of 0% replacement requires more dose of superplasticizer as compared to inclusion of ultrafine slag in themix for almost same flowability. The flow at different percentage replacement are given in Table 4 below:

Table 4: Flow in mm

Replacement	*Admixture Dose*	*Slump Flow w.r.t Time in mm*		
		0 min	*30 min*	*60 min*
0%	1.2%	690	680	650
5%	1.2%	690	680	660
10%	1.15%	710	690	670
15%	1.1%	720	710	690
20%	1.1%	720	710	700

The comparision between admixture doses at different percentage replacement are shown in Figure 1 below:

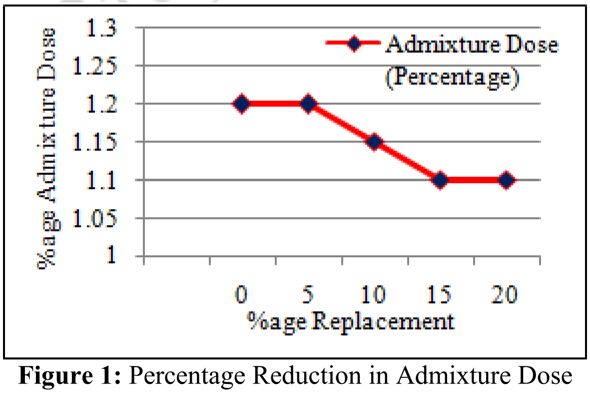

Figure 1: Percentage Reduction in Admixture Dose

This happens may be due to filling of pore spaces between cement by ultrafine slagby which the water in between the pore spaces expelled out thus increased the flowability of the mix and makes the concrete more cohesive. It improves the particle packing in the cementitious paste resulting in better flowability at low admixture dosage compared to control mix.

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4.2 Compressive Strength of Concrete

The compressive strength of specimens cube are given in Table 5 and it can be concluded by comparing control mix with ultrafine slag replacement mix that at every age the ultrafine slag mix has achieved higher strength than control mix.

Table 5: Compressive Strength

Days	*Compressive strength in N/mm² at different Replacement Percentage*				
	0	*5*	*10*	*15*	*20*
3	37.2	44.2	46.3	49.8	52.7
7	56.3	60.8	61.2	63.8	69.9
28	77.5	79.6	80.8	81.5	85.1

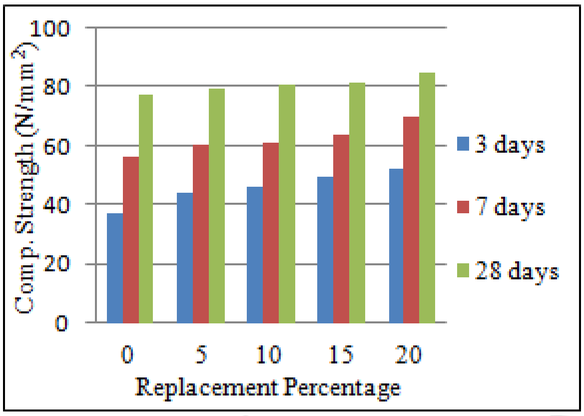

Figure 2: Strength Comparison Bar Chart

The 20 % replacement achieved higher strength as compared to other replacement. Thestrength gain may be due to high content of CaO in Ultrafine slag and it reacts both in pozzolanic and hydraulic manner which results in denser pore structure and high strength. It is also concluded that ultrafine slag mix exhibits early age strength as compared to control mix.

Concrete with Ultrafine Slag shows a higher early strength at every percentage replacement. The final strength is also more than the PPC concrete. At 3 days 20% replacement mix exhibits 29% more compressive strength than PPC concrete.

4.3 Acid Resistant Test of Concrete

After 28 days of wet curing the cubes were immersed in 5% H_2SO_4 solution. At 90 days the cubes were checked for weight and compressive strength. The percentage reduction was calculated comparing the cube under normal curing to the cube under H_2SO_4solution. The weight change of control PPC mix was more than the other mixes at every percentage replacement with UFS. There was 1.92 % of weight reduction in control mix, 1.69 % weight reductions in mix with 5% UFS and almost 1.08% weight reduction upto20% replacement of PPC with UFS.The compressive strength of acid resistant test in comparison to controlled mix and their percentage weight & strength reductions are given in Table 6 below:

Table 6: Acid Resistant Test Result

Replacement	*Compressive Strength in N/mm²*		*%age weight reduction*	*%age Strength reduction*
	90 days Control	*90 days H_2SO_4 solution*		
0%	89.20	83.40	1.92	6.50
5%	90.60	84.80	1.69	6.40
10%	91.30	85.70	1.08	6.13
15%	96.40	92.20	1.08	4.36
20%	98.10	95.10	1.08	3.06

It is clear from the result that strength of concrete decreases when exposed to H_2SO_4 solution. The strength reduction in control PPC mix was 6.5 % at 90 days and strength reduction percentage reduces as the percentage replacement increases. At 20% UFS the strength reduction was 3.06 %. Thus experiment shows that concrete with UFS are more resistance to acid attack than the concrete with only PPC.

The result also shows that concrete with UFS at every replacement percentage under normal curing depicts higher compressive strength than control PPC mix.

5. Conclusion

1) Ultrafine Slag (Alccofine 1203) performs in superior manner when used in concrete. Due to its inbuilt CaO content it has two way reactions during hydration: Primary reaction of cement hydration and pozzolanic reaction in which it consumes by product of calcium hydroxide from hydration of cement to form Calcium Silicate Hydrate (CSH) gel similar to pozzolans.
2) Hence with the use of Ultrafine Slag (UFS) results in denser pore structure & better particle packing and ultimately gain higher early strength and improved strength at all ages. So UFS can be used in concrete for high early strength and it is best microfine material for precast industries.
3) It is also concluded that with the inclusion of UFS in concrete, admixture dose reduce. This happens may be due to filling of pore spaces between cement by UFS which expels out the extra water from thepore spaces resulting in better flowability at low admixture dosage compared to control mix.
4) The experiment shows that concrete with UFS are more resistance to acid attack than the concrete with only PPC.
5) Use of UFS in concrete reduces the burden of greenhouse effect, save energy and conserves natural resources. In PPC fly ash is almost 30% and with the inclusion of UFS may lead to achieve green concrete.

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