

Enhancement Of Properties of Concrete by Optimizing the Proportions of Hybrid Mineral Admixtures and Sugarcane Bagasse Ash

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Abstract - concrete is the most widely used construction material in India with annual consumption exceeding 100 million cubic meters. It is well known that conventional concrete designed on the basis of compressive strength does not meet many functional requirements such as impermeability, resistance to frost, thermal cracking adequately.

The production of the Portland cement as a main constituent of concrete has basically led to the dangerous impacts on our environment by releasing substantive amount of CO₂. Production of one ton of Portland cement emits one ton of CO₂ and other greenhouse gases. Hence the cement must be effectively replaced by some other cementitious materials without compromising the desired properties of concrete.

The coal based power plant generates a huge amount of fly ash which is collected from electrostatic precipitator and Silica fume is a by-product of producing silicon metal or ferrosilicon alloys in smelters using electric arc furnaces. Disposal of these wastes may require huge land surface or any water bodies which in turn affects the environment, so recycling of these waste is indeed required.

The purpose of this study is to find the suitability of Fly Ash and Silica Fume as hybrid admixture replacement materials for cement without compromising the strength & durability of conventional cement based hybrid concrete. Replacement of cement partially by Fly Ash and Silica Fume also reduces the supply demand on cement and may also reduce the emission of CO₂ in to atmosphere.

The physical and chemical properties of Fly Ash and Silica Fume has been studied and both the industrial wastes are used to replace the cement at 25%F.A-5%S.F, 20%F.A,10%S.F,15%F.A-15%S.F and 10%F.A-20%S.F. And sugarcane bagasse ash used ratios were 10%, 15%, 20% and 25%. These specimens will be tested for its mechanical properties such as compressive strength, split tensile strength and flexural strength on 7, 28 & 90 days and durability properties like acid attack, sulphate attack, acid attack and water permeability.

After determining the properties of the concrete mixes, the optimum percentage of replacement levels of Fly Ash, Silica

Fume and sugarcane baggage ash will be found out for the optimized concrete Mix..

Key Words: Fly Ash, Silica Fume, sugarcane baggage ash, Hybrid Mineral Admixtures

1.INTRODUCTION

Concrete is considered to be very durable material that requires little or no maintenance. Concrete is a mixture of cement, fine aggregate, coarse aggregate and water. Concrete plays a vital role in the development of infrastructure viz., buildings, industrial structures, bridges and highways etc., leading to utilization of large quantity of cement and fine aggregate. Portland cement, already being a very expensive material constitutes a substantial part of the total construction cost of any project and the situation has further been aggravated by the energy crisis, which has further increased the cost of production of Portland cement.

Cement is the main constituent of the concrete which plays an important role in the life of the structure but due to the production of cement more amount of CO₂ is emitted which results in global warming.

The lower cement requirement also leads to a reduction of CO₂ generated by the production of cement. So, research steps have been taken to use mineral admixtures such as fly ash, Metakolin and silica fume in concrete as a replacement for cement because they improve durability, reduce porosity and improve the interface with the aggregate.

An important process in the concrete mixing is the formation of C-S-H gel which is primarily due to the addition of cement. The hydration of the Portland cement results from the production of Portlandite crystal [Ca(OH)₂] and amorphous calcium silicate hydrate gel [C₂S₂H₃] (C-S-H) in large amounts.

The Ca(OH)₂ which appears as the result of the chemical reactions affect the quality of the concrete adversely by forming cavities as it is partly soluble in water and lacks enough strength. The use of ground granulated blast-furnace slag has a positive effect on binding the Ca(OH)₂ compound, which decreases the quality of the concrete. At the end of the

reaction of the slag and $\text{Ca}(\text{OH})_2$, hydration products, such as $\text{C}-\text{S}-\text{H}$ gel is formed..

2.PROPERTIES OF MATERILAS USED

2.1Cement

Ordinary Portland cement of 43 grade confirming IS 8112 : 1989 was used in the experimental work and properties as mentioned in the table below. The brand used is Dalmia cements obtained from the Salem locality.

Table: 1 Properties of Cement

S.No	Types of Test	Values obtained
1	Standard Consistency Test	31%
2	Specific Gravity	3.15
3	Fineness test	2%
4	Initial Setting Time	32min
5	Final Setting Time	260min
6	Soundness	3mm

2.2. Fly Ash

The fly ash used in project is C lass F and was obtained from Mettur Thermal Power Station which is located in Salem district (T.N), India. The test results conducted on fly ash are reported below.

Table: 2 Properties of Fly Ash

S.No	Characteristics	Values obtained
1	Class	F
2	Specific gravity	2.23
3	Colour	Grey
4	Moisture content	Nil

2.3. Silica Fume

Silica Fume used was confirming to ASTM-C(1240- 2000) and was supplied by —ELKEM INDUSTRIESI was named Elkem- micro silica 920D. The Silica Fume is used as a partial replacement of cement. The properties of silica fume are shown below.

Table: 3 Properties of Silica Fume

S.No	Characteristics	Silica Fume
1	Specific Gravity	2.
2	Bulk Density	576,(Kg/m ³)
3	Size	0.1
4	Surface Area(m ² /kg)	20,000
5	Moisture content	Nil
6	Sio ₂	(90-96)%
7	Al ₂ O ₃	(0.5-0.8)%

2.4.Fine Aggregate

The sand used for the experimental programme was locally procured and conformed to grading zone II as per IS: 383 (1970).The sand was first sieved through 4.75mm sieve to

remove any practices greater than 4.75mm and then was washed to remove the dust. Properties of the fine aggregates used in the experimental work are tabulated below.

Table: 4 Properties of Fine Aggregate

S.No	Characteristics	Results
1	Grading Zone	Zone II
2	Specific Gravity	2.47
3	Water absorption	0.5%
4	Fineness Modulus	2.1
5	Moisture Content	Nil

2.5.Coarse Aggregate

In the present investigation, crushed hard blue granite aggregates were obtained from the locally available and approved quarries were used. Testing was done on the aggregates and the results were tabulated.

Table: 5 Properties of Coarse aggregate

S.No	Characteristics	Coarse Aggregate
1	Type	Crushed
2	Maximum size	20mm
3	Specific gravity	2.7
4	Total water adsorption	0.3%
5	Fineness Modulus	2.39
6	Impact value	13%
7	Crushing value	8%

2.6.Sugarcane bagasse ash

The bagasse was obtained from juice extractors factories, where the sugarcane bagasse waste is washed in a tank with water and then dried by placing it in the sun. Then, it was left to burn completely in air up to 600 °C until it is converted totally to ashes; then, the ashes were placed in an oven and heated up to 200 °C; then, the temperature was maintained for 2 h to get rid of the remaining organic matters (carbon). After the ash was taken out of the oven, it was ground in a grinder to obtain finer particles.

Table: 6 Properties of Sugarcane bagasse ash

S.No	Characteristics	Sugarcane bagasse ash
1	Specific Gravity	2.14
2	Fineness(m ² /kg)	310
3	Colour	Light grey

2.7. Water

Potable tap water available in laboratory with pH value 6 to 8 and conforming to the requirements of IS: 456-2000 is used for mixing concrete and curing the specimens as well.

3.MIX DESIGN

The concrete mix is designed for **M30** Grade of concrete as per IS 10262 – 1982, IS 456- 2000 and SP 23 for the conventional concrete and finally cement has been replaced by Fly Ash and Silica Fume by volume.

Table: 7 Trial Mix

Trial	Cement (kg/m ³)	Sand (kg/m ³)	Coarse Aggregate (kg/m ³)	Water (kg/m ³)	w /c
1	410	668.3	1244.35	176.3	0.43
2	370	603.1	1122.95	159.1	0.43
3	390	635.7	1183.65	167.7	0.43

SELECTION OF CONTROL MIX

Table: 8 Selection of control mix

Trial	Mix proportion	Average compressive strength (N/mm ²)
1	1: 1.63: 3.035: 0.43	41.856
2	1: 1.63: 3.035: 0.43	36.624
3 (control)	1: 1.63: 3.035: 0.43	38.804

3.NUMERICAL RESULTS

Results of fresh and hardened concrete with partial replacement of fly ash and silica fume are discussed below for various trial mixes and the control mix was selected. The optimum percentage of Fly Ash and Silica Fume was found by replacing the cement by 25%, 20%, 15%, 10% of Fly Ash and 5%, 10%, 15%,20% of Silica Fume.

Mix Designation

M0 – Control Mix

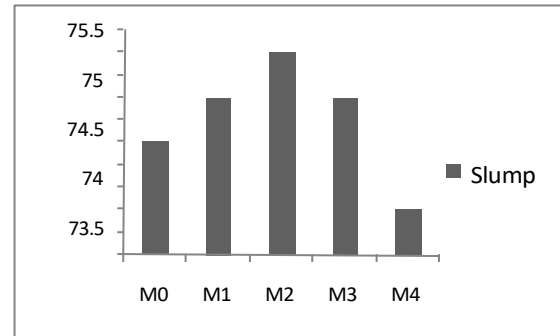
M1 – 25% Fly Ash and 5% Silica Fume

M2 – 20% Fly Ash and 10% Silica Fume

M3 – 15% Fly Ash and 15% Silica Fume

M4 – 10% Fly Ash and 20% Silica fume

3.1.Slump Value



3.2. Compressive Strength Results

The compressive strength is tested for the nominal concrete and different proportions of fly ash and silica fume. The test was carried out conforming to IS 516 - 1959 to obtain compressive strength of concrete at the age of 7, 28 and 90 days. . Cubes were casted in the size 150 x 150 x 150 mm. The results of compressive strength were presented in Table 8. The cubes were tested using Compression Testing Machine (CTM) of capacity 100 Tonnes.

Table: 9 Compressive Strength Results

S.NO	FLY ASH %	SILICA FUME %	Compressive strength (N/mm ²)		
			7 days	28 days	90 days
1	0	0	30.74	38.804	42.36
2	25	5	22.1	32.09	38.23
3	20	10	27.04	39.96	44.83
4	15	15	26.75	38.53	42.11
5	10	20	23.95	33.36	39.18

3.3.Flexural Test Results

Flexural strength test were performed on the prism of size 500 x 100 x 100 mm. The results of flexural strength were presented in Table10. The test was carried out conforming to IS 516-1959 to obtain Flexural strength of concrete at the age of 28 days. The prism were tested using Universal Testing Machine (UTM) of capacity 100 tonnes .

S.NO	FLY ASH %	SILICA FUME %	Flexural strength (N/mm ²) 28 days
1	0	0	4.32
2	25	5	4.22
3	20	10	5.93
4	15	15	5.57
5	10	20	4.19

3.4. Acid attack test

The concrete cubes of size 150mm x150mm x150 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 (H₂SO₄) and 5 % hydrochloric acid (HCl) solution for 28 days. After 28 days of immersion, the specimens are taken out and kept in the atmosphere for 2 days for constant weight. After drying, the changes in weight and the compressive strength of concrete cubes was found.

Table: 11 Average percentage Loss in weight of Acid attack

S.NO	FLY ASH %	SILICA FUME %	Average % Loss in Weight	
			H ₂ SO ₄ Solution	HCL Solution
1	0	0	3.31	3.21
2	25	5	3.51	3.43
3	20	10	2.17	2.37
4	15	15	2.45	2.67
5	10	20	2.97	3.17

Table: 12 Percentage loss in Strength of acid attack

S.No	FLY ASH %	SILICA FUME %	Strength (N/mm ²)		
			Before attack	After attack	
				H ₂ SO ₄	HCL
1	0	0	38.804	35.67	35.97
2	25	5	32.09	30.12	30.87
3	20	10	39.96	38.67	38.90
4	15	15	38.53	36.56	36.89
5	10	20	33.36	31.10	31.65

3.5. Compressive Strength Result of SCBA

The results of compressive strength of concrete at 7 and 28days with (10%, 15%, 20%, and 25%) and without (0%) Sugarcane bagasse ash are given in table table13. Compressive strength of concrete increased up to 15% replacement of cement by sugarcane bagasse ash in concrete compare to concrete without Sugarcane bagasse ash at 7 and 28 days.

Table: 13 Compressive Strength Results

% of replacement of cement by SBCA	Compressive strength in N/mm ²	
	7DAYS	28DAYS
0%	29.14	37.7
10%	25.22	35.14
15%	24.7	34.5
20%	20.51	30.51
25%	19.41	28.65

4. CONCLUSIONS

The following conclusions are drawn from the following study

- The Mix F.A20 – S.F10 found to be more optimized when compared to that of conventional concrete.
- Addition of Fly Ash reduces the initial setting time for concrete but the addition of silica fume tends to increase the setting time to a certain extent.
- Workability of concrete decreases with increase in silica fume.
- The durability test analysis shows that the addition of fly ash and silica fume will have greater resistance to acid attack, which is given in the above result.
- Workability of concrete decreased with increasing % of sugarcane bagasse ash in concrete.
- Usage of fly ash, silica fume and sugarcane bagasse ash will helps to control the environmentally disposed materials.
- Strength and flexural strength of both the conventional mix and the replaced mix were compared.
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- Compressive strength of concrete increased up to 20% replacement of cement by Sugarcane bagasse ash in concrete compared to concrete without Sugarcane bagasse ash at 7 and 28 days

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