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STUDY ON THE ENHANCEMENT OF THE PROPERTIES OF CONCRETE BY OPTIMIZING THE PROPOTIONS OF HYBRID MINERAL ADMIXTURES

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Abstract

Since advent of civilization various types of cementitous materials have been used for constructiuon practices. The arrival of Ordinary Portland Cement changed the construction activities completely. However, because of several drawbacks associated with properties of cement and manufactured building materials using OPC as well as the cost factor attempts one mode to utilize other materials for economical constructions and improved mortar and concrete characteristics. Now attempts were made to utilize these waste materials or industrial byproducts in construction activities to solve the environmental pollution problems, and safer and economical construction.

In this paper Fly Ash and Silica Fume has been used as a hybrid mineral admixture as a replacement material for cement..The physical and chemical properties of Fly Ash and Silica Fume has been studied and these materials are replaced for cement by the following proportions 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. Specimens have been casted to determine the mechanical properties such as compressive strength, split tensile strength and flexural strength to find out the optimum proportions of the admixture and durability properties like acid attack, sulphate attack and chloride attack to find out the resistance offered by the mineral admixtures in concrete which can undergo deterioration due to various salts.

Keywords: Silica fume, Fly ash, Compressive strength, Split tensile strength, Flexural Srength,Acid attack, Sulphate attack.

1. INTRODUCTION

1.1 General

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. Therefore, it is of current important for a country to explore and develop cementing materials cheaper than 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 CO_2 is emitted which results in global warming. It was observed and noted that since decade of years that the cost of building materials is currently so high that only corporate organizations, individual, and government can afford to do meaningful construction. Waste can be used as filler material in concrete, admixtures in cement and raw material in cement clinker, or as aggregates in concrete . Ordinary Portland cement (OPC) is acknowledged as the major construction material throughout the world.. Industrial wastes, such as silica fume, blast furnace slag, fly ash are being used as supplementary cement replacement materials and recently, agricultural wastes are also being used as pozzolanic materials in concrete .

When pozzolanic materials are incorporated to concrete, the silica present in these materials react with the calcium hydroxide released during the hydration of cement and forms additional calcium silicate hydrate (C – S – H), which improve durability and the mechanical properties of High strength and high performance concrete. High strength concrete means good abrasion, impact and cavitations resistance.

1.2. Fly Ash

Fly ash, also known as "pulverized fuel ash" in the United Kingdom, is one of the residues generated by coal combustion, and is composed of the fine particles that are driven out of the boiler with the flue gases. Two classes of fly ash are defined by ASTM C618: Class F fly ash and Class C fly ash. The chief difference between these classes is the amount of calcium, silica, alumina, and iron content in the ash. The chemical properties of the fly ash are largely influenced by the chemical content of the coal burned.

Fly ash could be used as prime material in blocks, paving or bricks, however, on the most important applications is PCC pavement. PCC pavements use a large amount of concrete and using fly ash provide great economic benefits. Coal-fired power plants produce fly ash, providing an excellent prime material used in blended cement, mosaic tiles, and hollow blocks among others. Fly ash has also been used recently for paving roads, and as embankment and mine fills.

1.3. Silica Fume

The American Concrete Institute(ACI) defines silica fume as "very fine non-crystalline silica produced in electric arc furnaces as a by-product of the production of elemental silicon or alloys containing silicon". It is usually a gray coloured powder, somewhat similar to Portland cement or some fly ashes. Silica fume is usually categorized as a supplementary cementitious material.

Silica fume is added to Portland cement concrete to improve its properties, in particular its compressive strength, bond strength, and abrasion resistance. These improvements stem from both the mechanical improvements resulting from addition of a very fine powder to the cement paste mix as well as from the pozzolanic reactions between the silica fume and free calcium hydroxide in the paste. Addition of silica fume also reduces the permeability of concrete to chloride ions, which protects the reinforcing steel of concrete from corrosion, especially in chloride-rich environments such as coastal regions and those of humid continental roadways and runways and saltwater bridges.

2. PROPERTIES OF MATERIALS USED

2.1 Cement

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.

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

Table: 1 Properties of Cement

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

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

Table: 2 Properties of Fly Ash

2.3. Silica Fume

Silica Fume used was confirming to ASTM-C(1240-2000) and was supplied by “ELKEM INDUSTRIES” 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.

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_2O_3	(0.5-0.8)%

Table: 3 Properties of Silica Fume

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.

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

Table: 4 Properties of Fine Aggregate

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.

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%

Table: 5 Properties of Coarse aggregate

2.6 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.

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 repaced by Fly Ash and Silica Fume by volume.

Trial	Cement (kg/m^3)	Sand (kg/m^3)	Coarse Aggregate (kg/m^3)	Water (kg/m^3)	w/c ratio
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

Table: 6 Trial Mix

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

Table: 7 Selection of control mix

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

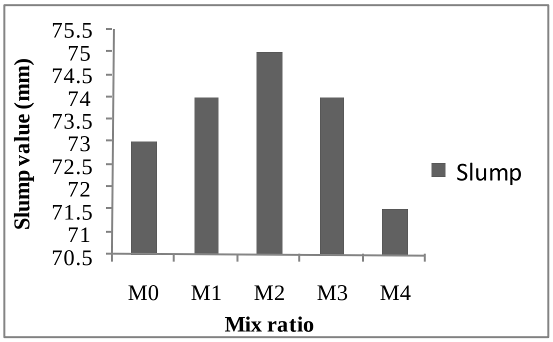

Figure: 1 Slump Values for different percentage of Fly Ash and Silica fume added to concrete

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.

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

Table: 8 Compressive Strength Results

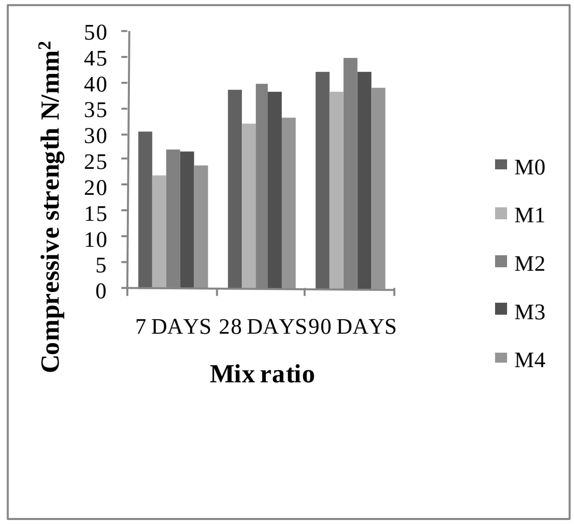

Figure: 2 Compressive Strength Values for different percentage of Fly Ash and Silica fume added to concrete

3.3 Split Tensile Test Results

The results of Split Tensile strength were presented in Table 9. The test was carried out conforming to IS 516-1959 to obtain Split tensile strength of concrete at the age of 7 and 28 days. The cylinders were tested using Compression Testing Machine (CTM) of capacity 100 tonnes.

S.NO	FLY ASH %	SILICA FUME %	Split tensile Strength (N/mm^2)	
			7 days	28 days
1	0	0	2.35	3.21
2	25	5	2.22	3.25
3	20	10	2.17	3.80
4	15	15	2.035	3.60
5	10	20	1.66	2.99

Table: 9 Split Tensile Test Results

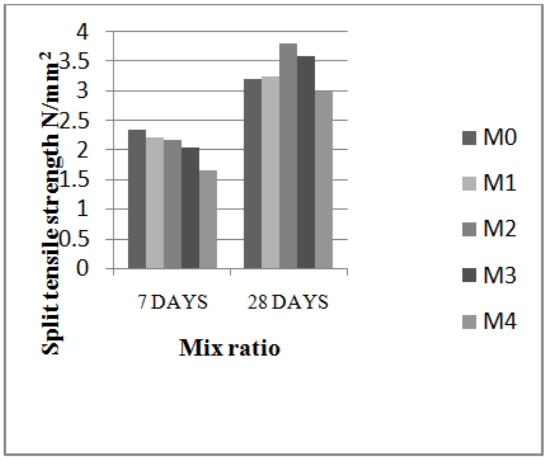

Figure: 3 Split Tensile Strength Values for different percentage of Fly Ash and Silica fume added to concrete

3.4 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 .

Figure: 4 Flexural Strength Test

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

Table: 10 Flexural Strength Test

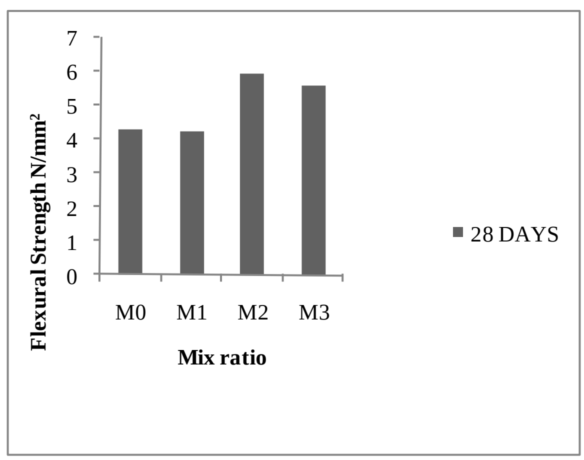

Figure: 5 Flexural Strength Values for different percentage of Fly Ash and Silica fume added to concrete

3.5 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: 6 Sulphate Attack Test

S.NO	FLY ASH %	SILICA FUME %	Average % Loss in weight
1	0	0	3.42
2	25	5	3.11
3	20	10	1.52
4	15	15	1.55
5	10	20	1.97

Table: 11 Average percentage loss in weight of sulphate attack

S.No	FLY ASH %	SILICA FUME %	Strength (N/mm^2)		% Loss in strength
			Before attack	After attack	
1	0	0	38.804	34.37	11.42
2	25	5	32.09	27.45	14.46
3	20	10	39.96	36.87	7.73
4	15	15	38.53	35.87	8.12
5	10	20	33.36	28.21	15.43

Table: 12 Percentage loss in Strength of sulphate attack

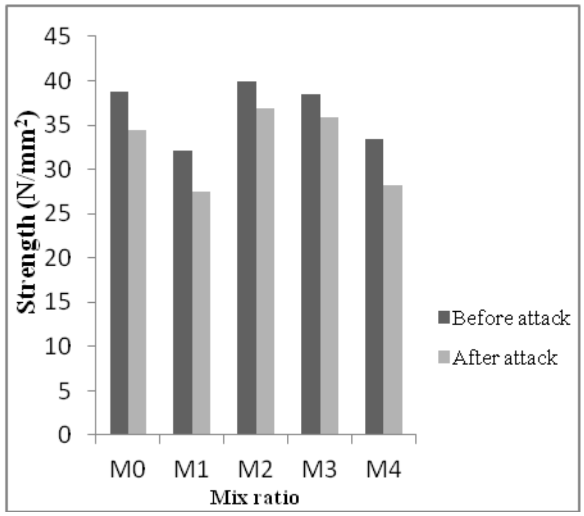

Figure: 7 Strength of Sulphate Attack

3.6 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.

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Figure: 8 Chloride Attack Test

S.NO	FLY ASH %	SILICA FUME %	Average % Gain in weight
1	0	0	2.25
2	25	5	1.98
3	20	10	0.97
4	15	15	0.98
5	10	20	1.87

Table: 13 Average percentage Gain in weight of chloride attack

S. NO	FLY ASH %	SILICA FUME %	Strength (N/mm^2)		% Loss in strength
			Before attack	After attack	
1	0	0	38.804	35.98	7.27
2	25	5	32.09	29.95	6.66
3	20	10	39.96	38.12	4.60
4	15	15	38.53	36.45	5.11
5	10	20	33.36	31.27	6.26

Table: 14 Percentage loss in Strength of Chloride attack

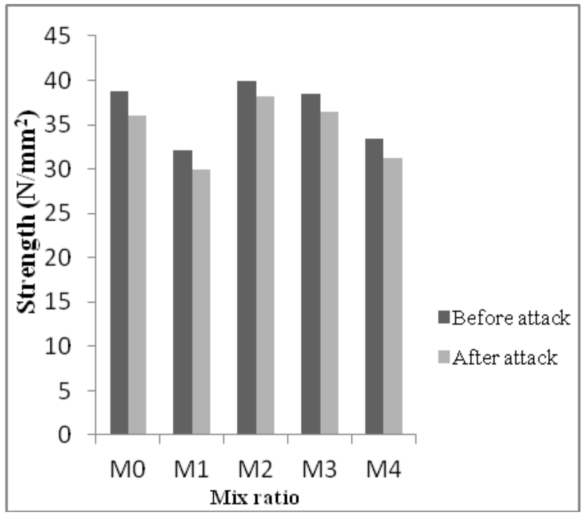

Figure: 9 Strength of Chloride Attack

3.7 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.

Figure: 10 Acid Attack Test

S.NO	FLY ASH %	SILICA FUME %	Average % Loss in Weight	
			H_2SO_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: 15 Average percentage Loss in weight of Acid attack

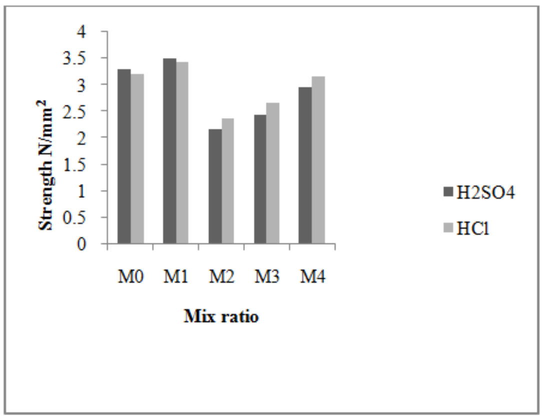

Figure: 11 Average % Loss in Strength

S.No	FLY ASH %	SILICA FUME %	Strength (N/mm^2)		
			Before attack	After attack	
				H_2SO_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

Table: 16 Percentage loss in Strength of acid attack

4. CONCLUSION

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.
- As silica fume is more finer material it fills the voids which helps to improve the strength drastically.
- 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 sulphate , chloride and acid attack, which is given in the above result.
- Presence of silica fume will make the concrete more lighter and highly resistance.
- Usage of both fly ash and silica fume will helps to control the environmentally disposed materials.
- Compressive strength, split tensile strength and flexural strength of both the conventional mix and the replaced mix were compared.

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