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Fly Ash as a Partial Replacement of Cement in Concrete and Durability Study of Fly Ash in Acidic (H_2so_4) Environment

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Abstract:- Cement production gives rise to CO_2emissions generated by the calcinations of CaCo3 $_{\text{and}}$ by the fossil, being responsible for about 5% of the Co_2 emissions in the world. This can be substantially reduced if cement replacement materials such as a fly ash are used Within the frame work of a comprehensive research concerning this residual of coal industries, studied some durability characteristics of concretes made with Fly ash. In this project report the results of the tests carried out on Sulphate attack on concrete cubes in water curing along with H_2SO_4 solution. Also, aiming the use of fly-ash as cement replacement. The present experimental investigation were carried on fly ash and has been chemically and physically characterized, and partially replaced in the ratio of 0%, 5%, 10%, 15%, 20% by weight of cement in concrete. Fresh concrete tests like compaction factor test was hardened concrete tests like compressive Strength at the age of 28 days, 60 days, 90 days was obtained and also durability aspect of fly ash concrete for sulphates attack was tested. The result indicates that fly ash improves concrete durability.

I. INTRODUCTION

In India, large amount of fly-ash is generated in thermal power plants with an imperative blow on environmental and living organism. The use of fly-ash in concrete can reduce the consumption of natural resources and also diminishes the effect of pollutant in environment. In recent studies, many researchers found that the use of additional cementitious materials like fly-ash in concrete is economical and reliable. Fly-ash is one of the residues generated in the combustion of coal. Fly-ash is generally captured from the chimneys of power generation facilities, whereas bottom ash is, as the name suggests, removed from the bottom of the furnace. In the past, fly-ash was generally released into the atmosphere via the smoke stack, but pollution control equipment mandated in recent decades now require that it be captured prior to release. It is generally stored on site at most US electric power generation facilities. Depending upon the source and makeup of the coal being burned, the components of the fly-ash produced vary considerably, but all fly-ash includes substantial amounts of silica (silicon dioxide, SiO2) (both amorphous and crystalline) and lime (calcium oxide, (CaO). Fly-ash is commonly used to supplement Portland cement in concrete production, where it can bring both technological and economic benefits, and is increasingly finding use in the synthesis of geopolymers and zeolites (Satish H 2013). The difference between fly-ash and Portland cement becomes apparent under a microscope. Fly-ash particles are almost totally spherical in shape, allowing them to flow and blend freely in mixtures. That capability is one of the properties making fly-ash a desirable admixture for concrete.

Objective: In this project objective is to study the influence of partial replacement of fly-ash in concrete subjected to different curing environments. Experimental investigation on acid resistance of concrete in sulphuric acid solution the variables factors considered in this study were concrete grade of $\mathbf{M_{35}}$ and curing periods of 28 days,60 days, and 90 days of concrete specimens. The parameter investigated was the time in days to cause strength deterioration factor of fully immersed concrete specimens in fresh water and in 0%, 1%, 3%,5% sulphuric acid solution. Fly-ash has been chemically and physically characterized and partially replaced in the ratio of 0%, 5%, 10%, 15% and 20%. Fresh concrete tests like compaction factor test and hardened concrete tests like compressive strength at the age of 28 days, 60 days, 90 days was obtained.

II. LITERATURE REVIEW

Fattuhi and Hugle (1987)[7] In his presentation stated that different cement pastes and concrete mixes were prepared using ordinary Portland cement and subjected to sulphuric acid attack. The main parameters investigated included w/c ratio (and cement content) and age of the cementitious materials. 102 mm cubes were immersed in a channel containing an approximately 2% solution of continuously flowing sulphuric acid. The changes in weight with time for each cube were determined continuously up to a maximum exposure period of 50 days. The results indicated that the deterioration of the cubes for this high acid concentration decreased with a decrease in the cement content. The effect of age was slightly more significant for cement paste than for concrete cubes.

Murthi p and Siva Kumar v (2008)[13] did detailed experimental investigation on the acid resistance of ternary blended concrete immersed up to 32 weeks in sulphuric acid (H_2SO_4) and hydrochloric acid (HCl) solutions. The results are compared with those of the control and binary blended concrete. ASTM class F fly-ash was considered to develop the binary blended concrete at the replacement level of cement as 20% by weight. Then silica fume was considered to develop the ternary blended concrete and the replacement of cement in the ternary system by silica fume was suggested as 8% of total powder content by weight. The variable factors considered in this study were concrete grades (M_{20}, M_{30} and M_{40}) and curing periods (28days and 90 days) of the concrete specimens. The parameter investigated was the time in days taken to cause 10% mass loss and strength deterioration factor of fully immersed concrete specimen in a 5% H_2SO_4 and 5% HCl solutions. The investigation indicated that the ternary blended concrete prepared by 20% fly-ash and 8% silica fume performed better acid resistance than the ordinary plain concrete and binary blended concrete.

Fareed Ahmed Memon et al (2010)[6] in this study concrete cube are made with OPC (Ordinary Portland Cement) and with different configurations of fly-ash by replacing cement and fine aggregate. To achieve the aim of this study, total 81 concrete cubes were cast. Among 81 cubes, 9 cubes were made with normal concrete, 36 cubes were made by replacing 25, 50, 75 and 100% of fine aggregate with fly-ash and 36 cubes were made by replacing 10, 25, 50 and 75% of cement with fly ash. The cubes were 6”X6” in cross-section, and the mix design was aimed for 5000 psi. After proper curing of all 82 cubes, they were tested at 3, 7 and 28 days curing age. The cubes were tested in Forney Universal Testing Machine. The compressive strength of concrete cubes made by replacing 100% fine aggregate by fly-ash was higher than the concrete cubes made with OPC at all 3, 7 and 28 days curing ages. On the other hand, the compressive strength of concrete cubes made by replacing 50 and 75% of cement by fly-ash were quite lower than the concrete cubes made with OPC at all curing ages.

Arivazhagan et al.(2011)[4] conducted a peculiar study on the environmental benefit with fly-ash stated that there is increases in crop yields and nutrient uptake due to release of major secondary and micro nutrients from fly-ash applied in the soil during crop growth. Basically fly-ash has slightly acidic in pH and its effect is more pronounced in soils having high pH.

Jayeshkumar Pitroda et al (2012)[9] It is shown in this paper that this research work describes the feasibility of using the thermal industry waste in concrete production as partial replacement of cement. The use of fly-ash in concrete formulations as a supplementary cementitious material was tested as an alternative to traditional concrete. The cement has been replaced by fly-ash accordingly in the range of 0% (without fly ash), 10%, 20%, 30% & 40% by weight of cement for M-25 and M-40 mix. Concrete mixtures were produced, tested and compared in terms of compressive and split strength with the conventional concrete. These tests were carried out to evaluate the mechanical properties for the test results for compressive strength up to 28 days and split strength for 56 days are taken.

Swaroop et al (2013)[16] In his presentation the study is mainly confined to evaluation of changes in both compressive strength and weight reduced in five different mixes of M30 Grade namely conventional aggregate concrete (CAC), concrete made by replacing 20% of Cement by fly-ash(FAC1), concrete made by replacing 40% of cement by fly ash(FAC2), concrete made by replacing 20% replacement of cement by GGBS (GAC1) and concrete made by replacing 40% replacement of cement by (GAC2). The effect of 1% H_2SO_4 and sea water of those concrete mixes are determined by immersing these cubes for 7 days, 28 days, 60 days in above solutions and the respective changes in both compressive strength and weight reduction had observed and upto a major extent we can conclude concretes made by that fly-ash and GGBS had good strength and durable properties comparison to conventional aggregate in severe environment.

Alvin Harison et al (2014)[2] conducted a peculiar study on the utilization of materials which can fulfill the expectations of the construction industry in different areas. In this study cement has been replaced by fly-ash accordingly in the range of 0%,10%,20%,30%,40%,50%,60%by weight of cement for M-25 mix with 0.46 water cement ratio. Concrete mixtures were produced, tested and compared in terms of compressive strength. It was observed that 20% of replacement of Portland pozzolana cement (PPC) by fly-ash strength is increased marginally (1.9% to 3.2%) at 28 days and 56 days respectively. It was observed that upto 30% replacement of PPC by fly-ash strength is almost equal to the referral concrete after 56 days. PPC gained strength after 56days curing because of slow hydration process.

III. EXPERIMENTAL INVESTIGATION

In the present experimental investigation fly-ash has been used as a partial replacement of cement as an additional ingredient in concrete mixes. The effect of adding different percentages of fly-as has additional material to concrete mixes on their compressive strength and effect of sulphuric acid on compressive strength were studied. The details of experimental investigations are as follows..

IV. TEST RESULTS & DISCUSSION

Table 4.1 Physical properties of Fly-ash as per (IS 1727-1967) Specification IS: 3812 (Part-1)-2003.

S.No.	Property	Test Result
1.	**Lime Reactivity**	**8 MPa**
2.	**Fineness (Blaine)**	**$316m^2/kg$**
3.	**Comp. Strength as percentage strength of corresponding Plain Mortar Cubes.**	**92.33%**
4.	**Soundness by Auto Clave Expansion**	**0.0233%**
5.	**Particle shape**	**Spherical**

Table 4.2 Physical Properties of H_2SO_4

S. No	Molecular formula	H_2SO_4
1	Molar mass	98.079 g/mol
2	Appearance	Clear, colourless, odourless liquid
3	Density	1.84 g/cm^3, liquid
4	Melting point	10^0C; 50^0F; 283 K
5	Boiling point	337^0C; 639^0 F; 610 K (When sulphuric acid is above 300^0C, it will decompose slowly.
6	Solubility in water	miscible

4.3 Compressive strength of concrete:

Table 4.3.1. Compressive Strength results for cubes cured in water

Sample Designation	% of FA	compressive strength at 28 days (f^1_{cu})	compressive strength at 60days (f^1_{cu})	compressive strength at 90days (f^1_{cu})
W1	0	46.19	56.82	57.98
W2	5	47.53	57.83	58.69
W3	10	48.67	58.27	60.23
W4	15	45.67	53.33	59.16
W5	20	44.33	54.16	56.23

4.4 DURABILITY STUDIES

Table 4.4.1 Compressive Strength results for cubes cured in Sulphuric acid 1%

Sample Designation	% of FA	compressive strength at 28 days (f^1_{cu})	compressive strength at 60days (f^1_{cu})	compressive strength at 90days (f^1_{cu})
S1-1	0	42.1	52.82	55.06
S1-2	5	43.85	53.85	56.13
S1-3	10	45.00	54.55	57.69
S1-4	15	42.15	49.85	56.60
S1-5	20	40.95	49.50	53.18

Table 4.4.2 Compressive Strength results for cubes cured in Sulphuric acid 3%

Sample Designation	% of FA	compressive strength at 28 days (f^1_{cu})	compressive strength at 60days (f^1_{cu})	compressive strength at 90days (f^1_{cu})
S3-1	0	39.53	50.76	54.50
S3-2	5	40.95	52.15	55.26
S3-3	10	42.50	53.05	56.80
S3-4	15	39.36	48.95	55.65
S3-5	20	38.15	47.44	52.95

Table 4.4.3 Compressive Strength results for cubes cured in Sulphuric acid 5%

Sample Designation	% of FA	compressive strength at 28 days (f^1_{cu})	compressive strength at 60days (f^1_{cu})	compressive strength at 90days (f^1_{cu})
S5-1	0	40.88	46.94	50.26
S5-2	5	42.53	52.56	50.94
S5-3	10	40.87	53.02	52.31
S5-4	15	40.87	48.20	51.34
S5-5	20	39.63	48.91	48.76

Table 4.4.4 Variation of Compressive strength with different % of sulphuric acid for 28days curing

Compressive strength of cement concrete cubes-28days curing (MPa)					
Sample Designation	% of FA	WATER	1%H_2SO_4	3%H_2SO_4	5%H_2SO_4
W1	0	46.19	42.1	39.53	40.88
W2	5	47.53	43.85	40.95	42.53
W3	10	48.67	45.00	42.50	43.70
W4	15	45.67	42.15	39.36	40.87
W5	20	44.33	40.95	38.15	39.63

Table 4.4.5 Variation of Compressive strength with different % of sulphuric acid for 60days curing

Compressive strength of cement concrete cubes-60days curing (MPa)					
Sample Designation	% of FA	WATER	1%H_2SO_4	3%H_2SO_4	5%H_2SO_4
W1	0	56.82	52.82	50.76	46.94
W2	5	57.83	53.85	52.15	52.56
W3	10	58.27	54.55	53.05	53.02
W4	15	53.33	49.85	48.95	48.20
W5	20	54.16	49.50	47.44	48.91

Table 4.4.6.Variation of Compressive strength with different % of sulphuric acid for 90days curing

Compressive strength of cement concrete cubes-90days curing (MPa)					
Sample Designation	% of FA	WATER	1%H_2SO_4	3%H_2SO_4	5%H_2SO_4
W1	0	57.98	55.06	54.50	50.26
W2	5	58.69	56.13	55.26	50.94
W3	10	60.23	57.69	56.80	52.31
W4	15	59.16	56.60	55.65	51.34
W5	20	56.23	53.18	52.95	48.76

Table 4.4.7: Reduction of Compressive strength with 1% H_2SO_4 cured for 28 days

Sample Designation	% of FA	(f_{cu})	(f^1_{cu})	% reduction
S1-1	0	46.19	42.1	8.85
S1-2	5	47.53	43.85	7.74
S1-3	10	48.67	45.00	7.5
S1-4	15	45.67	42.15	7.70
S1-5	20	44.33	40.95	7.62

Table 4.4.8: Reduction of Compressive strength with 3% H_2SO_4 cured for 28 days

Sample Designation	% of FA	(f_{cu})	(f^1_{cu})	% reduction
S3-1	0	46.19	39.53	14.40
S3-2	5	47.53	40.95	13.84
S3-3	10	48.67	42.50	12.67
S3-4	15	45.67	39.36	13.80
S3-5	20	44.33	38.15	13.90

Table 4.4.9: Reduction of Compressive strength with 5% H_2SO_4 cured for 28 days

Sample Designation	% of FA	(f_{cu})	(f^1_{cu})	% reduction
S5-1	0	46.19	40.88	11.49
S5-2	5	47.53	42.53	10.53
S5-3	10	48.67	43.70	10.21
S5-4	15	45.67	40.87	10.50
S5-5	20	44.33	39.63	10.61

Table 4.4.10: Reduction of Compressive strength with 1% H_2SO_4 cured for 60 days

Sample Designation	% of FA	(f_{cu})	(f^1_{cu})	% reduction
S1-1	0	56.82	52.82	7.03
S1-2	5	57.83	53.85	6.88
S1-3	10	58.27	54.55	6.38
S1-4	15	53.33	49.85	6.52
S1-5	20	54.16	49.50	8.60

Table 4.4.11: Reduction of Compressive strength with 3% H_2SO_4 cured for 60 days

Sample Designation	% of FA	(f_{cu})	(f^1_{cu})	% reduction
S3-1	0	56.82	50.76	10.66
S3-2	5	57.83	52.15	9.82
S3-3	10	58.27	53.05	8.95
S3-4	15	53.33	48.95	8.21
S3-5	20	54.16	47.44	12.40

Table 4.4.12: Reduction of Compressive strength with 5% H_2SO_4 cured for 60 days

Sample Designation	% of FA	(f_{cu})	(f^1_{cu})	% reduction
S5-1	0	56.82	46.94	9.88
S5-2	5	57.83	52.56	9.12
S5-3	10	58.27	53.02	9.01
S5-4	15	53.33	48.20	9.62
S5-5	20	54.16	48.91	9.70

Table 4.4.13: Reduction of Compressive strength with 1% H_2SO_4 cured for 90 days

Sample Designation	% of FA	(f_{cu})	(f^1_{cu})	% reduction
S1-1	0	57.98	55.06	5.04
S1-2	5	58.69	56.13	4.37
S1-3	10	60.23	57.69	4.21
S1-4	15	59.16	56.60	4.33
S1-5	20	56.23	53.18	5.43

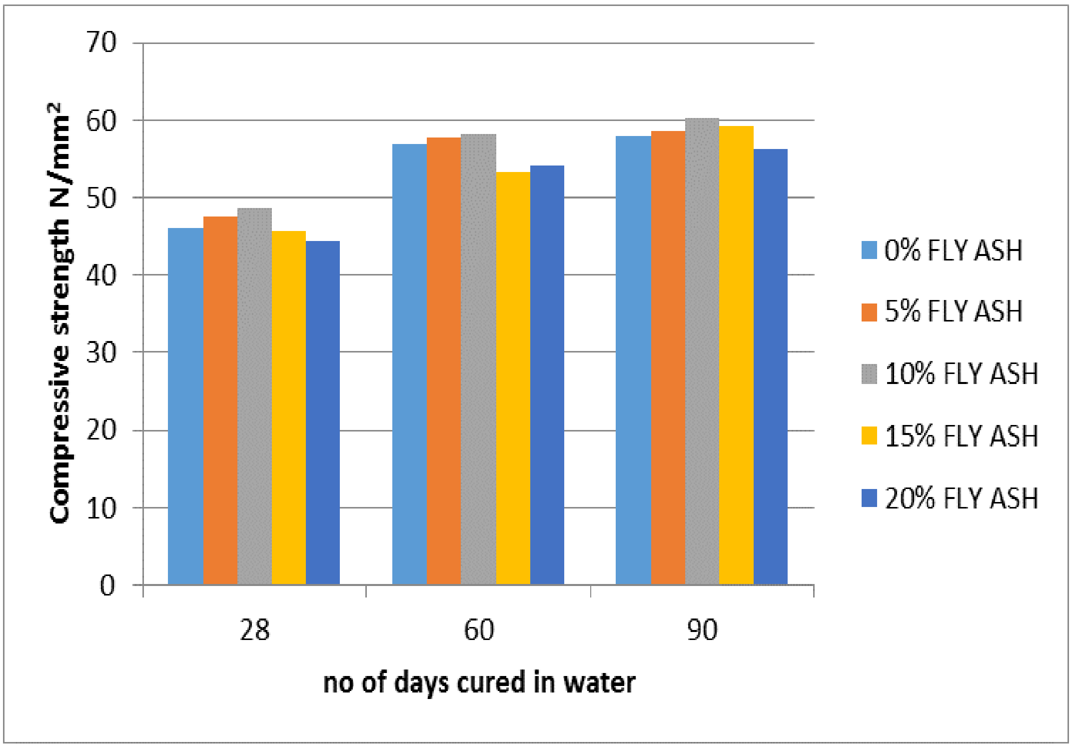
Table 4.4.14: Reduction of Compressive strength with 3% H_2SO_4 cured for 90 days

Sample Designation	% of FA	(f_{cu})	(f^1_{cu})	% reduction
S3-1	0	57.98	54.50	6.0
S3-2	5	58.69	55.26	5.84
S3-3	10	60.23	56.80	5.69
S3-4	15	59.16	55.65	5.93
S3-5	20	56.23	52.95	5.83

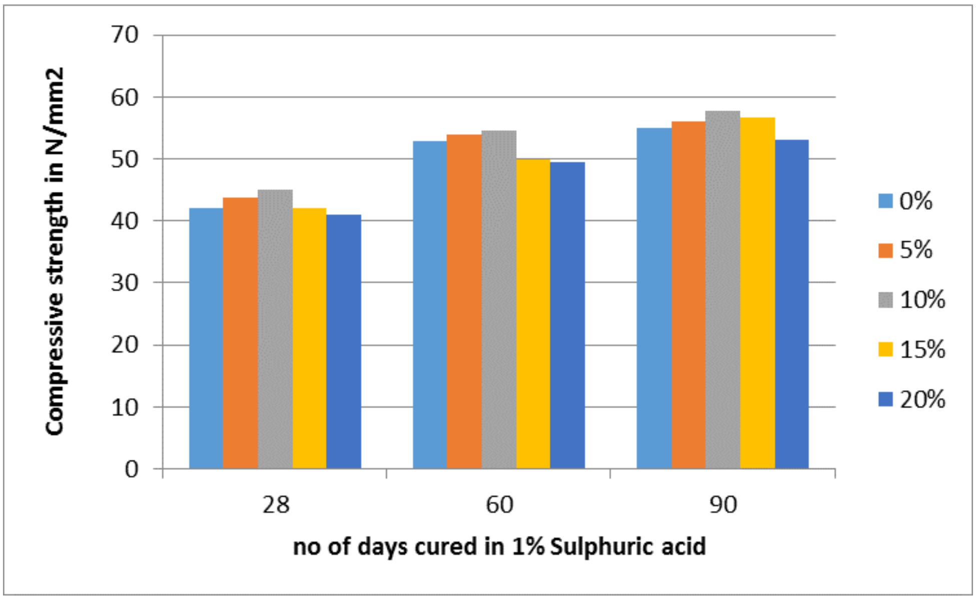
Table 4.4.15: Reduction of Compressive strength with 5% H_2SO_4 cured for 90 days

Sample Designation	% of FA	(f_{cu})	(f^1_{cu})	% reduction
S5-1	0	57.98	50.26	13.31
S5-2	5	58.69	50.94	13.20
S5-3	10	60.23	52.31	13.15
S5-4	15	59.16	51.34	13.22
S5-5	20	56.23	48.76	13.28

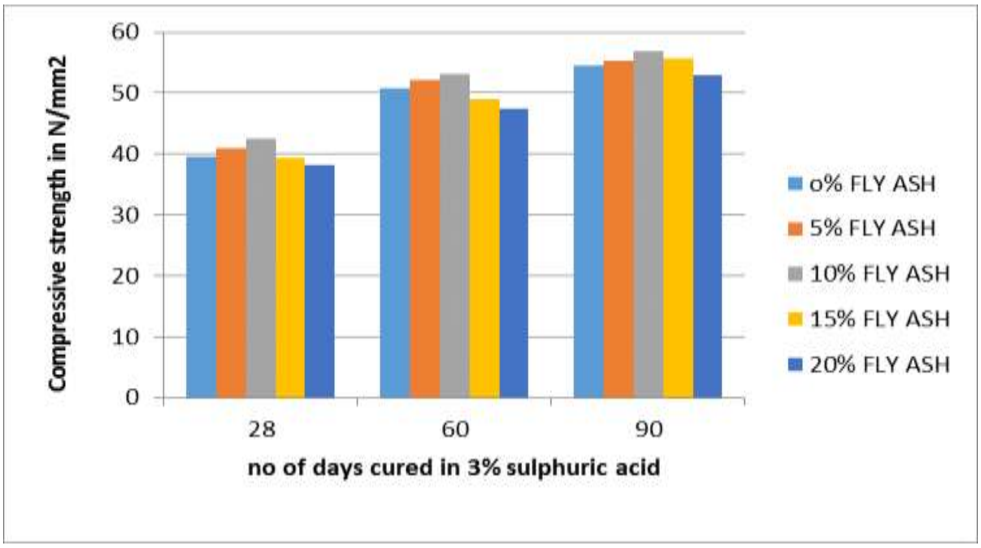
V. EXPERIMENTAL RESULTS GRAPHS:



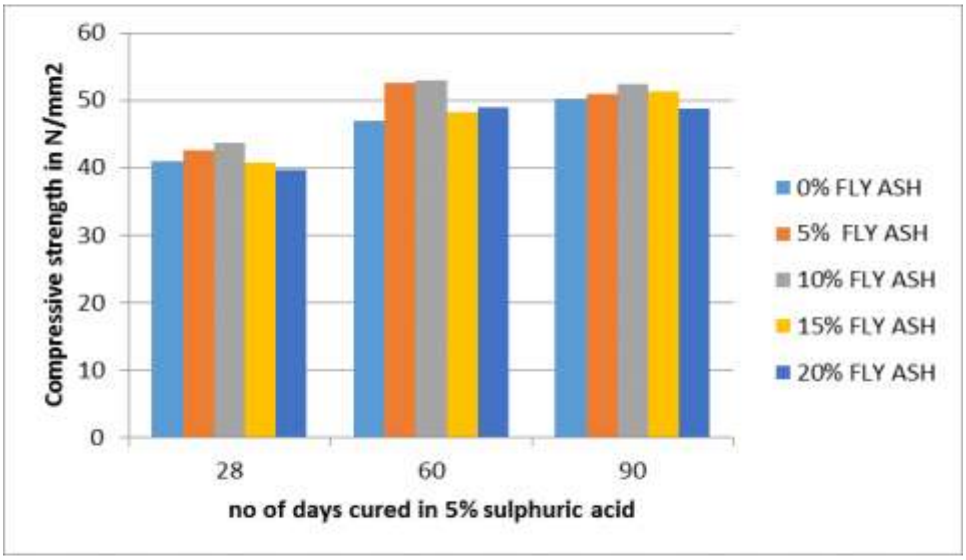
GRAPH.1: Compressive strength results of Fly-ash Concrete cured in normal Water



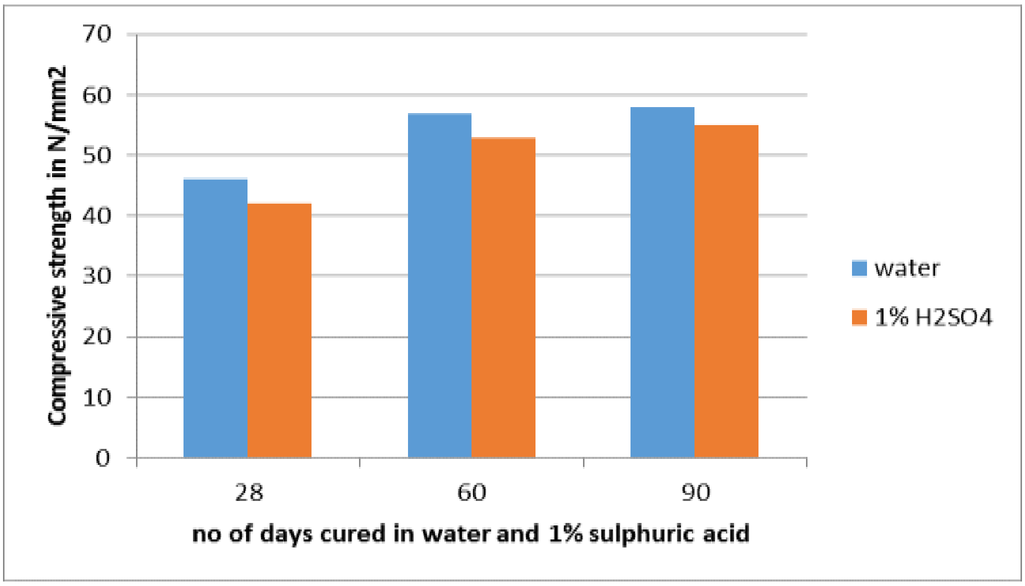
GRAPH.2: Compressive strength results of Fly-ash Concrete cured in 1% Sulphuric acid



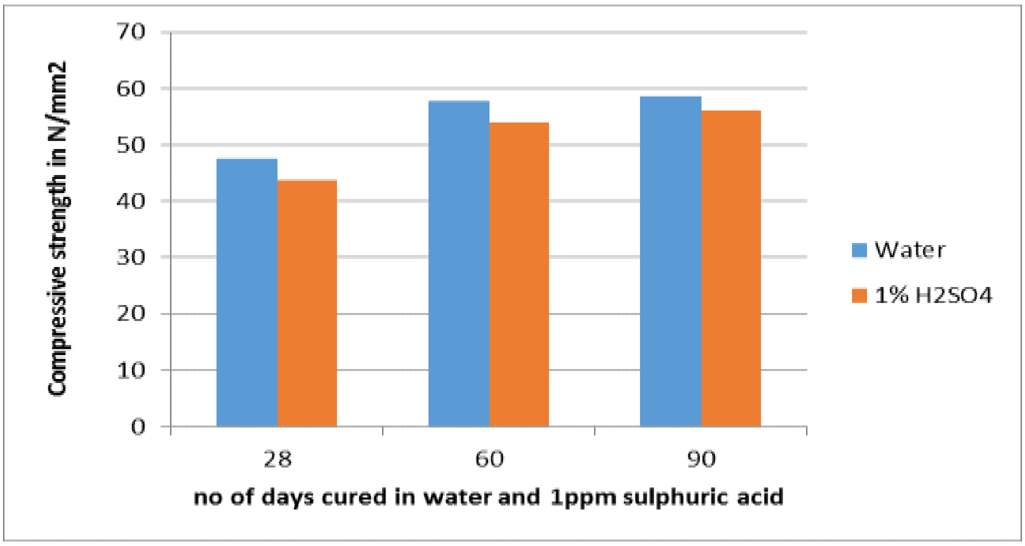
GRAPH.3: Compressive strength results of Fly-ash Concrete cured in 3% Sulphuric acid



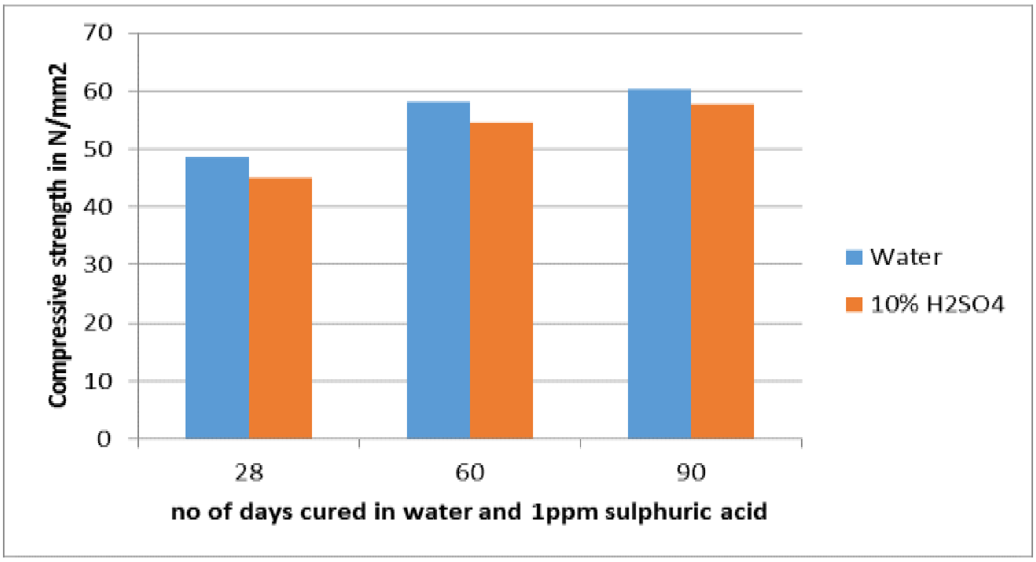
GRAPH.4: Compressive strength results of Fly-ash Concrete cured in 5% Sulphuric acid



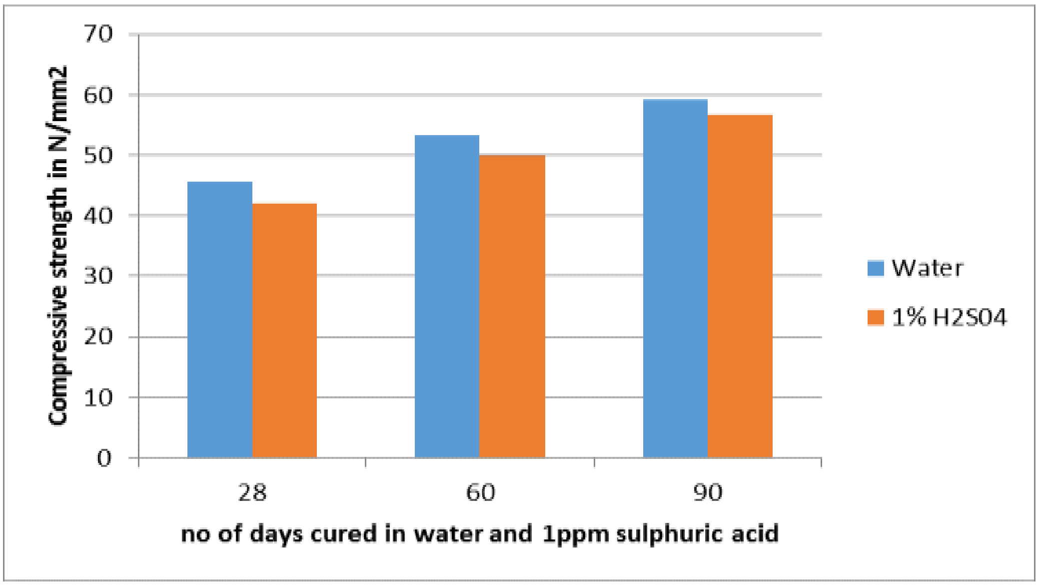
GRAPH.5: Compressive strength results of 0% Fly-ash Concrete cured in water % sulphuric acid



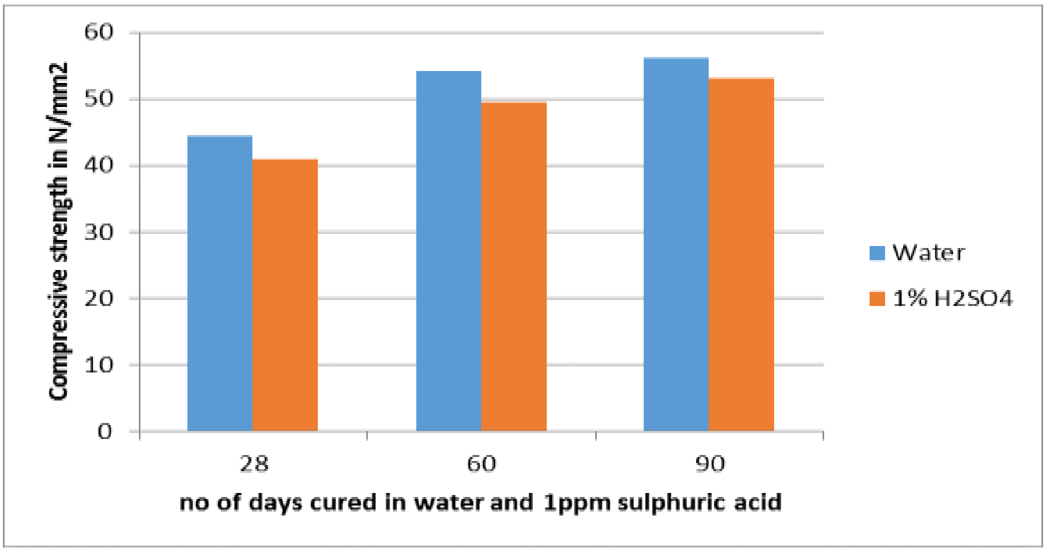
GRAPH.6: Compressive strength results of 5% Fly-ash Concrete cured in water and 1% sulphuric acid



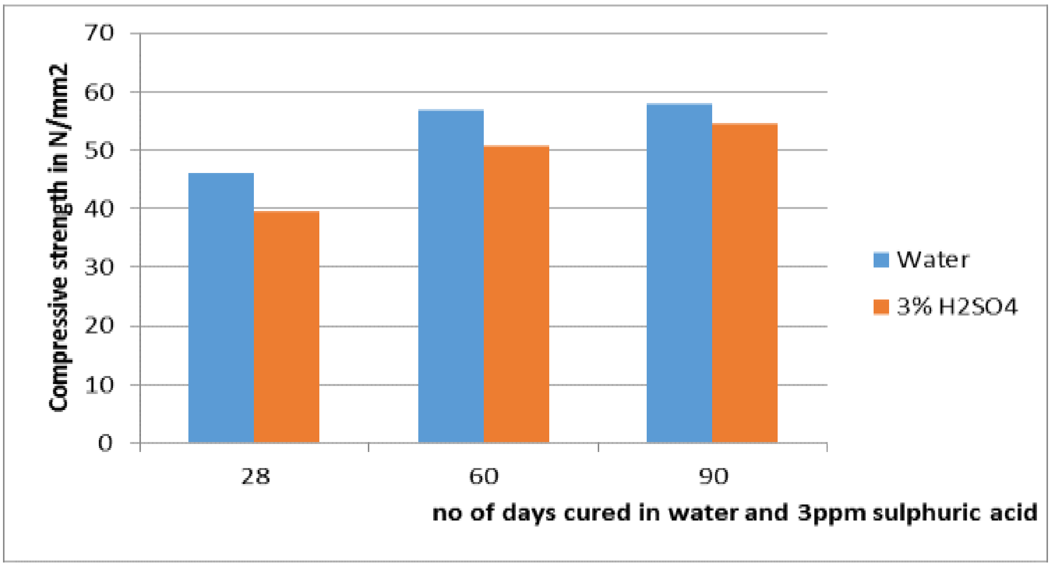
GRAPH.7: Compressive strength results of 10% Fly-ash Concrete cured in water and 1% sulphuric acid



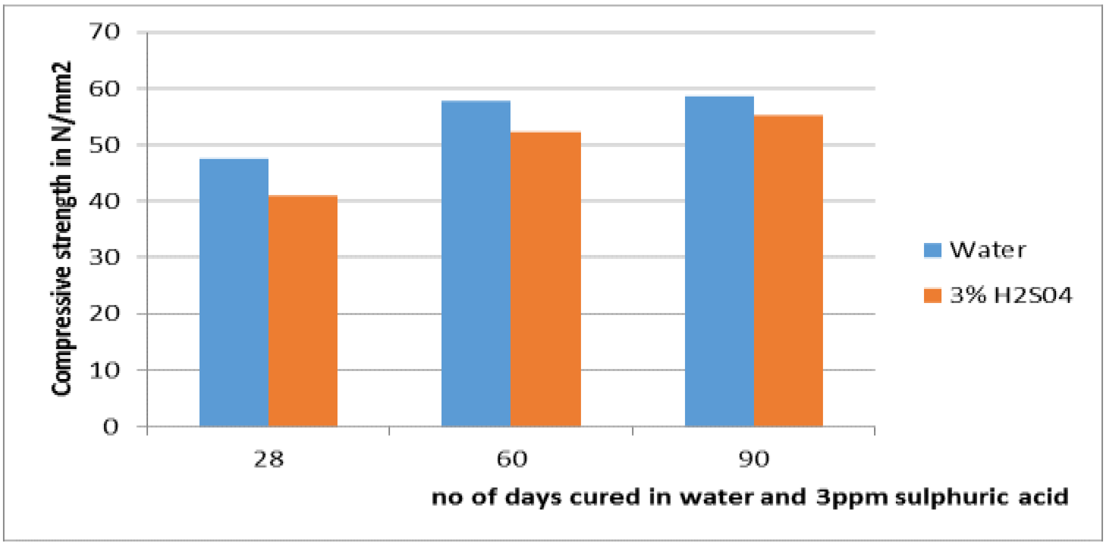
GRAPH.8: Compressive strength results of 15% Fly-ash Concrete cured in water and 1% sulphuric acid



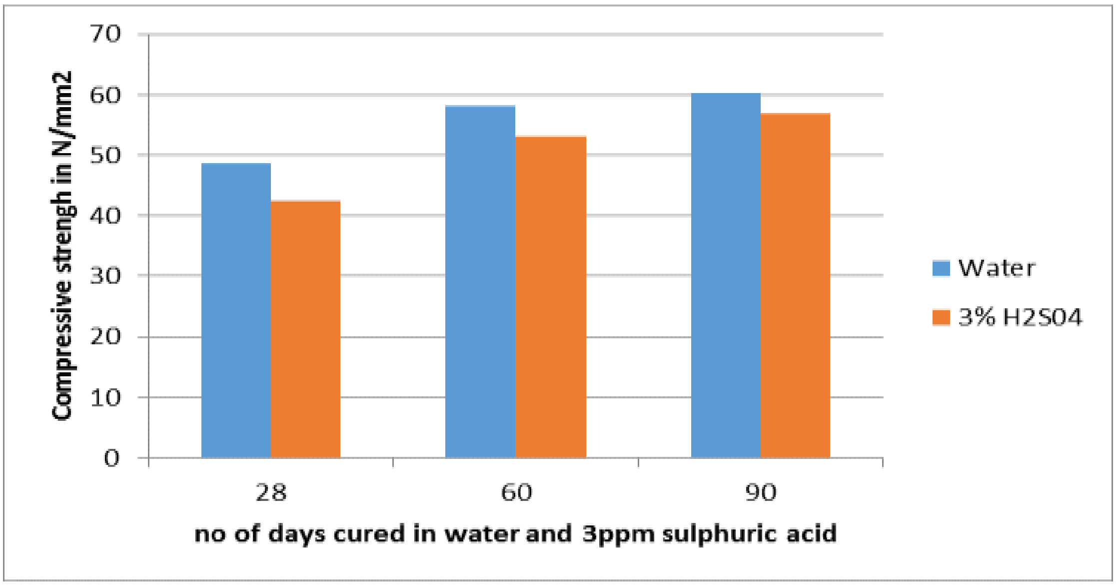
GRAPH.9: Compressive strength results of 20% Fly-ash Concrete cured in water And 1% sulphuric acid



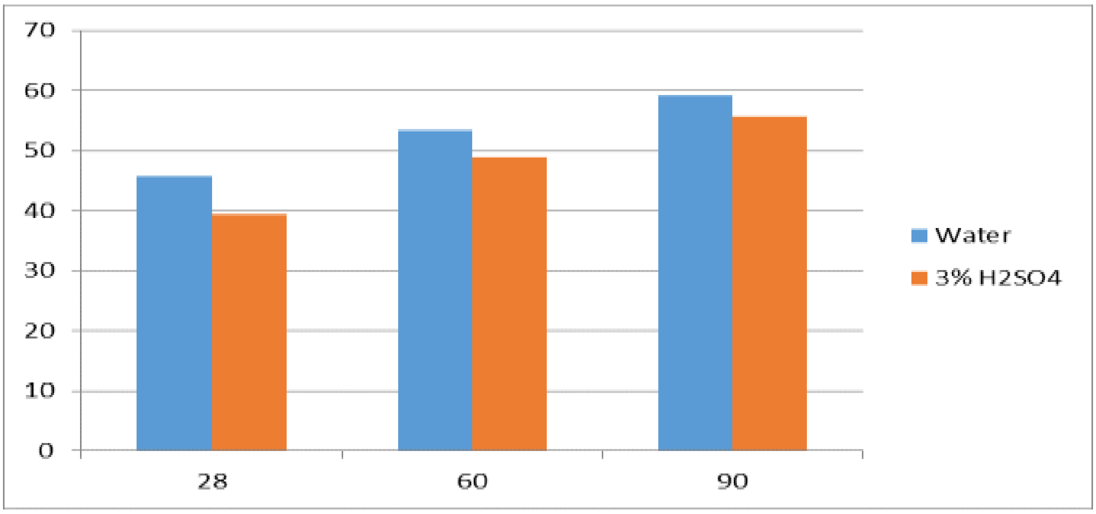
GRAPH.10: Compressive strength results of 0% Fly-ash Concrete cured in Water and 3% sulphuric acid



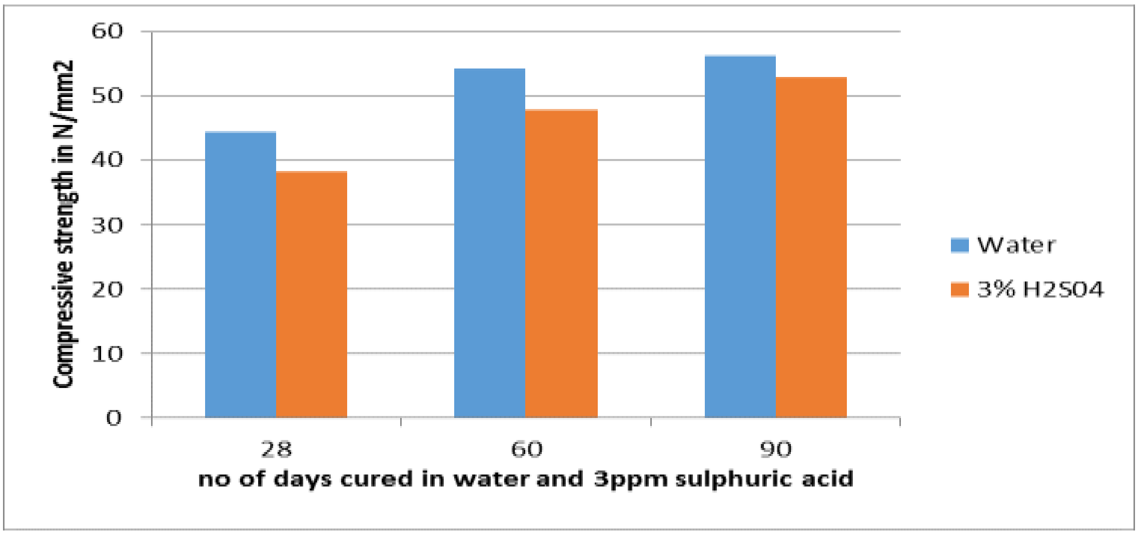
GRAPH.11: Compressive strength results of 5% Fly-ash Concrete cured in water and 3% sulphuric acid



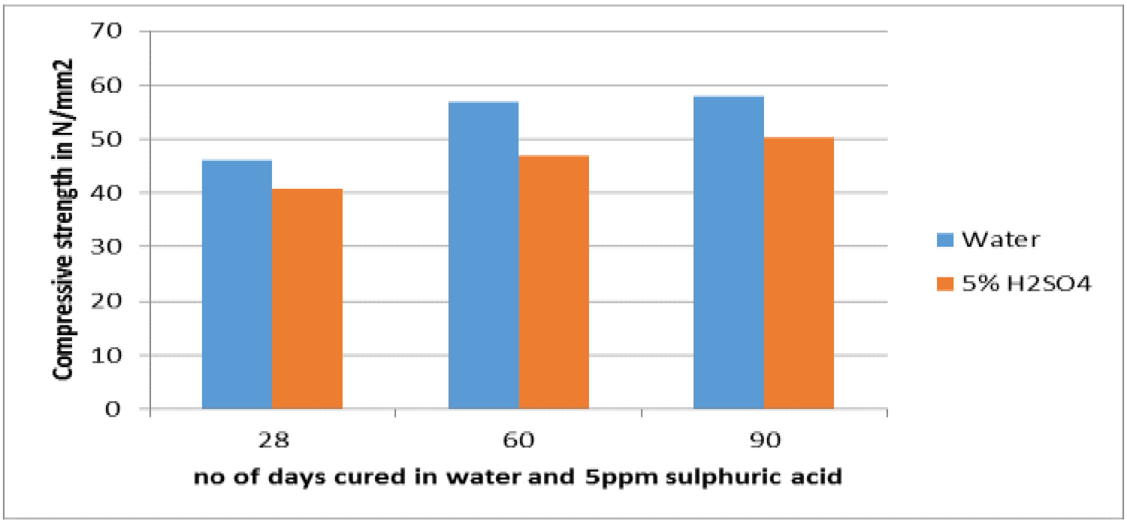
GRAPH.12: Compressive strength results of 10% Fly-ash Concrete cured in Water and 3% sulphuric acid



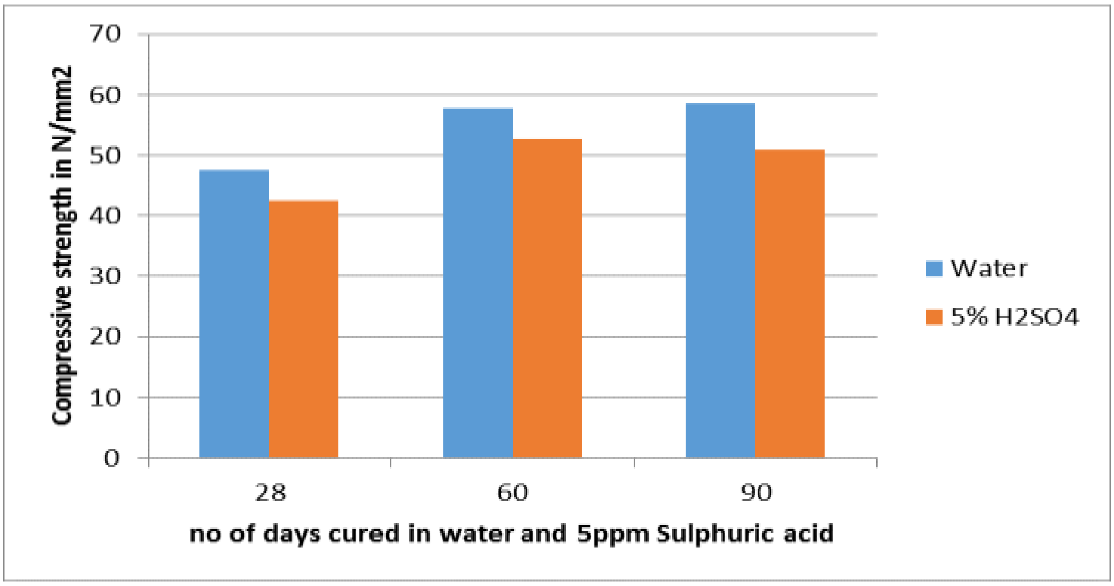
GRAPH.13: Compressive strength results of 15% Fly-ash Concrete cured in water and 3% sulphuric acid



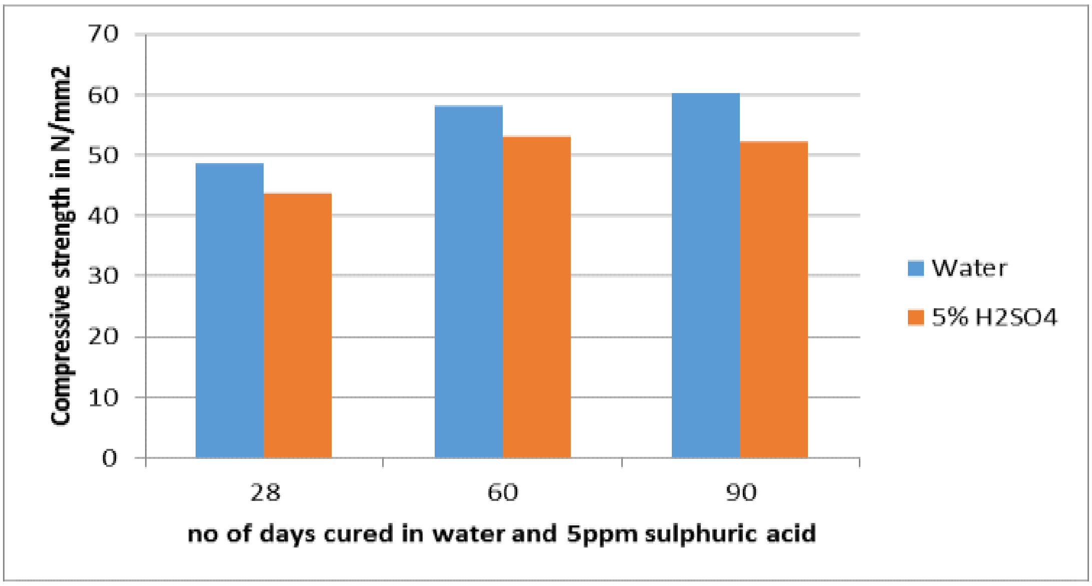
GRAPH.14: Compressive strength results of 20% Fly-ash Concrete cured in Water and 3% sulphuric acid



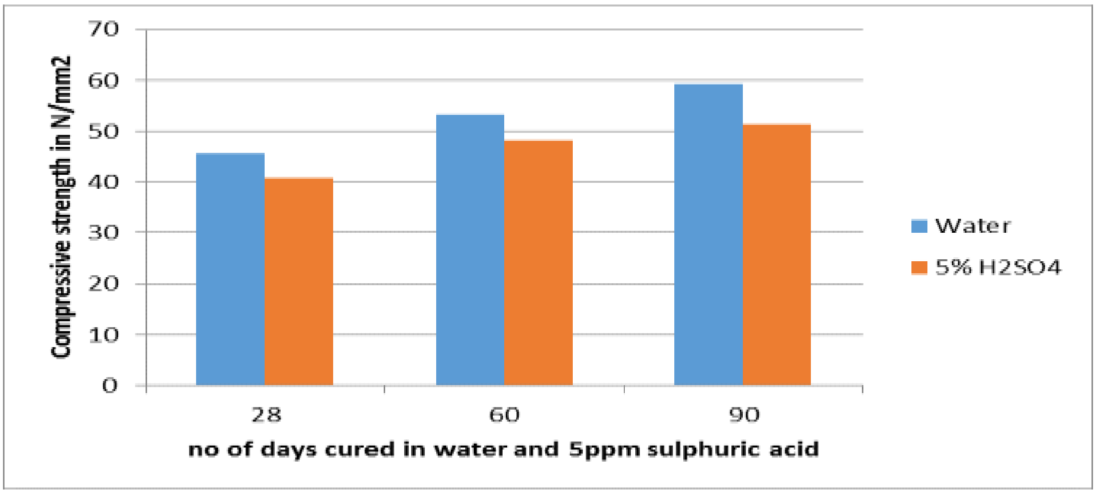
GRAPH.15: Compressive strength results of 0% Fly-ash Concrete cured in water and 5% sulphuric acid



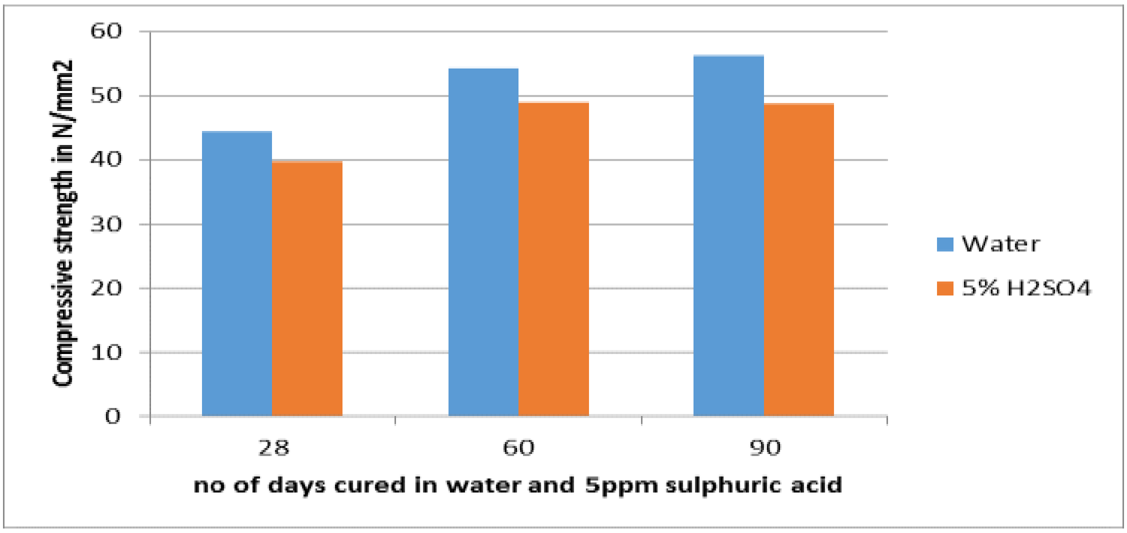
GRAPH.16: Compressive strength results of 5% Fly-ash Concrete cured in water and 5% sulphuric acid



GRAPH.17: Compressive strength results of 10% Fly-ash Concrete cured in Water and 5% Sulphuric acid



GRAPH.18: Compressive strength results of 15% Fly-ash Concrete cured in Water and 5% Sulphuric acid



GRAPH.19: Compressive strength results of 20% Fly-ash Concrete cured in Water and 5% Sulphuric acid

VI. CONCLUSIONS

1. The specific surface area of FA is 316.7 m^2/kg greater than 330 m^2/kg of cement. The compressive strengths of concrete (with 0%, 5%, 10%, 15% and 20%, weight replacement of cement with FA) cured in Normal water for 28, 60 and 90 days have reached the target mean strength.
2. The compressive strengths of concrete (with 0%, 5%, 10%, 15% and 20%, weight replacement of cement with FA) cured in different concentrations of (1%, 3%, and 5%) **Sulphuric acid** solution for 28, 60 and 90 days indicate that at 10% replacement there is increase in strength and beyond that the strengths decreased, but at 20% replacement FA strength less than to normal concrete.
3. The strength decreases in acidic environment with age of concrete also with increasing of FA content in concrete
4. In concrete cement can be replaced with 10% FA with maximum increase in strength beyond starts decreases.
5. Due to slow pozzolanic reaction the FA concrete achieves significant improvement in its mechanical properties at later ages.

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