A STUDY ON MECHANICAL AND DURABILITY PROPERTIES OF CONCRETE USING FLY ASH AS APARTIAL REPLACEMENT OF CEMENT UNDER MAGNESIUM ACID ENVIRONMENT

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ABSTRACT

Cement production gives rise to CO2emissions generated by the calcinations of CaCo3 and by the fossil, being responsible for about 5% of the Co2 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 objective is to study the influence of partial replacement of Portland cement with fly ash in concrete subjected to different curing environments. Experimental investigation on acid resistance of concrete in mgso4 solution. The variable factors considered in this study were concrete grade of M30 & curing periods of 7days, 28days, 56days, 90days, 180 days of the concrete specimens in 1%, 3%, and 5% MgSO4 solution. Fly ash has been chemically & physically characterized & partially replaced in the ratio of 0%, 5%, 10%, 15%, and 20% by weight

Keywords:

Portland Cement, Concrete, Fly Ash, Specimen Preparation, Testing,

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1. Introduction

The advancement of concrete technology can reduce the consumption of natural resources and energy sources and less the burden of pollutants on environment. In recent years, many researchers have established that the use of supplementary cementitious materials (SCMs) like fly ash (FA), blast furnace slag, silica fume, metakaolin (MK), and rice husk ash (RHA), hypo sludge etc. can, not only improve the various properties of concrete - both in its fresh and hardened states, but also can contribute to economy in construction costs.

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 flyash 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.

2. LITERATURE REVIEW

1.Biczoc (1972) He states that the sulphate attack, corrosion increase with increase in sulphate concentration.

2.Mehta and Haynes (1978) Dense concretes were in excellent shape but lean concrete showed loss of material and was soft and weak. A number of practical examples and results of a series of long-term investigations can illustrate successful use of blast furnace cements in offshore constructions. The storm surge barrier in the Netherlands was built with blast furnace cement. The expected service life of 200 years is an impressive sign of confidence in durable concrete with blast furnace cement.

3.Aigbodion, Hassan, Ause and Nyior(1993) In this paper, Bagasse ash has been chemically and physically characterized, in order to evaluate the possibility of their use in the industry. X-ray diffractometry determination of composition and presence of crystalline material, scanning electron microscopy/EDAX examination of morphology of particles, as well as physical properties and refractoriness of bagasse ash has been studied.

4.BilodeauA, Sivasundaram, Painter and Malhotra(1994): This paper presents the results of investigations to determine the various durability aspects of high-volume fly ash concrete using eight fly ashes and two Portland cements from U.S. sources. Based upon the test results, it is concluded that regardless of the type of fly ash and the cements used, the air – entrained high-volume fly ash concrete exhibited excellent durability characteristics in the tests investigated.

5. Chatveerand, Lertwattanaruk [2008]: In this paper, agro-wastes from an electricity generating power plant were ground and used as a partial cement replacement. The durability of mortars under sulfate attack including expansion and compressive strength loss were investigated. For the durability of mortar exposed to sulfate attack, 5% Sodium sulphate (Na_2SO_4) and Magnesium sulphate ($MgSO_4$) solutions were used. As a result, when increasing the percentage replacement of SCBA, the expansion and compressive strength loss of mortar decreased. At the replacement levels of 30% and 50% of SCBA, the expansion of the mortars was less than those mixed with sulfate-resistant cement. However, the expansion of the mortars exposed to Na_2SO_4 was more than those exposed to $MgSO_4$. Increasing the replacement level of SCBA tends to reduce the compressive strength loss of mortars exposed to Na_2SO_4 attack. In contrary, under $MgSO_4$ attack, when increasing the replacement level of SCBA, the compressive strength loss increases from 0% to 50% in comparison to Portland cement mortar. Results show that ground SCBA can be applied as a pozzolanic material to concrete and also improve resistance to sodium sulfate attack, but it can impair resistance to magnesium sulfate attack.

6. Chuslip , Nuntachai and Kiattikomol [2009]: Raw bagasse ash collected from the Thai sugar industry has a high loss on ignition (LOI) of ~20%. When ground and ignited at 550^{o}C for 45 min, the LOI was reduced to ~5%. These high and to give ground bagasse ashes with LOIs of 10% and 15%, respectively. Each of these ground bagasse ashes was used to replace Portland cement type I at 10%, 20%, 30%, and 40% by weight of binder to cast mortar. However, mortar bars containing high LOI (larger than 10%) of ground bagasse ashes showed greater deterioration from sulfate attack than the mortar bars containing low LOI (less than 10%) of ground bagasse ashes, especially at high replacement levels (30-40%).

7. Otuoze and Amartey (2010): This study investigates the strength performance of concrete using partial blends of Ordinary Portland Cement (OPC) and Sugar Cane Bagasse Ash (SCBA). SCBA was obtained by burning Sugar Cane Bagasse (SCB) at between 600-700^{o}C. Atomic Absorption Spectrometry (AAS) conducted confirmed SCBA to be good pozzolana since the sum of SiO_2, $Al2O_3$ and $Fe2O_3$ is 74.44%, thus, meeting the requirement of70% minimum recommended by ASTM C618 (1992). For strength test, mix ratio of 1:2:4 was used and OPC was partially replace with 0 (control), 5, 10, 15, 20, 25, 30,35 and 40% SCBA by weight of OPC in the concrete. Compressive strength values of crushed hardened concrete were obtained at the ages of 7, 14, 21 and 28 days. The result shows that the performance of concrete having up to 10% SCBA replacement the BS8110 (1997) but up to 35% SCBA could be adapted for use in mass concrete.

8. Noor- ur amin(2010): This study investigates the effect of industries produced quick lime on the strength development of the quick lime –bagasse ash –cement system was monitored and presented here. Moreover new efficiency factors were calculated for activated system in an attempt to seek for the optimum quick lime addition in each case . The addition of quick lime increased both the early and later strengths of the cement –bagasse ash specimens. A 3% addition of quick lime was found to be the optimum dosage for both short and longer curing periods.

9. Srinivasanan and Sathiya (2010): This paper presents experimental investigation carried on bagasse ash and has been chemically and physically characterized, and partially replaced in the ratio of 0%, 5%, 10%, 15%, 20% and 25% by weight of cement in concrete. Fresh concrete test like compaction factor test and slump cone test was undertaken as well as hardened concrete test like compressive strength, split tensile strength, modulus of elasticity at the age of 7 and 28 days was obtained and also durability aspect of bagasse concrete for marine, sulphates and chlorides attack was tested. The result shows that the strength of concrete increased as percentage of bagasse ash replacement increased

10. Corral-Higuera R., Arredondo-Rea S.P. and Almaral-Sánchez J.L[2011]: As strategies to contribute to the concrete industry sustainability, reinforced concrete was fabricated using recycled concrete coarse aggregate and replacing partially Portland cement with supplementary cementing materials as fly ash and silica fume. On test specimens, partially immersed in 3.5% Na_2SO_4aqueous solution, the effect of the recycled and supplementary materials against sulphate attack and reinforcement corrosion was evaluated. For such aim, weight loss of concrete and corrosion potentials, corrosion current density of reinforcement were determined by means of electrochemical techniques as open circuit potential and linear polarization resistance, respectively.

11. Maldonado-Bandala, Lizarraga and Zambrano R (2011): Corrosion is one of the most serious causes that reduce service life of Reinforced Concrete Structures (RCS). This is why it is necessary to create concrete mixtures that add durability for steel and that reduce impact on the environment. The use of agro-industrial waste materials rich in SiO_2, Al_2O_3 and Fe_2O_3, added to concrete, has been the subject of research in recent years, because these pozzolanic materials improve some characteristics of concrete, as mechanical strength, sulfate resistance and lower permeability. Binary Concretes were made and evaluated in the impact of Sugar Cane Bagasse Ash (SCBA) as a partial substitute for Portland cement, with the aim of reducing the rate of corrosion induced by chloride ions and sulfate. The behavior of corrosion was monitored for 14 months in two aqueous solutions of NaCl and Na_2SO_4 both at 3.5%, using electrochemical techniques of corrosion potential (Ecorr) and linear polarization resistance (Rp). Under the conditions of study, the binary mixture that showed a better corrosion protection was the one that contained 80% from sugar Cane bagasse ash and 20% Portland cement.

12. Eduaro M.R.Fairbadian: In this paper report the results of the tests carried out on chloride ion penetration and water sorption. Also, aiming the use of SCBA in large scale as cement replacement, its a study about the potential of the residue to be elected as carbon credits by the Kyoto protocol established methodologies. The results indicated that the SCBA improves concrete durability and that this material reduces CO_2 emissions being a potential candidate for carbon credit projects.

13. Junriz J.Abuyabor : This is a study that will determine the compressive strength, flexural strength, and physical appearance of CHB whose cement will be replaced by bagasse ash at 0%, 5%, 10%, 15%, 20% and 25% by weight. Laboratory tests will be conducted for the samples at each percentage of cement replacement. The results will be compared in order to find out the best percentage by weight of cement that will be replaced by BBA for compressive and flexural strength and physical appearance

14. Kilinkale F.M: The strengths are determined after the mortars are stored in solution for 56 days. The highest compressive strength occurs with silica fume in HCl.

15. Al-Amoudi: Investigate the mortar specimens made with plain cement and silica fume, immersed in Na_2SO_4 and beyond 460 days the strength is increased by 9%.

16. Lawrence: This paper presents the results of an experimental investigation in which the effects of sulfates on the initial and final setting times of ordinary Portland cement and compressive strength of concrete are investigated. It was observed that the type of sulfate and the ion concentration affect the setting times significantly, the increase in initial setting time is more prominent. The parameters reduce the compressive strength of concrete at different ages.

17. Semakoral and Nabiyuzer : An investigation was carried out on the effect of sodium sulfate concentration on the sulfate resistance of mortars. Experiments were carried out on the RILEM Portland cement standard mortars and Portland cement-silica fume mortars. Sulfate exposure of mortars was initiated after 28 days of lime saturated water curing. Some physical and mechanical properties were determined periodically up to 300 days of exposure. Low concentrations of sodium sulfate not exceeding 18000mg/lit had not any significant effect on the compressive and flexural strength of mortars. However, at a concentration of 18000mg/lit some of the properties i.e., volume density, volumetric water absorption indicated beginning of rapid deterioration of mortar structure at an exposure time which could be called critical time. Concentration of 72000 mg/lit caused sharp strength reduction between 90 and 180 days for both compressive and flexural strengths. Silica fume replacement caused significant increase in sulfate resistance of mortar even at highest sulfate concentration.

3. Experimental Investigations:

The properties of the materials used in the experimental work are presented in this chapter. The material specifications for cement, fine aggregate, coarse aggregate and admixtures are discussed. The various tests like sieve analysis, specific gravity.

3.1.Materials & their properties:

Table-1: Physical properties of Portland cement (53 grade)

S. No.	Properties/Characteristics	Test results	Requirements as per IS 12269-1987
1	Normal Consistency	32%	---
2	Setting time a) Initial Setting Time b) Final Setting Time	80 minutes 180 minutes	Not less than 30 minutes Not more than 600 minutes
3	Specific Gravity	3.10	---
4	Fineness of cement by sieving through sieve No.9 (90 microns) for a period of 15 min.	2.82%	<10%
5	Soundness (Le-Chatlier Exp.)	1.29 mm	Not more than 10mm
6	Compressive strength of cement (28 days)	53 MPa	53 MPa
7	Specific surface area	3200 cm^2/gm	---

Table 2: Physical properties of Fly ash:

S. No.	Property	Test Result
1.	Density	575Kg/m^3
2.	Specific Gravity	1.8
3.	Mean particle size	0.1-0.2 µm
4.	Min specific surface area	250m^2/ kg
5.	Particle shape	Spherical

Table 3: Chemical Composition of fly ash

S. No.	Characteristic	Test Results%
1	(SiO_2) + $A1_2O_3$ +Fe_2O_3 % by mass	85.14
2	SiO_2 % by mass	60.20
3	MgO % by mass	2.48
4	Total sulfur as SO_3 % by mass	0.10
5	Available alkali as sodium oxide (Na_2O) % by mass	4.32
6	Loss of ignition % by mass	5.10

Table 4: Sieve Analysis (Fine Aggregate)

S. No.	I.S. Sieve No.	Weight retained (gm)	Percentage weight retained	Cumulative percentage retained	Percentage passing
1.	40mm	0	0	0	100
2.	20mm	0	0	0	100
3.	10mm	0	0	0	100
4.	4.75mm	21	2.10	2.10	97.90
5.	2.36mm	65	6.50	8.60	91.40
6.	1.18mm	180	18.00	26.06	73.94
7.	600µ	278	27.80	54.04	45.96
8.	300µ	280	28.00	82.04	17.96
9.	150µ	176	17.06	100.00	0
Total :				274.00	

Fineness modulus= 274.1 / 100 = 2.74, Zone = II

Table 5: Sieve Analysis (Coarse Aggregate)

S .No.	I.S. Sieve No.	Weight Retained (gms)	Percentage weight retained	Cumulative Percentage Retained	Percentage Passing
1.	40mm	0	0	0	100
2.	20mm	877	17.54	17.54	82.46
3.	10mm	4085	81.70	99.24	0.76
4.	4.75mm	38	0.76	100.00	0
5.	2.36mm	0	0	100.00	0
6.	1.18mm	0	0	100.00	0
7.	600µ	0	0	100.00	0
8.	300µ	0	0	100.00	0
9.	150µ	0	0	100.00	0
Total :				716.78	

Fineness modulus= 716.78 / 100 = 7.17

Table-6: Physical Properties of Fine and Coarse Aggregate

S. No.	Properties	Test results	
		Fine Aggregate	Coarse Aggregate
1.	Specific gravity	2.60	2.74
2.	Bulk Density (Kg/m^3) a) loose b) compacted	 1600 kg/m^3 1750 kg/m^3	 1400 Kg/m^3 1580 Kg/m^3
3.	Fineness Modulus	2.74	7.17

Table-7: Analysis of Water (Limitations As Per IS: 456-2000)

S. No.	Impurity	Max. Limit	Results
1	PH Value	6 to 8.5	7
2	Suspended matter mg/lit	2000	220
3	Organic matter mg/lit	200	20
4	Inorganic matter mg/lit	3000	150
5	Sulphate (SO_4) mg/lit	500	30
6	Chlorides (Cl) mg/lit	2000 for P.C.C. 1000 for R.C.C.	60

Table-8: Properties of $MgSO_4$

Chemical	Volume (%)
pH (5% water)	6.3
Free Alkali sol. (as NaOH)	0.008
Free Acid (as H_2SO_4)	0.01
Chlorides	0.02
Heavy metals (Pb)	0.0005
Arsenic	0.0002
Iron (Fe)	0.01
Selenium (Se)	0.001
Loss of Drying (at 450°c)	50.4

3.2. Tests on Concrete

The following tests were conducted on concrete and concrete specimens at different ages

- Compressive strength test
- Split tensile strength test

Table-.9: Compressive Strength results for cubes cured in water

Sample Designation	% of FA	compressive strength at 28 days (f^1_{cu})	compressive strength at 56days (f^1_{cu})	compressive strength at 90days (f^1_{cu})
W1	0	40.19	51.82	52.98
W2	5	42.53	52.83	53.69
W3	10	43.67	52.27	55.23
W4	15	40.67	48.33	54.16
W5	20	39.33	49.16	51.23

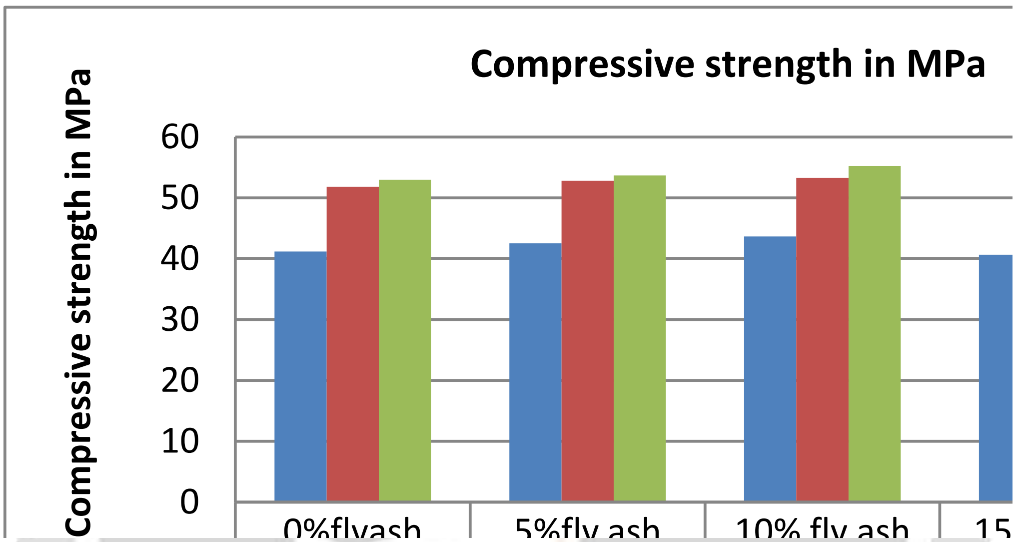

Chart -1: Comparison of Compressive strength

Fig-1: Compressive Strength of concrete

Table- 10: Tensile Strength results for cylinder cured in water

Sample Designation	% of FA	Tensile strength at 28 days (f^1_{cu})	Tensile strength at 56days (f^1_{cu})	Tensile strength at 90days (f^1_{cu})
W1	0	3.828	4.974	5.187

W2	5	4.075	5.187	5.247
W3	10	4.264	5.297	5.421
W4	15	4.112	4.933	5.375
W5	20	3.957	4.916	5214

Fig-2: Flexural Strength of concrete

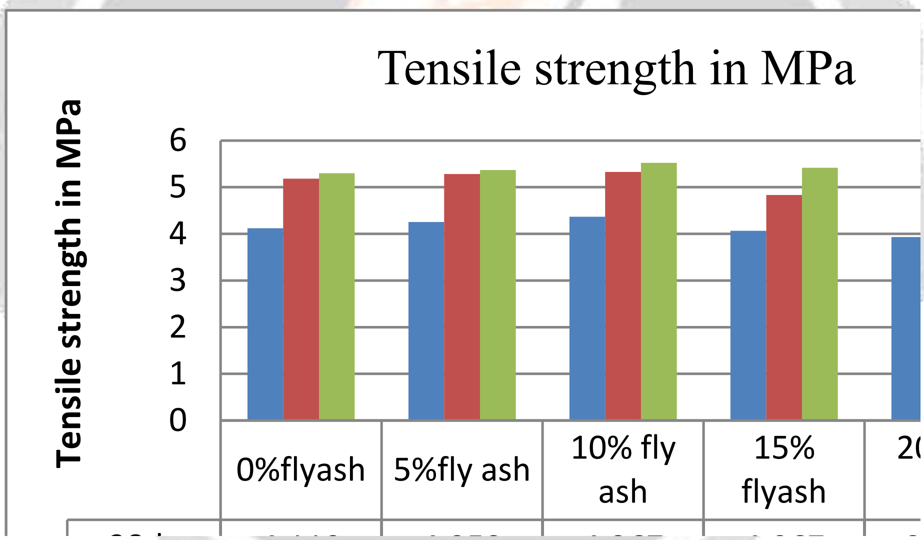

Chart -2: Comparison of Split tensile strength

Table -11: Variation of Compressive strength with different % of mgso4 solution for 28days curing

Compressive strength of cement concrete cubes-28days curing (MPa)					
Sample Designation	% of FA	WATER	1%mgSO_4	3%mgSO_4	5%mgSO_4
W1	0	41.19	47.24	34.53	35.88
W2	5	42.53	38.85	45.95	37.53
W3	10	43.67	40.00	37.50	38.70
W4	15	40.67	37.15	34.36	35.87
W5	20	39.33	35.95	33.15	34.63

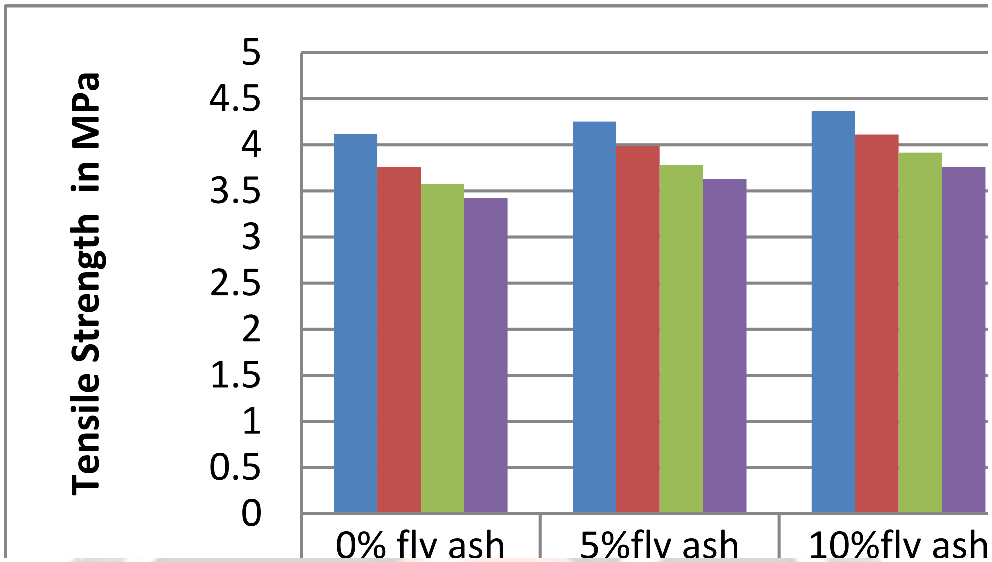

Chart 3 Compressive strength with different % of mgso4 solution for 28days curing

Table- 12: Variation of Compressive strength with different % of mgso4 solution for 56days curing

Compressive strength of cement concrete cubes-56days curing (MPa)					
Sample Designation	% of FA	WATER	1%$mgSO_4$	3%$mgSO_4$	5%$mgSO_4$
W1	0	51.82	47.82	45.76	41.94
W2	5	52.83	48.85	47.15	47.56
W3	10	53.27	49.55	43.05	48.02
W4	15	48.33	45.85	43.95	43.20
W5	20	49.16	44.50	42.44	43.91

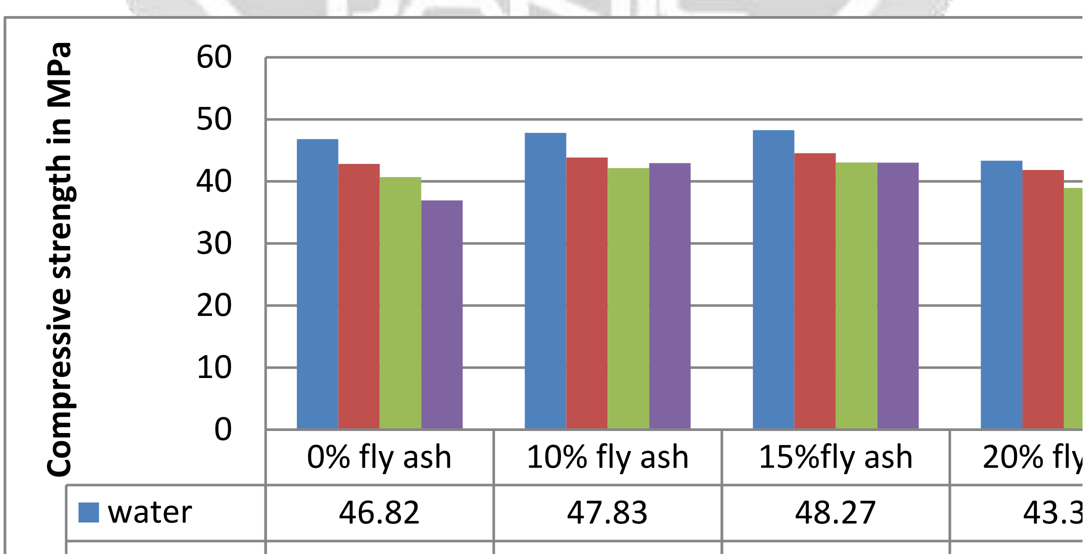

Chart 4.Variation of Compressive strength with different % of mgso4 solution for 56days curing

Table 13: Variation of Compressive strength with different % of mgso4 solution for 90days curing

Compressive strength of cement concrete cubes-90days curing (MPa)					
Sample Designation	% of FA	WATER	1%mgSO_4	3mgSO_4	5%mgSO_4
W1	0	52.98	49.9	49.50	45.26
W2	5	53.69	51.13	50.26	45.94
W3	10	55.23	52.69	51.80	47.31
W4	15	54.16	51.60	50.65	46.34
W5	20	51.23	48.18	47.95	43.76

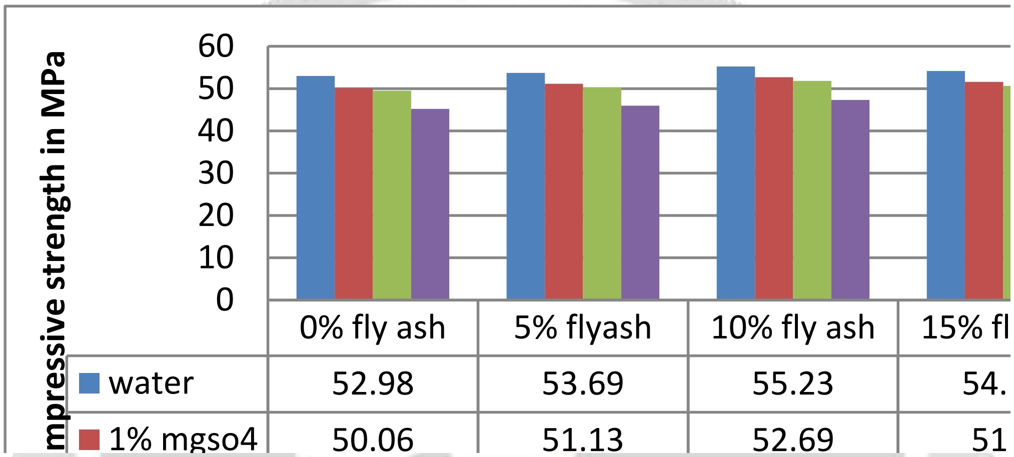

Chart 5. Variation of Compressive strength with different % of mgso4 solution for 90days curing

Discussion

- From table 4.3.1 the compressive strength of cubes cured in water the strength in increased with 0% to 10% weight replacement of cement with FA, and the strength is decreased at 15% and 20% weight replacement of cement with FA. For 28 days, 56days and 90days.
- From table 4.3.2 the tensile strength of cubes cured in water the strength in increased with 0% to 10% weight replacement of cement with FA, and the strength is decreased at 15% and 20% weight replacement of cement with FA. For 28 days,56days and 90days.
- From tables 4.4.1, 4.4.3, 4.4.5 the compressive strength of cubes cured in mgso4 solution 1%, 3%, 5% the strength in increased with 0% to 10% weight replacement of cement with FA, and the strength is decreased at 15% and 20% weight replacement of cement with FA. For 28 days, 56days and 90days.
- From tables 4.4.2, 4.4.4, 4.4.6 the tensile strength of cubes cured in mgso4 solution 1%,3%, 5% the strength in increased with 0% to 10% weight replacement of cement with FA, and the strength is decreased at 15% and 20% weight replacement of cement with FA. For 28 days, 56days and 90days.
- From the table 4.4.7, 4.4.8 and 4.4.9 the variation of compressive strength with different % of mgso4 for 28 days, 56days and 90 days curing is increased at 0%, 5%, and 10% decreased at 15% and 20% weight replacement of cement with FA.
- From the table 4.4.10, 4.4.11 and 4.4.12 the variation of tensile strength with different % of mgso4 for 28 days, 56days and 90 days curing is increased at 0%, 5%, and 10% decreased at 15% and 20% weight replacement of cement with FA.

From this study the following are the conclusions

1. Fly ash can be successfully used as a mineral mixture for replacement of cement.
2. The specific surface area of Fly ash is 400m2/kg greater than 330 m2/kg of cement. The workability of fly ash concrete have decreased in compared with ordinary concrete .it is inferred that reduction in workability is due to large surface area of fly ash

3 The compressive strength of concrete (with 0 % 5% 10% 15% and 20% weight replacement of cement with FA) cured in normal water with 7,28,56,90 days have reached the target mean strength

4. The compressive strength of concrete (with 0 % 5% 10% 15% and 20% weight replacement of cement with FA) cured in different concentrations of (1% 3% 5%) MgSo4 solution for 7,28,60,90 days (Table4.3.1 to Table4.3.2) indicated that at 5% replacement there is increase in strength and extended up to 10 % and then decreased in strength noticed at 15 and 20% replacement

5. The split tensile strength of concrete (with 0 % 5% 10% 15% and 20% weight replacement of cement with FA) cured in different concentrations of (1% 3% 5%) MgSo4 solution for 7,28,56,90 days (Table4.4.1 to Table 4.4.12) indicated that at 5% replacement there is increase in strength and extended up to 10 % and then decreased in strength noticed at 15 and 20% replacement

6. In concrete cement can be replaced with 10% FA without sacrificing strength

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