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Studies on the Corrosion Resistance of Reinforced Steel in Concrete with Fly Ash - An Overview

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Abstract:
Corrosion is a chemical process of destruction of material because of its reaction with the environmental conditions. Corrosion occurs when the relative humidity of air becomes more than 65%.Corrosion in concrete is the leading cause for the deterioration of structures. The corrosion resistance of concrete is tested after using fly ash as admixture and partial replacement of cement respectively. Fly ash is taken as partial replacement of cement in proportion of 10%, 15% and 20%. The corrosion resistance is studied for concrete by using Fly Ash. It has been concluded from the results that the corrosion resistance of concrete for 20% fly ash shows the best resistance among all the mixes.

Key words: Corrosion, Fly ash, Compressive strength, Pulse Velocity

1. INTRODUCTION

In today's world, a lot of steel is used to strengthen the concrete structures in the form of inserted rods hence the life of those embedded rods bear a persistent problem of corrosion and therefore is a cause of concern for scientists and engineers. Corrosion of reinforcing bars embedded in concrete is the most common cause of deterioration of concrete structures in aggressive environments ***(Jones A.E.K., 1997)***. Corrosion of steel reinforcement results in cracking and eventual spalling of concrete. In general, good quality concrete provides excellent protection for steel reinforcement. Due to the high alkalinity of concrete pore fluid, steel in concrete initially and, in most cases, for sustained long periods of time, remains in a passive state. Initiation of corrosion occurs either due to reduction in alkalinity arising from carbonation or the breakdown of the passive layer by the attack of chloride ions. The time to initiation of corrosion is determined largely by the thickness and the quality of concrete cover as well as the permeability of concrete. High quality and durable concrete is required to reduce the rapid deterioration of concrete under severe environmental conditions. In this context, the beneficial effects of alternative cementing materials should be considered. When alternative cementitious materials such as fly ash is used in concrete, not only reduced the porosity but also the pores become finer and the change in mineralogy of the cement hydrates leads to a reduction in the mobility of chloride ions***(S. Li & Roy, 1986)***. If the steel which is present in concrete corrodes an expansive force is generated due to increase in the volume of steel which can rupture the concrete. If a crack is being formed due to this expansive force in the structure then the rate of corrosion of steel starts even more rapidly leading to the complete failure of the structural member involved. Therefore worldwide, the chief concern is the early deterioration of reinforced concrete structures which is induced due to corrosion of the embedded steel. The prevention of the steel corrosion can be done by providing a waterproof coating which prevents the entry of salt, water and air. There are many objections from Civil Engineers on these ideas of preventing the reinforced RCC structures from corrosion. It has been found that even after applying waterproof coating the aggressive materials have still entered. Concrete carbonation is one of the important factors that affect the durability of concrete. With the ever increasing consumption of natural resources, carbon dioxide concentration in the atmosphere has continuously increased. Carbon dioxide reacts with cement hydrates in a process called carbonation, which leads to corrosion of steel bars. Many concrete structures around the world have suffered from the loss of durability due to carbonation, so it is urgent to solve the carbonation problem of concrete (***IS Yoon et al, 2007)***. There is one technique by which we can prevent the corrosion that is by screening the steel itself from the concrete and therefore from the aggressive medium. This is possible by using a non-reaching metal coating, paint or any other kind of coating. We can also screen the steel by creating a non-reactive film by means of inhibitors or polarization methods. The another alternative method of Corrosion Protection is the addition of Sodium benzoate, Sodium nitrate or Calcium chromate complexes to the mix or the application of slurry of Cement Paste over the steel and a layer of an epoxy base placed on the steel. Corrosion prevention techniques which are relied on addition of constituents in the mixture have been tried entirely for practical and cost-effective results as it can be easily determined if the additives have any compelling harmful effects on the concrete or not. Again methods concerning treatment of the steel in assessment are also much significant concern of probable loss of steel/concrete bond strength, either before or after some minor corrosion has arisen, this phase of the problem has also established consideration. Due to speedy growth all over the world, there is a necessity to construct and use concrete structures with reinforcement of steel namely multi-storey buildings, bridges, dams, railway sleepers, tunnels, nuclear power plants, turbo generator foundations, reservoirs etc. Reinforced steel corrosion of the pre-stressed concrete structure is a trouble worldwide and has restored scientific attentiveness in the last few decades. If humidity and oxygen are present there occurs corrosion in the reinforcement because of the entry of carbon dioxide which causes loss of alkalinity. Many progresses regarding to physical properties of entrenched metal and the concrete have come up. However, it's a very complicated task to regularly monitor the health of concrete structure because of the intricate and sophisticated design of structures and use of complicated instruments; this requires specialized knowledge for interpretation of data. Common materials which are easily available have been utilized to see their functioning on the potential growth at the metallic solution interface-Polystyrene, aluminum paint, red oxide and black Japan paint have been tested. When paint is utilized as an anti corrosive substance the key thing to be kept in the mind is the bond strength in between the reinforcement and concrete. Chemicals like CaCl2 and sodium Hexa-meta phosphate (HMP) were examined for their positive and negative performance of the maintenance/worsening of stable potential.

2. LITERATURE REVIEW

Naik et al, (1994) evaluated the effect of adding of a class C fly ash on the permeability of concrete by replacing cement with fly ash in the range of 0-70% by weight in the concrete composites. For the test results of air permeability, they have concluded that at lower ages upto 28 days, the concrete having high volume of fly ash showed higher levels of ingress of air relative to the normal Portland cement concrete. On water permeability test results, they have reported that concrete water permeability decreased with age. All three of the concrete mixes indicated fair resistance to water permeability upto the ages of 14-40 days. At 91-day age, the high volume (50%) fly ash concrete showed lower water penetrability to that of normal Portland cement concrete. They observed that chloride penetrability reduced with age. The 50% fly ash concrete showed the lowest permeability to chloride ions amongst all the mixture tested. The concrete composites with 50 and 70% replacements of cement with fly ash were better compared to the no fly ash concrete at 91 days with respect to w.r.t chloride-ion permeability.

V. Saraswathy et al, (2002) studied numerous activation methods to improve the resistance to corrosion and also strength of concrete by speeding up the hydration of fly ash blended cement. The compressive strength of the concrete specimens after 7, 14, 28 and 90 days were evaluated which were prepared by replacement levels 10%, 20%, 30% and 40% of the activated fly ash and after that the results were compared with ordinary Portland cement concrete (without fly ash). The activated fly ash cement showed better resistance to corrosion and strength of concrete when the replacement levels were 20–30% of activated fly ash cement. The better results were obtained when the fly ash was chemically activated as compared to the other activation investigated.

Ha et al, (2005) investigated the influence of fly ash on the rusting performance of steel in concrete and mortar by some accelerated short-term techniques in NaCl solutions. The various techniques adopted for determination of durability enhancements were weight loss method, OCP (Open Circuit Potential) measurements, impressed voltage and anodic polarization technique. Apart from this macro cell corrosion studies, pH measurements and approximation of free chloride content were also performed. The replacement of fly ash up to 30% level helped in improving corrosion resistance properties of the steel in concrete, improved the permeability characteristics, delayed initiation time of corrosion and decreased the rate of corrosion.

H.A.F. Dehwah, (2012) evaluated the corrosion resistance of SCC (Self-Compacting Concrete) which was prepared using QDP (quarry dust powder), SF (silica fume) plus quarry dust powder or fly ash . SCC specimens were prepared and tested for corrosion resistance, chloride penetrability and diffusion. The permeability was moderate for chloride in SCC specimens including QDP or fly ash and the permeability was low in the specimens including QDP plus SF.

M. Criado et al, (2012) examined the inhibitive consequence of two mixes of organic composites, disodium β-glycerol phosphate or GPH with sodium 3-aminobenzoate (3AMB) and glycerol phosphate with sodium N-phenylanthranilate (PhAMB), on the rusting of carbon steel reinforced bars implanted in carbonated chloride-polluted OPC and alkali-activated FA (fly ash) mortars. At room temperature and at 65% relative humidity, the carbonation in the mortar was achieved by keeping them in the CO_2 maintained chamber for 60 days. The mixture of PhAMB with GPH exhibited the utmost protective properties.

M. Kishore Kumar et al, (2012) studied the reinforced concrete durability w.r.t rusting of reinforcement. The initiation time and the time for cracking are determined by change in the slope of the specimens for different grades of concrete. For 30% replacement of cement with fly ash the initiation time of M25 grade was around 54 days as compared to other % of replacements. For 30% replacement of cement with fly ash the initiation time of M30 grade was around 63 days as compared to other % of replacements. For 30% replacement of cement with fly ash the initiation time was maximum in both grades of the concrete. For 30% replacement of cement with fly ash the compressive strength of the concrete specimens is higher in both grades of the concrete at 90 days of curing.

Rob B. Polder, (2012) reviewed the long lasting performance when the concrete was made with blast furnace slag and also fly ash linked to chloride induced reinforced steel corrosion. The penetration of chloride was deeper and faster in case of Portland cement concrete. According to the analysis of chloride profile for slag and Portland cement, the chloride surface fillings was similar, whereas the dispersal coefficient was consistently lower for slag cement in comparison to Portland cement. Compound cements with fly ash and slag at about 25% clinker replacement each behave similarly. Critical (corrosion initiating) chloride contents appear comparable for all cement types mentioned both fly ash and slag concrete show improved behavior compared to the Ordinary Portland cement in aggressive environments, in particular where penetration of chloride presents the risk of reinforcement corrosion. Replacement of clinker with slag at high-level (50 – 70%) and fly ash at intermediary level (20 – 30%) produces high chloride penetration resistance and high electrical resistivity, overall decreasing the risk of rusting in chloride corrupted environments.

Ana María Aguirre-Guerrero et al., (2016) tested the performance of 2 hybrid kind geopolymer mortars made of alkaline-activated FA and MK (Metakaolin) as defensive coatings against the chloride-induced rusting in reinforced cement concrete. In both cases, the coated, Portland cement (OPC)-based concretes (substrates) were subjected to accelerated techniques such as impressed voltage and wetting/drying cycles in the company of 3.5% NaCl solution.

The open circuit potential and linear polarization involving techniques were used to monitor the corrosion. To protect the structures that are open to marine locations, the geopolymer type mortars can be used.

3. MATERIAL AND METHODOLOGY:-

3.1 MATERIALS: 3.1.1 Cement: - Cement is a material that has cohesive and adhesive properties in the presence of water. Such cements are called hydraulic cements. These consist primarily of silicates and aluminates of lime obtained from limestone and clay. The physical properties of cement used for the experimental work was fulfilling all the criteria of IS: 12269 and IS: 4031 are as shown in Table-1.

Table.1. Physical property of cement as per IS: 12269(1987)

S. No.	Parameter	Result Obtained	Requirements as per IS:12269(1987)
1.	Fineness-Specific Surface (m^2/Kg) by sieve Analysis	285	Minimum 225.0(m2/Kg.)
2.	Standard consistency in (%)	30%	---
3.	Setting time in Min. (a) Initial setting time (Minute) (b) Final setting time (Minute)	47 min 260 min	--- Minimum - 30 Minute Maximum- 600 Minute

3.1.2 Aggregates: Aaggregate properties greatly influence the behavior of concrete, since they occupy about 80% of the total volume of concrete. The aggregate are classified as

(I) Fine aggregate

(II) Coarse aggregate

Fine aggregate are material passing through an IS sieve that is less than 4.75mm gauge beyond which they are known as coarse aggregate. Coarse aggregate form the main matrix of the concrete, where as fine aggregate form the filler matrix between the coarse aggregate. The most important function of the fine aggregate is to provide workability and uniformity in the mixture. The fine aggregate also helps the cement paste to hold the coarse aggregate particle in suspension. According to IS 383:1970 the fine aggregate is being classified in to four different zone, that is Zone-I, Zone-II, Zone-III, Zone-IV. Also in case of coarse aggregate maximum 20 mm coarse aggregate is suitable for concrete work. But where there is no restriction 40 mm or large size may be permitted. In case of close reinforcement 10mm size also used.

Table. 2. Physical property of fine aggregate

S. No.	Properties		
1	Zone of Sand	II	- -
2	Water Absorption (%)	1.1	Max - 2 %
3	Sp. Gravity of Sand	2.67	2.6 - 2.7

Table .3. Physical property of coarse aggregate

S. No.	Properties		
1	Water Absorption (%)	1.5	Max - 2 %
2	Sp. Gravity of Sand	2.72	2.6 - 2.9

3.1.3 Fly ash: Fly ash is finely divided residue resulting from the combustion of powdered coal and transported by the flue gases and collected by electrostatic precipitator. Fly ash is the most widely used pozzolonic material all over the world. In the recent time, the importance and use of fly ash in concrete has grown so much that it has almost become a common ingredient in concrete, particularly for making high strength and high performance concrete.

To use fly ash as a supplementary cementitious material extensive research has been done on the benefits that can be achieved by using fly ash. All over the world high volume fly ash concrete is becoming the subject of current interest as the use of fly ash as concrete admixture not only extends technical advantages to the properties of concrete but also contributes to the environmental pollution control. In India alone, we produce about 75 million tons of fly ash per year, the disposal of which has become a serious environmental problem. The concrete technologists and government departments are taking serious considerations on fly ash due to its effective utilization. The tests on fly ash were carried out as per IS: 1727-1967. The specific gravity of fly ash is 2.25 and fineness is 8 % (by dry sieving method).

Figure.1. Fly Ash

3.2 METHODOLOGY: In this research work fly was used as a pozzolonic material. In different weight fraction (0%, 10%, 15%, 20%) to cement it was used in M25 grade of concrete and study the 7 days and 28 days compressive strength, Durability test and flexural strength of concrete to that of normal concrete with maintaining the water cement ratio in the range of 0.50.

Table .4. Specimens for tests

S. No.	Tests	Specimen	Dimension
1.	Compression test	Cube	(150x150x150)mm
2.	Durability test	Cube	(150x150x150)mm
3.	Flexural test	Beam	(150x150x700)mm
4.	Durability test	Beam	(150x150x700)mm

4. RESULT AND DISCUSSION:

4.1 Compression Test: - Specimens of size 150x150x150 mm were casted for compression test. Testing of specimens was done after 7 days and 28 days of water curing. Compressive strength for different proportions of fly ash and control mix for 7 and 28 days are as follows:

Table: 4 Compressive strength (N/mm^2) of control mix and different proportions of fly ash

Control Mix Trial	7 days	28 days
1	19.11	31.11
2	18.22	30.66
3	20.44	31.55

MIX	7 days	28 days
0%	19.25	31.11
10%	25.32	39.85
15%	23.55	35.7
20%	21.03	33.18

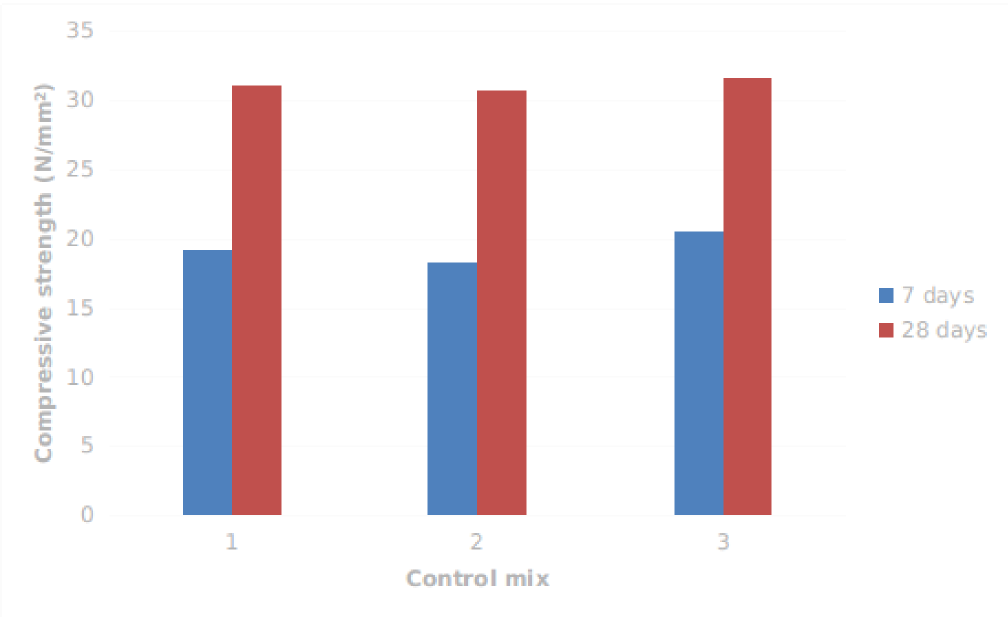

Figure.2. Compressive strength (N/mm^2) of control mix

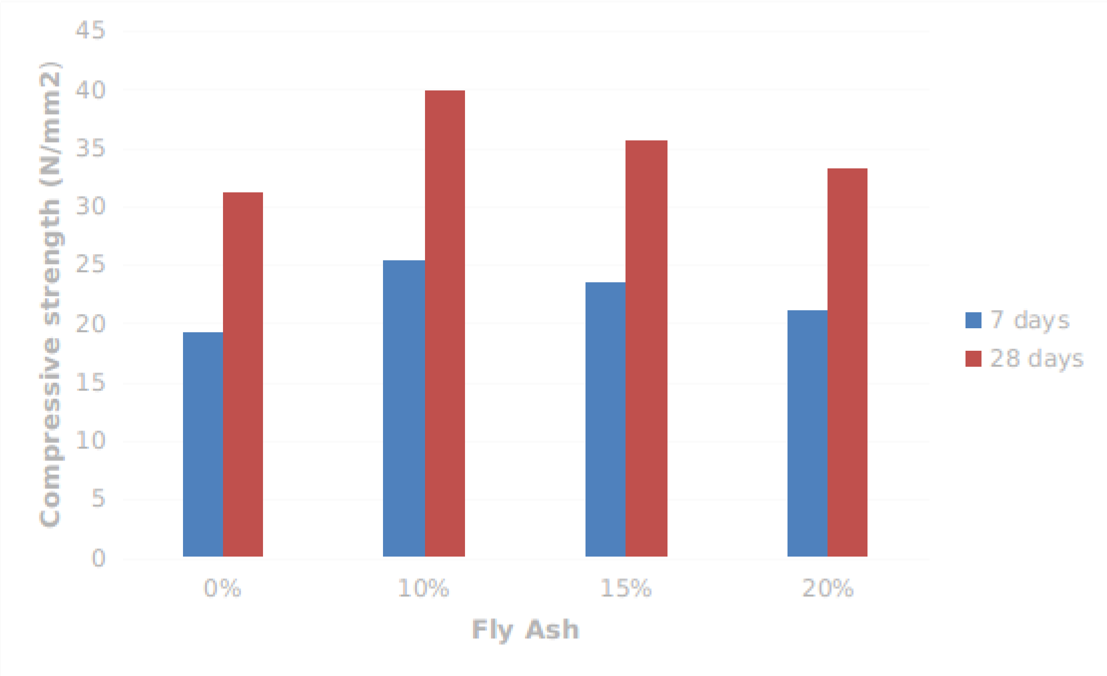

Figure.3. Compressive strength (N/mm^2) of different proportions of fly ash

4.2 Flexural test: Specimens of size 150x150x700mm were casted for flexural test. Testing of specimens was done after 28 days of water and acid curing to check its behaviour against acid.

Figure.4. casting specimen for Flexural Strength test

Flexural strength for different proportions of fly ash for 28 days is as follows:

Table.5. Flexural strength (N/mm^2) of control mix and different proportions of fly ash

Fly ash %	FLEXURAL STRENGTH (N/mm^2)	
	Before acid curing	After acid curing
0%	3.16	2.73
10%	3.97	3.50
15%	4.37	3.94
20%	4.98	4.62

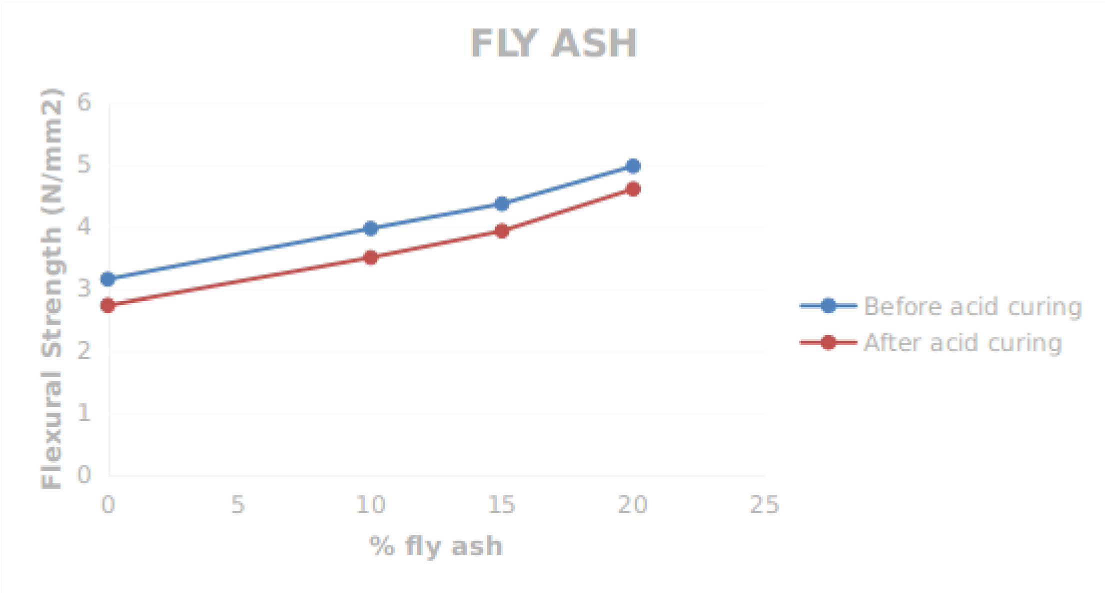

Figure.5. Flexural strength (N/mm^2) of different proportions of fly ash

4.3 Durability test [acid attack (H2SO4 Solution)]:
Cubes of size 150x150x150mm and Beams of size 150x150x700mm were casted for durability test. Testing of specimens was done after a period of 28 days of water curing and then 28 days of acid curing. Specimens were submerged in 10N H2SO4 solution for 28 days. Following tests were done to check durability test:

4.3.1 UPV (ULTRASONIC PULSE VELOCITY) TEST:
150x150x150mm size cubes were casted for UPV test. Testing of specimens was done after a period of 28 days of water curing and also after 28 days of acid curing. This test is used to check the quality of concrete. This test was performed using UPV instrument.

Pulse velocity (km/s) for different proportions of fly ash is as follows:

Table.6. Pulse velocity of control mix and different proportions of fly ash

	Before Acid curing	**After Acid curing**
	PULSE VELOCITY (km/s)	**PULSE VELOCITY (km/s)**
0%	**4.09**	**3.79**
10%	**4.37**	**4.09**
15%	**4.65**	**4.38**
20%	**4.7**	**4.49**

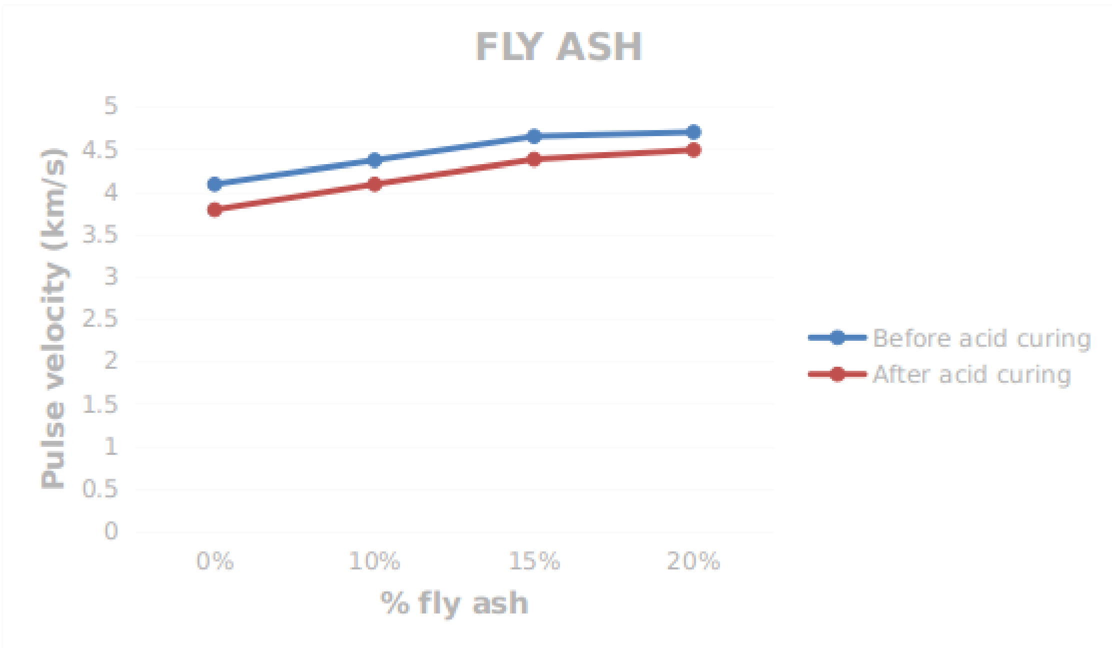

Figure.6. Pulse velocity of different proportions of fly ash

For fly ash, 10% has the highest Compressive strength while 20% has the highest flexural strength amongst the various proportions. Reduction in Compressive strength is least in the composite mix containing 20% fly ash while strength reduction ranges from 15%-22% for different mixes. Reduction in flexural strength is least in 20% fly ash amongst its various proportions. For fly ash, 20% Fly ash gives the best resistance to corrosion of concrete (acid attack).

5. CONCLUSION:-

Based on limited experimental investigation concerning the corrosion resistance of reinforced steel in concrete the following observations are made regarding the resistance of partially replaced fly ash for M25 grade concrete: For overall mixes, it is concluded that the mix having 20% fly ash gives the bestest resistance to corrosion as compared to different individual mixes.

6. REFRENCES:

[1]. C. Faella, C. Lima, E. Martinelli, et al., Mechanical and durability performance of sustainable structural concretes: an experimental study, Cem. Concr. Compos. 71 (2016) 85–96.

[2]. C. Thomas, J. Setien, J.A. Polanco, et al., Durability of recycled aggregate concrete, Constr. Build. Mater. 40 (2013) 1054–1065.

[3]. C.D. Atis, Accelerated carbonation and testing of concrete made with fly ash, Constr. Build. Mater. 17 (3) (2003) 147–152.

[4]. I.S. Yoon, O. Copuroglu, K.B. Park, Effect of global climatic change on carbonation progress of concrete, Atmos. Environ. 41 (34) (2007) 7274–7285.

[5]. Jones, A. E. K., Marsh, B., Clark, L., Seymour, D., Basheer, P., & Long, A. (1997). Development of an holistic approach to ensure the durability of new concrete construction. Camberley, UK:: British Cement Association.

[6]. K. Sisomphon, L. Franke, Carbonation rates of concretes containing high volume of pozzolanic materials, Cem. Concr. Res. 37 (12) (2007) 1647–1653.

[7]. Li, S., & Roy, D. M. (1986). Investigation of relations between porosity, pore structure, and C1− diffusion of fly ash and blended cement pastes. Cement and Concrete Research, 16(5), 749-759.

[8]. Naik, T. R., & Singh, S. S. (1997). Permeability of flowable slurry materials containing foundry sand and fly ash. Journal of Geotechnical and Geoenvironmental Engineering, 123(5), 446-452.

[9]. S.C. Kou, C.S. Poon, Long-term mechanical and durability properties of recycled aggregate concrete prepared with the incorporation of fly ash, Cem. Concr. Compos. 37 (2013) 12–19.

[10]. Song, H. W., & Saraswathy, V. (2002). Corrosion monitoring of reinforced concrete structures-A. Int. J. Electrochem. Sci, 2, 1-28.

[11]. V.G. Papadakis, Effect of fly ash on Portland cement systems: part I. Low-calcium fly ash, Cem. Concr. Res. 29 (11) (1999) 1727–1736.

[12]. V.G. Papadakis, Effect of fly ash on Portland cement systems: part II. High-calcium fly ash, Cem. Concr. Res. 30 (10) (2000) 1647–1654.