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A study on the pH Value of Fly Ash Concretes

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***Abstract*:-- Use of fly ash in concrete as replacement to cement is an established practice accepted all over the world. The reason is mainly due to the fact that replacement or addition of fly ash reduces the cement consumption and make the concrete economical. Flyash concretes are more durable than conventional concretes. However, the addition of fly ash in concrete decreases the pH of concrete and reduction in pH value disturbs the passivation layer formed around the rebars. The passivation layer is formed around the rebars in concrete due to the higher alkalinity of concrete. Thus the addition/replacement of cement by fly ash affect the pH and thereby the alkalinity. This article describes the effect of replacement of cement by fly ash on the pH value of the end product i.e., fly ash concrete. Fly ash concrete and mortar specimens are cast and tested for pH. It is found that replacement of cement by fly ash reduces the pH of the matrix. With the increase in the age of fly ash concrete reduction in pH value is found to be more. This indicates that the reaction of fly ash with Calcium Hydroxide present in concrete with time reduces the pH value. It is concluded that the treated flyash would be more effective and beneficial than replacement of cement with untreated fly ash..**

***Index Terms*—Corrosion, Durability, Fly ash, pH of concrete.**

I. INTRODUCTION

Corrosion of re-bars in reinforced concrete structures is recognized as a major problem in the maintenance of the structural integrity. The most important causes for initiation of corrosion of reinforcing steel are the ingress of chloride ions and carbon dioxide to the steel surface and pH of concrete surrounding the rebar. Chloride ion causes local destruction of the passive film leading to localized corrosion. Carbon dioxide, on the other hand, reacts with the hydrated cement matrix, leading to a decrease in pH and subsequent loss of steel passivity and to corrosion initiation. Chemical protection is provided by the high pH (12.5-13.5) of the concrete interstitial solution, which causes passivation of the reinforcing steel. Concrete also provides physical protection, by hindering the access of aggressive agents. Severe corrosion problems however occur in many structures.

Addition of fly ash to concrete has become common practice in recent years. Reasons for fly ash addition include economy and enhancement of certain mechanical properties of fresh concrete (workability and pumpability) and of hardened concrete. However the effect of fly ash addition/replacement to the cement on the corrosion aspects of the concrete needs careful consideration. In this investigation an attempt has been made to estimate the pH of fly ash concretes.

II. FLY ASH

Fly ash is a finely divided residue resulting from powdered coal combustion and acts as a pozzolanic material i.e., the particles react with water and lime to produce cementations products. The carbon content of fly ash is a major concern. Class C fly ash, most of which is produced from lignite coal contains little carbon. However, Class F fly ash, produced primarily from anthracite and bituminous coal, contains significant amounts of carbon. Class C and Class F material also differ from each other and from source to source with regard to strength, rate of strength gain, color and weather ability. Class C fly ash results in a buff-colored concrete; Class F is a darker grey. Class C fly ashes contain more calcium oxide (greater than 10%) compared to Class F fly ashes. High calcium fly ashes possess self-hardening properties while the low calcium fly ashes possess less or no self-hardening properties. The first equation in Fig.2 shows the chemistry of hydration of Portland cement. About 50% of Portland cement is composed of the primary mineral tri-calcium silicate, which on hydration forms calcium silicate hydrate and calcium hydroxide. If you have Portland-pozzolan cement, and fly ash is the pozzolan, it can be represented by silica because non-crystalline silica glass is the principal constituent of fly ash. The silica combines with the calcium hydroxide released on the hydration of Portland cement. Calcium hydroxide in hydrated Portland cement does not do anything for strength, so therefore use it up with reactive silica. Slowly and gradually it forms additional calcium silicate hydrate which is a binder, and which fills up the space, and gives impermeability and more and more strength.

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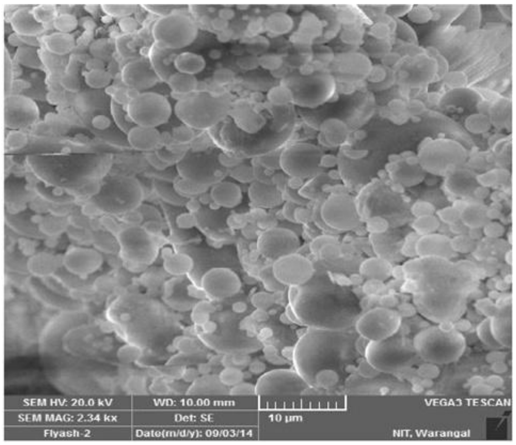

Figure 1SEM of Fly ash

Gel

$C_3S + H \rightarrow CSH + CH + Heat$ -----

Cement Calcium Hydroxide

$S + CH \rightarrow CSH$ ---------------------

Silica in Fly ash 2) Gel

Figure 2.Chemistry of Fly ash in concrete

The properties of hardened concrete that are significantly influenced by the addition of flyash are strength and permeability, and these in turn, influence several other durability and long term strength properties. Addition of fly ash in fly ash concrete may be as high as 60 percent of OPC content and because of the high replacement level; the fly ash concretes are characterized by their low early strength and high ultimate strength. The low early strength is attributed to the partial replacement of Portland cement, with a material that is not hydraulic. High dosage of fly ash in concrete may reduce the pH of the concrete. A drop in the pH of concrete reduces the passive alkaline layer over the rebar, thereby promoting the favorable conditions of corrosion. Thus the present study focuses on the tests on blended cement fly ash mortars for estimating the pH.

III. LITERATURE REVIEW

Kajsa Byfors (1987) reported the test results on high volume fly ash concrete examined for pore water content, Calcium Hydroxide (CH) content and pH of pore water solution. It is mentioned that the reduction in CH content increases with the progressing of hydration process and varies linearly with the logarithm of curing age. It is also mentioned that at 20°C, the pH of pore solution of high-volume fly ash cement paste was reduced to a great extent at early ages and it continued to decline at later ages due to the inclusion of large amount of fly ashes.

Yoon-Seok Choi, Jung-Gu Kim, Kwang-Myong Lee (2006), reported the half cell potential data of reinforced fly ash concretes. It is mentioned that the partial replacement of cement by fly ash showed better resistance to corrosion and a decrease in the chloride ion permeability. This indicates the improvement in the durability of fly ash concrete compared to conventional concrete.

V Saraswathy, S Muralidharan, K Thangavel, S Srinivasan (2003) reported the advantages of partial replacement of cement by activated fly ash. The activation adopted physical, chemical and thermal. It is mentioned that replacement of cement by activated fly ash to the tune of 20-30% improves the corrosion resistance and strength of concrete. It is also mentioned that activation of fly ash by chemical means is more useful than activation by other two methods.

Cengiz Duran Atis (2003) reported that 70% replacement of cement by fly ash carbonated more when compared to the same concrete with 50% replacement of cement by fly ash. It is also pointed that the normal concrete without fly ash showed more carbonation than concrete with 70% replacement of cement by fly ash.

IV. METHODOLOGY AND TEST RESULTS

pH tests are conducted at different levels of replacement of cement by fly ash in mortars and concrete specimens at different ages of curing. In the first phase of experimentation fly ash and cement mixture in solution is tested for its pH value. In the second phase of experimentation mortar planks of different proportions of cement and fly ash are tested for pH. River sand is used as fine aggregate and water to binder ratio is taken as 0.35. Binder to fine aggregate ratio is maintained constant as 1:3. In the third phase of experimentation concrete of 1:2:4 proportions with different replacement levels of cement by fly ash are considered for its pH. The fly used in this investigation is obtained from Vijayawada Thermal Power Station, Andhra Pradesh. Chemical composition of the same is presented in Table.1. Initially tests were conducted to know the pH of cement, fly ash and different replacements of cement with fly ash. The pH of the cement and fly ash solution for different replacements of cement by fly ash were shown in Table.2 and Fig.3.

From this phase of the investigation it is clear that fly ash alone has a pH value of 7.8. The results indicate that the pH of cement in solution state is around 11.89 & pH of fly ash in solution state is around 7.8. So by addition of fly ash, we can claim that the pH of the concrete as a whole will decrease. The test conducted on the mixture after 24 hours of preparation. As the curing period is very small the test result is taken as indicative only and in the next phase of investigation cement – fly ash mortar planks are cast and are tested for different age s of curing. However the test results indicate that the drop in pH value is noticeable if the percentage replacement of cement by fly ash is more than 90%.

In the second phase of investigation , PH tests were conducted on mortar planks prepared for different replacements of cement by fly ash were noted at the end of 3rd, 7th, 14th, 28th & 90th day of curing. The results are as presented in Table.3 and Figure 4. Mortar planks are cast with water to binder ratio of 0.35. The test results indicated that replacement of cement by fly ash decreased the pH value. Age of curing upto 28days showed little decrease in pH content while the decrease in pH value at 90days of curing is mark able. Decrease in pH value at 90 days of curing of mortar planks with 80% replacement of cement by fly ash showed about 14.83%. When the percentage replacement of cement by fly ash is 40%, then the decrease in pH value for 90days curing is found to be 9.11%. From this discussion it can be concluded that partial replacement of cement by fly ash reduces the pH of the matrix with age of curing. This issue may be detrimental to the corrosion resistance of such fly ash concrete.

In the third phase of investigation, concrete is prepared with cement, fly ash, fine aggregate and coarse aggregate with a water to binder ratio of 0.45. The PH tests were conducted on 1:2:4 concrete cubes with 0.45 w/c cubes with different fly ash replacement were cast. PH tests were conducted at the end of 3rd, 7th, 14th, and 28th day of curing. The results are presented in Table 4 and Figure 5. The test results of this phase of investigation indicated that the pH of concrete decreases with increase in the percentage replacement cement by fly ash. When the cement is replaced by fly ash to the tune of 40% the reduction in pH value in concrete at 28 days curing is observed to be 3.36%. This clearly indicates that reduction in pH value of mortars is pronounced with higher replacement levels of cement by fly ash than the same in concrete. Thus it can be inferred that the partial replacement of cement by fly ash needs an essential attention. Especially in case of rich mortar adopted in ferrocement elements this reduction in pH value may be detrimental. Research work in this direction is more needed for further recommendations.

V. CONCLUSIONS

Based on the experimental observations the following conclusions are presented.

1. Replacement of cement by fly ash decreases the pH of the mix.
2. Reduction in pH at higher replacement levels of cement by fly ash in mortars is more pronouncing than in concretes.
3. Higher replacement levels of cement by fly ash in rich mortar needs a careful study in respect of pH reduction or its corrosion resistance.
4. Further studies are needed in this direction for high strength concretes.

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Table 1. chemical composition of fly adopted

Specific surface	5840 cm^2/gram
Specific Gravity	2.01
SiO_2	58.14%
Al_2O_3	28.98%
Fe_2O_3	4.90%
CaO	5.68%
MgO	1.04
SO_3	0.64%
LOI	0.54%
Insoluble Residue	84.44%

Table.2 Effect of pH of cement fly ash solution for different replacements of cement by fly ash

Percentage of cement replaced by Fly ash	pH
0	11.89
5	11.85
10	11.83
20	11.82
30	11.80
40	11.79
50	11.76
60	11.68
70	11.52
80	11.42
90	11.30
95	11.24
98	10.76
99	10.62
99.2	10.58
99.4	10.50
99.5	10.42
99.6	10.15
99.7	9.84
99.8	9.55
99.9	8.17
100	7.28

Table.3. Variation of pH of the cement fly ash mortar planks made with for different replacements of cement by fly ash.

% cement replaced by fly ash.	3^{rd} day	7^{th} day	14^{th} day	28^{th} day	90^{th} day
0	12.61	12.40	12.36	12.49	12.18
5	12.60	12.38	12.32	12.47	11.71
10	12.60	12.32	12.28	12.45	11.62
20	12.59	12.29	12.26	12.44	11.54
30	12.57	12.27	12.24	12.42	11.41
40	12.54	12.23	12.20	12.35	11.07
50	12.52	12.20	12.17	12.26	11.04
60	12.37	12.14	12.08	12.14	10.69
70	12.28	11.88	11.82	11.82	10.54
80	12.20	11.77	11.72	11.58	10.39

Table 4. PH of concrete cubes for different replacements of cement by fly ash.

% Cement replacement by Fly ash	Concrete Cubes			
	3^{rd} day	7^{th} day	14^{th} day	28^{th} day
0	12.38	12.36	12.32	12.20
5	12.35	12.34	12.28	12.17

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10	12.32	12.32	12.22	12.12
20	12.28	12.29	12.18	12.09
30	12.24	12.22	12.10	11.94
40	12.20	12.16	12.03	11.83
50	12.15	12.05	11.98	11.79
60	12.10	11.92	11.91	11.64
70	11.78	11.81	11.84	11.54
80	11.55	11.48	10.84	10.76
90	11.20	11.21	10.54	10.15

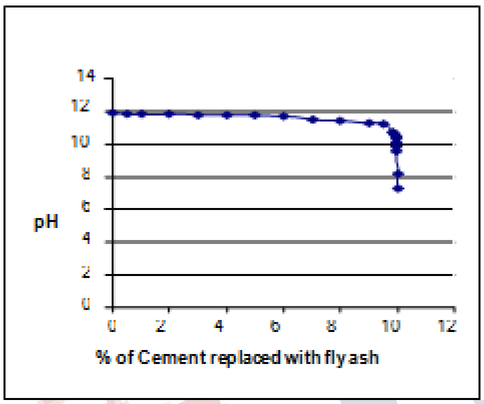

Fig.3 Variation in the pH of cement and fly ash solution for different replacements of cement by fly ash

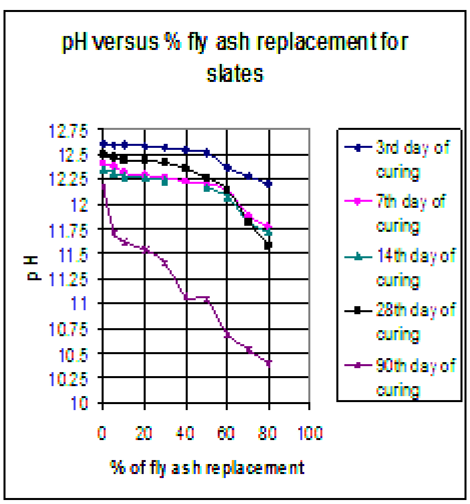

Fig.4. Variation of pH of the cement fly ash mortar for different replacements of cement by fly ash

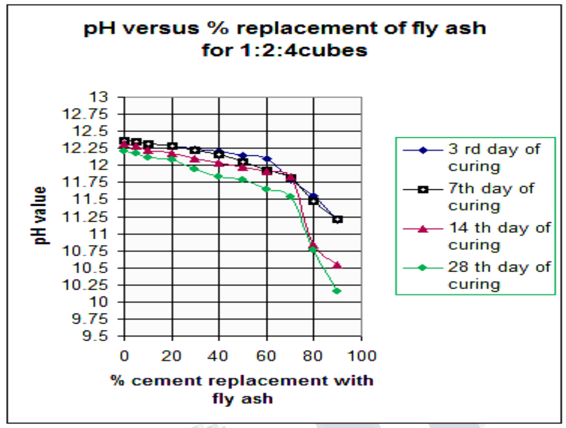

Fig.5. Variation of pH of the cement fly ash concrete made with different replacements of cement by fly ash