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AN EXPERIMENTAL INVESTIGATION ON FLY ASH BLENDED CEMENT CONCRETE

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ABSTRACT

Presence of chloride ions has been identified to be one of the major causes for the initiation and propagation of corrosion of reinforcement in reinforced concrete structures. Even though chlorides may not be present in the constituent materials, concrete structures can be exposed to penetration of chloride ions either in a marine environment, or in the case of use of deicing salts in cold climates. Some structures in industrial environments or in water treatment facilities are also susceptible to chloride penetration. In all these cases, chloride ions permeate in to concrete through different physical modes of penetration such as capillary absorption of salt solution ,migration of chloride ions through concentration gradient –driven diffusion. etc., Thus, ensuring the lowest possible levels for the chloride permeability of concrete is one of the basic requirements of corrosion. Use of pozzolanic materials is beneficial in reinforced concrete and mass concrete for reducing hydration temperature and improving pore structure. It is especially beneficial from durability point of view, when concrete is expected to severe exposure condition such as sea water etc. Structures exposed to such environment are attacked by chloride and sulphate ions and it has been found that due to chloride attack, the reinforcing bars become vulnerable to corrosion.

This work is aimed at a study on the effect of fly ash on strength development and chloride penetration resistance in concrete. The compressive strength development in concrete containing fly ash has been studied up to bath- cured ages of 7,28,90 and 180days for different percentages of fly ash replacement levels. The chloride penetration resistance study has been carried out using ponding test for exposure ages of 6,12 and 24 weeks using 3.5percent sodium chloride solution.

As such the principal objectives of the present investigation are

- *Experimental investigation of the penetration of chloride ions in concrete with different percentages of replacement of cement by fly ash used as binding material.*
- *Experimental investigation of strength developed in concrete having different percentages of replacement of cement by fly ash and their comparison with the concrete containing only OPC.*

Keywords: Admixtures, Fly Ash, Metakaolin, Chloride Penetration

I. INTRODUCTION

1.1 Pozzolanic Admixtures in Concrete

Pozzolanic materials are either naturally available or manufactured waste materials, the mainly contain silica, which becomes reactive in the presence of free lime available in cement. When pozzolanic admixtures are

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mixed with cements, the reactivity varies depending upon the type of pozzolanic, its chemical composition and its fineness. In developing countries like India, pozzolanic materials are available as industrial wastes by-products,. Extensive research work has been carried out on the use of pozzolons in construction materials. Fly ash, silica fume, stone dust, blast furnace slag, Rise husk ash etc, are some of the industrial wastes which possess pozzolanic properties. Out of the above pozzolanic admixtures, Fly ash can be considered as the one, which is abundantly available. Fly ash concrete possesses certain desirable and enhanced properties compared to ordinary plain concrete.

1.2 Over View on Pozzolonas in Concrete

In recent years, pozzolons in concrete materials are being used as an addition or partial replacement for the more expensive Portland cement to improve the properties of the concrete, pozzolanic materials are siliceous and aluminous materials which possess little or no cementitious value, but in finally divided form and in the presence of moisture, they chemically react with calcium hydroxide lime liberated on hydration at ordinary temperatures to form compounds calcium, silicate, hydrategel) possessing cementations properties. The calcium hydroxide, otherwise a water- soluble material, is converted into insoluble cementitious material by the use of pozzolanic material. The action is termed as 'pozzolanic action'. The rate of reaction is slow at early age and pozzolanic action is more pronounced at later ages.

1.2.1 Fly ash

Fly Ash known as pulverized-fuel ash, is a finely divided residue from the combustion of pondered coal in modern boilers in the thermal power plants,. There are 66 thermal power plants in India using about 110 million tons of coal and producing about 30 to 40 million tons of ash every year. If this ash is unused, its disposal will need 28,300 hectares of land, which is a serious ecological problem for land, water and air.

1.2.2 The Indian Fly ash

The main mineral species identified in fly ash are mullite, tridymite /quartz, magnetite and amorphous glassy phase along with unburnt carbon. As the glassy phase is between 30 to 60 percent, fly ash has a unique pozzolanic activity.

1.3 Reinforcement Corrosion in Concrete

It may be noted that the present work is largely focused on pore reinforcement and increased resistance to chloride penetration in concretes containing fly ash. Thus, though it is out of the preview of the present work, a brief explanation of the mechanism of reinforcement corrosion, and effect of presence of chloride ions on it, is discussed in this section.

1.3.1 Mechanism of corrosion of reinforcing steel deterioration of concrete

Corrosion of steel embedded in concrete is a oxidation-reduction reaction resulting in oxidation of iron present in steel. The reactions proceed by means of an electro chemical mechanism, which involves both micro cell and cell corrosion [guilders et al, 1996]. The electro chemical potentials needed to form these corrosion cells may be generated in RCC in two ways:

(i) Composition cells are formed due to non-uniformity in the surface characteristics of the reinforcing steel.

(ii) Concentration cells are formed due to differences in concentration of dissolved ions in the vicinity of steel.

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As a result of creation these potential differences some part of the embedded steel becomes anodic where as some other part becomes catholic and electrochemical current comes into existence. The above phenomenon is diagrammatically illustrated below as shown in Fig 1.1

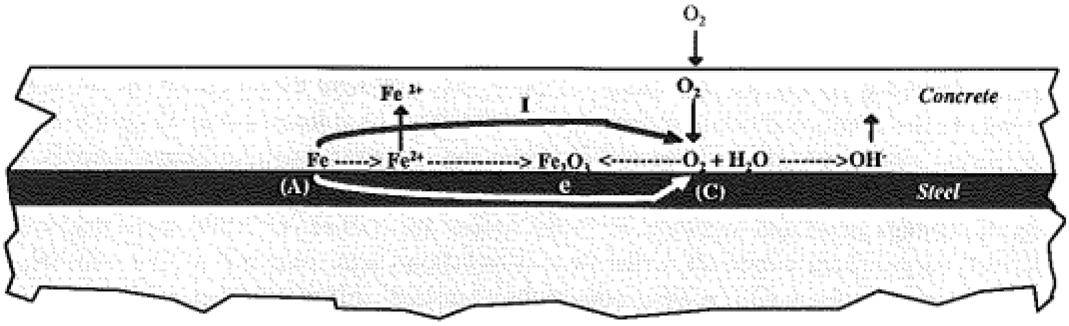

Fig.1.1 Schematic Representation of the Corrosion Process

II. EXPERIMENTAL WORK

2.1 Materials Used

The materials used in this study for preparation of specimens were Portland cement (OPC), fly ash, coarse aggregate, fine aggregate and water. The relevant details of all these materials are provided below and in the following tables.

2.2 Cement

A 53-grade ordinary Portland cement (Penna Cement), which confirms to IS: 12269-1987 was used in the present experimental investigation. All the tests are carried out in accordance with procedures described in IS: 4031-1968. Tests were conducted for the determination of physical properties of the cement and they are tabulated below

2.3 Fly Ash

Fly ash is obtained from the Krishnapatnam Thermal Power Plant meeting the desired specifications.

Table No.2.1 Physical Properties of Nellore Fly Ash

S.No	Characteristics	Results
1.	Color	Grey
2.	Specific gravity	2.18
3.	Residue on (90µ Sieve) %	44.20
4.	Residue on (150µ Sieve) %	17.50
5.	Specific surface cm^2/gm	2051.00
6.	P^H value of water content	8.75

2.4 Coarse Aggregate

Machine crushed granite 20mm maximum size of aggregate has been obtained from the 'Ithepalli' quarry. It has been tested for physical and mechanical properties such as specific gravity, sieve analysis and bulk density. The results have been shown in the following table. Sieve analysis of coarse aggregates is shown in the table.

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Table No 2.2: Physical Properties of Coarse Aggregate

SI.NO	PROPERTY	VALUE
1	Specific gravity	2.68
2	Bulk density	1620Kg/cu.m
3	Fineness modulus	6.7

2.5 Fine Aggregate

Fine aggregate obtained from Swarnamukhi river near Srikalahasti which conforms to zone –II of table 4 of IS 383-1970 has been used. Following tests have been carried out as per procedure given in IS 383-1970. The results have been shown in the following table.

Table No.2.4: Physical Properties of Fine Aggregate

SI.NO	PRPPERTY	VALUE
1	Specific gravity	2.52
2	Fine modules	2.8
3	Bulk density	1536kg/cu.m
4	Grading zone	Zone II

2.6 Water

Tap water available at our lab with a pH value of 6.7 is used in the preparation of concrete and curing.

2.7 Proportioning and Mixing of Concrete

The American Concrete Institute (ACI) method of mix design was used for calculating the properties of concrete used in the present study. The total water content and the coarse aggregate content in all the mixes were kept constant.

2.7.1 Water binder ratio

The binder id the sum of the cement (OPC) and the fly ash used. To study the effect of water-binder ratio, three different W/B ratios of 0.4, 0.5 and 0.6 were used for all replacement levels as well as the control concrete.

2.7.2 Fly ash properties

Five replacement levels of OPC with fly ash were adopted. Partial replacement of cement by 5%, 7%, 10%, 12% and 15% by weight of total binder content is adopted.

2.7.3 Coarse aggregate

The coarse aggregate of maximum size 20mm has been used in the present investigation. The coarse aggregate content in all the mixes was also kept constant at 1005Kg/cu.m

2.7.4 Water content

The water content was kept constant at 185Kg/cu.m in all the mixes.

2.7.5 Fine aggregate

The specific gravities of cement and fly ash are 3.15 and 2.5 respectively. Since the coarse aggregate content and total binder ratio (i.e. cement and fly ash) is kept constant, the fine aggregate content requires a suitable adjustment for the replacement of cement by fly ash

2.7.6 Ages of Curing Considered

Constant specimens were cured for 7, 28, 90 and 180 days for compressive strength and 28 days for split tensile strength.

For the chloride penetration specimens are immersed in 3.5 percent sodium chloride solutions for the periods of 6,12 and 24 weeks taken out from 28 days curing with tap water.

2.8 Details of Test Specimens

Properties of concrete considered

(a) Compressive Strength of Concrete

(b) Split Tensile Strength of Concrete

(c) Chloride Penetration into Concrete

2.8.1 Compressive Strength Test

Compressive strength test is carried out in a 400 ton capacity compressive testing machine

Table No. 2.5 Cube Compressive Strength with Percentage of Fly Ash

MIX	Percentage replacement of cement by Fly ash	compressive strength in MPa			
		7 Days	28 Days	90 Days	180 Days
Mix 1 W/B =0.4	0	32	35	37	38.5
	5	30.66	35	38	40.5
	10	29.33	35.33	38.7	41.9
	15	28.33	37	40.66	44.33
	20	27	36.1	37.8	42.6
	25	25	33.3	36.1	39.8
Mix 2 W/B =0.5	0	26.5	29	30.5	32
	5	25.66	28.7	31.33	33
	10	24.66	29.3	32.33	34
	15	24.33	30.33	33.66	35.33
	20	23.33	28.66	32.33	34.3
	25	22	27.66	29	33.4
Mix 3 W/B =0.6	0	22	24	25.5	26.5
	5	21.33	23.5	26	27.66
	10	20.33	23.7	26	28.66
	15	19.33	25.33	28	30.33
	20	18.33	24.33	27	29
	25	18	23.3	25.6	27

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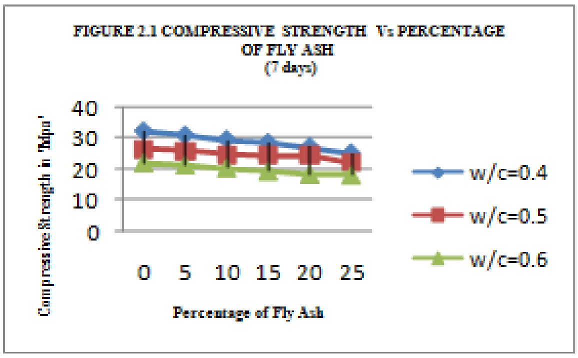

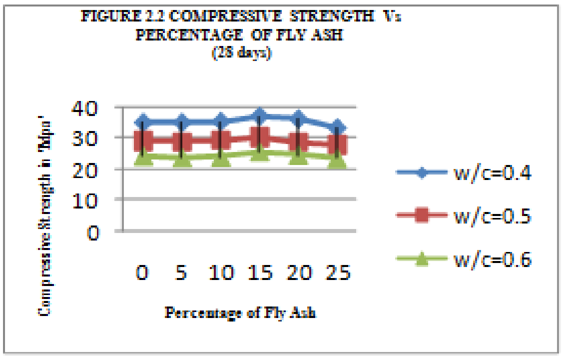

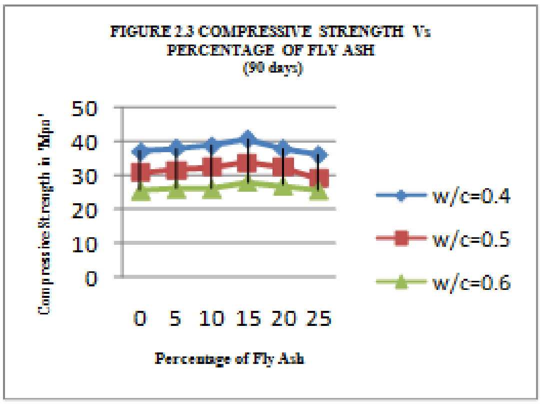

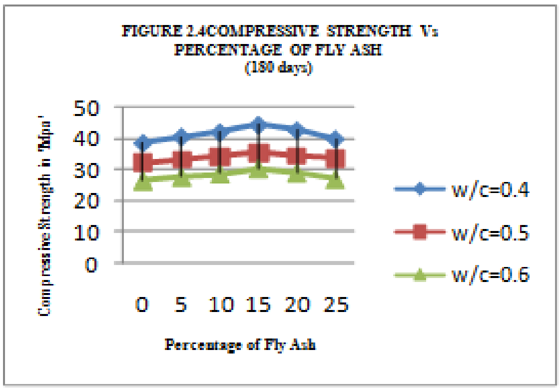

2.8.2 Cylinder Splitting Tension Test

Table No. 2.6: Split Tensile Strength of Concrete with Percentage of Fly Ash

MIX	Percentage replacement ofcement by Fly ash	Split Tensile Strength in MPa
		28 Days
Mix 1 W/B =0.4	0	3.92
	5	3.819
	10	3.85
	15	4.116
	20	3.58
	25	3.06
Mix 2 W/B =0.5	0	3.39
	5	3.39
	10	3.4
	15	3.56
	20	3
	25	2.57
Mix 3 W/B =0.6	0	2.75
	5	2.84
	10	2.81
	15	2.88
	20	2.57
	25	2.33

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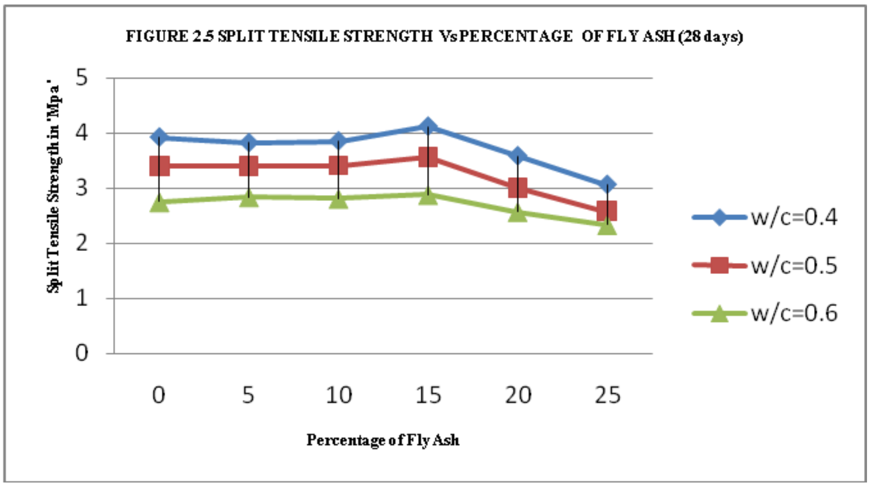

2.8.3 Chloride Penetration Test

Table 2.7: Chloride Penetration in to the Concrete After Complete Immersion on NaCl Solution After 24 Weeks

MIX	Percentage of Fly ash	Chloride concentration (g/L) at various Average depths of drilling			
		5mm	10mm	15mm	20mm
Mix 1 W/B =0.4	0	0.476	0.23	0.037	0.031
	5	0.44	0.193	0.046	0.034
	10	0.39	0.13	0.043	0.034
	15	0.302	0.121	0.042	0.039
	20	0.285	0.08	0.04	0.034
	25	0.242	0.048	0.027	0.04
Mix 2 W/B =0.5	0	0.526	0.268	0.103	0.066
	5	0.46	0.257	0.112	0.07
	10	0.41	0.16	0.039	0.074
	15	0.368	0.12	0.037	0.074
	20	0.297	0.091	0.032	0.07
	25	0.157	0.066	0.048	0.08
Mix 3 W/B =0.6	0	0.623	0.271	0.067	0.080
	5	0.584	0.232	0.078	0.041
	10	0.48	0.18	0.072	0.048
	15	0.372	0.15	0.08	0.111
	20	0.331	0.135	0.087	0.086
	25	0.357	0.106	0.08	0.092

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FIGURE 2.6 CHOLRIDE PENETRATION INTO CONCRETE OF W/B RATIO 0.4 AFTER CONTINUOUS IMMERSION IN 3.5 PERCENT NaCl SOLUTION FOR 24 WEEKS

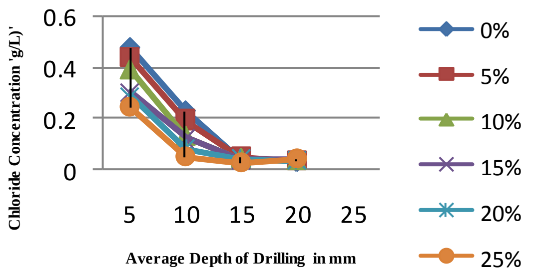


FIGURE 2.7 CHOLRIDE PENETRATION INTO CONCRETE OF W/B RATIO 0.5 AFTER CONTINUOUS IMMERSION IN 3.5 PERCENT NaCl SOLUTION FOR 24 WEEKS

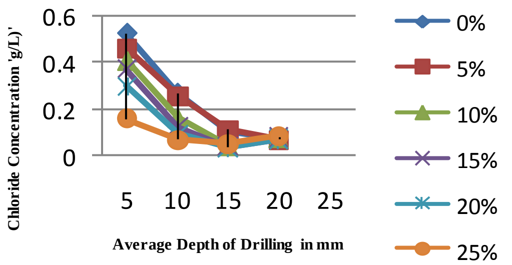
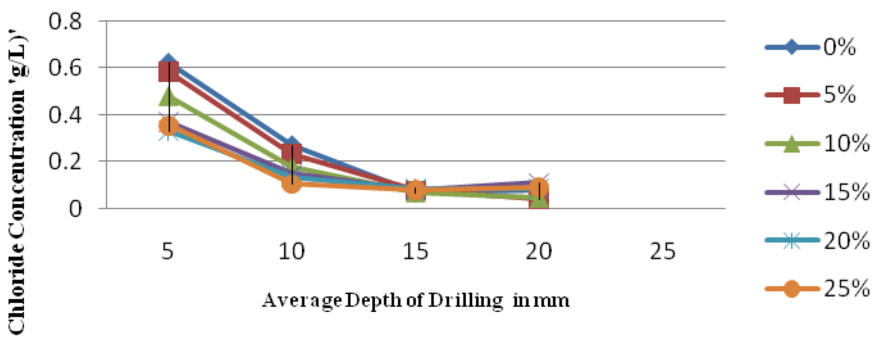


FIGURE 2.8 CHOLRIDE PENETRATION INTO CONCRETE OF W/B RATIO 0.6 AFTER CONTINUOUS IMMERSION IN 3.5 PERCENT NaCl SOLUTION FOR 24 WEEKS



III. CONCLUSIONS

1. Replacement of cement by fly ash does not improve the compressive strength at the early age for any W/B ratio considered (i.e., at 7 days) for any level of replacement compared to the control mix.

2.15% of fly ash can be taken as the optimum doses, which can be mixed as particle replacement to cement for giving maximum possible compressive strength beyond 28 days of curing

3. The optimum percentage replacement of cement by fly ash is again 15% only from the consideration of split tensile strength also

4. The W/B ratio increases the compressive strength as well as split tensile strength decreases for different percentage of replacement of fly ash

5. The percentage of replacement of cement by fly ash increase the workability decreases

6. As the percent of fly ash replacement increases chloride penetration resistance substantially increases for all periods of immersion

7. As the percentage of fly ash replacement level increases the chloride penetration level increase with depth of penetration.

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