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Author(s)	Ali Ajwad, Usman Ilyas, Nouman Khadim, Abdullah Muhammad Usman, Shakir Ahmad, Bilal Zahid, and Abdul Waqar Akhtar	
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Assessing the Durability of Concrete with the Addition of Low Quality Fly Ash

Ali Ajwad*, Usman Ilyas, Nouman Khadim, Abdullah Muhammad Usman, Shakir Ahmad, Bilal Zahid, and Abdul Waqar Akhtar

Department of Civil Engineering,
University of Management and Technology,
Lahore, Pakistan

*ali.ajwad@umt.edu.pk

Abstract

The life span of a structure is basically determined by its durability. Over the course of time, concrete carbonation and corrosion of steel reinforcement lead to weakness in concrete's structural elements and hence reduce its useful life. The addition of fibers in concrete can act as barrier and delays the activation of these processes. In this study, low quality fly ash was added to concrete to check its effect on the durability of concrete. It was found that the addition of low quality fly ash with an activator does have a positive impact on carbonation and reinforcement of corrosion resistance.

Keywords: structure, durability, carbonation, corrosion, fly ash

1. Introduction

Pulverized fuel ash or fly ash is a waste product of coal power stations. This waste is dumped into landfills and it poses a major threat to the environment. Using it in concrete as replacement can not only protect our environment but can also add to construction economy. In previous studies, fly ash has been used to improve the fresh and hardened properties of concrete but its effect on concrete's durability has not been investigated properly. Qingxin Zhao et al. studied the effect of extended curing of 90 days on carbonation resistance and found that extended curing did have the positive effect of dense interfacial zone and the negative effect of calcium hydroxide consumption [1]. Bagheri et al. compared the performance of fine fly ash and silica fume in enhancing the properties of concrete containing fly ash and found that silica fume is substantially more effective than fine fly ash in improving the properties of conventional fly ash based ternary mixes [2]. M. L. Berndt studied the properties of sustainable concrete containing fly ash, slag and recycled concrete aggregate [3]. He found that the mixes containing 50% slag gave the best overall performance. Cengiz Duran Atiş studied the properties of steel fiber reinforced fly ash concrete and found that the addition of fly ash improved the durability of concrete by increasing its freeze-thaw resistance [4].

It can be noticed that most of the researches in this regard used high-quality and well-refined fly ash, whereas the effects of the use of low quality fly ash on durability are still not well-studied. In this research, low quality fly ash was added to concrete in large volumes and its effects were studied.

2. Experimental Program

2.1. Materials Used

Locally available Portland cement was used that comes with the brand name 'Maple Leaf'. The fly ash used for cement replacement was obtained from Maple Leaf power plant located in Sahiwal, Pakistan. Table 1 shows the chemical analysis of fly ash used as cement replacement. The fineness of fly ash used was 27.3% (percentage retained on sieve size of 45 micrometer).

Table 1. Element Properties of added Fly Ash

SiO_2	CaO	Fe_2O_3	Al_2O_3	MgO	Na_2O	TiO_2	SO_3	K_2O
53.6	3.5	3.9	34.3	1.0	0.8	0.9	0.9	1.1

Locally available Lawrencepur sand was used as fine aggregate and in place of coarse aggregate waste crushed limestone was used. Water-reducing agent and activators were also added.

2.2. Concrete Specimens Preparation

For carbonation test, steel reinforcement corrosion test, and flexural strength, 100x100x400 mm^3 specimens were cast, whereas to test the compressive strength (corrosion resistance) cubes of 100 x100x100 mm^3 were cast. A concrete cover of 30mm was provided to all specimens and the minimum diameter steel, that is, 6mm bar was used. Specimens were cured by keeping them dipped into water for 28 days.

3. Results and Discussion

3.1. Carbonation

Two different concentrations of CO_2, that is 20% and 3% respectively, were used to check the effect of the addition of low quality fly ash in concrete. Table 3 shows the depth of carbonation in 28 days old concrete. M1 mix was normal concrete whereas M2 and M3 mixes were 35% cement replaced by low quality fly ash with the addition of activator in M3.

Table 2. Carbonation

Mix No.	Depth of Carbonation (mm)	
	20% CO_2 Concentration	**3% CO_2 Concentration**
M1	15.2	12.1
M2	23.1	17.3
M3	14.9	11.8

It can be seen from the results that the depth of carbonation increases with the addition of fly ash as cement replacement. This trend is similar for both types of carbon dioxide concentrations, although this increased carbonation can be controlled with the addition of the activator in the mix.

3.2. Corrosion of steel reinforcement

The results of tests performed to check the corrosion of steel reinforcement were similar to that of carbonation tests. The addition of fly ash increased corrosion in carbonated concrete, whereas the addition of activators reduced the corrosion rate and it was less than that in normal concrete. When corrosion was checked in concrete that was not carbonated, the corrosion of reinforcement was less in M2 as compared to M1 specimen and it was even lesser in M3 specimen.

Table 3. Corrosion Resistance

Mix No.	Compressive Strength (MPa)			Flexural Strength (MPa)		
	Water	**5% Na_2SO_4**	**5% HCl**	**Water**	**5% Na_2SO_4**	**5% HCl**
M1	41.2	40.1	31.7	3.11	3.78	2.45
M2	43.6	44.2	34.2	3.34	3.9	3.56
M3	43.1	41.1	36.7	2.99	3.12	2.78

3.3. Corrosion Resistance

In order to check corrosion resistance, specimens were cured for 120 days in 3 different solutions including normal curing, curing in 5%

sodium sulphate solution and 5% hydrochloric acid solution, respectively. The results are shown in table 3.

It can be seen from the table that the addition of fly ash improves the compressive and tensile strength of specimens. In addition to increased strength, resistance to corrosive environment also increases.

4. Conclusions

1. Carbonation resistance can be increased with the use of an activator in low quality fly ash reinforced concrete. This resistance is almost similar to that of control concrete.
2. Resistance to corrosion of steel reinforcement can be enhanced with the use of activator under harsh environments.
3. With the addition of low quality fly ash, resistance to corrosive environments can be improved in concrete. Fibrous concrete shows more resistance and retains more strength over longer spans of time.

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