USING LOCALLY AVAILABLE FLY ASH FOR MODIFYING CONCRETE PROPERTIES

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ABSTRACT

This paper suggests the possible use of fly ash, a bye-product produced in our thermal power plants operating on coal as fuel for improvement of concrete quality. In the present investigation, locally available finely divided fly ash has been used for modification Presently, it is being used extensively in concrete in modern countries and is considered as waste material in general. Behavior of fly ash modified concrete in comparison to normal concrete having same mix proportions, aggregates, net water-cement ratio and similar curing conditions has been studied in short terms up to the age of 56 days during which the specimens were subjected to normal water curing method. Tests were carried out for compressive strength at 3, 7, 14, 28 and 56 days, 24 hours %age water absorption at the age of 56 days and durability (resistance of concrete against N/2 sloutions of both nitric acid and hydrochloric acid for one month) of concrete were also carried out at the age of 56 days. It was seen that the compressive strength of concrete modified with the available type of fly ash was less than the normal concrete. But so far as the durability and %age water absorption are concerned, fly ash plays an important role here. 24 hours %age water absorption decreases with increase in fly ash content an admixture and as a cement replacement in concrete. But so far as durability is concerned, 20% replacement of fly ash with cement appears to be more effective than it is with 40%. The purpose of investigation was to introduce the use of fly ash in concretes to the Engineers and Architects in Pakistan.

Keywords: Fly ash, Modified concrete, Curing method, Durability of concrete, Acid resistance, Chemical resistance, %age water absorption.

INTRODUCTION

Fly ash is a byproduct of burning finely divided coal in electrically generating power plants. It is captured from exhaust gases of power plants by electrostatic precipitation which enables the relatively clean air to escape from smoke. Fly ash is rich in oxides of silica, alumina and iron. Chemically speaking, “fly ash looks for lime” when mixed with cement in presence of water. 100 kg of Portland cement when mixed with water liberates12-20 kg of free lime (CaO) during hydration. Fly ash with its chemically active silica and alumina readily reacts with this free lime to form additional cementitious compounds.

When used in concrete, fly ash acts like cement, and actually replaces a percentage of the Portland cement used. Fly ash generally replaces around 15% of cement in much of the concrete

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used today, but we can do much better by using it to replace up to 50% or more to be known as High Volume Fly Ash Concrete (HVFAC)

It is well known that modification of construction materials always aims at some predetermined and carefully selected objective. The choice of admixtures to be used also depends upon the objective of modification which may either be for strength, architectural finishes or durability or a combination of these. Modification with Fly ash usually results in cement savings, increased workability, increased strength after 56 days, increased cohesion of mix, increased frost and chemical resistance and reduced permeability of concrete etc which makes a high performance concrete.

When fly ash is added to the mix, the silica in fly ash reacts with these large crystals and transforms them into a strong cement paste that binds concrete together. This eliminates the micro cracking and creates concrete that is much less permeable, and therefore more durable.

USES OF FLY ASH IN CONSTRUCTION INDUSTRY

Concrete manufacturers, engineers, architects, developers and contractors all have an interest in specifying or using fly ash on a routine basis to improve the quality of concrete and to increase cost effectiveness.

PRE–MIX PRODUCERS

A pre–mix producer has several reasons for using fly ash in concrete:

1. Fly ash can compensate for fines not found in some sands and, thereby, enhance pumpability and concrete finishing.
2. Fly ash will result in a more predictable and consistent finished product which will ensure customer acceptance.
3. Fly ash offers flexibility in mix design providing a greater range of mixes - from "flowable fill" at about 1 MPa to high strength 50+ MPa concrete –produced by the same batch plant without exotic equipment. (1 Mpa = 145 psi)
4. Fly ash improves the flowability of concrete which translates into less wear and tear on the entire producer's equipment from batching facilities to trucks.
5. Fly ash enables the producer to customise designs to each customer's needs, thus providing the producer who uses it with a competitive advantage.

ENGINEERS AND ARCHITECTS

Engineers and architects will find that fly ash provides the following benefits:

1. It enables them to provide the client with a superior and more durable finished concrete.
2. Fly ash produces a high strength concrete that accommodates the design of thinner sections.
3. Fly ash permits design flexibility accommodating curves, arches and other pleasing architectural effects.
4. The addition of fly ash to the mix is a built-in insurance for later-age strength gain in concrete.

5. Fly ash ensures that the concrete will qualify as a durable building material.

6. Fly ash contributes to the aesthetic appearance of the concrete.

DEVELOPERS, CONTRACTORS, OWNERS

Fly ash concrete provides the following advantages to developers, contractors and owners:

1. The workability of fly ash concrete generally ensures that the speed of construction is faster which translates into a quicker return on investment.

2. Fly ash in the mix accommodates more creative designs.

3. Since fly ash concrete is not as vulnerable to deterioration or disintegration as rapidly as concrete without fly ash, it ensures low-maintenance buildings which will retain their value over the long-term.

Fly ash definitely enhances quality of concrete construction and returns real benefits to every member of the building team.

CASTINGS

In order to study the parameters, mentioned in the Abstract, for both normal and locally available fly-ash modified concretes, the castings were made using both conventional 1:1.5:3 and 1:2:4 concrete mix proportions by weight having net water-cement ratio (W/C) of 0.6 (called 'control concrete')at a room temperature of 34^0C and relative humidity of 55 %. Locally available Haro sand with a fineness modulus of 2.60 on ASTM Sieve 100 (BS sieve 100) and Margallah crushed stone (Lime stone or calcium carbonate) having a fineness modulus of 6.6 on sieve 100 was used (in market language 3/4" down).

Fly ash was added to the same mixes of concrete as an admixture and as a cement replacement of 20% and 40% as per ACI [1,2,3] Procedures.

It was mixed with sand firstly (in presence of 50% of total water content) and then other ingredients were mixed and water was subsequently added after 2-3 minutes of initial mixing. Workability tests were done.

Based on literature survey [4,5,6,7] the castings included 100x100x100 mm (4"x 4"x 4") cubes for compression testing and 50x50x50 mm (2"x 2"x 2") cubes for %age water absorption and durability tests. The coarse aggregates had an apparent specific gravity of 2.63. The total mixing time in a pan type mixer was about 4 minutes. Table 1 and 2 give the bulk densities of constituent materials and workability test results respectively.

Table-1: Bulk Densities of Constituent Materials

Material	Loose State (Kg/m^3)/(lb/ft^3)	Rodded State (Kg/m^3)/(lb/ft^3)
Haro Sand	1433.8/89.61	1586.0/99.12
Coarse aggregate (19 mm down)	1418.3/88.64	1595.6/99.72
Cement	1435.4/89.71	--
Fly ash	409.9/25.625	--

Some properties of locally available fly ash used in this investigation are given in Table-2 while Table-3 gives the results of workability tests.

Table-2: Properties of Locally Available Fly Ash

Specific Gravity	%age Voids	Fineness Modulus	% LOI (Loss on Ignition)
2.5	83.57	0.74	3.685

Table 3: Results of Workability Tests

Type of test	Type of mix	W/C Ratio	Normal concrete	20% modified concrete	40% modified concrete
Slump test (mm / in)	1:1.5:3	0.6	89 / 3.5	95 / 3.75	102 / 4.0
	1:2:4	0.6	0 / 0	38 / 1.5	60 / 2.375
Compacting factor test	1:1.5:3	0.6	0.99	1.0	1.0
	1:2:4	0.6	0.85	0.94	0.97

CURING OF SPECIMENS

For curing, all the specimens were kept in water for 28 days after demoulding at the age of 24 hours. During these 24 hours, specimens in moulds were kept in the laboratory at an average temperature of 32o at 55% relative humidity. After this time period, they were taken out of water and kept at normal laboratory conditions and tested at specified ages. Table-4 gives the compressive strength results.

Table-4: Compressive Strength Results on 4”x 4”x 4”cubes at 28 days

Type of Mix	Time (Days)	Normal Concrete (MPa) / (psi)	20% Modified Concrete (MPa) / (psi)	40% Modified Concrete (MPa) / (psi)
(1:1.5:3)	3	14.22 / 2065	11.57 / 1680	9.64 / 1400
	7	17.36 / 2520	14.22 / 2065	15.20 / 2205
	14	21.70 / 3150	16.40 / 2380	18.32 / 2660
	28	26.52 / 3850	21.00 / 3045	22.18 / 3220
	56	27.49 / 3990	26.00 / 3780	23.15 / 3830
(1:2:4)	3	13.74 / 1995	10.85 / 1575	10.61 / 1540
	7	17.36 / 2520	14.95 / 2170	14.47 / 2100
	14	19.05 / 2765	16.39 / 2380	16.88 / 2450
	28	24.35 / 3535	20.73 / 3010	20.73 / 3010
	56	30.38 / 4410	28.21 / 4095	25.80 / 3745

24 hours water absorption of control concrete and that modified with varying percentages of locally available fly-ash has been studied and is reported in table 5.

Table-5: Results of 24 Hour % Water Absorption Test at the Age of 56 Days

Type of mix	24 hours %age water absorption		
	Normal concrete	20% modified concrete	40% modified concrete
1:1.5:3	4.85	4.16	3.74
1:2:4	4.01	3.56	3.11

The Strength – Age relationships have also been plotted and are shown in Figures-1 and 2.

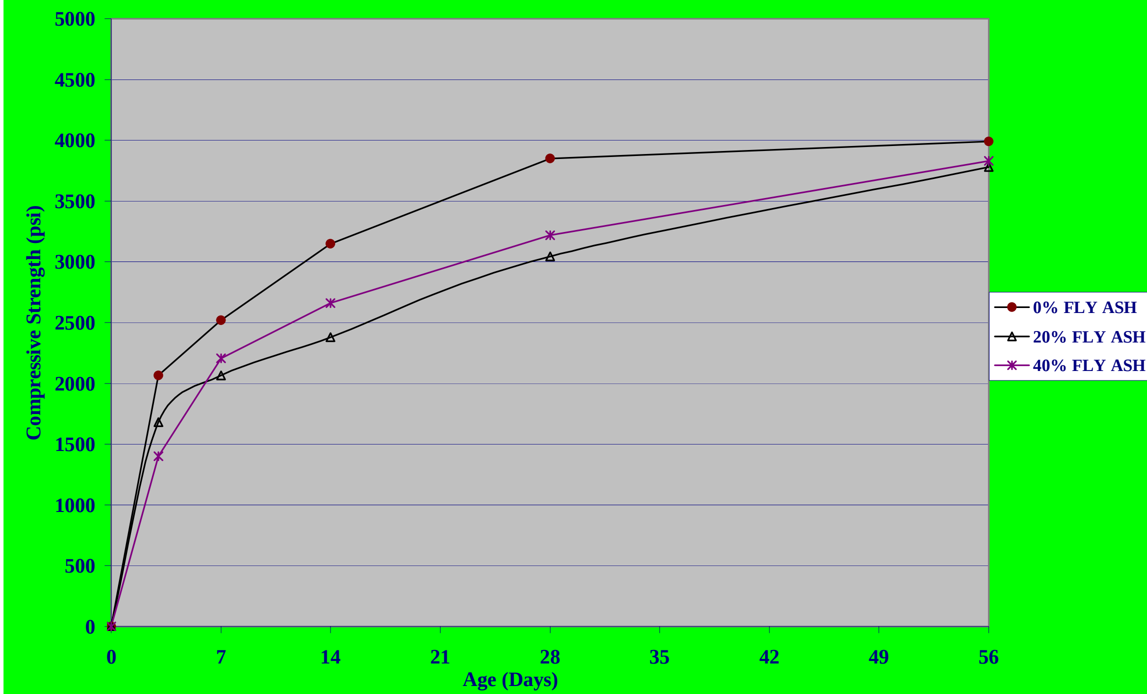

Fig. 1 Age ~ Strength Relationship [1:1.5:3]

Fig. 2 Age ~ Strength Relationship [1:2:4 Mix]

Because concrete has pH values in the alkaline range so it was recommended in literature(8) to test its durability for chemical resistance against acids which were selected considering the results of an earlier investigations by some researchers [9,10].. The reagents were HCL and HNO_3. Table 6 gives the details of commercially available acids used in the investigation.

Table-6: Properties of Commercially Available Acids used in Investigation

Type of test solution	Density (g/cc)	Purity (%)	1 N Solution of 100% strength (g/l)	1 N Solution of given purity (g/l)	N/2 Solution of given purity (g/l)
HCl	1.14	28.61	36.5	127.58	63.79
HNO_3	1.39	67.18	63	93.78	46.89

In chemical resistance tests specimens of the normal and modified concretes discussed above were earlier treated by N/20 and N/10 acid solutions which resulted in no appreciable weight and volume losses. Therefore it was decided to test them for N/2 acid normality. It was observed that a strong chemical reaction took place immediately after acid solutions came into contact with three different types of concrete specimens and CO_2 was liberated after observing severe efflorescence for N/2 Normality of acids only. Table 7 gives the weight loss after 28 days treatment with the above mentioned reagents when the age of specimens was 56 days.

Table–7: Weight Loss of Specimens after 28 Days Immersion in various Reagents at the Age of 56 Days

Reagent	Type of mix	Strength of solution	Type of concrete	Initial.wt. (grams)	Dry wt. after 28 days (grams)	Weight Loss (%)
HCl	1:1.5:3	N/2	Normal	302	257	15.07
		N/2	20% modified	294	251	14.54
		N/2	40% modified	307	254	17.26
	1:2:4	N/2	Normal	315	271	14.02
		N/2	20% modified	319	275	13.71
		N/2	40% modified	303	254	15.97
HNO_3	1:1.5:3	N/2	Normal	281	240	14.48
		N/2	20% modified	319	286	10.34
		N/2	40% modified	279	233	16.52
	1:2:4	N/2	Normal	319	283	11.28
		N/2	20% modified	294	267	9.34
		N/2	40% modified	311	268	13.83

pH value changes within reagent solutions during a weeks' use in a treatment cycle of 28 days (four weekly acid solution changes)have also been monitored by using pH sticks.. HCL showed low weakness and HNO_3 showed more weakness in terms of an increased pH value. These are presented in Table-8.

Table-8: pH Variations for One Weekly Change of Reagent

Reagent	Type of mix	Type of Concrete	Value at Day 1	Value at 28 Days
HCl	1:1.5:3	Normal	1	4
		10 %	1	5
		20%	1	5
HNO_3	1:1.5:3	Normal	1	5
		10%	1	5
		20%	1	5
HCl	1:2:4	Normal	1	5
		10 %	1	4
		20%	1	5
HNO_3	1:2:4	Normal	1	5
		10%	1	5
		20%	1	4

CONCLUDING REMARKS

1. Use of fly ash in concrete results in economical-high performance concrete.
2. The results are only for the materials and mix proportions used. For other mix proportions, same results may not be applicable.
3. Compressive strength of concrete decreases with an increase in %age of this type of fly ash as a cement replacement in concrete at early ages. However, at the age of 56 days, difference between compressive strength of normal and modified concrete is much less than it is at the age of 7 days for both mix proportions suggesting that long term strength of such modified concrete will be more than control concrete.
4. 24 hours %age water absorption of concrete reduces with increase in %age of fly ash in concrete. This trend is same for both mix proportions (1:1.5:3 and 1:2:4) investigated.
5. Permeability, durability and cohesion of concrete in general are improved.
6. Percentage weight loss in acid resistance tests is less for concrete having 20% fly ash than for 40% of fly ash. This trend is same for both mix proportions (1:1.5:3 and 1:2:4) investigated at water-cementitious materials ratio of 0.6.

7. HCl proves to be stronger acid than HNO_3 because it causes more loss in weight.
8. Workability of concrete is also increased when fly ash is added to it.

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SELECTED REFERENCES

1. ACI – 211 ***"Proportioning of Normal Weight Concrete Mix Proportions"***.
2. ACI – 212 ***"Concrete Admixtures"***.
3. ACI – 548 ***"State of the Art Report on Polymer Modified Concrete"***. ACI – 548.3 R-95.
4. Hielenz,R.C "***Mineral Admixtures – History and Background***", Concrete International Journal, August 1983, pp (34-68).
5. Cook,J.E "***Fly ash in Concrete-Technical Considerations***", Concrete International Journal. Sept 1983, pp (51-60).
6. Swamy, R.N "***Fly ash Concrete – Potential without Misuse***", ACI Journal of Materials and Structures, 1990,No 23, pp (397-411).
7. Melhotra,V. M, Corret G.G and Langley,W.S "***Structural ConcreteImparting High Volume of ASTM class F-fly ashes***", ACI Materials Journal,Title No 88-448,September-October 1989, pp (507-513).
8. Ohama, Y and Miyake, M. "***Resistance of Polymer-Modified Concrete to Inorganic Acids"*** National Symposium on Binder Economy and Alternate Binders in Road and Building Construction,1981, Japan
9. Rizwan,S.A., Hameed, A. and Ahmad,K. "**Latex Modified High Performance Concrete"** Proceedings of 6th International Symposium on High Strength/High Performance Concrete,Volume-2, pp 1313-1324,University of Leipzeig, June 2002,Germany.
10. Rizwan,S.A., and Hameed, A. "***Comparative Response of SBR Latex Modified Concrete"*** 6th International Congress on Changes to Concrete Construction, July 2002, Congress Proc copy titled "Sustainable Construction", pp 162-169,University of Dundee, Scotland, U.K.