A STUDY ON OPTIMUM FLY ASH CONTENT FOR YIELDING A PARTICULAR HIGH STRENGTH CONCRETE

R M Faysal*[1] & M R Karim*[2]

[1] *Lecturer, Presidency University, Bangladesh, e-mail: rayhanfaysal24@gmail.com*
[2] *Concrete Lab In charge of Holcim Cement (Bangladesh) Ltd, Bangladesh,e-mail: reza.pu12@gmail.com*

ABSTRACT

In Bangladesh Portland composite cement (PCC) are generally produced by incorporating fly ash into ordinary Portland (OPC) cement in a systematic manner. Though Fly ash, a Pozzolanic compound, increases workability, density and chemical resistance of concrete, Its percent should be controlled as it reduces early strength of concrete as well as overall strength of concrete. So, our paper aims to find out the optimum percent of Fly ash (Type F) to produce a particular high strength concrete (9000 psi). For this six batches of concrete samples having different percent of fly ash were tested. The batch containing 25 percent fly ash satisfied target strength defined by ACI code within 28 days of curing. So, PCC containing 25 percent of fly ash is best suitable for producing this particular high strength concrete.

Keywords: *OPC, Fly Ash, PCC, High strength concrete, optimum percentage.*

1. INTRODUCTION

The concrete that has a specified compressive strength equal or greater than 6000 psi is high strength concrete (ACI 363.2R, 1998). The low porosity of the high strength concrete (HSC) results in their superior durability and strength characteristics. However, HSCs require high cement paste volume which often leads to high shrinkage and greater heat evolution due to hydration. In an attempt to solve these problems, other cementious materials are often used as partial replacement for cement. The most used cementious materials in Bangladesh are Fly Ash . It is the finely divided residue that results from the combustion of ground or powdered coal and that is transported by flue gases from the combustion zone to the particle removal system (ACI , 2008). It makes efficient use of the byproducts of hydration of cement in concrete. For example, calcium hydroxide (CH), which are otherwise a source of weakness in normal cement concretes is converted into denser, stronger C-S-H (Calcium Silicate Hydrate) compounds by pozzolanic reaction of Fly ash (“Effect of cement”,2014).

But, due to differing chemical compositions depending on sources and types, the characteristics of fly ash will vary a lot. That yields necessity to perform batch tests to find out optimum percentage of fly ash for a particular high strength concrete. In this study the required design compressive strength was 9000 psi (62 Mpa). The reason behind chosing this stregth is to avoid confrontation with authors who consider 8000 psi (55 Mpa) as the dividing line between normal-strength and high-strength concrete. Besides, Fly ash was “Type F”. Fly ash containing lime less than 15 % is termed as Type F (Gamage et al, 2011). So, the aim of this paper is to find out the optimum percent of Fly ash described above to produce a particular high strength concrete (9000 psi).

2. METHODOLOGY

Six basic mixes designated by Batch-A, B, C, D, E and F were chosen to attain target strength (28 days cylinder compressive strength) of 10600 psi (73 MPa). The target strength was selected as per ACI 211-4R for the required design compressive strength of 9000 psi (62 MPa). Again, the corresponding mix ratios were selected according to ACI 211-4R (2008). After completion of the mix designs , trial mixes were done and the temperatures of the fresh concretes were measured as per ASTM C 1064. Then fifteen numbers of concrete cylinder samples were prepared for each batches of mix. The concretes for the compressive strength tests were prepared and tested according to ASTM C192, C39 and C150. Both metal and plastic cylinders that confirm ASTM C 39 were used. A small concre mixturer was used to prepare the concretes and three cylinders were manufactured for each point to be tested. The concrete were cured properly and each mix was tested at 1,3,7,14 and 28 days. The result of the three cylinder tests were averaged for each point and tabulated. Finally these results were evaluated to find out the optimum content of fly ash for target strength.

3. MATERIAL PROPERTIES AND MIXTURE PROPORTIONING

In this study, both local and forien materials were used. The properties of coarse aggregate, fine aggregate, cement and chemical admixture are mentioned in Table-1, 2, 3, and 4. Besides, Chemical composition of the used fly ash are represented in table 5. Again, Gradation of Coarse aggregates is shown in Table-6. Six basic mixes designated by Batch-A, B, C, D, E and F were chosen to attain target strengths (28 days cylinder compressive strength) of 10600 psi (73 MPa). The corresponding mix ratios were selected according to ACI 211-4R (2008). The mixture proportioning of six Batches are presented in Table-7.

Table 1: Properties of coarse aggregates (from Bolaganj)

Properties	20mm Nominal size aggregate	10mm Nominal size aggregate	Standard
Bulk specific gravity (oven dry basis)	2.646	2.614	ASTM C 127
Bulk specific gravity (S.S.D basis)	2.662	2.645	
Apparent specific gravity	2.688	2.696	
Absorption capacity (%)	0.59	1.16	
Crushed/uncrushed	Crushed	Crushed	-
Aggregate Crushing Value (ACV)	22.5	-	BS 812-110: 1990

Table 2: Properties of fine aggregate

Properties	Sand (Form Sylhet)	Standard
Bulk specific gravity (oven dry basis)	2.546	ASTM C 128
Bulk specific gravity (S.S.D basis)	2.595	
Apparent specific gravity	2.677	
Absorption capacity (%)	1.92	
Fineness modulus (FM)	2.768	ASTM C 136

Table 3: Properties of cement

Product information	Ordinary Portland Cement (OPC)	Standard
Notation	CEM I, 52.5N	ASTM C 150
Brand	Holcim	
28 days compressive strength (MPa)	≥52.5	
Initial setting time (minutes)	≥ 45	
Final setting time (minutes)	≤ 375	
Soundness (mm)	≤ 1	
Ingredients	Clinker (96%), Gypsum (4%)	

Table 4: Technical data of admixtures

Area	Description
Importer	BASF (Bangladesh) Ltd
Technical name	Glenium ACE 30 (JP)
Specification Type	ASTM C 494, Type F
Polymer	2nd generation poly-carboxylic ether based
Strength developments	Very early strength gain
Specific gravity	1.09±0.02 at 25°C
Addition rates (per 100 kg cement)	400ml to 1200ml at 25^0 C and dosage rate increase with temperature
Compatibility	Most of the POZZOLITH series products including POZZOLITH 55R

Table 5 : Chemical composition of used fly ash (Holcim, Bangladesh)

Sl. No.	Components	Results (%W/W)		Requirement (%W/W)
1	Silica (as SiO_2)	62.38	94.60	Min 90%
2	$Al_2O_3 + TiO_2+P_2O_5$	29.3		
3	Iron oxide (as Fe_2O_3)	2.92		
4	Silica (as SiO_2)	62.38		> 55
5	Lime (CaO)	0.80		
6	Magnesia (MgO)	0.29		< 2.0
7	Sulfate (as SO_3)	0.16		< 1.0
8	Loss On Ignition	2.43		< 3.5
9	Insoluble Residue (IR)	92.98		-
10	Moisture	0.20		< 0.50
11	Blaine	3203		> 3200
12	Above 90 micron sieve	27.17		-
13	Above 45 micron sieve	13.84		< 30
14	Color	Grey		-

Remarks: Methods of chemical analysis of Fly Ash (I.S. 1727-1967) Analysis on sample dried at 100ºC/110ºC

Table-6 : Combined Grading of Coarse aggregate (20mm & 10mm)

Sieve size (mm)	Percent passing		Combining proportion		Total Percentage passing	ASTM Specified limit (ASTM C 33)	
	20mm stone chips	10mm stone chips	20mm 60%	10mm 40%		Lower limit	Upper limit
25	100.0	100.0	60.0	40.0	100.0	100	100
19	75.0	100.0	45.0	40.0	85.0	90	100
12.5	21.5	99.7	12.9	39.9	52.8	-	-
9.5	5.3	96.5	3.2	38.6	41.8	20	55
4.75	0.2	21.5	0.1	8.6	8.7	0	10
2.36	0.0	3.6	0.0	1.4	1.4	0	5

Table 7: Mixture proportioning of Batch-A,B,C,D,E and F concrete (ACI 211-4R , 2008)

Mixture proportioning						
Materials (per m^3)	Basic mixtures no fly ash (Batch A)	Fly ash Mixture				
		Batch B	Batch C	Batch D	Batch E	Batch F
		10% Fly ash	15% Fly ash	20% Fly ash	25% Fly ash	30% Fly ash
Cement, (kg)	612	551	520	490	459	429
Fly ash, Class F, (kg)	-	61	92	122	153	183
Fine aggregate, dry, (kg)	505	483	473	463	451	441
Coarse aggregate, dry, (kg)	1119	1119	1119	1119	1119	1119
Water (kg)	175	175	175	175	175	175
Slump (mm)	25~50	25~50	25~50	25~50	25~50	25~50
HRWRA (kg)	4.284	4.284	4.284	4.284	4.284	4.284

After completion of the mix designs, trial mixes were done and the temperatures of the fresh concretes were measured as per ASTM C 1064. Then fifteen numbers of concrete cylinder samples were prepared for each batches of mix. The concretes for the compressive strength tests were prepared and tested according to ASTM C192, C39 and C150. Both metal and plastic cylinders that confirm ASTM C 39 were used. A small concrete mixturer was used to prepare the concretes and three cylinders were manufactured for each point to be tested. The concrete were cured properly and each mix was tested at 1, 3,7,14 and 28 days. The result of the three cylinder tests were averaged for each point and tabulated.

4. RESULT AND DISCUSSION

The compressive strengths of the cylindrical concrete samples whose cement quantities had been replaced with fly ash varying from 0 to 30 % are given in the next page.

Table 7: Compressive strength test results of concrete

Batch-ID	**Fly ash %**	**Fresh Concrete Temperature(°C)**	**28 days Target strength(Mpa)**	**Compressive Strength (Mpa)**				
				1 days	**3 days**	**7 days**	**14 days**	**28 days**
A	0	30.3	73	55.5	72.2	80.1	85.7	91.3
B	10	29.5	73	38.5	61.1	71.0	78.1	83.5
C	15	28.2	73	33.4	56.3	69.3	74.4	79.1
D	20	27.4	73	29.4	53.8	60.2	66.9	78.4
E	25	26.7	73	24.0	51.0	56.2	64.9	76.7
F	30	26.1	73	17.9	39.9	43.4	62.1	68.0

The initial strength gain of concrete composed of higher fly ash is significantly lower than of lower fly ash content. For example , the batch E (25 % fly ash) compressive strength is approximately 30% lower than Batch A (0% Fly ash) at 7 days. But these differences tend to minimize with the passage of time (see figure -1). Again, It is observed that incorporation of fly ash reduces fresh concrete temperature significantly.

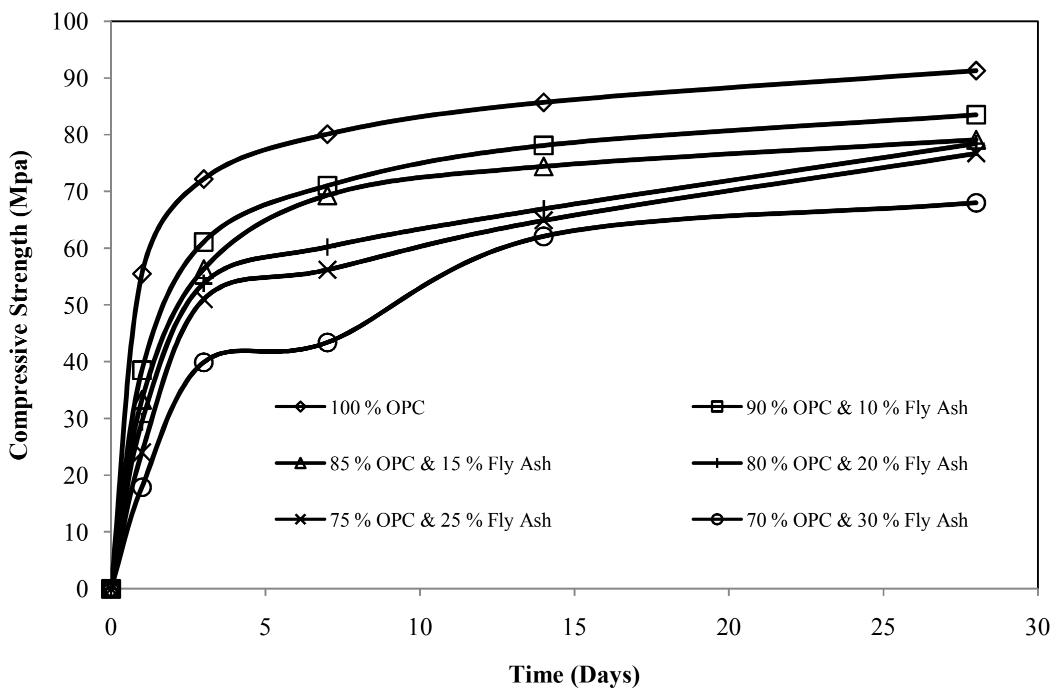

Figure 1 : Compressive strength curve

5. CONCLUSIONS

From the result it is evident that incorporating fly ash decreases the compressive strength of concrete within 28 days of curing. Since Fly ash not only increases workability, density and chemical resistance of concrete but also cheaper than OPC, Its percent should be higher without compromising the strength of concrete. The concrete of Batch E contained maximum (25 %) fly ash with fulfilling target strength 10600 psi (73 MPa). So, the Portland composite cement (PCC) containing 25 % fly ash is perfectly suitable for producing this particular high strength concrete (9000 psi). Again, it was found that incorporating fly ash in cement reduced fresh concrete temperature to a significant amount. So, it is recommended to use Portland composite cement (PCC) where lower temperature of fresh concrete is preferable. Any massive concrete structure (i.e. dam, bridge etc.) requires lower temperature generating fresh concrete to minimize cracks in it. Further, durability of concrete largely depends on the low porosity of concrete. Fly ash serves as filler materials for porous concrete. Besides its lubricant property helps aggregate to be arranged in a dense manner. So, optimum amount of fly ash is recommended for producing durable concrete.

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