EXPERIMENTAL STUDY TO INVESTIGATE THE USABILITY OF FLY ASH AS ADMIXTURE OF CEMENT

Sampa* & A T. M. Masum

Department of Civil Engineering, Military Institute of Science and Technology, Dhaka, Bangladesh
**Corresponding Author: sampakhanam@yahoo.com*

ABSTRACT

Concrete strength is considered as a function of water to cementitious materials (w/c) ratio, aggregates quality, admixtures and proper quality control. But the properties of cement such as cement ingredients and fineness also affect the strength and workability of concrete. In this research, total of four concrete trial mixes with different amount of fly ash were prepared and investigated for 45 days in which fly ash was used as the replacement of Ordinary Portland Cement (OPC) and other parameters were kept constant. The experimental results showed that the strength gaining rate (SGR) for concrete containing 100% OPC is higher at early ages and almost negligible at later ages. On the other hand, SGR of concrete containing 25% fly ash and 75% OPC is higher at later ages rather than at early ages. It is interesting to note that fly ash content more than 25% significantly decreases the concrete strength and workability. In industrial application where early strength is not a primary requirement, 25% fly ash as an admixture of OPC is recommended as materials cost, workability and compressive strength consideration.

Keywords: Fly ash; OPC; strength gaining rate; mineral admixture

INTRODUCTION

In the year of 1950s, ready-mixed concrete with design strength of 35 MPa was considered as HSC. The increased use of chemical and mineral admixtures in the decade of 1960s quickly led to significant increases in attainable compressive strength and in the 1960s, 41 MPa and 52 MPa concrete were produced commercially. In the early 1970s, 62 MPa concrete was produced. Today, compressive strengths approaching 138 MPa have been used in cast-in-place buildings. Laboratory researchers using special materials and processes have achieved compressive strength of concrete in excess of 800 MPa [Schmidt and Fehling, 2004].

The major difference of HSC from conventional concrete is essentially the use of Supplementary Cementitious Materials (SCM) or mineral admixtures. The Supplementary Cementitious Materials physically act as a filler to decrease the average size of the pores in the matrix of HSC [Safiuddin and Zain, 2006] which is known as micro filling. Most of the SCMs contribute to increase the strength of HPC due to enhanced cementing efficiency resulting from secondary hydration or pozzolanic reaction [Safiuddin, 1998; Safiuddin and Zain, 2006]. Some of the SCMs are Fly Ash (type-F, type-C), Silica Fume, Ground Granulated Blast-furnace Slag (GGBS), carbon black powder, and anhydrous gypsum based mineral additives. Most widely used SCM for HSC are obtained as industrial by-products.

Fly ash reduces the water demand and thus improves the workability of concrete. In contrast, Silica Fume and rice husk ash increase the water demand due to lower particle size and excessive surface fineness and thus decrease the concrete workability for given water content but increase density of concrete mix [Safiuddin and Zain, 2006]. The content of Silica Fume differs from 3% to 30% by weight of cement depending on the strength and durability requirements. However, the practical and economical optimum content of Silica Fume is chosen toward 10% to 15% due to high cost and workability problem encountered in fresh concrete [De Larrard and Malier, 1994]. Class C Fly Ash has been used with a content varying from 20 to 40% [Ellis, 1992] whereas the content of Class F Fly Ash is usually limited to 15% to 25% and the GGBS is in the range of 30% to 50% in HSC [Safiuddin, 1998; Safiuddin and Zain, 2006].

The chemical admixtures used for HSC are mainly Water Reducer (WR), High Range Water Reducer (HRWR) or super plasticizers. Sometimes to increase the setting time, retarder is also used. HRWR can reduce the quantity of mixing water in the range of 12 to 45% [Safiuddin, 2008; ASTM C 494/C 494M-99a, 2002]. Very high dosage of HRWR might cause segregation and bleeding, delayed setting, plastic shrinkage, and air entrainment in fresh HSC and may delay cement hydration. The dosage limit of liquid HRWR for HSC generally varies from 5 to 20 l/m3, but dosage limit should be higher for hot weather than cold weather [Aïtcin et al., 1994].
The plasticizing effect and water reduction will be higher if HRWR or WR are mixed with damp concrete [ACI 211.4R-93, 1998]. According to Canadian Association's Preliminary Standard A 266.5-M 1981, tests have shown that HRWR is most effective and produce the most consistent results when added at the end of the mixing cycle after all the ingredients have been introduced and thoroughly mired.

Following are the objective of this study:

1. To investigate the parameters that affects the strength of concrete and finding the optimum Fly Ash content as ingredients of cement that produce High Performance concrete.
2. To develop a mix design with the above combination by trial and error procedures to achieve desired compressive strength and workability of concrete using locally available materials of Bangladesh.
3. To optimize the cost of concrete

METHODOLOGY

In this study, ingredients used were ½'' L/C Stone (Table 1), Sylhet sand of FM 2.5(Table 2) , Ordinary Portland Cement (OPC), Class F fly ash (Table 3) and admixture named as Glenium ACR 30 (JP) (Table 4) which are locally available in Bangladesh. The properties of materials such as specific gravity and absorption capacity of coarse and fine aggregates and crushing values of coarse aggregates are determined according to the procedure specified in ASTM C127, ASTM C128, ASTM C29 and BS 812.The graded aggregates, both fine and coarse aggregates, were washed and soaked in water for 24 hours and then air-dried to Saturated Surface Dry (SSD) condition before mixing with other ingredients. The proportioning of the materials was done according to British method of mix design. The mixer machine (rotating drum) was used for mixing the various constituents of concrete. The ingredients were fed into the machine into three layers. In the first layer one-third of estimated sand, cement, and coarse aggregate fed into the mixer machine and 30 sec time was allowed to mix the ingredients thoroughly. Simultaneously other two layers of ingredients fed into the machine and 30sec time was allowed for each layer to mix thoroughly. After the ingredients were mixed thoroughly about 70% of the water was poured in the machine then 60 sec time was allowed for the mixing of all three layers. Remaining 30% of the water was mixed with admixtures and then it was fed in the mixer machine with damp concrete and allowed to mix about 40 sec. If the admixture is fed with dry mix, it will not mix thoroughly with other ingredients. When mixing was completed, the mixtures were poured on a large tray. The workability of the fresh concrete was measured with a standard slump cone immediately after mixing. The test specimens were cast in steel mold of 100 x 200 mm cylinders. The concrete was poured into the mold in three layers each layer being compacted approximately 20 sec with a vibrator nozzle. After compaction of the third layer the upper surface of the concrete was levelled. Precautions were taken to avoid over compaction which leads to segregation of concrete. The test specimens were demolded 24 hours after casting and cured under water for 3, 7, 14, 28 and 45 days. Three cylinder of each strength level were tested after 3, 7, 14, 28 and 45days. Concrete Compressive strength was performed on the cylinder at least after three hours of removal from the curing tank. Crushing strength was performed on the cylinder at least after three hours of removal from the curing tank. Load was applied continuously till the cracks in the specimen were developed with a rate of 2.4KN/sec according to ASTM C31. Casting procedures used in this study are shown in Figure-2.

Table 1: Properties of Coarse Aggregate

Properties	½ ″ LC stone
Bulk specific gravity (oven dry basis)	2.638
Bulk specific gravity (S.S.D basis)	2.652
Crushing value (%)	25
Crushed/uncrushed	crushed
Absorption capacity (%)	0.57

Table 2: Properties of Fine Aggregate

Properties	Sylhet sand
Bulk specific gravity (oven dry	2.530
Bulk specific gravity (S.S.D	2.579
Apparent specific gravity	2.659
Absorption capacity (%)	1.91
Fineness modulus (FM)	2.5

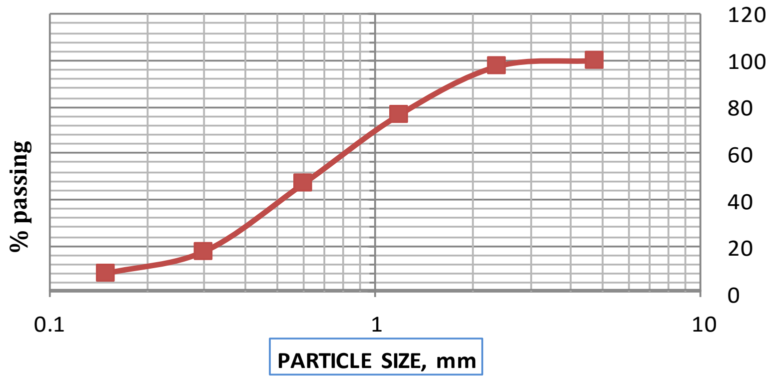


Fig. 1: Particles size distribution of fine aggregate

Table 3: Properties of Fly Ash

Properties	Fly Ash Class F
Pericles retained on 45µm sieve(%)	30%
Specific Surface Area (m^2/kg)	200-250
Specific gravity	2.70

Table 4: Properties of Admixtures

Product information	**Glenium ACR 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 250C
Addition rates (per 100 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: Proportioning of Ingredients used to produce 1m^3 of concrete (Density=2400 Kg/m^3)

Batch-ID	Fly Ash (%)	Design Strength (28 days) (MPa)	Ingredients used to produce 1m^3 concrete					
			Cement (Kg)	Coarse Aggregate (CA) (Kg)	Fine Aggregate (FA) (Kg)	Free water (Kg)	Admixture (Kg)	w/c ratio
A	0	80	636.4	990.90	633.00	140	8.30	0.22
B	15	80	540.6	990.90	633.00	140	8.30	0.22
C	25	80	467.15	990.90	633.00	140	8.30	0.22
D	30	80	445.48	990.90	633.00	140	8.30	0.22

(a) Compaction of specimen by vibrator nozzle
(b) Levelling of the top surface of specimen
(c) Specimens after casting

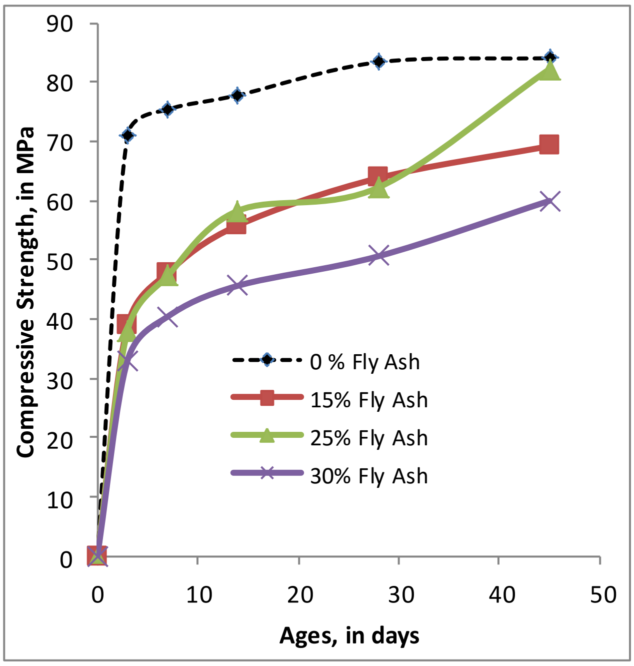
Fig. 2: Casting of Cylinder Specimens

ANALYSIS OF RESULTS

In this section the experimental results of slump values and compressive strength of concrete for each trial mixes are represented.

Table 6: Slump values and compressive strength test results of concrete

Batch-ID	Fly Ash (%)	Design Strength(28 days) (MPa)	Experimental results of cylindrical concrete specimen					
			Compressive strength (MPa)					Slump values (mm)
			3 days	7 days	14 days	28 days	45 days	
A	0	80.00	70.97	75.38	77.84	83.41	84.10	75
B	15	80.00	38.87	47.82	55.87	63.85	69.24	100
C	25	80.00	38.00	47.33	58.33	62.28	82.23	125
D	30	80.00	33.00	40.35	45.67	50.66	60.00	150



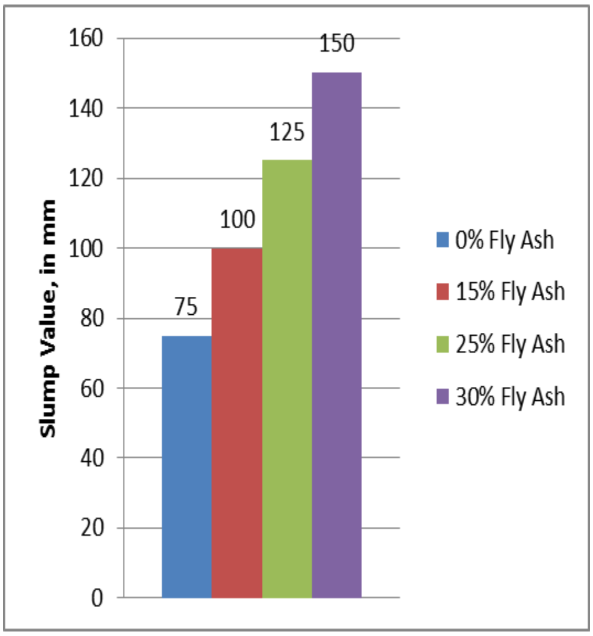


Fig. 3: Compressive Strength VS Ages of concrete

Fig. 4: Slump Value of concrete mixes with Fly Ash Content

Experimental result revealed that with the increment of fly ash content in concrete there was a significant increase in the workability. On the other hand, this increased amount of fly ash exhibited almost same compressive strength of concrete as that of prepared using only OPC at the latter stage (45 days) up to the optimum content (25%) of fly ash. It is mentionable that this phenomenon is due to the pozzolanic reaction of fly ash with cement.

Compressive Strength:

From Figure-3, it is observed that all four trial mixes (Batch-A, B, C and D) of concrete were mixed with same materials as shown in Table-1, 2,3, and 4 except but the amount of Fly Ash varies. Moreover, these Batches were designed with 28 days compressive strength of 80 MPa but after experimental investigation it was not achieved. Followings are the sources of deviations:

1. Aggregate Size was not used as specified in the mix design. ½ inch downgrade aggregates was used.
2. According to design, the specified cement type was Type-1 Ordinary Portland Cement (OPC) but in the all three fly ash was also used which provides lower strength at early age due to the pozalonic reaction of fly ash with cement.
3. Designed aggregate properties and used aggregate properties were different.
4. Gradation of Fine aggregate was not fully matched with the Specified (ASTM 136).

Workability:
The workability of concrete as slump (in mm) is shown in Figure-4, slump values of concrete increase as the % of Fly Ash were increased, and thus workability of concrete also increases.

CONCLUSION

I) Due to the POZALONIC reaction of Fly Ash with cement, it has lower strength at early age and higher at later age than Ordinary Portland Cement concrete. On the other hand, incorporation of Fly Ash as partial replacement of Ordinary Portland Cement increases the workability and decrease the materials cost of concrete.
II) Proper gradation of aggregate having smaller inter-particle voids, smaller size aggregate and appropriate compaction increase the strength of concrete
III) With the increase of cement contents the strength of concrete also increases.
IV)Lower water-binder ratio along with High Range Water Reducer and retarder are essential to produce High Strengt

REFERENCES

Aïtcin, PC., 1994. The use of superplastisizer in high performance concrete, High Performance Concrete: From Material to Structure, E & FN Spon, London, UK, pp.14-33.
De Larrard, F., and Malier, Y., 1994. Engineering properties of very high performance concretes, High Performance Concrete: From Material to Structure, 1st English Language Edition, E & FN Spon, London, UK, pp. 85-114.
Safiuddin M., 1998. Influence of Different Curing Methods on the Mechanical Properties and Durability of High Performance Concrete Exposed to Medium Temperature, M.Sc. Thesis, The National University of Malaysia, Bangi, Malaysia.
Safiuddin M., and Zain M.F.M., 2006, "Supplementary cementing materials for high performance concrete", BRAC University Journal, Vol. 3, No. 2, pp. 47-57.
Schmidt, M., Fehling, E., and Geisenhanslüke, C., 2004," Proceedings of the International Symposium on Ultra High Performance Concrete, ed., Kassel University Press, Kassel, Germany, pp. 11–23.