FUTURE PROSPECT OF COAL COMBUSTION PRODUCTS: BANGLADESH PERSPECTIVE

Md. M Islam*[1] and Md. S Islam[2]

[1]*Professor, Chittagong University of Engineering & Technology, Bangladesh, e-mail: moinul91@yahoo.com*
[2]*Professor, Chittagong University of Engineering & Technology, Bangladesh, e-mail: msislam@cuet.ac.bd*

ABSTRACT

Bangladesh government has launched a mega plan to reach a capacity 40,000 MW of electricity by 2030, half of which will be generated from coal. Coal, a fossil fuel, is the largest source of energy and plays a vital role in electricity generation worldwide. Bangladesh is very lucky that it has got substantial natural resources reserve including significant amount high quality coal resource. But the most hazardous waste of coal burnt power plant is fly ash, bottom ash and liquid ash which contain hazardous and radioactive metals like arsenic, lead, mercury, nickel, vanadium, beryllium, barium, cadmium, chromium, selenium and radium. Ash is found dumped in surrounding plant locations which spirally affect the environment. The experimental program was planned to study the effect of replacement of cement with Bangladeshi fly ash on the strength and durability characteristics of hardened concrete. Two different grades of concrete M28 and M38 made with seven different cement replacement levels (10, 20, 30, 40, 50, 60 and 70%) with fly ash were used for the experimental program. Ordinary Portland cement (OPC) concrete was also prepared as reference concrete. Water permeability, Rapid chloride penetration resistance and compressive strength of concrete were determined upto 365 days of curing. Test results show that the properties of concrete improve with the increase of fly ash level up to an optimum value and then start to decrease. Among all the concretes studied, the optimum amount of cement replacement is reported to be around 30 to 40%.

Keywords: *compressive strength, concrete, fly ash, water permeability, rapid chloride penetration resistance,*

1. INTRODUCTION

Bangladesh government has set up a target of power generation of 40,000MW by 2030. Half of this power will be generated from different power plants by using coal as fuel. Worldwide coal is used as the largest source of energy for the generation of electricity. Coal-fired power plants currently generating 41% of global electricity. Bangladesh has significant coal reserve besides natural gas. Coal reserves of about 3.3 billion tons comprising 5 deposits at depths of 118-1158 meters have been discovered so far in the north-western part of Bangladesh. The name of these deposits are-Barapukuria, Phulbari and Dighipara coal field in Dinajpur district, Khalashpir in Rangpur district and Jamalganj in Joypurhat district and only Barapukuria coal field is under production. Barapukuria coal fired power plant is the first coal based power plant in Bangladesh with capacity of 250 MW. Target for power generation in Bangladesh is shown in following bar diagram.

Coal for Barapukuria power plant is supplied from Barapukuria Coal Mining Company Limited. Adjacent to the Barapukuria Power Plant, another plant of 250 MW is supposed to be set up by the Power Development Board. A coal fired power plant is going to set up at Matabari, Cox's Bazar. The 1200 MW power plant will be built using ultra super critical technology with the funding of both the Bangladesh government and Japan International Cooperation Agency (JICA). In addition 1320 MW coal fired power plant, "Maitree Super Thermal Power Project" at Rampal, Khulna is going to be installed as a joint venture between India and Bangladesh. Bangladesh has recently signed a memorandum of understanding with China Huadian Hong Kong Co. Ltd for setting up a coal-fired power plant of 1320 MW capacity at Maheshkhali island in the southeastern coast of the country under a joint venture agreement. BPDB and China Huadian will set up a joint venture company soon for implementing the project on a build-own-operate (BOO) basis by 2019. Bangladesh government has planned to install one of the plants at Mawa, Munshiganj with a capacity of 522 MW and two other with the total capacity of 566 MW in Khulna region, all of which are coal based.

Now in Bangladesh 250 MW coal based power plant is in running condition. Additional 5250 MW coal based power plant is going to be installed. According to the EIA report, 28.1 million tons of coal will be burnt to produce the estimated 5500 MW of electricity at the proposed power plant. In coal burnt power plant coal is first milled to a fine powder which increases the surface area and allows it to burn more quickly. In these pulverized coal combustion (PCC) systems, the powdered coal is blown into the combustion chamber of a boiler where it is burnt at high temperature. When coal is burnt, ash is left as a residue. The majority of ash is stored near the power station while the rest is disposed into the river or pond. Considering 10% ash generation, it will produce around 2.8 million tons of fly ash. These ashes comprising of fly ash, bottom ash and liquid ash are extremely hazardous containing hazardous and radioactive metals like arsenic, lead, mercury, nickel, vanadium, beryllium, barium, cadmium, chromium, selenium and radium. If some ash release to the atmosphere, it would not only fatally affect the forest, but also cause a range of lung diseases including pneumonia to the people living nearby. Regarding managing the waste, fly ash could be used in cement factories and brickfields. Taking Barapukuria as an example, it produces more than 300 metric tons of fly ash in one day, none of which has ever been used in cement factories and brickfields. Rather, they are found dumped in surrounding locations which is spirally affecting the environment. Depending on the location of each power plant, the unused fly ash is disposed at the ponds, lagoons or landfills. The unused fly ash and bottom ash disposed from coal combustion power plants, makes major negative environment effects such as air pollution and groundwater quality problem due to leaching of metals from the ashes, specially unused fly ash which has very small particle size (Janos, 2002). Table 1 shows the installed capacity of power plants according to fuel type as on 2015.

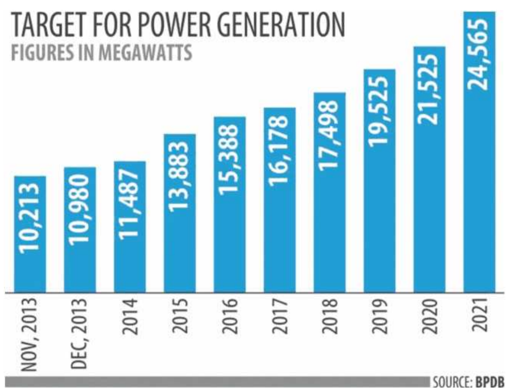

Table 1: Installed Capacity of Power Plants as on August 2015

Fuel Type	Capacity(Unit)		Total(%)
Coal	250.00	MW	2.14 %
Gas	7280.00	MW	62.31 %
HFO	2507.00	MW	21.46 %
HSD	916.00	MW	7.84 %
Hydro	230.00	MW	1.97 %
Imported	500.00	MW	4.28 %
Total	11683.00	MW	100 %

Portland cement substitution by supplementary cementitious materials also called mineral admixtures or mineral additives such as natural pozzolana, slag, coal fly ash, silica fume, rice husk ash and wood fly ash is one of viable alternatives to reduce the amount of cement requirement (Zichao, 2003). Fly ash is one of the most common pozzolan and is being used quite extensively. Fly ash contains high amount siliceous and aluminous compounds and has high potential to be used as pozzolanic material to partially replace cement in concrete (Singh, 2015). Through pozzolanic activity, fly ash chemically combines with water and calcium hydroxide, forming additional cementitious compounds which result in denser as well as higher strength concrete. The calcium hydroxide that chemically combine with fly ash is not subject to leaching, thereby helping to maintain high density. The conversion of soluble calcium hydroxide to cementitious compounds decreases bleed channels, capillary channels, void spaces and thereby reduces permeability (Homnuttiwong, 2012). With the help of these admixtures, less permeable and a denser calcium silicate hydrate (C–S–H) concrete can be obtained as compared with Portland cement (Oner, 2012). Fly ash replacement in concrete would be remarkable cement saving as well as cost minimizing steps for the construction of concrete structures without sacrificing the strength of concrete (Abubakar, 2012).

When fly ash is used as pozzolanic material in concrete, through its pozzolanic properties, it chemically reacts with $Ca(OH)_2$ and water to produce C-S-H gel. The $Ca(OH)_2$ is consumed in the pozzolanic reaction and is converted into a water-insoluble hydration product. This reaction reduces the risk of leaching $Ca(OH)_2$ as it is water soluble and may leach out of hardened concrete (Xie, 2015). The incorporation of fly ash can result in considerable pore refinement. The use of fly ash in concrete decreases the water requirement and this combined with the production of additional cementitious compounds leads to a low porosity and discontinuous pore structure which reduces the permeability of the concrete (Xie, 2015).

Previous studies have shown that use of cement replacement materials such as fly ash, silica fume, blast-furnace slag, etc. may reduce greatly the probability of steel corrosion as well as the permeability of concrete (Hossain, 2004). The monitoring of concrete resistance to chloride penetration is possible on the basis of electrical resistivity measurements. The electrical resistivity of concrete structure exposed to chloride indicates the risk of early corrosion damage because a low resistivity is related to rapid chloride penetration and to high corrosion rate (Ampadu, 2002). The current is carried by ions dissolved in the pore liquid and increased pore saturation (wet concrete) as well as increased number of larger diameter pores (higher water-to-cement ratio) decrease resistivity (Polder, 2001). The use of supplementary cementing materials such as ground blast furnace slag, silica fume, metakaoline, coal fly ash and natural pozzolan can have a very significant effect on the pore solution chemistry of concrete depending on the dosage and composition of these supplementary cementing materials (Madhavi, 2014). The aim of this research is to evaluate and explore the suitability of the use of Bangladeshi fly ash in structural concrete and its efficiency in enhancing concrete durability performance as well as strength characteristics through improvement of concrete microstructure.

2. EXPERIMENTAL PROGRAMS

The experimental program was planned to study the effect of replacement of cement with supplementary cementing material fly ash on the strength and permeability characteristics of hardened concrete at different curing ages.

2.1 Properties of Materials Used

(a) Cement: ASTM Type-I Portland Cement was used as binding material. Chemical compositions of ASTM Type-I (OPC) are given in Table 2.

(b) Fly ash: A low calcium ASTM Class F fly ash collected from Barapukuria Power Plant, Bangladesh was used as supplementary cementitious material. Chemical analysis of fly ash conducted using X-ray fluorescence (XRF) study is shown in Table 2.

(c) Aggregate: Locally available natural sand with fineness modulus 2.58, specific gravity 2.61, passing through 4.75 mm sieve and retained on 0.075 mm sieve was used as fine aggregate. The coarse aggregate was crushed stone with a maximum nominal size of 12.5 mm with fineness modulus 6.58 and specific gravity 2.70.

Table 2: Chemical composition of ordinary portland cement and fly ash

Types	OPC	Fly ash
Chemical analysis (%)		
Calcium oxide, CaO	65.18	8.6
Silicon dioxide, SiO_2	20.80	59.3
Aluminum oxide, Al_2O_3	5.22	23.4
Ferric oxide, Fe_2O_3	3.15	4.8
Magnesium oxide, MgO	1.16	0.6
Sulfur trioxide, SO_3	2.19	0.1
Sodium Oxide, Na_2O	--	3.2
Loss on ignition	1.70	--
Insoluble residue	0.6	--

Table 3: Mix proportions and properties of fresh concrete

Mixture constituent & properties	Grade of Concrete	
	M28	M38
Cement (kg/m^3)	435	500
Water (kg/m^3)	218	218
Sand (kg/m^3)	545	520
Stone Chips (kg/m^3)	1150	1120
w/(c+fa)	0.50	0.44
Slump (mm)	68	60
Air content %	1.3	1.1

2.2 Mix Design

Two different grades of concrete namely M38 and M28 were used in the program. Seven different mix proportions of cement fly ash (90:10, 80:20, 70:30, 60:40, 50:50, 40:60, 30:70) were used as cmentitious material. Cement fly ash mix ratio of 100:0 i.e. plain concrete specimens were also cast as reference concrete for comparing the properties of fly ash concrete. Fly ash concrete means the concrete made by using cement and fly ash as cementitious material with sand, stone chips and water. Relevant information of different concrete mixes is given in Table 3.

2.3 Sample Description

A total of 250 no's of cylindrical specimen of size 150 mm diameter and 175 mm high and 350 no's of cubical specimens of 100 mm size from eight different types of fly ash concretes were cast according to the mix proportion as described for water permeability and strength test. Another 250 no's of cylinder specimen of size 100 mm diameter and 50 mm height were also cast for Rapid chloride permeability test. The specimens were demoulded after 24 hours of casting and cured in plain water at ambient temperature. Concrete specimens were designated as per grade of concrete and amount of fly ash as a percentage of total cementitious material. Thus M38FA40 concrete means grade of concrete is M38 and cement fly ash mix ratio is 60:40.

2.4 Test Conducted

2.4.1 Strength Tests

Compressive strength of concrete specimens was tested at the ages of 3, 7, 28, 56, 90, 180 and 365 days in accordance with the BS EN 12390-3:2009. Reported strength is taken as the average of three tests results.

2.4.2 Water Permeability Test

Water permeability test were carried out for different types of concrete specimens at the ages of 28, 56, 90, 180 and 365 days after drying in the oven at 105°C. The specimens were coated with epoxy coating in the circular side to prevent water leakage from the side during the test. After placing the specimen in the apparatus, a water pressure of (500 ±50) kPa was applied for (72 ± 2) h. After the saturation of the specimen, the flow rate reading was taken using burette by measuring the changing of volume of water with time. During the test, the appearance of the surfaces of the test specimen not exposed to the water pressure was observed periodically to note the presence of water. Coefficient of permeability is calculated by using the following equation,

$$k = (QL/AH)$$

where, k = permeability coefficients (m/s), Q = flow rate (m3/s), A = area (m2), L = depth of specimen (m), H = head of water (m). Depth of water penetrated in the test specimen was calculated in accordance with the EN 12390-8.

2.4.3 Rapid Chloride Penetration Tests

Cylindrical sample of 100 mm diameter and 200 mm height were prepared in accordance with ASTM C39. They were demoulded after 24 hrs and cured in plain water. After specific curing period they were cut into 50 mm thick slices. The cut cylinders were left to dry in laboratory condition for 24 hrs before application of epoxy coatings. All specimens were epoxy coated around the cylindrical surface. At the ages of 28, 56, 90, 180 and 365 days, the prepared cut cylinders were tested using the procedures described in the ASTM C1202. The average result of three test specimens was taken as the representative data.

3. RESULTS AND DISCUSSIONS

3.1 Compressive Strength

Compressive strength of OPC and fly ash concrete of two different grades M28 and M38 presented in Figure 1 and Figure 2. Also the relative compressive strengths are plotted in Figure 3 and Figure 4.

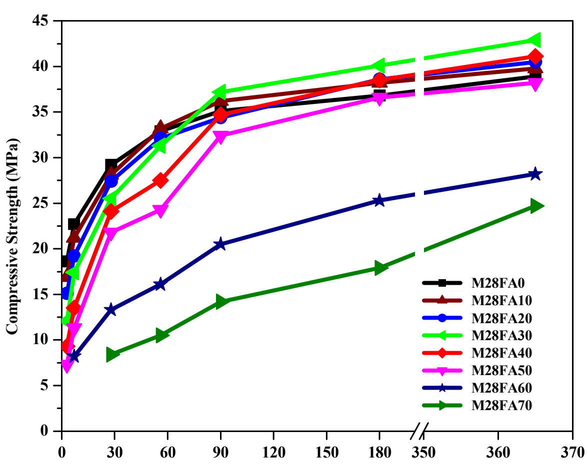

Figure 1: Compressive strength - exposure period relation for M28 fly ash concretes

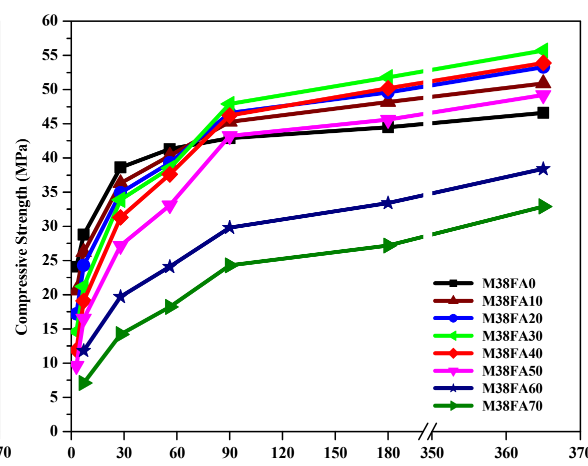

Figure 2: Compressive strength - exposure period relation for M38 fly ash concretes

At early ages of curing, OPC concretes achieve relatively higher compressive strength as compared to fly ash concrete. Test result shows that 7 days compressive strength for OPC concrete is around 9%, 16%, 26%, 34%, 43%, 59% and 75% higher than M38FA10, M38FA20, M38FA30, M38FA40, M38FA50, M38FA60 and M38FA70 concrete respectively; whereas the same value for OPC concrete is around 7%, 15%, 23%, 41%, 50% and 64% higher for M28FA10, M28FA20, M28FA30, M28FA40, M28FA50 and M28FA60 concrete. After that compressive strength of fly ash concrete starts to increase compared to OPC concrete. 90 days compressive strength test result of the concrete specimens up to 50% replacement level are slightly higher than OPC concrete. Compressive strength is higher by 6%, 9%, 12% 8% and 1% for M38FA10, M38FA20, M38FA30, M38FA40 and M38FA50 concrete respectively; whereas the 90 days strength for M38FA60 and M38FA70 concrete is reported to be lower by 31% and 43% respectively when compared with no fly ash concrete. For relatively longer period of curing, compressive strength of the fly ash concrete specimens up to 40% replacement level are higher than that of OPC concrete for all grade of concrete. 180 days compressive strength data shows almost similar trend. 180 days compressive strength for M38FA10, M38FA20, M38FA30, M38FA40 and M38FA50 concrete are respectively 8%, 11%, 16%, 13% and 2% higher than no fly ash concrete; whereas the same value for M38FA60 and M38FA70 concrete are lower by 25% and 39% than OPC concrete. After 365 days of curing, relatively higher percentage of strength gaining was observed for fly ash concrete as compared to OPC concrete. At this stage of curing, compressive strength for M28FA10, M28FA20, M28FA30 and M28FA40 concrete are respectively 2%, 4%, 10% and 6% higher than corresponding no fly ash concrete and 9%, 14%, 20% and 16% higher compared to OPC concrete for M38FA10, M38FA20, M38FA30 and M38FA40 concrete respectively.

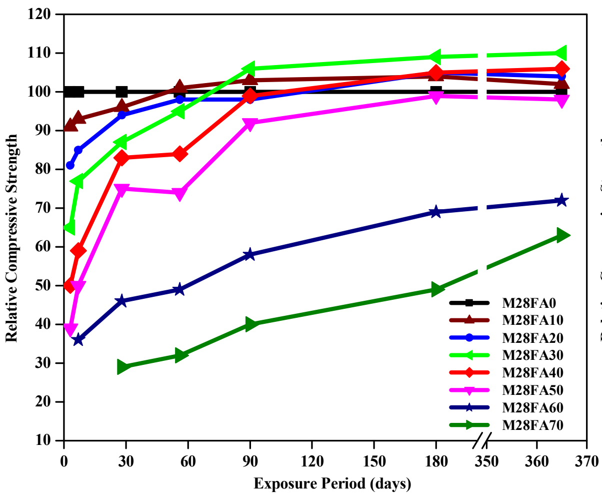

Figure 3: Relative compressive strength - exposure period relation for M28 fly ash concretes

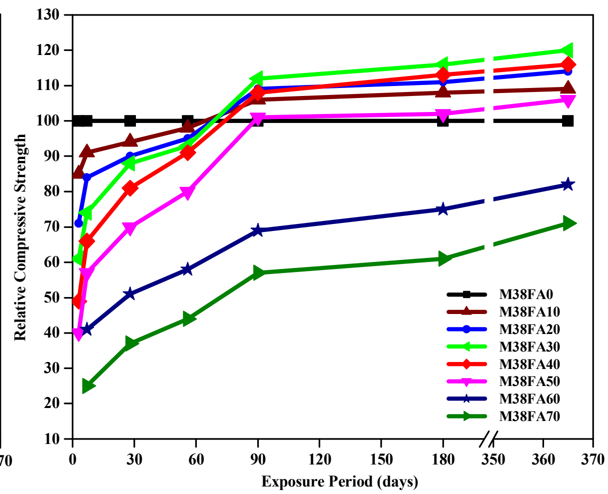

Figure 4: Relative compressive strength - exposure period relation for M38 fly ash concretes

Rate of strength gaining for different types of concrete is observed to vary with the grade of concrete and is higher for the higher grade of concrete. In case of 90 days of curing, compressive strength for M28FA0, M28FA10, M28FA20, M28FA30, M28FA40 and M28FA50 concrete are 120%, 124%, 118%, 127%, 119% and 111% as compared to 28 days compressive strength of OPC concrete of same grade; whereas the similar value for M38FA0, M38FA10, M38FA20, M38FA30, M38FA40 and M38FA50 concrete are 111%, 117%, 121%, 124%, 120% and 112% as compared to 28 days compressive strength of OPC concrete of same grade. Among all the concrete studied, 365 days compressive strength for M28FA0, M28FA10, M28FA20, M28FA30, M28FA40 and M28FA50 concrete are 133%, 136%, 139%, 147%, 141% and 131% and for M38FA0, M38FA10, M38FA20, M38FA30, M38FA40 and M38FA50 concrete are 121%, 132%, 138%, 144%, 140% and 127% as compared to 28 days compressive strength of OPC concrete of similar grade respectively. At the end of 365 days curing period, the overall strength gaining for M38 grade concrete is around 8% higher as compared to M28 grade concrete. So it can be concluded that strength gaining is relatively faster for higher grade concrete as compared to lower grade concrete.

3.2 Water Permeability

Permeability characteristics of M38 and M28 grade concrete for various curing period are graphically presented in Figure 5 and Figure 6. Fly ash concrete shows relatively higher value of permeability coefficient compared to OPC concrete for early age of curing. But at later age of curing reverse trend was observed. Coefficient of permeability value for M28FA10, M28FA20, M28FA30, M28FA40, M28FA50, M28FA60 and M28FA70 concrete are 5%, 12%, 17%, 27%, 35%, 49% and 59% higher as compared to M28FA0 concrete for 28 days curing period; whereas the similar values are 6%, 13%, 16%, 26%, 34%, 50% and 55% higher for M38FA10, M38FA20, M38FA30, M38FA40, M38FA50, M38FA60 and M38FA70 concrete respectively compared to M38FA0 concrete. But this values were observed as 5%, 8%, 11%, 12% and 9% lower for M28FA10, M28FA20, M28FA30 M28FA40 and M28FA50 concrete respectively; 10%, 12%, 13%, 16% and 14% lower for M38FA10, M38FA20, M38FA30, M38FA40 and M38FA50 concrete respectively when compared with OPC concrete of respective grade. Overall observation shows that for 180 days of curing period, coefficient of permeability values for 10%, 20%, 30%, 40% and 50% fly ash concrete after are observed respectively 8%, 10%, 13%, 15% and 14% lower for M28 grade concrete and respectively 15%, 16%, 18%, 20% and 19% lower for M38 grade concrete. Fly ash has high fineness and can react with the products liberated during hydration. It forms secondary C-S-H gel that fills all the pores inside concrete specimen that makes the concrete dense and compact and as a result coefficient of permeability decreases with the increase of fly ash content upto certain level. In case of 365 days of curing, coefficient of permeability is decreased by around 9%, 11%, 14%, 15% and 12% for concrete M28FA10, M28FA20, M28FA30, M28FA40 and M28FA50 respectively as compared to OPC concrete; 15%, 20%, 23%, 22% and 18% for concrete M38FA10, M38FA20, M38FA30, M38FA40 and M38FA50 respectively as compared to the no fly ash concrete.

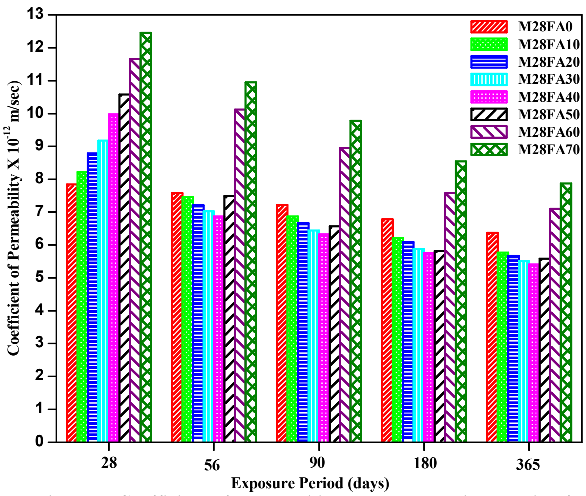

Figure 5: Coefficient of permeability - exposure period relation for M28 fly ash concretes

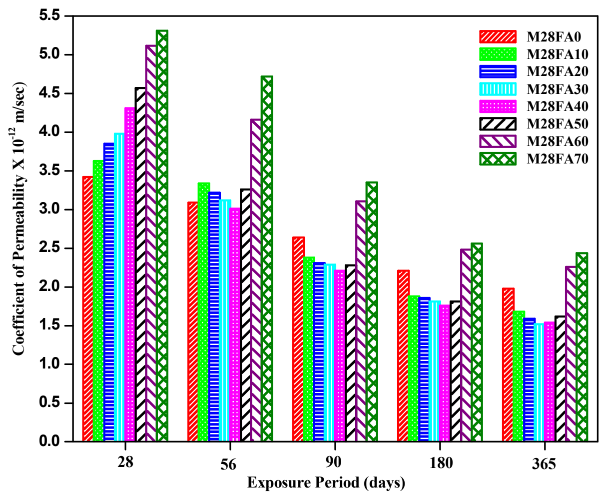

Figure 6: Coefficient of permeability - exposure period relation for M38 fly ash concretes

Also relatively lower values of coefficient of permeability are found to associate with relatively higher grade of concrete. At the end of 365 days curing period, the overall value of coefficient of permeability for M38 grade concrete is around 7% lower as compared to M28 grade concrete. Permeability decreases very rapidly at the initial ages of curing and the rate depends on grade of concrete. The progressive decrease in permeability may be connected to the micro voids dispersed in the mortar matrix of the concrete. As the hydration of cement progresses, crystallization of compounds take place as a result of which the concrete micro voids keep on getting subdivided into capillary micro pores of increasingly smaller sizes. Many of the micro pores lose their connectivity with the passage of time. The reduction in pore sizes coupled with the loss of pore connectivity result in a substantial progressive decrease in the permeability. Among all the fly ash concretes studied upto 365 days curing period, 30%, 40% and 50% fly ash concrete shows better result from water permeability test point of view.

3.3 Rapid Chloride Penetration

Rapid chloride penetration value for OPC and fly ash concrete at 28, 56, 90, 180 and 365 days curing period are graphically presented in Figure 7 and Figure 8. At the initial age of curing RCPT values for fly ash concrete are higher compared to OPC concrete. In case of OPC concrete, amount of passing charge is observed as 4240 and 6295 coulombs for M38 and M28 grade concrete; whereas the similar value for fly ash concretes of cement replacement level of 20%, 30%, 40% and 50% are 4512, 4621, 4766 and 5280 coulombs for M38 grade concrete and 7295, 7465, 7870 and 8013 coulombs for M28 grade concrete at the curing age of 28 days. But for longer age of curing, fly ash concrete shows better resistance against chloride ion penetration. At an age of 90 days of curing, rapid chloride penetration values are 50%, 55%, 60%, 58% lower for M38FA20, M38FA30, M38FA40, M38FA50 concretes respectively and 27%, 33%, 38%, 35% lower for M28FA20, M28FA30, M28FA40, M28FA50 concretes respectively as compared to OPC concrete of similar grade. Also after 180 days of curing, RCPT values for 20%, 30%, 40%, 50% cement replaced level concrete are respectively 45%, 50%, 57%, 66% lower for M38 grade concrete and 22%, 34%, 37%, 33% lower for M28 grade concrete as compared to OPC concrete of similar grade. This is due to high fineness of fly ash. It can react with the products liberated during hydration, forming secondary C-S-H gel that fills all the pores inside concrete and makes it more impermeable (Sarkar, 1995). So it reduces the amount of charge passed through the concrete. The study result also shows that as the amount of fly ash used in concrete is increased, charge flow through the concrete sample is decreased. This is due to the reduction of the pore spaces inside the concrete specimen that makes the concrete dense and compact and as a result the amount of charge flow is decreased. After 365 days of curing, rapid chloride penetration values are respectively 31%, 27%, 23%, 18%, 15% for M38FA10, M38FA20, M38FA30, M38FA40, M38FA50 concretes and 34%, 32%, 31%, 26%, 29% for M28FA10, M28FA20, M28FA30, M28FA40 and M28FA50 concretes as compared to the 28 days RCPT values of OPC concrete of similar grade. The incorporation of pozzolanic materials improved the resistance to chloride penetration of concrete as confirmed by other researchers (Janotka, 2000). A close observation of the data shows that fly ash concrete has relatively better resistance against chloride ion penetration and hence the use of fly ash in structural concrete may inhibits the risk rebar corrosion. It was also observed that at the end of 365 days curing period, the overall RCPT values for M38 grade concrete is around 9% lower as compared to M28 grade concrete.

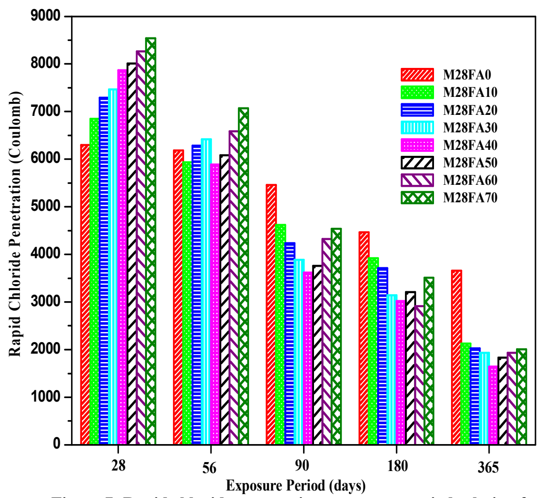

Figure 7: Rapid chloride penetration - exposure period relation for M28 fly ash Concretes

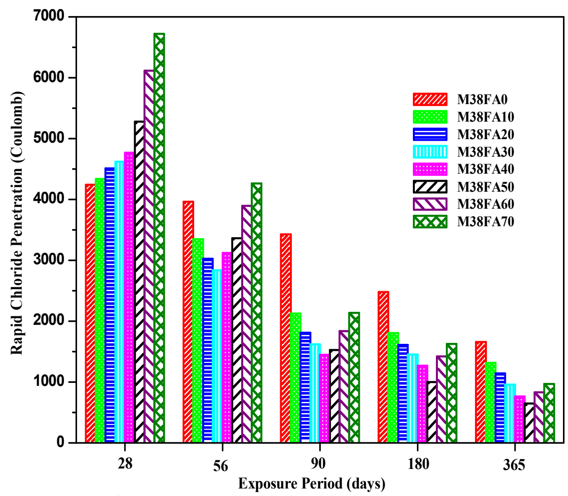

Figure 8: Rapid chloride penetration - exposure period relation for M38 fly ash Concretes

The study results reflect the overall suitability of using Barapukuria fly ash in making structural concrete. Fly ash generated as a waste product from coal burnt process at Barapukuria power plant can be effectively utilized in making portland composite cement (PCC). It would definitely encourage the stack holder i.e. the different cement companies to utilize these materials in making their products without import from foreign countries. In near future huge amount of fly ash waste material, if not properly utilized, may be a huge burden as its natural disposal cause a series of problems including health hazard, destroying of fertile lands, water logging, environmental pollutions etc.

4. CONCLUDING REMARKS

Based on the results of the investigation conducted on different fly ash concrete made with various level of cement replacement and cured for varying curing period up to 365 days, the following conclusions can be drawn:

(1) At early ages of curing upto 28 days, the rate of gain in compressive strength of fly ash concrete specimens is relatively lower as compared to the corresponding OPC concrete.

(2) Optimum fly ash content is observed to be around 30% of cement. Fly ash concrete with 30% cement replacement shows around 16% higher compressive strength than OPC concrete after 365 days curing.

(3) The resistance to water permeability of concrete is significantly increased with the incorporation of fly ash. Fly ash concretes with 30% cement replacement shows around 18% lower coefficient of permeability as compared to OPC concrete.
(4) Chloride penetration resistance for fly ash concrete is observed to be improved compared to OPC concrete. Fly ash concretes with 40% cement replacement shows around 55% lower rapid chloride penetration value compared to OPC concrete. Also this value is around 45% lower for 30% cement replacement.

(5) Higher grade concrete showed around 8% higher gain in strength, 9% lower coefficient of permeability value and 9% lower RCPT value as compared to lower grade concrete.

(6) Use of fly ash in any construction work as a partial replacement of cement reduces CO_2 emission in environment and cost of cement production. It also ensures the judicious use of resources which otherwise been dumped making environmental pollution and reduces available land area for cultivation.

(7) Fly ash obtained as by product of Barapukuria coal burnt power plant can be effectively utilized in making Portland composite cement.

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