Experimental Study on Combined Effect of Fly Ash and Pond Ash on Strength and Durability of Concrete

S.A. Haldive, Dr. A. R. Kambekar

Abstract— Energy generation is increasing day by day due to rapid industrialization. Energy generation through thermal power plants is very typical now days. Fly ash (FA) from these thermal plants is available in large quantities in fine and coarse form. Fine fly ash is used in construction industry in some amount and coarse fly ash is subsequently disposed over land in slurry forms. In India around 160 MT fly is produced and only 40% of that is being utilized in different sectors. Balance fly ash is being disposed over land. Currently around 65000 acres of land is occupied by fly ash. It needs one acre of land for ash disposal to produce 1MW electricity from coal. The worldwide requirement of construction aggregate is estimated to be more than 40 billion MT and more than 3 billion MT of raw materials is required for cement production. Fly ash and pond ash utilization helps to reduce the consumption of natural resources. This paper presents laboratory investigation of concrete produced using fly ash, pond ash (PA) and OPC53 grade. An attempt has been made to investigate characteristics of OPC concrete and combined fly ash- pond ash mixed concrete for various parameters like compressive strength, water permeability and rapid chloride penetration test (RCPT). Results of the laboratory investigation conclude that the performance of concrete made up of combination of fly ash and pond ash is superior to that of Ordinary Portland Cement concrete.

Index Terms— Ordinary Portland cement,fly ash, pond ash, river sand, compressive strength,water permeability test, Rapid chloride permeability test,

1 INTRODUCTION

CONCRETE is a most widely used construction material today. Flexibility, molding ability of concrete material, its high compressive strength and the steel reinforcing and pre-stressing technique in concrete facilitates to improve its strength as against its low tensile strength property and contributed largely for its wide spread use. Many researchers working in the concrete area are trying to understand and modify various concrete properties along with optimizing the cost of concrete. Nowadays concrete is readily prepared for placing at site and is supplied at the site directly from the RMC (Ready Mix Concrete) plant. Chemicals in the form of admixture, polymers and epoxies have been extensively used in concrete mix in order to improve its performance. Use of various fibre materials mixed with concrete is also an option to improve performance of the concrete. Various alternatives of improving performance of concrete are leading towards increasing the cost of concrete[6]. To economize the cost of concrete, use of ground granulated blast furnace slag, rice husk, fly ash etc. have already been tried by many researchers as a partial replacement of cement in concrete mix.

Concrete is most widely used construction material worldwide. Cement concrete industry is one of the major users of fly ash in structural concrete, mass concrete construction like highways, mortars for building etc. Fly ash in concrete is used for the purpose of economy and at the same time fly ash contributes in better durability, reduced permeability, reduction in W/C ratio, reduction in expansion due to alkali aggregate reaction, and improved long term strength and most importantly reduction in cement content.

It has been seen that in the production of Portland cement, the essential constituent of concrete, releases large amount of CO_2 into the atmosphere. Around one ton of CO_2 is released for every ton of Portland cement produced[16]. CO_2 gas is a major contributor to greenhouse effect. Also the production of around one ton of Portland cement requires in the range of around 1.55 to 1.6 tons of raw material[17].The natural resources widely used for construction are likely to be exhausted in coming days due to rapid construction.

In the present scenario, the use of complementary cementing material such as fly ash, slag and silica fume as a partial replacement for Portland cement in concrete presents a viable alternative solution in addition to multiple benefits for sustainable development of concrete industry. Due to its abundant availability, the most commonly available complementary cementing material used worldwide is a fly ash. Fly ash is a by-product from combustion of pulverized coal in thermal power plants. Fly ash, if not utilized properly, has to be disposed off in landfills, ponds or in river system. If construction industry does not increase the utilization of fly ash considerably, it may be disposed off as waste and at the same time it will have significant impact on greenhouse gas emission. Hence, it is indispensable to propose the use of concrete that will incorporate large amount of fly ash as replacement of cement.

2 GLOBAL SCENARIO

Fly ash in developed countries is generally used for brick manufacturing, road construction, land filling, dam construction, agriculture etc. In global context it has been seen that countries like Italy, Denmark and Netherlands have annual fly ash generation of 2 MT and have 100% utilization of the same. Whereas, USA, Germany, which produce more fly ash (10-75 MT/Year) utilize around 50-85% of fly ash produced[13]. Major application of fly ash in these countries are in cement, concrete, mine fill and bricks manufacturing etc. Fly ash generated in India (112 MT/year) and China (100 MT/year) is uti-

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lized only up to 38% and 45% respectively[13]. In Poland and Germany, bulk quantity of fly ash is used for mine filling, cement and concrete production[13].

3 Indian Scenario

Generation of energy has been increasing at a very fast rate due to high growth of industrialization and urbanization. At present, India produces around 112 million ton of fly ash annually[11]. In the installed power generation capacity of 157229 MW, 64% comes from thermal power, 24.7% from hydropower, 2.9% from nuclear and 7.7% from renewable energy sources[11]. Coal alone contributes around 82% of the total power produced from thermal sources. Indian coal contains alround 35% to 45% of ash content. It is estimated that about 65000 acres of land of India is occupied by ash.This is a particularly important concern for India as India currently produces over 100 million of fly ash annually[12]. Disposal of fly ash is a growing difficulty in India. One acre land is required for every MW of power generated for ash disposal[14]. Huge amount of water is also required for fly ash disposal in slurry form[12]. The concerned authorities have already started taking positive steps in the utilization of fly ash in construction such as mandating the use of fly ash in road and building construction projects within a 100 km. radius of a coal fired power plants. They have also made it mandatory for every construction agency engaged in construction of buildings with in radius of 100 km from a coal or lignite based thermal plants to use clay bricks tiles and blocks made up of fly ash[15].

Ash generated in thermal power plants is classified as a bottom ash and fly ash. In thermal power plants, pulverized coal is blown into a burning chamber where it ignites to heat the boiler tubes and leaves behind ash. Heavier ash particles fall to the bottom of furnace and are known as 'bottom ash'. The lighter particles are fine enough to be carried away suspended in the exhaust gases and hence they are called as 'fly ash'[9].

Blended cement not only enhances the life of concrete roads by protecting them from chloride and sulphate attack, but also reduces thermal cracking, plastic and drying shrinkages that are common with ordinary Portland cement constructions[7]. One of the advantages of the concrete roads is the lower lifecycle cost compared to bituminous road. Bitumen, a byproduct from petroleum crude processing is supplied globally and its price has been rising. Nearly 70% of India's petroleum crude is imported[7]. The demand for bitumen in the coming years is likely to grow compared to its availability. Therefore it may be in the interest of construction industry to explore alternative binder material for road construction.

4 Problem Formulation

The purpose of this study is to evaluate the effect of fly ash and pond ash as a partial replacement to cement and fine aggregate respectively on the strength and durability of concrete samples.

4.1 Material List

Ordinary Portland Cement (OPC) 53 grade confirming to IS 12269:1987.

4.2 Sand

Locally available river sand confirming to IS 383:1970 with fineness modulus of 3.2 and specific gravity of 2.7 was used.

4.3 Flyash

Fly ash sample was collected from Nashik Thermal Power Plant station, Nashik, Maharashtra, India. Fly ash confirmed to low calcium ash (Class F) as per IS 3812 -2008. The chemical properties of fly ash are given in Table 1.

4.4 Pond Ash

Pond ash sample was also collected from Nashik Thermal Power Plant. Its sieve analysis is given in Table 2.

4.5 Coarse Aggregates

Crushed 20 mm aggregate had negligible water absorption and had specific gravity of 2.78. The overall grading requirement of coarse aggregate is as per IS: 383-1970.

5 Mix Proportions

M40 grade concrete was used for the laboratory investigation as M30 to M40 grade concrete is being used in high rise towers in foundation work to stand against aggressive condition. The mix design for OPC concrete was confirming to IS 10262: 2009. Then fly ash was used as partial replacement of cement by 20%, 30% and 40% using modified replacement method[8]. In this combination, cementitious material was more than control mix cementitious material. Pond ash was used as partial replacement of river sand in control mix by 10 % and 20%[10].Again in each fly ash mix concrete pond ash was used as partial replacement to river sand by 10% and 20%. The curing was carried out for 3, 7, 28, 45 and 90 days for compressive strength determination and 45 days for durability test. Table3 gives mix proportion used in this study.

6 Results and Discusssions

6.1 Compressive Strength Test

Results obtained from compressive strength test at 3, 7, 28, 56 and 90 days for control, fly ash mix, pond ash mix, and fly ash-pond ash mix are shown in Fig. 1. It was observed that at the age of 3, 7, 28 and 45 days of OPC concrete (control mix) shows higher value of compressive strength than fly ash concrete. At 90 days, 20% fly ash and 40% fly ash concrete show more strength as compared to OPC concrete. Initially, in fly ash concrete the amount of cement quantity is less, hence it is having less compressive strength. But at later age, secondary reaction starts between fly ash and calcium hydroxide and forms additional cementitous material.

For pond ash concrete, results are shown in Fig.2. At the age of 3, 7, 28 and 45 days of OPC concrete shows higher value of compressive strength than pond ash. At 90 days, 10% pond ash and 20% pond ash concrete shows more compressive strength as compared to OPC concrete. Pond ash initially acts as pore filler. Only later, .i.e., after 10-12 days, finer particles of pond ash react with calcium hydroxide from cement and formed additional cementitous material and the larger particles of pond ash acts as filler material. Pond ash is porous in nature, needs more water in concrete compare to OPC concrete.

For fly ash-pond ash mix concrete, results are shown in Fig.3. It is observed that, at age of 3, 7, 28 days OPC concrete shows higher value of compressive strength. At 45 days, (fly ash-20% + pond ash-10%) and (fly ash-20% + pond ash-20%) shows higher value of compressive strength than OPC concrete. At 90 days, (fly ash 20%+ pond ash 10%), (fly ash 20% + pond ash 20%) and (fly ash 30% + pond ash 20%) shows higher value of compressive strength than OPC concrete.

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6.2 Water Permeability Test

This test was performed as prescribed in DIN 1048-199110. Water penetrates into the concrete to a certain depth. A depth of less than 50mm classifies the concrete as "impermeable"[6].A depth of less than 30 mm classifies the concrete as "impermeable under aggressive conditions"[6].The results obtained from water impermeability test at 28, 45 and 90 days for control and fly ash pond ash concrete at are given in Fig.4. From these test results, it was observed that for 28, 45 and 90 days, water permeability was very low i.e. it is impermeable under aggressive condition. Pond ash is porous in nature and hence increases permeability as percentage of pond ash increases.

6.3 Rapid Chloride Penetration Test

The Table 4 shows, the limits on amount of chloride penetration in concrete in terms of electrical charge in Coulombs and the classification from very high to negligible[1]. The results obtained from rapid chloride penetration test at 45 days for control and fly ash mixes are given in Figure 5. From the test results given in the table, it is observed, all fly ash – pond ash concrete, except (fly ash 20% +pond ash 20%) mix concrete, show very low value of Rapid Chloride Penetration Test (RCPT) than OPC concrete. Pond ash is porous in nature. As the amount of pond ash in concrete increases, the value of RCPT also increases. The value is found to be in lower ranges.

TABLE 1
CHEMICAL PROPERTIES OF FLY ASH

Sr. No.	Characteristics	Result	IS 3812 part-I
1	Silicon dioxide (SiO2), + aluminum oxide (Al2O3), + iron oxide (Fe2O3) in percent by mass. (minimum)	93.303	70
2	Silicon dioxide(SiO2) in percent by mass.(minimum)	59.06	35
3	Reactive silica in percent by mass, Min	-	20
4	Magnesium oxide (MgO) in percent by mass. (maximum)	1.763	5
5	Total sulphur as sulphur trioxide (SO3) in percent by mass. (maximum)	0.759	3
6	Available alkalis as sodium oxide (Na_2O) in percent by mass.(maximum)	0.607	1.5
7	Total chlorides in percent by mass.(maximum)	0.029	0.05
8	Loss of ignition in percent by mass.(maximum)	1.214	5

TABLE 2
SIEVE ANALYSIS OF POND ASH

Sieve size	10 mm	4.75 mm	2.36 mm	1.18 mm	600 micron	300 micron	150 micron
Passing (%)	100	100	100	100	100	81.2	53.2
I.S. limit	100	90 - 100	60 - 95	30 – 70	15 - 34	20 - 5	0 – 10

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TABLE 3
MIX PROPRTION OF M40 GRADE CONCRETE

		Fly ash mix			Pond ash mix		Fly ash + pond ash					
Mix No	Control mix	20% fly ash	30% fly ash	40% fly ash	10% pond ash	20 % pond ash	20% fly ash + 10% pond ash	20% fly ash + 20% pond ash	30% fly ash + 10% pond ash	30% fly ash + 20% pond ash	40% fly ash + 10% pond ash	40% fly ash + 20% pond ash
Total cementitous material (Kg)	450	495	495	495	450	450	495	495	495	495	495	495
OPC (Kg)	450	396	347	297	450	450	396	396	347	347	297	297
Fly ash (Kg)	0	99	149	198	0	0	99	99	149	149	198	198
W/C ratio	0	0	0	0	0	0	0	0	0	0	0	0
Total water (Kg)	154	154	154	154	154	154	154	154	154	154	154	154
Total aggregate (Kg)	1917	1840	1821	1803	1901	1884	1824	1795	1806	1777	1787	1772
Sand (Kg)	814	771	763	756	733	651	694	617	687	611	680	605
Pond ash (Kg)	0	0	0	0	65	130	61	123	61	122	60	120
CA -10 mm (Kg)	439	426	421	417	426	421	426	426	421	421	417	417
CA -20 mm (Kg)	664	643	636	630	643	636	643	643	636	636	630	630
Admixture (% of total cementations material)	1.30%	1.30%	1.30%	1.30%	1.30%	1.30%	1.30%	1.30%	1.30%	1.30%	1.30%	1.30%

TABLE 4
LIMIT FOR RCPT VALUES IN COULOMBS

> 4000	very high
2000-4000	moderate
1000-2000	low
100-1000	very low
< 100	negligible

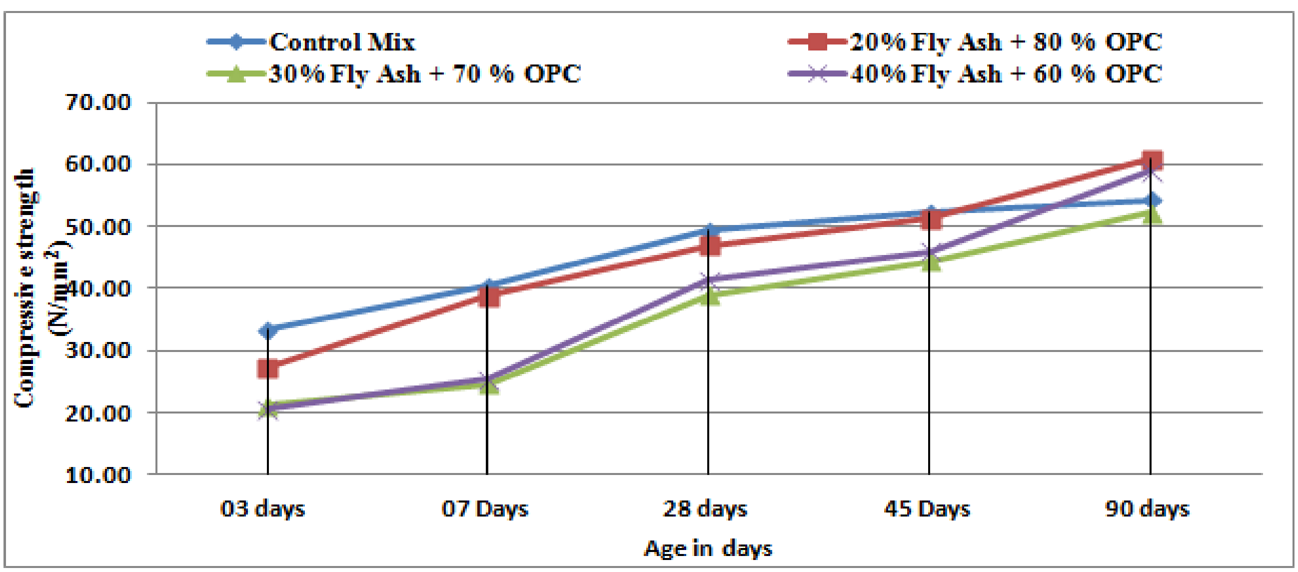

Fig. 1 Comparision of compressive strength of control concrete and fly ash

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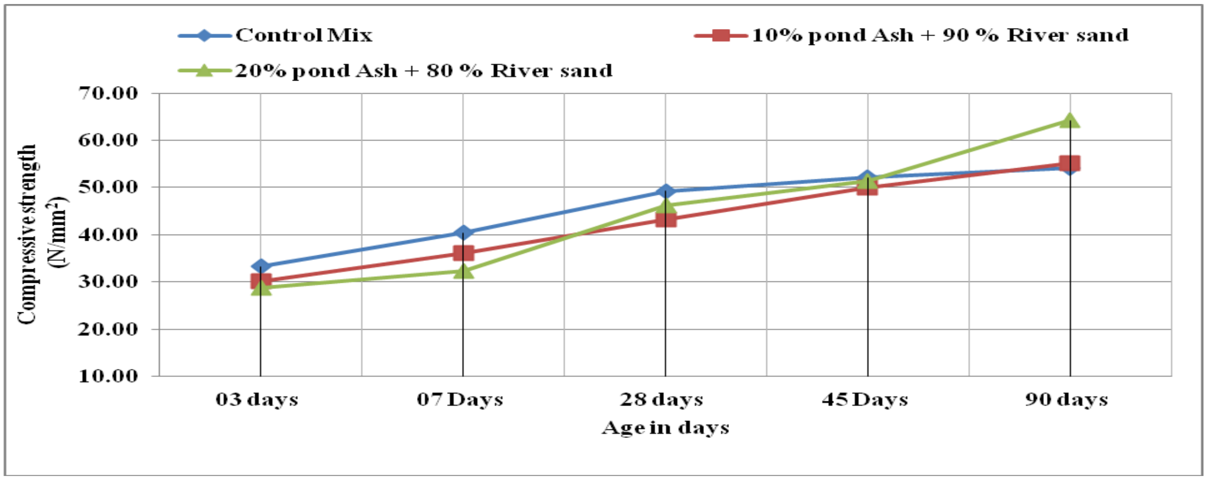

Fig. 2 Comparision of compressive strength of control concrete and pond ash concrete

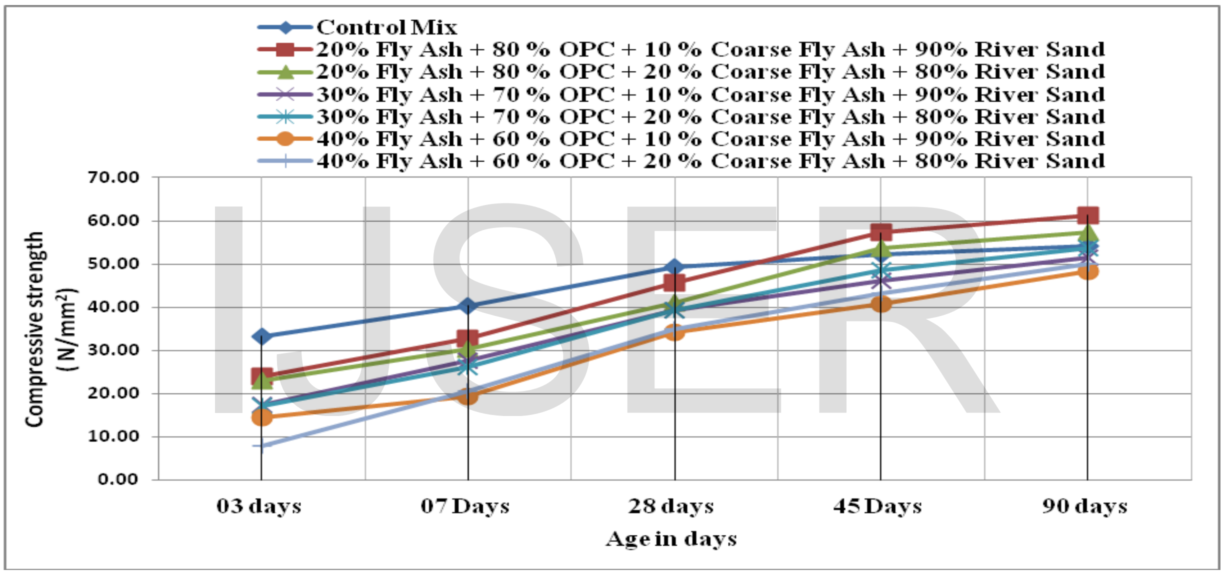

Fig. 3 Comparision of compressive strength of control concrete and combine fly ash –pond ash concrete

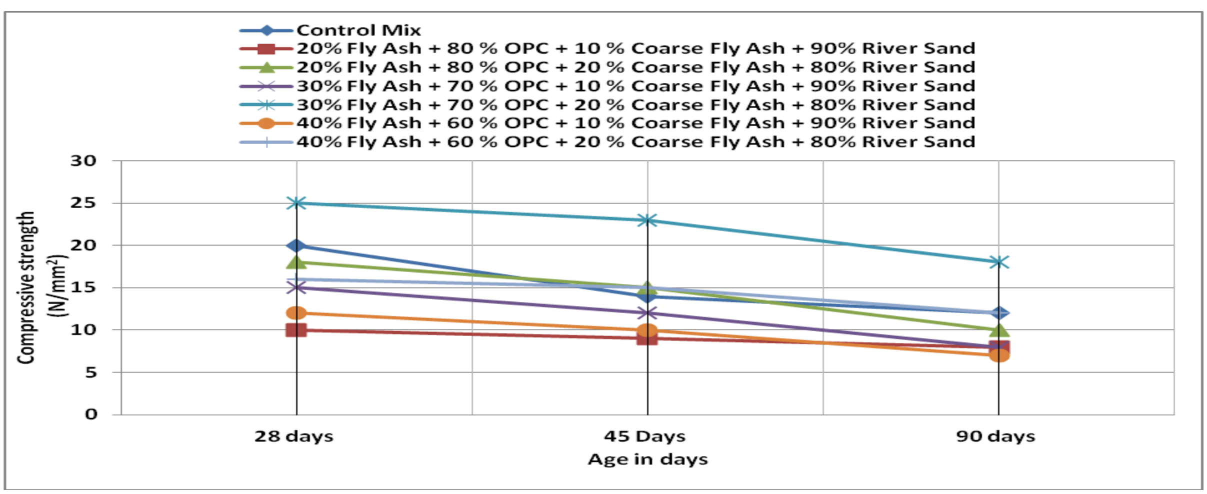

Fig. 4 Comparision of water permeability of control concrete and combine fly ash-pond ash mix

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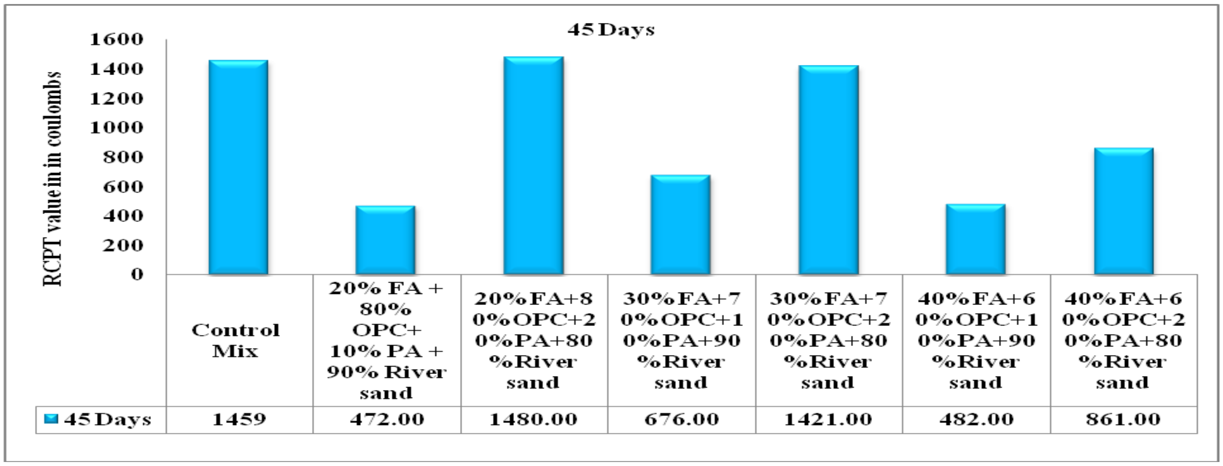

Fig. 5 Comparision of rapid chloride penetration test of control mix and combine fly ash- pond ash concrete

7 CONCLUSION

Based on the experimental investigation, following conclusions can be drawn

- Water permeability of fly ash and pond ash concrete is less than OPC concrete; it would be impermeable in aggressive condition
- As pond ash added in fly ash concrete, value of RCPT increases, particularly at 20% pond ash
- Overall fly ash and pond ash can be replaced by 20% and 10% as a partial replacement to cement and river sand in concrete respectively. This can be concluded from compressive strength, water permeability and RCPT.

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