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# EXPERIMENTAL INVESTIGATION ON DURABILITY OF FLY ASH BASED CONCRETE

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**Abstract** — *Concrete's durability and strength to sustain imposed loads makes it one of the most widely accepted building materials. The present trend in concrete technology is to increase both it strength and durability to meet the demands of the modern construction. The durability can be improved by adding mineral or chemical admixtures or by blending such material with cement. This paper reports and experimental investigation under taken to study the durability characteristics of ordinary Portland cement (OPC) and Portland pozzolana cement (PPC) concrete with and without fly ash. The concrete mix was designed as per IS 10260 : 28 days. Specimens were cast totest strength resistivity, chloride permeability, diffusion and accelerated corrosion.The rapid chloride permeability test (RPCT) value of PPC concrete was found to be 24% less than that of OPC concrete. Similarly the resistivity respectively. By replacing 10% of the cement fly ash in OPC concrete the durability properties was comparable to that of PPC concrete. Increased replacement levels of 10%, 20% , 30% , 40% and 50% further improved the durability properties.*

***Keywords***- *Compressive strength, Concrete, fly ash*

## I. INTRODUCTION

Ash is a residue resulting from combustion of pulverised coal or lignite in Thermal Power Plants (TPPs).About 80% of total ash is in finely divided form which is carried away with flue gases and is collected by electrostatic precipitator or other suitable technology. This ash is called Fly Ash or chimney Ash or Hopper Ash. In an industry, fly ash usually refers to ash produced as an industrial by-product during combustion of coal in TPPs. Fly ash is a fine (85% of its mass passing through a 45µm screen), pozzolaneous or a siliceous and/or aluminous glassy powdered material having micron-sized earth elements, which in the presence of water and lime, will react to form a cementitous material. It consists of inorganic materials mainly silica and alumina with some quantum of organic material in the form of unburnt carbon. Fly ash also contains environmental toxins in significant amounts, including arsenic (43.4 ppm); barium (806 ppm); beryllium (5 ppm); boron (311 ppm); cadmium (3.4 ppm); chromium (136 ppm); chromium VI (90 ppm); cobalt (35.9 ppm); copper (112 ppm); fluorine (29 ppm); lead (56 ppm); manganese (250 ppm); nickel (77.6ppm); selenium (7.7 ppm); strontium (775 ppm); thallium (9 ppm); vanadium (252 ppm); and zinc (178 ppm).

The utilization of fly ash as cement replacement material in concrete or as additive in cement introduces many benefits from economical, technical and environmental points of view. Depending on the burning temperature, coal type and some other factors fly ashes show different properties in different size fractions. In this study, combined effects of these different properties on the strength of fly ash incorporated mortars were investigated by using different size fractions separately. The object was to correlate overall effect of fly ash incorporation on strength to the effects of separate size fractions. One of the previous studies showed that granulometry of ash has important effect on mortar strength . Using this information, effects of changes in the granulometry of same ash on mortar strength were analyzed in the present research. In another study, concrete strengths were correlated to fly ash addition amount and fineness . The study successfully formulized the strength of concretes including coarse and fine fly ashes of similar chemical and mineralogical compositions. But this study was not concentrated on ash granulometry, as was the former one. The result have Some of the material characteristics of the fly ashes used in the study.

### A. TYPE OF FLY ASH

ASTM-C 618-93 categories fly ash into the following three categories.

- Class N Fly ash:

 

Raw or calcined natural pozzolana such as some diatomaceous earths, option line chart and shale, stuffs, volcanic ashes and pumice come in this category. Calcined kaolin clay and late rite shale also fall in this category of pozzolana.

- Class F Fly ash:
  Fly ash normally produced from burning anthracite or bituminous coal falls in this category. This class of fly ash exhibits pozzolanic property but rarely if any, self hardening property.
- Class C Fly ash:
  Fly ash normally produced from lignite or sub-bituminous coal is the only material included in this category.
  This class of fly ash has both pozzolana and varying degree of self cementation properties.

The Objective Of the present study are:

- Reducing the cement content which reduces the cost.
- Obtaining reduced heat of hydration.
- Improving workability.
- Attaining required levels of strength in concrete at age > 90 days.
- Improving durability.

## II. TEST FOR MATERIAL:

***TABLE-1 PROPERTIES OF CEMENT***

| Sr.No | Physical properties of ULTRATECH PPC 53cement | Result | Requirement As per 1481(part1) : 1991 |
|---|---|---|---|
| 1 | Fineness | 1% | |
| 2 | Consistency(%) | 35% | 30-35% |
| 3 | Initial setting time(min) | 110minute | 30minimum |
| 4 | Final setting time (min) | 225minute | 600minimum |
| 5 | Soundness | 1mm | |

***TABLE-2 FLYASH CHEMICAL PROPERTIES***

| Sr.No | Characteristic | Requirements | |
|---|---|---|---|
| | | Siliceous flyash | Calcareous flyash |
| 1 | Silicon Dioxide+Aluminium oxide+Iron oxide in % by mass,min. | 95.1 | 20 |
| 2 | Silicon dioxide in % by mass,min | 35 | 25 |
| 3 | Reactive silica in % by mass,min(optical test) | 20 | 20 |
| 4 | Total chlorides in % by mass,max | 5.0 | 5.0 |
| 5 | Magnesium dioxide in % by mass,min | 0.15 | 0.65 |
| 6 | Totalsulphar trioxide in % by mass,min | Nil | Nil |
| 7 | Available alkalies as sodium oxide in % by mass,min | 0.05 | 0.05 |
| 8 | Loss on ignition in % by mass,max | 1.01 | 2.0 |

***TABLE-3 FLYASH PHYSICAL PROPERTIES***

| Characteristic | Result |
|---|---|
| Fineness-specific surface in $m^2$ / kg (min) | 364 |
| Particles – retained on 45 micron IS sieve in percent,max | 34 |

 

| | |
|---|---|
| Specific Gravity- | 2.00 |

### B. Concrete mix design:

RECOMMENDED CONCRETE MIX PROPORTION:

Based on the properties of the ingredients supplied the proportion by weight was worked out using I.S. method of Mix Design IS: 10262 – 1982. "Recommended procedure for Designing Concrete Mixes for General types of Construction." Trial mixes were prepared based on the proportion obtained from calculation and based on the compressive strength and the slump observed for trial mixed the following proportion if recommended. The testing of the concrete was done according to IS : 516 – 1959.

***TABLE-4CONCRETE MIX PROPORTION (BY WEIGHT)***

| Cement | Fine Aggregate | Coarse Aggregate | Water |
|---|---|---|---|
| 1 | 1.425 | 3.10 | 0.50 |

Cement Content = 400 kg/$m^3$ Slump Observed = 100 mm

## III. EXPERIMENTAL METHODLOGY

### *A. Testing Methodology:*

Concrete derives its strength by the hydration of cement particles. The hydration of cement is not a momentary action but a process continuing for long time. The water is used in the concrete evaporates and the water available in the concrete will not be sufficient for effective hydration to take place particularly in the top layer. If the hydration is to continue unbated, extra water must be added to replenish the loss of water on account of absorption and evaporation. There for the curing can be considered as creation of a favorable environment during the early period for uninterrupted hydration. Curing can also be described as keeping the concrete moist and warm enough so that the hydration of cement can continue. Curing may be done by following method by Water curing done by Immersion, Ponding, Spraying or fogging, wet covering. By Membrane curing and Application of heat.

### *B. Compressive Strength Test:*

- The moulds of size 15cm x 15cm x 15cm with oiling the inside.
- Take cement, sand and course aggregate in proportionate 1:2:4 in a non-porous enamel tray and dry mix them.
- Now add water of required quantity as a product of water/cement ratio and the weight of cement and mixed ingredient thoroughly until the mixture becomes homogeneous, uniform in colour and consistency.
- Immediately after mixing, the concrete is filled into a cube mould.
- Compact the concrete either by hand compaction in a standard specified manner or on the vibrating equipment.
- Prepare nine cubes in above manner.
- Keep the filled moulds at a temperature of 27± 2°C in an atmosphere at 90 percent relative humidity for 24 hours.

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***Figure.1***- **CONCRETE STRENGTH MACHINE**

- After 24 hours remove the cubes from the moulds and immediately immerse in clean fresh water and keep it for required period of curing.
- Three cubes are tested for compressive strength at the period mention in observation table.

***TABLE-5 TOTAL NUMBER OF SPECIMEN***

| Type of Specimen | Compressive strength of cube | | | Compressive strength (NaCl) | | Cylinder Casting |
|---|---|---|---|---|---|---|
| | 3 days | 7 days | 28 days | 30 days | 60 days | |
| PPC | 3 | 3 | 3 | 3 | 3 | 3 |
| OPC | 3 | 3 | 3 | 3 | 3 | 3 |
| 10% | 3 | 3 | 3 | 3 | 3 | 3 |
| 20% | 3 | 3 | 3 | 3 | 3 | 3 |
| 30% | 3 | 3 | 3 | 3 | 3 | 3 |
| 40% | 3 | 3 | 3 | 3 | 3 | 3 |
| 50% | 3 | 3 | 3 | 3 | 3 | 3 |
| Total | 21 | 21 | 21 | 21 | 21 | 21 |
| | 63 | | | 42 | | 21 |
| Total Specimen | 126 nos | | | | | |

 

*Figure.2- STANDARD CYLINDER*

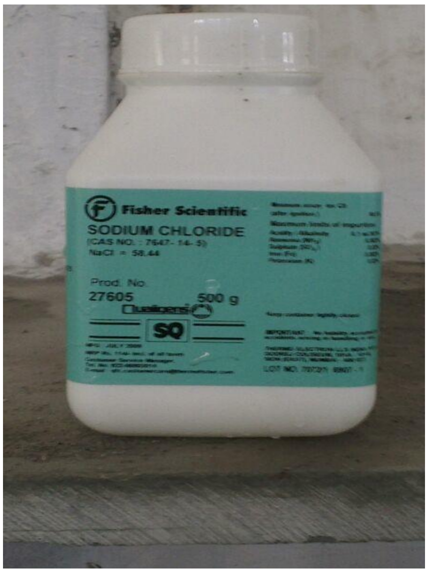


*Figure.3- NACL*

*Figure.4-STANDARD CUBE*

## C. TEST FOR DURABILITY

➢ POLARISATION TEST:

This test is based on the electrochemical polarization principle. It essentially consists of a non-metallic container, in which 3.5% NACL solution is filled to the required level. In this container the cylindrical concrete specimen with rebar at centre and stainless steel plate is placed. The rebar's top is onnected to the anode terminal (-ve) of a DC power supply, and the tainless steel plate is connected to the cathode terminal (+ve). This setup forms an electrochemical cell with the rebar acting as anode and the stainless steel plate as cathode. A number of such cells were made and connected to a multi channel D.C power pack. A constant voltage of 5.0V was applied from the D.C power pack. Since chloride ions are negatively charged, they migrated towards rebar through the concrete that served as anode. For the applied voltage, the current was measured using an ammeter. This current depends on the total resistance of the system. The applied voltage was kept constant and the current was monitored at different time. With time, the chloride ion migration increases and once sufficient chloride, equal to the critical chloride content for the type of steel rebar used, reaches the steel surface, de-passivates and this gets reflected in the sudden increase in current. The experiment is discontinued on observing the first crack on the concrete surface. A plot was made between current in mA versus time in days to obtain the corrosion initiation and propagation period.
On completion of the test, the cylinders were taken out to determine the chloride contnt and rebar's weight loss due to corrosion.

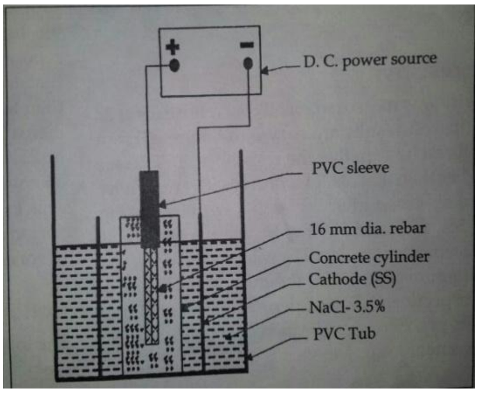


***Figure.5-TEST SETUP FOR POLARIZATION EXPERIMENT***

➢ RESISTIVITY TEST:

The corrosion of a specific length of reinforcement, the algebraic summation of the electric currents originating from the corroding sites and flowing through the moist surrounding concrete and non-corroding sites. Hence the electric resistance of the concrete plays an imported role in determining the magnitude of corrosion at any specific location. This parameter is expressed as "Resistivity" in ohm centimeters or kiloohms centimeters .
The test method essentially consists of a four-probe technique, in which a known current is applied between two outer probes and the voltage drop between the inner two probes is recorded allowing for a direct evaluation of resistance R. Resistivity is calculated as p=2(3.14)R.a, where 'a' is he spacing of probes as illustrated in fig.
**The following limitations are important to note while analyzing the result:**
-The resistiity value represents the average evaluation between the probe spacing and not of concrete at the steel interface.
-The skin effect of concrete with varying drying conditions affects the measurements and the instrument should have adequate 'IR' drop compensation for the measurement.

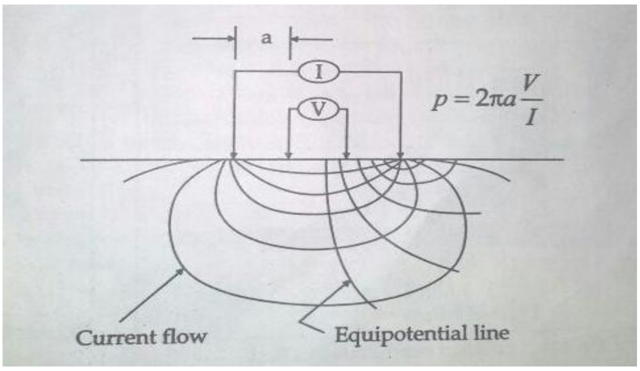


***Figure.6- RESISTIVITY TEST***

➢ RAPID CHLORIDE ION PENETRATION TEST(RCPT):

This test measures the chloride ion transportation in concrete by measuring the amount of charge passed through the concrete. The RCPT is performed by monitoring the amount of current passing through a sample (50mm thick x 100 mm diameter ) in 6 hours. A voltage of 60V is maintained across the ends of the sample throughout the test. One lead is immersed in a 0.5N Sodium Chloride (NaCl) solution and the other in a 0.3n sodium hydroxide (NAOH) solution. The total charge Q, passed is calculated in coulombs by the following equation,
$Q=900x10^{-3}[I_0+I_{360}+2(I_{60}+I_{120}+I_{180}+I_{240}+I_{300})]$
Where'
Q=Charge passed (Coulombs)
$I_0$=Current(Amperes) immediately after applying the voltage and
$I_{360}$=Current (amperes) at t min. after applying voltage applied.
The RCPT value of PPC concrete was slightly less than that of OPC concrete. The RCPT values was observed to be less when flyash was added to the concrete.

***Figure.7-FLEXURAL STRENGTH TEST***

## IV. RESULTS:

***TABLE-6 RESULT OF CEMENT CONCRETE CUBE (CEMENT REPLACING BY % OF FLYASH)***

| Sr.No | Type | Replacement of Fly Ash | Compressive strength(N/mm$^2$) | | | | Average |
|---|---|---|---|---|---|---|---|
| 1. | PPC | Nil | 3 Days | 14.45 | 15.10 | 14.89 | 14.81 |
| | | | 7 Days | 15.67 | 15.85 | 15.98 | 15.84 |
| | | | 30 Days | 21.66 | 21.78 | 21.99 | 21.81 |
| 2. | OPC | Nil | 3 Days | 13.74 | 14.10 | 14.65 | 14.16 |
| | | | 7 Days | 15.89 | 16.32 | 16.78 | 16.33 |
| | | | 30 Days | 20.67 | 21.23 | 21.78 | 21.228 |
| 3. | OPC | 10% | 3 Days | 15.37 | 15.50 | 14.97 | 15.283 |
| | | | 7 Days | 16.90 | 16.45 | 15.10 | 16.151 |
| | | | 30 Days | 22.35 | 22.00 | 21.92 | 22.091 |
| 4. | OPC | 20% | 3 Days | 14.99 | 15.77 | 15.34 | 15.36 |
| | | | 7 Days | 17.60 | 17.90 | 16.78 | 17.42 |
| | | | 30 Days | 21.67 | 21.10 | 22.53 | 21.76 |
| 5. | OPC | 30% | 3 Days | 14.77 | 15.25 | 16.33 | 15.45 |
| | | | 7 Days | 17.22 | 19.47 | 19.68 | 18.79 |
| | | | 30 Days | 20.06 | 20.88 | 12.16 | 21.37 |
| 6. | OPC | 40% | 3 Days | 15.79 | 16.12 | 16.98 | 16.33 |
| | | | 7 Days | 18.33 | 19.02 | 19.38 | 18.91 |
| | | | 30 Days | 21.88 | 22.28 | 24.81 | 22.99 |
| 7. | OPC | 50% | 3 Days | 16.18 | 17.38 | 17.76 | 17.11 |
| | | | 7 Days | 18.47 | 79.40 | 20.66 | 19.51 |
| | | | 30 Days | 21.08 | 24.33 | 24.79 | 23.79 |

***TABLE-7 RATE OF GAINED PER DAY OF CONCRETE MIXES***

| Mix | 0-3 Days | 3-7 Days | 7-28 Days |
|---|---|---|---|
| Opc | 14.16 | 16.33 | 21.23 |
| Ppc | 14.81 | 15.84 | 21.81 |
| Opc 10% | 15.28 | 16.15 | 22.09 |
| Opc 20% | 15.36 | 17.42 | 21.76 |
| Opc 30% | 15.45 | 18.79 | 22.37 |
| Opc 40% | 16.33 | 18.91 | 22.99 |
| Opc 50% | 17.11 | 19.51 | 23.79 |

 

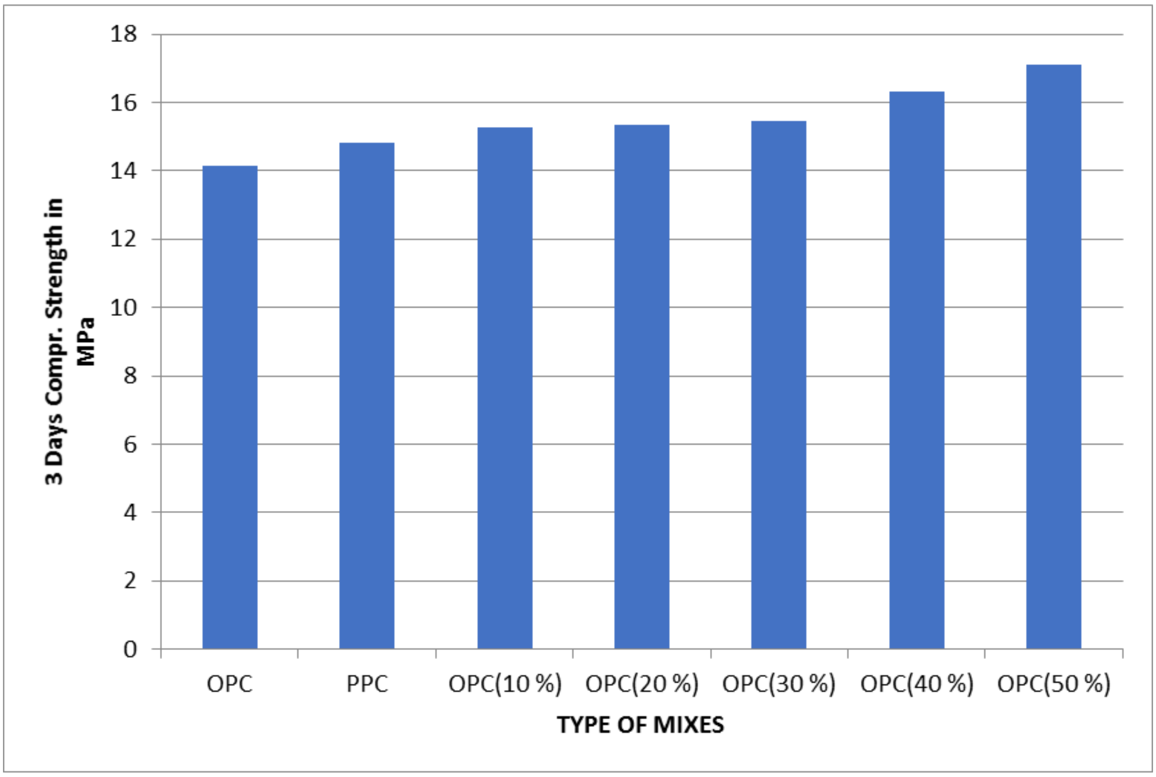


*Figure.8-3 DAYS STRENGTH*

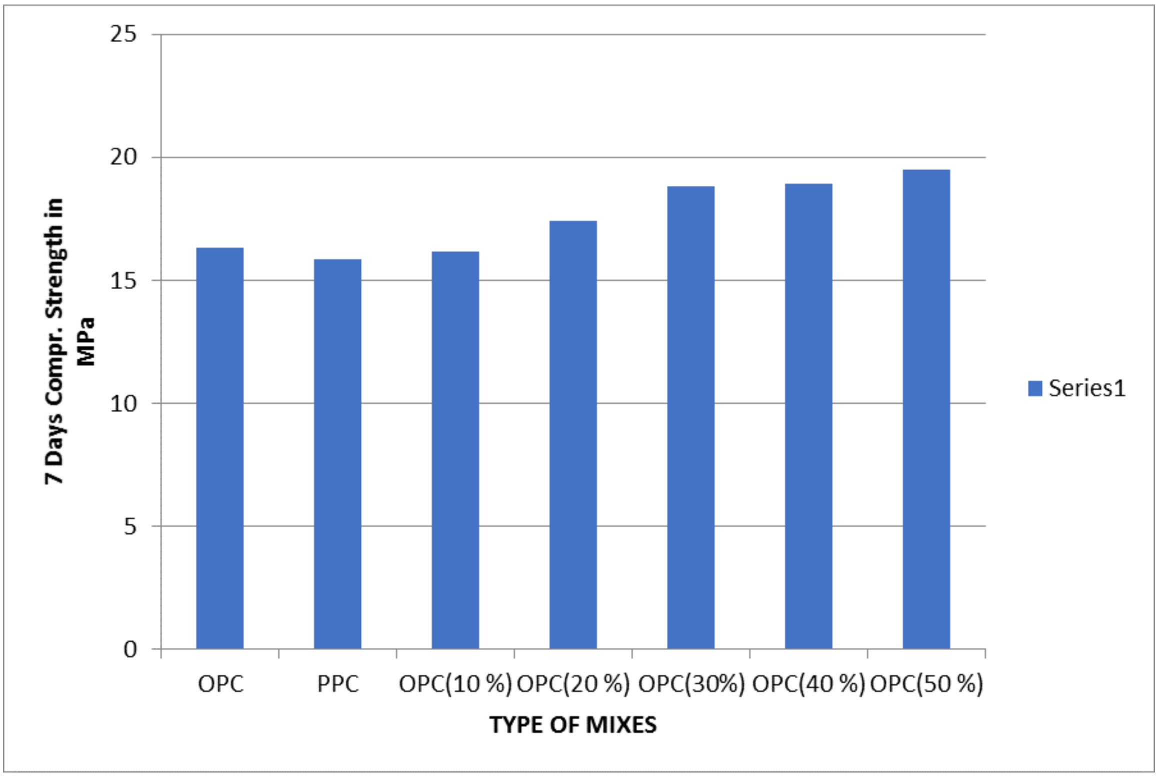


*Figure.9-7 DAYS STRENGTH*

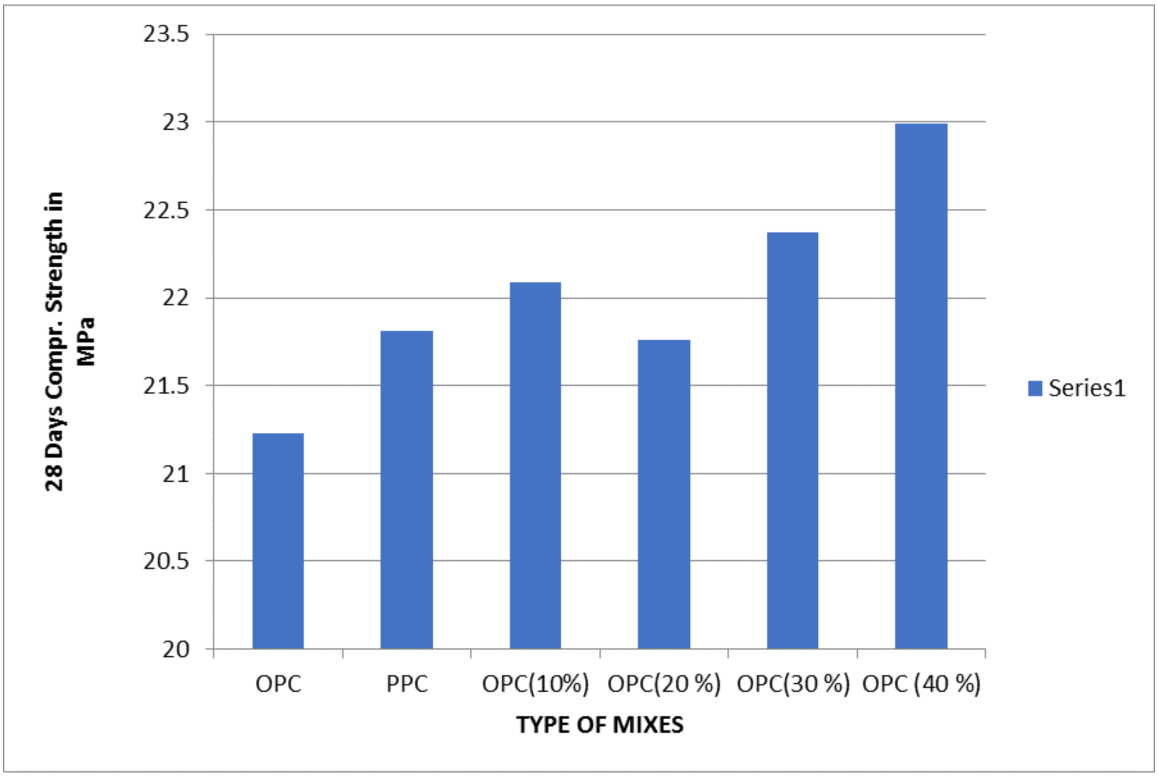


*Figure.10-28 DAYS STRENGTH*

Test for Polarization

*TABLE-8 RESULT OF POLARIZATION*

| | Corrosion Time (days) |
|---|---|
| OPC | 4 |
| PPC | 5 |
| OPC(10%) | 7 |
| OPC(20%) | 14 |
| OPC(30%) | 22 |
| OPC(40%) | 33 |
| OPC(50%) | 38 |

 

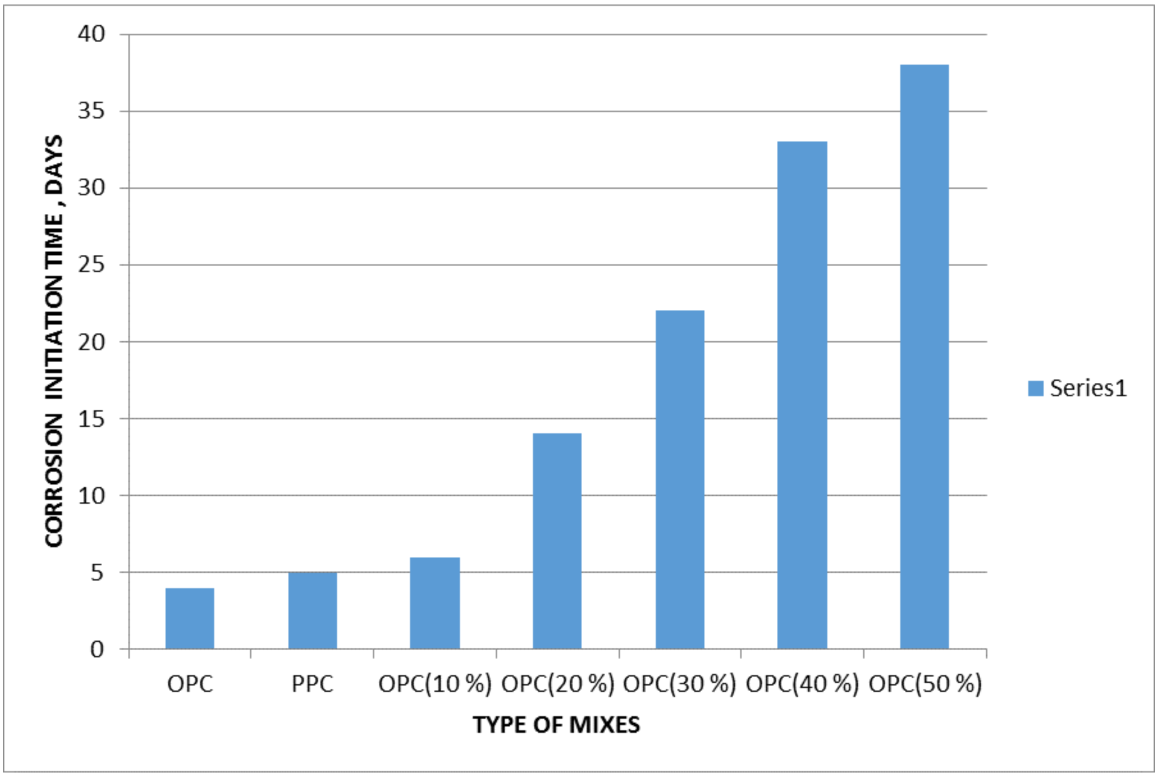


***Figure.11- EFFECT OF FLY ASH ADDITION ON POLARIZATION TEST***

RCPT TEST :-

***TABLE-9 RESULT OF RCPT***

| | Coulombs |
|---|---|
| OPC | 4 |
| PPC | 5 |
| OPC(10%) | 7 |
| OPC(20%) | 14 |
| OPC(30%) | 22 |
| OPC(40%) | 33 |
| OPC(50%) | 38 |

 

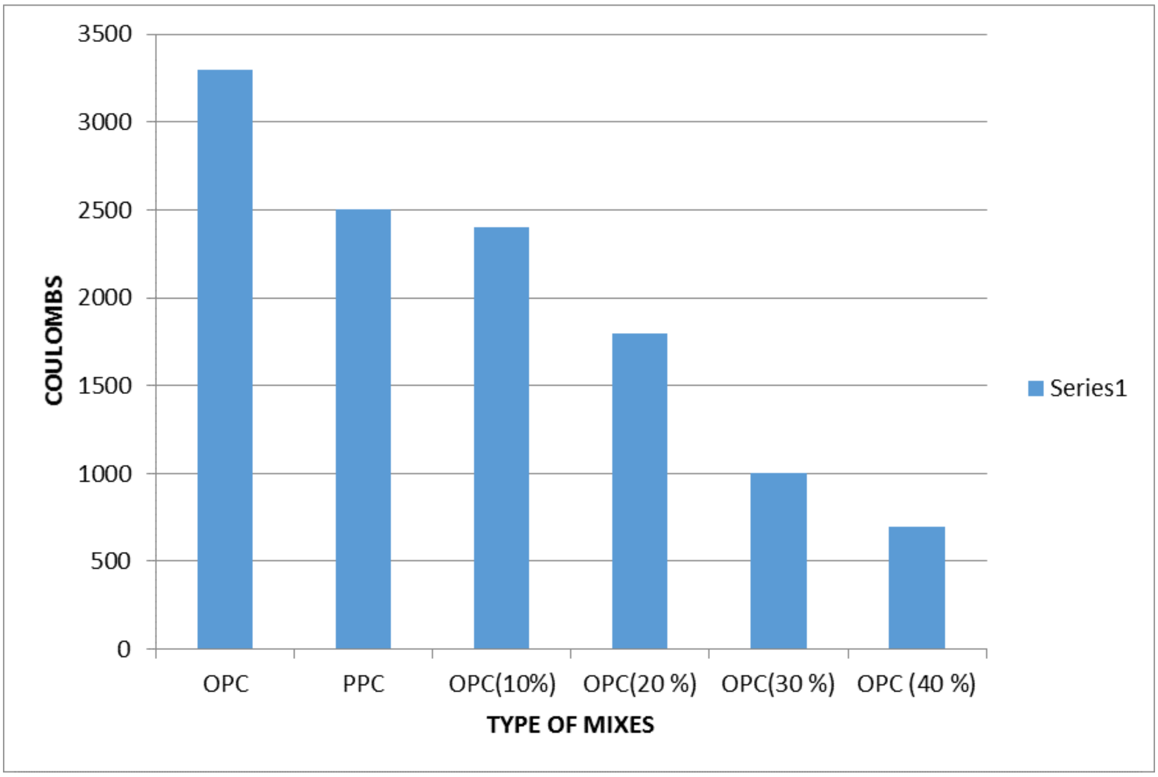


***Figure.12-EFFECT OF FLYASH ADDITION ON RCPT***

Test for Resistivity:-

***TABLE-10 RESULT OF RESISTIVITY***

| | Resistivity(k-Ohm-cm) |
|---|---|
| OPC | 6 |
| PPC | 7 |
| OPC(10%) | 9 |
| OPC(20%) | 13 |
| OPC(30%) | 19 |
| OPC(40%) | 25 |
| OPC(50%) | 29 |

 

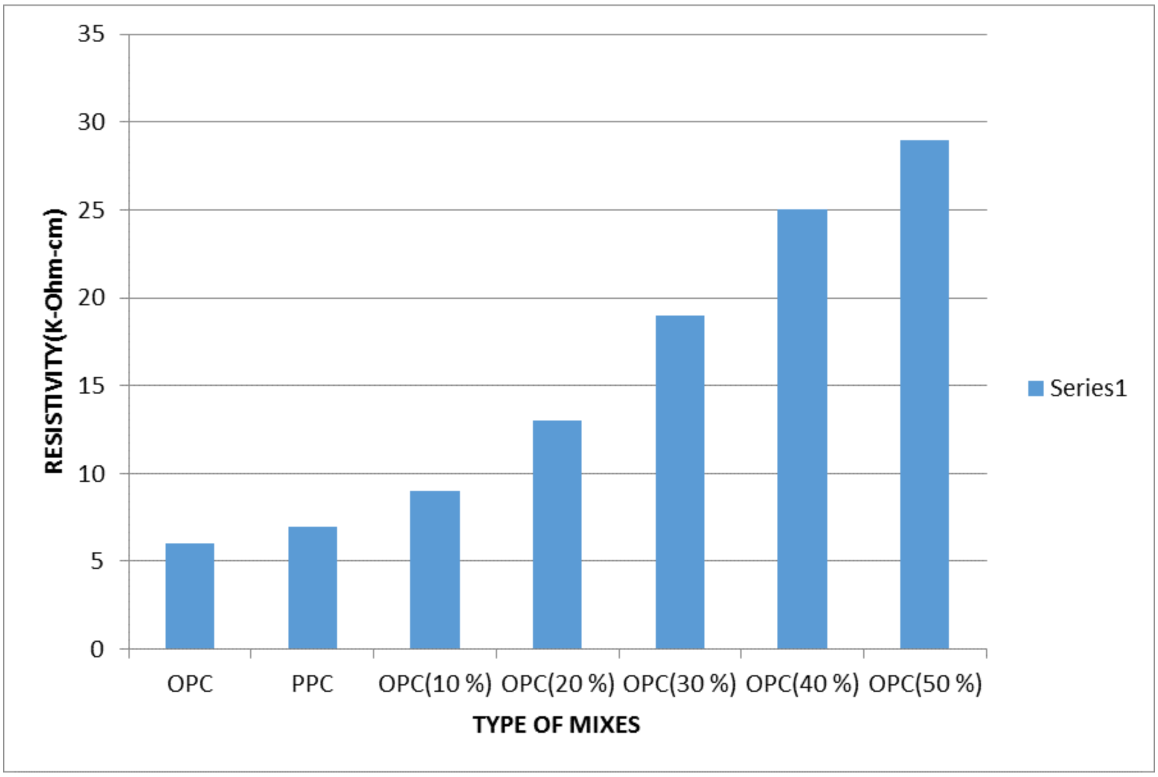


***Figure.13-EFFECT OF FLYASH ADDITION ON RESISTIVITY***

## V. CONCLUSION:

The Result indicate that the durability of concrete structures could be improved by using fly ash as a mineral admixture up to 50 % of cement could be replaced with fly ash without affecting the mechanical properties of concrete.

- **POLARISATION TEST :**
  The Conclusion can be drawn by comparing the control sample of concrete with the sample of fly ash replacement 10%, 20%, 30%, 40%, 50% of concrete. the polarisation test value of concrete can be observe to increase the Corrosion initiation time , days of concrete OPC 50% replacement of fly ash better than that of normal OPC concrete.

- **RAPID CHLORIDE ION PENETRATION TEST :-**
  The RCPT value of concrete can be observe to decrease coulomb value of 50% replacement of fly ash better than that of normal OPC concrete.

- **RESISTIVITY TEST :-**
  The RESISTIVITY value of also improved for the fly ash based concrete with to 50% of replacement of cement by fly ash than in OPC concrete

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## ACKNOWLEDGEMENT

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