# Experimental Research on Durability Properties of High Volume Fly Ash Concrete with Polypropylene Fibre

D. Jayalin, N.Vellingiri, S.Janaki Raman

***Abstract*— This study focuses on the influence of the durable properties of Conventional concrete and High volume fly ash concrete. Fly ash is replaced in various percentages as 0%,40%,50%,55% and 60% by the weight of ordinary Portland cement in addition to that polypropylene fibre of 0.2% is added for improving the strength and Durability of concrete. Water absorption test, chloride resistance test, sulphateresistance test and Rapid Chloride Penetration test (RCPT) were evaluated. The test results show that the addition of high volume fly ash and polypropylene fibre improves the flexural strength and Durability of concrete.Fly Ash replacement of 55% by the weight of cement is considered as the optimum replacement level***

***Key words:*— cement;fly ash;polypropylene fibres;flexural strength;chlorideresistance: sulphate resistance: water absorption**

## 1. INTRODUCTION

Concrete plays a vital role in the construction field in the modern world. Concrete incorporates large amount of natural resources as aggregates and cement with water. Cement is the main ingredient of concrete. Cement production consumes huge energy and causes about 7% of total green-house gas emission in the world. Each one ton of Portland cement production generates about one ton of CO2 emissions, which is a green-house gas. The environmental issues related with green-house gases emissions and depletion of natural resources play and important role in the sustainable development of concrete and construction industry. Hence, utilization of supplementary cementitious materials such as fly ash, slag and silica fume is being researched extensively over the last few decades to enhance durability and sustainability of concrete.

Fly ash is a byproduct from coal based thermal power plants. It has been generally considered a waste material in the past and disposal of which has posed numerous ecological and environmental problems. However, recent researches have shown that fly ash has potential to act as invaluable ingredient in cement and concrete.The fly ash is now considered as a resource material rather than a waste in civil engineering and material science. In addition fly ash can be gainfully used for various other applications.

In developing countries like India power generation is most important requirement for economic and social development. In India, about 67% of electricity requirements are fulfilled by the coal fired thermal power plants.Thegeneration of 1 MW power with Indian coal results in co-generation of nearly 1800t of fly ash.As per Central Electricity Authority, India, report, 143 no coal fired thermal power plants with installed capacity of 133381 MW produce about 200 million tons of coal ash annually. With the capacity addition of 22282 MW by the end of 2017, the production of coal ash is estimated to about 185 million tons per year. Nearly 100 million tons of fly ash is being utilized out of 185 million tons generated. Though percentage utilization has gone to nearly 56% but in absolute terms, very large quantity of fly ash still remains unutilized. This huge quantity is being stored / disposed off in ash pond areas. The ash ponds acquire large areas of agricultural land. Use of fly ash reduces area requirement for pond, thus saving of good agricultural land.

## 2. MATERIALS USED:

### *2.1 Cement*

Ordinary Portland cement (OPC) of 53 grade conforming IS 10269-1987[12] was used. The specific gravity of cement was used 3.21 and fineness of cement was 2%.

### *2.2 Fly Ash*

Pozzocrete 60 of Class F fly ash acquired from Eklahare Thermal Power station, Nashik conforming to IS 3812-2003[9] (part I) was used compression of chemical properties of cement and fly ash shown in tabe 1 and EDAX result of fly ash are shown in figure 1. The specific gravity of fly ash is 2.30.

**Table 1: Chemical composition of cement and fly Ash**

| Chemical Composition (Wt%) | Cement | Fly Ash |
|---|---|---|
| $SiO_2$ | 21.0 | 55.47 |
| $Al_2O_3$ | 5.4 | 26.89 |
| $Fe_2O_3$ | 3.3 | 4.34 |
| CaO | 65.6 | 1.30 |
| MgO | 1.1 | 0.58 |
| $SO_3$ | 2.7 | 0.90 |
| $K_2O$ | - | 0.67 |
| $TiO_2$ | - | 1.30 |
| $Na_2O$ | - | 0.98 |
| LOI | 1.2 | 1.10 |

Revised Manuscript Received on April 12, 2019.

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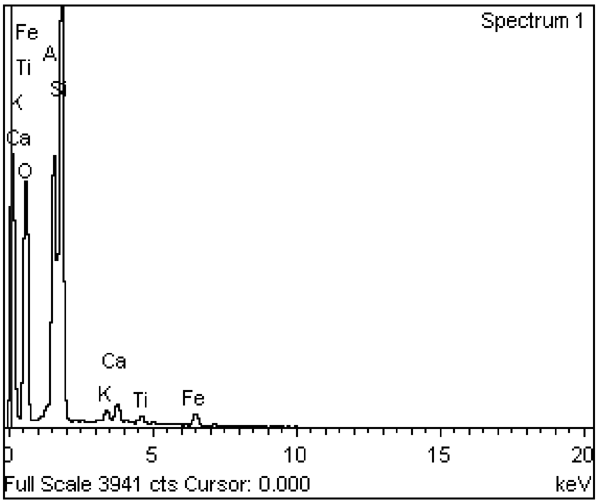


**Fig 1: Edax result of Fly Ash**

*2.3 Aggregates*

Coarse aggregates of 20 mm size obtained locally conforming to IS 383-1970 was used. The various properties of coarse aggregate and fine aggregate shown in table 2.Locally available river sand passing through IS 4.75 mm sieve conforming to zone II of IS 383-19709 (part 30 was used.

**Table 2. Properties of Aggregate**

| S.No. | Particulars | Fine Aggregate | | Coarse Aggregate | |
|---|---|---|---|---|---|
| 1. | Specific Gravity | 2.56 | | 2.79 | |
| 2. | Fineness Modulus | 3.91 | | 3.56 | |
| 3. | Bulk Density | Loose | Rodded | Loose | Rodded |
| | | 1.640 | 1.728 | 1.414 | 1.420 |

*2.4 Fibres*

Polypropylene fibres of monofilament type having 12 mm length were used for improve the mechanical properties and Durability properties of concrete.

*2.5 Admixtures*

Polycarboxylate ether based superplasticizer(SP) conforming to IS 9103-1999 was used to reduce the water-cement ratio.

*2.6 Mix Proportion and Proportion of Specimen*

Six mixes were made. A reference mix was designed without fly ash replacement in accordance with 10262-2013 to target strength of 48.25 N/mm2 at 28 days of curing. Four mixes were made with fly ash replacement in 40,50,55 and 60% of ement. Polypropylene fibres were added at 0.2% to all five mixes. The water cement ratio was kept as 0.33 and super-plasticizer was added to all mixes at 0.8% of cementitious material. Table 3 shows the mix proportion of all mixes. Concrete mixtures were mixed using drum mixer and placed in required moulds. The concrete specimens were demolded after 24 hours and placed in curing tank for curing

**Fig 2: Mixing of concrete**

| Mix Designation | Cement | | Fly Ash | | FA | CA | W/C | Water | Super plasticizer | | Fibre | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | % | kg | % | kg | kg | kg | | kg | % | kg | % | kg |
| M1 | 100 | 448 | 0 | 0 | 732 | 1125 | 0.33 | 148 | 0.8 | 2.24 | 0 | 0 |
| M2 | 100 | 448 | 0 | 0 | 732 | 1125 | 0.33 | 148 | 0.8 | 2.24 | 0.2 | 1.8 |
| M3 | 60 | 268.8 | 40 | 179.2 | 732 | 1125 | 0.33 | 148 | 0.8 | 2.24 | 0.2 | 1.8 |
| M4 | 55 | 224 | 50 | 224 | 732 | 1125 | 0.33 | 148 | 0.8 | 2.24 | 0.2 | 1.8 |
| M5 | 50 | 201.6 | 55 | 246.4 | 732 | 1125 | 0.33 | 148 | 0.8 | 2.24 | 0.2 | 1.8 |
| M6 | 40 | 179.2 | 60 | 268.8 | 732 | 1125 | 0.33 | 148 | 0.8 | 2.24 | 0.2 | 1.8 |

**Table 3:Mix Proportion**

## 3. EXPERIMENTAL PROGRAM

*3.1 Flexural Strength*

Flexural strength of concrete beam specimens was tested in accordance with IS 516:1959 in this study. The beam specimen of size 100mm x 1000mm x 500mm was casted for testing the flexural strength. Average of three specimens tested in each mix is considered as the flexural strength of the concrete.

*3.2 Sulphate Resistance test*

The test was carried out in order to study the effect of high volume flyash on the resistance against magnesium sulfate attack. The 100 × 100 × 100 mm concrete cube specimens were cast and cured in water for 28 days. Magnesium Sulphate is used as the chemical in this test.

*3.3 Chloride Resistance test*

The test was carried out in order to study the effect of high volume flyash on the resistance against chloride attack. The 100 × 100 × 100 mm concrete cube specimens were cast and cured in water for 28 days. Sodium Chloride is used as the chemical in this test.

*3.4 Rapid Chloride Penetration Test*

The test was performed on cylindrical specimens of diameter100 mm and height 200 mm to determine the rate of permeability as per ASTM C 1202 (2009).

*3.5 Water absorption test*

This test was carried on hardened concrete specimens (BS 1881: Part122, 1983). The 100 × 100 × 100mmcube specimen were prepared and cured for 28 days to find the percentage of water absorbed by the specimen.

## 4. RESULT AND DISCUSSION

*4.1 Flexural Strength*

Flexural strength of all mixes was determined at the age of 28 days. Table.4 shows the flexural strength of all mixes. From table.4, it can be noted that, the flexural strength of concrete increases with the addition of fibre and flyash. By addition of fibre, the fibre acts as a bridge between cracks and reduces the formation of cracks. This action of fibre bridging increases the flexural strength of concrete. From fig.3, it can be noted that the flexural strength increases with the increase in flyashcontent upto 50% and thereafter decreases. The increase in flexural strength is due to the secondary CSH gel formed by the pozzolanic action of flyash.

**Table 4: Flexural strength**

| Mix | Flexural Strength in N/mm$^2$ |
|---|---|
| M1 | 6.27 |
| M2 | 6.4 |
| M3 | 6.8 |
| M4 | 6.92 |
| M5 | 6.53 |
| M6 | 5.73 |

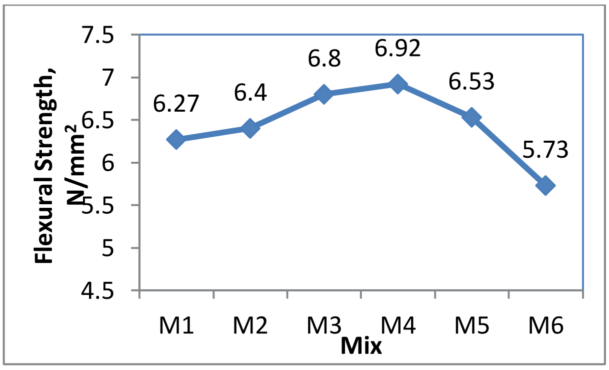


**Fig3: Flexural strength**

*4.2 Sulphate Resistance test*

Sulphate resistance of concrete was tested after 28 days for the reference mix and the optimum mix. Table.5. and fig.5 shows the values of weight loss and strength loss due to sulfate attack. From table.5 it can be noted that the sulfate resistance of concrete increased with the addition of flyash and fibre.Fig.4, shows the weight loss and strength loss of concrete specimens due to sulfate solution.

**Table 5: Strength loss and weight loss due to sulfate attack**

| Mix | Weight loss (%) | Strength loss (%) |
|---|---|---|
| M1 | 0.2784 | 9.28 |
| M2 | 0.2318 | 8.1667 |
| M5 | 0.1159 | 5.9738 |

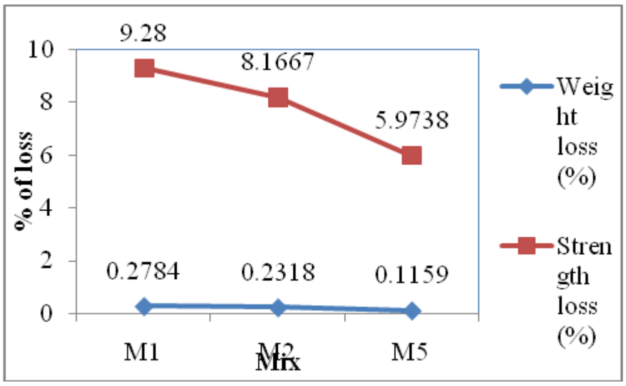


**Fig 4: Weight loss and strength loss due to sulfate attack**

*4.3. ChlorideResistance test*

Chloride resistance of concrete was tested by immersion of concrete cubes in 0.5% Nacl solution after 28 days of curing. Table.6. shows the weight loss and strength loss due to chloride attack. From table.6.it can be noted that the addition of fibre and flyash increases the resistivity of concrete towards chloride attack. The formation of secondary CSH gel reduces the pore voids in concrete and thereby increases the resistivity towards sulfate attack. Fig.5.shows the cumulative weight loss of concrete specimens due to chloride attack. Fig.6. indicates that the mix with 55% flyash and 0.2% polypropylene fibre showed the lowest value of weight loss and strength loss due to chloride attack. The mix with 55% flyash and 0.2% polypropylene fibre offered greater resistivity towards chloride attack.

**Table 6: Strength loss and weight loss due to chloride attack**

| Mix | Weight loss (%) | Strength loss (%) |
|---|---|---|
| M1 | 0.2308 | 12.312 |
| M2 | 0.1917 | 10.125 |
| M5 | 0.0785 | 7.1399 |

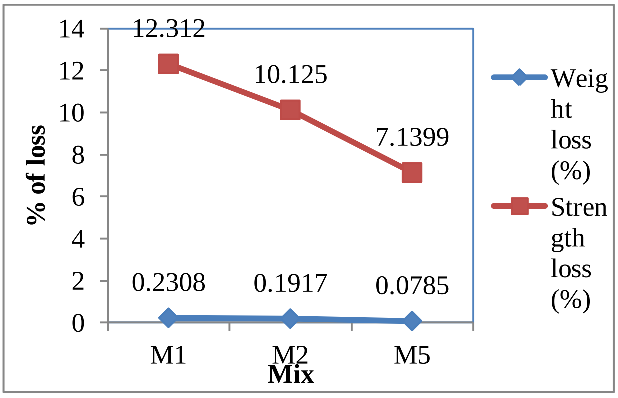


**Fig 5: Weight loss and strength loss due to chloride attack**

*4.4. Rapid Chloride Penetration Test*

RCPT was done in concrete specimens after 28 days of curing. Table.7 shows the RCPT results. From table.7, it can be noted the mix with 55% flyash and 0.2% polypropylene fibre showed the lowest chloride permeability. This maybe due to action of fibre bridging and the formation of secondary CSH gel

**Table 7: RCPT Results**

| Mix | Charge passed in coulombs | Permeability class as per ASTM C 1202 |
|---|---|---|
| M1 | 903 | Very low |
| M2 | 783 | Very low |
| M5 | 102 | Very low |

*4.5. Water Absorption Test*

Water absorption of concrete specimens was found out at the age of 28 days curing. Table.8.7 shows the water absorption values. Table.8 indicates that the mix with 55% flyash and 0.2% polypropylene fibre had the lowest value of water absorption. The reduction in water absorption values maybe due to the formation of secondary CSH gel. The secondary CSH fills the capillary pores in concrete and hence reduces the water absorption in concrete

**Table 8: Water absorption Test**

| Mix | % of water absorption |
|---|---|
| M1 | 3.6 |
| M2 | 1.91 |
| M5 | 0.85 |

## 5. CONCLUSION

From, the experimental results, the following conclusion can be drawn:

1. The 7 days strength decreased with increase in fly ash content
2. The results show that high volume fly ash concrete with polypropylene fibre attained higher strength at a later days on flexural strength.
3. The mix M5 with 55% flyash and 0.2% polypropylene fibre is considered as the optimum mix since at higher replacement the mix showed higher strength than the reference mix
4. Optimum mix (M5) showed high sulphate resistance and chloride resistance in terms of strength loss and weight loss.
5. Permeability level of high volume fly ash concrete with polypropylene fibre was very low, considerable amount of charge passed is 102 Coulombs only.
6. High volume flyash concrete with polypropylene fibre offered a greater resistance to water absorption compared to reference concrete.
7. High volume flyash concrete with polypropylene fibre enhanced the durability properties of concrete

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