

# Strength and Durability Characteristics of Concrete Replaced with Pond Ash and Alcofine

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**ABSTRACT:** Concrete is the most widely used construction material in the world. Increase in demand and decrease in natural resource of fine aggregate for the production of concrete has resulted in the need of identifying a new source of fine aggregate. Cement, the binding material in concrete emits vast amounts of carbon-dioxide gas in to the atmosphere during its hydration, which has major contributions to greenhouse effect and thereby causing global warming. Possibility of use of pond ash as a partial replacement for fine aggregate and alcofine 1203 as a partial replacement for cement, which can cause lowest environmental impact is considered in this project. Pond ash is a by product formed during combustion of pulverised coal at thermal power station. Alcofine 1203 is a specially processed product based on slag of high glass content with high reactivity obtained through the process of controlled granulation and marketed in India by Ambuja Cement Company. The project covers experimental investigation on the possibility of effective replacement of fine aggregate with pond ash (0%, 10%, 20% and 30%) and cement with alcofine 1203 along with optimum pond ash (at 0%, 5%, 10% and 15%) for M30 grade concrete. The laboratory tests for materials, fresh concrete properties, hardened concrete properties such as compressive strength, flexural strength and split tensile strength and durability tests such as water absorption, acid resistance and chloride resistance are conducted. Test results shows that concrete strength is maximum for 20% replacement of fine aggregate with pond ash and 10% replacement of cement with alcofine and has better durability performance comparing with conventional concrete and other mixes.

**KEYWORDS:** Pond ash, Alcofine 1203, Compressive strength, Flexural strength, Split tensile strength, Durability tests.

## I. INTRODUCTION

Concrete is the most widely used construction material in the world. It is composed mainly of cement, fine aggregate (sand), coarse aggregate, water and admixture. In concrete one of the largest consumed materials is fine aggregate. River sand is the most commonly used fine aggregate in many parts of the world. The huge demand for concrete has made this natural resource to get impoverished. Increase in demand and decrease in natural resource of fine aggregate for the production of concrete has resulted in the need of identifying a new source of fine aggregate. Partial replacement of sand by any other supplementary waste materials or by products with similar properties can leave aggregates for future generation and save the cost. Cement, the binding material in concrete emits vast amounts of carbon-dioxide gas into the atmosphere during its hydration, which has major contributions to greenhouse effect and thereby causing global warming. Use of alternate supplementary cementitious materials or pozzolanic materials as a partial replacement for cement can cause lowest possible environmental impact. Possibility of effective replacement of fine aggregate with pond ash and cement with alcofine 1203 is checked in this project.

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The project aims to evaluate material properties of pond ash and alccofine 1203 and to evaluate workability, strength and durability characteristics for different percentages of replacements of fine aggregate with pond ash and cement with alccofine. The study also compares the engineering properties of replaced concrete with normal concrete.

## Pond Ash

Combustion of pulverized coal at the thermal power station leaves bottom ash, fly ash and vapours as the products. As a general practice in India, fly ash and bottom ash in thermal power plants are mixed with water and transported to ash ponds. The ash thus deposited in pond is called as Pond ash. The disposal of this waste will be a big challenge to environment as huge quantity of this waste consumes more space for disposal. Pond ash is coarse granulated and its colour is grayish-black. Particle size is 1 micron to 600 micron. The possibility of utilization of thermal power plant by product pond ash as replacement to fine aggregate in concrete is taken into consideration.

## Alccofine 1203

Alccofine or Ultra fine slag is a recently introduced mineral admixture marketed in India by Ambuja Cement Company. It's a better alternative for the cement replacement. Alccofine 1100 series - high calcium silicate products (cement base), Alccofine 1200 series - low calcium silicate products (slag base) and Alccofine 1300 series - alumino silicate products (fly-ash based) are the three classifications of alccofine. Alccofine 1200 series is of 1201, 1202, 1203 which represents fine, micro fine, ultrafine particle size respectively. Alccofine 1203 is a specially processed product based on slag of high glass content with high reactivity obtained through the process of controlled granulation. The particle size range is from 0.1 to 17 microns, with average particles size of 4 microns. Alccofine shows properties that reduces water demand, increases compressive strength, durability and workability of OPC concrete. The performance of alccofine is superior to all the other admixtures used in India due to high Calcium Oxide (CaO) content. Alccofine works in concrete as a cementitious material, as pozzolanic material and by packing effect. The reactivity of alccofine can be explained in two ways;

- Primary reaction of cement hydration due to its inbuilt CaO content.
- Pozzolanic reaction: Alccofine also consumes by product calcium hydroxide from the hydration of cement to form additional C-S-H gel, similar to pozzolans. This results in denser pore structure and ultimately higher strength gain.

## II. LITERATURE REVIEW

**Aparna K.A, et.al, (2015)** conducted comparative study of fly ash and pond ash on compressive and flexural strength of concrete. The mix selected was M40. Keeping the fly ash 20% constant the percentage of pond ash is varied from 15% to 20%. Compression test is done for cubes of cross section 150mmx150mmx150mm. Flexural strength test is done on beams of cross section 100mmx100mmx500mm. The curing period for cubes and beams was 28 days and 56 days. 20% replacement of cement by fly ash and 18 % replacement of fine aggregate by pond ash were found to be optimum percentage of replacement.

**Deepak Kumar Bandewar, et.al, (2015)** conducted analysis and testing of concrete using various parameters for M30 grade concrete by replacing cement with alccofine 1203. Study was conducted for 10%, 15% and 20% replacement of cement. Tests were conducted for workability and compressive strength for 7 days and 28 days. The optimum percentage of replacement of cement was found to be 10%.

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## III. MATERIALS USED

### Cement

53 grade Ordinary Portland Cement of RAMCO, collected from local market was used. The material testing results of cement is given in Table 1.

Table 1 Material testing results of cement

| Tests                | Test Results | Requirement as per IS specification  |
|----------------------|--------------|--------------------------------------|
| Fineness             | 8%           | < 10%, IS: 4031 – Part 1 – 1996      |
| Specific Gravity     | 3.15         | 3-3.15, IS: 4031 – Part 11 – 1988    |
| Standard Consistency | 34%          | 33-35%, IS: 4031 – Part 4 – 1988     |
| Initial setting time | 35 min.      | > 30 min., IS: 4031 – Part 5 – 1988  |
| Final setting time   | 360 min.     | < 600 min., IS: 4031 – Part 5 – 1988 |

### Alccofine 1203

Alccofine 1203 was collected from Ambuja Cements Ltd., Willingdon Island, Cochin. The chemical composition and material testing results (provided by the manufacturer) are given in Table 2.



Fig. 1 Alccofine 1203

Table 2 Material testing results of alccofine provided by the manufacturer

| Physical properties               | Values  |            |
|-----------------------------------|---------|------------|
| Fineness (cm <sup>2</sup> /gm)    | >12000  |            |
| Specific Gravity                  | 2.9     |            |
| Bulk Density (Kg/m <sup>3</sup> ) | 700-900 |            |
| Particle Size Distribution        | D10     | < 2 micron |
|                                   | D50     | < 5 micron |
|                                   | D90     | < 9 micron |

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## Fine aggregate

M-sand collected from local sources was used as fine aggregate and its material testing results are given in Table 3.

Table 3 Material testing results of fine aggregate

| Tests                             | Test Results  | Requirement as per IS specification |
|-----------------------------------|---------------|-------------------------------------|
| Specific Gravity                  | 2.76          | 2.6-2.8, IS 2386 – Part 3 – 1963    |
| Seive Analysis (Fineness Modulus) | 3.21, zone II | 2.1-3.37, IS 2386 – Part 1 – 1963   |
| Moisture Content                  | 2.4%          | Up to 10%                           |
| Water Absorption                  | 2%            | 2-4%                                |

## Pond ash

Pond ash was collected from Hindustan News Print, Kottayam, India. The chemical composition and material testing results are given in Table 4.



Fig. 2 Pond ash

Table 4 Material testing results of pond ash

| Tests                             | Test Results |
|-----------------------------------|--------------|
| Specific Gravity                  | 2.38         |
| Seive Analysis (Fineness Modulus) | 2.71         |
| Moisture content                  | 0.42%        |
| Water absorption                  | 8.12%        |

## Coarse aggregate

Aggregate of size of 20 mm collected from local sources was used and its material testing results are given in Table 5.

Table 5 Material testing results of coarse aggregate

| Tests            | Test Results | Requirement as per IS specification |
|------------------|--------------|-------------------------------------|
| Specific Gravity | 2.86         | 2.5-2.9, IS 2386 – Part 3 – 1963    |

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|                                   |       |                                |
|-----------------------------------|-------|--------------------------------|
| Seive Analysis (Fineness Modulus) | 6.2   | 6-6.9, IS 2386 – Part 1 – 1963 |
| Moisture Content                  | 0.23% | -                              |
| Water Absorption                  | 0.5%  | 0.5-1%                         |

## Water and Super Plasticizer

The drinking tap water has been used for both mixing and curing of concrete. A chemical admixture based on modified poly carboxylic ether, which is known commercially as Glenium 51 of specific gravity 1.08 is used as the super plasticizer. It was collected from RMC plant, Edayar.

## IV. MIX DESIGN

Normal concrete mix having a characteristic compressive strength of 30 N/mm<sup>2</sup> and water-cement ratio 0.40 was designed according to IS 10262:2009 guidelines. Mix proportion for 1 m<sup>3</sup> is given in Table 6.

Table 6 Mix proportion for 1 m<sup>3</sup>

| Cement<br>Kg/m <sup>3</sup> | Fine aggregate<br>Kg/m <sup>3</sup> | Coarse aggregate<br>Kg/m <sup>3</sup> | Water<br>litre |
|-----------------------------|-------------------------------------|---------------------------------------|----------------|
| 383.15                      | 718.37                              | 1323.38                               | 153.26         |
| 1                           | 1.87                                | 3.45                                  | 0.40           |

## V. RESULTS AND DISCUSSIONS

### A. Pond ash alone is used

#### Slump Test Results

Fig. 3 indicates graph of variation of slump for different percentages of pond ash replacement. As the percentage replacement of pond ash increases slump decreases. Decrease in slump may be due to high water absorption rate of pond ash.

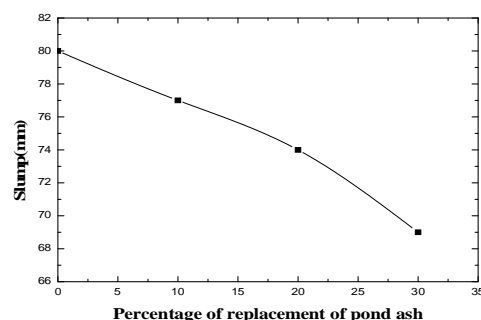


Fig. 3 Graph showing variation of slump for different percentages of pond ash replacement

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## Strength Test Results

Fig. 4 (a), (b) and (c) indicates the graphs of compressive strength, split tensile strength and flexural strength for different percentages of pond ash replacement. The maximum strength is obtained with 20% pond ash replacing fine aggregate. The values of compressive strength, split tensile strength and flexural strength obtained at 28 day testing are 37.11 N/mm<sup>2</sup>, 2.62 N/mm<sup>2</sup> and 8 N/mm<sup>2</sup>. But these values are slightly less than that of values obtained for control mix.

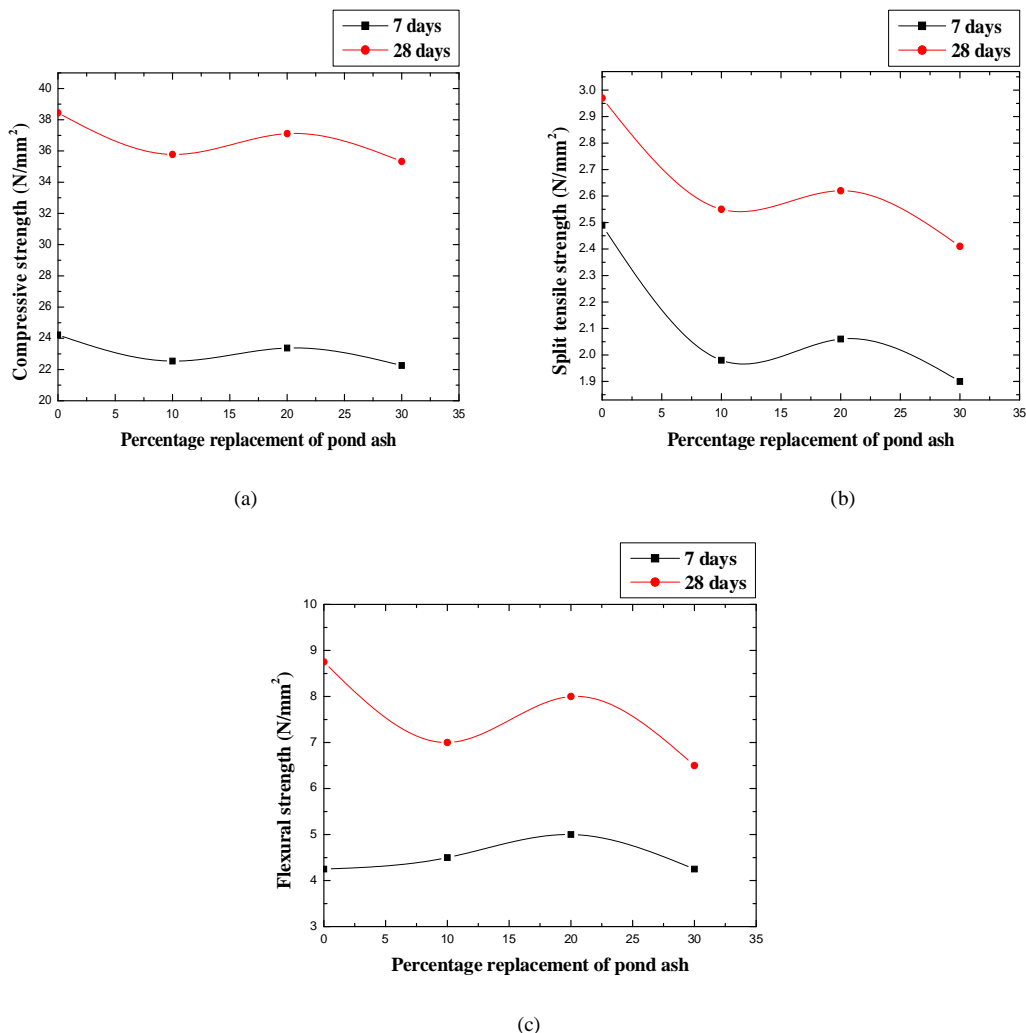


Fig. 4 Strength test results for pond ash replacement (a) Compressive strength (b) Split tensile strength (c) Flexural strength

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## Durability Test Results

### (i) Water absorption

Fig. 5 indicates the graphs of water absorption of pond ash replacing fine aggregate. Results indicate that water absorption of mixes with pond ash replacement is high comparing with control mix. The minimum percentage of water absorption is obtained with 20% pond ash replacing fine aggregate among the mixes with pond ash replacement and on comparing with water absorption of control mix the value is slightly higher.

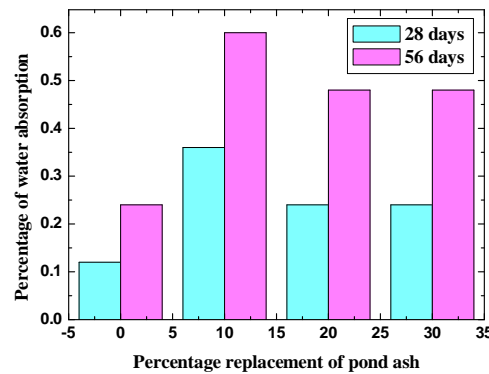
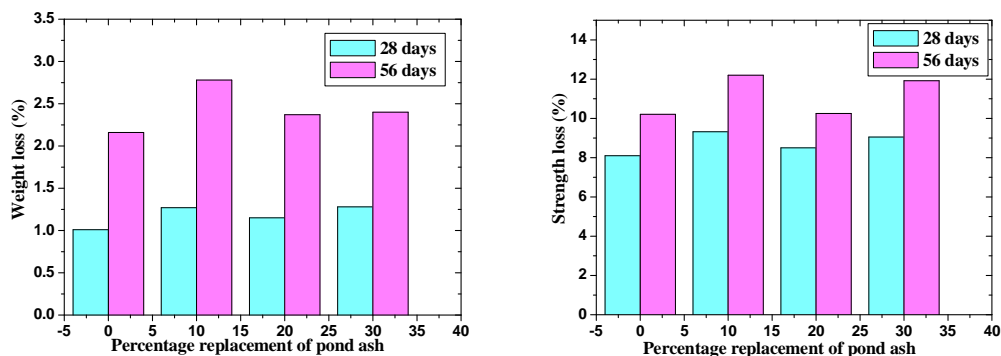


Fig. 5 Water absorption of pond ash replacing fine aggregate

### (ii) Acid resistance

Fig. 6 (a) and (b) indicates the graphs of weight loss and strength loss on acid resistance test of pond ash replacing fine aggregate. Results indicate that weight loss and strength loss of mixes with pond ash replacement is slightly high comparing with control mix. The minimum percentage of weight loss and strength loss is obtained with 20% pond ash replacing fine aggregate among the mixes with pond ash replacement and on comparing with control mix the value is slightly higher.



(a)

(b)

Fig. 6 Acid resistance test results for pond ash replacement (a) Weight loss (b) Strength loss

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### (iii) Chloride resistance

Fig. 7 (a) and (b) indicates the graphs of weight loss and strength loss on chloride resistance test of pond ash replacing fine aggregate. Results indicate that weight loss and strength loss of mixes with pond ash replacement is slightly high comparing with control mix. The minimum percentage of weight loss and strength loss is obtained with 20% pond ash replacing fine aggregate among the mixes with pond ash replacement and on comparing with control mix the value is slightly higher.

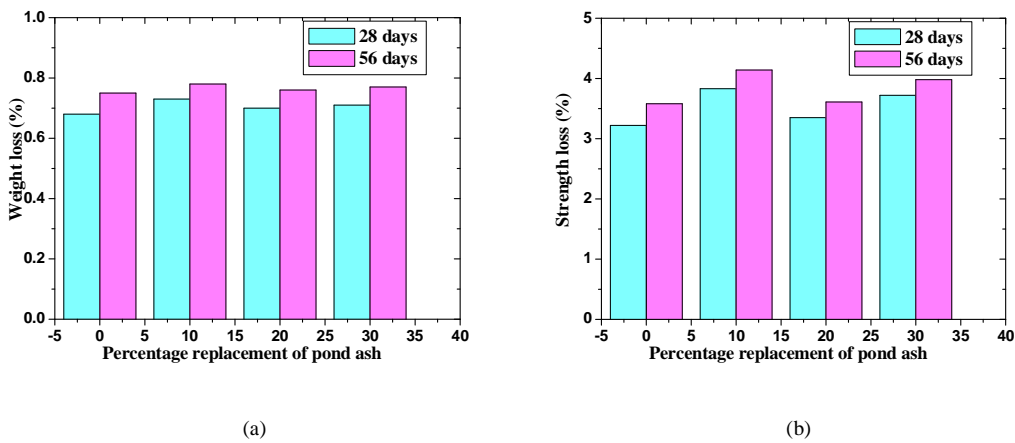


Fig. 7 Chloride resistance test results for pond ash replacement (a) Weight loss (b) Strength loss

### B. Pond ash + Alccofine is used

#### Slump Test Results

Fig. 8 indicates graph of variation of slump for different percentages of alccofine replacement. As the percentage replacement of alccofine increases slump increases. Increase in slump may be due to lower water absorption rate of alccofine.

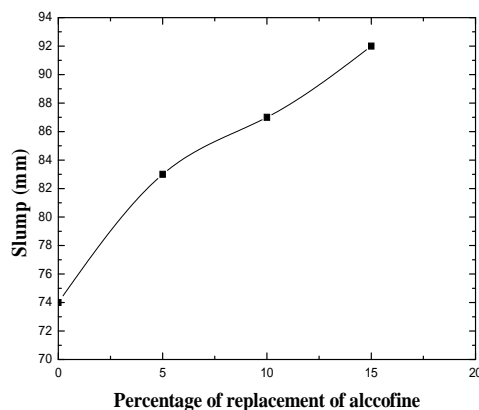


Fig. 8 Graph showing variation of slump for different % replacement of alccofine



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## Strength Test Results

Fig. 9 (a), (b) and (c) indicates the graphs of compressive strength, split tensile strength and flexural strength for different percentages of alccofine replacement. The maximum strength is obtained with 20% pond ash replacing fine aggregate and 10% alccofine replacing cement. The values of compressive strength, split tensile strength and flexural strength obtained at 28 day testing are 40.22 N/mm<sup>2</sup>, 3.04 N/mm<sup>2</sup> and 9.25 N/mm<sup>2</sup>. These values are higher than that of values obtained for control mix.

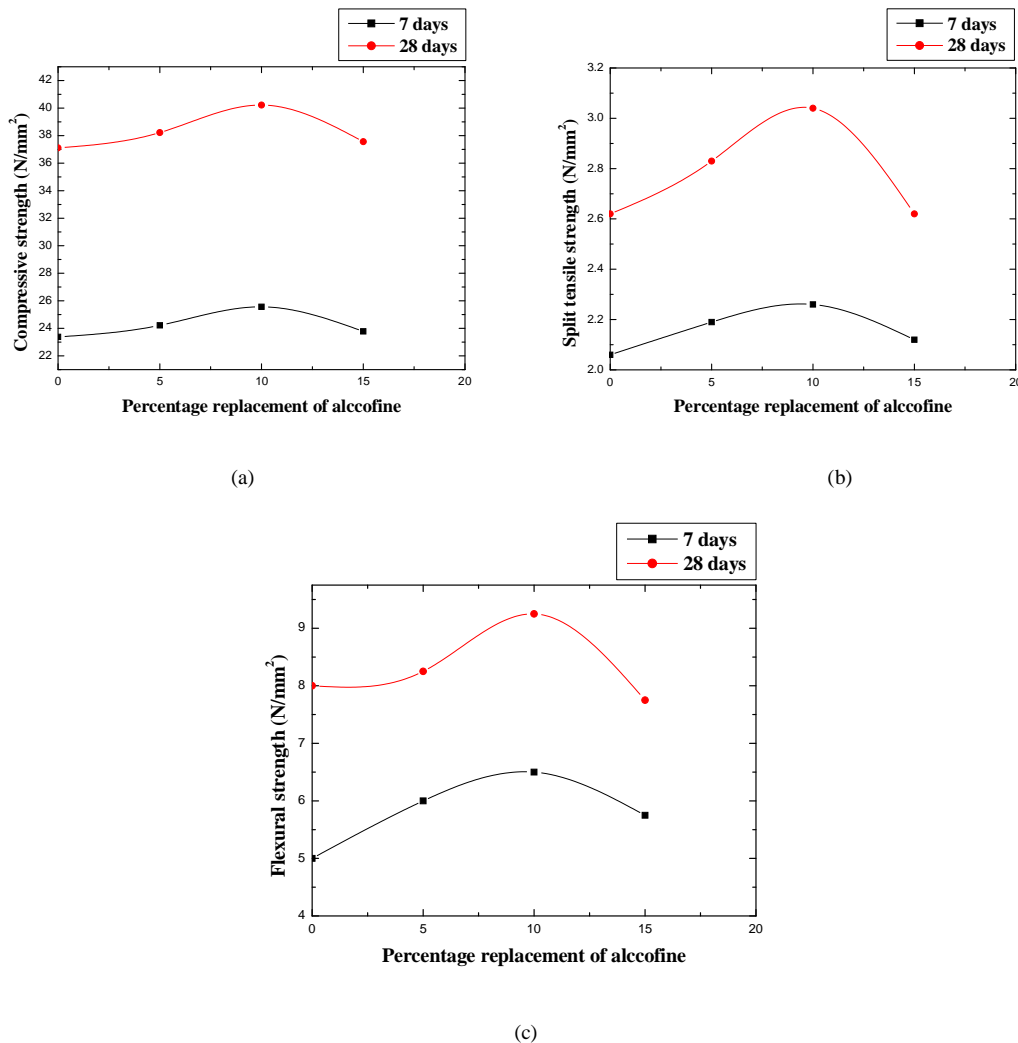


Fig. 9 Strength test results for alccofine replacement (a) Compressive strength (b) Split tensile strength (c) Flexural strength

## Durability Test Results

### (i) Water absorption

Fig. 10 indicates the graphs of water absorption of alccofine replacing cement. Results indicate that water absorption of mixes with alccofine replacement is low comparing with control mix. The minimum percentage of water absorption is

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obtained with 20% pond ash replacing fine aggregate 10% alccofine replacing cement among the mixes with alccofine replacement and on comparing with water absorption of control mix the value is lower.

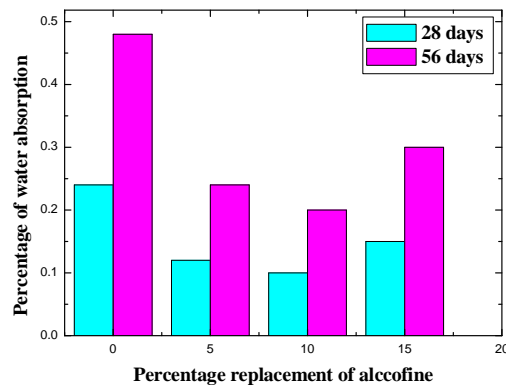


Fig. 10 Water absorption of alccofine replacing cement

## (ii) Acid resistance

Fig. 11 (a) and (b) indicates the graphs of weight loss and strength loss on acid resistance test of alccofine replacing cement. The minimum percentage of weight loss and strength loss is obtained with 20% pond ash replacing fine aggregate and 10% alccofine replacing cement among the mixes with alccofine replacement and on comparing with control mix the value is lower.

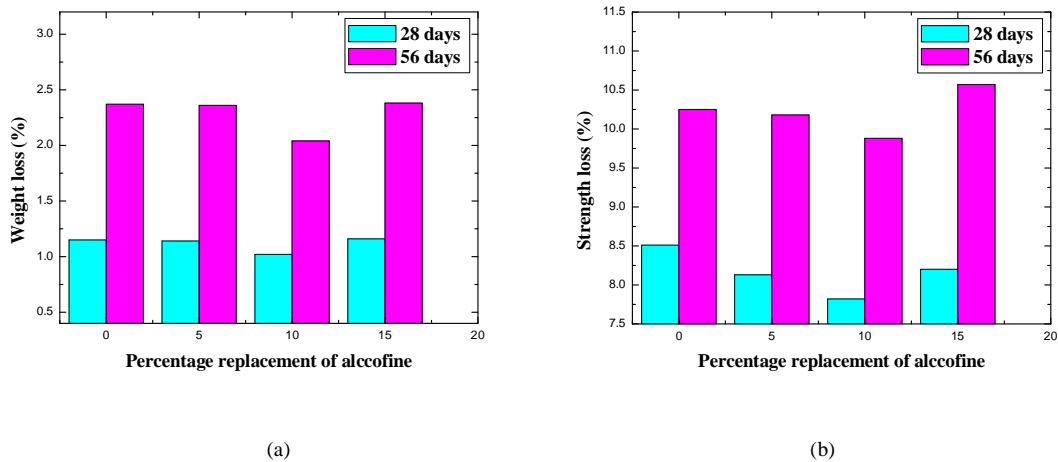


Fig. 11 Acid resistance test results for alccofine replacement (a) Weight loss (b) Strength loss

## (iii) Chloride resistance

Fig. 12 (a) and (b) indicates the graphs of weight loss and strength loss on chloride resistance test of alccofine replacing cement. The minimum percentage of weight loss and strength loss is obtained with 20% pond ash replacing fine

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aggregate and 10% alccofine replacing cement among the mixes with alccofine replacement and on comparing with control mix the value is lower.

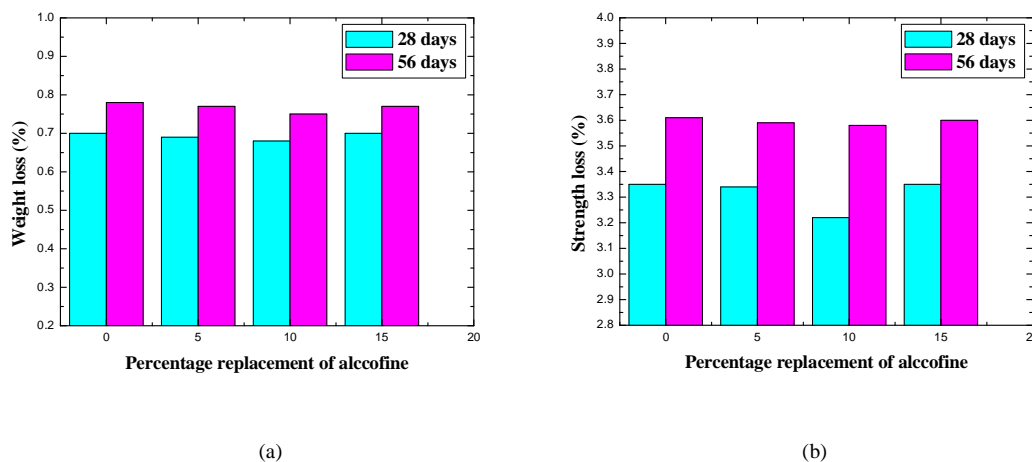


Fig. 12 Chloride resistance test results for alccofine replacement (a) Weight loss (b) Strength loss

## VI. CONCLUSION

- Replacement of fine aggregate with pond ash and cement with alccofine 1203 can improve the strength of concrete.
- Workability of concrete decreased as the percentage addition of pond ash increased since pond ash is having a high rate of water absorption. On the other hand increase in addition of alccofine leads to the increase in workability of concrete since it is having a low rate of water absorption.
- The compressive, split tensile and flexural strength of M30 grade concrete increased with the replacement of fine aggregates with pond ash. The maximum strength is obtained with 20% pond ash replacing fine aggregate. The values of compressive strength, split tensile strength and flexural strength obtained at 28 day testing are 37.11 N/mm<sup>2</sup>, 2.62 N/mm<sup>2</sup> and 8 N/mm<sup>2</sup>. But these values are slightly less than that of values obtained for control mix.
- Maximum values of strength are achieved by the combined replacement of fine aggregate with pond ash and cement with alccofine. The maximum strength is obtained with 20% pond ash replacing fine aggregate and 10% alccofine replacing cement. The values of compressive strength, split tensile strength and flexural strength obtained at 28 day testing are 40.22 N/mm<sup>2</sup>, 3.04 N/mm<sup>2</sup> and 9.25 N/mm<sup>2</sup> which is greater than values obtained for control mix.
- Durability test results shows that concrete mix with 20% pond ash replacing fine aggregate and 10% alccofine replacing cement has minimum percentage of water absorption and better acid resistance and chloride resistance results comparing with control mix and other mixes.

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