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Experimental Investigation on Internally Cured Concrete Using Fly Ash Aggregate

Sumi S, Pradeep P

Abstract— Nowadays, High Performance Concrete (HPC) plays an important role in the building construction due to its superior mechanical and durability properties. HPC exceeds the properties and constructability of normal concrete such as it reduces the maintenance costs and enhances service life. HPC made with low w/c ratios results in self-desiccation that leads to autogenous shrinkage. Autogenous shrinkage leads to cracking and failure of the structure thus reduces the mechanical properties. In order to reduce autogenous shrinkage of HPC and to prevent its early- age cracking, it was suggested to introduce lightweight aggregate using sintered fly ash aggregate as it has better water absorption property. The lightweight aggregate plays a vital role in enhancing these properties of concrete. In this experimental study the conventional coarse aggregates are replaced by pelletized fly ash aggregates as 5, 10, 15, 20, 25, and 30 %. This research paper deals with the effect of variations in strength parameters such as compressive strength, splitting tensile strength, flexural strength, bond strength and the Ultrasonic Pulse Velocity of M35 grade concrete are determined.

Index Terms— High Performance Concrete, autogenous, light weight, pelletized, fly-ash, flexural, ultrasonic pulse velocity.

1 Introduction

Internal curing provides a set of water-filled reservoirs within the concrete that supply water on demand to the hydrating cement paste from the time of mixing (i.e., for reducing plastic shrinkage and maintaining workability) until the time when moisture equilibrium is achieved between the reservoirs and the surrounding cement paste for reducing dry shrinkage [14]. Internal curing is achieved by replacing a percentage of coarse aggregate with light weight aggregate such as expanded shale, fly ash aggregate, expanded clay aggregate. The light weight aggregate ie., fly ash aggregate which it is soaked in water and mixed with cement and fine aggregate. This mixture is been poured into the mould and external vibration was used to consolidate the specimen after casting immediately. The water stored in the lightweight aggregates is typically stored in pores that are larger than those in a hydrating cement paste. As a result, the water moves from the light weight aggregate to the surrounding cement paste keeping the small pores saturated. The internal curing process utilizes cement more efficiently during the hydration process. Internal curing improves the workability and reduces the cracks due to plastic, drying and thermal shrinkage. The strength of the concrete is increased as the bond between the light weight aggregate and the hydrated cement becomes continuous due to decrease in permeability.

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- Disposal of fly ash is another vast problem encountered in day-to-day life. The usage of fly ash in a construction industry makes tremendous change all over the world. There are different ways of using fly ash in industry like it can be used as partial replacement of cement. So, fly ash can be used in making artificial light weight coarse aggregates. The aggregates so prepared are known as Fly ash aggregates, the method of formation is known as palletization. These aggregates can be manufactured in different proportion of fly ash, cement, the aggregate which is manufactured is light weight aggregate. When this aggregate used in concrete i.e., indirectly in construction industry having so much application. Due to use of this type of aggregate in concrete production of light weight concrete can be done. Design and construction by this type of concrete is economical, because due to nature of light weight reduces the self-weight. It leads to decrease in self-weight of structure, so that there is no need of any other additional structures.

- The use of huge amount of fresh water in production and curing of concrete is an area of major concern in today's construction industry. In many of the big cities the desired quantity and quality of water is not available at reasonable price. This leads to misuse of natural resources like pond and tube wells. Internal curing is a new technique used to save water in construction. In this study the concrete specimens are cured for 7 days and it

2 Aim And Objective

- The main aim of the work is to experimentally investigate the use of pelletized fly ash aggregate as an internal curing agent.

- The main objectives of the work are:
- To obtain the optimum replacement percentage of pelletized fly ash aggregates
- To obtain the strength parameters like compressive strength, flexural strength and splitting tensile strength
- To obtain the durability parameters of the concrete specimens
- To check the quality of the concrete by Ultrasonic Pulse velocity

3 Research Significance

Disposal of fly ash is another vast problem in day today life. Hence use of fly ash based light weight aggregate gives a better solution for waste management problem.

- To obtain the durability parameters of the concrete specimens
- To check the quality of the concrete by Ultrasonic Pulse velocity

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4 Methodology

- Study as well as review of literatures related to internal curing
- Collection of raw materials
- Preliminary study of the materials involved in the study. Tests are conducted to determine the physical as well as chemical properties
- The mix for the internally cured high performance concrete is formulated
- Laboratory test on fresh and hardened concrete properties are to be conducted
- Test on hardened concreted are conducted
- Results are analyzed and conclusion is drawn from the available data

5 Experimental Investigation

5.1 Materials Used

- Laboratory tests were carried out on various materials used for this study. Physical properties of materials were tested and found that all properties are conforming to IS standards. OPC 53 grade cement, M sand as fine aggregate, coarse aggregate, fly ash aggregate, silica fume, CONPLAST SP430 were used for this work.

Ordinary Portland Cement Ordinary Portland Cement of 53grade confirming to IS 12269-1987 having specific gravity 3.15 and fineness 7.33% was used in this study. Manufactured sand (M sand) confirming to grading zone II of IS 383 - 1970 was used as a fine aggregate. Well graded coarse aggregate passing through 20mm sieve according to IS 383 - 1970 was used. Fly ash aggregate passing through 12.5mm sieve. Micro silica was a byproduct of the silicon and Ferro-silicon production. It is a white colored powder having a pack density of 0.76 g/cc and specific gravity 2.63. It contains more than 80% silica in non-crystalline state. Portable water was used in the investigations for both mixing and curing purposes. Conplast SP430 used as super plasticizer. It was a dark brown solution having specific gravity of 1.2 at 30^{0}C. The optimum dosage of addition is generally in the range of 0.6 – 1.5 liters/ 100 kg cement. The properties of cement is shown in Table I. The properties of coarse aggregate, fine aggregate, and waste tire rubber are shown in Table II and their gradation curves shown in Fig. 1, Fig. 2, Fig. 3.

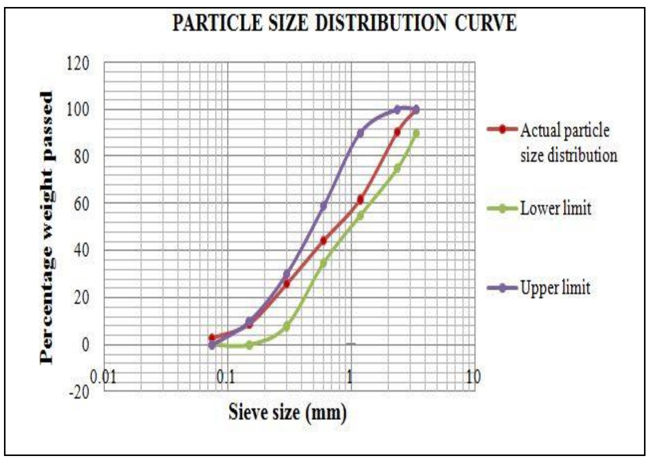

Fig. 1. Gradation curve for Manufactured sand

TABLE I. PROPERTIES OF CEMENT

Properties	Test Values
Standard Consistency	39%
Initial and Final Setting Time	145 and 350 min
Compressive Strength	54.5 N/mm^2

TABLE II. PROPERTIES OF FINE, COARSE AND FLY ASH AGGREGATE

Properties	Coarse Aggregate	Fine Aggregate	Fly ash Aggregate
Type	Crushed Stone Aggregates	Locally Available M- Sand	Pelletized Fly ash aggregate
Specific gravity	2.71	2.67	1.3
Fineness modulus	5.60	4.66	
Bulk density(kg/m^3)	1.564	1.847	838
Water absorption(%)	0.43	1.69	14.42

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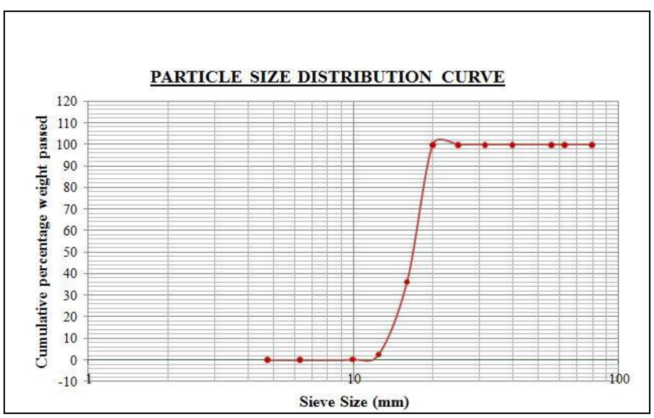

Fig. 2. Gradation curve of coarse aggregate

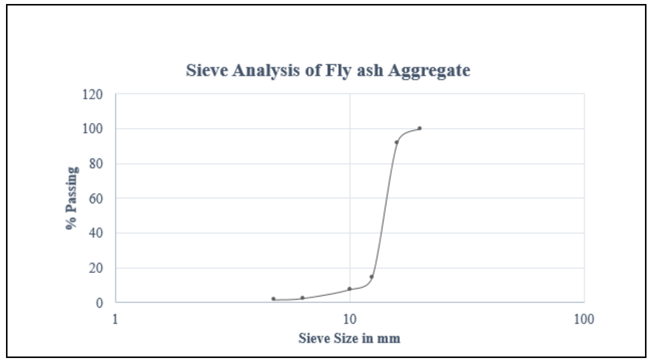

Fig. 3. Gradation curve of fly ash aggregate

6 MIX DESIGN

- Mix proportion of M35 grade was obtained by making certain modifications in the mix proportion, arrived by using the guidelines of IS: 10262-2009.
- Quantity of cementitious materials – 400 kg/m^3
- Quantity of Fine aggregate –704.23 kg/m^3
- Quantity of Coarse aggregate –1230.336 kg/m^3
- Quantity of Silica fume – 3% of cementitious material
- Quantity of Super plasticizer – 1.2% of cementitious materials
- The trial mixes were prepared by varying super plasticizer. The mix which satisfied the slump and target strength was selected as the control mix having a mix proportion of 1:1.8:3.0 with a w/c ratio 0.38. PFAC0 is the control mix and PFAC5, PFAC10, PFAC15, PFAC20, PFAC25, PFAC30 are the mixes with equivalent volume replacement of coarse aggregate with fly ash aggregate at 5, 10, 15, 20, 25 and 30 percentages respectively.

7 EXPERIMENTAL DETAILS

Determination of strength of concrete specimens, using Ordinary Portland Cement with 3% silica fume and increasing fly ash aggregate content as a partial replacement of coarse aggregate. The different proportion of rubber will be 0%, 5%, 10%, 15%, 20, 25, 30 %. The different mixes are conveniently designating as PFAC5, PFAC10, PFAC15, PFAC20, PFAC25, PFAC30 respectively. The cubes of 150 x 150 x 150 mm size, cylinder of diameter 150 mm and length 300 mm and beam of 100 x 100 x 500 mm were tested. The concrete specimens will be tested for following strengths: i) Compressive strength for 28 days curing using cube specimen, ii) Flexural strength after 28 days curing using beam specimen and iii) Split tensile strength, iv) Bond Strength

8 Results and Discussion

8.1 Tests on Fresh Concrete

The fresh properties such as slump and compaction factor

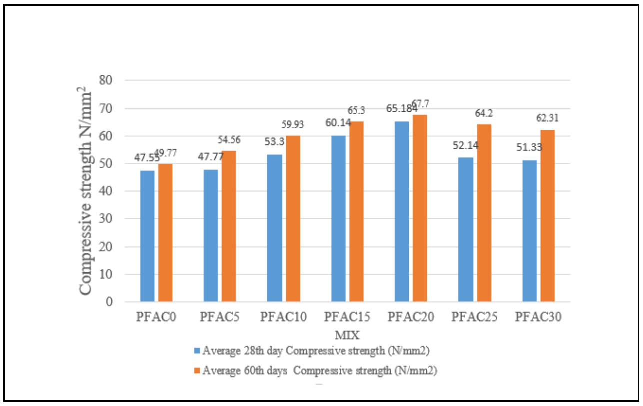

Fig. 4. Graphical representation of compressive strength of cube specimens

tests are conducted. The table shows the test results.

TABLE III. SLUMP AND COMPACTION VALUE

Designation	w/c	% Of SP	Slump(mm)	Compaction value
S0	0.38	0	15	0.70
S1	0.38	0.8	48	0.85
S2	0.38	1.0	65	0.87
S3	**0.38**	**1.2**	**80**	**0.95**
S4	0.38	1.4	95	0.98

8.2 Test on Hardened Concrete

Several tests were carried out on the hardened concrete specimens to determine to determine its strength as per IS: 516 - 1959.

8.2.1 Compressive Strength Test

Compressive strength test was carried out in cube specimens of size 150mm after 28 days and 60 days of water curing. It was done in compression testing machine and the failure load was noted to calculate the compressive strength. For each mix, three cubes were casted to take the mean value. Table IV shows the compressive strength of concrete with various percentage of fly ash aggregate and Fig. 4. Shows the graphical representation of compressive strength.

TABLE IV. C

OMPRESSIVE STRENGTH TEST RESULT

Mix	28 days Compressive strength N/mm^2	60 days Compressive strength N/mm^2
PFAC0	47.55	49.77
PFAC5	47.77	54.56
PFAC10	53.3	59.93
PFAC15	60.14	65.3
PFAC20	65.184	67.70
PFAC25	52.14	64.2
PFAC30	51.33	62.31

From the test results, compressive strength of internally cured concrete 20% replacement of fly ash aggregate is 37% higher compared to conventional concrete. From the 60 days strength the normal concrete has increased 4.7 % compared to 28 days compressive strength, whereas the 20% replacement with fly ash aggregate has increased 5.4 % compared to 28 days strength.

8.2.2 Flexural Strength of P.C.C and R.C.C

Plain cement concrete beams having dimension 100mm x 100mm x 500mm was used to study the flexural strength. Test was carried out after 28 days of water curing and three specimens were cast for each mix to take the average. Table V shows the flexural strength at different replacements of fly ash aggregate Fig. 5. Shows the graphical representation of flexural strength.

TABLE V. FLEXURAL STRENGTH TEST RESULTS

Mix	28th day Flexural Strength P.C.C (N/mm^2)	28th day Flexural Strength R.C.C (N/mm^2)
PFAC0	7.0	`15.2
PFAC5	7.16	15

PFAC10	7.28	15.15
PFAC15	7.41	15.92
PFAC20	8.2	16.8
PFAC25	7.62	16.2
PFAC30	7.2	15.6

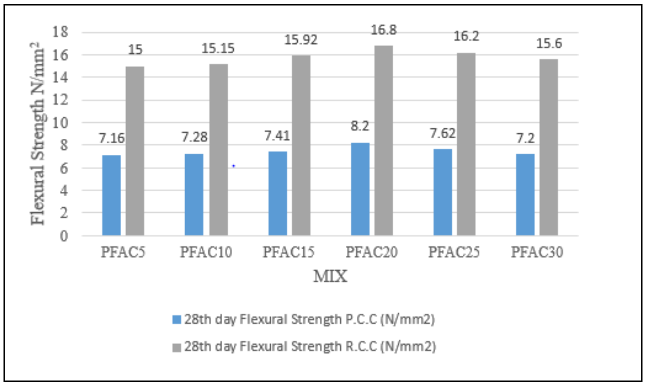

Fig.5. Graphical representation of flexural strength test of beam specimens

The results showed that the flexural strength of concrete mix with 20% replacement of fly ash aggregate is almost greater than control mix in both P.C.C and R.C.C.

8.3.3 Split Tensile Strength Test

The concrete is not usually expected to resist direct tension because of the low tensile strength and brittle nature. Cylindrical specimens of length 300mm and 150mm diameter was used to find the split tensile strength at 28 days of curing. Three cylinders were cast for each replacement of fly ash aggregate to find the average tensile strength. The results were shown in table VI and the graphical representation is shown in Fig. 6 below.

TABLE VI. SPLIT TENSILE STRENGTH TEST

Mix	28th day Split Tensile Strength (N/mm^2)
PFAC0	5.6
PFAC5	4.6
PFAC10	4.8
PFAC15	5
PFAC20	5.4
PFAC25	5.1
PFAC30	4.8

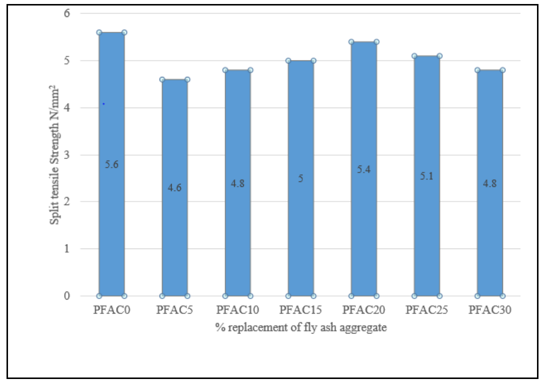

Fig. 6. Graphical representation of split tensile strength of cylindrical specimens

The results showed that the split tensile strength of concrete mix with 20% replaced light weight aggregates at the 28day of test is $5.4 N/mm^2$ and is found to be almost similar to control mix. Split tensile strength developed for all the mixes are satisfactory

8.3.4 Ultrasonic Pulse Velocity Test

Table VII and Fig.7. Represents the UPV values of different concrete mix at 7 days of curing. Concrete mixes are categorized as excellent, good, medium, and doubtful for the UPV values of above 4.5 km/s, 3.5 – 4.5 km/s, 3.0 – 3.5 km/s and below 3.0 km/s respectively.

TABLE VII. ULTRASONIC PULSE VELOCITY TEST

Mix	**Pulse Velocity Value (km/s)**	**Concrete Quality (Grading)**
PFAC0	5.19	Excellent
PFAC5	4.707	Excellent
PFAC10	4.886	Excellent
PFAC15	4.532	Excellent
PFAC20	4.491	Good
PFAC25	4.335	Good
PFAC30	4.325	Good

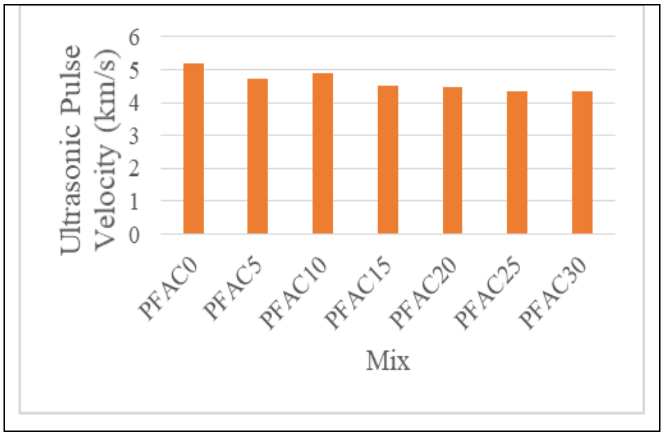

Fig. 7. Graphical representation of pulse velocity values for cube specimens

9 Conclusions

This experimental study is indented to explore fly ash aggregate to attain internal curing property. Huge amount of water is polluted in construction scenario. Effect of internal curing property for reducing the conventional curing period was also investigated in the study.

The fly ash aggregates contribute internal curing property to the concrete mix. The optimum percentage replacement of fly ash aggregate was obtained as 20% with increase of 37% compressive strength, with 5.4 N/mm^2 split tensile strength and flexural strength almost greater than control mix.

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