EXPERIMENTAL STUDY ON INTERNALLY CURED CONCRETE USING PELLETIZED FLYASH AGGREGATE

Sumi S[1]
A P J Abdul Kalam University
sumi84sce@gmail.com

ABSTRACT: Now a days, 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, 30 %. This research paper deals with the effect of variations in strength parameters such as compressive strength, splitting tensile strength, flexural strength and the Ultrasonic Pulse Velocity of M35 grade concrete are determined.

1. INTRODUCTION

Concrete is one of the key elements of civil engineering structures. Concrete is more acceptable among civil engineering construction because of its inherent properties like economy of use, durability and that it can be manufactured at site in any shape. Concrete attain its strength by the chemical reaction called 'hydration', between the cement particle and water. For proper hydration presence of enough amount of water is essential and this is more than what is actually required for the formation of the hydration products. Curing is an important process at the early ages of concrete to prevent loss of moisture and reducing shrinkage cracks. By definition curing is a process of maintaining the sufficient moisture content and temperature in concrete for a period of time after the placing and finishing, so that the desired strength properties develop. Proper curing can improve strength, durability, abrasion resistance, resistance to freeze–thaw cycles and also reduce concrete autogenous shrinkage. By proper curing strength can be increased and at the same time permeability can be decreased. Curing is also having a major role in mitigating cracks in the concrete, which severely offers durability. Curing plays a major part in developing the concrete pore structure and microstructure. Inadequate field curing result in concretes inability to get fully cured internally and a portion of cement remains unhydrated within the structure. Adequate curing is not practically possible in most of the cases. In such cases self-curing or internal curing becomes more prominent.

Self-curing allows uniform curing inside the concrete through internal water reservoirs. Internal curing refers to the process by which the hydration of cement occurs because of the availability of additional internal water that is not part of the mixing water.

The usage of fly ash in a construction industry make 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 pelletization. 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 in 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 followed curing in room condition till the day of testing.

Fig.1. Fly ash aggregate

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 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.

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 (Class F Fly ash), silica fume, Sulphonated naphthalene formaldehyde condensate based super plasticizer 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 is used. There are different post processing techniques for fly ash aggregates which includes, sintering, autoclaving and cold bonding. Sintering is the process by which the green pellets are allowed to fuse together at high temperatures normally more than 1200 degree Celsius. Autoclaving process involves addition of some chemical like cement, lime or gypsum in agglomeration stage. This induces bonding property in the material. The green pellets are then cured in pressurized saturated steam at a temperature of 140 degree Celsius. Cold bonding is nothing but normal water curing. Pelletizer of 0.55 m in diameter and 0.250 m depth with a rotating speed of 40 rpm is used in the process of pelletization. Micro silica was a byproduct of the silicon and Ferro-silicon production. It is a white coloured 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. Sulphonated naphthalene formaldehyde condensate based super plasticizer was used as super plasticizer. It was a dark brown solution having specific gravity of 1.2 at 300C. 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. 2.

TABLE 1. 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 2. 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	0.8

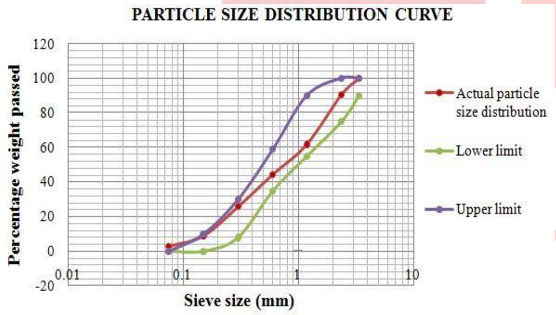

Fig. 2. Gradation Curve of M Sand

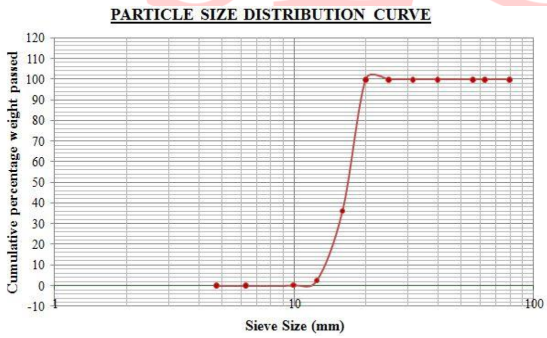

Fig. 3. Gradation Curve of Coarse aggregate

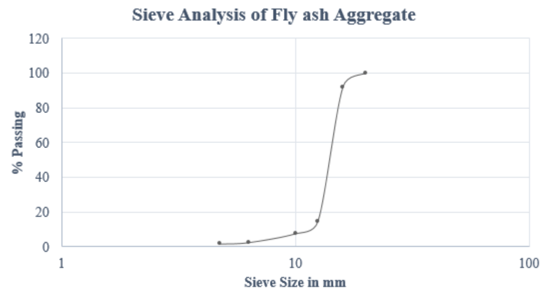

Fig. 4. Gradation curve of Fly ash aggregate

5.2 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 Silicafume – 3% of Cementitious material

Quantity of Superplastizier – 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.

5.3 Experimental Program

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, and 30%. The different mixes are conveniently designates 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 after 28 days curing using cylindrical specimen in compression testing machine. Also the quality of concrete mixes was tested using ultrasonic pulse velocity method.

6. RESULTS AND DISCUSSION

6.1 Test on Fresh Concrete

The fresh properties such as slump and compaction factor tests are conducted. The table shows the test results.

Table 3. 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

6.2 Tests on Hardened Concrete

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

6.2.1 Ultrasonic Pulse Velocity Test:

Table 4 and Fig. 5. 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. The Ultrasonic Pulse Velocity test results shows that concrete mixes are of excellent quality up to 20% percentage and there after the mixes changes to good quality.

TABLE 4. UPV TEST RESULTS

Mix	Pulse Velocity Value (m/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

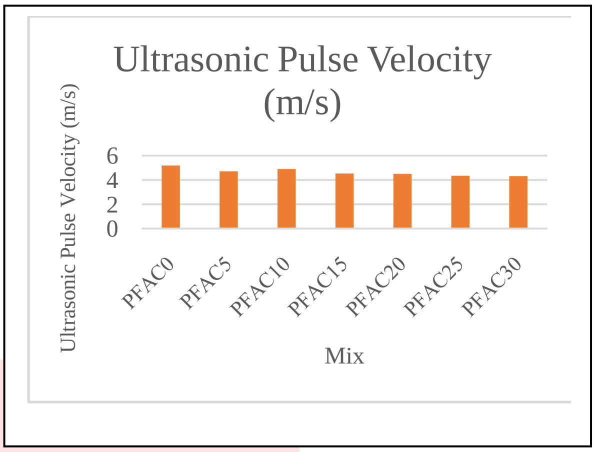

Fig. 5. Graphical representation of pulse velocity values for cube specimens

6.2.2 Compressive Strength Test

Compressive strength test was carried out in cube specimens of size 150mm after 28 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 V shows the compressive strength of concrete with various percentage of fly ash aggregate and Fig. 6. shows the graphical representation of compressive strength.

TABLE 5. COMPRESSIVE STRENGTH TEST RESULTS

Mix	Compressive strength N/mm^2
PFAC0	47.55
PFAC5	47.77
PFAC10	53.3
PFAC15	60.14
PFAC20	65.184
PFAC25	52.14
PFAC30	51.33

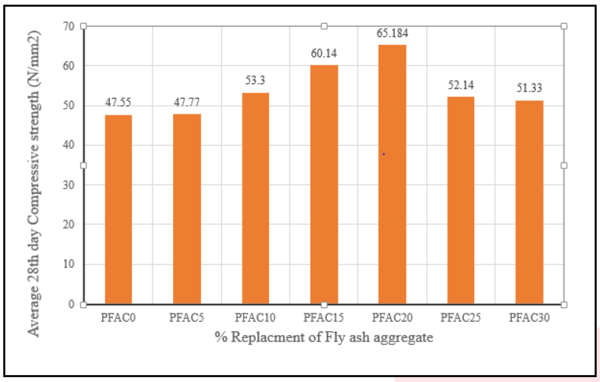

Fig. 6. Graphical representation of compressive strength for cube specimens

From the test results, compressive strength of internally cured concrete with 20% replacement of fly ash aggregate is 37% higher compared to conventional concrete.

6.2.3 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 6 and the graphical representation is shown in fig. 7. Below.

TABLE 6. SPLIT TENSILE STRENGTH TEST RESULTS

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

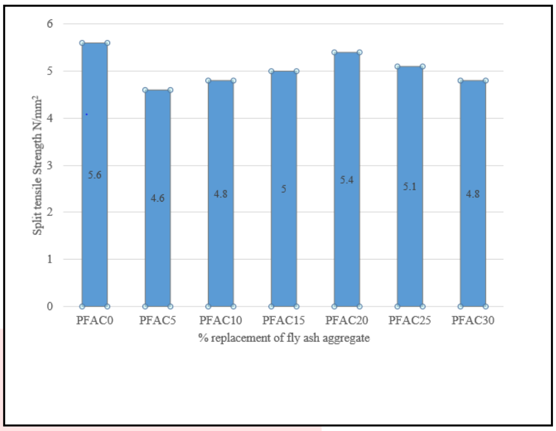

Fig. 7. Graphical representation of tensile strength for cylindrical specimens

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

6.2.4 Flexural Strength Test

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 7 shows the flexural strength at different replacements of fly ash aggregate Fig. 8. Shows the graphical representation of flexural strength.

TABLE 7. FLEXURAL STRENGTH TEST RESULTS

Mix	28th day Flexural Strength (N/mm^2)
PFAC0	7.0
PFAC5	7.16
PFAC10	7.28
PFAC15	7.41
PFAC20	8.2
PFAC25	7.62
PFAC30	7.2

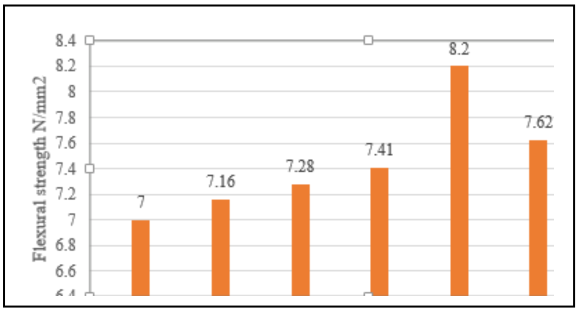

Fig. 8. Graphical representation of flexural strength for beam specimens

The results shows that the flexural of internally cured concrete with 20% replacement of fly ash aggregate is 17% greater than conventional concrete.

7. CONCLUSIONS

The experimental investigation consists of mechanical properties of the test specimens with the replacement of coarse aggregate by fly ash aggregate and to find its optimum percentage of replacement. All the fresh properties were satisfied as per IS specifications. But increasing the percentage of fly ash aggregate in mixtures showed a reduction in the fresh properties, compressive and flexural strengths of the concrete mixtures after 20% replacement. In the case of hardened properties, all strength parameters were present in the acceptable limit up to 20% replacement. The compressive strength and tensile strength of internally cured concrete with 20% replacement of fly ash aggregate is 37 % and 17% higher compared to conventional concrete. The presence of internal moisture content helps to obtain hardened cement paste compared to conventional concrete. This results in increased compressive and tensile strength of internally cured concrete.

8. REFERENCES

[1] Roberts, J.,(2004)"Internal curing in Pavements, Bridge Decks and Parking Structures, Using Absorptive Aggregates to Provide Water to Hydrate cement not Hydrated by Mixing Water",83rd Annual Meeting of the Transportation Research Board, Washington, DC

[2] Hoff G C.,(2006) "Internal Curing of Concrete Using Lightweight Aggregates", American Concrete Institute, 234, pp.621-640

[3] Kayali, O., (2005), "Flashag–New Lightweight Aggregate for High Strength and Durable Concrete", Proceedings of the 2005 World of Coal Ash (WOCA), Lexington, KY, USA, pp.11-15

[4] Cerny, V., Kocianova, M and Drochytka, R., (2017), "Possibilities of lightweight high strength concrete production from sintered fly ash aggregate", Procardia Engineering, 195, pp.9-16.

[5] Diane Reynolds., et.al (2009) "Lightweight Aggregates as an Internal Curing Agent for Low-Cracking High Performance Concrete", Structural Engineering and Engineering Materials. Lawrence

[6] Biswaroop Ghosh., Dr. A K Rath., (2017), "Fly Ash Pellets: A Replacement of Coarse Aggregate, International Journal of Technical Research and Application, 5[2], pp. 03-07

[7] Kumar, D., Kumar, A. and Gupta, A., Replacement of Coarse Aggregate with Sintered Fly Ash Aggregates for Making Low Cost Concrete

[8] Seimon Zhutovsky and Konstantin Kovler (2012), "Effect of Internal Curing on Durability Related Properties of High Performance Concrete", Cement and Concrete Research, pp 20-26

[9] Ya Wei , Yaping Xiang and Qianqian Zhang., (2014), " Internal Curing Efficiency of Prewetted LWFAS on Concrete Humidity and Autogenous Shrinkage Development", ASCE, 26[5], pp.947-954

[10] Yudong Dang, Xianming Shi., et.al (2015), "Influence of Surface Sealers on the Properties of Internally Cured Cement Mortars Containing Saturated Fine Light Weight Aggregate", ASCE, 27[12]

[11] B B Patil and P D Kumbhar (2012), "Strength And Durability Properties of High Performance Concrete Incorporating High Reactivity Metakoalin",International Journal of Modern Engineering Research, 2[3], pp.1099-1104

[12] Manikandan R., Ramamurthy, K., (2008), "Effect of Curing Method on Characteristics of Cold Bonded Fly Ash Aggregates, Cement & Concrete Composites", 30, pp.848–853