

AN EXPERIMENTAL INVESTIGATION ON STRENGTH PROPERTIES OF CONCRETE BY PARTIAL REPLACEMENT OF NATURAL COARSE AGGREGATE WITH FLY ASH AGGREGATE

N.Vyshnavi¹, Dr.D.V.Prasada Rao²

¹Civil & Sri Venkateswra university college of engineering, Tirupati,

² Civil & Sri Venkateswra university college of engineering, Tirupati,

Abstract— The present boom in day by day growing buildings is leading to excessive use of concrete, thereby resulting in depletion of natural resources such as sand and natural aggregates. On the other hand, fly ash which is a byproduct from thermal plants creating environmental problems. To overcome such kind of situation it may be better approach to retrieve aggregates from fly ash and use it again in the preparation of concrete in the form of Cold Bonded Fly ash Aggregate.

The present work is directed towards the evaluation of concrete using partial replacement of Natural Coarse Aggregates of size 20 mm (NCA) with 25%, 50%, 75% and 100% cold bonded fly ash aggregates (CBFA). The experimental results of strength properties are evaluated and compared with NCA concrete. Compressive Strength, Split Tensile Strength, Modulus of Elasticity and Flexural Strength of M25 grade concrete were obtained using the standard concrete specimens. Based on the experimental test results, it can be observed that with increase in percentage of Cold Bonded Fly ash Aggregates in concrete, the Compressive Strength increases with 100% replacement of Natural Coarse Aggregates(20 mm) with Cold Bonded Fly ash Aggregate. Test results indicates that the use of Cold Bonded Fly ash Aggregates as partial replacement of coarse aggregates improved strength properties compared to controlled concrete.

Keywords— fly ash, cold bonded fly ash aggregates, natural coarse aggregates, curing, controlled concrete

I. INTRODUCTION

A. Introduction

In the present scenario, construction industry is growing very fast manner. The continuous usage of natural resources for the production of the concrete in some locations create many threatens to the environmental conditions. Researchers have carried out extensive work on this area are trying for new alternative materials for this deficiency in the construction industry.

Coal is a very useful material for a developing country like India. In this country for most of the industry (like: thermal power plant, iron industry) coal is burnt a large number. Thus a significant amount of fly-ash is produced in our country and it becomes a threat to our society as fly ash is injurious to our health. In account to solve this problem fly-ash is now a days using for dumping the low-land and it is also using in making of fly ash bricks and in a concrete mix with a proper proportion with the fine aggregate. But there is another option is to use the fly-ash aggregate in a replacement of coarse aggregate. The coarse aggregate which is produced with a mix of cement as a binder have a good pozzolanic property and it also help us to solve the environmental problem as well.

In this study the fly ash is collected from thermal plant belongs to class F type and is shown in Fig 1. The chemical analysis of RTPP (Rayalaseema Thermal Power Plant) fly ash is shown in Table I.

TABLE I
CHEMICAL ANALYSIS OF RTPP CLASS F TYPE OF FLY ASH

Component	Value
SiO ₂	56.6%
Al ₂ O ₃	22.6%
Fe ₂ O ₃	8.14%
MgO	1.17%
CaO	12.14%



Fig 1. Class F Type of Fly ash (RTPP)

B. Fly ash aggregate

The fly ash coarse aggregate is produced by Cold Bonding processes of minimum energy utilization method. The shape of aggregate produced is angular in shape. The binder Ordinary Portland cement of different percentages by weight of raw material is added in the mix for the production of aggregate. Three types of aggregate are produced with different percentages of raw materials is then kept for curing in water for 28days and also kept for curing of 30minutes before aggregate taken for concrete production.

Fly ash aggregate (FAA) is typically classified according to grain size. Typically coarse FAA (>4.75 mm) is much easier to use in concrete production than fine FAA (<4.75 mm). This is because the proportion of good natural aggregate is much higher in the coarse portion than in the fine portion. Fly ash aggregate (FAA) typically contains fly ash and cement particles which absorbs water and makes the concrete production more challenging.

The present investigation is focused on the use of Fly ash Aggregate concrete and to find its influence on various strength characteristics. The properties of Fly Ash aggregates are compared with the Natural Coarse Aggregate.

II. REVIEW OF LITERATURE

Dr.J.B.Behera,Dr.B.D.Nayak, Dr.H.S.Ray and Dr.B.Sarangi (2004) examined the use of Fly ash Aggregate in concrete as a partial replacement of Granite Aggregate. They concluded that in addition to light weight characteristics, the sintered Fly ash concrete possesses strength and deformation characteristics similar to concrete with Natural Granite aggregate.

N.P.Rajamani and P.S. Ambily, (2006) scientist, SERC, Chennai carried out the research work on “Selection of Mortar for Light weight Aggregate concrete made with Fly ash based aggregate”. They concluded that conversion of fly ash with aggregate is technically feasible and are found to be light weight in nature. They found fly ash aggregate concrete up to 20Mpa can be used for production of concrete blocks for masonry construction in structures. They also suggested to select mortar which can produce Fly ash Aggregate concrete of strength up to 40Mpa. However concrete strengths more than 40Mpa can also be produced using less content of Fly ash Aggregates.

Mehnet Gesoglu, Turan Ozturan and Erhan Gunegisi (2007) found the Compressive Strength of concrete ranging from 20 to 50Mpa was practically produced by using light weight fly ash aggregates. They also found the increase in Splitting Tensile Strength of concrete due to increase in Aggregate Crushing Strength of Fly ash Aggregates.

Priyadarshiny (2011) have observed that the Fly ash Aggregates produced by normal curing showed comparable results with the aggregates produced with other methods of curing, when the experimental study on Cold Bonded Fly ash aggregates with number of days of curing period is increased.

Dr. M.Vijaya Sekhar Reddy, Dr. M.C. Nataraja and K.Sindhu (2016) studied the performance of light weight concrete using Fly ash pellets as coarse aggregate replacement. This paper mainly focuses on manufacturing process of Fly ash light weight aggregates using pelletizer and curing has been done in Cold Bonded technique. The properties of these Fly ash Aggregates have been tested and the results indicated that Cold Bonded Fly ash Aggregates can be effectively used as a coarse aggregate replacement material in concrete.

III. PROPERTIES OF MATERIALS

The materials used in experimental investigation are:

1. Ordinary Portland Cement(OPC) of 53 grade
2. Fine Aggregate
3. Coarse Aggregate-20 mm(Fly ash Aggregates and Natural Aggregates)
4. Coarse Aggregate-12 mm
5. Potable water

A. Cement

Cement is the most important ingredient in concrete. One of the important criteria for the selection of cement is its ability to produce improved microstructure in concrete. The cement used throughout the experimental investigation was Ordinary Portland Cement (OPC 53 grade) conforming to IS specifications. The cement sample was tested as per the procedures given in IS codes. The results of the tests on cement are shown in Table II.

TABLE II. PROPERTIES OF CEMENT

S. No	Property	Test result
1.	Normal Consistency	30%
2.	Specific Gravity	3.04
3.	Fineness of Cement	4%
4.	Initial Setting time	90 minutes
5.	Final Setting time	568 minutes
6.	Type of Cement	OPC 53 grade
7.	Company name	Ultra tech

B. Aggregates

Aggregates are the important constituents of the concrete. They give body to the concrete, reduce shrinkage and effect economy. The mere fact that the aggregates occupy 70-80% of the volume of the concrete.

B.1 Fine Aggregate

The locally available river sand confirming to Zone-II of IS 383:1970 has been used as Fine aggregate. The various tests conducted on Fine aggregate and the results as given in the Table III.

TABLE III. PHYSICAL PROPERTIES OF FINE AGGREGATE

S. No	Property	Test results
1.	Specific Gravity	2.61
2.	Bulk Density	1532 kg/m ³
3.	Fineness Modulus	2.6
4.	Grading of sand	Zone-II
5.	Bulking of sand	40% at water content of 9%

B.2 Coarse Aggregate

The coarse aggregate used for this investigation is confirmed to IS specifications. In this study, nominal size of 20 mm and 12 mm crushed granite coarse aggregate is used. The coarse aggregate was tested for its physical properties and the results are presented in Table IV and V.

TABLE IV. PROPERTIES OF 20 mm SIZE COARSE AGGREGATE

S.No	Property	Value
1.	Specific Gravity	2.87
2.	Bulk Density	1469 kg/m ³
3.	Fineness Modulus	6.8
4.	Water absorption	0.4%

TABLE V. PROPERTIES OF 12 mm SIZE COARSE AGGREGATE

S. No	Property	Value
1.	Specific Gravity	2.85
2.	Bulk Density	1399 kg/m ³
3.	Fineness Modulus	6.4
4.	Water absorption	0.45%

B.3 Fly ash Coarse Aggregate

The Fly ash aggregate used in this investigation is prepared using the procedure as discussed in this paper. The fly ash aggregate obtained is shown in Fig 2. The fly ash aggregate was tested for its physical properties and the results are presented in Table VI.

TABLE VI. PROPERTIES OF 20 mm SIZE FLY ASH AGGREGATE

S. No	Property	Value
1.	Specific Gravity	2.15
2.	Bulk Density	894 kg/m ³
3.	Fineness Modulus	6.7
4.	Water absorption	9.58%
5.	Crushing Strength	22.7%
6.	Impact value	25.4%
7.	Abrasion value	3.17%



Fig 2. Fly Ash Coarse Aggregate of 20 mm Size

C. Water

The water, which is used for making concrete, should be clean and free from harmful impurities such as oil, alkali, acid etc.

IV. PREPARATION OF FLY ASH AGGREGATES

A. Formation of Fly ash Aggregate

The constituents like cement, fly ash and water produce the fly ash aggregates. Water is the binding material that paves the way for the function of the aggregate with good bond property. In this preparation Ordinary Portland Cement of 53 grade is used as binding material. Fly ash of class F type from RTPP (Rayalaseema Thermal Power Plant) is used.

B. Proportions of Fly ash Aggregate

Three different proportions of cement and fly ash such as 10:90, 15:85 and 20:80 were tried.

C. Preparation of Fly ash Aggregate

- Cement and fly ash were mixed in above three proportions in a concrete mixture.
- Water was added to the mix by adopting water to cement and fly ash ratio 0.3.
- The contents are thoroughly mixed in a mixer until it forms a paste as shown in Fig 3.



Fig 3. Mixing of Fly ash Aggregate Ingredients in Concrete Mixer

D. Drying & Curing of Fly ash Aggregate

- After that, paste is placed in concrete cube moulds and kept the specimens at room temperature for about 24 hrs.
- Specimens are removed from cube moulds after 24 hrs, and then kept in water for curing for about 28 days.
- After completion of water curing for about 28 days, specimens are removed from water. This type of curing process is called Cold Bonding process.

E. Crushing & Separation of Aggregate

- Specimens are crushed under Compression Testing machine and forms aggregates of different sizes.
- Aggregates are then crushed manually by hammer to required size i.e., 20mm approximately as shown in Fig 4.
- The crushed aggregates are sieved through sieves of sizes 20mm, 16 mm, 12.5 mm, 10 mm, and 4.75 mm.



Fig 4. Manual Breaking of Fly Ash Aggregates with Hammer

F. Mix proportion

Mix design of M25 grade concrete was made using IS method. As per design, the mix proportion is 1: 1.93: 3.47: 0.5.

G. Casting of test specimens

The Concrete Cubes (control specimens) were cast by using Fly ash Coarse Aggregates obtained from the above three cement fly ash proportions and controlled concrete proportion. The specimens were demoulded after 1 day and immersed in water for 3, 7 and 28 days for curing.

Similarly 3 fly ash concrete cubes for each proportion were cast using fly ash aggregates obtained from cement and fly ash proportions 10:90, 15:85, 20:80 and controlled concrete proportion for different days of curing.

H. Compressive Strength test

15cm x 15cm x 15cm concrete cubes were tested as per IS 516:1959. The test was conducted in 120T Compression Testing machine. The load was applied at the rate approximately 140 kg/cm²/min until the failure of the specimen. The maximum load applied to the specimen until failure was recorded and shown in Table VII.

TABLE VII. COMPRESSIVE STRENGTH OF FLY ASH AGGREGATE CONCRETE AND CONTROL CONCRETE WITH VARIOUS PROPORTIONS OF CEMENT AND FLY ASH WITH DIFFERENT AGES OF TESTING

Proportion of Cement: Fly ash	Compressive strength (N/mm ²)		
	3 Days	7 Days	28 Days
10:90	18.07	22.49	27.40
15:85	26.96	30.36	35.40
20:80	17.77	23.54	28.29
CC	20.29	25.18	32.44

Hence from above results, it is clearly observed that with Cement: Fly as proportion 15: 85 and water: cement+ fly ash ratio of 0.3 gives more strength. So this proportion is used in preparation of fly ash aggregate concrete.

V.CONCRETE MIX DESIGN

- In the present work mix design was carried out using IS 10262:2009 and IS 456:2000.
- Mix proportion for M25 grade Natural Coarse Aggregate concrete is 1:1.93:3.47:0.5.
- Mix proportion for M25 grade Fly ash Aggregate concrete is 1:1.93:2.94:0.5.

VI.RESULTS AND DISCUSSIONS

The following tests were conducted on M25 grade of concrete made with Fly ash Aggregates as partial replacement of Natural Coarse Aggregate of size 20 mm and then results were compared with the Controlled Concrete.

- Compressive Strength
- Split Tensile Strength
- Flexural Strength
- Modulus of Elasticity

A.Compressive Strength

The Compressive Strength Test was conducted on concrete cubes at 3, 7, 28, 56 and 90 days after curing. Results of the Compression Strength of various concrete mixes are listed in Table VIII. The results were also compared with Controlled concrete in order to illustrate the percentage change in Compressive Strength due to addition of Fly ash aggregate.

Fig 5 represents the Compressive Strength of concrete prepared with replacement of NCA of size 20 mm (Natural Coarse Aggregate) with FAA (Fly Ash Aggregate) by 25%, 50%, 75% and 100%. It can be observed that the Compressive Strength of concrete prepared using FAA exhibits more strength than the Control concrete up to 100% replacement of NCA. The 28 days Compressive Strength of Controlled concrete is 32.44 N/mm².

TABLE VIII. RESULTS OF CUBE COMPRESSIVE STRENGTH FOR VARIOUS CONCRETE MIXES

S.No	Type of concrete	Compressive Strength(N/mm ²)					% Increase in Compressive Strength				
		3 Days	7 Days	28 Days	56 Days	90 Days	3 Days	7 Days	28 Days	56 Days	90 Days
1	Control mix	20.3	25.2	32.4	34.1	34.9	-	-	-	-	-
2	FAA-25%	20.7	29.9	33.3	35.2	35.5	1.9	18.6	2.7	3.2	1.7
3	FAA-50%	22.3	30.1	34.2	35.8	36.1	9.8	19.4	5.5	4.9	3.4
4	FAA-75%	25.0	30.2	34.9	36.3	37.1	23.1	19.8	7.7	6.4	6.3
5	FAA-100%	26.9	30.3	35.4	36.7	37.4	32.5	20.2	9.2	7.6	7.1

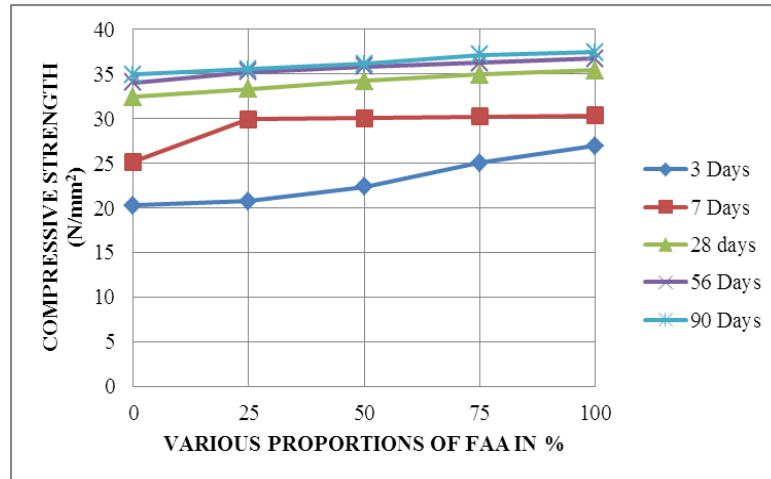


Fig 5. Variation of Cube Compressive Strength of Fly Ash Aggregate Concrete with Age of Concrete

The Compressive Strength Test was conducted on concrete cylinders at 28 days after curing. Results of the Compression Strength of various concrete mixes are listed in Table IX. The results were also compared with Controlled concrete.

Fig 6 represents the Compressive Strength of concrete cylinders prepared with replacement of NCA of size 20 mm (Natural Coarse Aggregate) with FAA (Fly Ash Aggregate) by 25%, 50%, 75% and 100%. It can be observed that the Compressive Strength of concrete prepared using FAA exhibits more strength than the Control concrete up to 100% replacement of NCA of size 20 mm.

TABLE IX. RESULT OF CYLINDERS COMPRESSIVE STRENGTH OF VARIOUS CONCRETE MIXES

Type of Concrete	Average Compressive Strength for 28 days (N/mm ²)	% Increase in Compressive Strength for 28 days
Control Mix	25.82	-
FAA-25%	27.14	5.1
FAA-50%	28.46	10.2
FAA-75%	28.84	11.7
FAA-100%	30.16	16.8

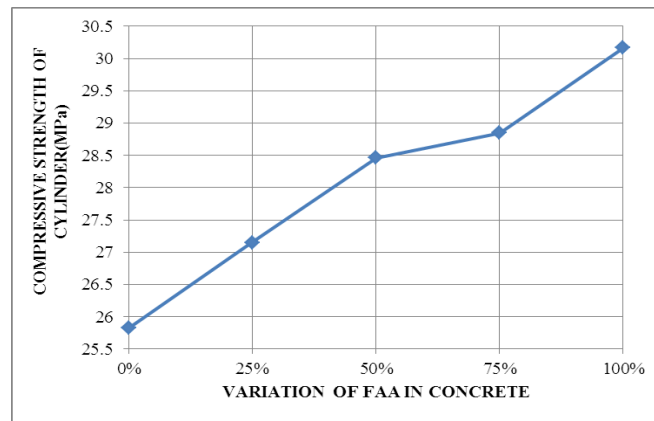


Fig 6. Variation of Cylinder Compressive Strength of Fly Ash Aggregate concrete with Age of Concrete

B.Split Tensile Strength

The Split Tensile Strength Test was carried according to IS 5816:1999. The results of Split Tensile Strength of Natural Coarse Aggregate concrete and Fly ash Aggregate concrete are presented in Table X and Fig.7.

It is observed that the Split Tensile Strength of Control concrete increases from 3.44 MPa of Control concrete to 5.56 MPa when natural coarse aggregate of size 20 mm is replaced with 100 % of Fly ash aggregate.

TABLE X. TEST RESULTS OF SPLIT TENSILE STRENGTH OF CONCRETE

Type of Concrete Mix	Average Split Tensile for 28 days (N/mm ²)	% Increase in Strength
Control Mix	3.44	-
FAA-25%	3.82	11.04
FAA-50%	4.28	24.4
FAA-75%	5.04	46.5
FAA-100%	5.56	61.6

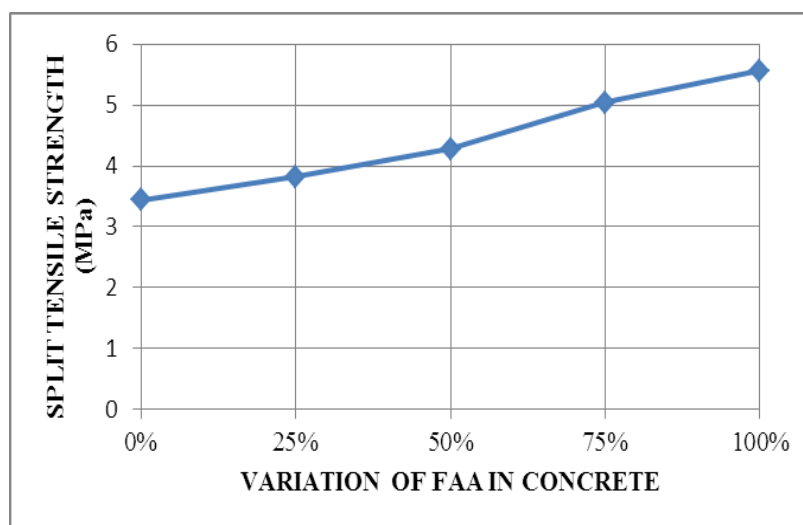


Fig 7. Variation of Split Tensile Strength of Fly Ash Aggregate Concrete for 28 Days

C. Flexural Strength

The Flexural Strength Test was carried out on plain concrete beams conforming to IS 516:1959, to obtain the Flexural Strength of concrete. The values of Flexural Strength are presented in Table IX and Fig 8. The Flexural Strength of Control Concrete is 5.5 N/mm².

TABLE XI. RESULTS OF FLEXURAL STRENGTH OF VARIOUS CONCRETE MIXES

Type of Concrete Mix	Average Flexural Strength for 28 days (N/mm ²)	% Increase in Strength
Control Mix	5.5	-
FAA-25%	6.70	21.9
FAA-50%	6.98	26.9
FAA-75%	8.48	54.3
FAA-100%	9.60	74.7

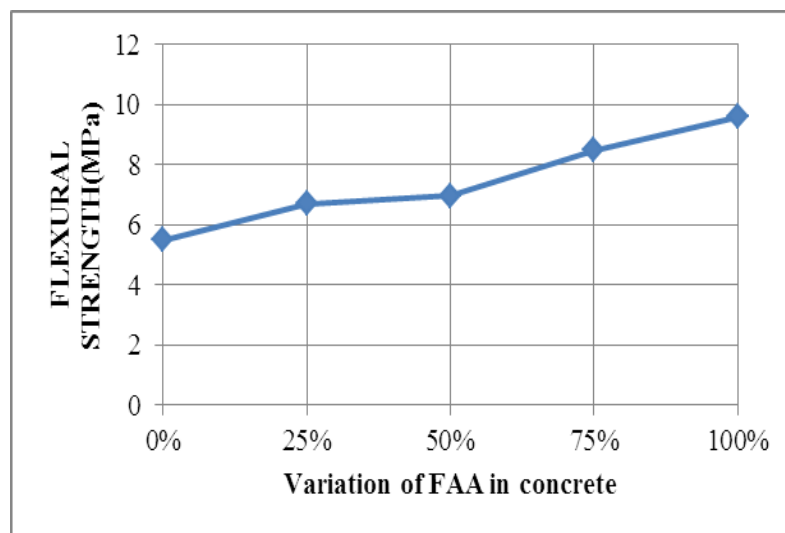


Fig 8. Variation of Flexural Strength for Various Concrete Mixes

From the results, with variation in proportion of Fly Ash Aggregate in concrete Flexural Strength of concrete increases. It can be observed that with 100 % replacement of Natural Aggregate of size 20 mm with Fly Ash Aggregate Flexural Strength was increased up to 74.76% compared to controlled concrete i.e., 9.6 N/mm².

D. Modulus of Elasticity

Modulus of Elasticity of concrete is obtained by using cylindrical specimens at the age of 28 days. The values of Modulus of Elasticity of concrete for various proportions of FAA in concrete are presented in Table XII and Fig 9. The Modulus of Elasticity of Controlled concrete is 25.76 GPa. It can be observed that the Modulus of Elasticity of concrete has attained the maximum value of 74.92 GPa for 100% replacement of Natural aggregates of size 20 mm with Fly Ash aggregates i.e., 190.8 % increase in strength when compared to Controlled concrete.

TABLE XII. RESULTS OF MODULUS OF ELASTICITY OF VARIOUS CONCRETE MIXES

Type of Concrete Mix	Average Modulus of Elasticity for 28 days (GPa)	% Increase in Strength
Control Mix	25.76	-
FAA-25%	29.95	16.2
FAA-50%	47.46	84.2
FAA-75%	62.94	144.3
FAA-100%	74.92	190.8

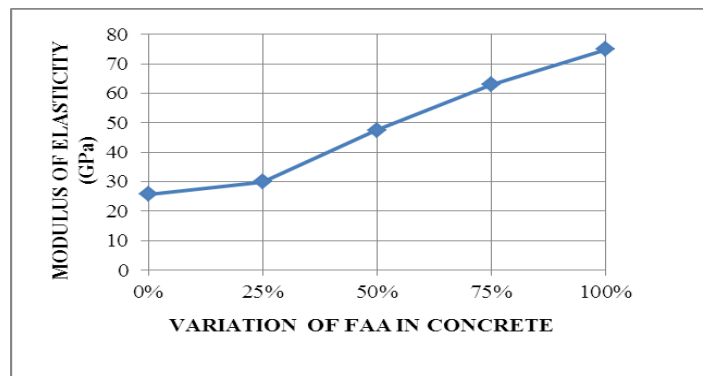


Fig 9. Variation of Modulus of Elasticity for Various Concrete Mixes

E. Density of Concrete

By taking weights of concrete cubes for various proportions of Fly Ash aggregates density of concrete can be determined and obtained results are shown in Table XIII. Actually density of Control concrete mix was 2.4 g/cm^3 . With 100% replacement of natural coarse aggregate with Fly Ash aggregate density was decreased to 2.16 g/cm^3 i.e., 10.0% density of concrete was decreased.

Table XIII. RESULTS OF DENSITY OF CONCRETE FOR VARIOUS CONCRETE MIXES

Type of Concrete Mix	Weight of Concrete cube(g)	Density of Concrete Cube (g/cm^3)	% Decrease in Density of Concrete
Control Mix	8100	2.40	-
FAA-25%	7900	2.34	2.5
FAA-50%	7700	2.28	5.0
FAA-75%	7500	2.22	7.5
FAA-100%	7300	2.16	10.0

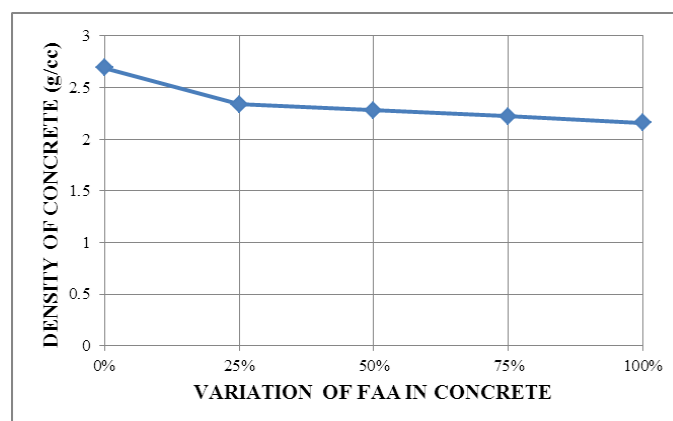


Fig 10. Variation of Density of concrete for various Concrete Mixes

VII.CONCLUSIONS

Based on the results of experimental investigation, it can be concluded that,

- From the experimental investigation, it was found that the compressive strength was increased for fly ash aggregate concrete cubes with cement fly ash proportion **15:85**, when compared to the control concrete cubes at all the ages of curing.
- The fly ash aggregate concrete cubes containing fly ash aggregates made using cement fly ash proportions 10:90 and 20:80 showed reduction in compressive strength when compared to the control concrete at all the ages of curing.
- Low specific gravity compared to natural gravel proves it to be a light weight aggregate material and fly ash has been consumed in large volume when it is used as a coarse aggregate replacement material due to its occupation of large volume in concrete. This in turn reduces the problem of dumping as landfills to greater extent.
- Concrete with density 2.16 g/cm^3 can be achieved using fly ash aggregates while density of normal concrete mix goes up to 2.69 g/cm^3 .
- The Compressive Strength of Control Concrete (32.44 N/mm^2) has increased by 9.2% with full replacement of Natural Coarse aggregate with Fly Ash Coarse aggregate (35.40 N/mm^2).
- The Split Tensile Strength of Control Concrete (3.44 N/mm^2) has increased by 61.6% with full replacement of Natural Coarse Aggregate with Fly Ash Coarse aggregate (5.56 N/mm^2).
- The Flexural Strength of Control Concrete (5.5 N/mm^2) has increased by 74.7% with full replacement of Natural Coarse aggregate with Fly Ash Coarse aggregate (9.61 N/mm^2).
- The Modulus of Elasticity of Control concrete (25.76 GPa) has increased by 190.8 % with full replacement of Natural Coarse aggregate with Fly Ash Coarse aggregate (74.9 GPa).
- The results also indicate that the Fly Ash aggregate Concrete specimens have higher mechanical properties due to pozzolanic activity.
- Finally it can be concluded that the performance of concrete increases with 100 % replacement of Natural Coarse aggregate with Fly Ash aggregate.

VIII.ACKNOWLEDGEMENT

I owe a great many thanks to a great many people who helped and supported me during the project work.

I express my sincere and deepest indebtedness to my beloved guide **Dr.D.V.PRASADA RAO**, Professor, Department of Civil Engineering, Sri Venkateswara University College of Engineering, Tirupati, for assigning this work and giving all the motivation, constant encouragement and valuable guidance throughout the work.

I express my sincere gratitude to our Head of the Department, **Dr.M.Srimurali**, Professor, Department of Civil Engineering, Sri Venkateswara University College of Engineering, Tirupati, for extending administrative support and to conduct my project work.

I thank **Prof.G.N.PRADEEP KUMAR**, Principal, Sri Venkateswara University College of Engineering, Tirupati, for providing facilities for completion of work.

I express my sincere thanks to my parents and friends who are the constant source of inspiration and encouragement throughout my project work.

Finally I like to thank one and all who directly or indirectly helped me in making the project a reality.

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