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Study of Concrete Made using Fly Ash Aggregate

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ABSTRACT

In this study, the fine and coarse aggregates were completely replaced by fly ash aggregates in fly ash concrete. A mix design was done for M20 grade of concrete by IS method. Ordinary Portland cement of 43 grade was selected and fly ash aggregates were prepared by mixing fly ash with cement and water. The properties of fly ash fine aggregates and fly ash coarse aggregates were studied. The aggregate crushing value and aggregate impact value of fly ash coarse aggregates were also studied. The cement and fly ash proportions of 10:90, 12.5:87.5, 15:85, 17.5:82.5, 20:80 and 22.5:77.5 were tried with a suitable water cement ratio 0.3 to get the fly ash aggregates. The concrete cubes, cylinders and beams were cast with the fly ash aggregates obtained from the above six cement fly ash proportions. Then the compressive strength, split tensile strength and flexural strength were tested and compared with control concrete. This paper briefly presents the compressive strength development of fly ash aggregate concrete at different ages. The split tensile strength and flexural strength of all the concrete mixes were also investigated at different days of curing.

Keywords: Fly ash aggregates (FAA), Fly ash Fine Aggregates (FAFA), Fly ash Coarse Aggregate (FACA), Fly ash Aggregate Concrete (FAAC), Compressive Strength, Split tensile strength, Flexural strength, Control concrete (CC)

1. INTRODUCTION

In conventional concrete, weight of concrete is one of the parameters to compare with weight of fly ash aggregate concrete. Normally density of concrete is in the order of 2200 to 2600 kg/m^3. This heavy self-weight makes an uneconomical structural material compared to low self-weight of fly ash aggregate concrete. In order to produce concrete of desired density to suit the required application, the self-weight of structural and nonstructural members are to be reduced. Hence economy is achieved in the design of supporting structural elements which lead to the development of light weight concrete. Lightweight concrete is defined as a concrete that has been made lighter than the conventional concrete by changing material composition or production method. Lightweight aggregate concrete is the concrete made by replacing the usual material aggregate by lightweight aggregates. Though lightweight concrete can't always substitute normal concrete for its strength potential, it has its own advantages like reduced dead load, and thus economic structures and enhanced seismic resistance, high sound absorption and good fire resistance. Because of the above reasons the study on fly ash aggregate concrete is taken in this research work.

2. LITERATURE REVIEW

This chapter presents the literature reviewed on the effect of using crushed rock material, quarry dust in place of sand in the preparation of concrete. Some of the experimental investigations on the strength and durability behaviour of concrete on the use of quarry dust in the place of natural sand are listed here.

In addition to crushed rock material, the fly ash may be used as an alternative material for fine aggregate sand. To increase the workability and strength of concrete super plasticizer may be used. These criteria viewed from different literature are listed in this chapter.

Hudson (1997) has conducted experiments to study the performance of concrete by adding manufacturing sand instead of sand. He prepared trial mixes by using 3 to 20 percentage partial replacement of sand by manufactured sand of minus 75 micron or dust. The w/c ratio was fixed as 0.7. From the experimental results it was found that there was remarkable increase in compressive strength in the concrete manufactured with 20 percentage replacement of sand with manufactured sand. This was due to the inclusion of high percentage of minus 75 micron dust in a suitably graded form with a good particle shape that allows aggregate packing and results in a denser concrete. The concrete has lesser permeability and so more durable.

This was due to the increased efficiency in void filling particle force to close capillaries, thereby stopping the passage of liquids decreasing permeability and durability preventing chemical or liquid ingress into the concrete. He concluded that the concrete may be used with 20% replacement of sand by manufactured sand and it was more durable and less permeable.

Patagundi and Patil (2002) have conducted experiments to investigate the properties of concrete when cement was partially replaced by fly ash and natural sand by crusher stone powder simultaneously. The compressive strength and flexural strength were studied. The behaviour of concrete when subjected to heat cycles was also studied. The replacement of sand was from 0- 40% at increments of 10%. Using OPC the design mix 1: 1.2: 2.4 was prepared with water cement ratio 0.30. To facilitate the flow of concrete a super plasticizer was used. In temperature resistance test, the concrete cube specimen were subjected to heat cycles say 8 hours of heating at 60°C followed by 16 hours of cooling at 25°C. Two heat cycles say 15 day cycle and 30 day cycle were adopted.

Mithanthaya and Jeyaprakash Narayan (2002) have conducted experiments to find the suitability of quarry dust as fine aggregate for plastering and pavement design. Test was conducted for the mix proportion of cement and quarry dust in 1:3, 1:4, 1:5, 1:6 and 1:7. Tests were conducted and the values obtained were compared with control mortar containing cement and sand. From test results it was observed that voids present in the quarry dust mortar was lesser as compared to that of sand, hence high compressive strength. No cracks were found after 28 days of curing. Cement quarry dust mortar 1:4 mix was used to plaster inside the water tank and found that it was free from leakage. Based on the test results it was concluded that quarry dust can be utilized for plastering instead of sand and with proper investigation it may be utilized in the preparation of concrete also.

Selvakoodalingam and Palanikumar (2002) have analysed through experimental study the use of quarry dust as fine aggregate in cement concrete. M15 mix was considered with three proportions say 100% sand, 50% sand and 100% quarry dust. Workability and compressive strength tests were conducted. From the test results it was observed that the 28 day compressive strength was maximum at 50% sand replacement. Compared with sand, quarry dust was more workable. It was concluded that quarry dust can be utilized as replacement material in place of sand with higher strength at 50% replacement.

Naidu et al (2003) have conducted experiments to investigate the influence of partial replacement of sand with quarry dust in the compressive strength and pull out force concrete. Four types of concrete using OPC were prepared using M20 mix with 20% sand replacement in w/c ratios 0.4 and 0.45. The specimens were cast and tested at the age of 7, 14, 28 and 56 days.

3. MATERIALS AND METHODOLOGY

- Ordinary Portland cement 43 grade confirming to IS:8112-1989
- Fly ash (FA) obtained from Thermal power plant , Mettur confirming to IS:3812-1981
- Local river sand confirming to Grading Zone II of IS: 383-1970
- Fly ash Fine Aggregate (FAFA) obtained from

cement fly ash proportions 10:90, 12.5:87.5, 15:85, 17.5:82.5, 20:80 and 22.5:77.5.

- Hard Broken Granite stone (HBG) confirming to graded aggregate of size 20mm as per IS: 383-1970
- Fly ash Coarse Aggregates (FACA) obtained from cement fly ash proportion 10:90,12.5:87.5,15:85,17.5:77.5,20:80 and 22.5:77.5

Fly ash brick sizes (mm)	Fly ash brick sizes (inches)
150x230x300	6x9x12
150x200x400	6x8x16
75x100x225	3x4x9

3.1 MIX PROPORTIONS

The mix proportion for the M20 grade of concrete was arrived through trial mixes. Mix design is done as per IS: 10262-2009.The mix proportion for M20 grade of concrete

Design Mix Proportion = 1 :1.69 :2.94 and W/C 0.5

4. RESULTS AND DISCUSSIONS

Table 1. Physical properties of Conventional Fine Aggregate (CFA) and Fly ash fine aggregate (FAFA)

S. No	Properties	CFA	(FAFA)
1	Specific gravity	2.70	1.28
2	Bulk density (Kg/m^3)	1808	838
3	Size (mm)	Below 4.75	Below 4.75
4	Fineness modulus	2.68	2.70

Table 2. Physical properties of Conventional Coarse Aggregate (CCA) and Fly ash Coarse Aggregate (FACA)

S. No	Properties	CCA	FACA
1	Shape	Angular	Spherical
2	Specific gravity	2.75	1.3
3	Bulk density (Kg/ m^3)	1685	913
4	Size (mm)	4.75mm to 20mm	4.75mm to 20mm
5	Crushing value (%)	24.94	25.6
6	Impact Value (%)	23.86	21.6

Table 3. Comparison of Workability of FAAC with Conventional Concrete

Type of Concrete	Workability Test			
	Slump (mm)	Workability	Compaction factor	Workability
Control concrete	40	Medium	0.91	High
Fly ash aggregate concrete	60	Medium	0.9	High

4.1 Compression 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 140kg/cm^2/min until the failure of the specimen. The maximum load applied to the specimen until failure was recorded and shown in Table – 4.

Table 4. Compressive strength of fly ash aggregate concrete and control concrete with different ages of testing

Age of testing	Proportion Cement: Fly ash	Compressive Strength in N/mm^2
1 day	10 :90	2.62
	12.5:87.5	2.76
	15 :85	3.84
	17.5:82.5	2.57
	20 :80	2.21
	22.5:77.5	2.13
	Control concrete	3.33
3 days	10 :90	6.41
	12.5:87.5	6.55
	15 :85	9.43
	17.5:82.5	6.81
	20 :80	6.61
	22.5:77.5	6.28
	Control concrete	8.37
7 days	10 :90	11.62
	12.5:87.5	12.89
	15 :85	15.93
	17.5:82.5	13.10
	20 :80	12.90
	22.5:77.5	10.24
	Control	14.34
	concrete	
	10 :90	14.20

	12.5:87.5	15.60
	15 :85	20.24
	17.5:82.5	16.20
	20 :80	15.80
	22.5:77.5	12.60
	Control concrete	17.62
	10 :90	16.30
	12.5:87.5	20.80
	15 :85	23.71
	17.5:82.5	17.90
	20 :80	17.20
	22.5:77.5	14.80
	Control concrete	

	concrete	
14 days	10 :90	14.2 0
	12.5:87.5	15.6 0
	15 :85	20.2 4
	17.5:82.5	16.2 0
	20 :80	15.8 0
	22.5:77.5	12.6 0
	Control concrete	17.6 2
28 days	10 :90	16.3 0
	12.5:87.5	20.8 0
	15 :85	23.7 1
	17.5:82.5	17.9 0
	20 :80	17.2 0
	22.5:77.5	14.8 0
	Control concrete	

Fly ash aggregate concrete with fly ash aggregates prepared from cement fly ash proportions 15:85 showed 15%, 13%, 11%, 15%, 14%, 13% and 8% increase in Compressive strength at the ages of 1day, 3days, 7days, 14days, 28days, 56days and 90days respectively over the control concrete.

Fly ash aggregate concrete with fly ash aggregates prepared from other cement fly ash proportions 10:90, 12.5:87.5, 17.5:82.5, 20:80 and 22.5:77.5 showed reduction in compressive strength at the ages of 1day, 3days, 7days, 14days, 28days, respectively over control concrete.

Development of Strength compared with respective 28days Compressive Strength

The strength development of control concrete compared with its corresponding 28days strength are16%, 40%, 69%, 85%, 108% and 120% for 1, 3, 7, 14, days respectively.

The strength development of fly ash aggregate concrete with aggregates made from cement fly ash proportion 10:90 compared with its corresponding 28days strength are 16%, 39%, 71%, 87%, 105% and 117% for1, 3, 7, 14, 56 and 90days respectively.

The strength gain for fly ash aggregate concrete with fly ash aggregates made from cement fly ash proportion 12.5:87.5 compared with its corresponding 28 days strength are 16%, 38%, 75%, 91%, 106% and 113% for 1, 3,

7, 14, 56 and 90days respectively.

The strength gain for fly ash aggregate concrete with fly ash aggregates made from cement fly ash proportion 15:85 compared with its corresponding 28days compressive strength are 16%, 40%, 67%, 85%, 106% and 114%

at the age of 1, 3, 7, 14, 28days respectively.

The compressive strength gain at the ages of 1, 3, 7, 14, 28ays for the fly ash aggregate concrete with fly ash aggregates made using cement fly ash proportion 17.5:82.5 are 14%, 38%, 73%, 91%, 107% and 113% respectively.

The strength gain for the fly ash aggregate concrete containing fly ash aggregates made by using cement fly ash proportion 20:80 showed the compressive strength at 1, 3, 7, 14, 28days were 13%, 38%, 75%, 92%, 107% and 114% respectively when compared to its 28days strength.

When comparing the strength gain at 28days of fly ash aggregate concrete with fly ash aggregates obtained from cement fly ash proportion 22.5:77.5 was 23%, 42%, 69%, 85%, 109%, and 126% at the ages of 1, 3, 7, 14, 28days respectively.

4.2 Split Tension Test

Concrete cylinders of 15cm diameter and 30 cm height were tested for Split tensile strength as per IS 5816-1976. The specimen was placed horizontally between the loading surfaces of the compression testing machine and the load was applied without shock until the failure of the specimen. The maximum load at failure was tabulated in Table - 6.

Table 5. Split tensile strength of fly ash aggregate concrete and control concrete with different ages of testing

Age of testing	Proportion Cement: Fly ash	Splitting tensile Strength in N/mm²
7 days	10:90	3.15
	12.5:87.5	3.45
	15:85	4.60
	17.5:82.5	3.20
	20:80	3.05
	22.5:77.5	2.95
	Control concrete	4.10
28 days	10:90	3.70
	12.5:87.5	4.10
	15:85	5.56
	17.5:82.5	3.90
	20:80	3.65
	22.5:77.5	3.20
	Control concrete	4.84

The fly ash aggregate concrete beam with fly ash aggregate made from cement fly ash proportion 15:85 showed an increase in split tensile strength of 12% and 15% respectively at the ages of 7days and 28days compared with control concrete beam.

The cement fly ash proportions of 10:90, 12.5:87.5, 17.5:82.5, 20:80 and 22.5:77.5 showed reduction in split tensile strength of 35%, 16%, 22%, 26%, and 28%, respectively at the age of curing in 7days and 24%, 15%, 19%, 25%, and 34%, respectively at the age of curing in 28 days than control concrete specimen.

4.3 FLEXURAL STRENGTH

The concrete beams of size 10cm x 10cm x 50cm were tested as per IS 516-1959. The load was applied through two similar rollers mounted at one third points of the supporting span. The load was applied without shock until the failure occurs. The maximum load at failure was tabulated in Table - 7.

Table 6. Flexural strength of fly ash aggregate concrete and control concrete with different ages of testing

Age of testing	Proportion Cement: Fly ash	Flexural Strength in N/mm²
7 days	10:90	4.10
	12.5:87.5	4.50
	15:85	5.49
	17.5:82.5	4.40
	20:80	4.20
	22.5:77.5	3.95
	Control concrete	4.95
28 days	10:90	4.40
	12.5:87.5	4.75
	15:85	6.22
	17.5:82.5	4.60
	20:80	4.35
	22.5:77.5	4.15
	Control concrete	5.36

The fly ash aggregate concrete containing fly ash aggregate made from cement fly ash proportion 15:85 showed increase in flexural strength of 11% and 16% respectively at the ages of curing in 7days and 28days than the control concrete specimen.

The cement fly ash proportions 10:90, 12.5:87.5, 17.5:82.5, 20:80 and 22.5:77.5 showed reduction in flexural strength of 17%, 9%, 11%, 15%, and 20%, respectively at the age of curing in 7days and 18%, 11%, 14%, 18%, and 23%, respectively at the age of curing in 28days than control concrete specimen.

5. CONCLUSIONS

- 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, 12.5:87.5, 17.5:82.5, 20:80 and 22.5:77.5 showed reduction in compressive strength when compared to the control concrete at all the ages.
- The split tensile strength of fly ash aggregate

concrete beams with fly ash aggregates of cement fly ash proportion **15:85** was increased when compared to the control concrete beams at all the ages of 7days and 28days of curing.

- The reduction in split tensile strength of FAAC specimen made with FAA of cement fly ash proportions 10:90, 12.5:87.5, 17.5:82.5, 20:80 and 22.5:77.5 while comparing the control concrete specimens at all the ages of 7days and 28days of curing.
- The increase in flexural strength of the specimen was observed for the fly ash aggregate concrete containing fly ash aggregates made using cement fly ash proportion **15:85** when compared to the control concrete at the ages of 7days and 28days of curing.
- The specimen made with FAA of cement fly ash proportions 10:90, 12.5:87.5, 17.5:82.5, 20:80 and 22.5:77.5 showed the reduction in flexural strength of fly ash aggregate concrete over the control concrete at the ages of 7days and 28days.
- The aggregates are vital elements in concrete. The usage of enormous quantities of aggregates results in destruction of hills causing geological and environmental imbalance.
- The environmental impacts of extracting river sand and crushed stone aggregates become a source of increasing concern in most parts of the Country. Pollution hazards, noise, dust, blasting vibrations, loss of forests and spoiling of natural environment are the bad impacts caused due to extraction of aggregates. Landslides of weak and steep hill slopes are induced due to unplanned exploitation of rocks.
- Considering the depletion of natural sources and the effect on environment, the disposal problems involved in disposing fly ash, light weight characteristics of fly ash aggregates with good mechanical properties (Compression strength, Split Tension strength and Flexural strength) as seen in the above investigation, a particular attention may be focused on the usage of fly ash aggregates in concrete.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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