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Suitability of Fly Ash Aggregates as Coarse Aggregates in Concrete

NEHA.S

[1]PG student, Department of civil engineering, Govt. SKSJTI, Bangalore, Karnataka, India

Abstract: **The effects of replacing coarse aggregate by fly ash on strength, compressive stress-strain relationship, and fracture behavior of concrete were investigated. The investigation covered concrete mixes at different water-cementitious material ratios, which contained low and high volumes of fly ash. It was found that fly ash substantially improved the post-peak compressive behavior of concrete, with a relatively smaller gradient in the descending part of the stress-strain curve. Low volumes of fly ash improved the tensile strength of concrete. The specific gravity and the bulk density of fly ash aggregates when compared to the conventional aggregates are lesser. Because of the porous nature of aggregates the water absorption is more compared to the natural aggregates. Compressive strength of fly ash aggregates is more compared to the other proportion and conventional concrete. The weight and density of fly ash aggregate concrete is comparatively less when compared to conventional concrete.**

Keywords: **Suitability of fly ash, Palletisation technique, fly ash, light weight aggregates, Production & characterization of fly ash, Tests on fine and coarse aggregates, Mix design, Crushing and impact value, Compression Strength values, Properties.**

1. INTRODUCTION

The environmental impacts of crushed stone aggregate extraction are a source of increasing in demand many parts of the country. The impacts include loss of forests, noise, dust, blasting vibrations and pollution hazards. Unplanned exploitation of rocks may lead to landslides of weak and steep hill slopes. The concern about the depletion of natural sources and the effect on environment has particularly focused attention on possibility of use synthetically produced (from waste materials) aggregates as an alternative to naturally occurring materials. In order to achieve an alternative as over natural aggregates, the waste products have to be used effectively. Each industry or Power plants have their own waste products. Nowadays due to industrialization there is a scarcity of electricity in India. In India there are 85 thermal power plants for generation of electricity, in each thermal plant 85 million tons of fly ash is coming out as residual per annum.

Almost in all thermal power plants fly ash is produced as a by-product, but some amount of fly ash is used in cement industry for manufacturing cement (PPC) and remaining is a waste. In spite of this we are facing huge disposal problems. In order to overcome this disposal problem and to avoid an extraction and depletion of natural source this residual fly ash can be effectively used in a construction industry.

Scope of the Present Study:

The water absorption of fly ash aggregates is more; in order to reduce this, zinc coating can be tried around the surface of the aggregates, so that porous fly ash aggregates become less water absorption. The mix design is redesign for improving the tensile strength and durability property of concrete. The fly ash aggregates can be effectively use in construction industry.

2. LITERATURE REVIEW

R. WASSERMAN AND A. BENTUR et al., (1997): In this paper, structure and properties of sintered fly ash lightweight aggregate was modified by heat and polymer treatments to obtain aggregates different in their strength, absorption and pozzolanic activity. These properties of the aggregates were accounted for by changes in their microstructure. The author has shown that the strength of the concrete could not be accounted for by the strength of the has aggregates only, and he suggested that the absorption and pozzolanic activity of the aggregates can have an influence on the strength developed.

K. RAMAMURTHY, K.I. HARIKRISHNAN et al (2005): In his study, Research and development work on the utilization of fly ash for various productive uses have been carried out and major attention has been devoted to the use of fly ash in concrete as a cement replacement. The salient observations are (i) the characterization studies on sintered fly ash aggregates show that the properties of aggregates depend on the type of binder and its dosage, (ii) the significant improvement in strength and reduction in water absorption of sintered fly ash aggregate is observed when bentonite is added with fly ash, (iii) the binders used did not alter the chemical composition.

H. ARSLAN (2006) et al: He had recognized that there exists a serious need for recovery and reuse of industrial wastes. Agglomeration by palletisation method can alleviate the problems associated with fly ash. He evaluated the engineering properties of the manufactured aggregates experimentally, crushing strength, specific gravity, water absorption, particle size distribution, surface characteristics and shear strength properties of the manufactured aggregates. For all practical purposes, his study showed that the manufactured aggregates are a good an alternative for wide range civil engineering applications.

3. PRODUCTION AND CHARACTERIZATION OF FLY ASH AGGREGATES

Introduction:

This chapter deals with the material testing and their outcomes are determined. The applicable codes of practice have been referred to at all stages and the materials have been tested according to the procedure in the codes of practice.

Materials:

In this study the materials used are:

1. Cement
2. Fly ash
3. Potable water
4. Fine aggregate
5. Coarse aggregate
6. Fly Ash Aggregate

Cement:

In the present experimental studies, Birla super cement of 53 grade confirming to IS 8112- 1989 was used and the cement sample was tested as per IS-4031-1988 and IS 269-1976. The physical properties like specific gravity, normal consistency and setting time of cement are determined using the following codes.

Standard consistency: (IS: 4031-1988)

Initial setting time: (IS: 4031-1988)

Final setting time: (IS: 4031-1988)

Table Test results of Cement Properties	**Test Results**
Specific Gravity	3.15
Standard Consistency	29
Initial setting time(min)	28
Final setting time(min)	540

Aggregate:

In the present work, the river sand which was generally available was utilized, the tests were on sand conducted as per IS: 2386-1968, Part-III.

Table: Fine aggregates basic properties.	Results
Specific Gravity	2.53
Fineness modulus	2.9
Bulk density (kg/m3)	1570
Water absorption (%)	0.4
Gradation	Zone – II

Coarse aggregate:

For the experimental work, crushed stone aggregates of size 20mm to 4.75mm were utilized the different tests were carried out on the aggregates as per IS 2386-1988 part III .The tests conducted are specific gravity, water absorption, crushing value, impact value and bulk density.

Specific gravity: (IS 2386-1968 Part-III) Bulk density: (IS 2386-1968 Part-III)

Table : COARSE AGGREGATES BASIC PROPERTIES	Values
Specific Gravity	2.66
Fineness Modulus	2.9
Bulk Density (kg/m3)	1640
Water absorption (%)	0.3
Gradation	Well graded

Fly ash:

Fly ash is an end product obtained from burning of coal in thermal power plants, for generating power. Fly ash contains 62% of silica, so it can be used as a pozzolanic material in construction industry. It can be used as replacement to cement up to some extent. Many research workers show that microstructure interfacial zone improves.

Water*:*

Potable water was utilized for the project work and which is free from chloride.

Methodology of producing FAA Concrete: Process of preparing concrete specimens:

1. Cement, fine aggregates, fly ash aggregates and coarse aggregates are used for preparing concrete specimens.

2. The above materials are weighed and placed in the mixing tray. Dry mix the materials uniformly.

3. After dry mixing, these constituents are placed in tilting drum type concrete mixer; the optimum amount of water is added in controlled manner and allowed for mixing.

4. The fresh concrete is placed in to moulds of size150mm x150mmx150mm in three uniform layers, each layer is compacted using table vibrator and finally the top surface is levelled properly.

5. Allow the Specimen to dry for one day, then de-moulded and kept for water curing until the specified days of test.

Process of curing specimens:

After casting the specimen, allow it for drying for 1 full day, then demould the specimen and soaked into the water for curing .Curing develops the strength and durability property of the concrete. The continuous hydration process attains the strength development if concrete and also resistance to abrasion, freezing and thawing.

Compressive strength test procedure for concrete specimens:

1. After curing in specified curing days, the specimens are taken out from water bath and allowed dry.

2. Using electronic weighing balance, total weight of the specimen is taken and also using vernier caliper dimensions of the specimens are measured.

3. The specimen is tested in CTM as shown in Figure 3.7 to obtain the failure load of the specimen. The CTM is loaded at 1.2 mm/minute up to the failure. The average of three identical specimen's compressive strength gives compressive strength of specimen.

4. The compressive strength is calculated as failure load by cross sectional area.

Compressive strength is calculated by

σ = F / A

MIX DESIGN:

where,

F = Compressive load [kN]

A = C/S Area of the cube [mm²]

Mix Design for M20 grade of concrete (as per IS 10262:2009)

Design stipulations

1. Characteristic compressive strength required at 28 days: 20 N/mm2
2. Maximum size of aggregate: 20mm
3. Degree of quality control: Good
4. Type of exposure: severe

1. Target mean strength

The target mean strength for specified characteristic cube strength is

fck = fck + 1.65s

Referring to table 1, for M20 concrete and good quality control,

S = 4.0 N/mm2 and fck = 20 N/mm2 fck1 = fck + 1.65s

= 25 + 1.65 x 4 = 26.6 N/mm2

2. Selection of W/C ratio

From the graph of IS 456 table 5, maximum W/C ratio for severe is 0.50. Based on experience. Adopt w/c ratio as 0.50 0.50= 0.50, Hence OK.

3. Selection of water content

From the table 2, maximum water content for 20 mm aggregate = 186 litres (for 25 to 50 mm slump range).

Estimated W.C. for 100mm slump = 186+ (6/100) x 186=197 litres

4. Determination of cement content

OK.

5. Proportion of volume of coarse aggregate and fine aggregate content

From table 3, volume of coarse aggregate corresponding to 20 mm size aggregate and fine aggregate (Zone II) for W/C In the present case W/C ratio is 0.50=0.60.Therefore, volume of coarse aggregate is required to be increased to decrease the fine aggregate content. As the W/C ratio is lower by 0.08, the proportion of volume of coarse aggregate is increased by 0.01(at the rate of ±0.01 for every ±0.05 change in W/C ratio). Therefore, corrected proportion of volume of coarse aggregate for the W/C ratio of 0.50=0.63.

Therefore,

Volume of coarse aggregate =0.60 Volume of fine aggregate =1-0.60 = 0.40

6. Mix calculations

The mix calculations per unit volume of concrete shall be has follows.

a) Volume of concrete = 1 m3

b) Volume of cement = (Mass of cement/ specific gravity of cement) x (1/1000)

= (394/3.15) x (1/1000)

= 0.127m3

c) Volume of water = (Mass of water/ specific gravity of water) x (1/1000)

= (197/1) x (1/1000)

= 0.197 m3

d) Volume of all in aggregate = a- (b + c)

= 1-(0.127+0.197)

= 0.676 m3

e) Mass of coarse aggregate = d x Volume of coarse aggregate x Sp. gravity of coarse Aggregate x 1000

= 0.676X 0.6X 2.63

= 1068 Kg/m3

f) Mass of fine aggregate = d x Volume of fine aggregate x specific gravity of fine aggregate x 1000

= 0.676x 0.40x 2.56 x 1000 703.11 Kg/m3

7. Proportions of ingredients are as follows:

(C: F.A:C.A)=1:1.7:2.7 with water/cement ratio of 0.50.

With the above proportion number of slumps has been tried. At the end we reached the proportion 1:1.7:2.7with w/c ratio of 0.50.

Table : Mix design for M20 grade of concrete as per IS code 10262:200 M20 Grade of Conventional Concrete Mix Proportion	**Values**
Cement	394 kg/m3
Fine Aggregate	703 kg/m3
Coarse Aggregate	1068 kg/m3
Water	197 Litres

Table: Mix proportions of M20 MIX DESIGNATION	**CEMENT kg/m3**	**FINE AGGREGRATE kg/m3**		**COARSE AGGREGRATE kg/m3**
NATURAL COARSE AGGREGRATE		**FLYASH AGGREGRATE**		
CC	394	703	1068	0
A10	394	703	961.2	106.8
A20	394	703	854.4	213.6
A30	394	703	747.6	320.4
A40	394	703	640.8	427.2
A50	394	703	534	534

CRUSHING AND IMPACT VALUE OF AGGREGATES:

The manufactured fly ash aggregates can be cured in two different methods. Oven dried curing and water curing. In the oven dried curing 8hrs ,16hrs, 24 hrs and 48 hrs the aggregates are put in the oven and maintaining the temperature of 60 degree and crushing and impact test is carried out for this manufactured aggregates. The compression testing machine is loaded 400KN and 200KN load is applied for crushing value.

7 Days Cured Aggregates:

The 7days and 28 days water cured fly ash aggregates, the crushing and impact test is done. The 28 days water cured aggregates give better compressive and impact value compared to the 7 days water cured fly ash aggregates.

Table : Crushing value and Impact value of 7 days cured fly ash aggregates Tests	**Impact value (%)**	**Crushing value (%)**
15:85 (flyash : cement)	40	38
Conventional aggregates	28.01	28.9

4. RESULTS & DISCUSSIONS OF CONSTITUENT MATERIALS OF CONCRETE

Introduction:

In this chapter compressive strength of concrete with different percentage replacement of fly ash aggregates (10%, 20%, 30%, 40% & 50%) into coarse aggregate is tested. Compressive strength also depends on the curing period of the concrete specimen. The cement-sand-coarse aggregate and fly ash aggregate mixes are prepared with a proper water cement ratio (w/c) using vibrating table or vibrator. The compacted specimens are cured for 7 & 28 days. After curing, compressive strength of specimen determined using compressive testing machine (CTM).

Crack pattern of Cube:

Analysis & Interpretation of Compressive strength test results:

The compressive strength of concrete specimen with different percentage replacement of fly ash aggregate to conventional aggregate is noted in the table below. In the present experimental work M20 grade of concrete is prepared with fly ash aggregate replaced at 0%, 10%, 20%, 30%, 40% and 50% level and water cement ration of 0.48 is taken. The control concrete M20 shows the compressive strength 26.75 MPa for 28 days curing. The specimen prepared with (15:85) fly ash aggregate replacement 30%, compressive strength is 26.75Mpa is slightly higher than the conventional concrete, for (15:85) proportion fly ash aggregate 100% replacement the compressive strength is 14 MPa is low compare to conventional concrete and other proportions fly ash aggregate concrete.

Slump of Fly Ash Aggregate Concrete:

The slump is one of the important factors for strength property of the concrete. The fly ash aggregate concrete is maintained near 100mm slump by increasing water-cement ratio from 0.48 to .52 percent of water added by increase of fly ash aggregate in concrete up to 0% to 50%.

Table : Fly ash aggregate concrete Slump in mm PROPORTION (CA:FAA)	**SLUMP VALUE**	**w/c ratio**
(100:0)	102	0.48
(90:10)	98	0.48
(80:20)	95	0.50
(70:30)	91	0.50
(60:40)	94	0.52
(50:50)	92	0.52

Compressive Strength Values For Concrete Specimens Fly Ash Aggregate:

Table: Compressive Strength values of Fly ash aggregate concrete of 7days Sl. No.	**% variation of Steel slag partial replacement of coarse aggregate**	**Ultimate Load (KN)**	**Compressive Strength of 28 days(N/mm2)**
1.	CC	321.75	14.3
317.25		14.1	
326.25		14.5	
AVERAGE		**14.3**	
2.	90% COARSE AGGREGATE + 10% FLY ASH AGGREGATE	380.25	16.9
378		16.8	
391..5		17.4	
AVERAGE		**17.03**	
3.	80% COARSE AGGREGATE + 20% FLY ASH AGGREGATE	389.25	17.3
398.25		17.7	
400.5		17.8	
AVERAGE		**17.6**	
4.	70% COARSE AGGREGATE + 30% FLY ASH AGGREGATE	420.75	18.7

425.47		18.9	
420.07		18.6	
AVERAGE		**18.7**	
5.	60% COARSE AGGREGATE + 40% FLY ASH AGGREGATE	374.57	16.9
376.87		16.7	
371.92		16.5	
AVERAGE		**16.7**	
6.	50% COARSE AGGREGATE + 50% FLY ASH AGGREGATE	334.57	14.87
336.6		14.96	
333.22		14.81	
AVREAGE		**14.88**	

5. CONCLUSION

Properties of fly ash aggregates:

- The specific gravity of the manufactured FA aggregates is 1.63 and specific gravity of conventional concrete is 2.73. It clearly indicates that the manufactured FA aggregates are light weight material.
- The bulk density of fly ash aggregates is 940 kg/m3**,** the fly ash aggregates are low density compared to the natural aggregates.
- The Water absorption of fly ash aggregate is 8.7 % for 15:85 ratio. Because of the porous nature of aggregates the water absorption is more compared to the natural aggregates.

Mechanical properties of fly ash aggregate concrete:

- The compressive strength of M20 grade fly ash aggregate with 30% replacement of 15:85 fly ash aggregate 26.72 **Mpa** is more compared to the other proportion and conventional concrete.
- The weight of conventional concrete was found to be **8.1 kg** per cube and weight of fly ash aggregate concrete was **7.6 kg**. The density of conventional concrete is **2459** kg/m3 and fly ash aggregate concrete is **2084** kg/m3

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