Experimental Study on the Mechanical Properties of Light Weight Fly Ash Aggregate Concrete Reinforced with Steel Fiber

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***Abstract*– An experimental study was carried to study the behaviour of light weight fly ash aggregate concrete reinforced with steel fibers. The light weight fly ash aggregate were replaced for natural coarse aggregates in 0%, 20%, 40% and 60% (by weight) and steel fiber were added to the concrete in 0.5% by Volume of concrete. Properties of fly ash aggregates were studied and compared with the conventional natural aggregates. The standard specimens were cast and tested to ascertain the mechanical properties (compressive, tensile and flexural strength) of fly ash aggregate concrete and compared with conventional concrete.**

***Key words* – Fly Ash Aggregate (FAA), Steel Fiber (SF), compressive strength, split tensile strength, flexural strength.**

I. Introduction

In India, the generation of electricity is overwhelmingly dependent on combustion of high-ash coal and as a result fly ash is produced. The present availability of fly ash generated by combustion has been measured to be 184.4 million tonnes according to Central Electricity Authority for the year 2014-15 and its generation is likely to touch 225 million tonnes by 2017. The present utilization of fly ash is close to 55% of the quantity generated out of which 42% is used with cement. Hence it is proposed to use the fly ash, an industrial waste product in concrete for partial replacement of coarse aggregate.

Concrete is one of the most widely used construction materials, due to its good quality and durability. However, as the concrete is weak in tension, the concrete is often reinforced with various fibers. Steel fiber is the most commonly used type among the various fibers for most structural and non-structural purposes. The steel fiber concentration, orientation and distribution as well as geometry influence the characteristics and performance of the concrete.

Light weight concrete can be classified according to the purpose for which it is to be used: it can distinguish between structural lightweight concrete, concrete used in masonry units, and insulating concrete. The 28-day cylinder compressive strength of structural lightweight concrete should not be less than 17 MPa. The density (unit weight) of such concrete (determined in the dry state) should not exceed 1840 kg/m³ and is usually between 1400 and 1800 kg/m³. The main specialties of lightweight concrete are low density, reduction in dead loads making savings in foundations and reinforcement, improved thermal properties and improved fire resistance.

Light weight aggregates are classified as Natural light weight aggregates and Artificial light weight aggregates. Natural light weight aggregates are crushed stone, pumice, volcanic cinders, rice husk and saw husk, while Artificial light weight aggregates are expanded shale, foamed slag, sintered fly ash, expanded glass, expanded polystyrene beads, brick rubble, vermiculite and ceramics.

Lightweight aggregate concrete can be produced using a variety of lightweight aggregates. Lightweight aggregates originate from (i) Natural materials, like volcanic pumice, (ii) The thermal treatment of natural raw materials like clay, slate or shale i.e. Leca, (iii) Manufacture from industrial by-products such as fly ash, i.e. Lytag, (iv) Processing of industrial by-products such as pelletized expanded slab, i.e. Pellite.

II. MATERIAL

All through the experimental study, Ordinary Portland Cement conforming to IS 12269:1987 was used. Its specific gravity, fineness, consistency and initial setting time were 3.15, 4%, 33% and 35minutes respectively. Both fine and coarse aggregate used were conform to IS 383:1970. Locally available river sand which passes through 2.36 mm IS sieve was used as a fine aggregate. The specific gravity, fineness modulus, bulk density and water absorption of fine aggregates are 2.64, 2.55, 1704.108kg/m^3 and 1% respectively. By conducting sieve analysis it is found that sand confirms to grading zone II as per table 4 as of IS 383-1970. In this study the natural coarse aggregates with maximum size 12.5mm was used. Potable water was used for mixing and curing of the concrete. The production of FAA by sintering process was carried out as follows: Fly ash, cement and water were thoroughly mixed and then fed into a mixer drum and made to rotate in the mixer drum approximately for 20minutes, thus forming pellets and this process is called pelletizing. Then the pellets are heated at a temperature rate of 1000°C to 1200°C in a muffle furnace, thus resulting in high strength of the aggregate. The super plasticizer used in the present work is a commercially available brand, Conplast SP430. The properties of both natural aggregates and Fly Ash aggregates found as per IS 2386(Part 3) -1963 are shown in following tables.

TABLE 1 PROPERTIES OF NATURAL AGGREGATES

Sl. No	Property	Value
1	Specific gravity	2.65
2	Impact Value	15.63%
3	Crushing value	12.77%
4	Water absorption	0.9%
5	Bulk density (loose)	1490 kg/m^3
6	Bulk density (dense)	1626 kg/m^3
7	Void ratio	38.65

TABLE 2 PROPERTIES OF FLYASH AGGREGATES

Sl. No	Property	Value
1	Specific gravity	1.4
2	Impact Value	27.78%
3	Crushing value	19.42%
4	Water absorption	16.8%
5	Bulk density (loose)	830 kg/m^3
6	Bulk density (dense)	895 kg/m^3
7	Void ratio	35.84

TABLE 3 PROPERTIES FOR HOOKED END STEEL FIBER

Sl. No	Property	Value
1	Diameter	0.55 mm
2	Length	30 mm
3	Aspect ratio	55
4	Density	7680 kg/m^3
5	Tensile strength	>1450 MPA

FIGURE 1 FLY ASH AGGREGATE

FIGURE 2 HOOKED END STEEL FIBER

III.EXPERIMENTAL INVESTIGATION

A. *Mix Proportioning*

Mix design depends on the properties of the different materials used in concrete. Mix design is carried out according to IS 10262-2009. Mix design for the mix ratio of M30 grade concrete of aggregate size 12.5mm is obtained as follows

Minimum cement content : 320 kg/m3
Maximum water-cement ratio : 0.35
Workability : 75-100 mm slump
Exposure condition : Severe
Maximum cement content : 450 kg/m3
Cement used : OPC 53 grade
Chemical Admixture : Super Plasticizer
Percentage of steel fiber : 0.5%
Mix ratio =1 : 2.05 : 2.23 : 0.35 (C: FA: CA: W/C)

TABLE 4
MIX DESIGNATION

Mix ID	Combinations
CC	Conventional concrete
LWA20	20% FAA replacement for CA
LWA40	40% FAA replacement for CA
LWA60	60% FAA replacement for CA

TABLE 5 MIX DESIGN OF M30 GRADE CONCRETE

Mix ID	Mixture Constituents (kg/m^3)						
	C	FA	CA	FAA	W	SP	SF
CC	435.4	891.5	969.4	0	152.4	8.7	38.4
LWA 20	435.4	891.5	775.52	193.88	152.4	8.7	38.4
LWA 40	435.4	891.5	581.64	387.76	152.4	8.7	38.4
LWA 60	435.4	891.5	387.76	581.64	152.4	8.7	38.4

B. Results and Discussions

1) Properties of Aggregates

The properties of both Natural aggregates and Fly Ash aggregates found as per IS 2386(Part 3) -1963 and the test results are tabulated in Table 6.

TABLE 6 COMPARISON OF AGGREGATE PROPERTIES

S. No	Property	Natural Aggregate	Fly Ash Aggregate
1	Specific gravity	2.65	1.4
2	Impact Value	15.63%	27.78%
3	Crushing value	12.77%	19.42%
4	Water absorption	0.9%	16.8%
5	Bulk density (loose)	1490 kg/m^3	830 kg/m^3
6	Bulk density (dense)	1626 kg/m^3	895 kg/m^3
7	Void ratio	38.65	35.84

From the comparison of the properties of both aggregates, it can be inferred that the density of fly ash aggregate is nearly 50% of the conventional aggregate. The water absorption of fly ash aggregate is more than the permissible limit (10%), according to IS code. The crushing and impact value of both aggregates are well within the permissible limit (45) according to IS code. The void ratio of both the aggregates are nearly same. The impact value of fly ash aggregate is almost double than the impact value of natural aggregates.

2) Slump Test

The workability of fresh concrete was determined by slump test, and the result is shown in the Figure 3.

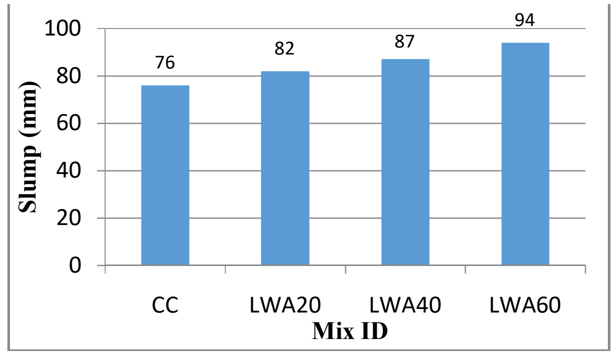

FIGURE 3 SLUMP VALUE

From the figure, the results indicate that there is an increase in the slump value as the FAA content in the concrete increases.

3) Compressive strength of cube

The compressive strength test was carried out for the cubical specimens for partial replacement of coarse aggregate and addition of steel fiber for 3, 7 and 28 days of curing. The test results are tabulated in the Table 7.

TABLE 7 COMPRESSIVE STRENGTH OF CUBE

S.NO	MIX ID	COMPRESSIVE STRENGTH (MPa)		
		3-DAY	7-DAY	28-DAY
1	CC	20.9	28.2	33.5
2	LWA20	22.3	31.4	35.3
3	LWA40	30.5	36.8	41.6
4	LWA60	27.3	34.5	39.2

From the above values it can be concluded that LWA40 produced optimum value than the conventional concrete. And also LWA 20 and LWA 60 produced greater values than conventional concrete.

4) Split Tensile Strength of Cylinder

The split tensile strength test was carried out for the cylindrical specimens for 28 days. The test results are tabulated in Table 8.

TABLE 8 SPLIT TENSILE STRENGTH OF CYLINDER

S.NO	MIX ID	SPLIT TENSILE STRENGTH (MPa)
		28-DAY
1	CC	3.92
2	LWA20	5.12
3	LWA40	4.61
4	LWA60	4.04

From the tabulated values it is found out that the LWA20 mix produce optimum Split tensile strength of 5.12 MPa which is greater compared to the conventional concrete. After the maximum value next combination LWA40 and LWA20 have lesser tensile strength than the optimum but higher than the conventional concrete.

5) Flexural Strength of Prism

The flexural strength test was carried out for the prism specimens for 28 days of curing. The test results are tabulated in Table 9.

TABLE 9 FLEXURAL STRENGTH OF PRISM

S.NO	MIX ID	FLEXURAL STRENGTH (MPa)
		28-DAY
1	CC	6.28
2	LWA20	6.58
3	LWA40	5.85
4	LWA60	5.81

From the obtained flexural strength values LWA20 produced optimum value than the other combinations compared to conventional concrete. And LWA40 and LWA60 combination carried less flexural stress than conventional concrete. Two point load condition is followed while carrying out the test.

6) Density of concrete

The density of concrete is calculated for both fresh and hardened concrete and the test results are tabulated in Table 10.

TABLE 10 DENSITY OF CONCRTE

S.NO	MIX ID	WET DENSITY (kg/m^3)	DRY DENSITY (kg/m^3)
1	CC	2434	2571
2	LWA20	2356	2420
3	LWA40	2267	2303
4	LWA60	2198	2253

CONCLUSIONS

Based on the findings presented, the following conclusions are drawn :

- The results of the comparison of aggregate properties indicate that the density of fly ash aggregate is 895kg/m^3 while that of natural aggregate is 1626kg/m^3.
- The water absorption of the fly ash aggregate is 16.8% and is greater than the permissible limit.
- The results of fresh concrete indicate that there is a increase in the workability as the amount of LWFA increases in the concrete.
- The compressive strength of Light Weight Fly ash Aggregate Concrete (LWFAC) reinforced with steel fibers, increased by 5.37%, 24.18% and 17.01% than that of control concrete, for LWFA replacement of 20%, 40% and 60% respectively.
- The tensile strength of Light Weight Fly ash Aggregate Concrete (LWFAC) reinforced with steel fibers, increased by 30.88%,17.85% and 3.19% than that of control concrete, for LWFA replacement of 20%, 40% and 60% respectively.
- The flexural strength of Light Weight Fly ash Aggregate Concrete (LWFAC) reinforced with steel fibers, increased by 4.78% than that of control concrete, for LWFA replacement of 20% and decreased by 6.85% and 7.48% than that of control concrete, for LWFA replacement of 40% and 60% respectively.
- The density of fresh concrete, decreased by 9.7% than that of control concrete, for LWFA replacement of 60% and the density of hardened concrete, decreased by 12.37% than that of control concrete, for LWFA replacement of 60%.

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