Experimental Investigations on Mechanical Properties of Artificial Aggregate Concrete

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Abstract— The creation of artificial aggregates from fly ash facilitates the use of a substantial proportion of fly ash in concrete. This component has recently gained popularity worldwide because to its extensive use, which reduces environmental degradation and the depletion of natural resources. Aggregate is used as an inert filler in concrete manufacture to add bulk volume and rigidity. The chemical and physical properties of fly ash aggregate have been determined. The M20, regular concrete, and lightweight concrete mix designs are evaluated. Natural aggregate replaces fly ash aggregate in M20 grade conventional concrete at percentages of 5%, 10%, 15%, and 20%, with a water-to-cement ratio of 0.44. A 0.45 water-to-cement ratio is used to make lightweight concrete out of fly ash. Concrete's mechanical properties are examined for 7, 14, and 28 days, in that sequence. According to this study, lightweight concrete has a lower compressive strength than standard concrete. Furthermore, the outcomes of replacing concrete with various quantities of fly ash aggregates were investigated, and it was determined that 15% of the replacement with fly ash aggregate demonstrates better strength than other percentages and weights of the concrete.

Index Terms- Artificial aggregates, flyash aggregates, lightweight concrete, slump, split tensile strength, flexural strength, and compressive strength

I. INTRODUCTION

Among the most often used building materials in the world is concrete. Its amazing versatility and capacity to take on almost any desired shape account for its enormous popularity. Concrete can be made to fulfil precise criteria for both compressive and flexural strength, which makes it a very adaptable material for a wide range of building applications. Nevertheless, its usefulness goes beyond simple flexibility.

Cement, fine aggregates, coarse aggregates, and water are the basic ingredients of concrete. This mixture is the foundation of this sturdy building material. However, concrete may profit from the addition of cutting-edge chemicals and admixtures as well; it is not just restricted to these essential components. Concrete can benefit from these additions in a number of ways, including increased workability, durability, and certain performance qualities.

A type of concrete called lightweight concrete, often referred to as lightweight aggregate concrete, is designed to be significantly lighter than ordinary concrete while maintaining a respectable level of strength and durability. This kind of concrete is used in many construction applications where it reduces structural weight and improves insulating properties. It is important to remember that the properties of lightweight concrete can be greatly influenced by the lightweight aggregate used and the mix design. The proper formulation of lightweight concrete must be carefully chosen by engineers and builders to meet the specific requirements of their construction projects.

Building materials called lightweight aggregates are used to create lightweight concrete, which has a lower weight and density than conventional concrete but yet maintains a respectable level of strength and durability. Due to their low density, which is achieved by combining less dense materials with more conventional aggregates like sand and gravel, these aggregates are frequently selected.

Fly ash aggregate is a lightweight, porous construction material derived from the residue of coal combustion in power plants. Fly ash is derived from flue gases produced during combustion and is commonly disposed of in landfills. It may, however, be recycled into fly ash aggregate, which has various beneficial properties for a wide range of building applications.

II. EXPERIMENTAL INVESTIGATION

MATERIAL

A. Cement

The cement used in this study is Ordinary Portland Cement (OPC 53), which complies with IS 12269:2013. TABLE I shows the results of the physical tests on cement.

Table 1

NAME OF THE TEST	CEMENT
Specific Gravity	3.15
Fineness	8%
Consistency	33%
Initial Setting time	30mins

B. Fine aggregate

The experiment involved passing locally available M-sand through a 4.75 mm IS sieve to reduce it to 150 µm, verifying its specific gravity of 2.65 and zone II. TABLE II shows the fine aggregate characteristics calculated according to IS 2386:2021.

C. Coarse aggregate

In this investigation, 12.5mm graded aggregates that are easily obtained locally were used. It validates the specific gravity of 2.73. TABLE II presents the fine aggregate characteristics as established by IS 2386:2021.

D. Flyash aggregate

The flyash aggregates used in this investigation ranged in size from 8 to 12 mm. It checks the specific gravity of 1.8. IS 2386:2021 was used to determine the characteristics of flyash aggregates, as shown in Table II.

III. MIX DESIGN

The M20 grade of concrete, with a compressive strength of 20 N/mm^2, was employed in both experimental and analytical studies. The concrete mix percentage and material quantities were calculated using the IS 10262:2019 requirements. The low-weight concrete mix design is computed. Table 3 lists the material amounts for the different concrete compositions. This experiment looked at F100, conventional concrete, and four different amounts of fly ash aggregates (5%, 10%, 15%, and 20%) compared to the weight of natural coarse aggregates.

TEST SPECIMENS

The fresh and hardened properties of lightweight and conventional concrete with five mix proportions were studied experimentally using Indian standards. The workability of the concrete was evaluated using a slump test in line with IS 1199:2018. Concrete cubes of 100 x 100 x 100 mm were cast and tested over 7, 14, and 28 days. The compressive strength of the concrete was determined in accordance with IS 516: 2018. Concrete cylinders with a diameter of 100 mm and a length of 200 mm were cast and tested for 28-day split tensile strength in accordance with IS 5816: 1999. Concrete prisms measuring 500 x 100 x 100 mm were tested to determine the 28-day flexural strength as per IS 516: 2018.

IV. RESULTS AND DISCUSSION

EFFECT OF WEIGHT

Weight testing is conducted on all concrete mixes, and it is discovered that increasing the proportion of fly ash aggregates decreases the weight of the concrete, as seen in Figure 1. F100 weighs 27.47% less than standard concrete. The substitution of 5%, 10%, 15%, and 20% fly ash aggregate reduces weight by 11.15%, 14.12%, 15.3%, and 18.8%, respectively.

Table II

Name of the test	Fine aggregates	Coarse aggregates	Flyash aggregates
Specific Gravity	2.65	3	1.95
Water Absorption (%)	1.92	0.8	10.04
Fineness Modulus	3.1	-	-
Sieve Analysis	Zone II	-	-
Bulk density (kg/m^3)	1711	1602	1365
Impact value (%)	-	34	32

Table III

Mix ID	Cement (kg/m^3)	Fine Aggregate (kg/m^3)	Coarse Aggregate (kg/m^3)	Flyash Aggregate (kg/m^3)	Water (kg/m^3)
F00	401	911	794	-	189
F100	294	602	-	504	174
F05	401	911	754	40	189
F10	401	911	715	79	189
F15	401	911	675	119	189
F20	401	911	635	159	189

EFFECT OF WORKABILITY

A slump test is used to assess workability for all concrete proportions, and it is obvious that the slump value of concrete reduces as the amount of fly ash aggregates increases, as shown in Figure 2. The slump cone test results show that adding fly ash aggregate impairs workability because it absorbs more water than natural coarse aggregate. F100 concrete has a slump that is 26.45% lower than standard concrete. When conventional concrete was substituted with 5%, 10%, 15%, and 20% fly ash aggregates, the slump decreased by 10.37%, 12.78% , 14.11% and 14.98%, respectively.

EFFECT ON COMPRESSIVE STRENGTH

Figure 3 illustrates the compressive strength data for all specimens of different proportions. Figure 3 demonstrates that the compressive strength of F100 concrete decreased by 24.15% when compared to conventional concrete. The highest compressive strength was achieved with a 15% replacement of fly ash aggregates representing a 0.74% increase over conventional concrete. Further increases in fly ash aggregate resulted in lower compressive strength because to its low density.

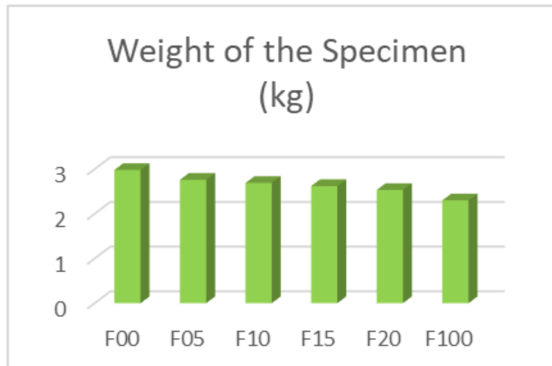

Figure 1 Weight of the Specimen

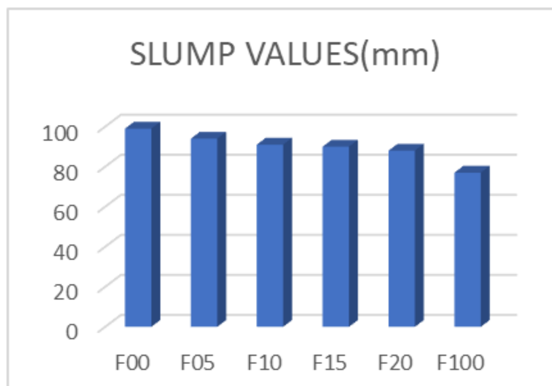

Figure 2 Slump values

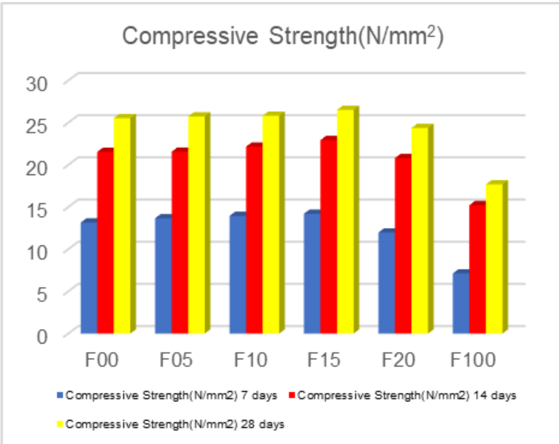

Figure 3 Compressive strength

EFFECT ON SPLIT TENSILE STRENGTH

Figure 4 shows the 28-day compressive strength results for all specimens with various fractions. The graph indicates that using fly ash aggregates increases split tensile strength by 19% compared to standard concrete. F100 concrete has an 18.4% lower split tensile strength than regular concrete. The split tensile strength is higher at 15%, and adding more fly ash aggregates diminishes it. The increase in fly ash aggregates after 15% results in a reduction owing to porosity and permeability.

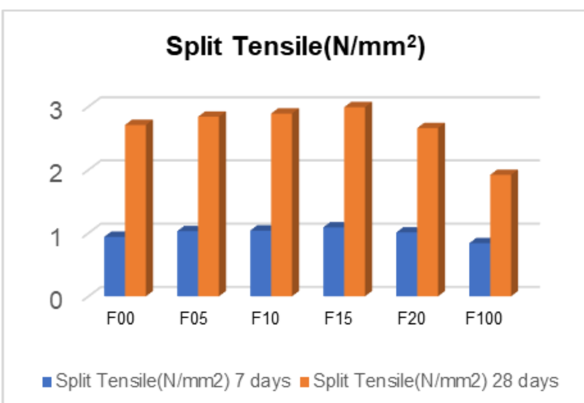

Figure 4 Split tensile strength

EFFECT ON FLEXURAL STRENGTH

Figure 5 depicts the 28-day compressive strength findings for all specimens of varying proportions. The maximum flexural strength is achieved with 15% fly aggregate substitution, which is 6.78% more than ordinary concrete. The flexural strength of lightweight concrete is 27.4% lower than standard concrete. The flexural strength at 5%, 10%, 15% and 20% seems to be 3%, 5.21%, and 10.5% lower than the F15. This is due to lack of homogenous structure and reduced density, at higher percentage of replacement of fly ash aggregate reduces flexural strength.

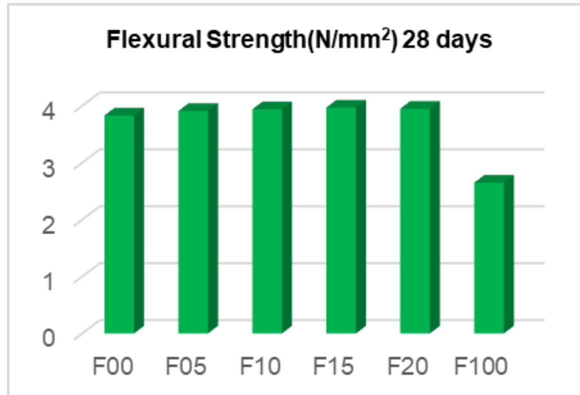

Figure 5 Flexural strength

CONCLUSION

1) Fly ash aggregates can replace coarse aggregates up to 15%. A 15% replacement of fly ash aggregate resulted in a better compressive strength than other mixtures. However, increasing the amount of fly ash aggregate results in a decrease because to its low density, high water absorption, and hollow spherical shapes.
2) Incorporating fly ash aggregates reduces weight. Therefore, lightweight concrete may be created utilizing flyash aggregates.
3) Adding additional fly ash aggregates to concrete decreases workability owing to high water absorption.
4) Concrete with 100% fly ash aggregate has lower strength after 28 days compared to conventional concrete.
5) Replacing fly ash aggregates by more than 15% decreases split tensile strength due to porosity, permeability, and spherical shape.
6) Using 20% fly ash aggregates decreases flexural strength due to brittleness, lack of uniformity, and lower density.

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