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Experimental Study on Concrete Prepared By Artificial Aggregate

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Abstract— ***Introducing fly ash aggregate concrete, a sustainable solution revolutionizing the construction industry. Derived from coal combustion residue, fly ash aggregates offer enhanced strength, durability, and environmental benefits. This research paper explores the mechanical properties, and applications of fly ash aggregate concrete. By analyzing its performance in structural elements and comparing it with traditional concrete, we aim to highlight its potential as a viable alternative. With a focus on sustainability and resource efficiency, this study contributes to the ongoing discourse on sustainable construction materials, paving the way for a greener and more resilient built environment. This experimental study investigates the viability and performance of concrete produced using fly ash artificial aggregate (FAAA) as a substitute for natural coarse aggregate. The escalating demand for concrete, coupled with environmental concerns regarding the depletion of natural resources, necessitates exploring alternative materials for construction. Fly ash, a byproduct of coal combustion, poses disposal challenges due to its environmental impact. However, through innovative processes, fly ash can be transformed into artificial aggregates suitable for concrete production. Preliminary findings indicate that concrete utilizing FAAA exhibits comparable mechanical properties to conventional concrete, with certain mixes demonstrating superior performance in terms of durability. The study also explores the economic and environmental implications of utilizing FAAA in concrete production, considering factors such as material availability, energy consumption, and waste reduction.***

Keywords— ***Fly ash, fly ash Artificial Aggregate, Concrete, Conventional aggregates.***

I. INTRODUCTION

1.1 General Overview

Concrete, a vital construction material, is primarily composed of cement, aggregates, and water. Its versatility, durability, and affordability make it ubiquitous in infrastructure projects worldwide. However, concerns over resource depletion and environmental impact drive research into alternative materials like fly ash artificial aggregate, aiming for sustainable construction solutions. The construction industry is constantly seeking innovative solutions to address the dual challenges of meeting rising demand while mitigating environmental impacts. Concrete, as one of the most widely used construction materials, plays a pivotal role in infrastructure development worldwide. However, the production of concrete heavily relies on the extraction of natural aggregates, leading to concerns about

resource depletion and environmental degradation. In this context, the utilization of alternative materials in concrete production has emerged as a promising avenue to achieve sustainable development goals.

Fly ash, a byproduct of coal combustion in thermal power plants, is abundantly available globally. Despite its potential as a supplementary cementitious material in concrete, large quantities of fly ash are typically disposed of in landfills, posing environmental hazards. However, recent advancements in materials science and engineering have paved the way for transforming fly ash into artificial aggregates, offering a sustainable solution to both waste management and construction material supply chain challenges.

This experimental study aims to investigate the feasibility and performance of concrete prepared using fly ash artificial aggregate (FAAA) as a substitute for natural coarse aggregate. By harnessing the intrinsic properties of fly ash and employing innovative manufacturing techniques, FAAA can be tailored to meet the specific requirements of concrete production. The research seeks to evaluate the physical, mechanical, and durability properties of concrete incorporating FAAA, with a focus on its compressive strength, flexural strength, water absorption, and resistance to chloride ion penetration.

The introduction of FAAA into concrete has the potential to offer several benefits, including reduced reliance on natural aggregates, decreased environmental impact through fly ash utilization, and improved long-term durability of concrete structures. Moreover, the economic viability of FAAA production and its implications for sustainable construction practices will be examined. By addressing these key aspects, this study contributes to advancing knowledge in the field of sustainable construction materials and provides valuable insights for industry stakeholders, policymakers, and researchers seeking to promote environmentally responsible building practices. In recent times, fly ash has been used much more often in India. Sand and stone mining

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is prohibited in many cities and towns around the globe, including India, and both coarse and fine aggregates needed to make concrete are becoming more rare. Future developments will make this issue much worse. These aggregates are not prone to alkali-aggregate interaction in addition to being lightweight. Currently, India generates over 100 million tons of fly ash each year. According to forecasts based on India's energy demands, by 2023, this number will have increased to around 200 million tons, since coal will continue to be the primary energy source in both India and the rest of the globe. Fly ash is used in the construction sector for a variety of purposes, including fire resistance, insulating screed, soil stabilization, road creation, bridge abutment, land reclamation, void filling, and roof insulation. The substitute materials include coarse aggregate made of fly ash. The method has produced acceptable aggregates, and studies have shown that adding 20–100% artificial aggregate and 80–0% natural stone to medium-grade concrete does not impair the material's qualities. Aggregates are utilized extensively in concrete.

1.2 Objective of the Project

Depending on the particular aims and scope of the project, the objectives of this experimental research on concrete produced with fly ash artificial aggregate may change. Nonetheless, these are a few typical goals that investigators may try to accomplish in this kind of investigation.

1.2.1 Mechanical Property Assessment: Use fly ash artificial aggregate to measure compressive strength. Assess the effect of artificial aggregate use by comparing these attributes with conventional concrete mixes.

1.2.2 Workability and Setting Time: Evaluate the new concrete mix's workability by looking at elements like slump. In order to comprehend how the addition of fly ash artificial aggregate affects these features, you need also evaluate the setting time.

1.2.3 Impact on the Economy and Environment: Examine the advantages for the environment and the economy of using fly ash artificial aggregate in the manufacturing of concrete. This might include assessing resource efficiency, waste material reduction, and cost reduction.

1.2.4 Optimization of Mix Proportions: To get the required durability and mechanical qualities, ascertain the best mix proportions for concrete that contains fly ash artificial aggregate. Investigate several material combination to determine the test blend.

1.2.5 Comparative Studies: Evaluate how fly ash artificial aggregate performs in concrete in comparison to other supplemental cementitious materials and traditional concrete mixtures. Determine the possible benefits and adverse effects of employing artificial aggregate made of fly ash.

1.2.6 Suitability for Various Applications: Determine if fly ash artificial aggregate concrete is appropriate for a certain use, such as precast elements, pavements, or structural parts. Examine how well it performs under various loading scenarios.

1.3 Significance of Project

This analysis focuses on the ashes produced by coal-operated thermal power plants, including data on their overall creation, consumption, and disposal. Additionally, alternate methods for using these ashes in cement and concrete are discussed. The residue produced from coal combustion is classified as fly ash (FA), bottom ash (CBA), and pond ash (PA). Previously, the ashes produced by coal industry furnaces were immediately disposed of in landfill sites, necessitating a large amount of land for storage. However, the increasing need for space to dispose of trash has become an issue, prompting researchers to seek significant alternatives to outright dumping. The sense of urgency has prompted the concrete industry to explore the use of coal ashes as a more affordable and environmentally friendly building material. Extensive research has been conducted to evaluate the fresh, mechanical, and durability qualities of concrete by using various types of coal ashes. Prior literature reviews examine the impact of various coal ashes on the fresh, strength, and durability characteristics of a certain kind of concrete. Unlike the present research, the prior studies focused on evaluating the fresh, strength, and durability qualities of various types of concrete by using FA, CBA, and PA. The present analysis examines the general characteristics of traditional concrete and self-compacting concrete, using both natural and recycled particles. In addition, advancements in technology have led to the production of well-burnt ashes from burning coal. These ashes have excellent pozzolanic properties, which has encouraged the concrete industry to consider using them as a substitute for cement, particularly in the case of fly ash (FA), and as a fine aggregate in the case of coal bottom ash (CBA) and pulverized ash (PA). The replacement of more than 50% of cement in concrete effectively addresses and resolves the issues often connected with regular concrete. In summary, incorporating ashes into concrete, either as a binding agent or as filler in the form of aggregate, leads to the preservation of natural resources and results in cost-effective, sustainable, long-lasting, and energy-efficient concrete.

II. MATERIALS

In order to ensure that the materials' qualities fall within the bounds specified by pertinent regulations and guidelines, they were initially examined using standard processes. Fly ash's physical, morphological, and chemical behaviors were contrasted and analyzed to determine whether or not they were suitable for use in concrete mixes.

2.1 Aggregates (Coarse and Fine)

Concrete is a composite material that appears likes artificial stone. It is formed by combining non-reactive coarse

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and fine aggregate particles with cement paste. Hence, admixture or aggregate constitutes the primary constituent of concrete. These components may be regarded as comprising around 70-75% of the whole composition of concrete.

2.1.1 Fine Aggregate:

This category of aggregate has a particle size that allows 90% of it to pass through a sieve with a diameter of 4.75 mm. This category include both naturally occurring and artificially produced sand. The minimal measurement of sand may be defined as 0.07 mm. Mixtures with particle sizes ranging from 0.002 mm to 0.06 mm are categorized as silt, whereas particles smaller than that are referred to as clay. Fine aggregates may be categorized into the following classifications:

(i) Natural sand is derived from the natural weathering and breakdown of stones and rocks.
(ii) Artificial sand, produced by the process of grinding stones.
(iii) Artificial sand is produced by pulverizing gravel.

Fine aggregates may be categorized as coarse sand, medium sand, and fine sand based on their size. Typically, it is more advantageous to use coarse sand in the construction of buildings.

Figure 1. Fine Aggregate

2.1.2 Coarse aggregate:

Refers to the kind of aggregate that is retained on a maximum sieve size of 4.75 mm, often known as the 1.S. Sieve. The sorts of materials mostly include: (i) Stone grit (ii) Naturally occurring gravel (iii) A combination of the two mentioned before.Coarse aggregate is used in various size classifications such as 40 mm, 20 mm, 16 mm, and 12.5 mm in dense mixtures.

Figure 2. Coarse Aggregate

Table 1. Physical and mechanical properties of Natural Aggregate

Property	Result
Los Angeles Abrasion %	24
Impact %	10
Combined Flakiness and elongation %	29.5
S.G Coarse aggregate	2.71
S.G of fine aggregate	2.65
Water absorption of coarse aggregate, %	0.7
Fineness Modulus fine aggregates	2.2
Water absorption of fine aggregate, %	1.4

2.2 Fly Ash

Fly ash is a fine, powder substance that is produced when pulverized coal is burned in power plants for electricity production. The composition is mostly comprised of silica, alumina, and iron, with lesser quantities of calcium, magnesium, and trace metals. There are two primary classifications of fly ash depending on its chemical composition.

Class F Fly Ash: is generated from the combustion of aged anthracite and bituminous coal, which are known for their higher density and greater hardness. The substance has a low amount of calcium and has pozzolanic qualities, which means that it combines with calcium hydroxide when water is present to create compounds that have cement-like properties.

Class C Fly Ash: is produced by the combustion of relatively young lignite or sub-bituminous coal. It has a greater amount of calcium and exhibits both pozzolanic and self-cementing characteristics, enabling it to create cement-like compounds when it reacts with water.

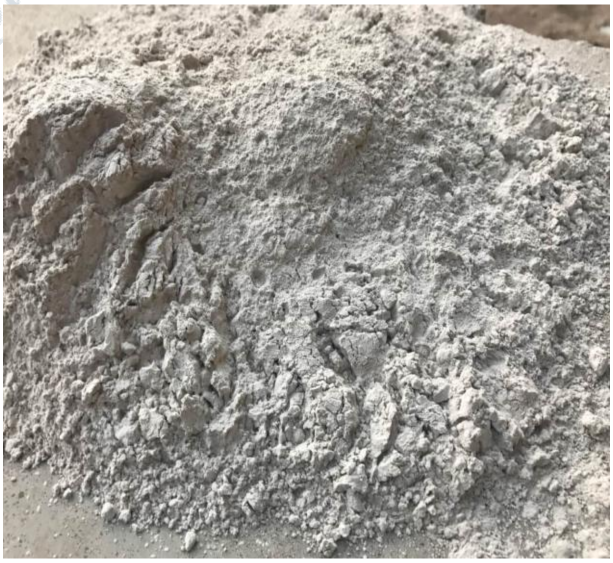

Figure 3. Fly Ash

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Table 2 Chemical composition of Fly Ash by using EDS spectrum

Spectrum Label	Spectrum 8
O	57.94
Mg	1.42
Al	2.80
Si	12.04
K	1.03
Ca	16.77
Fe	8.00
Total	100.00

2.2.1 EDS spectrum of Fly ash

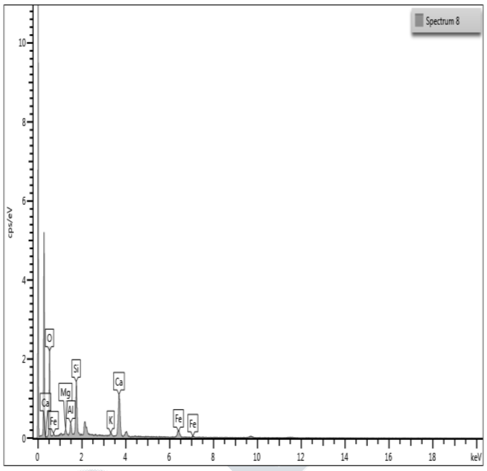

Figure 4. EDS spectrum of Fly ash

Table 3. Chemical composition of Fly Ash by using EDS spectrum

.	O	Mg	Al	Si	K	Ca	Fe
Max	57.9	1.42	2.8	12.4	1.03	16.77	8
Min	57.9	1.42	2.8	12.4	1.03	16.77	8
Average	57.9	1.42	2.8	12.4	1.03	16.77	8
Standard Deviation	0.0	0.00	0.0	0.0	0.00	0.00	0

FA is collected from a nearby thermal/electric power generation plant. The entire sum of the ingredients O, Al, and Fe was determined to be larger than 68%, confirming the class F fly ash standards in accordance with BIS 3812 (part 1). The physical characteristics and elemental composition of FA are demonstrated in the following Table 2 and 3, in the same order. EDS (Energy dispersive spectroscopy) analysis revealed that the fly ash is largely made of Silica, Alumina, and iron (Figure. 4).

Table 4. Physical characteristics of fly ash

Property	Fly Ash	BIS Value
Fineness(m^2/kg)	423	>320
Lime Reactivity N/mm^2	5.5	4.5
Particle retained on 45 micron IS sieve wet sieving in %	24.3	<34

2.3 Artificial Aggregates:

Artificial aggregates may be created using several processes like as autoclaving, cold bonding, or sintering. Research investigations indicate that the use of waste items, such as mining wastes as artificial aggregates yields improved outcomes. The production of sintered fly ash aggregate has been extensively researched by While fly ash contains CaO, which enhances its binding properties, the addition of Ca(OH)2 increases the efficiency, duration, and dose of binders in the palettization process. Additionally, this process facilitates the creation of CSH gel via a reaction with the silica found in fly ash, resulting in improved strength. Therefore, 2% of the total weight of fly ash is supplemented with Ca (OH)2 to enhance agglomeration. Additionally, a greater rate of hydration may be attained by the creation of bigger CSH gel. The binder element in Ordinary Portland cement constitutes 8% of its composition. The fly ash and binder are thoroughly combined for an initial duration of 2 minutes in a pelletizer, after which water containing Ca(OH)2 is sprayed over the mixture. Applying water should be performed with caution to ensure that it is distributed evenly and not concentrated in one area, thereby preventing the formation of muddy clumps. The newly produced pellets were then stored at room temperature for one day to achieve initial strength, followed by a 28-day water curing process. The incorporation of calcium hydroxide resulted in improved initial strength of the pellets, facilitating their convenient handling.

Figure 5. Fly Ash Aggregate

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Table 5. Properties of Fly Ash Artificial Aggregate

Property	Result
Impact %	17
Combined Flakiness and elongation %	29.5
S.G Coarse aggregate	1.7
Water absorption of coarse aggregate, %	12

2.4 Cement

Cement is a very effective bonding substance used in civil construction. The production of cement, as we know it today, began around 150 years ago and quickly supplanted the use of quicklime. It has consistently shown superior performance compared to lime in all circumstances. Cement is produced by the combination of calcareous and argillaceous materials, which are then subjected to high temperatures in a furnace and then finely ground. When combined with water, it solidifies into a stone-like substance. Unlike lime, this substance does not undergo slaking when water is added, but instead begins to set. Cement is used in the production of masonry mortar and concrete. Currently, there are several varieties of cement available, each designed for certain applications and circumstances. However, for ordinary building purposes, only Ordinary Portland Cement (O.P.C.) is used. In the following pages, we will provide a comprehensive analysis of this cement.

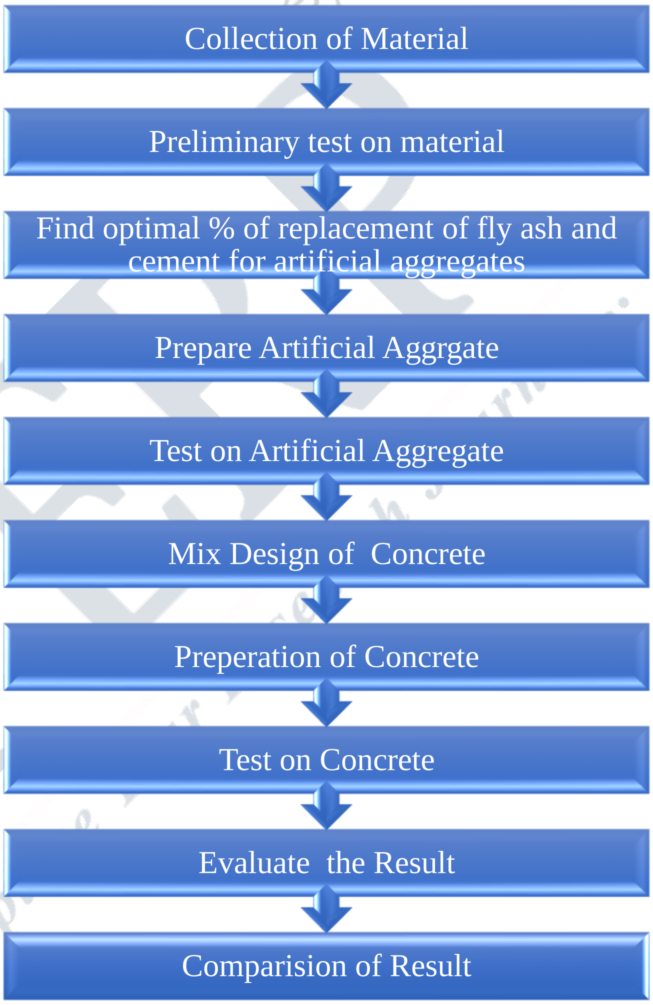
Figure 6. Cement

Table 6. Physical properties of cement used

Property	Test result	BIS value
Fineness	254	>225
Initial setting time (min)	35	>30
Initial setting time (min)	550	<600
Consistency (%)	26	-
Compressive strength (N/mm^2)	25	>23

Property	Test result	BIS value
7 Days		
14 days	36	>33
28days	44	>43

III. METHODOLOGY TO BE ADOPTING



3.1 Gathering Materials:

Acquire the necessary materials, including cement, aggregates (Natural & Artificial Aggregate) & water.

3.2 Preliminary Test on Material:

All the preliminary test its results and which has done on material are mentioned mention above in material sections.

3.3 Find optimal percentage of replacement of fly ash and cement for production of artificial aggregates

Using a concrete mixer, various proportions of cement and fly ash were combined. By using the water cement ratio of 0.45, water was added to the mixture. Up until the fly ash aggregates were fully formed, the contents of the drum were extensively stirred. Palletisation is the process used to create

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fly ash aggregates. After trial on various percentage of cement and fly ash some test on performed on those aggregates sample then the result of cement:fly ash 35:65 is best. So we do produce the aggregates in this ratio.

3.4 Mix Design of Concrete:

Here we adopted the The concrete mix ratio (by Mix Design) is 1:1.45:2.87, where 1st part is cement, 2nd parts are fine aggregates (sand), and 3rd parts are coarse aggregates (Natural & Artificial Aggregate).

3.5 Preperation of Concrete:

Measure and combine the dry ingredients (cement, fine aggregates & Coarse Aggregate) in the correct proportions. The concrete mix ratio (by Mix Design) is 1:1.45:2.87, where 1st part is cement, 2nd parts are fine aggregates (sand), and 3rd parts are coarse aggregates (Natural & Artificial Aggregate). During preparation of concrete, natural coarse aggregate is replaced (0%, 20%,40%,60%,80% & 100%) by Fly Ash based Artificial Aggregate.Gradually add water to the dry mixture while continuously mixing. The amount of water used is critical and should be precisely controlled, as it affects the workability and strength of the concrete. The adopted water-cement ratio is 0.42 (According to IS 10262:2009).

Figure 7. Mixing of Concrete Ingredients

3.6 Placement:

Place the concrete into the molds (15x15x15) cm, ensuring proper consolidation and the elimination of air pockets.

Figure 8. Placement of concrete

3.7 Compaction:

Compact the concrete to eliminate voids and improve its strength. This can be achieved through compaction by tamping rod & by using concrete surface vibrators.

3.8 Finishing:

Finish the surface of the concrete to achieve the desired texture or appearance.

3.9 Curing:

Protect the freshly placed concrete from drying out too quickly by curing it. This involves maintaining adequate moisture and temperature conditions for a specified period, typically 28 days.

Figure 9. Curing

IV. RESULT AND DISCUSSION

The fly ash aggregate has been produced using the process of pelletizing and cold bonding. Different proportions of replacement have been used to conduct an experimental investigation on the strength properties of lightweight aggregate (LWA)'aggregate. The round form of fly ash aggregate provides superior workability in comparison to the angular natural gravel. The low specific gravity of fly ash, compared to natural materials, makes it a lightweight aggregate. This characteristic allows fly ash to be utilized as a substitute material for coarse aggregates in concrete, since it occupies a significant volume. Consequently, this also significantly mitigates the issue of landfill dumping.

4.1 Compressive Strength Test

By definition, the compressive strength of a material is that value of uniaxial compressive stress reached when the material fails completely. The compressive strength is usually obtained experimentally by means of a compressive test on 15cm concrete cubes. The test was conducted in 120T compressive 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.

Table 7 Compressive strength and % Replacement

Age of Concrete (days)	AA(%):NA(%)	Compressive Strength (MPa)
7 Days	0(%):100(%)	23.4
	20% :80%	22.51
	40%:60%	18.07
	60%:40%	16.44
	80%:20%	14.51
	100%:0%	16.29
14 Days	0(%):100(%)	33.3
	20% :80%	32.88
	40%:60%	30.06
	60%:40%	29.92
	80%:20%	27.97
	100%:0%	26.36
28 Days	0(%):100(%)	37.92
	20% :80%	35.99
	40%:60%	32.88
	60%:40%	31.4
	80%:20%	30.21
	100%:0%	30.07

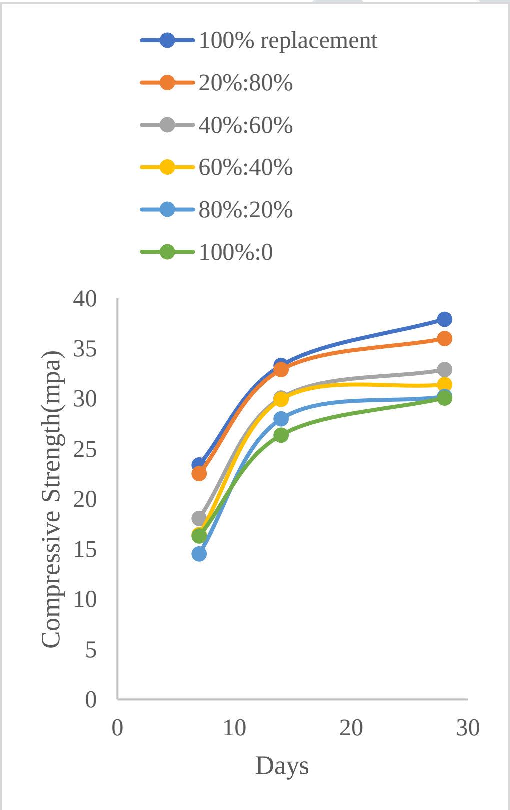

Figure 10. Comparison of Compressive Strength

V. CONCLUSIONS

The particle size distribution, specific gravity, bulk density, and impact test on aggregate were conducted. M30 grade of concrete was considered. The conventional and artificial fly ash aggregates concrete cubes and beam specimens were cast. All the specimens were cured in curing tank. The normal and fly ash aggregate concrete cube specimens were tested for 7,14,28 days. Compressive and strength tests were conducted on these normal and artificial fly ash aggregates concrete specimens.

While comparing the compressive strength, the fly ash aggregate concrete with aggregate made from cement fly ash proportion 20:80 showed high compressive strength than control concrete at all ages of concrete.

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