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PARTIAL REPLACEMENT OF CEMENT WITH FLY ASH IN CONCRETE MIX DESIGN

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ABSTRACT

The construction industry's quest for sustainable and environmentally responsible practices has led to innovative approaches in concrete design. Cement production, while essential for construction, is a significant source of carbon emissions. In an effort to reduce the environmental impact of concrete, the partial replacement of cement with supplementary cementitious materials (SCMs) has gained prominence. Among these materials, fly ash, a byproduct of coal combustion in thermal power plants, has shown great promise. Typically disposed of as waste in landfills, fly ash can be repurposed as an SCM, offering dual benefits of waste reduction and enhanced concrete properties. This study delves into the utilization of fly ash as a partial replacement for cement in concrete design. It investigates various mix proportions, evaluating their effects on essential properties such as compressive strength, workability, and sustainability. The findings not only reveal the potential for reducing carbon emissions in the construction sector but also highlight the economic and environmental advantages of incorporating fly ash in concrete design. This research contributes to the ongoing quest for greener construction practices and more resilient concrete structures.

Keywords: Fly Ash, Compressive Strength, Split Strength.

I. INTRODUCTION

In India, the concept of a smart city is now growing swiftly. Taking into account that green and sustainable growth is the main priority. The foundation is infrastructure, and intelligent material is required to carry out that work appropriately. A smart material is one that provides better results at a reasonable price. These industrial wastes contaminate both the nearby soil and the natural fertiliser. To address the issues of resource depletion and environmental deterioration, the construction industry is undergoing a paradigm shift toward sustainable and environmentally friendly practises. Concrete, a fundamental component of construction, is crucial to this change. Cement manufacture, a key ingredient in concrete, generates significant amounts of carbon emissions, which add to environmental degradation and climate change. In order to lessen these environmental Concrete, a fundamental component of construction, is crucial to this change. Cement manufacture, a key ingredient in concrete, generates significant amounts of carbon emissions, which add to environmental degradation and climate change. Researchers and professionals from the industry have been looking into alternative materials and methods to improve the sustainability of concrete in order to lessen these negative effects on the environment. The partial substitution of cement with supplemental cementitious materials (SCMs), such as fly ash, is one noteworthy tactic. Thermal power stations produce fly ash as a byproduct of burning coal, and its landfill disposal has caused environmental issues. Fly ash, however, can have a number of advantages when used as an SCM in concrete. It not only reduces waste in a sustainable manner but also enhances the strength, durability, and workability of concrete. This method is appealing for implementing greener construction methods since it conserves natural resources while also helping to protect the environment by minimising carbon emissions. This introduction lays the ground for a thorough investigation of the benefits and drawbacks of using fly ash instead of cement in concrete, illuminating the possibilities for a more environmentally friendly construction sector.

II. DESIGN MIX MATERIALS

1. Cementitious Material: Fly Ash

The non-combustible mineral part of coal makes up fly ash. One of the byproducts of combustion, fly ash is made up of the tiny particles that rise with the flue gases. Bottom ash is ash that does not rise. Fly ash is typically used in an industrial setting to describe the ash created during coal burning. The fly ash may contain higher levels of contaminants than the bottom ash in some situations, such as when burning solid waste to produce electricity. By mixing the fly and bottom ash together, the proportional levels of contaminants are brought into the range necessary to qualify as nonhazardous waste in a given state, whereas unmixed fly ash would be within the range necessary to qualify as hazardous waste.

Figure 1: Fly Ash

Cement: The following specific gravity of regular Portland cement (Ultra-Tech Cements of 53 grades) was employed: 3.15, 32.5 % consistency, and 54 MPa compressive strength

Table 1. Properties of Cement (OPC 53 grade)

Sr.No	Physical Properties Of Cement	Result	Requirement As Per Is:8112-1989
1	Specific Gravity	3.15	3.10-3.15
2	Standard Consistency (%)	28%	30-35
3	Initial Setting Time (Hours,Min)	36 Min	30 Minimum
4	Final Setting Time (Hours,Min)	178 Min	600 Maximum
5	Compressive Strength-7 Days	37.49 N/Mm^2	43 N/Mm^2
6	Compressive Strength -28 Days	51.42N/Mm^2	53 N/Mm^2

Fine Aggregate Natural sand with a maximum size of 4.75 mm and specific gravities of 2.6 and 2.63 was employed (zone II).

Figure 2: Fine aggregate

Coarse Aggregate: Utilized were natural aggregates with a maximum particle size of 40 mm, a specific gravity of 2.7, and a fine modulus of 7.51

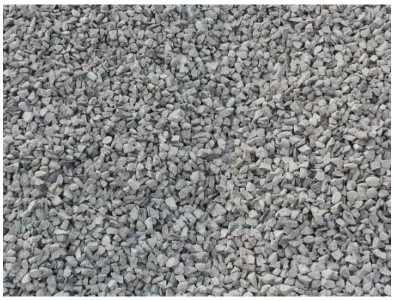

Figure 3: Coarse aggregate

Table 2: Properties of Aggregates

Property	Fine Aggregate	Coarse Aggregate	
		20 Mm	10 Mm
Fineness Modulus	3.35	7.54	3.19
Specific Gravity	2.38	2.76	2.69
Water Absorption (%)	1.20	1.83	1.35
Bulk Density (Gm/Cc)	1753	1741	1711

Water: Concrete was prepared using drinking water from BIT SINDRI. The water samples are uniformly good and fit for drinking. The PH value must be lower than 7. Since it actively participates in the chemical reaction with cement, water is a crucial component of concrete.

III. DESIGN MIX METHODOLOGY

a. Design Mix

S. No	Concrete Type	Concrete Design Mix Proportion (By Weight)				Cement Replacement By Fly Ash
		W/C Ratio	C	F.A	C.A	
1	A1-M25	0.40	1.00	1.01	2.50	-
3	B1-M25	0.40	0.90	1.01	2.50	0.10
4	B2-M25	0.40	0.80	1.01	2.50	0.20
5	B3-M25	0.40	0.70	1.01	2.50	0.30
6	B4-M25	0.40	0.60	1.01	2.50	0.40

In accordance with IS 10262:2009, a mix M25 grade was created, and this mix was used to create the test samples.

Table 3: Concrete Design Mix Proportions

For compressive and split strength, standard metallic cube moulds (150*150*150 mm) were cast. The hand-filled concrete cubes were compacted using a table vibrator.

Figure 4: Compressive strength testing

The specimens were demolded and placed in water for various testing ages after 24 hours. The average compressive and split strengths of three samples were measured for each age. The test was conducted using compression testing equipment with a 200 MT capacity. The testing setup for compressive and split strength on the testing apparatus is shown in Figures 6 and 7.

Figure 5: Split strength testing

IV. RESULTS

The compressive strength results are compiled in Table-4 and split strength in Table-5. The compressive strength vs % replacements of cement results are graphically shown in figure 8 and 9. The same for split strength is in figure 9. 28 days for M25.

Table 4: Compressive Strength and % Change of Strength at 7, 14, 28 days for M25

Concrete grade	Concrete type	Average ultimate compressive strength at			% change in compressive strength at		
		7 days (N/mm^2)	14 days (N/mm^2)	28 days (N/mm^2)	7 days	14 days	28 days
M 25	A1-M25	28.77	32.00	44.59	0	0	0
	B1-M25	21.33	30.96	34.67	25.86	3.35	22.24
	B2-M25	16.15	23.70	24.30	43.86	25.93	45.50
	B3-M25	13.04	15.11	22.22	54.67	52.78	50.16
	B4-M25	9.93	14.81	17.33	65.48	53.71	61.13

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Table 5: Split Strength and % Change of Strength at 56 days for M25

Concrete type	Average spilt strength forcube @56 days N/MM^2	% change in split strength @56 days
A1-M25	3.44	2.32
B1-M25	3.52	-6.68
B2-M25	3.21	-25.87
B3-M25	2.55	-29.94
B4-M25	2.41	0

Table 6: Materials for designed M25

Concrete Grade	% ReductionIn Cement	Materials					Total Cost (M^3)	% ChangeIn Cost
		Cement (Kg/M^3)	Fine Aggregate (Kg/M^3)	Coarse Aggregate (Kg/M^3)	Grit (Kg/M^3)	Fly Ash (Kg/M^3)		
M 25	0	479	485.75	718.22	478.81	0	4135.12	0
	10	431.1	485.75	718.22	478.81	47.9	3850.59	6.88
	20	383.2	485.75	718.22	478.81	95.8	3566.07	13.76
	30	335.3	485.75	718.22	478.81	143.7	3281.54	20.64
	40	287.4	485.75	718.22	478.81	191.6	2997.02	27.52

V. CONCLUSION

The following results are reached based on short experimental research into the compressive & split strength of concrete:

- When fly ash was replaced with cement, compressive strength decreased. Compressive strength and split strength both decline when fly ash percentage rises.
- Utilizing fly ash in concrete can reduce disposal costs for the coal and thermal industries and create "greener concrete for buildings.
- According to the cost research, reducing the cement percentage lowers the cost of concrete while simultaneously lowering strength.
- This study comes to the conclusion that fly ash can be an inventive supplemental cementitious construction material, but engineers must make wise choices.

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