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Research Article

Experimental Inventigation On Partial Replacement Of Cement With Fly Ash In Concrete Mix Design

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ARTICLE INFO	ABSTRACT

The potential of fly ash as a substitute for cement in the concrete industry has been explored since the early 19th century. Researchers have investigated the compressive strength of concrete by replacing varying proportions of cement with fly ash. However, the optimal amount of fly ash to be used depends on factors such as its properties, application methods, geographic location, and climatic conditions. Numerous studies have examined the use of fly ash as an additive in cement, admixture, and concrete, as well as its potential as a cement replacement material. Most of these studies focused on replacing small percentages of cement in lower-grade concretes. This study aims to investigate the effects of fly ash on the compressive strength of high-grade concretes, considering different curing periods and quantities of fly ash. The research also explores the impact of fly ash on the mechanical properties of fresh and hardened concrete by mixing different grades of concrete with varying percentages of fly ash. The compressive strength of concrete was measured at 7, 28, and 60 days, and the compaction factor was determined from workability measurements. A comparative study was conducted, considering different rates and strengths as parameters. By partially replacing cement with fly ash, the compressive strength of concrete was evaluated, and the results were found to be effective and applicable. This study provides a comprehensive analysis of the effects of fly ash as a partial replacement for cement in concrete, aiming to determine the optimal quantity of fly ash for different concrete qualities that is acceptable, applicable, and economical. The study also explains the variations in compressive strength of different concrete qualities at various percentages of fly ash and curing periods.

Keywords: Cement, Fly ash, Admixtures, Ordinary Portland cement

1. INTRODUCTION

Concrete is the most widely used construction material globally, with cement being its primary binding agent. Over the past three decades, cement production has experienced rapid growth worldwide. India's cement production, in particular, is expected to triple by 2050. However, the environmental implications of cement production have raised concerns globally. The production process emits significant amounts of CO_2, with approximately one tonne of CO_2 released for every tonne of clinker manufactured. This contributes substantially to global anthropogenic carbon dioxide emissions, accounting for around 5-7%. The primary sources of gas emissions during cement manufacturing are fuel combustion and the decomposition of $CaCO_3$ into CaO and CO_2. To mitigate these harmful emissions, supplementary cementitious materials are being used to partially replace clinker. India has emerged as the second-largest cement producer worldwide, with an annual production of 280 million tonnes in 2014. The industry is expected to experience an annual growth rate of 8-10% in the coming years. As demand continues to rise, cement prices have been increasing due to escalating raw material costs. Fortunately, most Indian cement plants have adopted state-of-the-art technologies that prioritize energy and resource efficiency. Projections indicate that India's cement production will reach 550 million tonnes by 2020. To minimize the environmental impact, further improvements in efficiency are necessary. The increasing production of cement is expected to lead to proportional growth in emissions, unless significant changes are made to the production technology or cement composition. In this context, supplementary cementitious materials like fly ash offer a promising solution to reduce emissions and mitigate the environmental footprint of the cement industry.

2. Objectives

This research aims to explore the feasibility of utilizing fly ash as a sustainable alternative to traditional cement. To achieve this goal, the following specific objectives have been identified:
1. Investigate the physical and mechanical characteristics of concrete mixtures incorporating fly ash to determine its suitability as a building material.
2. Assess the viability of fly ash as a supplementary cementitious material in concrete applications.
3. Determine the optimal replacement ratio of fly ash to cement that yields the most desirable concrete properties, balancing performance, sustainability, and environmental considerations.

3.Materials and Methadolology

3.1 Materials

Cement: Ultra-Tech Cements of 43 grades, conforming to Ordinary Portland cement standards, was employed. Its physical characteristics included a specific gravity of 2.98 , consistency of 33%, density of cement is 1400 and compressive strength is 43 MPa after 28 days. Cemnt vastly discusses the classification, workability, strength, durability and mix design of cement concrete.

Figure 1: Cement

The above brand cement has been used to investigate the strength of cement after 28 days as per codal provision IS 4031-1988. The below enlisted table 1 shows the properties of cement.

Table 1: Properties of cement

S.NO.	Characteristics	Experimental Values	Specified Value
1.	Consistency of cement percentage	33 %	-
2.	Specific gravity	2.98	3.15
3.	Initial setting time (minutes)	35	Greater than 30 As per IS 4031
4.		282	Less than 600 As per IS 4031
5.	Compressive Strength (n/mm^2)		
a)	3 days		Greater than 23
b)	7 days		Greater than 33
c)	28 days		Greater than 43
6.	Soundness	1.00	10
7.	Fineness of Cement	5%	10% As per IS 269-1976

Fly ash: Fly ash is a fine, powdery byproduct generated during the combustion of pulverized coal in thermal power plants. It is primarily composed of oxides of silicon, aluminium, iron, and calcium, along with trace amounts of other elements. Due to its unique properties and widespread availability, fly ash has garnered significant attention in research and industrial applications. During this process the fly ash used was a finely divided residue obtained from the combustion of pulverized coal at a thermal power station. Prior to use, the fly ash was dried.

Figure 2: Fly Ash

Fine Aggregate: Fine aggregates are naturally occurring or manufactured materials that consist of small particles typically used in construction applications, particularly in concrete, mortar, and plaster. They play a crucial role in ensuring the strength, durability, and workability of construction materials. During this process the natural sand, classified under zone II, was used as the fine aggregate. Its properties included a maximum size of 4.75 mm, specific gravity of 2.6, and fineness modulus of 2.63.

Figure 3: Fine aggregates

Coarse Aggregate: Coarse aggregates are one of the essential components of construction materials, particularly in concrete, asphalt, and other building applications. They consist of larger particles than fine aggregates, providing bulk, strength, and stability to the mixture. In this study natural aggregates with a maximum size of 40 mm were employed as the coarse aggregate. They exhibited a specific gravity of 2.7 and fineness modulus of 7.51.

Figure 4: coarse aggregate

Water: Water is a crucial ingredient in concrete, playing a vital role in the chemical, physical, and workability properties of the mixture. It participates in the hydration of cement, which is essential for setting, hardening, and gaining strength in concrete. The quality, quantity, and type of water used significantly affect the performance and durability of concrete. Potable water, sourced from NIT Srinagar was used for concrete preparation.

3.2 Methodology

This section describes the work flow of current study what mixes while prepared with proportions and how many cubes were casted and what are the tests that were performed. The concrete mix design was performed for M25, M30, M35, and M40 grades, adhering to IS 10262-1982 and IS 456-2000 standards. The mix design took into account the properties of the concrete constituents. Concrete mixes with varying fly ash content percentages were produced by replacing 0% (reference concrete), 10%, 15%, 20%, 25%, 30%, 35%, and 40% of cement by weight. Cubic specimens (150 mm in size) were cast for compressive strength testing. The cubes were cast in stainless steel Molds and wet-cured at standard temperature until testing. The curing periods were 7, 28, and 60 days.

Table 2: Methodology table of M25, M30, M35 and M40

Mix proportion	No. of Cubes	Test Carried out	Equipment required
M25R10 10% fly ash similarly M30R10 M35R10 M40R10	Six cubes of 100mm x100mmx100mm	1) Slump test 2)water absorption 3)compressive strength test	1)compressive machine 2) weighing machine 3) slump cone
M25R15 20% fly ash Similarly M30R15 M35R15 M40R15	Six cubes of 100mm x100mmx100mm	1) Slump test 2)water absorption 3)compressive strength test	1)compressive machine 2) weighing machine 3) slump cone
M25R20 20% fly ash Similarly M30R20 M35R20 M40R20	Six cubes of 100mm x100mmx100mm	1) Slump test 2)water absorption 3)compressive strength test	1)compressive machine 2) weighing machine 3) slump cone
M25R25 25% fly ash Similarly M30R25 M35R25 M40R25	Six cubes of 100mm x100mmx100mm	1) Slump test 2)water absorption 3)compressive strength test	1)compressive machine 2) weighing machine 3) slump cone
M25R30 30% fly ash Similarly M30R30 M35R30 M40R30	Six cubes of 100mm x100mmx100mm	1) Slump test 2)water absorption 3)compressive strength test	1)compressive machine 2) weighing machine 3) slump cone

3.3. Water absorption of concrete cube

Water absorption of a concrete cube is an important test to assess the porosity and permeability of concrete, which directly influences its durability and performance in various environmental conditions. As per IS 456 2000 the weight of 100x100x100 mm concrete cube should not be more than 2.6kg

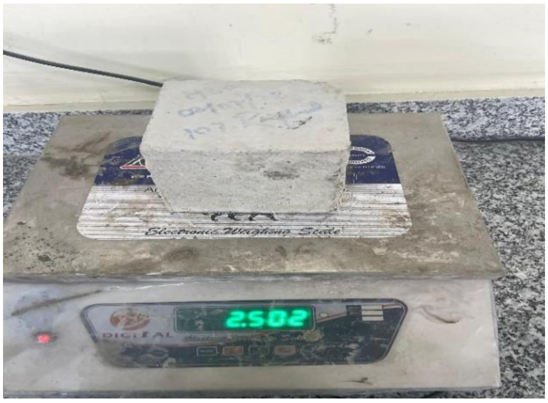


Figure 4: Water absorption tests

3.4 Compressive strength test

To investigate the compressive strength test of the specimen prepared by fly ash, cube of 100mmx 100mm used in this work. Around 80-90 cubes were casted. Batching of materials with required proportion as per grade M25, M30, M35 and M40 mixed in dry then fly ash also added to make the mixture homogenous, then water was added in required dosage. Now the cube mould is first prepared by oiling to make surface smooth, then this concrete is filled into mould in three layers with tamping rod for proper compaction. The mould is then levelled with the help of trowel. This mould is then detached after 24 hours. Then the cube is the allowed for curing into water tank which contains the water which meets the codal provision of IS 456-2000. The specimen is then tested after 7, 28 and 60 days under CTM as per Is code 516-1959.

Figure 4: Compression Test

3.5 Slump Test

The slump test is a simple and widely used method to measure the workability or consistency of freshly mixed concrete. It evaluates the ease with which concrete can be mixed, placed, and compacted without segregation. This test is essential for ensuring that concrete meets the required specifications for various construction projects. The slump test is a simple and widely used method to measure the workability or consistency of fresh concrete. It provides an indication of the ease with which concrete can flow and be placed. The test is especially useful in ensuring uniformity in concrete during construction.

Figure 5: Slump test

4. RESULTS AND DISCUSSIONS

4.1 Compressive strength

The compressive strength variations of different concrete mixes, in relation to curing time and fly ash percentage, are illustrated in Figures 1 to 8. These figures demonstrate the temporal evolution of concrete strength. A notable observation is that the rate of strength gain over time differs among the various mixes. While some mixes exhibit low initial strength that increases significantly with time, others display high early strength that plateaus or even decreases over time. This variability highlights the complex interactions between fly ash, curing time, and concrete strength.

Table 3:Variation in compressive strength of Different Concrete Mixes for 7,28 and 60 Days Curing and Different percentages of Fly Ash.

% of fly ash	GradeM25 Compressive strength in N/mm2			GradeM30 Compressive strength in N/mm2			GradeM35 Compressive strength in N/mm2			GradeM40 Compressive strength in N/mm2		
	7	**28**	**60**	**7**	**28**	**60**	**7**	**28**	**60**	**7**	**28**	**60**
0	12.5	21.5	23	15	25.5	28	17.5	30	32.5	20	34	37
10	13	22	23.5	16	26	28.5	18	30.5	33	21	34.5	37.5
15	13.5	22.5	24	17	26.5	29	19	31	33.5	22	35	38
20	14	23	24.5	18	27	29.5	20	31.5	34	23	35.5	38.5
25	15	23.5	25	19	27.5	30	21	32	34.5	24	36	39
30	14	22	24	17	26	27	19	31	32	22	34	38
35	13	21	23	16	25	26	17	30	31	20	32	37
40	11	20	22	14	24	25	16	29	30	19	31	35

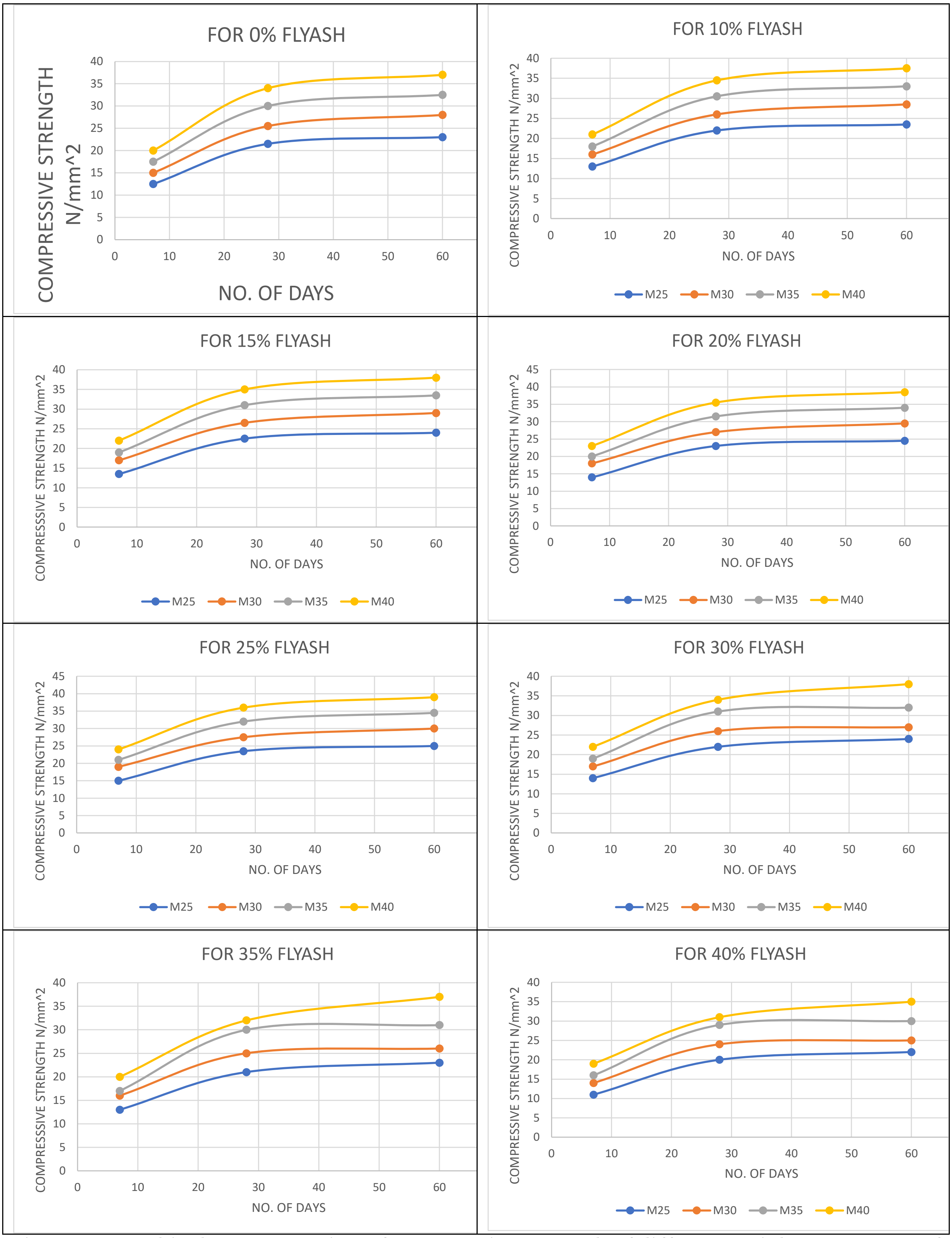


Figure 6: Graphical representation of compressive strength of different weight percentage of Ash

4.2 slump Test

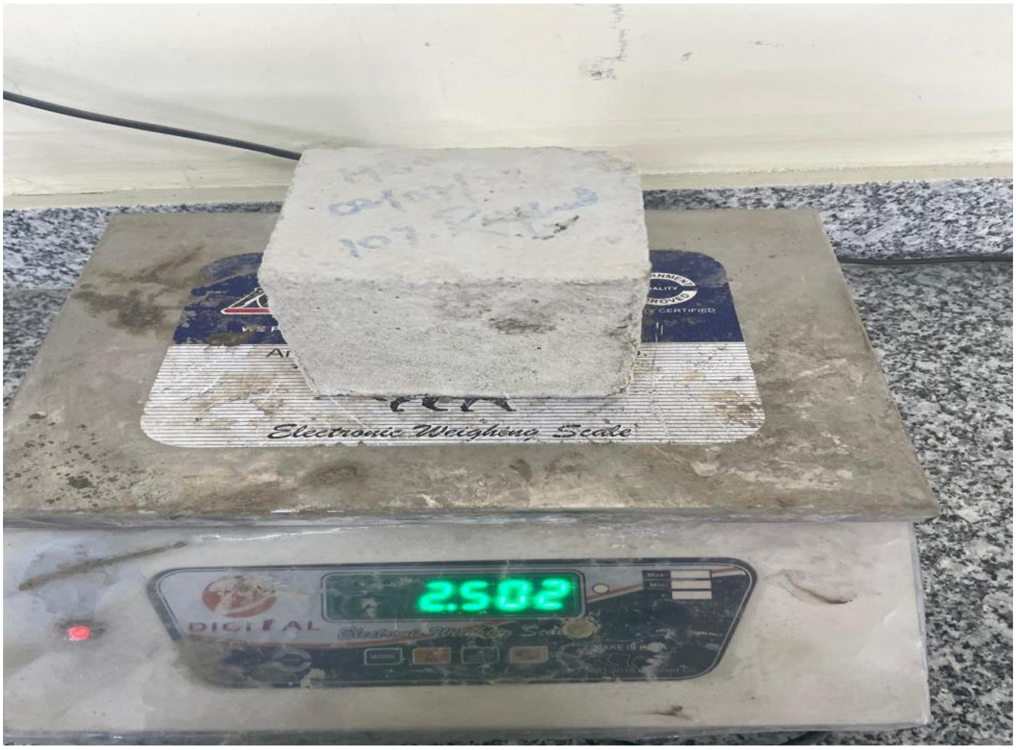
Slump test is a method used to measure of workability or consistency of concrete that means the ease with which the concrete can be placed or mixed. The slump measued during the cube casting is given in the table below.

cubes	slump
1-24	80mm
25-49	76mm
50-73	82mm
74-95	81mm
96-120	79mm

4.3 Weight concrete cube

The water absorption test is used to measure the density of concrete cube. The equation to measure the porosity and density of concrete. The weight of concrete measured during the test is given in the table below.

cubes	Average weight
Sample 1	2.471kg
Sample 2	2.433kg
Sample 3	2.502kg
Sample 4	2.421kg
Sample 6	2.440kg



3. CONCLUSIONS

The experimental findings lead to the following conclusions:
1. The results indicate that excessive fly ash replacement can compromise the compressive strength of concrete mixes. Therefore, it is essential to maintain an optimal fly ash content, ideally not exceeding 25%, to ensure the structural integrity of various concrete mixes.

2. The data suggests that while fly ash can contribute to significant strength gains between 7 and 28 days, its increasing proportion can adversely affect the early strength of concrete. Notably, the variation in early strength is more pronounced than in later strength.
3. A comprehensive analysis of the results reveals that, depending on the fly ash percentage and curing time, certain high-strength mixes can be more economical than their lower-strength counterparts.
4. The experimental findings confirm that concrete incorporating fly ash exhibits enhanced workability and durability compared to traditional cement concrete.
5. Furthermore, the results demonstrate that increasing fly ash content can effectively reduce concrete shrinkage, thereby improving its overall performance and longevity.

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