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EFFECT OF FLY ASH ON COMPRESSIVE STRENGTH AND WORKABILITY OF CONCRETE

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Abstract
Ordinary Portland cement (OPC) is one of the main ingredients used in concrete production and remains largely irreplaceable in the civil construction industry, despite being a versatile but relatively high-cost material. Large scale cement production causes significant environmental problems, including CO_2 emissions, while also contributing to the depletion of natural resources. This has led researchers to investigate the use of industrial by-products as supplementary cementitious materials in concrete. The main parameter investigated in this study is normal concrete (1:2:4 at 0.5 w/c) with partial replacement of cement by fly ash at 0%, 3%, 6%, 9%, and 12% by weight. This paper presents a detailed experimental study on compressive strength at 7 and 28 days, along with workability. Test results indicate that the use of fly ash in concrete improved performance in both strength and durability, with the highest 28-day compressive strength of 28.55 MPa recorded at 12% fly ash replacement, compared to 21.75 MPa for the control mix.

INTRODUCTION

Concrete is a widely used construction material for various types of structures due to its structural stability and strength. During the first half of the last century, concrete structures were commonly built using Ordinary Portland Cement (OPC) and plain round mild steel bars. The relative ease of procuring constituent materials regardless of their quality and the assumption that almost any combination of these constituents would produce usable concrete led to a degree of complacency in practice, with strength often prioritized over durability. OPC remains one of the main ingredients used in concrete production and has no true alternative in the civil construction industry. Unfortunately, cement production involves the emission of large amounts of carbon dioxide into the atmosphere, making it a major contributor to the greenhouse effect and global warming. It has therefore become necessary either to find alternative materials or to partially replace cement with supplementary materials. Identifying materials that can serve as alternatives or supplements to cement supports global sustainable development while minimizing environmental impact. Substantial energy and cost savings can result when industrial by-products are used as a partial cement replacement. Fly ash, Ground Granulated Blast Furnace Slag (GGBFS), Rice Husk Ash (RHA), High Reactive Metakaolin (HRM), and silica fume are among the pozzolanic materials commonly used for this purpose.

Numerous studies, both in Pakistan and internationally, have investigated the impact of using these pozzolanic materials as cement replacements, with encouraging results. The

addition of fly ash to concrete offers several advantages, including higher strength, improved durability, and reduced cement consumption. The optimum fly ash replacement percentage for achieving maximum 28-day strength typically ranges from 3% to 12%, with cement replacement levels up to 12% shown to increase compressive strength in normal concrete. This paper examines the suitability of fly ash as a partial cement replacement by testing varying replacement percentages and comparing the resulting strength parameters against conventional concrete.

METHODOLOGY

2.1 Materials and Methods

The materials utilized in this study were:

- Ordinary Portland Cement (OPC)
- Fine Aggregate (Bolhari Pakistan)
- Coarse Aggregate
- Fly Ash
- Water

A.CEMENT

Cement is a fine powder by adding water it will bind aggregate together, as a hard mass after the hydration of water with in few days. In this research we use Lucky OPC. It confirms the specification of BS-12.

Table 1: Properties of Cement

S.No	Name of Test	Test Finding	
01	Setting Time (ASTM C- 191)	Initial	145 minutes
		Final	310 minutes
02	Soundness (Le-Chatillers) Expansion BS-12		1 mm
03	Compressive Strength (ASTM C-109)	3Days	2250psi (15.5MPa)
		7Days	3150psi (21.7MPa)
		28Days	4910psi(33.8MPa)

B. Fine Aggregate

Bholari hill sand was used as fine aggregate, conforming to Zone II of BS 882. Properties of the fine aggregate are shown in Table 2.

Table 2: Properties of fine aggregate

S.No	Property	Result
01	Specific gravity	2.63
02	Water Absorption	2.55
03	Grading Zone	II

C. Coarse Aggregate

Crushed aggregate of 20 mm and 12.5 mm size, with specific gravity of 2.67 and water absorption of 0.52%, was used, procured from the local market in Karachi, Pakistan.

D. Fly Ash

The sample of fly ash was collected from the Lakhra coal-fired power plant in Sindh, Pakistan, which operates using coal as fuel. This power plant is approximately 35 km from Jamshoro and 193 km from Karachi, Sindh. Fly ash generated from the Lakhra power plant is a very fine powder recovered from the flue gases produced during coal combustion for electric power generation.

Table 3 CHEMICAL ANALYSIS OF FLY ASH

Constituent	Chemical analysis
SiO2	21.53
Al2O3	15.45

Fe2O3	32.09
SO3	9.98
CaO	6.9
MgO	3.7
Na2O	1.79
K2O	0.16
LOI	8.34

E. Water

According to ACI guidelines, water used for preparing concrete should be of potable quality. In this investigation, ordinary tap water fit for drinking was used in preparing all concrete mixes and for curing.

Table 1. Mix Composition Rice husk Ash

Mix ID	Cement %	Fly Ash %	Aggregate %	W/C Ratio
M1	100	00	100	0.5
M2	97	03	100	0.5
M3	94	06	100	0.5
M4	91	09	100	0.5
M5	88	12	100	0.5

3. Experimental Methodology

3.1 Workability

Workability is defined as the property of freshly mixed concrete or mortar that determines the ease and homogeneity with which it can be mixed, placed, consolidated, and finished. Workability was measured using the slump cone test.

3.2 Experimental Procedure

Standard cube specimens (150 mm × 150 mm × 150 mm) were used to determine compressive strength. Three specimens were tested at each of 7 and 28 days for every fly ash replacement level, resulting in a total of 30 cubes cast for strength testing. Constituent materials were weighed and mixed by hand. The water-binder ratio (W/B, where binder = cement + fly ash replacement) was maintained at 0.5 by weight of binder. Concrete was placed in layers, with each layer compacted before the next was added. Specimens were demolded after 24 hours, cured in water for periods of 7 and 28 days, and subsequently tested for compressive strength.

RESULTS AND DISCUSSION

4.1 Workability

Workability refers to the ease with which a concrete mix can be handled and placed, and is commonly assessed using the slump test. Figure 1 illustrates the workability of concrete mixes with varying proportions of fly ash as a partial replacement for cement. Slump values increased progressively with increasing fly ash content, from 40 mm at M1 (control, 0%) to 43 mm, 45 mm, 48 mm, and 52 mm at 3%, 6%, 9%, and 12% fly ash replacement, respectively. This improvement in workability can be attributed to the spherical particle shape and fine texture of fly ash, which reduces internal friction between particles and improves the flow of the mix.

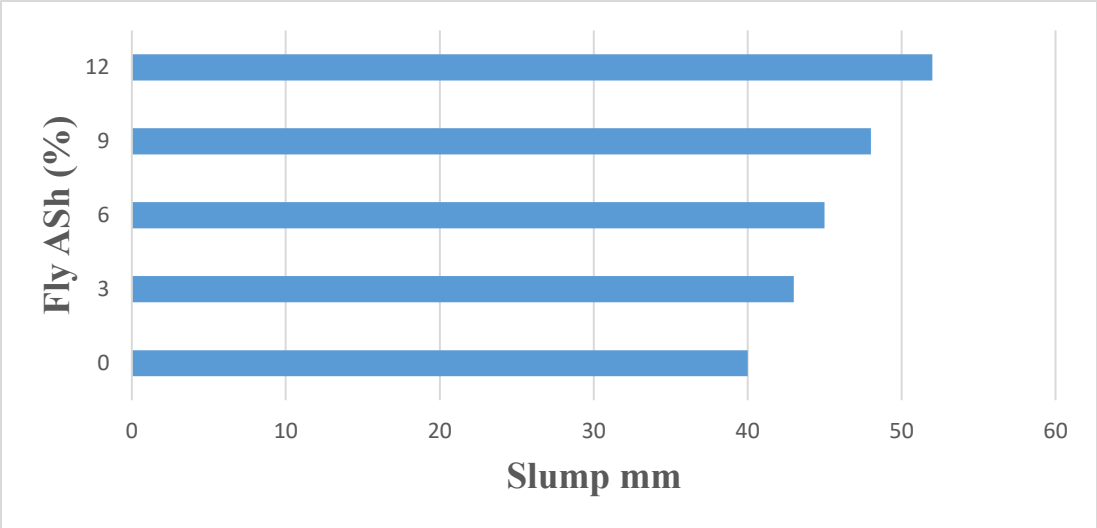


Figure 1: Slump vs Fly Ash (%)

4. 2 Compressive Strength

Figure 2 presents the results of laboratory compressive strength tests conducted at curing periods of 7 and 28 days. The results show that cube strength increases progressively as the percentage of fly ash increases. At 28 days, compressive strength rose from 21.75 MPa for the control mix (0% fly ash) to 22.9 MPa, 24.05 MPa, 25.25 MPa, and 28.55 MPa at 3%, 6%, 9%, and 12% fly ash replacement, respectively representing an increase of approximately 31% at the 12% replacement level compared to the control. A similar trend was observed at 7 days, with strength increasing from 15.01 MPa (control) to 19.7 MPa at 12% fly ash replacement. Based on these results, fly ash is recommended for use in concrete at up to 12% replacement, offering both improved compressive strength and reduced cement consumption

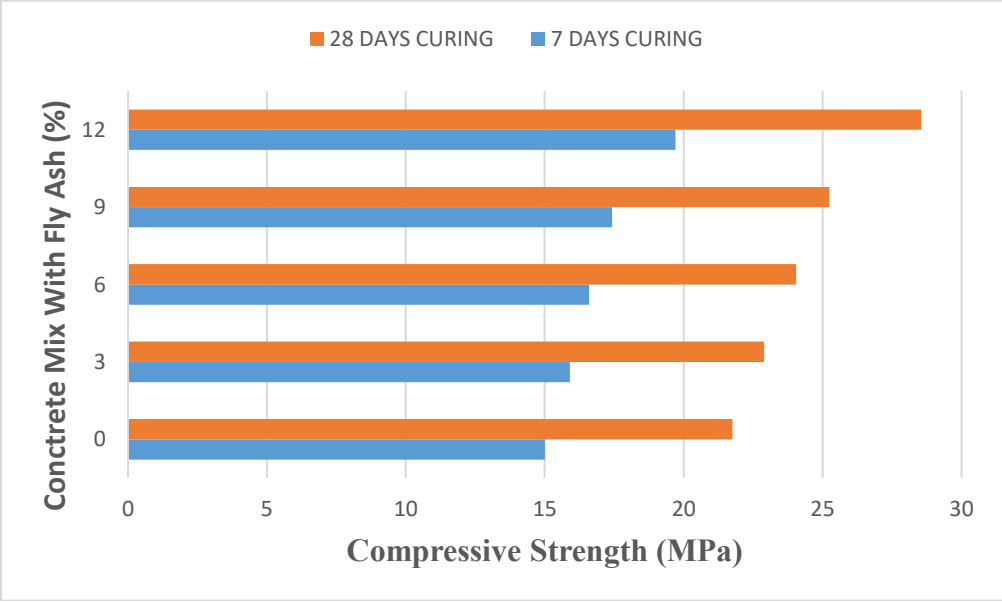


Figure 2: Compressive Strength of Fly Ash Concrete Mixes at 7 and 28 Days

5. CONCLUSION

Based on the findings of this investigation, the following conclusions were drawn:

- The research revealed that fly ash, an industrial by-product, can be effectively utilized in concrete production as a partial cement replacement.
- Cubes made with 12% fly ash showed the highest compressive strength after 28 days of curing (28.55 MPa), with strength increasing progressively as fly ash content increased from 0% to 12%, representing an improvement of approximately 31% over the control mix.
- These results indicate that concrete containing up to 12% fly ash can be effectively utilized in structural applications requiring higher compressive strength.
- Workability increased progressively with increasing fly ash content, with slump values rising from 40 mm (control) to 52 mm at 12% replacement, remaining within an acceptable range for practical use.

This research indicates that incorporating industrial by-products such as fly ash in concrete production can achieve two important outcomes: improving mechanical performance while reducing cement consumption, and mitigating environmental harm by reducing CO_2 emissions from cement production. Additionally, it offers a method for the beneficial reuse of an industrial waste material that would otherwise require disposal.

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