The Asian Review of Civil Engineering
ISSN: 2249-6203 (P); 2583-7893 (E)
Vol.13 No.1, 2024, pp.1-5

DOI: https://doi.org/10.70112/tarce-2024.13.1.4206

Experimental Study on Partial Replacement of Cement with Fly Ash in Concrete Mix Design

Sheikh Hayath Mahmud*, Md. Maruf Hasan and Liton Chandra Das
Pundra University of Science & Technology (PUB), Bogura, Bangladesh
E-mail: hayathmahmud@gmail.com*, mh.maruf101@gmail.com, litondaspubce@gmail.com
(Received 20 January 2024; Revised 6 February 2024; Accepted 25 February 2024; Available online 17 March 2024)

Abstract - **The development of advancements in concrete technology might lessen the amount of natural resources destroyed, thereby reducing the pollutants released into the environment. Currently, industries produce large amounts of fly ash, which adversely affects the environment and human health. Recent studies have shown that additional cementitious materials can improve various concrete qualities. These materials include fly ash, slag, silica fume, metakaolin, rice husk, and hypo sludge. These materials not only enhance the properties of fresh and hardened concrete but also help constructors save money. The aim of this study is to determine whether thermal industrial waste can partially replace cement in concrete manufacturing. Specifically, fly ash was tested as an additional cementitious ingredient to replace conventional concrete. It was added to the cement in different amounts: 0% (fly ash-free), 5%, 10%, and 20% by weight of cement to produce the M-20 mix. Concrete mixtures were created, tested, and their compressive strengths were compared to those of conventional concrete. Results were collected up to 28 days after curing to assess the strength attributes. The use of 5% fly ash results in a decrease in strength, but it is not significant. For 5% replacement of cement, the strength was found to be 2984.57 psi, which is satisfactory.**
Keywords: **Fly Ash, Industrial Wastes, Cementitious Materials, Partial Replacement, Compressive Strength**

I. INTRODUCTION

In today's rapidly expanding smart city concept in Bangladesh, sustainable and environmentally responsible development is the main priority [1]. Infrastructure acts as the cornerstone, and effective materials are required to accomplish this. Even in situations with minimal costs, efficient materials produce superior outcomes. Regrettably, natural soil fertility is compromised by the frequent dumping of industrial waste on neighbouring property [2].

Fly ash is one such substance produced when ground or powdered coal is burned in thermal plants that generate electricity [8]. For concrete, fly ash is a useful mineral additive. It is a by-product of burning coal in power plants to produce electricity. Fly ash is a natural pozzolan, meaning it is a siliceous or siliceous and aluminous substance that chemically combines with calcium hydroxide (CH) to generate composites with cementitious qualities. Fly ash significantly affects several characteristics of concrete, both when the concrete is fresh and when it has hardened [7].

The manufacture of cement requires a significant amount of energy, which is one of the main causes of CO2 emissions in the cement sector. The cement and concrete industry can meet the increased demand in building while simultaneously lowering environmental pollution by substituting some cement with pozzolanic materials like fly ash [5]. Cement, fine aggregates, coarse aggregates, and water are the usual ingredients of concrete; fly ash can replace part of the cement. Despite the paucity of research, fly ash concrete shows potential for use in both reinforced and ordinary concrete.

II. METHODOLOGY

The successive processes are to be done in order to accomplish the necessary objectives, have shown below.

A. Selection of Materials

1. Supplementary Cementious Material

Fly ash is the term used to describe the ash that is left behind after burning coal in an industrial setting. Fly ash may have higher levels of impurities than bottom ash in some cases, such as when solid waste is burned to create power [3].

When fly ash and bottom ash are combined, the proportionate amounts of contaminants fall under the range that allows the waste to be classified as nonhazardous in that state. Fly ash would be considered hazardous waste if it were to remain unmixed [2].

Fig. 1 Fly Ash

Fig. 2 Natural sand

2. Fine Aggregate

Zone II natural sand, with a maximum size of 4.75 mm and a specific gravity of 2.6 and fineness modulus of 2.63, was utilized.

3. Cement

Shah Cement, a regular Portland cement with a specific gravity of 3.15, consistency of 32.5%, and compressive strength of 54 MPa, was utilized. It is a 52.5 N grade cement.

TABLE I PROPERTIES OF CEMENT (OPC 52.5 N GRADE)

Sl. No.	Physical Properties of Cement	Result	Requirement As ACI Code
1	Specific Gravity	3.15	3.10-3.15
2	Standard Consistency (%)	28%	30-35
3	Initial Setting Time	33 Min	30 Minimum
4	Final Setting Time	170 Min	600 Maximum
5	Compressive Strength-7 Days	37.49 N/mm^2	43 N/mm^2
6	Compressive Strength -28 Days	51.31 N/mm^2	53 N/mm^2

Fig. 3 Cement

Fig. 4 Coarse aggregate

4. Coarse Aggregate

A maximum size of 40 mm was achieved by using natural aggregates with a specific gravity of 2.7 and a fine modulus of 7.51.

TABLE II PROPERTIES OF AGGREGATES

Property	Fine Aggregate	Coarse Aggregate	
		20 mm	10 mm
FM	3.35	7.54	3.19
Specific Gravity	2.38	2.76	2.69
Moisture Absorption (%)	1.20	1.83	1.35
Bulk Density (gm/cc)	1753	1741	1711

5. Water

For the creation of the concrete, water from Pundra University of Science & Technology was used. The water samples are regularly of high quality and fit for consumption. The pH level need to be lower than 7. As it actively participates in chemical reactions with cement, water is an essential component of concrete [7].

B. Manufacture of the Specimen

1. Mix Design

A mix M20 grade was designed as per ACI Code and the same was used to prepare the test samples.

TABLE III CONCRETE MIX DESIGN PROPORTIONS

Sl. No.	Concrete Type	Concrete Mix Design proportion (by weight)				Cement Replaced by Fly Ash
		W/C Ratio	C(kg)	F.A(kg)	C.A(kg)	
1	Cement Concrete (M20)	0.4	3	4.5	9	0
2	Cement Concrete (M20)	0.4	3	4.5	9	5%
3	Cement Concrete (M20)	0.4	3	4.5	9	10%
4	Cement Concrete (M20)	0.4	3	4.5	9	20%

2. Workflow Diagram to Manufacture of the Specimen

The specimen are cast in laboratory for this study. Here, concrete was casted in sylendrical mould (according to ASTM standard). For laboratory casting the steps followed are described below.

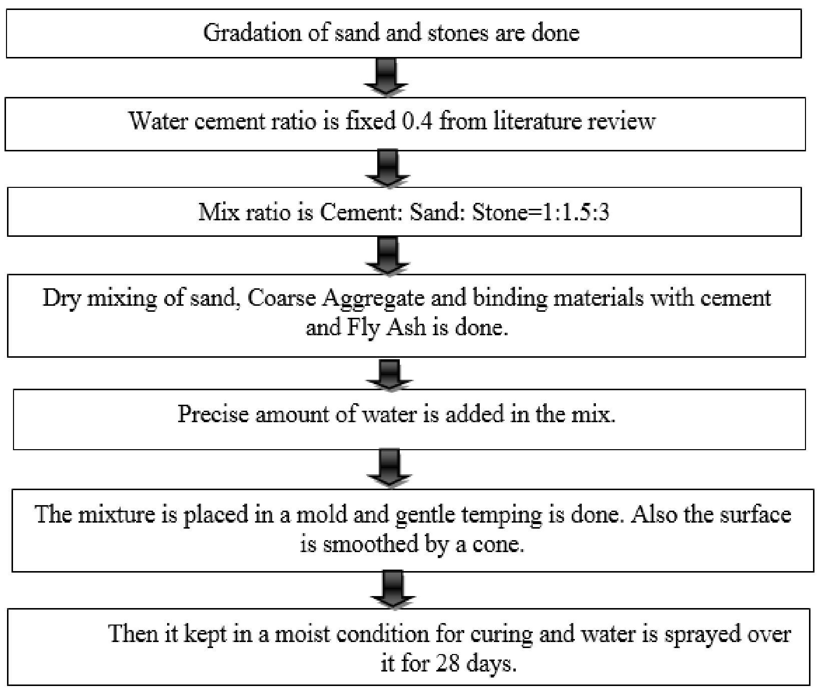

Fig. 5 Work Flow Diagram

Test samples were made using a combination that included fly ash in the following percentages: 0%, 5%, 10% and 20%. Compressive strength was measured by casting in standard cylinder molds (4×8). The manually filled concrete cylinders were compacted using a standard vibrator. For the purpose of casting these examples, the mix ratio for M20 grade concrete was 1:1.5:3. We remolded the specimens after 24 hours, and we allowed them to cure for 28 days in a curing pond [8].

III. COMPRESSION TEST

The cylinders were remoulded and submerged in water for testing at various ages after a 24-hour period. Three specimens were evaluated for each age group in order to calculate the average compressive strength [7]. A compression testing apparatus with a 200 metric ton capacity was used for the test.

Fig. 6 Compressive strength test

IV. RESULTS AND DISCUSSION

The compressive strength test results are presented in Table IV. Figure 7 shows the compressive strength vs % replacements of cement.

TABLE IV COMPRESSIVE STRENGTH

Concrete Grade	Concrete Type	Dimension of Cylinder (inch)	Compressive Strength (psi)	Average Compressive Strength (psi)
M20	Without Fly ash (0%)	8×4	3156.29	3124.47
			3038.91	
			3178.21	
	With fly ash (5%)	8×4	2910.79	2984. 57
			3057.51	
			2985.40	
	With fly ash (10%)	8×4	2790.47	2838.36
			2876.05	
			2848.57	
	With fly ash (20%)	8×4	2342.33	2300.37
			2302.05	
			2256.76	

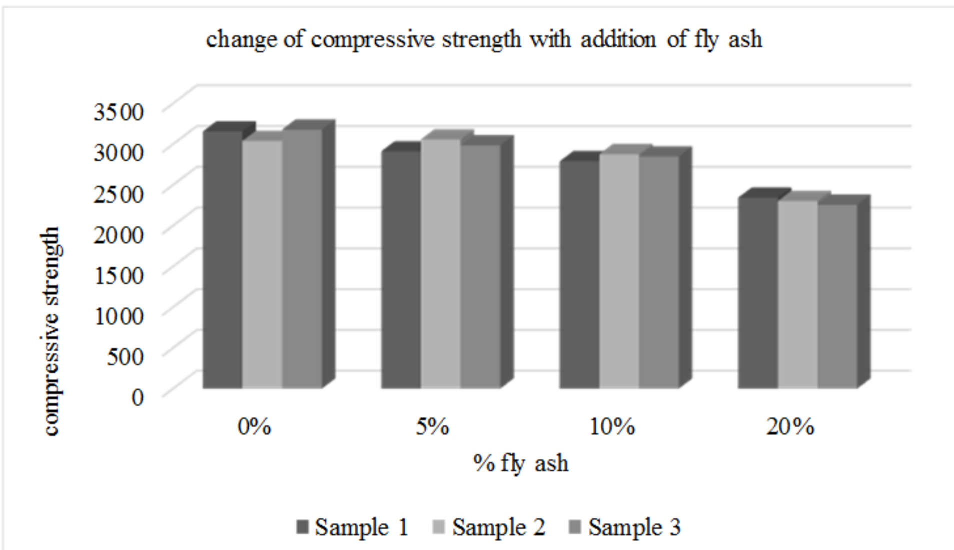

Fig. 7 Compressive strength of specimen at 28 days for M20

A. Cost Analysis

TABLE V COST OF MATERIALS

Sl. No.	Materials	Rate(tk/kg)
1	Cement	11
2	Fly ash	2
3	Fine aggregate	0.8
4	Coarse aggregate	3.74

TABLE VI MATERIALS COST FOR DESIGN M20 CONCRTETE

Concrete Grade	% Reduction in Cement	Materials				Total cost (tk)	% Change Cost
		Cement (kg)	Sand (kg)	Stone (kg)	Fly Ash(kg)		
M20	0	403	630	1277	0	9424	0
	5	383.03	630	1277	20.16	9383.68	0.65
	10	362.87	630	1277	40.32	9343.36	0.87
	20	322.55	630	1277	80.64	9262.72	1.72

V. CONCLUSION

Based on experimental investigations concerning the strength of concrete, several conclusions have been drawn. Compressive strength decreases when cement is replaced by fly ash, and as the percentage of fly ash increases, the compressive strength further decreases. However, the use of fly ash in concrete can lead to cost savings for the coal and thermal industry disposal while also contributing to the production of environmentally friendly concrete for construction. The cost analysis report indicates that reducing the percentage of cement decreases the cost of casting concrete. Although using 5% fly ash results in a decrease in strength, it is not significant and is quite acceptable for concrete production. The outcome of the research is that fly ash can serve as an efficient supplementary cementitious material and can be used in limited amounts as a replacement for cement. Engineers should make judicious decisions regarding its use.

REFERENCES

[1] L. C. Das and S. H. Mahmud, “Assessment of Water Pollution in the Korotoa River: Implications for Ecosystems and Human Welfare in Bogura, Bangladesh,” *TARCE*, vol. 12, no. 2, pp. 30–34, Dec. 2023.

[2] S. Kotey, Z. Mustapha, B. Boahene Akomah, M. Michael, A. Sampson, and A. Solomon, “Exploring Sawdust as a Sustainable Alternative in Block Production: A Study on Compressive Strength and Environmental Impact,” *TARCE*, vol. 12, no. 2, pp. 16-23, Dec. 2023.

[3] S. Aynharan, M. U. Faris, M. H. F. Afrose Banu, D. S. Joachim, and P. R. Fernando, “Utilization of Waste Plastic in the Way of Synthetic Bricks,” *TARCE*, vol. 12, no. 1, pp. 1–5, Apr. 2023.

[4] N. Anuja and M. Balaji, “A Review on Recycled Aggregate based Thermal Insulated Concrete,” *TARCE*, vol. 10, no. 1, pp. 4-7, May 2021.

[5] G. Hemanth Kumar and B. Ajitha, “Prediction of Compressive Strength of Nano Alumina, Micro Alumina & Fly Ash Blended with Cement by Using Coefficient of Correlation,” *TARCE*, vol. 9, no. 2, pp. 8–11, Nov. 2020.

[6] S. Vivek, V. Priya, S. T. Sudharsan, K. Thanukrishna, and R. Vignesh, “Experimental Investigation on Bricks by Using Cow Dung, Rice Husk, Egg Shell Powder as a Partial Replacement for Fly Ash,” *TARCE*, vol. 9, no. 2, pp. 1-7, Nov. 2020.

[7] V. Kannan and K. Ganesan, “Mechanical and transport properties in ternary blended self-compacting concrete with metakaolin and fly ash,” *IOSRJMCE*, vol. 2, no. 4, pp. 22-31, Sep.-Oct. 2012.

[8] J. I. Bhatty, J. Gajda, P. E. Botha, and M. M. Bryant, “Utilization of Discarded Fly Ash as a Raw Material in the Production of Portland cement,” *Journal of ASTM International*, vol. 3, no. 10, 2006.