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Strength and Durability Study of Concrete with Partial Cement Replacement by Pulverized Fly Ash and Metakaolin

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Abstract:

Concrete is the most frequently used building material in the world. However, because of its extraordinary use, there are serious environmental worries about the harm that comes from the extraction of raw materials and the emissions of CO2 during the cement manufacturing process. A huge amount of electrical power and fuel energy are needed to make one ton of cement, which emits roughly one ton of CO2. The best way has been to employ supplemental cementing materials (SCMs), which can increase or maintain the overall performance of the concrete while also reducing the amount of cement used.

One such pozzolanic substance that has been widely utilized as calcined clay is Metakaolin (MK), which is produced by calcining kaolinitic clay. This essay examines the body of research on the use of MK in concrete and mortar as a partial substitute for cement. A thorough review of the literature is done and presented here.

One component of Malaysia's primary energy resources is coal. 2010 was predicted to use more than 22.5 million tons of coal, which resulted in a large amount of coal ash being produced as waste. Pulverized Fuel Ash, or PFA, has garnered a lot of attention as a cement substitute for concert mixtures in recent years. This study's laboratory work involves figuring out the optimal mix design to produce soil-cement bricks enhanced with PFA that have the best compressive strength, water absorption, and initial extraction rate. In this work, M25 grade concrete was developed by replacing cement via 5%, 10%,15%,20%,25% and 30% of PFA and Metakaolin. These tests were carried out to evaluate the mechanical properties, like compressive strength, of Mix concrete, which was 13.41% and 8.11% stronger than conventional concrete at 7 days and 28 days of curing of cubes. and the flexural tensile strength of Mix concrete is 12.35% more than conventional concrete at 28 days of curing of beams.

Keywords — **Pulverized Fly Ash (PFA), Metakaolin, Portland cement, cement replacement, cement, concrete, Supplementary cementing materials.**

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I. INTRODUCTION

This The purpose of this study is to compare the qualities of concrete when cement is partially replaced with pulverized fuel ash (PFA) and metakaolin. This involves examining the impact of these additional cementitious materials on a range of concrete properties. In comparison to traditional concrete mixes without additives, the purpose of this study is to examine the effects of PFA and Metakaolin incorporation on the strength, durability, workability, and other critical qualities of concrete.

Concrete's cost-effectiveness, durability, and adaptability make it one of the most commonly used building materials in the world. But the production of concrete the old-fashioned way adds a lot to carbon dioxide emissions, so scientists are looking into substitute materials that can lessen the environmental effect of concrete without sacrificing its functionality. Two often used supplemental cementitious materials that have showed promise in improving the characteristics of concrete when partially replacing cement are pulverized fuel ash (PFA) and metakaolin.

II. OBJECTIVE OF VIEW

To investigate the structural behavior of concrete that has been blended with Pulverized-Fuel Ash (PFA) & Metakaolin.

To determine the percentage that gives the maximum workability of multi-blended concrete when compared to conventional concrete of using Pulverized-Fuel Ash (PFA) & Metakaolin as partial replacements for cement.

To determine the percentage that gives the maximum Compressive strength of multi-blended concrete when compared to conventional concrete of using Pulverized-Fuel Ash (PFA) & Metakaolin as partial replacements for cement.

To determine the percentage that gives the maximum Flexural strength of multi-blended concrete when compared to conventional concrete of using Pulverized-Fuel Ash (PFA) & Metakaolin as partial replacements for cement.

To investigate the suitability of using Pulverized-Fuel Ash (PFA) & Metakaolin as partial replacements for cement.

III. USED MATERIALS

A.OPC 43 Grade Cement

OPC 43 Grade Cement is a hydraulic cement produced by grinding clinker and gypsum. It is known for **good strength, good workability, and moderate heat of hydration**.

B. Pulverized-Fuel Ash (PFA)

In In thermal power plants, pulverized fuel ash (PFA) is a byproduct of burning coal. It is created when coal is burned at a high temperature to produce energy and is also referred to as fly ash. PFA is made up of tiny particles that power plants' electrostatic precipitators or bag filters gather after the flue gases carry them away.

C. Metakaolin

Metakaolin is an amorphous alumina silicate that is created by subjecting refined kaolin clay to a particular calcination procedure. By interacting with calcium hydroxide to generate additional binding elements, such as calcium silicate hydrate, this mineral additive greatly improves a number of cement-based product qualities, including strength and durability in concrete.

D. Fine Aggregate

It is the aggregate most of which passes through a 4.75 mm. IS sieve and contains only that much coarser material as is permitted by the specifications. Sand is generally considered to have a lower size limit of about 0.07 mm. Material between 0.06 mm and 0.002 mm is classified as silt, and still smaller particles are called clay. The soft deposit consisting of sand, silt and clay in about equal proportions is termed loam.

E. Coarse Aggregate

The aggregates most of which are retained on the 4.75 mm IS sieve and contain only that much of fine material as is permitted by the specifications are termed coarse aggregates. The coarse aggregate may be one of the following types:

1. Crushed gravel or stone obtained by the crushing of gravel or hard stone,
2. Uncrushed gravel or stone resulting from the natural disintegration of rock, or
3. Partially crushed gravel or stone obtained as a product of the blending of the above two types.

F. Water-cementitious materials ratio

The ratio of the amount of water, minus the amount of water absorbed by the aggregates, to the amount of cementitious materials by weight in concrete is called the water-cementitious ratio and commonly referred to as the w/cm ratio. The w/cm ratio is a modification of the historical water-cement ratio (w/c ratio) that was used to describe the amount of water, excluding what was absorbed by the aggregates, to the amount of the portland cement by weight in concrete. Because most concretes today contain supplementary cementitious materials such as fly ash, slag cement, silica fume, or natural pozzolans, the w/cm ratio is more appropriate. To avoid confusion between the w/cm and w/c ratios, use the w/cm ratio for concretes with and without supplementary cementitious materials.

IV. METHODOLOGY

The methodology for investigating the workability of concrete incorporating combinations of pulverized fuel ash (PFA) and metakaolin (MK) involves several key steps:

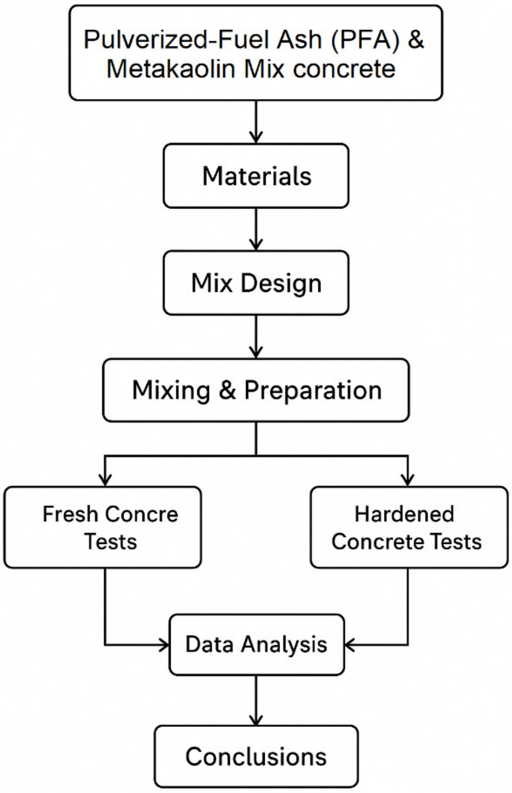

Fig. 1 Methodology Flow Chart

A. *Mix Design – (For the Grade M25 Plain Concrete)*

Cement	Fine aggregate	Coarse aggregate
1	1.90	3.13

V. RESULT DISCUSSION

Testing

Fresh Concrete Tests

Slump Test (IS 1199)

Fresh Density

Workability Observation

Hardened Concrete Tests

Compressive Strength Test

Performed at 7, 28, 56 days (IS 516).

Flexural Strength Test

Universal testing machine

A. Workability of various concrete mixes design

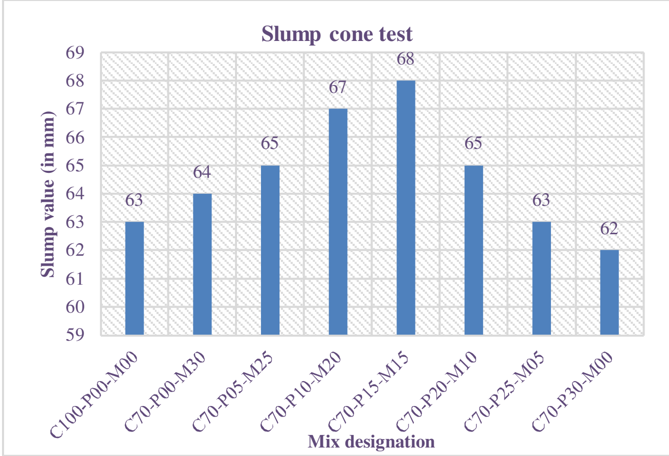

Fig. 2 Workability of various concrete mixes design

B. Compared Compressive strength's result (in N/mm²) at 7 and 28 days

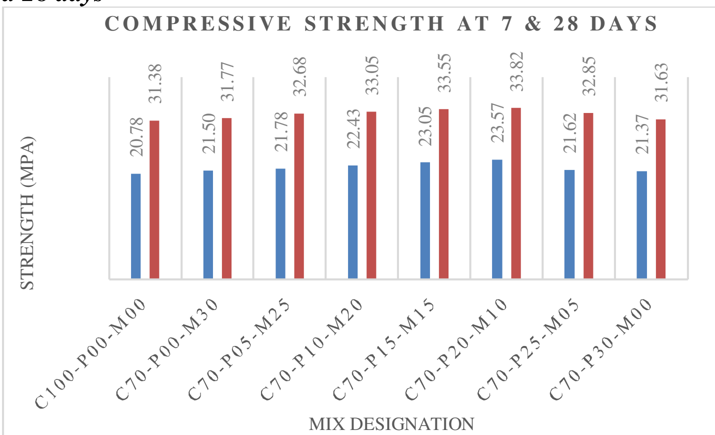

Fig. 3 Compared Compressive strength's result (in N/mm²) at 7 and 28 days

C. Flexural strength in N/mm² at 28 days

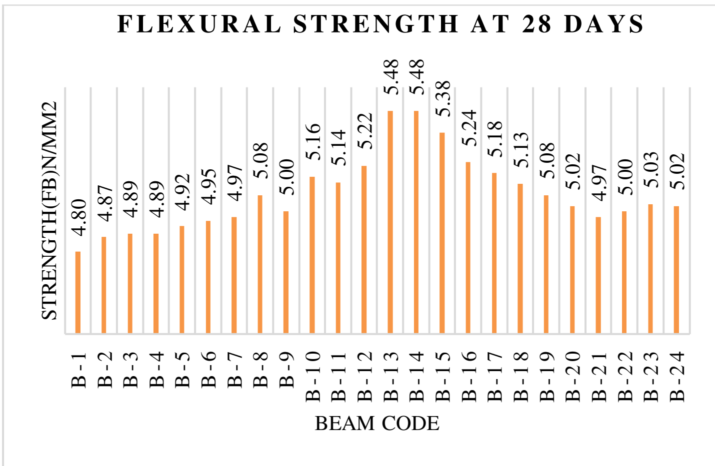

Fig. 4 Flexural strength in N/mm² at 28 days

VI. CONCLUSION

1.The concrete mix made using Pulverized-Fuel Ash (PFA) & Metakaolin as partial replacement of Cement showed good workability and Fluidity similar to normal concrete mixes.

2.The workability of concrete increased with the addition of Pulverized-Fuel Ash (PFA) & Metakaolin as partial replacement of Cement.

- Mix design codes M-3
- Slump cone test in mm. 85mm

3.The compressive strength of concrete increased with the addition of Pulverized-Fuel Ash (PFA) & Metakaolin as partial replacement of Cement. (at 7 days, and 28 days).

Compressive strength (N/mm2)	Days	Mix design	strength (N/mm^2)	% Increase in strength
Conventional concrete	at 7 days	C100-P00-M00	20.78	0.00%
	at 28 days	C100-P00-M00	31.38	0.00%
Mix Concrete PFA & Metakaolin	at 7 days	C70-P20-M10	23.57	13.41%
	at 28 days	C70-P20-M10	33.82	8.11%

4. The flexural tensile strength of concrete increased with the addition of Pulverized-Fuel Ash (PFA) & Metakaolin as partial replacement of OPC cement.

Flexural tensile strength (n/mm2)	Days	Mix design	strength (N/mm^2)	% Increase in strength
Conventional concrete	at 28 days	C100-P00-M00	4.85	0.00%
Mix Concrete PFA & Metakaolin	at 28 days	C100-P00-M00	5.45	12.35%

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