International Scientific Journal of Engineering and Management (ISJEM) ISSN: 2583-6129
Volume: 05 Issue: 04 | April – 2026 DOI: 10.55041/ISJEM06686
An International Scholarly || Multidisciplinary || Open Access || Indexing in all major Database & Metadata

Behavior of High-Strength Concrete with Partial Cement Replacement by Clay Pozzolana and PCE

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ABSTRACT:
Concrete is a versatile composite material widely used in both small- and large-scale construction due to its high compressive strength and availability. Increasing environmental concerns and demand for raw materials have encouraged the use of clay pozzolana as a partial replacement for cement. This study investigates the feasibility of substituting cement with clay pozzolana in proportions ranging from 0% to 25%. A slump test was conducted to evaluate fresh concrete properties, while mechanical properties such as compressive, tensile, and flexural strength were tested at 7, 28, and 56 days. Results showed that higher replacement levels reduced the induction period and setting times. Clay pozzolana improved microstructure and pore distribution, enhancing early hydration. Concrete mixes were prepared at a constant water-cement ratio of 0.35, and Poly Carboxylic Ether (PCE) admixture was used for performance improvement. Water absorption was measured at 28 days, and durability tests at 56 days. A cost comparison with M50 grade concrete indicated potential economic benefits.

KEYWORDS: Clay Pozzolana, Cement Replacement, High-Strength Concrete, Poly Carboxylic Ether (PCE) & Hydration Process

INTRODUCTION

Concrete is a widely used construction material because it is strong, durable, and easily available. It resists weather, fire, and wear, making it suitable for all types of projects. Concrete is made from cement, water, aggregates, air, and sometimes admixtures to improve its properties.
With rapid development, especially in countries like India and China, the demand for concrete and cement is increasing very fast. This puts pressure on resources and the environment. To meet future needs, it is important to use materials wisely, adopt better production methods, and reduce costs over the life of structures. Using pozzolanic materials and chemical admixtures can improve concrete quality while making construction more sustainable and efficient.

Objective of the study:

Objective means something or somebody that's without basis. The objectives of following study are listed below:

- To Increase the compressive strength of concrete.
- To replace cement in mortar & concrete with pozzolanic materials.
- To improve durability of concrete.
- To reduce the quantity of cement used in construction materials.
- To improve the tensile strength of concrete.
- To improve the flexural strength of concrete.

METHODOLOGY

Materials, studied in materials science, can be modified or combined to enhance properties. Concrete is made from aggregates, water, and cement, with additives improving durability. Alternatives like basalt fiber increase strength, corrosion resistance, and sustainability in modern construction.

Figure:I Constituents of Concrete

1. Cement:-

OPC 53 grade cement is widely used for its strength and availability. It binds aggregates, forms paste through hydration, releases heat, and its fineness depends on particle surface area.

Figure: II-OPC Cement

2. Coarse aggregate 10mm (grit):

IS 383:1970 defines 10 mm coarse aggregate as material retained on a 10 mm sieve. It improves concrete strength, durability, and workability, especially in thin or reinforced sections, and is cost-effective, lightweight, and widely used in construction.

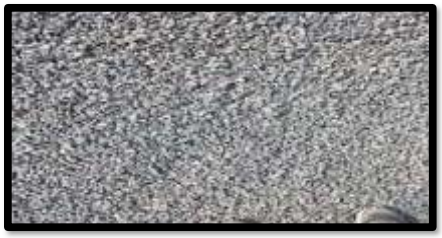

Figure:III- Course aggregate 10mm (Grit)

3. Fine aggregate:

Fine aggregate, defined by IS 383:1970 as material passing a 4.75 mm sieve, is clean sand used in concrete, mortar, roadwork, and foundations, offering easy processing and local availability.

Figure:IV- Fine aggregate

1. Clay Pozzolana:

Clay pozzolana is a processed clay material, often calcined, that reacts with calcium hydroxide to form cementitious compounds. Used as a partial cement replacement, it enhances concrete strength, durability, and sustainability while reducing carbon emissions and dependence on energy-intensive Portland cement.

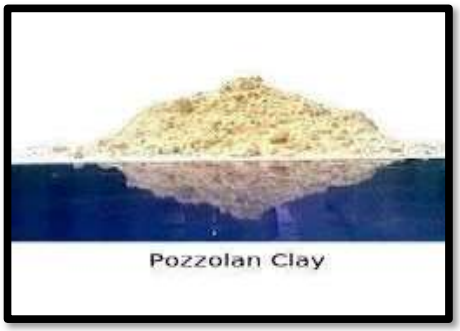

Figure:V-Clay pozzolana

2. Superplasticiser:

Poly carboxylic either: A special blend of the most recent generation of super plasticizers, built on long lateral chain poly carboxylic polymers. This enhances cement dispersion significantly. Although the cement particle's ability to separate and disperse, there is an electrostatic dispersion at the beginning of the mixing process. It makes it possible to produce concrete with excellent workability and/or performance. Dosage: 0.4% to 1.5% of cement material weight.

Figure:VI- Superplasticizer

Sources of Materials:

The list of sources for the information used in the research is shown below:

Sr.No.	Experimental Materials	Source
1	Cement OPC 53 Grade	Locally available (Vadodara, Gujarat)
2	Coarse Aggregate 10mm (grit)	Locally available (Vadodara, Gujarat)
3	Coarse Aggregate 20mm	Locally available (Vadodara, Gujarat)
4	Fine Aggregate	Locally available (Bodeli, Gujarat)
5	Clay Pozzolana	Kotak Manufacture (Vadodara, Gujarat)
6	Superplasticizer	Manjusar (Vadodara, Gujarat)

Table:I Sources of Material

Mix Design of Grade M 50 Concrete:

Water	Cement	Fine Aggregate	Coarse Aggregate
197.16 lit	563.31 kg/m^3	651.85 kg	1056.15
0.35	1	=651.85/563.31 = 1.157	=1056.15/563.31 =1.874

RESULTS:

The mathematical models are created utilizing regression for the compressive strength of the concrete when subjected to concrete mix 50 grade. The leading fit polynomial equations are obtained for compressive .The equations produced will offer assistance in finding out the strength that any desired mix proportion.

% Replacement	Compressive (Cube)Strength (N/mm^2)	Flexural (Beam)Strength (N/mm^2)	Tensile (Cylinder)Strength (N/mm^2)
5(M1)	50.74	5.05	10.02
10(M2)	43.53	4.01	9.44
15(M3)	40.76	4.63	10.62
20(M4)	41.43	2.22	9.80
25(M5)	37.46	5.43	10.82

Table: II- Mathematical Modelling for compressive strength of M50 Grade Concrete Mix 7 days

% Replacement	Compressive (Cube)Strength (N/mm^2)	Flexture (Beam)Strength (N/mm^2)	Tensile (Cylinder)Strength (N/mm^2)
5(M1)	57.02	5.62	12.73
10(M2)	56.40	8.90	12.84
15(M3)	51.66	7.55	12.96
20(M4)	52.66	6.27	13.03
25(M5)	51.36	7.39	12.53

Table: III - Mathematical Modelling for compressive strength of M50 Grade Concrete Mix 28 days:

CONCLUSION:

This study shows clay pozzolana can replace cement with minimal environmental impact. Workability improved, especially at 15% replacement. Strength increased at 5–10% replacement but decreased at higher levels. Flexural and tensile strengths improved at 10%. Durability under sulphate attack improved slightly at 5% replacement, while higher replacements showed reduced performance compared to normal concrete

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