Assessment on Characteristics of High Performance Concrete using Calcium Bentonite and Silica fume

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***Abstract*— Concrete is a widely utilized building material that has played a significant role in human civilization for centuries. Known for its strength, concrete is capable of withstanding substantial damage and is highly resilient, with the ability to endure for many years without deteriorating or disintegrating. In addition to its durability, concrete is cost-effective and relatively simple to manufacture. Consequently, concrete has been employed in a variety of construction projects, ranging from residential dwellings to towering skyscrapers, despite its drawbacks. Concrete has the drawback of causing air pollution during production and certain uses. Additionally, it is not environmentally friendly as it demands significant energy for manufacture. Consequently, it is crucial to decrease ordinary Portland cement consumption by replacing it partially. This research centers on identifying the ideal percentage for substituting OPC with calcium bentonite powder. The study involves the Examination of cube and beam samples containing different proportions (5%, 10%, 15%) of calcium bentonite powder and 5% Silica Fume based on the weight of cement. The research examines the fresh and hardened properties of concrete, such as workability, compressive strength, flexural strength, and water absorption. Additionally, the durability of the concrete is assessed through an acid attack test. It was observed that the specimens with 10% calcium bentonite and 5% silica fume demonstrated superior strength and durability performance.**

Index Terms— Calcium Bentonite, High Strength Concrete, Compressive Strength, Flexure Strength, Water Absorption.

I. INTRODUCTION

Concrete is one of the most used construction materials. It has been a major part of our civilization for centuries. Concrete is a very strong material, and it can withstand a lot of damage. It is very durable, and it can last for decades without rotting or breaking down. It is also easy to produce and very affordable. For these reasons, concrete has been used for many different types of buildings, from houses to skyscrapers. Even though it has disadvantages as well. One of the disadvantages of concrete is that it can create pollution in the air when produced and when it is used in certain ways. Another disadvantage is that it is not very environmental-friendly since it requires a lot of energy to make. It also creates a lot of waste during production, such as sand, cement, and water. Fortunately, there are ways that we can use concrete in ways that reduce the impact on the environment and still create structures that are strong and durable by using Supplementary Cementitious Materials such as Calcium Bentonite. It is known as a kind of natural pozzolana that can improve the mechanical properties of Supplementary Cementitious materials and reduce the overall CO_2 emission from cement production.

A. Calcium Bentonite:

Bentonite consists chiefly of crystalline clay minerals belonging to the smectite group, which are hydrous aluminium silicates containing iron and magnesium as well as calcium. Calcium bentonite is a useful adsorbent of ions in solution, as well as fats and oils. It is the main active ingredient of fuller's earth, probably one of the earliest industrial cleaning agents. It has significantly less swelling capacity than sodium bentonite. Calcium bentonite may be converted to sodium bentonite (termed sodium beneficiation or sodium activation) to exhibit many of sodium bentonite's properties by an ion exchange process. As commonly practiced, this means adding 5–10% of a soluble sodium salt such as sodium carbonate to wet bentonite, mixing well, and allowing time for the ion exchange to take place and water to remove the exchanged calcium. Some properties, such as viscosity and fluid loss of suspensions, of sodium-beneficiated calcium bentonite (or sodium-activated bentonite) may not be fully equivalent to those of natural sodium bentonite. For example, residual calcium carbonates (formed if exchanged cations are insufficiently removed) may result in inferior performance of the bentonite in geosynthetic liners.

II. METHODOLOGY

A. Objectives:

The Main Objectives of the present investigation are

- To investigate the effect of Calcium Bentonite on Fresh Properties of Concrete.
- To examine the effect of Calcium Bentonite on Hardened Properties of High Performance Concrete.
- To investigate the durability of high performance concrete under the influence of Calcium Bentonite for Acid Attack Test.

B. Materials:

Cement is the main ingredient in manufacturing of concrete. The characteristics of concrete will be greatly affected by changing the cement content. The cement used in this project is Ordinary Portland cement of 53 grade confirming to IS 12269 – 1987.

Table 1 – Physical Properties of Cement

S. No	Property	Test Results
1	Fineness (%)	98
2	Specific Gravity	3.15
3	Initial Setting Time	98 min
4	Final Setting Time	260 min
5	Normal Consistency	30.34%

The material that remains on a 4.75 mm sieve after being sieved through it is referred to as coarse aggregate. Natural river sand from the closest supplier is used as a fine aggregate. The closest crusher unit's 20 mm size aggregates are utilized as coarse aggregate in this investigation.

C. Calcium Bentonite:

Calcium bentonite is a useful adsorbent of ions in solution, as well as fats and oils. It is the main active ingredient of fuller's earth, probably one of the earliest industrial cleaning agents. It has significantly less swelling capacity than sodium bentonite. The calcium bentonite is a naturally found pozzolana, rich in silica and alumina, that has been extensively used for many years to improve the mechanical and durability properties of conventional concrete The Physical Properties of Calcium Bentonite are given in Table 2.

Table 2 – Physical Properties of Calcium Bentonite

S. No	Properties	Test Results
1	Specific Gravity	2064
2	Fineness	98%

Fig 1 – Calcium bentonite

Table 3 – Properties of Fine Aggregate and Coarse Aggregate

S. No	Properties	Fine Aggregate	Coarse Aggregate
1	Fineness Modulus	2.66	7.11
2	Specific Gravity	2.63	2.64
3	Water Absorption (%)	1.2%	0.75
4	Bulk Density	1560 Kg/m^3	1700 Kg/m^3

III. MIX DESIGN

IS-10262:2019 and IS-456:2000 is the two Standard Codes which are used in the mix design process.

Table 4 - Mix Proportions as per IS 10262 – 2019 for M40 Grade

Material	Quantity (Kg/m^3)
Cement	450 Kg/m^3
Fine Aggregate	676 Kg/m^3
Coarse Aggregate	1024 Kg/m^3
Water	200 Lit
SP Dosage	1%

IV. RESULTS AND DISCUSSIONS

A. Workability of Concrete (Slump Cone Test):

Concrete slump test is to determine the workability or consistency of concrete mix prepared at the laboratory or the construction site during the progress of the work.

The workability of concrete is observed by the Slump Cone method. From the slump cone test it can be observed that for the nominal mix of concrete, the workability is high and for 5%, 10%, and 15% replaced concrete has got medium workability as per Indian Standards. The Average Slump Values of the concrete are shown in Table 7.

Table 5 - Variation of Slump

Trail Name	Slump (mm)
Trial 1 (0%)	96
Trial 2 (5%)	75
Trial 3 (10%)	68
Trial 4 (15%)	65

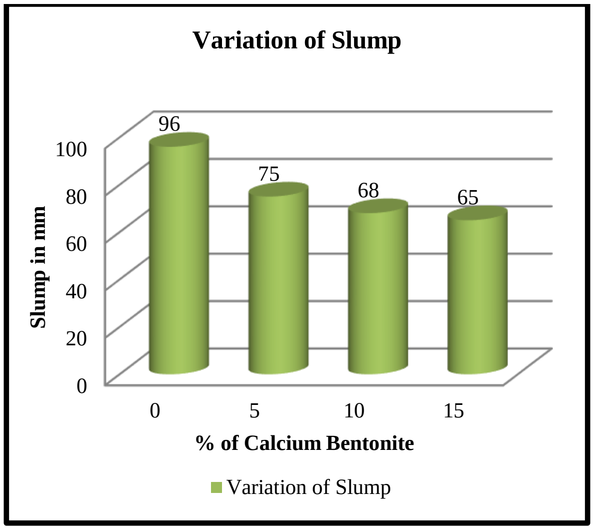

Fig 2 – Variation of Slump

B. Compressive Strength:

It can be observed that the addition of calcium bentonite has gradually improved the compressive strength of concrete. From the table it can be observed that 5% replacing of cement with calcium bentonite has increased its compressive strength by 8.70% and for 10% replacement it increased by 15.80%. From the table and the graph we can conclude that maximum replacement of cement with calcium bentonite is 10%. The graph shows that there is a gradual decrease in compressive strength at 15% replacement.

Table 6 - Compressive Strength of Concrete at 7 Days and 28 Days

S.No.	Trial percentage	Compressive Strength (N/mm²)		Percentage variation at 28 Days (%)
		7 Days	28 Days	
1	0	26.2	40.30	-
2	5	28.5	43.80	8.70
3	10	30.4	46.75	15.8
4	15	28.7	44.20	9.50

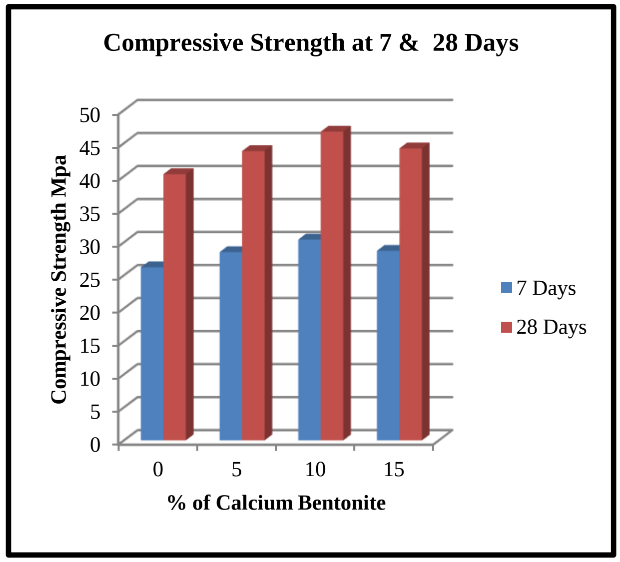

Fig 3 – Compressive Strength of Concrete

C. Flexural Strength:

The Flexural Strength of concrete can be analyzed by casting Beams of Size 750 mm X 150 mm X 150 mm.

Table 7 - Flexural Strength of Concrete

S.No.	Trial percentage	Flexural Strength (N/mm²)		Percentage variation at 28 Days (%)
		7 Days	28 Days	
1	0	1.25	1.92	-
2	5	1.33	2.05	3.70
3	10	1.43	2.20	9.50
4	15	1.28	1.96	1.05

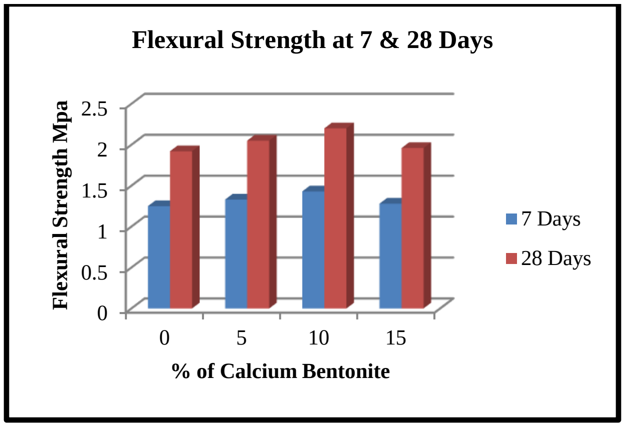

Fig 5 - Variation of Flexural Strength

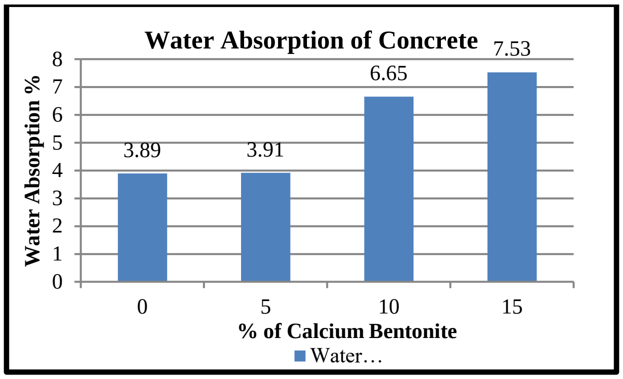

Fig 6 – Water Absorption of Concrete

V. DURABILITY STUDIES

In this experiment, the durability of the concrete was evaluated by testing its acid resistance at various curing ages. The acid durability factor test and the acid attack factor test were the two methods used to measure the acid resistance of concrete. Water has an acid content of 5% HCL.

1. Acid Attack Test:

2.1 Acid Attack Factor:

Acid Attack Factor values immersed in 5% HCl are tabulated as follows

Table 8 - Acid attack factor immersed in 5% HCl

Mix	Average Acid attack factor in 5% HCL	
	7days	28days
Trail 1	4.95	12.65
Trail 2	4.68	12.32
Trail 3	3.85	11.00
Trail 4	4.13	11.33

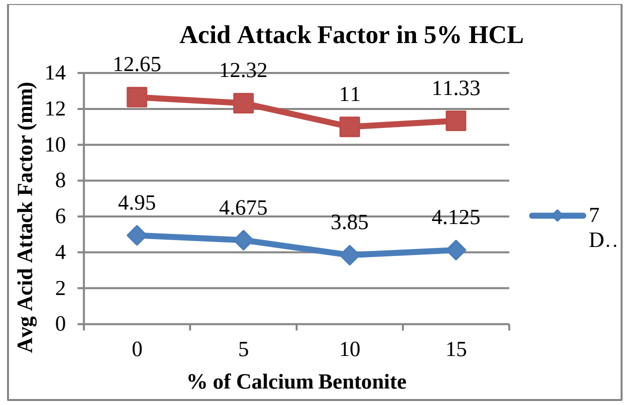

Fig – 7 Acid Attack Factor in 5% HCl

VI. CONCLUSION

- In this experimental investigation it is observed that there is a gradual increase in strength from 5% to 10% and decreased at 15%.
- For Trial mixes of 5% and 10% passed the required acceptance criterion in case of strength point of view.
- It is observed that for cube specimens there is an increase from 5% to 10% and decrease at 15% trial mixes in case of strength.
- For cube specimens trial mixes of 5% and 10% Calcium Bentonite were passed the required acceptancecriterion in case of strength point of view.
- As a conclusion 10% of maximum replacement of cement with calcium bentonite is achieving required strength parameters.
- There was a gradual decrease in strength at 15% when compared to that of 10%.
- The Percentage weight of Loss while immersed in 5% HCL was minimum at Trial 3 i.e., for 10% Calcium Bentonite.
- In case of durability the Trail mix 3 i.e., 10% CB and 5% SF has shown better results in attaining resistance when compared with other Trail mixes.
- In 5% HCL, the minimum Acid attack Factor is obtained at Trail 3 i.e., with 10% Calcium Bentonite is 11.
- By comparing the results, it is concluded that Calcium Bentonite can be useful to produce high strengths and the optimum percentage is obtained at Trail 3 i.e., 10% Calcium Bentonite and 5% silica fume.

VII. REFERENCE

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