

Experimental Study on Partial Replacement of Cement by Zeolite in M30 Grade Concrete

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Abstract- This study investigates the partial replacement of cement with Zeolite in M30 concrete. Zeolite, a natural aluminosilicate, was used at varying percentages (5%, 15%, 25%, and 35%) to evaluate its impact on workability and mechanical properties. Findings showed improved compressive, tensile, and flexural strength at 25% replacement. Both fresh and hardened properties of the concrete were evaluated. Workability and setting time were found to be within acceptable limits. Zeolite powder positively influenced the concrete without compromising quality. The study confirms that Zeolite is a viable alternative to traditional cement. Based on overall performance, 25% Zeolite replacement is recommended as the optimal level.

Index Terms- Zeolite Powder, Cement Replacement, Concrete, Slump test, Flexural strength, Compressive Strength, split tensile strength, Sustainability.

I. INTRODUCTION

Cement production is widely recognized as one of the major contributors to global carbon dioxide (CO₂) emissions. It is an energy-intensive process that emits large quantities of CO₂, primarily during the calcination phase, which is essential to produce clinker—the main component of Portland cement. Depending on the production methods and fuel used, CO₂ emissions range from 0.73 to 0.99 tons per tons of cement manufactured. More than half of these emissions result from the chemical decomposition of limestone (calcium carbonate) into lime (calcium oxide) and CO₂. Given the increasing global demand for infrastructure and urban development, the volume of cement produced continues to rise, leading to a parallel increase in greenhouse gas emissions. This has become a serious concern, as cement production alone accounts for nearly 8–10% of total global CO₂ emissions. Given the urgency of reducing atmospheric CO₂

levels and adapting to climate-resilient construction methods, research into natural alternatives is both timely and essential. This study presents an experimental investigation into the mechanical and durability characteristics of concrete when cement is partially replaced with natural zeolite powder. Various replacement levels were examined to determine the optimal proportion that balances performance, durability, and environmental impact.



Figure 1: Zeolite Powder

II. LITERATURE REVIEW

G. Sandeep Reddy et al. (2018) According to an experimental study, zeolite is used to replace 15% of the cement content (by weight) in conventional concrete of grade M40. The analysis takes into account the significant factors that affect concrete strength, including the water-binder ratio (0.37, 0.38, 0.39, and 0.40) and the binder content (440, 450, 460, and 470 kg/m³). In accordance with IS 516, 16 mixtures in total were cast and subjected to compressive strength testing. A 150 x 150 x 150 mm cube was used to test the concrete's compressive strength at 7 and 28 days of age. According to the acquired experimental results, M40 grade concrete may be produced with a water-binder ratio of 0.37 and a binder quantity of 440 kg per cubic meter (85% cement + 15% zeolite). At 28 days, it was discovered

that the concrete with 25% zeolite had greater compressive, split tensile, and flexural strengths than the standard concrete.

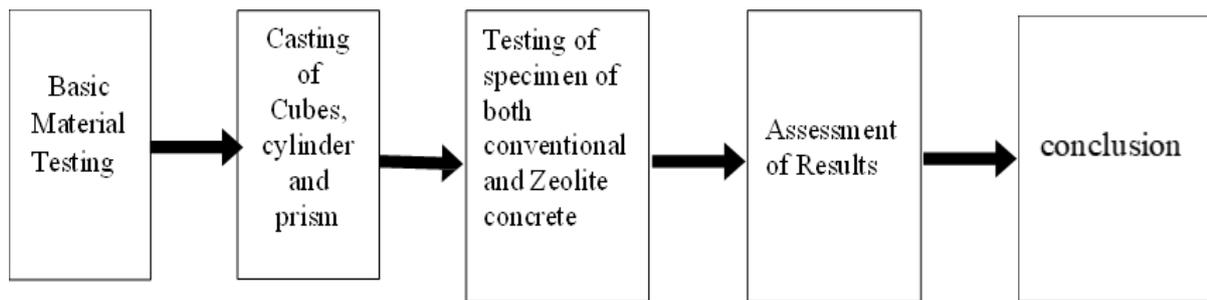
G Arun Kumar et al. (2023) The use of zeolite powder in concrete as a partial cement substitute is the main topic of this study. The core goal of this endeavor is to promote the supplement product as a building material. Zeolite powder is a naturally occurring substance that is produced when volcanic ash and seawater combine chemically. In this project, we employed M30 grade concrete and the I.S. approach for mix design. prepared concrete mixtures with varying zeolite powder amounts (5% to 30%) for cube construction. Compared to typical concrete, the concrete's compressive strength was lower. However, as the amount of cement replaced with zeolite powder increased, so did the compressive strength. At 28

days, it was discovered that the concrete with 15% zeolite had greater compressive, split tensile, and flexural strengths than the standard concrete.

III. OBJECTIVE

- [1] To perform the Physical tests for evaluating the basic properties of Zeolite.
- [2] To study the fresh concrete and hardened concrete properties of M30 grade with different replacement level of zeolite to cement.
- [3] To compare the Mechanical properties of zeolite concrete with conventional concrete.
- [4] To suggest the best replacement level with respect to strength and durability requirements.

IV. METHODOLOGY



V. MATERIAL

V.1 Cement: In this examination, we employed Ordinary Portland Cement (OPC) Grade 53, adhering to IS:12269-1987 and IS: 8112-1989 standards. To assess the cement's characteristics, we conducted essential tests, and you can find the test results presented in tabular format within Table 5.1.

Table 5.1: Properties of cement			
SI NO.	Characteristics	Results obtained	According to codal requirements
1	Specific gravity	3.14g/cc	As per IS: 456-2000, ≤ 3.15
2	Fineness of cement	8%	As per IS: 12269:1987, >225
3	Normal consistency	27%	-
4	Initial setting time	25min	As per IS: 8112-1989, ≥ 30
5	Final setting time	400min	As per IS: 8112-1989, ≤ 600

V.2 Fine Aggregate: For the fine aggregate, we utilized manufactured sand (M-sand). To ensure the quality of the fine aggregate, we conducted essential tests, and it meets all the IS: 383-1970 standards. You can refer to Table 5.2 for the test results presented in tabular format.

Table 5.2: Properties of fine aggregate			
SI NO.	Characteristics	Results obtained	REMARKS
1	Specific gravity	2.46	from IS:2386 (Part-III)-1963
2	Water absorption	1%	from IS:2386 (Part-III)-1963
3	Zone of sand	2	according to IS: 383-1970. 4

V.3 Coarse aggregate: We utilized 20mm crushed granite coarse material that had been downsized. Essential tests were conducted to determine the characteristics of the coarse aggregate, and it complies with all IS: 383-1970 [202] standards. You can find the test results presented in tabular format within Table 5.3.

Table 5.3: Properties of coarse aggregate			
SI NO.	Characteristics	Results obtained	REMARKS
1	Specific gravity	2.75	from IS:2386 (Part-III)-1963
2	Water absorption	1.16%	from IS:2386 (Part-III)-1963

V.4 Zeolite Powder: Zeolites are crystalline aluminosilicates that are porous. The zeolite framework is made up of a collection of SiO₄ and AlO₄ tetrahedra that are connected in different regular configurations by shared oxygen atoms to create an open crystal lattice with molecular-sized pores that allow molecules to pass through. The zeolites are based on TO₄ tetrahedra, where T is an atom of silicon or aluminum, like the majority of silicates. Low-density microporous materials are created by sharing all four corners of the tetrahedra, resulting in the enormous 3-dimensional networks. One could consider zeolite structures to be made up of finite parts.

Table 5.4: Properties of Zeolite Powder		
SI NO.	Characteristics	Results obtained
1	Specific gravity	3.1 g/cc
2	Fineness of Zeolite	5%
3	Normal consistency	33%
4	Initial setting time	55Min

VI. TESTING PROGRAM

VI.1 Slump test

Workability of concrete to assesses the behavior of fresh concrete from mixing up to compaction. The terms mix-ability, transportability, mouldability and compatibility collectively represent workability. Tests were performed to measure workability of concrete and the effects of Zeolite on workability properties of concrete were studied. The workability values in terms of Slump (mm) for varying Zeolite percentage of concrete mix.



Figure 2: Slump Test

Table 6.1: Slump value of different percentage of zeolite

CONCRETE MIX	SLUMP VALUE
0% replacement	120
5% replacement	114
15% replacement	105
25% replacement	100
35% replacement	95

VI.2 Compressive strength test

Here 150 mm cube specimens were tested under compressive load testing machine in respect to the age of curing. All the specimens were tested in saturated surface dry condition after wiping out the surface moisture. For each mix combination, three identical specimens were tested at the age of 28 days using a compression testing machine of 200-ton capacity. The compressive strength was calculated as per IS: 516-1959.



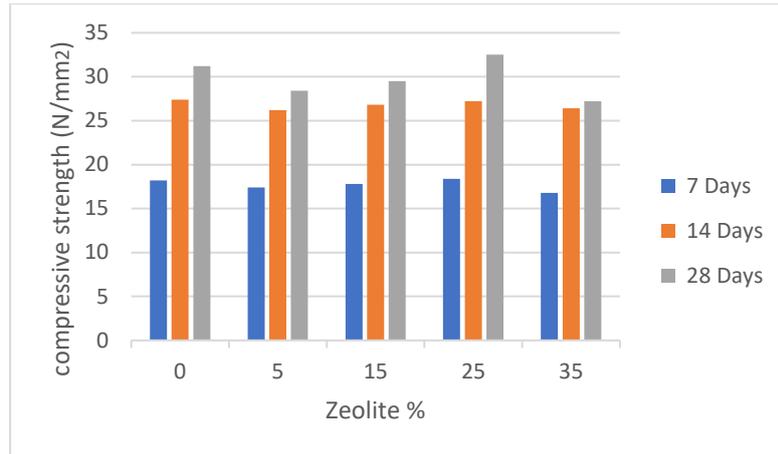


Figure 3: Compressive Strength Test

VI.3 Split tensile strength test

It is an indirect test to determine the tensile strength of cylindrical specimen of concrete. Split tensile strength tests were carried out on 150 mm dia.x300 mm high cylindrical specimen at the ages of 28 days of moist curing, using compression strength testing machine of 100 Ton capacity as per IS 5816-1999.

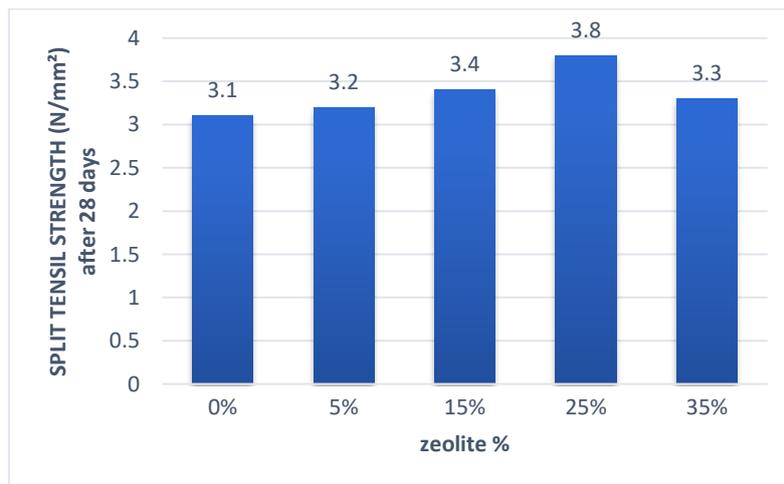


Figure 4: Split Tensile Strength Test

VI.4 Flexural strength test

In order to determine the flexural strength of concrete, prismatic specimens of a size of 100x100x500 mm were cast with various proportions of all the concrete mixtures. After 28 days of moist curing, the specimens were

tested in a flexural testing machine. Flexural strength of specimens expressed as the modulus of rupture (f_b) is then calculated using the formula and procedure given in IS: 516-1959.

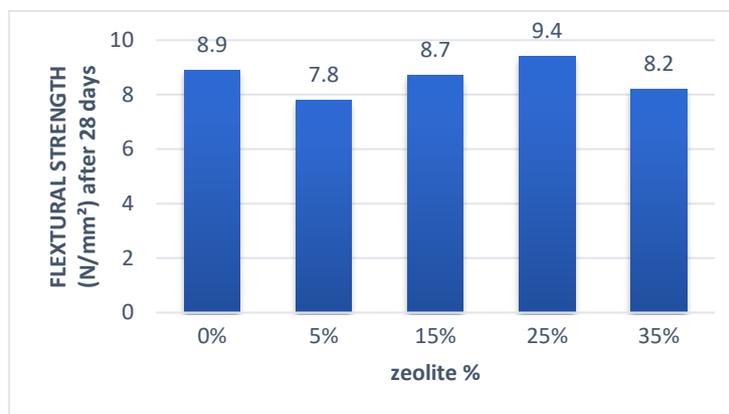


Figure 5: Flexural Strength Test

VII. CONCLUSIONS

Prior to beginning the primary experimental work, basic experimental investigations on the replacement of cement with zeolite powder in concrete. In this study, an organized investigation was conducted to examine the applications of zeolite powder in concrete.

- The compressive strength, split tensile strength, and flexural strength of concrete were found to be higher when it compared with the nominal concrete.
- The optimal percentage to replace cement with zeolite has been concluded to be 25%.
- The workability of concrete goes on decreasing as the replacement of cement by zeolite increases.
- Zeolite is cost-effective when compared to cement.

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