iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 14 **Issue:** III **Month of publication:** March 2026

DOI: https://doi.org/10.22214/ijraset.2026.77846

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International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 14 Issue III Mar 2026- Available at www.ijraset.com

An Experimental Study on Mechanical and Durability Properties of Zeolite Concrete

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***Abstract:** This study investigates the effects of adding zeolite in concrete mix on the mechanical and durability properties of concrete, aiming to enhance performance and sustainability. Zeolite, a microporous aluminosilicate mineral, is renowned for its molecular sieve properties, which enable it to improve strength of concrete, reduce permeability, and offer environmental benefits by decreasing the cement content required in concrete mixtures. By introducing zeolite as a partial substitute, this research aims to identify the optimal replacement percentage that maximizes structural integrity while maintaining or improving durability.*

The experimental methodology involves preparing a series of concrete mixes with varying zeolite contents to systematically assess changes in key mechanical properties, such as compressive, flexural, tensile, and bond strength. Durability characteristics are also evaluated, including resistance to acid and base exposure, chloride-induced corrosion which measures the material's susceptibility to water absorption.

The approach combines meticulous material collection, precise mix proportioning, and rigorous mechanical and durability testing to capture the effects of zeolite on concrete performance comprehensively. These insights are expected to contribute to sustainable construction practices by reducing cement dependency and, consequently, the carbon footprint of concrete production.

If effective, zeolite could be a promising addition to the construction industry, potentially increasing lifespan of concrete, resilience to environmental stressors, and suitability for eco-friendly infrastructure. Through this research, potential of zeolite as a sustainable additive is highlighted, offering an innovative approach to develop concrete with enhanced structural integrity and extended service life, supporting green building initiatives, and contributing to more durable and environmentally conscious infrastructure solutions.

Keywords: Zeolite, Partial Cement Replacement, Carbon Foot Print, Structural Integrity, Concrete Performance.

I. INTRODUCTION

Concrete is a fundamental construction material, valued for its strength, workability, and cost-effectiveness, forming the backbone of buildings, bridges, roads, and infrastructure. However, conventional concrete has limitations affecting durability and sustainability.

Despite its compressive strength, it is prone to cracking under tensile stress, which can lead to durability issues over time. Additionally, performance of concrete can deteriorate in aggressive environments, such as those with high chloride or sulphate exposure, where chemical reactions weaken the matrix and lead to structural degradation. Another critical concern is its environmental impact, as the production of cement, a primary component of concrete, is highly energy-intensive and generates significant CO_2 emissions, making the development of more sustainable alternatives imperative.

Zeolite, an aluminosilicate mineral, is known for its high porosity, molecular sieving capacity, and ion-exchange capabilities, making it highly versatile and useful in a range of applications beyond construction, including water purification, agriculture, and environmental protection.

When incorporated into concrete, zeolite has demonstrated potential benefits in enhancing both mechanical and durability properties. It acts as a pozzolan, reacting with free calcium hydroxide in the cement paste to produce additional C-S-H gel, which strengthens the concrete matrix. This reaction not only contributes to increased compressive and tensile

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II. MAIN MATERIALS USED

A. Synthetic Zeolite

Zeolite, an aluminosilicate mineral, is known for its high porosity, molecular sieving capacity, and ion-exchange capabilities, making it highly versatile and useful in a range of applications beyond construction, including water purification, agriculture, and environmental protection. When incorporated into concrete, zeolite has demonstrated potential benefits in enhancing both mechanical and durability properties. It acts as a pozzolan, reacting with free calcium hydroxide in the cement paste to produce additional C-S-H gel, which strengthens the concrete matrix. This reaction not only contributes to increased compressive and tensile strength but also reduces the permeability of the concrete, making it less susceptible to environmental degradation. Additionally, the ion exchange properties of zeolite allow it to bind harmful ions such as chlorides, which are typically responsible for corrosion in reinforced concrete structures, thus enhancing the concrete’s durability in harsh conditions

B. Auramix 200 (High Performance Super Plastisizer)

Auramix 200 is a high-performance super plasticizer (also called a *high-range water-reducing admixture*) used in concrete technology to significantly improve concrete properties. It’s a polycarboxylate ether (PCE)-based chemical admixture supplied as a light brown liquid that disperses readily in water

Key Features & Benefits
1) Improved Workability
2) Higher Strength & Performance
3) Pumpability
4) Durability Enhancements

C. Cement
Cement is the binding component most commonly utilized in concrete. Concrete, which relies on cement as a bonding agent, is commonly employed in engineering projects because it satisfies the necessary strength and durability criteria. The type of cement utilized in this research was OPC 53. The different characteristics of cement determined from different experiments are presented in the below table. The properties were verified to meet the IS standards.

D. Fine and coarse aggregate
The presence of fine aggregate is significant in the composition of concrete. M sand is commonly used as a substitute for fine aggregate due to its cost-effectiveness and ready availability. This study utilized M-sand. Experiments were carried out on fine aggregate in accordance with IS regulations.

E. Mix design
Mix proportioning for normal concrete involves a systematic process to determine the optimal combination of ingredients, ensuring that the resulting concrete meets the desired performance criteria. Initially, project requirements are specified, including factors like strength, workability, and durability. The appropriate concrete mix type is then chosen based on the intended application. The water-cement ratio, a crucial factor influencing concrete properties, is determined, and the total water content is estimated accordingly. The quantity of cementitious materials, encompassing PPC and supplementary materials was calculated and .

Proportions of coarse and fine aggregates are carefully calculated to achieve the desired mix properties. Adjustments are made for moisture content in aggregates, and the quantities of admixtures, if needed, are estimated. The next step involves conducting trial mixes to validate the chosen proportions, with adjustments made based on the results. Once the mix design is finalized, accurate batching and thorough mixing of ingredients during concrete production are critical. Quality control measures and testing procedures are implemented throughout production and placement to ensure the concrete's performance and durability align with project specifications and industry standards. The concrete mix is prepared by using IS method (IS 10262). From the first set of trial and error itself correct mix of M30 with water cement ratios 0.38 was obtained. The characteristic compressive strength required for M30 mix concrete was obtained at water- cement ratio of 0.38 and hence that was adopted as the optimum water-cement ratio. The final mix proportion of normal concrete is calculated and the mix design was done. This mix proportion of 1: 1.42: 3.09 with water cement ratio 0.38 was adopted for the further mixes with zeolite.

F. Optimisation Of Zeolite
Optimizing the zeolite content in concrete is crucial for enhancing both its mechanical and durability properties while maintaining cost-effectiveness and sustainability. Zeolite, a natural aluminosilicate, has demonstrated pozzolanic activity that contributes to the development of additional calcium silicate hydrate (C-S-H) gel, improving concrete strength and reducing permeability. However, excessive replacement of cement with zeolite can lead to a reduction in early-age strength and workability, making it essential to identify the optimal percentage that maximizes performance without compromising structural integrity. Through careful optimization, concrete mixtures can achieve superior compressive strength, improved bonding between aggregate and cement paste, and reduced susceptibility to microcracking, ultimately leading to longer-lasting structures. Beyond mechanical benefits, the proper optimization of zeolite content significantly enhances the durability of concrete in aggressive environments. Concrete exposed to chloride and sulphate-rich conditions often suffers from deterioration due to corrosion of embedded reinforcement and chemical degradation of the matrix. Ability of zeolite to act as a molecular sieve and bind harmful ions helps mitigate these effects, increasing resistance to chemical attack and reducing water absorption. Additionally, optimized zeolite content improves the microstructure of concrete, making it more resistant to freeze-thaw cycles, carbonation, and alkali-silica reactions, which are critical factors in extending the lifespan of infrastructure projects.

From an environmental and economic standpoint, optimizing zeolite in concrete promotes sustainability by reducing the dependency on traditional Portland cement, a major contributor to CO_2 emissions. The cement industry accounts for a significant portion of global greenhouse gas emissions, and partial replacement with zeolite can help lower the overall carbon footprint of construction materials. By determining the optimum zeolite percentage, construction projects can balance sustainability goals with economic feasibility, as excessive replacement may necessitate additional admixtures or processing adjustments. Thus, optimizing zeolite content not only improves the structural and durability aspects of concrete but also aligns with global efforts toward greener, more resilient infrastructure.

G. Optimisation Result

Optimization results for the compressive strength of concrete specimens containing varying percentages of zeolite (0%, 4%, 8%, 12%,) after 28 days of curing. The results indicate that the compressive strength initially increases with the addition of zeolite up to a certain percentage, after which it begins to decline. The highest compressive strength is observed in the specimen with 12% zeolite content, suggesting that this is the optimal percentage for maximizing strength. This trend is consistent with the hypothesis that zeolite, as a supplementary cementitious material, enhances the pozzolanic reaction, leading to improved strength. However, beyond the optimal percentage, the strength decreases, likely due to the dilution effect of cement, which reduces the binding capacity of the concrete mix. These findings are crucial for determining the ideal zeolite content to achieve the desired mechanical properties in concrete.

The graph illustrates the relationship between the percentage of zeolite in the concrete mix and the corresponding compressive strength. The x-axis represents the percentage of zeolite, while the y-axis denotes the compressive strength in MPa. The graph clearly shows a parabolic trend, with the compressive strength peaking at 5% zeolite content and then gradually decreasing as the zeolite percentage increases further. This visual representation reinforces the data presented in the table, highlighting the importance of optimizing zeolite content to achieve the best possible strength. The initial increase in strength can be attributed to the pozzolanic activity of zeolite, which reacts with calcium hydroxide to form additional calcium silicate hydrate (C-S-H) gel, enhancing the microstructure of concrete. However, the subsequent decline in strength beyond the optimal percentage underscores the need for careful proportioning of zeolite in the mix.

From an experimental perspective, these results are significant as they provide a clear guideline for the optimal use of zeolite in concrete. The data suggests that while zeolite can significantly improve the compressive strength of concrete, its benefits are maximized only within a specific range. This finding is particularly relevant for practical applications, where the goal is to enhance the mechanical properties of concrete without compromising its overall performance.

1) Compression test on cube
2) Split tensile strength on cylinder specimen
3) Flexural strength on beam specimen
4) Carbon emission test

a) Compression Test on Cube

Concrete is homogeneous blend of coarse aggregate, cement and sand and sufficient amount of water. Because all the physical characteristics of concrete have direct or indirect relation to crushing strength, it is most critical of all the characteristics of concrete. Maximum strength is developed by concrete at the place where hydration of cement is complete. Any surplus of water brings about porosity in concrete because of evaporation of the surplus water, and thereby decreases the strength of concrete. That is, the strength of concrete is negatively impacted when the water-cement ratio is greater

b) Split Tensile Strength

The split tensile test measures the material's tensile strength of concrete using a cylindrical concrete sample with diameter 150 mm and length 300mm, placed horizontally between the plates of a CTM. Two plates of the testing machine are positioned at the top and bottom of the cylinder across its diameter, creating a line load as load is applied. Under uniform loading across this setup, the cylinder fails under tensile stress perpendicular to the direction of the load. This failure mode allows calculation of the tensile strength of concrete using the load at failure, the diameter, and the length of the cylinder. This method offers a practical and efficient alternative to direct tensile testing, providing valuable insights into the behavior of concrete under tension. Two cylinders were cast and kept for water curing.

c) Flexural Strength on Beam Specimen

In the flexural strength test of concrete, a prismatic specimen typically measures 100 mm x 100 mm x 500 mm is commonly used. These dimensions ensure uniformity and comparability of test results across different laboratories and projects. During testing, the specimen is positioned horizontally on two supports with a specified span length in a three-point bending setup of a universal testing machine. A load is then applied at the midpoint between these supports until failure occurs. The flexural strength of the concrete, representing its ability to withstand bending stresses, is then calculated based on the applied load and specimen dimensions. This parameter is essential in structural design to ensure the safety and integrity of concrete elements such as beams, slabs, and columns. Two beams were cast and kept for water curing than that required for the total hydration of cement. For a given water-cement ratio and workability, the rise of aggregates-cement enhances the strength of concrete. Aggregate grading is crucial as graded aggregate will yield a mix with maximum voids. With the rise in concrete density, the strength of concrete rises. It is also evident that density increases with the increased compaction and this leads to higher strength. Curing is performed in the early stages of hardening to maintain concrete saturation until products of hydration have filled the originally water-filled space in fresh concrete.

III. TEST RESULTS

A. Compression Test

Mix designation	28^{th} day compressive strength				
	cube 1	cube 2	cube 3	average compressive strength (n/mm^2)	% increase in strength
z0	38.7	39.2	38.5	38.80	13.75
z12	44.2	43.5	44.7	44.13	

B. Split Tensile Stregth

% ZEOLITE CONTENT	Sl.No	LOAD (TONNE)	28 DAYS STRENTH (N/mm^2)	% INCREASE IN STRENGTH
Z0	1	40	5.55	18.02
Z12	1	45	6.55	

C. Flexural Stregth

FLEXURAL STRENGTH (N/mm^2)				
% ZEOLITE CONTENT	Sl.No	LOAD (KG)	28 DAYS STRENTH (N/mm^2)	% INCREASE IN STRENGTH
Z0	1	1000	4.8	20.83
Z12	1	1200	5.8	

IV. CONCLUSIONS

The study on the mechanical and durability properties of concrete incorporating zeolite has provided significant insights into its effectiveness as a sustainable supplementary cementitious material. The results demonstrated that an optimal zeolite replacement of 12% led to improvements in compressive, tensile, flexural, with respective increases of 13.75%, 18.02%, 20.83%, These enhancements were attributed to zeolite's pozzolanic activity, which promotes additional calcium silicate hydrate (C-S-H) gel formation, strengthening the concrete matrix. Additionally, the microporous nature of zeolite improves particle packing, reducing internal voids and enhancing overall density, making it a viable alternative to traditional cement-based materials.

Beyond mechanical properties, durability assessments indicated superior performance of zeolite-modified concrete in aggressive environments. The material exhibited increased resistance to acid attack by 11.38% and sulfate attack by 10.05%. A decrease in water absorption and capillary rise by 12.55% and 21.36%, respectively, confirmed reduced permeability, minimizing chloride ingress and improving long-term durability.

V. ACKNOWLEDGMENT

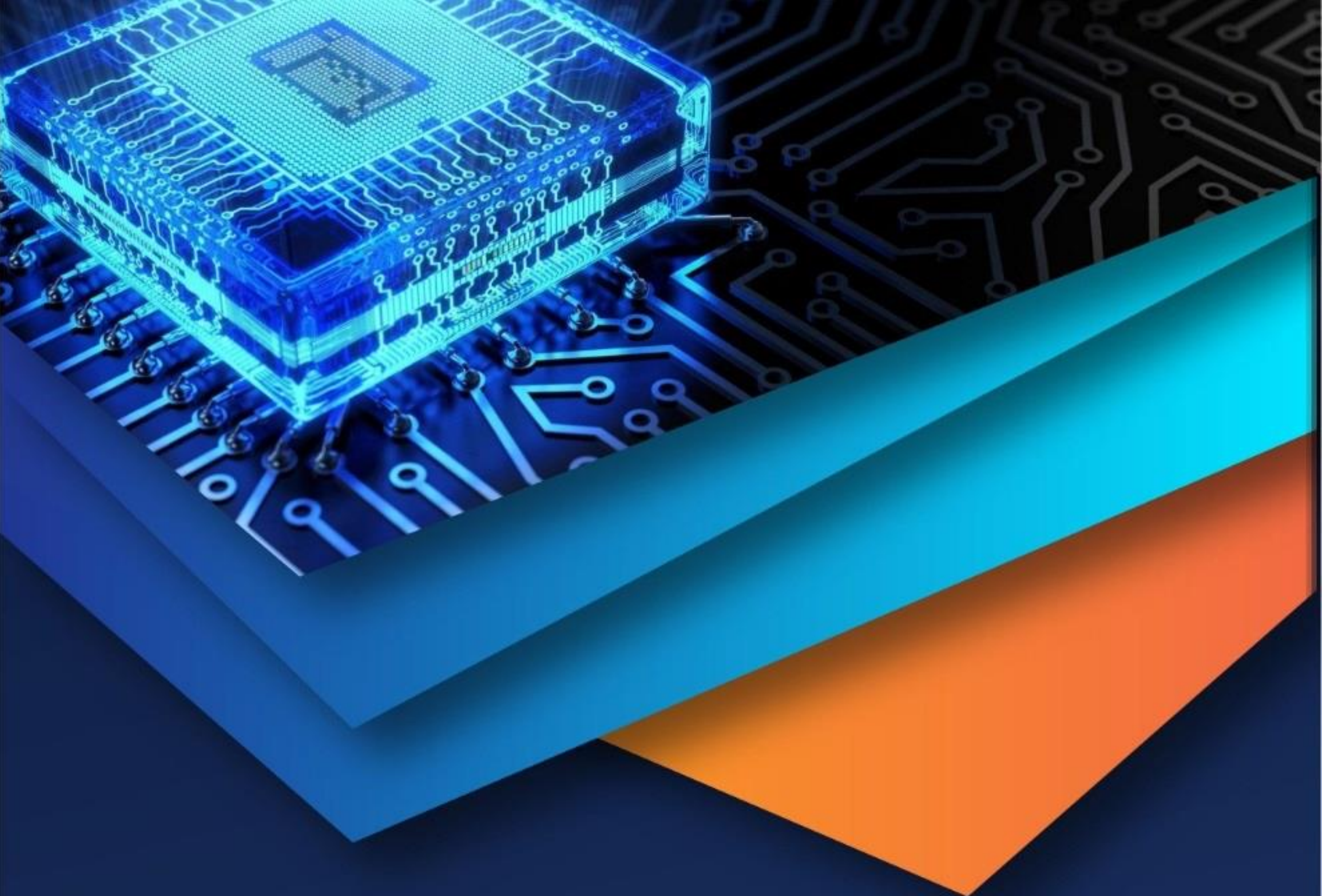
We would remember with grateful appreciation, the encouragement and support rendered by the authority of Eranad Knowledge City Technical Campus, especially Mr.ADARSH.T.K, Principal, Eranad Knowledge City Technical Campus, Manjeri, to successfully complete this project and Michael Shell and other contributors for developing and maintaining the IEEE LaTeX style files which have been used in the preparation of this template.

We express our deepest sense of gratitude to Mrs. Fathima Fayiza Elachola, Head of the Department of Civil Engineering and project coordinator Mrs. Rineesha p, Assistant Professor, Department of CE for their keen interest and constant encouragement with our work during all stages.

We greatly acknowledge all other staff members of the department and all our friends and well- wishers, who directly or indirectly contributed in this work and and Michael Shell and other contributors for developing and maintaining the IEEE LaTeX style files which have been used in the preparation of this template.Our heartfelt thanks to my family members for their kind cooperation in completing this project and last but not least, we are indebted to God Almighty for being the guiding light throughout this project and helped us to complete the same within the stipulated time.

REFERENCES

[1] Alexa-Stratulat et al. (2023). The use of natural zeolites in cement-based construction materials. A state of the art review. Coatings, 14(1), 18.
[2] Dr. Setiabudi (2019). How to read and interpret FTIR spectroscope of organic material. Indonesian Journal of Science and Technology, 4(1), 97-118.
[3] Gilar Wisnu Hardi, Muhammad Artha (2020). A Review of Natural Zeolites and
[4] Their Applications: Environmental and Industrial Perspectives. International Journal of Applied Engineering Research, Volume 15, 730-734.
[5] Gowram Iswarya, Beulah M (2021). Use of zeolite and industrial waste materials in high strength concrete-A review. Materials Today: Proceedings, 46, 116-123.
[6] Meysam Najimi etal. (2012). An experimental study on durability properties of concrete containing zeolite as a highly reactive natural pozzolan. Construction and building materials, 35, 1023-1033
[7] M. T. Nooman (2016). Effect of zeolite inclusion on some properties of concrete and corrosion rate of reinforcing steel bars imbedded in concrete. Journal of Mechanical and Civil Engineering, 13(6), 51-59..
[8] Nabil M et al.(2006). Durability of metakaolin concrete to sulfate attack. Cement and concrete research, 36(9), 1727-1734.
[9] Nafisa N. Shaikh, A.V.Karvekar (2020). Study of strength properties of concrete with zeolite as a partial replacement of cement" JETIR, vol.7.
[10] Paulson, B. M., Joby Thomas, K., Raphael, V. P., Shaju, K. S., & Ragi, K. (2020). Mitigation of concrete reinforced steel corrosion by penta sodium triphosphate: physicochemical and electrochemical investigations. SN Applied Sciences, 2, 1-
[11] Pawan Kumar et al..(2019). Natural zeolite and its application in concrete composite production. Composites Part B: Engineering, 165, 354-364.



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