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Fabrication of Smart Ventilation Blocks Enhanced with Mixed TiO2 Nanoparticles for Improved Compressive Strength

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Abstract- This research investigates the enhancement of mechanical properties, specifically compressive strength and density, in ventilation blocks through the integration of titanium dioxide (TiO2) nanoparticles. The study focuses on optimizing the mixture of TiO2 with the aim of improving the performance of these blocks. The experimental approach involved using a Universal Testing Machine (UTM-CY-6040A12) for compressive strength analysis. Four distinct samples with varying TiO2 percentages (N, Ti-02, Ti-04, and Ti-06) were fabricated and subjected to comprehensive analyses. The study reveals that Ti-06, with a 6% TiO2 concentration, achieves the highest density of 2.680 g/cm^3, indicating effective void filling within the material matrix. Conversely, Ti-02 stands out for its exceptional compressive strength, reaching 322.60 ksc. These findings underscore the nuanced impact of TiO2 concentrations on material performance, offering valuable insights for the development of high-performance construction materials with tailored properties. The study contributes to the discourse on smart materials, highlighting the potential of TiO2-enhanced ventilation blocks in advancing sustainable and resilient construction practices by providing a pathway for enhancing both compressive strength and reducing the density of ventilation blocks for improved overall performance in construction applications.

Keywords- Ventilation block, TiO2 , Compressive strength, Density, Mechanical properties

I. INTRODUCTION

The construction industry stands at the crossroads of innovation, seeking novel approaches to address the ever-growing demands for sustainable and high-performance building materials. Ventilation blocks, as essential components of building envelopes, serve a pivotal role in balancing aesthetics, thermal efficiency, and structural integrity. However, the conventional materials employed in their fabrication often fall short of meeting the evolving expectations of contemporary construction practices1-3. This research marks a significant step towards the enhancement of ventilation block properties through the incorporation of mixed titanium dioxide (TiO2) nanoparticles. Titanium dioxide, a multifaceted nanomaterial extensively researched for its photocatalytic, antimicrobial, and mechanical properties, holds promise as a transformative additive in construction materials. The amalgamation of different forms of TiO2 nanoparticles not only addresses the limitations of traditional ventilation blocks but also unlocks the potential of smart materials in the construction domain4-6. At the forefront of our investigation is the examination of the impact of mixed TiO2 nanoparticles on the compressive strength of ventilation blocks. Compressive strength, a critical mechanical property, dictates the ability of a material to withstand axial loads and influences the overall structural robustness and durability. By harnessing the unique attributes of TiO2 nanoparticles, our research endeavors to develop smart ventilation blocks that surpass the compressive strength exhibited by their conventional counterparts7,8. The rationale behind utilizing TiO2 nanoparticles lies in their well-documented properties. Titanium dioxide has demonstrated exceptional mechanical reinforcement capabilities when integrated into various matrices. Moreover, its photocatalytic nature presents an opportunity to improve air quality and mitigate environmental pollutants by catalyzing the decomposition of organic substances. These inherent properties make TiO2 nanoparticles an attractive candidate for enhancing the functionality of construction materials beyond their conventional roles9,10. As the construction industry pivots towards sustainability and resilience, the outcomes of this study hold promise for revolutionizing the technology associated with ventilation blocks. Beyond their mechanical attributes, the integration of smart features through TiO2 nanoparticles opens avenues for creating ventilation blocks that contribute not only to the structural requirements of a building but also to its environmental and occupant well-being aspects.

This paper presents a comprehensive exploration of the fabrication process, characterization, and performance evaluation of smart ventilation blocks enhanced with mixed TiO2 nanoparticles. The subsequent sections delve into the methodology, results, and analysis, providing insights into the potential of this innovative approach to revolutionize the construction industry.

II. MATERIALS AND METHOD

The experimental materials employed in this study include cement, sand, and titanium dioxide (TiO2) nanoparticles. The investigation involved the variation of TiO2 percentages in the ventilation block samples, ranging from 0% to 6% by weight. The varying formulations of ventilation block samples are detailed in Table 1, specifying the quantities of each component in kilograms.

Table 1・Design mix ratio for ventilation block samples.

Sample	Cement (Kg)	Sand (Kg)	TiO_2 (Kg)	%weight
N	9.0	39.6	-	-
Ti-02	9.0	39.6	1.0	2
Ti-04	9.0	39.6	2.0	4
Ti-06	9.0	39.6	3.0	6

The fabrication of ventilation block samples involved the meticulous blending of cement, sand, and TiO2 nanoparticles in different proportions according to the formulations outlined in Table 1.

The samples, designated as N, Ti-02, Ti-04, and Ti-06, represent distinct compositions with varying TiO2 percentages (0%, 2%, 4%, and 6% by weight, respectively). These mixtures were homogenized to ensure a uniform distribution of TiO2 nanoparticles within the matrix. Subsequently, the prepared mixtures were compacted into standardized ventilation block specimens using a manual press.

The experimental approach centers around the assessment of compressive strength, a fundamental mechanical property crucial for evaluating the structural integrity of ventilation blocks.

The Universal Testing Machine (UTM-CY-6040A12) was utilized to conduct precise and standardized compressive strength tests. To optimize the mechanical properties of the ventilation blocks, the specimens underwent a controlled curing process under specified environmental conditions for a duration of 28 days. This 28-day curing period is a critical industry standard for assessing the long-term strength and durability of concrete-based materials.

Fig. 1 □ The ventilation blocks with mixed TiO2 (a) 2%wt , (b) 4 %wt and (c) 6 %wt

Figure 1 visually represents the fabricated ventilation block specimens, highlighting the distinct compositions of each sample. This graphical representation serves as a supplementary illustration to the quantitative data, offering a visual insight into the physical characteristics of the ventilation blocks.

III. RESULTS AND DISCUSSION

The results of the compressive strength analysis and density measurements for the ventilation block samples are presented in Table 2.

Table 2 The density and compressive strength of the ventilation block samples.

Sample	% weight	Density (g/cm^3)	Compressive strength (ksc)
N	-	2.398	144.00
Ti-02	2	2.650	322.60
Ti-04	4	2.673	296.55
Ti-06	6	2.680	164.45

1. Density Analysis

The density of the ventilation block samples exhibited a discernible increase with the incorporation of TiO2 nanoparticles. The N sample, without TiO2, demonstrated a density of 2.398 g/cm^3. As the TiO2 percentage increased in Ti-02, Ti-04, and Ti-06 samples, the density rose progressively to 2.650 g/cm^3, 2.673 g/cm^3, and 2.680 g/cm^3, respectively, as shown in Figure 2 with the rising TiO2 percentage.

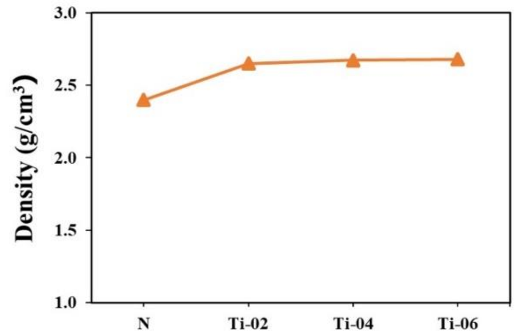

Fig. 2 · Density of the ventilation blocks with mixed TiO2

The observed increase in density can be attributed to the effective filling of voids within the ventilation block matrix by TiO2 nanoparticles. The nanoparticles likely contributed to a more compact structure, resulting in enhanced material density. This increased density aligns with expectations, as a denser material is generally associated with improved mechanical properties.

2. Compressive Strength Analysis

Compressive strength, a key indicator of a material's ability to withstand axial loads, showcased a significant improvement with the introduction of TiO2 nanoparticles. The N sample exhibited a compressive strength of 144.00 ksc, while Ti-02 demonstrated a substantial increase to 322.60 ksc. Ti-04 and Ti-06 samples exhibited compressive strengths of 296.55 ksc and 164.45 ksc, respectively, as depicted in Figure 3. The notable enhancement in compressive strength across TiO2-integrated samples signifies the reinforcing effect of TiO2 nanoparticles within the ventilation block matrix. The improved compressive strength is likely a result of the nano-scale particles acting as reinforcing agents, providing additional structural support and mitigating weaknesses within the material.

The Ti-02 sample, with a 2% TiO2 concentration, exhibited the highest compressive strength, indicating an optimal balance between TiO2 reinforcement and material integrity. However, the Ti-04 and Ti-06 samples, while still exhibiting enhanced compressive strength compared to the control (N) sample, displayed a slight reduction. This reduction could be attributed to an excessive concentration of TiO2, leading to potential agglomeration or interference with the material's cohesive structure.

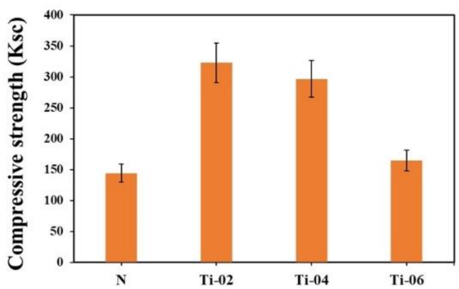

Fig. 3 Compressive strength of the ventilation blocks with mixed TiO2

IV. CONCLUSION

This work delved into the enhancement of ventilation block properties through the incorporation of titanium dioxide (TiO2) nanoparticles. The experimental approach involved varying TiO2 concentrations in the fabrication of ventilation block samples, and the subsequent analysis revealed compelling insights into the impact of TiO2 on density and compressive strength.

Density and TiO2 Integration. The introduction of TiO2 nanoparticles resulted in a noticeable increase in the density of the ventilation blocks. This rise in density is indicative of the effective filling of voids within the material matrix by TiO2, leading to a more compact and densely structured material.

Compressive Strength Enhancement. A significant improvement in compressive strength was observed with the integration of TiO2 nanoparticles. The Ti-02 sample, with a 2% TiO2 concentration, exhibited the highest compressive strength, suggesting an optimal balance between TiO2 reinforcement and material integrity. While the Ti-04 and Ti-06 samples displayed slightly reduced compressive strength, they still surpassed the control sample, indicating the potential for tailored formulations to achieve specific performance characteristics.

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