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OPTIMIZATION OF MARBLE DUST AND BRICK POWDER IN CEMENT MORTAR FOR SUSTAINABLE CONSTRUCTION: A STRENGTH PERFORMANCE ANALYSIS

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ABSTRACT

The present research focuses on developing a sustainable cement mortar by incorporating marble dust and brick powder as partial replacement materials for cement and fine aggregate. Different mix combinations were prepared with varying replacement levels, and their mechanical performance was assessed through compressive strength tests conducted at 14 and 28 days. The findings reveal that controlled replacement levels contribute to improved strength performance, with optimum results achieved at 10% marble dust and combined 20% replacement levels. The improvement in strength is mainly associated with better particle packing and reduced internal voids within the mortar matrix. However, higher replacement percentages showed a decline in strength due to increased porosity and weaker interfacial bonding. The study also highlights the potential utilization of industrial waste materials in reducing environmental burden and conserving natural resources. The outcomes of this research provide a practical basis for selecting suitable replacement levels in mortar production while maintaining structural efficiency. Further investigation is required to evaluate long-term durability and large-scale application of such materials.

KEYWORDS: Sustainable Cement Mortar, Marble Dust, Brick Powder, Waste Material Utilization, Compressive Strength, Eco-Friendly Construction, Mix Optimization

1. INTRODUCTION

Cement mortar is one of the most widely used construction materials due to its strength and versatility. However, the increasing consumption of cement and natural sand has led to serious environmental concerns, including high carbon emissions and depletion of natural resources. To address these issues, recent research has focused on incorporating industrial and construction waste materials as partial replacements in cement-based composites.

Marble dust and brick powder are two such waste materials generated in large quantities from marble processing and brick manufacturing industries. Marble dust, owing to its fine particle size and calcium-rich composition, can enhance the packing density of the cement matrix. Brick powder, on the other hand, exhibits pozzolanic characteristics that contribute to improved mechanical properties when used appropriately. The utilization of these materials not only reduces environmental impact but also supports sustainable construction practices.

Previous studies have investigated the use of marble dust and brick powder individually or in limited combinations. However, there is a lack of systematic studies focusing on their combined and optimized utilization in cement mortar. In this context, the present study aims to evaluate the effect of marble dust and brick powder as partial replacements for cement and fine aggregate, with a focus on identifying optimum replacement levels and analyzing their influence on compressive strength performance.

2. MATERIALS AND METHOD

A systematic experimental technique was used to evaluate the mechanical characteristics of cement mortar containing marble dust and brick powder as partial substitutes for cement and sand, respectively. The work was divided into several stages, including material selection, mix design, specimen preparation, testing, and analysis.

Materials: The principal binder used was Ordinary Portland Cement (OPC). Marble dust, obtained from industrial waste, was used as a partial replacement for cement, while brick powder, produced from crushed waste bricks, was used as a partial replacement for sand. Natural river sand, potable water, and standard cube molds of 70.6 mm and 100 mm size were used for specimen preparation.

Mix Design: A basic mortar mix ratio of 1:2 (cement:sand) with a water-cement ratio of 0.4 was adopted. Different mix combinations were prepared by replacing cement with marble dust and sand with brick powder at varying levels (0%, 5%, 10%, 20%, and 100%).

Casting and Curing: The materials were dry mixed, followed by the addition of water to obtain a uniform mix. The mortar was placed in molds and compacted using a mechanical vibrator to eliminate air voids. After demolding, the specimens were cured in water for 14 and 28 days, as per IS specifications. (as shown in Fig. 1).

Testing: Compressive strength tests were conducted using a standard compression testing machine in accordance with IS guidelines. The results were analyzed to evaluate the effect of waste material incorporation.

This methodology ensured a consistent and reproducible process, thereby contributing to sustainable and cost-effective construction practices..

Fig.1: Methodology stages from Casting to Testing.

3. RESULTS & DISCUSSION

The experimental results indicate that the incorporation of marble dust and brick powder significantly influences the strength characteristics of cement mortar. The compressive strength results obtained at 7 and 28 days show a clear variation with different replacement levels. The mix containing 10% marble dust (M10, B0) exhibited the highest compressive strength of 8.4 MPa at 28 days,

which is higher than the control mix. This improvement can be attributed to the filler effect of finely divided marble particles, which enhances particle packing and reduces voids within the mortar matrix. As a result, a denser and more compact microstructure is achieved, leading to improved strength. Similarly, the combined mix (M20, B20) demonstrated comparable compressive strength (8.4 MPa at 28 days), indicating a beneficial synergistic interaction between the two materials. The presence of brick powder contributes to pozzolanic activity, which enhances the bonding within the matrix, while marble dust improves the packing density. This combined effect results in better mechanical performance compared to individual replacements. However, higher replacement levels such as 100% substitution (M0, B100 and M100,B0) showed a reduction in compressive strength. This decrease is primarily due to increased porosity and weaker bonding caused by excessive replacement of cement and natural sand. The results suggest that controlled and optimized replacement levels are essential to achieve improved performance.

Figure 2 presents the variation in compressive strength at 14 days for different mix proportions, while Figure 3 illustrates the corresponding results at 28 days. It is observed that strength increases up to optimum replacement levels and decreases beyond that due to increased porosity and reduced bonding.

Fig. 2 Compressive Strength at 14 days variation across different mixes (Comparison of compressive strength of mortar mixes at 14 days)

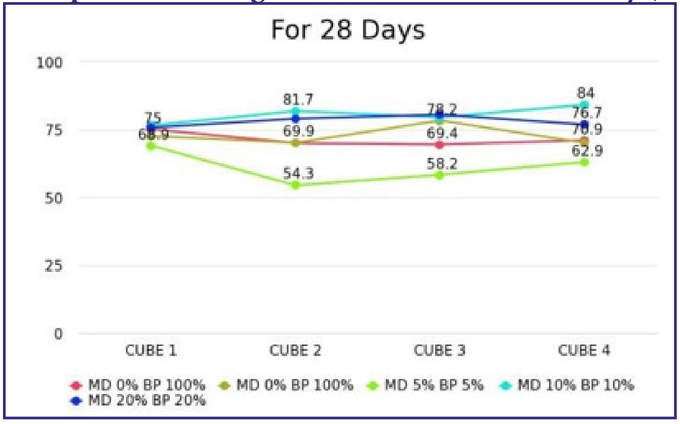

Fig. 3 Compressive strength of mortar mixes at 28 days (Comparison of compressive strength of mortar mixes at 28 days).

Split Tensile strength

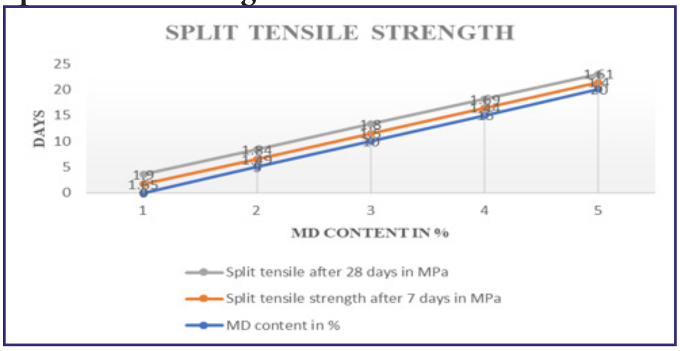

Fig. 4 (Comparison of compressive strength of mortar mixes at 7 & 28 days).

Flexural Strength

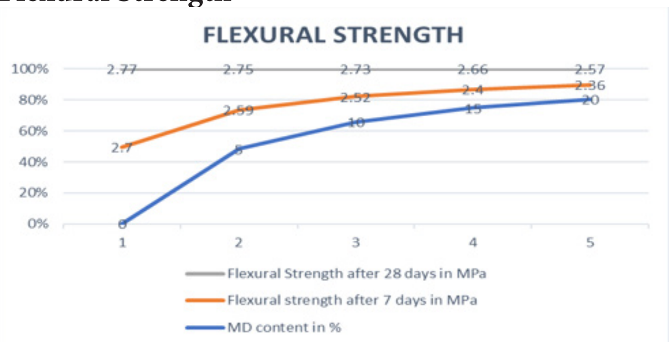

Fig. 5 (Comparison of compressive strength of mortar mixes at 7 & 28 days).

The split tensile and flexural strength results follow a trend similar to compressive strength. Optimum performance is observed at moderate replacement levels, indicating improved bonding characteristics and crack resistance due to better particle packing and pozzolanic interaction of brick powder.

Overall, the findings highlight that the combined and optimized use of marble dust and brick powder can enhance the strength performance of cement mortar while promoting sustainable utilization of waste materials. The study clearly demonstrates that an optimum replacement range of 10–20% provides the best balance between strength and sustainability.

4. CONCLUSION

This study evaluates the use of marble dust and brick powder as partial replacements for cement and fine aggregate in cement mortar. The results indicate that controlled replacement levels can improve compressive strength, with optimum performance observed at 10% marble dust and combined replacement levels up to 20%.

The improvement in strength is primarily attributed to enhanced particle packing and the contribution of brick powder towards better bonding within the mortar matrix. However, higher replacement levels resulted in a reduction in strength due to increased porosity and weaker interfacial characteristics, indicating that excessive substitution is not suitable for structural applications.

The findings suggest that the combined utilization of marble dust and brick powder can serve as a viable approach for developing sustainable construction materials while maintaining acceptable mechanical performance. Further research is recommended to investigate long-term durability and practical field applications of the proposed mixes.

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Author contributions

All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by Ravneet Singh Sidhu, Anish Tayal and Sandeep Maan. The first draft of the manuscript was written by Ravneet Singh Sidhu. All authors read and approved the final manuscript.

Competing Interest

The authors declare that they have no known competing personal and financial interest relationships that could have appeared to influence the work reported in this paper.

Ethical Approval

This study does not involve any human participants or animals. Therefore, ethical approval was not required.

Consent to Participate

Not Applicable Consent to Publish Not Applicable

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Data and Code Availability

The datasets generated during and/or analyzed during the current study are available from the corresponding author upon reasonable request.