A COMPARATIVE STUDY ON THE EFFECTS OF PARTIAL REPLACEMENT OF FINE AGGREGATE WITH MARBLE DUST IN CONCRETE

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Abstract - *Concrete is a versatile and commonly used construction material designed to withstand compressive stresses. The cost of sand production and utilization is higher, leading to various environmental issues. Sand is a natural product, but mining it along the Narmada River poses risks due to natural disasters. It is crucial to prepare for potential challenges in the future. The substance mistaken for dust is actually marble, a novel composite material that can enhance material efficiency in the concrete industry, yield economic advantages, and facilitate the construction of environmentally friendly, robust, and long-lasting structures. Lime can enhance the reactivity of marble dust, making it a viable option as a cement binder. Environmental issues are often a result of industrial waste, underscoring the importance of recycling. Annually, millions of metric tons of marble dust are produced globally during quarrying operations. The effective use of marble powder in concrete has significantly improved the material's ability to maintain its hardened state. To incorporate marble dust as a binding agent in concrete and mortar production, an analysis from both physical and chemical perspectives is necessary. Pure limestone transforms into marble through metamorphism, typically containing over 50% calcium oxide. By substituting sand with marble dust in concrete, we can reduce our environmental impact, save costs, and increase durability. Various mixtures of M20(1:1.5:3) grade concrete with marble dust replacing sand at different percentages were tested for compressive strength at 7 and 28 days using 150 mm x 150 mm x 150 mm cubes. Enhancing concrete with high-quality binding elements like marble dust can improve workability, durability, strength, fracture resistance, and permeability. Modifying the microstructure of cement composites in the future may enhance their compressive strength, flexural strength, split tensile strength, durability, and service life..*

Key Words: Concrete, marble dust, fine aggregate replacement, sustainable construction, mechanical properties, compressive strength, tensile strength.

1.CONCRETE

Concrete, a ubiquitous material in modern construction, embodies the essence of durability and versatility. Composed primarily of cement, water, and aggregates such as sand and gravel, it forms a robust matrix capable of withstanding immense compressive forces. Its history traces back to ancient civilizations like the Romans who used a similar substance called "opus caementicium" in their architectural marvels. Today, concrete's applications are boundless, from towering skyscrapers to intricate bridges, and even humble sidewalks. Its adaptability allows for the realization of intricate designs while ensuring structural integrity. Beyond its strength, concrete offers thermal mass properties, aiding in temperature regulation within buildings. However, despite its durability, concrete production bears environmental consequences, notably due to cement manufacturing's high carbon footprint. Efforts are underway to innovate sustainable alternatives, such as using recycled materials or developing new cement formulations with reduced emissions. Concrete stands as a cornerstone of modern civilization, symbolizing both the ingenuity of human engineering and the ongoing pursuit of sustainable progress in construction practices.

Figure-01: PPC Concrete

1.1.Component of the Concrete

Concrete is primarily composed of four main components:

1.1.1.Binding Material

Cement, the binding material in concrete, serves as the foundational component that imparts strength and cohesion to the mixture. Derived from a finely ground blend of limestone, clay, and other minerals, cement undergoes a chemical transformation when mixed with water, resulting in hydration. This hydration process forms a paste that coats and binds together the aggregates, filling the voids between particles. As the cement paste hardens and solidifies, it creates a robust matrix that binds the entire concrete mixture into a cohesive unit. The quality of cement greatly influences the properties of the concrete, including its strength, durability, and resistance to environmental factors. Consequently, selecting the appropriate type and quality of cement is crucial in ensuring the structural integrity and performance of concrete in various construction applications.

1.1.2.Coarse Aggregate

Coarse aggregate, a fundamental component of concrete, contributes to its structural integrity and overall performance. Comprising materials such as gravel, crushed stone, and recycled concrete, coarse aggregates provide bulk and stability to the concrete mixture. These aggregates typically range in size from 3/8 inch to several inches in diameter, depending on the specific application and design requirements. Their primary function is to provide strength and support by distributing loads evenly throughout the concrete mass. Additionally, coarse aggregates interlock with each other and the cement paste, enhancing the concrete's resistance to deformation and improving its durability under various stresses. The selection of coarse aggregate type and size plays a critical role in determining the concrete's strength, workability, and appearance. Proper grading and quality control of coarse aggregates are essential to ensure the desired performance and longevity of the concrete structure.

The purpose of coarse aggregate in concrete is multifaceted, serving crucial roles in its overall performance and structural integrity. Firstly, coarse aggregates provide bulk and volume to the concrete mixture, reducing the amount of cement paste needed while maintaining the desired workability. By occupying the spaces between cement particles, coarse aggregates enhance the concrete's resistance to shrinkage and cracking during the drying and curing process. Moreover, they contribute significantly to the concrete's compressive strength, distributing applied loads and stresses throughout the structure. Through interlocking and bonding with the cement paste, coarse aggregates reinforce the concrete matrix, improving its resistance to deformation and enhancing durability under various environmental conditions and loading scenarios. Additionally, coarse aggregates help control thermal expansion and contraction, as well as provide thermal mass properties, aiding in temperature regulation within concrete structures. Overall, the presence of coarse aggregates is indispensable for ensuring the stability, strength, and longevity of concrete in diverse construction applications.

1.1.3.Fine Aggregate

Fine aggregate, a vital constituent of concrete, serves several critical functions essential for the material's overall performance and characteristics. Comprising materials such as sand, crushed stone dust, or recycled concrete particles smaller than 5mm in size, fine aggregates play a pivotal role in enhancing the workability, cohesion, and durability of concrete mixtures. By filling the voids between coarse aggregate particles, fine aggregates improve the packing density of the concrete mix, thereby reducing the amount of voids and optimizing the particle distribution within the matrix. This optimized particle distribution enhances the concrete's strength and density while minimizing the risk of segregation and bleeding during placement and compaction. Furthermore, fine aggregates contribute to the formation of a dense and impermeable cement paste, which enhances the concrete's resistance to moisture ingress, chemical attack, and abrasion over time. Additionally, fine aggregates help control the overall volume and consistency of the concrete mixture, ensuring proper bonding between particles and facilitating the attainment of desired surface finishes in finished concrete structures. Overall, the presence of fine aggregates is essential for achieving the desired properties of concrete, including strength, durability, and workability, making them indispensable components in modern construction practices.

2. REPLACEMENT OF THE FINE AGGREGATE WITH OTHER MATERIAL

Replacing fine aggregate in concrete with alternative materials is a topic of ongoing research and innovation in the construction industry. Some common reasons for exploring alternatives include scarcity of natural sand, environmental concerns related to sand mining, and the desire to create more sustainable construction practices. Here are some materials that have been considered or used as replacements for fine aggregate:

2.1.Manufactured Sand (M-Sand)

Produced by crushing rocks, M-sand is a viable alternative to natural river sand. It has similar properties to river sand and can be used in concrete production. Its use reduces the strain on natural sand reserves.

2.2.Crushed Rock Fines (CRF)

Crushed rock fines obtained from quarries can be used as a replacement for natural sand. These fines are produced during the crushing process of rock aggregates and have similar properties to natural sand.

2.3.Recycled Concrete Aggregate (RCA)

Crushed concrete from demolished structures can be used as a substitute for natural sand. This not only reduces the demand for virgin materials but also helps in managing construction waste.

2.4.Recycled Glass

Finely crushed recycled glass can be used as a partial replacement for fine aggregate. It offers benefits such as reduced landfill waste and can impart unique aesthetic qualities to concrete.

2.5.Recycled Plastics

Some researchers have explored the use of finely shredded plastic waste as a replacement for fine aggregate. While still in experimental stages, this approach aims to address both waste management issues and reduce the environmental impact of concrete production.

2.6.Fly Ash

A byproduct of coal combustion in power plants, fly ash can be used as a partial replacement for cement as well as fine aggregate. It improves concrete's workability, durability, and reduces its environmental footprint.

2.7.Silica Fume

Also known as microsilica, silica fume is a byproduct of silicon and ferrosilicon alloy production. It is highly reactive and can be used as a partial replacement for cement as well as fine aggregate. Its use improves concrete's strength and durability.

2.8.Expanded Clay or Shale

Lightweight aggregates like expanded clay or shale can be used as a replacement for fine aggregate in lightweight concrete applications. They offer reduced density and improved thermal insulation properties.

3.REPLACEMENT OF THE FINE AGGREGATE WITH DUST OF MARBLE

Replacing fine aggregate with marble dust is an innovative approach in concrete production, offering both environmental and aesthetic benefits. Marble dust, a byproduct of marble processing, is finely powdered and can serve as a sustainable alternative to natural sand. Utilizing marble dust in concrete not only reduces the environmental impact of marble quarrying but also alleviates the strain on natural sand resources. Additionally, incorporating marble dust can enhance the visual appeal of concrete, imparting a distinctive finish that reflects the elegance of marble. However, careful consideration must be given to factors such as particle size distribution, chemical composition, and the effect on concrete's mechanical properties when determining the optimal mix proportions. Thorough testing and experimentation are essential to ensure that concrete containing marble dust meets the required standards for strength, durability, and workability, thus realizing the potential of this alternative material in sustainable construction practices.

4.IMPORTANT OF THE MARBLES DUST AS FINE AGGREGATE

The use of marble dust as a fine aggregate in concrete offers several important advantages:

4.1.Environmental Sustainability

Marble dust is a byproduct of marble processing, which means its use in concrete reduces the environmental impact associated with marble quarrying and processing. By utilizing this waste material, it helps in conserving natural resources and reducing landfill waste.

4.2.Resource Conservation

Incorporating marble dust as a fine aggregate reduces the demand for natural sand, which is often sourced from riverbeds and coastal areas. By substituting marble dust for natural sand, the strain on these natural resources is alleviated, contributing to their preservation.

4.3.Improved Aesthetic Appeal

Concrete made with marble dust as a fine aggregate can have a visually appealing finish, reminiscent of the elegance of marble. This can be particularly desirable in architectural applications where aesthetics are important, adding a touch of sophistication to the finished structure.

4.4.Enhanced Mechanical Properties

Properly engineered concrete mixes containing marble dust can exhibit favorable mechanical properties. While the exact effects may vary depending on factors such as particle size distribution and chemical composition, marble dust can contribute to improved strength, durability, and workability of concrete.

4.5.Potential Cost Savings

Utilizing waste materials like marble dust in concrete production can lead to cost savings for construction projects. Instead of disposing of marble dust as waste, its incorporation into concrete provides a value-added use, potentially reducing material procurement costs.

4.6.Reduced Carbon Footprint

By substituting marble dust for traditional fine aggregate, the carbon footprint associated with concrete production may be reduced. This is especially significant if marble dust is sourced locally, minimizing transportation-related emissions.

4.7.Innovation and Research

Exploring alternative materials like marble dust encourages innovation and research in the construction industry. Researchers and engineers continually investigate the properties and potential applications of such materials, contributing to the development of more sustainable construction practices.

5.RESULT AND DISCUSSION

The task's fulfillment encompasses two separate phases, with the first stage yielding a visual portrayal of the result. Through meticulous examination, cubes, cubes with bars, and cylinders have all been scrutinized to ascertain their individual capacities at 7 days and 28 days. This information forms the basis for assessing the different mix ratios in terms of strength. Furthermore, a comparison has been established between the strengths demonstrated at 7 days and 28 days for additional scrutiny and assessment.

5.1.Result of Compressive Strength

It is apparent that there is a substantial 21.74% enhancement in compressive strength when marble dust is utilized to substitute sand by 10%. Nevertheless, with an increase in the percentage of marble dust replacement to 15%, the strength begins to diminish, ultimately reaching a minimum level. Conversely, the graph illustrating the 28-day strength (graph 2) displays a 16.85% escalation in strength when an additional 10% of marble dust is incorporated into the standard concrete mixture. Intriguingly, surpassing this threshold of marble dust addition leads to a decline in the concrete strength once again. These findings underscore the significance of carefully assessing the quantity of marble dust utilized in concrete mixtures to attain optimal strength characteristics.

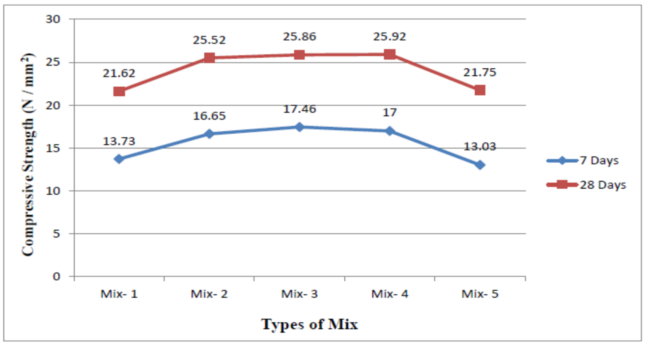

Figure-02: Result of Compressive Strength

5.2.Strength of Split Tensile

It is apparent that the split tensile strength demonstrates a remarkable increase of 15% when 15% of the sand is substituted with marble dust. However, with a further 20% increase in the proportion of marble dust, the concrete strength begins to exhibit a decrease after 28 days. Figure 5.4 visually depicts a substantial 35% enhancement in strength with the replacement of 15% marble dust in the standard concrete mix. Yet, with a subsequent 20% increment in the amount of marble dust, the concrete strength once again declines. This data highlights the influence of marble dust on the strength characteristics of concrete, showcasing both the positive and negative impacts of its inclusion in the mixture.

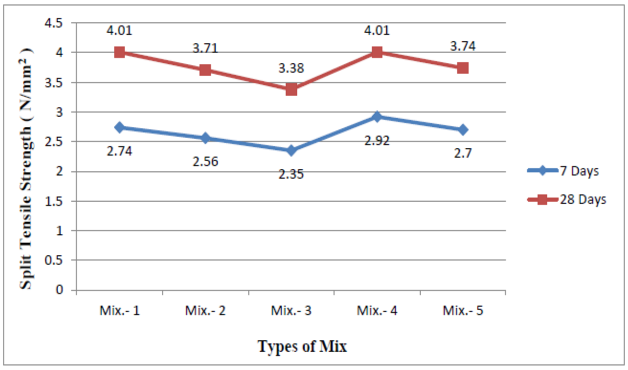

Figure-03: Result of Split Tensile Test

5.3.Bond Strength Test

The bond strength was assessed through testing two cubes from each batch mix after seven days and then again after twenty-eight days. A total of five distinct batch mixes were examined, with each mix containing two cubes for evaluation. This method facilitated a thorough evaluation of bond strength evolution over time and across various mixtures, yielding valuable data for detailed analysis and comparison.

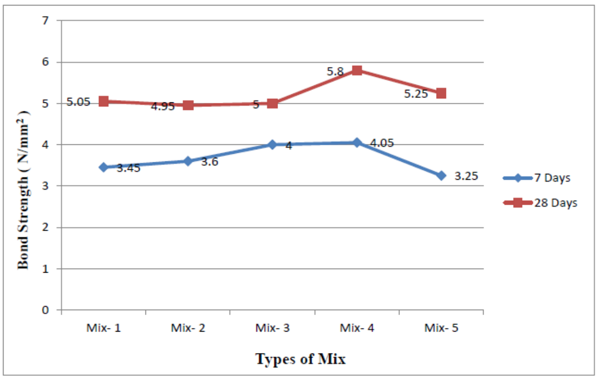

Figure-04: Bond Strength Test

6.CONCLUSION

The research revealed that the substitution of ten percent of sand with marble dust (mix-03) resulted in a substantial improvement in the compressive strength of the concrete.

Furthermore, replacing 15% of the sand with marble dust (mix-04) led to a significant increase in the bond strength of the concrete. Additionally, the study demonstrated that when 15% of sand (mix-04) was replaced by weight with marble dust, the split tensile strength of the concrete reached its maximum value. These results underscore the positive influence of marble dust on various strength properties of concrete, underscoring its potential as a beneficial additive in concrete mixtures. At 7 and 28 days after curing, the compressive strength, split tensile strength, bond strength, and density of concrete mixtures are evaluated following the incorporation of a specific quantity of marble dust. In our research, the optimal proportion of Marble Dust is identified as five percent (in relation to the weight of Sand), and a variety of concrete characteristics are scrutinized. Marble Dust is added to the concrete in different ratios ranging from zero percent to twenty percent relative to the weight of Sand. The following conclusions can be drawn after completing all assessments and analyzing their results.

REFERENCE

1. Pozzolanic properties of marble industrial waste and its used in concrete. 7(3), 1083–1090. https://doi.org/10.33379/gtech.v7i3.2765.

2. Experimental Investigation of Concrete by Partial Replacement of Fine Aggregate with Red Soil. (2023). Experimental Investigation of Concrete by Partial Replacement of Fine Aggregate with Red Soil. 5(3). https://doi.org/10.36948/ijfmr.2023.v05i03.3973

3. Feasibility study of fine-metakaolin and coal bottom ash as cement and fine aggregate replacement in seawater-mixed concrete. (n.d.). Feasibility study of fine-metakaolin and coal bottom ash as cement and fine aggregate replacement in seawater-mixed concrete. 1205(1), 012041–012041. https://doi.org/10.1088/1755-1315/1205/1/012041

4. Experimental Study on Light Weight Concrete using Plastic Waste as a Partial Replacement of Fine Aggregate. (n.d.). Experimental Study on Light Weight Concrete using Plastic Waste as a Partial Replacement of Fine Aggregate. https://doi.org/10.21203/rs.3.rs-2552757/v1

5. Recycling of Waste Glass as Partial Replacement to Fine Aggregate and Rice Husk Ash as Partial Replacement of Cement in Concrete Production. 2(1). https://doi.org/10.30880/jsmbe.2022.02.01.006+

6. Quality Assessment of Concrete produced with Marble dust as Partial Replacement of Cement using Ultrasonic Pulse Velocity Test. 1, 1305–1310. https://doi.org/10.38208/acp.v1.655

7. Effect of the Partial Replacement of Cement with Waste Granite Powder on the Properties of Fresh and Hardened Mortars for Masonry Applications. 15(24), 9066–9066. https://doi.org/10.3390/ma15249066

8. Evaluation of Fresh and Hardened Concrete Properties Incorporating Glass Waste as Partial Replacement of Fine Aggregate. 14(23), 15895–15895. https://doi.org/10.3390/su142315895

9. Effects of Waste Powder, Fine and Coarse Marble Aggregates on Concrete Compressive Strength. (n.d.). Effects of Waste Powder, Fine and Coarse Marble Aggregates on Concrete Compressive Strength. 14(21), 14388–14388. https://doi.org/10.3390/su142114388

10. Prediction of Strength Properties of Concrete Containing Waste Marble Aggregate and Stone Dust—Modeling and Optimization Using RSM. 15(22), 8024–8024. https://doi.org/10.3390/ma15228024

11. Cement Kiln Dust (CKD) as a Partial Substitute for Cement in Pozzolanic Concrete Blocks. (n.d.). Cement Kiln Dust (CKD) as a Partial Substitute for Cement in Pozzolanic Concrete Blocks. 13(2), 568–568.