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Investigation of Concrete's Strength Properties Employing a Partial Marble Powder Supplement

Dr. V. Ramesh Babu[1]; D. Pavan Kumar[2]; D. Dhanya[3]; B. Anusha[4]; M. Anuvardhan[5]

[1]Associate Professors of B. Tech, Civil Engineering Department, Geethanjali Institute of Science and Technology, Nellore, Andhra Pradesh
[2]Assistant Professors of B. Tech, Civil Engineering Department, Geethanjali Institute of Science and Technology, Nellore, Andhra Pradesh
[3,4,5]UG Students of B. Tech, Civil Engineering Department, Geethanjali Institute of Science and Technology, Nellore, Andhra Pradesh

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Abstract: One of the biggest users of natural resources is the building sector, and the rising demand for cement has raised serious environmental issues. A by-product of the marble processing industry, marble powder presents disposal and environmental issues. This study examines the viability of substituting some of the cement in concrete with marble powder and assesses the impact on the concrete's strength characteristics. Marble powder was substituted for cement in concrete mixes at various weight percentages, including 0%, 5%, 10%, 15%, and 20%. After 7 and 28 days of curing, standard specimens were cast and tested for compressive strength, split tensile strength, and flexural strength. According to the experimental findings, concrete's workability and mechanical qualities can be enhanced to an ideal degree by partially substituting marble powder for cement. A replacement level of about 10% was found to represent the maximum strength, beyond which the strength progressively declined. The study shows that marble powder can be successfully added to concrete as an additional ingredient, lowering pollution levels and encouraging environmentally friendly building methods. In addition to reducing issues with the disposal of industrial waste, the use of marble powder helps create more affordable and environmentally friendly concrete.

Keywords: *Marble Powder, Partial Cement Replacement, Compressive Strength, Split Tensile Strength, Sustainable Concrete, Waste Utilization, Eco-Friendly Construction.*

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I. INTRODUCTION

Based on its affordability, durability, and adaptability, concrete is the most often used building material worldwide. As the main binding agent in concrete, cement is essential to the material's strength and longevity. Nevertheless, the manufacturing of cement is linked to substantial carbon dioxide emissions and high energy usage which contribute to environmental pollution and global warming. With the rapid growth of the construction industry, There is an urgent need to look into sustainable and eco-friendly alternatives because the demand for cement is still rising. The use of waste materials and industrial byproducts in concrete has drawn a lot of attention recently as a sustainable strategy to lessen environmental impact and preserve natural resources. Among these waste materials, marble powder has emerged as a potential supplementary material in concrete production. The cutting, grinding, and polishing procedures in the marble industry produce marble powder as a byproduct. Every year, large amounts of this trash are created, and inappropriate disposal causes environmental issues like contaminated land and water. Incorporating marble powder into concrete improves some of its qualities while also aiding in the management of industrial waste. Marble powder can increase the packing density and workability of concrete because of its fine particle size and filler properties. Numerous studies have shown that the mechanical characteristics of concrete, such as its compressive strength, split tensile strength, and flexural strength, can be affected by partially substituting marble powder for cement. The use of marble powder in concrete also supports the concept of sustainable construction by reducing the consumption of cement and minimizing the environmental burden associated with marble waste disposal. However, the strength performance of concrete depends on the proportion of marble powder used as a replacement material. Therefore, it is essential to determine the optimum

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percentage of marble powder that can be used without adversely affecting the structural performance of concrete. This study's primary goal is to examine the strength characteristics of concrete when marble powder is used in place of some of the cement. This study tests the concrete's compressive strength, split tensile strength, and flexural strength at various curing times after substituting marble powder for cement in varying proportions. The study's findings will aid in assessing the viability of employing marble powder as an economical and environmentally beneficial component in the manufacturing of concrete.

II. LITERATURE REVIEW

Environmental concerns about the environment and the growing need for sustainable building materials have drawn a lot of attention to the use of industrial waste materials in concrete. To improve concrete's performance while lessening its environmental impact, researchers have investigated using a variety of waste products, including metakaolin, fly ash, rice husk ash, and marble powder, as partial cement substitutes.

Kumar et al. (2025) examined the mechanical performance of high-performance concrete by partially substituting steel fibres and metakaolin in ordinary concrete. The study assessed the durability, tensile strength, and compressive strength of concrete mixes with additional cementitious ingredients. The findings showed that the pozzolanic qualities and fine particle size of metakaolin greatly enhanced the concrete's overall performance and compressive strength. The authors concluded that concrete performance can be improved while cement consumption and environmental effect are decreased by partially substituting appropriate industrial components for cement.

In the same way, Krishna et al. (2025) carried out an experimental study on cement bricks made from leftover rice husk and fly ash. The study's main goal was to create sustainable building materials by reusing industrial and agricultural waste. According to experimental findings, adding these waste elements enhanced several strength attributes and decreased production costs. The study demonstrated that waste management concerns can be successfully addressed while preserving the mechanical qualities of building materials by using waste-based materials.

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➢ *Scope & Research Objectives*

- To investigate the viability of using marble powder in place of some of the cement used in the construction of concrete.
- To develop concrete mixtures with different marble powder replacement percentages and assess how they affect the concrete's mechanical qualities.
- To use conventional testing methods to assess the compressive strength of concrete with marble powder at various curing times.
- To ascertain the concrete's split tensile and flexural strengths when marble powder is partially substituted.
- To identify the optimum percentage of marble powder replacement that provides improved strength characteristics without compromising the performance of concrete.
- To persuade environmentally friendly building methods by efficiently using industrial waste resources to make concrete.

III. MATERIALS & METHODOLOGY

Cement, fine aggregate, coarse aggregate, marble powder, and potable water are the materials utilised in this experimental study. To make certain the quality and functionality of the concrete, all materials were chosen in compliance with the applicable Indian Standard (IS) requirements.

➢ *Cement*

Portland Slag Cement (PSC), produced by JSW Cement, was utilised in the current investigation as the binding agent while creating concrete. The cement complies with IS 455:2015 criteria. Cement's physical characteristics were assessed in compliance with IS 4031. It was discovered that the cement's specific gravity was roughly 3.10. Cement was found to have a typical consistency of about 32%. The reported start and ultimate setting times of 45 and 480 minutes, respectively, meet the Indian Standard standards. The cement's fineness was roughly 320 m^2/kg, which indicates an excellent particle dispersion appropriate for making concrete.

➢ *Fine Aggregate*

The fine aggregate in the concrete mix was natural river sand from the Penna River basin. The sand was clear, well-graded, and devoid of clay, silt, and organic contaminants. The fine aggregate met IS 383:2016's Zone II grading requirements. The IS 2386 (Part I–VIII):1963 was used to determine the fine aggregate's physical characteristics. It was discovered that the fine aggregate had a specific gravity of about 2.62 and a water absorption of about 1.5%. The sand's fineness modulus was found to be approximately 2.70,

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suggesting that it might be used in concrete mixes.

➢ *Coarse Aggregate*

Concrete was prepared using crushed coarse aggregates with a nominal maximum size of 20 mm. The mining operations in the Kalahasthi mining area produced the aggregates as virgin material. The aggregates were clean, angular in shape, and devoid of harmful substances and dust. The characteristics of the coarse aggregates met the specifications outlined in IS 383:2016 and were determined in compliance with IS 2386:1963. It was discovered that the coarse aggregate had a specific gravity of about 2.70 and a water absorption of about 0.8%. It was found that the aggregate crushing value was approximately 18%, suggesting sufficient strength for concrete applications.

➢ *Marble Powder*

Anjani Tiles Ltd. in Gudur, Andhra Pradesh, provided the marble powder used in this investigation. The substance was acquired as a waste by-product produced during the cutting and polishing of marble. The marble powder was dried and sieved before usage to get rid of bigger particles and contaminants. The marble powder was made up of tiny particles less than 75 µm. The marble powder had a specific gravity of roughly 2.65. When used as a partial substitute for cement, marble powder's tiny particle size and filler qualities may enhance the packing density of concrete.

➢ *Water*

The concrete specimens were mixed and cured using potable water devoid of hazardous materials like acids, oils, salts, and organic contaminants. The water met IS 456:2000's specifications for making concrete.

➢ *Methodology*

The purpose of the experimental program was to assess the strength characteristics of concrete when marble powder was used in place of some of the cement. Different amounts of marble powder replacement—0%, 5%, 10%, 15%, and 20% by weight of cement—were used to create concrete mixes.

The design of the concrete mix was done in compliance with IS 10262:2019 requirements. To create a consistent concrete mixture, the ingredients were precisely weighed and properly combined. After that, standard moulds were filled with fresh concrete to cast specimens. To ascertain compressive strength, split tensile strength, and flexural strength, concrete specimens in the shapes of cubes, cylinders, and beams were constructed. Before being demolded, the specimens were appropriately crushed and given a full day to solidify. The specimens were cured in water for seven and twenty-eight days following demolding. Concrete cubes were tested for compressive strength in accordance with IS 516:2018. IS 5816:1999 was used to measure the split tensile strength of cylindrical specimens, and IS 1199:2018 was followed for other pertinent methods for testing and sampling fresh concrete. The results were examined to see how replacing marble powder affected the concrete's strength properties.

➢ *Design Mix*

The guidelines outlined in IS 10262:2019 and IS 456:2000, which are displayed in Table 1, were followed while designing the concrete mix for M50 grade concrete. The necessary goal mean strength, workability, water-to-cement ratio, and characteristics of the available materials were taken into consideration when determining the mix proportions. To account for differences in materials and site conditions, a target mean compressive strength greater than the characteristic strength was taken into consideration. Strength and durability needs were considered when choosing the water-to-cement ratio. The percentages of coarse and fine aggregate were calculated in accordance with IS 383:2016's grading specifications. In this study, marble powder was utilised in varying weight percentages to partially substitute cement. Marble powder replacement amounts of 0%, 5%, 10%, 15%, and 20% were used to create five different concrete mixtures. Marble powder was used to replace the equivalent amount of cement while maintaining a steady total binder content. To guarantee uniformity in comparison, all mixtures were made using the same water-to-binder ratio. Before the tests depicted in Figure 1, concrete specimens were cast for each mix proportion and cured under conventional circumstances. To find the ideal percentage of marble powder replacement, the mechanical characteristics of concrete, such as compressive strength, split tensile strength, and flexural strength, were assessed at various curing times.

Table 1 Mix Proportion of M50 Grade Concrete

Mix ID	Marble Powder Replacement (%)	Cement (kg/m³)	Marble Powder (kg/m³)	Fine Aggregate (kg/m³)	Coarse Aggregate (kg/m³)	Water (L/m³)
M0	0%	450	0	650	1200	158
M5	5%	427.5	22.5			
M10	10%	405	45			
M15	15%	382.5	67.5			
M20	20%	360	90			
M50 Grade ratio 1:1.48:3.05						

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Fig 1 Mix of Marble Powder M50 Grade Concrete, Cast and Curing

➢ *Experimental Investigation*

The goal of the experimental program was to assess how well M50 grade concrete performed when marble powder was used as a partial replacement. The study's main objective was to evaluate the mechanical characteristics of concrete using tests for split tensile strength and compressive strength at various curing times. JSW Portland Slag Cement (PSC) was used as the main binder in the preparation of concrete mixes. Crushed coarse aggregates from the Kalahasthi mining region were utilised as coarse aggregate, while natural river sand from the Penna river basin was used as fine aggregate. Anjani Tiles Ltd., Gudur provided marble powder, which was used as a mineral filler in the concrete mixture. In compliance with IS 456:2000 guidelines, concrete was mixed and cured using potable water free of hazardous contaminants. The goal of the experimental program was to assess how well M50 grade concrete performed when marble powder was used as a partial replacement. The study's main objective was to evaluate the mechanical characteristics of concrete using tests for split tensile strength and compressive strength at various curing times. JSW Portland Slag Cement (PSC) was used as the main binder in the preparation of concrete mixes. Crushed coarse aggregates from the Kalahasthi mining region were utilised as coarse aggregate, while natural river sand from the Penna river basin was used as fine aggregate. Anjani Tiles Ltd., Gudur provided marble powder, which was used as a mineral filler in the concrete mixture. In compliance with IS 456:2000 guidelines, concrete was mixed and cured using potable water free of hazardous contaminants. The specimens were left undisturbed at room temperature for a full day following casting. The samples were then demolded and cured for seven and twenty-eight days in a curing tank filled with drinkable water. In order to guarantee sufficient hydration and strength development of the concrete, proper curing was maintained. The specimens were taken out of the curing tank at the conclusion of each curing time, cleaned to eliminate surface moisture, and put through a compression testing machine (CTM) test. IS 516:2018 was followed for the compressive strength testing, while IS 5816:1999 was followed for the split tensile strength tests. The performance of the marble powder-infused concrete depicted in Figure 2 was examined using the average strength values from the tested specimens.

Fig 2 Experimental Investigation of Marble Powder M50 Grade Concrete

IV. RESULTS & DISCUSSION

➢ *Workability Test Results*

The slump test was used in compliance with IS 1199:2018 to assess the workability of fresh concrete mixes. Workability is a crucial factor that affects how simple it is to mix, transport, place, and compact concrete. The slump values for the concrete mixes including marble powder and the control mix showed that the addition of marble powder had a minor impact on the concrete's workability properties. When compared to regular concrete, it was found that the inclusion of marble powder caused a little decrease in slump. This behavior can be attributed to the finer particle size and higher surface area of marble powder, which increases the water demand of the concrete mixture. The fine particles tend to absorb a portion of the mixing water and reduce the

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lubrication effect between aggregates. However, the reduction in workability remained within acceptable limits for M50 grade concrete, and the mixes exhibited adequate cohesiveness without any signs of segregation or bleeding. The marble powder acted as a micro-filler, improving the packing density of the cementitious matrix and enhancing the overall homogeneity of the fresh concrete mix.

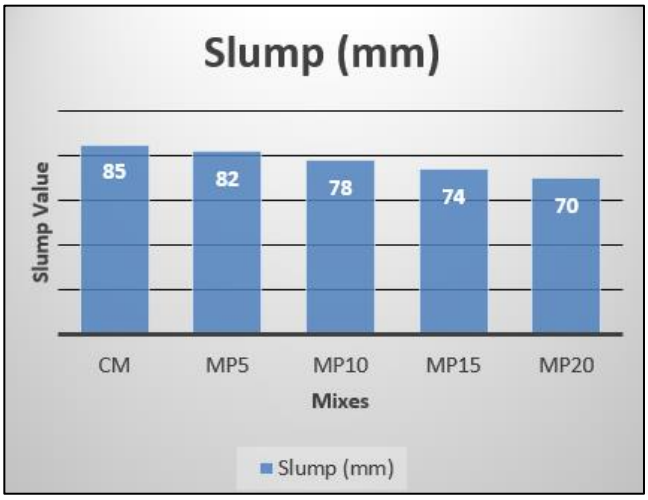

Fig 3 Graph Plotted Between Slump of Marble Powder Concrete M50 Grade

➢ *Compressive Strength Results and Discussion*

In compliance with IS 516:2018, 150 mm × 150 mm × 150 mm cube specimens were used to measure the compressive strength of concrete specimens. After seven and twenty-eight days of curing, the specimens were examined to assess the strength development properties of concrete that had been mixed with marble powder. The findings showed that adding marble powder to the concrete mix significantly increased its compressive strength when compared to the control mix. The filler effect of marble powder, which helps to fill the micro-voids in the concrete matrix and produces a denser and more compact microstructure, is responsible for this increase in strength. Furthermore, the fine marble powder particles increase the particle packing density, which strengthens the binding between cement paste. In compliance with IS 516:2018, 150 mm × 150 mm × 150 mm cube specimens were used to measure the compressive strength of concrete specimens. After seven and twenty-eight days of curing, the specimens were examined to assess the strength development properties of concrete that had been mixed with marble powder. The findings showed that adding marble powder to the concrete mix significantly increased its compressive strength when compared to the control mix. The filler effect of marble powder, which helps to fill the micro-voids in the concrete matrix and produces a denser and more compact microstructure, is responsible for this increase in strength. Furthermore, the fine marble powder particles increase the particle packing density, which strengthens the binding between cement paste. Overall, the experimental results demonstrate that marble powder can be effectively utilized as a supplementary material in high-strength concrete, improving compressive strength while also contributing to sustainable waste utilization.

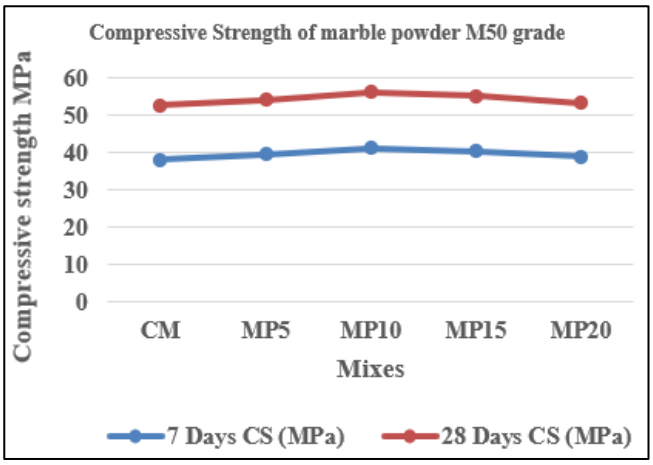

Fig 4 Graph Plotted Between Compressive Strength of Marble Powder Concrete M50 Grade 7 Days and 28 Days

➢ *Split Tensile Strength Results*

In accordance with IS 5816:1999, cylindrical specimens of 150 mm in diameter and 300 mm in height were used to calculate the split tensile strength of concrete. The test was carried out to assess the tensile behaviour of concrete that had been mixed with marble powder after seven and twenty-eight days of curing. According to the trial results, adding marble powder to concrete improved its split tensile strength when compared to the traditional mix. The tiny particle size of marble powder leads to improved bonding properties inside the cementitious matrix, which is responsible for this enhancement. By reducing cavities in the concrete construction, marble powder's micro-filling ability increases density and enhances the stress transmission mechanism between aggregates and cement paste. Consequently, the concrete shows improved resistance to tensile stresses. Additionally, increased tensile strength is a result of an improved interfacial transition zone (ITZ) between aggregate particles and cement paste. The 28-day improvement in split tensile strength suggests that marble powder enhances concrete's overall structural performance and longevity. The results confirm that marble powder can be effectively utilized as a sustainable supplementary material in high-performance concrete, improving both compressive and tensile properties while reducing environmental impacts associated with industrial waste disposal.

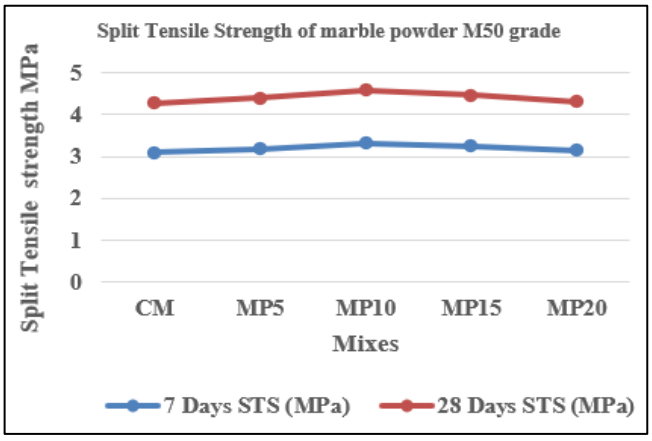

Fig 5 Graph Plotted Between Split Tensile Strength of Marble Powder Concrete M50 Grade 7 Days and 28 Days

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V. CONCLUSIONS

- The following conclusions are derived from an experimental study conducted on M50 grade concrete that partially substitutes marble powder for cement:
- Marble powder can be used to partially replace cement in the manufacturing of concrete, offering a sustainable way to dispose of waste from the marble industry while lowering the amount of traditional cement used.
- Due to marble powder has a bigger surface area and finer particle size, it somewhat decreased the workability of fresh concrete mixtures. Nonetheless, the slump values stayed within permissible bounds for M50 grade concrete, suggesting that practical mixes can be produced with no difficulty.
- Adding marble powder to concrete increased its compressive strength up to the ideal replacement level. This was mostly because of the filler effect and increased particle packing density, which improved the cementitious matrix's microstructure.
- The findings of the experiment showed that the best compressive strength at 28 days was achieved when 10% of the cement was replaced with marble powder, indicating better bonding and densification within the concrete matrix.
- Because of the improved interfacial transition zone between aggregates and cement paste, marble powder concrete's split tensile strength also improved as compared to conventional concrete, showing superior resistance to tensile stresses.
- By recycling industrial waste into useful building materials, the study demonstrates that adding marble powder to high-strength concrete not only enhances mechanical qualities but also encourages environmentally friendly building methods.

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