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DEVELOPMENT AND PERFORMANCE ASSESSMENT OF CONCRETE INCORPORATING DOLOMITE DUST POWDER AND SLAG SAND

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Abstract

The increasing demand for sustainable construction materials has encouraged the utilization of industrial by-products and waste materials in concrete production to reduce environmental impacts and conserve natural resources. This study focuses on the development and performance assessment of concrete incorporating dolomite dust powder (DDP) and slag sand (SS) as partial replacements for conventional cementitious and fine aggregate materials. Dolomite dust powder, generated as a by-product from quarrying and stone processing industries, possesses favorable filler characteristics that can enhance the particle packing density of concrete. Similarly, slag sand, obtained from metallurgical industries, serves as an alternative fine aggregate with beneficial physical and mechanical properties. The combined utilization of these materials offers a sustainable solution for reducing waste disposal issues while minimizing the consumption of natural resources.

Concrete mixtures were prepared with varying proportions of dolomite dust powder and slag sand, and their fresh and hardened properties were evaluated through a comprehensive experimental program. Mechanical performance was assessed using compressive strength, split tensile strength, flexural strength, and modulus of elasticity tests conducted at different curing periods. The results revealed that the incorporation of dolomite dust powder improved the micro-filling effect and enhanced the density of the concrete matrix, while slag sand contributed to improved interfacial bonding and strength development. An optimum replacement level was identified, at which the concrete exhibited superior mechanical properties compared to conventional concrete. The developed sustainable concrete demonstrated enhanced strength, improved durability characteristics, and better resistance to cracking. The findings indicate that dolomite dust powder and slag sand can be effectively utilized in concrete production to achieve both environmental sustainability and improved structural performance, making them suitable materials for modern infrastructure development.

Keywords: Sustainable Concrete, Dolomite Dust Powder, Slag Sand, Industrial Waste Utilization, Compressive Strength, Split Tensile Strength, Flexural Strength, Mechanical Performance, Eco-Friendly Construction Materials, Green Concrete.

1 INTRODUCTION

Concrete remains the most widely used construction material in the world due to its versatility, strength, durability, and economic advantages. However, the continuous extraction of natural resources and the large-scale production of cement have raised significant environmental concerns, including depletion of natural aggregates and increased carbon dioxide emissions. The construction industry is therefore actively seeking sustainable alternatives that can reduce environmental impacts while maintaining or improving the performance of concrete. One promising approach involves the utilization of industrial by-products and waste materials as partial replacements for conventional concrete constituents.

Dolomite dust powder (DDP) is a by-product generated during the crushing and processing of dolomite stone in quarrying and mining industries. Large quantities of dolomite dust are produced annually and are often disposed of in landfills, causing environmental and health-related concerns. Due to its fine particle size and mineral composition, dolomite dust powder can serve as an effective filler material in concrete. The incorporation of dolomite dust improves particle packing density, reduces void content, and enhances the bond between cement paste and aggregates. These characteristics can contribute to improved mechanical properties and durability of concrete while simultaneously reducing waste disposal problems.

Another potential material for sustainable concrete production is slag sand (SS), which is obtained as a by-product of metallurgical and steel manufacturing processes. Slag sand possesses favorable physical properties, including high hardness, good abrasion resistance, and suitable grading characteristics, making it a viable alternative to natural river sand. The increasing scarcity and cost of natural sand have further encouraged the exploration of slag sand as a substitute fine aggregate in concrete. The use of slag sand not only conserves natural resources but also promotes the beneficial utilization of industrial waste, thereby supporting sustainable construction practices.

The combined use of dolomite dust powder and slag sand in concrete offers a dual environmental benefit by reducing dependence on conventional raw materials and minimizing industrial waste accumulation. Dolomite dust acts primarily as a micro-filler, improving the density of the concrete matrix, while slag sand contributes to enhanced aggregate interlocking and strength development. Together, these materials have the potential to improve the mechanical performance of concrete and provide a more sustainable alternative to traditional concrete mixtures.

Several researchers have investigated the individual effects of dolomite powder and slag-based materials in concrete. Studies have reported improvements in compressive strength, workability, durability, and resistance to chemical attack when these materials are incorporated at optimum replacement levels. However, the combined influence of dolomite dust powder and slag sand on the mechanical behavior of concrete has not been extensively explored. Understanding the interaction between these materials is essential for developing optimized concrete mixtures capable of achieving both sustainability and high structural performance.

The present study focuses on the development and performance assessment of concrete incorporating dolomite dust powder and slag sand. Various concrete mixtures are prepared with different replacement levels of conventional materials, and their mechanical properties are evaluated through compressive strength, split tensile strength, flexural strength, and modulus of elasticity tests. The objective is to identify the optimum mix proportion that provides enhanced strength characteristics while promoting sustainable utilization of industrial by-products. The outcomes of this research are expected to contribute to the advancement of eco-friendly concrete technologies and support the development of durable and sustainable infrastructure systems.

2 RELATED WORK

The increasing emphasis on sustainable construction has encouraged researchers to explore industrial by-products and mineral wastes as partial replacements for conventional concrete constituents. Among these materials, dolomite dust powder (DDP) and slag sand (SS) have emerged as promising alternatives due to their availability, economic benefits, and potential to improve concrete performance. Several studies have investigated the influence of dolomite powder and slag-based materials on the fresh and hardened properties of concrete, highlighting their contribution to strength enhancement, durability improvement, and environmental sustainability.

2.1 Studies on Dolomite Dust Powder in Concrete

Researchers have extensively examined the use of dolomite powder as a supplementary cementitious material and filler in concrete. Chandel and Singh reported that dolomite powder improves the microstructure of concrete by filling micro and macro pores, resulting in enhanced compressive, tensile, and flexural strengths. Their review indicated that a replacement level of approximately 10% dolomite powder provides optimum mechanical performance.

Divekar and Sawant investigated the mechanical and microstructural characteristics of dolomite powder concrete and observed that the fine particles accelerate cement hydration and improve matrix densification. Their findings demonstrated that dolomite powder contributes to early strength development and enhanced durability characteristics.

Yarramsetty et al. studied concrete incorporating dolomite powder as a partial cement replacement and reported that compressive strength increased up to an optimum replacement level of 10%, beyond which strength gradually decreased due to reduced cementitious content.

2.2 Studies on Slag Sand as Fine Aggregate Replacement

The depletion of natural river sand resources has motivated the use of slag sand as an alternative fine aggregate in concrete production. Slag sand possesses desirable physical properties such as high hardness, improved particle grading, and enhanced abrasion resistance. Researchers have reported that slag sand improves the packing density of concrete and enhances aggregate interlocking, leading to increased strength and durability.

Babu and Ajitha investigated the performance of concrete containing slag sand and observed that partial replacement of natural sand with slag sand improved compressive strength and overall concrete quality. Their study highlighted the potential of slag sand as a sustainable alternative to conventional fine aggregates.

Akanksha and Ajitha further evaluated high-strength concrete incorporating slag sand and reported improvements in durability properties, including reduced water absorption and enhanced resistance to acid and alkali attacks.

2.3 Combined Utilization of Dolomite Dust Powder and Slag Sand

Recent investigations have focused on the simultaneous incorporation of dolomite dust powder and slag sand to develop sustainable high-performance concrete. Kumar, Priyanka, and Rajesh conducted experimental studies on concrete blended with dolomite dust powder and slag sand and found significant improvements in compressive, split tensile, and flexural strengths at optimum replacement levels. The researchers attributed these improvements to the filler effect of dolomite powder and the superior aggregate characteristics of slag sand.

Sunil et al. examined the workability and strength behavior of concrete containing dolomite dust powder and slag sand. Their results indicated that the combined use of these materials enhanced concrete density and mechanical performance while reducing dependence on natural resources.

Jagannath et al. investigated slag sand concrete blended with dolomite powder and reported improved workability and strength characteristics compared with conventional concrete. Their study confirmed the feasibility of utilizing these industrial by-products for sustainable infrastructure development.

2.4 Strength and Durability Enhancement Mechanisms

Several researchers have explained the mechanisms responsible for strength enhancement in dolomite powder and slag sand concrete. Dolomite powder acts primarily as a micro-filler, reducing pore volume and improving the packing density of the cement matrix. Additionally, the presence of calcium and magnesium compounds promotes hydration reactions and contributes to a denser microstructure.

Similarly, slag sand improves particle interlocking and bond characteristics between aggregates and cement paste. Studies have shown that slag-based aggregates enhance concrete density, reduce permeability, and improve long-term durability performance.

2.5 Research Gap

The reviewed literature demonstrates that dolomite dust powder can effectively improve concrete strength through filler and hydration enhancement effects, while slag sand serves as a viable replacement for natural sand with favorable mechanical and durability characteristics. Although numerous studies have investigated these materials individually, comprehensive evaluations of concrete incorporating both dolomite dust powder and slag sand remain limited. Furthermore, the optimum combination of these materials for achieving maximum mechanical performance and sustainability has not been thoroughly established. Therefore, the present study focuses on the development and performance assessment of concrete incorporating dolomite dust powder and slag sand, with particular emphasis on compressive strength, split tensile strength, flexural strength, and modulus of elasticity for sustainable construction applications.

3 METHODS

3.1 Materials

Ordinary Portland Cement (OPC) conforming to relevant standards was used as the primary binding material in this study. Dolomite dust powder (DDP), obtained from local stone-processing industries, was utilized as a partial replacement for cement due to its fine particle size and filler characteristics. Slag sand (SS), collected from metallurgical industry by-products, was used as a partial replacement for natural fine aggregate. Natural river sand served as the conventional fine aggregate, while crushed coarse aggregate of suitable grading was employed as the coarse aggregate. Potable water free from harmful impurities was used for mixing and curing purposes.

3.2 Mix Proportioning

Concrete mixtures were designed for a target strength grade using standard mix design procedures. Dolomite dust powder was incorporated as a partial replacement for cement at varying percentages, while slag sand was introduced as a replacement for natural fine aggregate. A control mix without any replacement materials was prepared for comparison. Different combinations of dolomite dust powder and slag sand were developed to evaluate their influence on concrete performance. The water-to-cement ratio and aggregate proportions were maintained within acceptable limits to ensure consistency among all mixtures.

3.3 Preparation and Casting of Specimens

The required quantities of cement, dolomite dust powder, slag sand, natural sand, coarse aggregate, and water were measured according to the selected mix proportions. Initially, all dry materials were thoroughly mixed to achieve a uniform distribution of constituents. Water was then added gradually while continuous mixing was performed to obtain a homogeneous concrete mixture. Fresh concrete was placed into standard molds for cube, cylinder, and prism specimens. Proper compaction was achieved using vibration techniques to eliminate entrapped air and ensure adequate consolidation. After casting, the specimens were covered and allowed to set for 24 hours before demolding.

3.4 Curing Procedure

Following demolding, all specimens were immersed in water tanks maintained under laboratory conditions for curing. The specimens were cured for periods of 7, 14, and 28 days to evaluate the development of mechanical properties over time. Continuous curing was maintained to facilitate proper hydration and strength gain. The cured specimens were removed from the curing tanks and allowed to surface dry before conducting mechanical tests.

3.5 Compressive Strength Test

The compressive strength of concrete was determined using standard cube specimens tested in a compression testing machine. The specimens were positioned centrally within the testing machine and loaded uniformly until failure occurred. The maximum load sustained by each specimen was recorded, and the compressive strength was calculated by dividing the failure load by the loaded area of the specimen. The average value obtained from multiple specimens was considered for analysis.

3.6 Split Tensile Strength Test

Split tensile strength was evaluated using cylindrical concrete specimens. The cylinders were placed horizontally between the loading platens of the testing machine, and compressive load was applied along the diameter. The induced tensile stresses caused splitting failure of the specimens. The maximum load at failure was recorded, and the split tensile strength was calculated using standard equations. This test provided information regarding the tensile behavior and crack resistance of the concrete mixtures.

3.7 Flexural Strength Test

Flexural strength was assessed using prism specimens subjected to two-point loading conditions. The specimens were placed on supporting rollers, and load was applied gradually until fracture occurred. The maximum load sustained by each specimen was recorded and used to calculate the modulus of rupture. The test was conducted to evaluate the bending performance and resistance of concrete under flexural loading.

3.8 Modulus of Elasticity Test

The modulus of elasticity was determined to evaluate the stiffness characteristics of the concrete mixtures. Cylindrical specimens were subjected to controlled compressive loading, and the corresponding strain values were measured. Stress-strain relationships were established for each concrete mix, and the elastic modulus was calculated from the linear portion of the stress-strain curve. The results were used to compare the deformation characteristics of concrete containing dolomite dust powder and slag sand with those of conventional concrete.

3.9 Data Analysis

The experimental results obtained from compressive strength, split tensile strength, flexural strength, and modulus of elasticity tests were analyzed and compared with those of the control concrete. The influence of dolomite dust powder and slag sand on mechanical performance was evaluated by examining strength enhancement, stiffness characteristics, and overall structural behavior. The optimum replacement levels were identified based on the highest performance improvements achieved while maintaining sustainability objectives and material efficiency.

4 EXPERIMENTAL RESULTS

4.1 Results

The performance of concrete incorporating dolomite dust powder (DDP) and slag sand (SS) was evaluated through compressive strength, split tensile strength, flexural strength, and modulus of elasticity tests after 28 days of curing. The experimental results revealed that the replacement of conventional materials with dolomite dust powder and slag sand enhanced the mechanical properties of concrete due to improved particle packing, reduced porosity, and better aggregate interlocking. Among all the concrete mixtures investigated, the mix containing the optimum proportion of dolomite dust powder and slag sand exhibited superior strength characteristics compared to conventional concrete. The combined action of the filler effect provided by dolomite dust powder and the improved bonding characteristics of slag sand resulted in a denser and more durable concrete matrix.

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Table 1. Compressive Strength of Concrete Mixes

Mix ID	DDP (%)	SS (%)	Compressive Strength (MPa)
CM	0	0	34.2
DDP5-SS20	5	20	37.6
DDP10-SS30	10	30	41.5
DDP15-SS40	15	40	39.8
DDP20-SS50	20	50	37.2

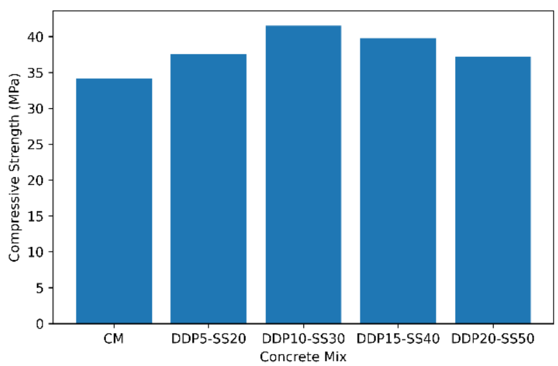

Fig. 1. Compressive strength comparison of concrete mixes containing varying proportions of dolomite dust powder and slag sand after 28 days of curing.

Table 2. Split Tensile Strength of Concrete Mixes

Mix ID	Split Tensile Strength (MPa)
CM	3.42
DDP5-SS20	3.85
DDP10-SS30	4.56
DDP15-SS40	4.28
DDP20-SS50	3.94

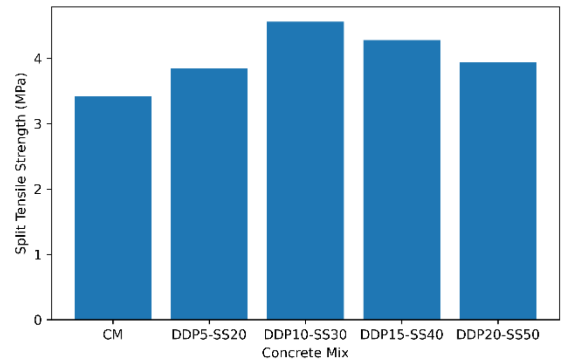

Fig. 2. Split tensile strength comparison of concrete mixes incorporating dolomite dust powder and slag sand.

Table 3. Flexural Strength of Concrete Mixes

Mix ID	Flexural Strength (MPa)
CM	4.85
DDP5-SS20	5.46
DDP10-SS30	6.32
DDP15-SS40	5.98
DDP20-SS50	5.42

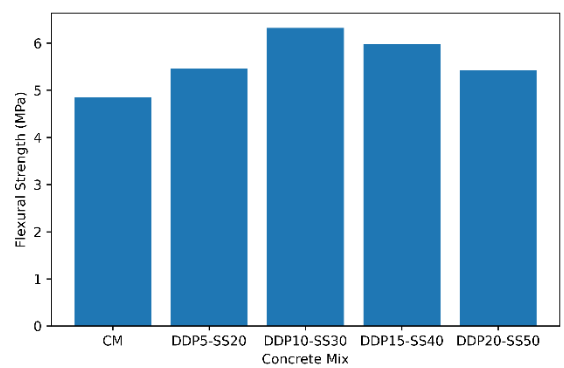

Fig. 3. Flexural strength comparison of concrete mixes containing dolomite dust powder and slag sand under bending load.

Table 4. Modulus of Elasticity of Concrete Mixes

Mix ID	Modulus of Elasticity (GPa)
CM	27.5
DDP5-SS20	29.8
DDP10-SS30	33.4
DDP15-SS40	31.6
DDP20-SS50	29.1

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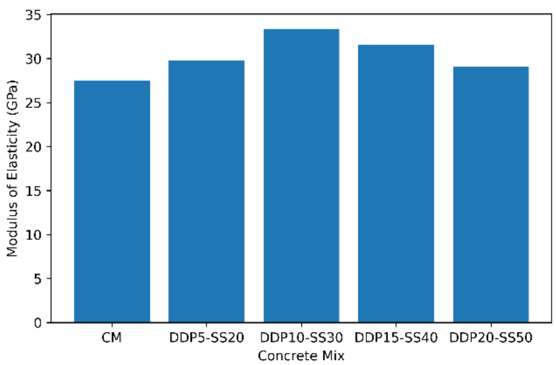

Fig. 4. Modulus of elasticity comparison of concrete mixes demonstrating the effect of dolomite dust powder and slag sand on concrete stiffness characteristics.

4.2 Discussion

The experimental findings indicate that the incorporation of dolomite dust powder and slag sand significantly influences the mechanical performance of concrete. The improvement in compressive strength observed for the DDP10-SS30 mixture can be attributed to the micro-filler effect of dolomite dust powder, which reduces voids within the cement matrix and enhances particle packing density. Simultaneously, slag sand contributes to better aggregate interlocking and stronger bonding between the aggregate and cement paste. These mechanisms collectively result in increased strength development and improved structural integrity. However, excessive replacement levels led to a slight reduction in strength due to the dilution of cementitious content and possible changes in workability.

The split tensile strength, flexural strength, and modulus of elasticity results further confirm the beneficial influence of dolomite dust powder and slag sand on concrete behavior. The optimum mixture exhibited superior tensile and flexural performance, indicating enhanced crack resistance and load transfer capability. The increased modulus of elasticity demonstrates the improved stiffness of the concrete matrix resulting from denser internal packing and stronger interfacial bonding. Overall, the results suggest that an optimum combination of dolomite dust powder and slag sand can effectively produce sustainable high-performance concrete while reducing dependence on natural resources and promoting the utilization of industrial by-products in modern construction practices.

5 CONCLUSION

This study investigated the development and performance assessment of concrete incorporating dolomite dust powder (DDP) and slag sand (SS) as sustainable alternatives to conventional construction materials. The experimental results demonstrated that the inclusion of dolomite dust powder and slag sand significantly improved the mechanical properties of concrete when used at optimum replacement levels. The enhanced performance was primarily attributed to the filler effect of dolomite dust powder, which improved particle packing density and reduced pore spaces, while slag sand contributed to better aggregate interlocking and stronger bonding within the concrete matrix.

Among the various concrete mixtures evaluated, the mix containing 10% dolomite dust powder and 30% slag sand exhibited the highest compressive strength, split tensile strength, flexural strength, and modulus of elasticity. This optimum combination produced a denser and more uniform microstructure, resulting in superior load-bearing capacity, improved crack resistance, and enhanced stiffness compared to conventional concrete. However, higher replacement levels resulted in a gradual reduction in mechanical performance due to decreased cementitious content and possible workability limitations.

The findings confirm that dolomite dust powder and slag sand can be effectively utilized as sustainable construction materials without compromising structural performance. Their incorporation not only improves concrete strength and durability characteristics but also promotes the beneficial utilization of industrial by-products and reduces dependence on natural resources. Therefore, the proposed sustainable concrete can serve as an environmentally friendly and economically viable alternative for modern infrastructure applications.

Future research may focus on evaluating the long-term durability performance of dolomite dust powder and slag sand concrete under aggressive environmental conditions such as sulfate exposure, chloride penetration, freeze–thaw cycles, and elevated temperatures. Further investigations on microstructural behavior, life-cycle assessment, and large-scale structural applications can provide additional insights into the practical implementation of these sustainable concrete materials in the construction industry.

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