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STUDY ON UTILIZATION OF STONE DUST AS PARTIAL REPLACEMENT OF CRUSHED STONE SAND AND MINERAL ADMIXTURES AS PARTIAL REPLACEMENT OF CEMENT IN HIGH STRENGTH CONCRETE: A DETAILED REVIEW

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ABSTRACT:
Concrete, a fundamental construction material, comprises cement, fine and coarse aggregates, and water. Aggregates typically occupy 60-80% of concrete's volume and 70-85% of its mass, playing a critical role in determining strength and stability. As river sand becomes increasingly scarce and expensive, the construction industry is pivoting towards alternatives like manufactured sand (M-sand) and stone dust, which offer cost-effective solutions, especially in developing countries like India. Cement, while essential for concrete's structural properties, poses environmental challenges, with each ton of clinker production releasing an equivalent ton of carbon dioxide. To address this, researchers are exploring mineral admixtures such as fly ash, ground granulated blast furnace slag, silica fume, rice husk ash, and metakaolin. These materials not only improve concrete's resistance to thermal cracking and chemical attacks but also enable reduced cement content.
Innovative research is now focusing on materials like Kadapa and Bethamcherla marble powder from stone polishing industries as potential partial cement replacements. The primary goals are to discover alternative aggregate materials, reduce cement consumption, minimize environmental impact, and maintain concrete's structural integrity. By embracing these approaches, the construction sector can develop more sustainable and economically viable concrete production methods that balance performance with environmental responsibility.
KEY WORDS: Sustainable Concrete, Stone Dust, Mineral Admixture, Mechanical Properties, Cement Replacement, Sand Replacement.

INTRODUCTION:

In the evolving landscape of construction materials, concrete remains a cornerstone of modern infrastructure. However, the industry faces significant challenges related to resource scarcity, environmental sustainability, and increasing construction demands. Traditional concrete production relies heavily on natural river sand and Portland cement, both of which are becoming increasingly expensive and environmentally problematic. The growing environmental consciousness and diminishing natural resources have prompted researchers and engineers to explore innovative alternatives in concrete technology. Stone dust, a byproduct of stone crushing operations, and various mineral admixtures present promising opportunities for sustainable concrete production. These alternative materials not only offer potential cost reductions but also address critical environmental concerns associated with traditional concrete manufacturing. By investigating the utilization of stone dust as a partial replacement for crushed stone sand and exploring mineral admixtures as partial cement substitutes, researchers aim to develop

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high-strength concrete with enhanced performance characteristics. This approach addresses multiple challenges simultaneously: reducing waste, minimizing natural resource extraction, lowering carbon emissions, and potentially improving concrete's mechanical and durability properties. The significance of this study lies in its potential to contribute to more sustainable construction practices, offering a scientifically validated approach to reducing the environmental footprint of concrete production while maintaining or potentially improving the material's critical performance parameters.

LITERATURE REVIEW:

The extent of research that has been undertaken on this topic thus far is relatively constrained. This section gives an outline of the key findings from previous studies, encapsulating their importance in the field.

Kummara Siva Prasad (2024) This research explores the potential use of stone cutting dust as a cement substitute in M20 grade concrete, addressing both construction needs and environmental concerns. The investigation focuses on analysing how different proportions of stone cutting powder affect concrete's key properties, including workability, compressive strength, and flexural strength. Given that stone cutting waste poses environmental challenges and inhibits plant growth in disposal areas, the study evaluates replacement ratios of 10%, 20%, and 30% in cement mixtures. Through comprehensive testing, the research reveals that a 10% replacement level yields optimal results in terms of workability and durability characteristics. The study extends beyond performance metrics to evaluate both economic feasibility and environmental benefits of this substitution. By employing systematic experimental methods, this investigation seeks to determine the ideal stone cutting powder content that achieves a balance between structural performance and environmental sustainability in M20 grade concrete applications.

Parea R. Rangan (2023) This investigation examines the effects of stone dust substitution on cellular lightweight concrete (CLC) brick properties, specifically focusing on compressive strength and volume weight characteristics. The experimental methodology involved producing lightweight bricks with varying stone dust proportions (0%, 50%, and 100%) as fine aggregate replacements, followed by strength and weight measurements at curing intervals of 3, 7, 14, and 28 days. The findings demonstrate that stone dust's superior binding properties enhance the brick's compressive strength, reaching a peak value of 24.62 kg/cm2 at 100% replacement after 28 days of curing. Volume weight measurements showed progressive increases, with 0.66 gr/cm3 at initial stone dust incorporation, rising to 0.67 gr/cm3 at 50% replacement (2% increase), and reaching 0.68 gr/cm3 at 100% replacement (4% increase). Notably, despite these weight increases, the final products maintain their lightweight concrete classification, as their volume weights remain within the accepted range of 0.6-1.8 gr/cm3.

Olga Vladimirovna Aleksandrova (2022) The experimental findings demonstrate significant improvements in concrete strength properties when implementing a complete substitution of river sand with finely ground natural white sand, combined with a multicomponent binder consisting of 20% fly ash and 5-15% silica by weight. After 28 days of curing, the concrete exhibited superior performance metrics compared to conventional river sand mixtures, achieving compressive strengths ranging from 118.5 to 128 MPa, bending tensile strengths of 18.8 to 25.4 MPa, and splitting tensile strengths of 10.2 to 11.9 MPa. These results validate the effectiveness of finely ground natural white sand as a sustainable alternative to river sand in high-strength concrete applications, particularly beneficial for conserving Vietnam's river sand resources. Furthermore, the incorporation of industrial byproducts such as fly ash and micro silicon as cement replacements in the multicomponent binder system offers dual environmental benefits: reducing the carbon footprint associated with binder production while simultaneously addressing industrial waste management challenges.

Danish et al. (2021) This comprehensive analysis evaluates the influence of marble residue (MD) and granite dust (GD) on cementitious material properties, drawing insights from 100 scientific experts regarding the sustainability advantages and implementation challenges of using these materials as cement replacements. Based on extensive literature review and expert consultations, the research confirms that MD/GD can effectively substitute significant portions of cement in cementitious composites, offering environmental and economic benefits without compromising the engineering properties of the final products. The collective scientific consensus supports the viability of marble and granite dust as partial cement replacements in the production of cementitious materials, highlighting their potential for sustainable construction practices.

Tang Chao-Wei et al. (2021) The research investigates the initial performance characteristics of Ultra-High-Performance Concrete (UHPC) with emphasis on safety, durability, and long-term serviceability. The experimental design incorporated varying proportions of cement replacement using silica fume, SFP, steel fibres, and polypropylene fibres as key test variables. The study evaluated both fresh mixing properties and early-age engineering characteristics at 7 days. Performance testing revealed exceptional strength development, with the C8 mixture achieving a peak compressive strength of 111.5 MPa at 7 days, while the C1 mixture demonstrated superior strength of 128.1 MPa at 28 days of curing.

Ravi Kumar et al. (2020) The research conducted comprehensive testing on M25 concrete mixtures incorporating stone residue and sand, following established IS code specifications. The investigation focused on evaluating compressive strength and durability characteristics, comparing the results against control specimens made with conventional river sand. The findings demonstrate that stone residue exhibits adequate strength properties, validating its potential adoption as a fine aggregate replacement in concrete applications.

Anukarthuika et al. (2019) A study was conducted to investigate the potential use of Waste Quarry Dust (WQD) as a partial replacement for fine aggregates in concrete construction, along with the incorporation of glass fibres. The research explored the effects of systematically replacing natural sand with quarry dust at varying percentages (25%, 50%, 75%, and 100%) while simultaneously introducing glass fibres in incremental proportions of 0.2%, 0.4%, 0.6%, and 0.8%. The experimental analysis focused on evaluating crucial mechanical properties including compressive strength, flexural strength, and split tensile strength. The findings revealed that the optimal performance characteristics were achieved with a combination of 25% quarry dust substitution and 0.4% glass fibre content. This research contributes to sustainable construction practices by demonstrating the viable utilization of industrial by-products while maintaining concrete performance standards.

Manpreet Singh et al. (2019) A comprehensive investigation was conducted to evaluate the long-term properties of concrete when cement was partially substituted with dehydrated waste marble powder slurry. The study incorporated varying replacement percentages (0%, 10%, 15%, 20%, and 25%) and three distinct water-cement ratios (0.35, 0.40, and 0.45). The experimental results spanning from 28 to 360 days demonstrated enhanced physical strength and durability characteristics in concrete specimens with up to 15% marble slurry replacement. Higher substitution levels of marble dust were found to create an effective dense mixture, leading to improved long-term performance properties. The research established correlations between strength and durability parameters with compressive strength for marble slurry-substituted concrete, providing valuable insights into the optimization of this sustainable concrete formulation.

Biswaprakash et al. (2018) A study was conducted to evaluate the viability of Quarry Dust (Q.D.) as an alternative to river sand in concrete production. Using an M25 grade mix design, sand was partially replaced with quarry dust at varying percentages (0%, 20%, 40%, 60%, and 80%). The physical properties of quarry dust were thoroughly examined, including specific gravity, water absorption, silt content, and Fineness Modulus (F.M.) using standardized testing methods. The research investigated the mechanical properties through comprehensive testing of compression, split tensile, and flexural strengths using cubes, cylinders, and beams respectively. The results were compared against conventional concrete (0% replacement) as a control specimen. The findings revealed that 40% quarry dust replacement yielded optimal strength characteristics, beyond which a decline in strength parameters was observed.

Ali Khodabakhshian et al. (2018) A laboratory investigation was conducted to analyse the mechanical properties of concrete mixtures incorporating Marble Waste Powder (MWP) and Silica Fume (S.F.) as partial cement replacements for Ordinary Portland Cement (OPC). The experimental program examined sixteen different mix designs with varying replacement levels of Silica Fume (0%, 2.5%, 5%, 10%) and Marble Waste Powder (0%, 5%, 10%, 20%). All mixtures maintained a constant water-binder ratio of 0.45 and an initial slump of S2 class (50-90 mm). The research findings indicated that while concrete containing MWP exhibited satisfactory performance at replacement levels up to 10%, the mechanical properties showed a declining trend when the replacement ratio exceeded this threshold.

Shaik Fayaz et al. (2017) The investigation demonstrated that the application of quarry dust (Q.D.) at different displacement levels caused a decline in the workability of concrete by 1 to 6%. Test results indicated that the replacement of standard sand with quarry dust increased the compressive strength of concrete by 5 to 22%. The maximum compressive strength was recorded with a 40% replacement of sand with quarry dust.

Singh Srivastava et al. (2017) A comprehensive study was conducted to investigate the effects of marble slurry on concrete properties, examining hydration processes, fresh and hardened characteristics, and durability aspects using locally developed equipment. The research revealed that marble slurry functioned as an effective filler, contributing to a more uniform and dense concrete structure. The incorporation of dehydrated marble slurry at 15% replacement level demonstrated enhanced mechanical properties. Quality assessments through ultrasonic pulse velocity and durability testing indicated significant improvements in concrete performance. Additionally, reinforced concrete incorporating marble slurry showed promising results with enhanced bond strength characteristics. The research culminated in the development of a compressive strength prediction model utilizing artificial neural network technology.

Sanjay Mundra et al. (2016) A research study was conducted to evaluate the effectiveness of crushed stone sand as an alternative to natural sand in cement concrete. Multiple concrete mix designs were developed following Indian Standards (IS), American Concrete Institute (ACI), and British code specifications, utilizing both natural sand and crushed stone sand. The investigation included extensive testing of compressive and flexural strengths for each mix design. The experimental results demonstrated that concrete produced with crushed stone sand exhibited mechanical properties nearly identical to those of conventional concrete made with natural sand.

Madzura et al. (2015) A study was conducted to characterize concrete composites incorporating quarry dust as a partial replacement for sand at varying proportions. The experimental program examined quarry dust substitutions ranging from 10% to 20% by weight of sand. Results indicated that a water-cement ratio of 0.45 was optimal for the mixtures, with slump values showing improvement as the quarry dust content increased in the concrete composites. Analysis of compressive strength revealed a 2.5% reduction at both 7 and 28 days of curing. Based on the compressive strength results, the research concluded that 12.5% quarry dust substitution represents the optimal replacement level for sand in concrete composites.

Bahoria et al. (2014) A research study investigated concrete mixtures using various proportions of quarry dust (25%, 50%, 75%, and 100%) as a sand replacement, combined with waste plastic in fabric form, comparing them against conventional sand-based concrete. The incorporation of quarry dust alongside waste plastic significantly enhanced the concrete matrix properties, particularly in terms of strength characteristics. Regression analysis was performed and models were validated to correlate compressive strength results across different curing periods (7, 14, 28, and 90 days). The combination of fine quarry dust with LDPE waste plastic resulted in enhanced matrix densification compared to conventional concrete. The microstructural characteristics were qualitatively analysed through petrographically examination using digital optical microscopy, complemented by XRD and SEM analyses to evaluate the material structure.

CONCLUSION:
Based on the comprehensive literature review, it is evident that industrial by-products like quarry dust, marble waste powder, and stone cutting dust show promising potential as partial replacements for conventional materials in concrete. The optimal replacement levels generally range from 10-40% depending on the specific material, with most studies reporting enhanced mechanical properties and durability characteristics. These alternative materials not only contribute to sustainable construction practices but also offer economic benefits while maintaining or improving concrete performance standards. The integration of supplementary materials like glass fibres and waste plastic further enhances the composite properties, opening new avenues for sustainable concrete development.
Based on the past research of the experts outlined above, many conclusions can be drawn:

- Stone cutting dust shows optimal results at 10% cement replacement in M20 grade concrete, balancing performance and environmental benefits.
- Stone dust in cellular lightweight concrete achieves peak compressive strength of 24.62 kg/cm² at 100% replacement after 28 days.
- Finely ground natural white sand with fly ash and silica achieves compressive strengths of 118.5-128 MPa after 28 days.
- Marble and granite dust are viable cement replacements without compromising engineering properties.
- Ultra-High-Performance Concrete with silica fume achieves 128.1 MPa strength at 28 days.
- Waste Quarry Dust with 0.4% glass fibre content shows optimal performance at 25% replacement.
- Marble powder slurry demonstrates enhanced strength up to 15% replacement with varying water-cement ratios.
- Quarry dust shows optimal strength at 40% replacement in M25 grade concrete.
- Combined Marble Waste Powder and Silica Fume perform well up to 10% replacement.
- Quarry dust increases concrete compressive strength by 5-22% with optimal results at 40% replacement.
- Marble slurry at 15% replacement improves mechanical properties and durability.
- Crushed stone sand shows comparable strength properties to natural sand concrete.
- 12.5% quarry dust substitution is optimal for concrete composites.
- Quarry dust with waste plastic enhances matrix densification and strength properties.
- Stone dust integration in concrete offers both environmental and economic advantages.
- Material replacement levels above optimal percentages generally show declining strength properties.

- Water-cement ratio of 0.45 proves suitable for most alternative material mixtures.
- Microstructural analysis confirms improved matrix densification with alternative materials.
- Long-term durability characteristics show improvement with optimal replacement levels.
- Combined use of industrial by-products with supplementary materials enhances overall concrete performance.

STATEMENTS AND DECLARATIONS:

Data Availability Statement:

Data supporting the study's conclusions are accessible from ResearchGate (https://www.researchgate.net) and DOI.org (https://doi.org) upon reasonable request.

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