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EXPERIMENTAL INVESTIGATION OF POLYPROPYLENE FIBRE REINFORCED SELF-COMPACTING CONCRETE WITH QUARRY DUST AS FINE AGGREGATE: A DETAILED REVIEW

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ABSTRACT
The scarcity of natural river sand, traditionally preferred as fine aggregate in concrete due to its superior characteristics, has prompted exploration of sustainable alternatives. Extensive sand mining operations have resulted in severe environmental degradation, affecting land, water resources, ecosystems, and local communities. This pressing concern necessitates the investigation of environmentally responsible and cost-effective alternatives, particularly industrial by-products such as quarry dust and bottom ash, as potential fine aggregate substitutes in concrete production. Quarry dust, often considered a waste material that poses disposal challenges, presents a promising opportunity for sustainable concrete production. Its incorporation as fine aggregate not only addresses environmental concerns but also transforms an industrial waste product into a valuable construction resource, contributing to both waste reduction and sustainable construction practices.
Hence, an attempt has been made in the present work to review the effect of quarry dust on the performance of self-compacting polypropylene fibre reinforced concrete. Innovative research is now focusing on materials like quarry dust from industries as potential partial sand replacements. The primary goals are to discover alternative aggregate materials, reduce sand 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.
Keywords: Sustainable Concrete, Quarry Dust, Polypropylene Fibre, Mechanical Properties, Sand Replacement.

I. Introduction
The construction industry heavily relies on Ordinary Portland Cement (OPC) as the primary binding agent in concrete production, with natural sand serving as a crucial fine aggregate component. River courses and flood plains have traditionally been the primary sources of fine aggregate, with sand's inherent durability and sorting characteristics making it the preferred choice in construction. However, the escalating demand for concrete has led to increased sand extraction, resulting in the rapid depletion of natural sand resources and unreliable supply chains.
The excessive mining of sand and gravel beyond natural replenishment rates has caused severe ecological damage. This over-exploitation has resulted in numerous environmental challenges, including the lowering of water tables, diminished groundwater resources leading to drinking water scarcity, riverbed degradation, increased frequency of flash floods, river bank erosion, and structural damage to bridge foundations. These environmental concerns have necessitated the exploration of eco-friendly and cost-effective alternatives, particularly industrial by-products, as substitutes for natural sand in concrete production.
Over the past three decades, extensive research has been conducted to evaluate the potential of quarry dust and its impact on both fresh and hardened concrete properties. Quarry dust, a by-product of stone crushing operations, is abundantly available in many regions at minimal cost. Currently considered a waste material creating disposal challenges, its utilization as fine aggregate in concrete

offers a dual benefit: addressing environmental concerns while reducing concrete production costs. The successful integration of quarry dust as a fine aggregate replacement effectively transforms an industrial waste product into a valuable construction resource, promoting sustainable practices in the concrete industry.

II. Literature

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.

Jonatha Roberto Pereira et al. (2023) The research investigated the effectiveness of polypropylene (PP) microfibers in controlling shrinkage behavior in self-compacting concrete (SCC) through the development and analysis of testing methodologies. The study specifically examined the correlation between crack formation patterns and the timing of their occurrence, focusing on how PP fibres influence this concrete pathology. For experimental purposes, SCC mixtures were prepared incorporating PP microfibers of two different lengths (6 mm and 12 mm), with testing conducted according to established standards ASTM C1579:2013 for plate specimens and ASTM C1581:2016 for ring specimens. The experimental results demonstrated significant improvements in crack resistance with the addition of PP microfibers, achieving crack reduction rates between 40% and 70%. Furthermore, the incorporation of these fibres substantially delayed the onset of initial cracking, extending the crack-free period by 9 to 20 days compared to reference specimens. These findings validate the effectiveness of PP microfibers as a viable solution for shrinkage control in self-compacting concrete applications.

Parea R. Rangan et al. (2023) This research explored the application of stone dust as a fine aggregate replacement in Cellular Lightweight Concrete (CLC) brick production, focusing on its effects on compressive strength and volume weight characteristics. The experimental methodology involved manufacturing lightweight bricks with varying stone dust proportions (0%, 50%, and 100%) as fine aggregate substitutes, followed by comprehensive testing at multiple curing intervals (3, 7, 14, and 28 days). The investigation revealed that stone dust's superior binding properties enhanced the brick's compressive strength, achieving a peak value of 24.62 kg/cm² at 100% replacement after 28 days of curing. Volume weight measurements demonstrated 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 maintained their lightweight concrete classification, as their volume weights remained within the accepted range of 0.6-1.8 gr/cm³.

M Sofyan et al. (2022) This investigation examined the feasibility of incorporating polypropylene (PP) plastic granules as a sand replacement in concrete mixtures, evaluating its impact on both physical and mechanical properties. The study focused on key performance parameters including compressive strength, split tensile strength, workability, and density characteristics. Experimental results revealed that increasing proportions of PP plastic granules (10%, 20%, 30%, and 40%) as fine aggregate replacement resulted in progressive improvements in workability, with slump values ranging from 8.1 cm to 8.8 cm. However, this enhancement in workability came at the cost of significant mechanical performance deterioration, particularly evident in both compressive and split tensile strengths. Most notably, at 40% PP plastic granule substitution, the concrete exhibited a substantial 58.06% reduction in strength properties compared to conventional concrete.

Kinuthia Mugi (2022) This investigation focused on evaluating the performance implications of incorporating quarry dust as a replacement for natural fine aggregates in Concrete Block (CB) production. The experimental methodology involved casting 150 mm cubic specimens, which underwent curing periods of 7, 14, and 28 days. The research encompassed comprehensive testing of both fresh and hardened concrete properties, including particle size distribution analysis, workability assessment through slump tests, and compressive strength measurements. Durability performance was evaluated by subjecting 28-day cured specimens to alternating wet-dry cycles. Additionally, the study included a cost-benefit analysis to assess the economic viability of quarry dust as a fine aggregate substitute in CB production. Statistical validation of the results was conducted using T-test analysis to determine significant performance variations between quarry dust-modified blocks and control specimens.

Vikas Patel et al. (2021) A comprehensive experimental investigation was conducted to evaluate the performance of Polypropylene fibre reinforced concrete (PFRC) compared to standard concrete mixtures. The research examined three distinct water-to-cement ratios: 0.47, 0.36, and 0.20, with granite serving as the primary aggregate. Test specimens were prepared using two-cylinder sizes - 100 mm × 200 mm and 150 mm × 300 mm - incorporating a 0.5% fibre volume fraction. These specimens underwent thermal exposure tests at temperatures of 400°C and 600°C, with each exposure lasting one hour. The study aimed to assess various mechanical properties including elastic modulus, Poisson's ratio, splitting tensile strength, flexural strength, and compressive strength. Testing was performed both at ambient temperature and after heat exposure. The experimental findings revealed that the addition of polypropylene fibres did not result in substantial improvements to any of the measured mechanical properties, regardless of whether the specimens were tested at room temperature or after exposure to elevated temperatures.

Wael Zatar and Hai Nguyen (2020) A study was conducted to develop an eco-friendly self-consolidating fibre-reinforced concrete (SCFRC) incorporating recycled polypropylene fibres for urban construction applications. The research explored various mix designs incorporating micro silica, fly ash, and PP fibres, using a trial-and-adjustment approach to achieve optimal combinations that balanced cost, workability, and performance. While maintaining constant Portland cement content, researchers varied the proportions of aggregates, water, and admixtures. Fresh concrete properties were assessed through slump flow and air content tests, while compressive strength was evaluated at three and seven days. The mixtures demonstrated promising results, with peak values reaching 43.17 MPa for three-day compressive strength and 736.6 mm for slump flow. A particularly effective mixture achieved a seven-day compressive strength of 39.26 MPa, with 4.8% air content and 660.4 mm slump flow. The study concluded that these SCFRC mixtures would be particularly suitable for architectural applications where both structural performance and aesthetic appeal are crucial, such as building facades and decorative bridge elements.

Nur Liza Rahim et al. (2020) An investigation was conducted to analyse the potential of quarry dust as a partial cement replacement in concrete mixtures. Chemical composition analysis using X-Ray Fluorescence Spectrometry (XRF) revealed that quarry dust shares important characteristics with Ordinary Portland Cement (OPC), particularly its high Calcium Oxide (CaO) content. Through extensive testing, researchers determined that the optimal mixture consisted of 25% quarry dust and 75% cement, which achieved the required strength standards for concrete applications. This modification proved to be cost-effective, resulting in savings of RM 33 per cubic meter of concrete produced. The findings demonstrate that quarry dust waste can be effectively utilized as a cement substitute to produce strong and durable concrete, offering both an economical construction material solution and an environmentally beneficial way to repurpose industrial waste.

Reza Keihani et al. (2019) This study, examined the effects of replacing fine aggregate with polypropylene in concrete. Their experimental work involved six concrete batches with polypropylene replacement levels ranging from 0.5% to 3.0%. While the results showed an overall decrease in compressive strength when plastic aggregate was added, this reduction became less pronounced as plastic content increased. Notably, two mixtures containing 1.50% and 2.50% plastic aggregates surpassed the ST5 standardized prescribed concrete mix compressive strength requirements at 28 days, suggesting potential applications in structural construction as a partial replacement for fine aggregate.

Kutikuppala Vidyasagar and Chappa Damodar Naidu (2018) This current project work studied the impact of polypropylene fibres combined with either quarry dust or fly ash on concrete's mechanical

properties. They prepared two distinct concrete mix series: one combining polypropylene fibre (1% to 3%) with quarry dust (0.1% to 0.3%), and another mixing polypropylene fibre (1% to 4%) with fly ash (0.1% to 0.4%), both measured by cement weight. Their comparative analysis against conventional concrete revealed improvements in compressive, split tensile, and flexural strengths for both combinations. The research identified optimal mixtures at 3% polypropylene with 0.3% quarry dust, and 4% polypropylene with 0.4% fly ash by cement weight. The study also included a cost analysis comparing conventional concrete against fibre-reinforced variants with different admixtures.
Vishal Agrawal (2017) This research is conducted to evaluate the viability of quarry dust, a quarrying waste product, as a substitute for fine aggregates in conventional concrete. The study involved comparing various physical and engineering properties of quarry dust against sand, followed by testing concrete's compressive strength using different ratios of sand replacement with quarry dust. The findings were particularly positive when 50% of sand was replaced with quarry dust.

K. Premchand et al. (2015) This research investigated the effects of incorporating quarry dust and other materials in concrete mixtures. Their research highlighted various improvements in concrete properties, including enhanced durability, better resistance to chloride, sulphate, freezing and thawing, alkali silica reaction, and frost attack. The study noted that quarry dust, also known as granite fines or rock dust, is generated during granite rock crushing processes. The researchers also explored the use of Fly Ash as a partial cement replacement to enhance workability, long-term strength, and economic efficiency. Their experimental work specifically examined the fresh and hardened properties of ternary blended self-compacting concrete, where they replaced 10% of cement with Metakaolin and 30% with fly ash by weight, while also varying quarry dust content as fine aggregate replacement at levels of 0%, 20%, 40%, and 60%.

Anjali H Jamale et.al (2015) A research investigation was conducted to understand how quarry dust and fly ash influence high-strength concrete properties. The findings revealed contrasting effects on concrete workability: while quarry dust decreased workability, the addition of fly ash significantly enhanced it. The study determined that replacing river sand with 15% quarry dust yielded optimal strength results. Additionally, the research showed that concrete mixtures containing up to 35% quarry dust-maintained strength levels comparable to traditional concrete mixes.

Jofferey chiruiyot et.al (2014) investigated the impact of quarry dust on high-performance concrete characteristics. Their research demonstrated that locally sourced quarry dust could be effectively used to produce high-performance concrete, achieving impressive results with compressive strengths exceeding 80 kN/mm2 and an elasticity modulus of 49.4 GPa. The study revealed that using high-strength concrete allowed for significant reductions in both structural member sizes and the total amount of reinforcement steel required.

Prajapati Krishnapal et al. (2013) conducted extensive testing to examine the rheological and strength properties of self-consolidating concrete (SCC) containing fly ash. In their study, cement was partially substituted with fly ash at rates of 10%, 20%, and 30% by weight. Fresh concrete properties were evaluated following EFNARC guidelines, and compressive strength tests were performed at 7 and 28 days. Their findings showed that incorporating fly ash reduced the required amount of superplasticizer while maintaining or improving workability. All concrete mixtures achieved compressive strengths of at least 39 MPa at 28 days. The research concluded that increasing fly ash content enhanced the concrete's flow ability, passing ability, and resistance to segregation.

III. Conclusion

The comprehensive review of literature has revealed significant developments in concrete technology through the incorporation of various materials like quarry dust, polypropylene fibres, and fly ash. These innovations have demonstrated promising results in terms of strength, durability, and cost-effectiveness, while also addressing environmental concerns through the utilization of waste materials. The research findings collectively suggest that these alternative materials can effectively

replace traditional concrete components in specific proportions without compromising structural integrity, opening new possibilities for sustainable construction practices.
Based on the past research of the experts outlined above, many conclusions can be drawn:

- PP microfibers in self-compacting concrete reduce crack formation by 40-70% and delay initial cracking by 9-20 days.
- Stone dusts as fine aggregate in CLC bricks achieves optimal compressive strength of 24.62 kg/cm² at 100% replacement.
- PP plastic granules improve workability but decrease strength by 58.06% at 40% substitution.
- Quarry dust as cement replacement at 25% provides optimal strength while saving RM 33 per cubic meter.
- SCFRC with PP fibres achieves 43.17 MPa three-day compressive strength and 736.6 mm slump flow.
- 1.50% and 2.50% plastic aggregate mixtures surpass ST5 strength requirements at 28 days.
- Optimal mixture combines 3% polypropylene with 0.3% quarry dust or 4% polypropylene with 0.4% fly ash.
- 50% quarry dust replacement for sand shows positive results in conventional concrete.
- Ternary blended SCC with 10% Metakaolin and 30% fly ash improves durability.
- 15% quarry dust replacement of river sand provides maximum strength enhancement.
- High-performance concrete with quarry dust achieves 80 kN/mm2 compressive strength.
- Fly ash in SCC at 30% replacement achieves minimum 39 MPa compressive strength at 28 days.
- PP fibres at 0.5% volume fraction show no significant mechanical property improvements.
- SCFRC mixtures with 4.8% air content achieve 39.26 MPa seven-day strength.
- Quarry dust's high CaO content makes it suitable as cement replacement.
- 35% quarry dust concrete maintains strength comparable to conventional concrete.
- Fly ash improves workability while reducing superplasticizer requirements.
- Local quarry dust produces high-performance concrete with 49.4 GPa elasticity modulus.
- Combined quarry dust and fly ash show complementary effects on concrete properties.
- Fly ash enhances flow ability and segregation resistance in self-consolidating concrete.

IV. 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.

V. Disclaimer:

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Both authors were involved in the study's conception and design. Md Tarique Anwar handled material preparation, data collection, and analysis. Md Tarique Anwar wrote the first draft of the manuscript, while Dr Ravindra Gautam reviewed previous versions. Both authors have reviewed and approved the final manuscript.

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