

A Systematic Review on the Use of Quarry Dust in the South African Construction Industry

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Abstract

The construction industry's environmental impact has led to growing interest in alternative materials, and this paper reviews quarry dust by evaluating its effectiveness in concrete, road construction, and other applications while addressing its enabling factors within the South African construction industry. A systematic review of literature was conducted by analysing relevant publications from four databases (Academia, ResearchGate, ScienceDirect, and Springer Link) published between 2015 and 2024. The research is limited to the complexities of using quarry dust in South Africa, and the findings aim to inform the feasibility of adopting similar materials in other regions. The review highlights the effectiveness of quarry dust in construction applications, emphasising its significant contribution to both economic and environmental sustainability as a viable alternative material. Quarry dust not only enhances concrete strength and durability as an acceptable aggregate replacement but also stabilises soil in road construction, improving road durability. Additionally, it reduces the carbon footprint by replacing cement and traditional aggregates, which helps lower construction costs and offers an eco-friendly and readily available solution. However, it is important to note that there is an optimal replacement ratio for quarry dust in various studies, beyond which further increases may adversely affect concrete performance. Policy support and the establishment of standards could further promote its adoption in South Africa, unlocking its full potential in the construction industry. This study provides actionable insights for policymakers, construction professionals, and researchers, promoting the sustainable use of quarry dust and fostering environmentally friendly construction practices in South Africa.

Keywords: Construction industry, Construction materials, Policy support, Quarry dust, South Africa, Sustainability, Systematic Literature Review

1. Introduction

The construction industry is essential for the advancement of the contemporary world, but it also possesses considerable environmental challenges. The substantial demand for construction materials, along with resource-intensive methods, leads to significant carbon emissions, resource depletion, and environmental damage (Chakraborty and Elzarka 2019). To resolve these difficulties, it is imperative to implement sustainable construction procedures that reduce the sector's ecological footprint. An essential element in this initiative is the extensive utilisation of eco-friendly and sustainable construction materials. Selecting these resources significantly reduces the industry's ecological footprint, enhances resource conservation, and fosters a more sustainable future (Xie, Huo, Qi, and Zhu, 2016). Quarry dust has become a feasible alternative to sand and cement, potentially mitigating material shortages and environmental issues (Prakash, 2017). It can be employed in concrete manufacturing, soil stabilisation, brick fabrication, and mortar production, among other applications. In all these uses, quarry dust partially or fully replaces traditional materials. Opara and Eziefula (2018) and

Karim, Samueel, and Jassem (2020) assert that these advantages can be attributed to the superior qualities of the materials employed; quarry dust was utilised in place of conventional materials to produce more sustainable, cost-effective, and efficient outcomes. This systematic analysis aims to deliver a thorough assessment of quarry dust within the South African construction sector, emphasising the elements that can promote its incorporation into construction methodologies. This review seeks to enhance the discourse on sustainable construction materials and practices in South Africa by integrating existing research and pinpointing knowledge gaps from materials in selected databases. This review's findings will inform industry stakeholders and offer valuable insights for policymakers and researchers focused on advancing sustainable development in South Africa's construction sector.

2. Literature Review

2.1. Environmental Challenges and the Need for Sustainable Construction in South Africa.

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The South African construction industry faces significant environmental challenges, such as carbon emissions, resource depletion, and environmental degradation due to traditional resource-intensive practices (Chakraborty and Elzarka, 2019). Quarry dust offers a viable alternative to traditional materials like sand and cement, potentially alleviating material shortages and reducing environmental impact (Prakash, 2017). Nevertheless, research on strategies for systematically adopting quarry dust across the country's industry remains limited.

2.2. Economic Importance and the Role of Sustainable Materials

The construction sector is vital to South Africa's economy, driving employment and infrastructure development (Alagidede, 2021). Despite its importance, the sector is vulnerable to cyclical fluctuations, making the integration of sustainable materials like quarry dust essential for economic stability (Thwala, 2022). However, research on how quarry dust can support economic resilience and be scaled in the South African market is still lacking.

2.3. Benefits and Barriers to Quarry Dust Adoption

Quarry dust contributes to sustainable construction by reducing waste and improving concrete properties, such as compressive and flexural strengths (Alabduljabbar, Huseien, Sam, Alyouef, Algaifi, & Alaskar 2020). While its environmental and mechanical advantages are well-documented, there is insufficient analysis on barriers to its widespread adoption in South Africa, including cost-effectiveness, availability, industry standards, and the regulatory framework (Sarvade and Nayak, 2014; Panchal and Mathew, 2015). Moreover, quarry dust adoption strategies can be outlined from its adoption barriers. Therefore, overcoming these challenges and integrating quarry dust at a broader industry level requires more research.

3. Methodology

This paper consists of a literature overview and analysis of current research findings about the utilisation of quarry dust in South Africa. Nwokocha, Okorafor and Ikegwuoha cited prior research and discoveries concerning the application of quarry dust in developing nations. The review evaluated the efficacy of quarry dust utilisation in diverse construction activities relative to traditional construction methods. The review analysed the tactics employed for the adoption of quarry dust utilisation in South Africa. A systematic literature review differs from and is favoured above the traditional or narrative review methodology. A systematic literature review necessitates a thorough, complete, and exhaustive examination of all pertinent articles and is characterised by objectivity, balance, and impartiality.

Conversely, the conventional review process is excessively open and adaptable, and the reviewer is not required to furnish a methodological report (Jesson et al. 2011). Fink (2014) presents a systematic, explicit, and thorough approach for discovering, analysing, and summarising the current literature. This approach delineates the search strategy, inclusion and exclusion criteria, standards for assessing study quality, and methods for summarising and analysing findings comprehensively. This provides valuable direction for crafting a cutting-edge review. Consequently, the literature review of this study adheres to Fink's (2014) methodology.

3.1. Searched for Study selection

The systematic literature review (SLR) of the publications related to the use of quarry dust in the SA construction industry comprises four stages.

Stage One encompassed selecting research questions, databases, and websites, along with defining search phrases. This systematic research aims to elucidate the role of quarry dust as an alternative construction material in South Africa, with an emphasis on adoption strategies. The primary research question for this analysis was: *What are the adoption strategies for employing quarry dust in the South African construction sector?*

Stage Two consisted of screening titles and abstracts for relevance through an initial appraisal. Publications deemed repetitive or irrelevant were excluded. Abstracts were reviewed to ensure the focus was on quarry dust in the construction industry. General research was conducted to summarise studies (2015–2024) on quarry dust utilisation in construction, without excluding based on journal rankings to ensure a broad overview.

Stage Three involved a full text review of potential relevant studies to confirm their relevance, based on results and conclusions. Irrelevant papers were discarded after thorough reading. Inclusion and exclusion criteria were applied during this phase. Studies were included if they were published in English, focused on quarry dust in sustainable construction, and were peer-reviewed articles, conference proceedings, or government reports.

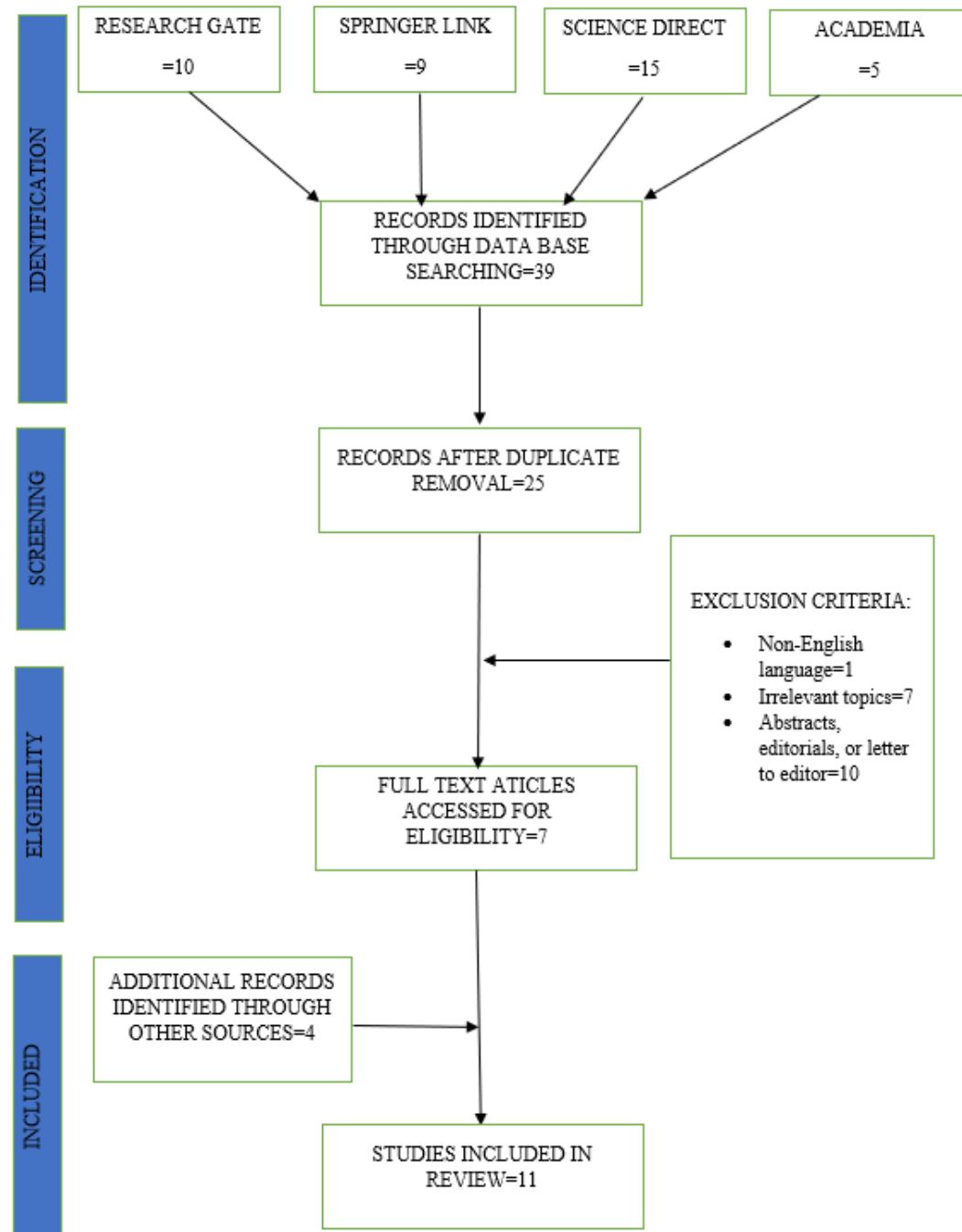


Figure 1: Flow diagram of the literature search
(Source: Authors: 2025)

Excluded studies were non-English, focused on unrelated topics, or were abstracts, editorials, or letters to the editor.

Stage Four concentrated on combining the gathered knowledge to establish the conclusive perspective. This phase entailed the identification of research deficiencies, prospective recommendations, and findings derived from the review process. The objective was to examine and synthesise findings to enhance the understanding of quarry dust's viability as a

construction material in South Africa. Figure 1 presents a comprehensive overview of the processes involved in the systematic literature review.

3.2. Search Strategy

The academic publications reviewed in this study were sourced from four reputable databases: ResearchGate, Springer Link, Academia, and ScienceDirect, which are known for hosting high-quality, peer-reviewed content. These platforms offer extensive coverage across various fields, such as engineering, environmental

science, and construction management. This broad scope is crucial for capturing a wide range of literature related to quarry dust utilisation, sustainable construction materials, and the South African construction industry. To ensure the inclusion of recent research, studies from 2015 to 2024 were selected. Keywords tailored to the research questions, including "Review on the utilisation of quarry dust," "Sustainable construction materials," "Overview of the South African construction industry," "Quarry dust environmental impacts," and "Adoption strategies to quarry dust utilisation," were used for searches. In addition to these databases, hand searches of relevant journals, conference proceedings, and government reports were conducted to enrich the review. A variety of publication types, such as journal articles, books, conference papers, and reports, were included to ensure comprehensive coverage of the topic.

3.3. Data Extraction

As a result, 11 publications were eventually selected for further reading and analysis. Interestingly, most of them were found out from the Science Direct database, with the highest percentage and accounting for 55% of the total selected publications, followed by Internet search engine (30%), Research Gate (10%), Springer Link (7%), and Academia (3%).

4. Findings

4.1. Key Findings from Reviewed Studies on Quarry Dust in South African Construction

The study by Ajamu et al. (2020) found that replacing up to 50% of fine aggregate with quarry dust in concrete improved both compressive and tensile strength. However, higher replacements led to reduced workability. This supports previous research, emphasising quarry dust's potential to enhance strength while underscoring the importance of precise material proportions. Similarly, Sridharan et al. (2006) demonstrated that quarry dust significantly improved the shear strength of clayey soils, particularly with 60% replacement, further validating its effectiveness in soil stabilisation and infrastructure applications.

The integration of quarry dust as a partial replacement for traditional materials like sand and cement in concrete and sandcrete blocks has been explored in multiple studies, including those by Ma'aruf A., Abba S.I. and Nuruddeen (2017) and Akorli et al. (2023). These studies align with earlier findings and offer deeper insights into the optimal use of quarry dust in construction. Both studies identified a 20% replacement of cement or pit sand as the optimal level for achieving the highest compressive strength. Specifically, Ma'aruf A., Abba S.I. and Nuruddeen (2017) found that a 20% cement replacement led to the best compressive strength and durability, while greater replacements caused a reduction in strength. Similarly,

Akorli et al. (2023) found that a 20% sand replacement resulted in a compressive strength of 1.46 N/mm², which met the Ghana Building Code for non-load-bearing walls.

However, both studies observed a decline in compressive strength when quarry dust replacements exceeded 20-30%. Ma'aruf A., Abba S.I. and Nuruddeen (2017) noted that quarry dust contents greater than 20% resulted in reduced strength, with noticeable strength loss at 30-40%. Akorli et al. (2023) found that at 30% replacement, the compressive strength was 1.41 N/mm², dropping to 1.32 N/mm² at 40%, and significantly decreasing to 0.60 N/mm² at 60-80% replacement. Additionally, Akorli et al. (2023) found that blocks made with only pit sand exhibited the highest compressive strength, while blocks made solely from quarry dust had the lowest strength, confirming that quarry dust is not an ideal substitute on its own. Ma'aruf A., Abba S.I. and Nuruddeen (2017) similarly observed that pure cement concrete was stronger than mixtures with high quarry dust content.

Beyond strength considerations, the durability of materials incorporating quarry dust has also been investigated. Ma'aruf A., Abba S.I. and Nuruddeen (2017) tested concrete durability against dilute sulfuric acid and found that concrete with quarry dust exhibited better abrasion resistance than pure materials, highlighting the material's potential for enhancing durability.

Supporting the trend toward sustainable construction, Febin et al. (2019) found that replacing 30% of the fine aggregate in concrete blocks with quarry dust not only improved strength but also reduced the environmental impact and cost, aligning with broader efforts to reduce construction costs and environmental footprints. Rahim et al. (2020) demonstrated that replacing up to 25% of cement with quarry dust enhanced concrete durability and reduced carbon emissions, reinforcing quarry dust's role in sustainable building practices and contributing to the global movement toward reducing the carbon footprint of construction materials.

Moreover, Silver et al. (2022) cautioned that the properties of quarry dust can vary significantly based on its origin, highlighting the need for local material testing before using it in construction projects. Additionally, Febin et al. (2019) (in a separate study) further emphasised the dual benefits of quarry dust in reducing both environmental impact and production costs in building block production, reinforcing its value in specialised construction applications.

4.2. *Relation of the Findings to Existing Literature*

Enhanced Mechanical Properties

The findings from Ajamu et al. (2020) regarding compressive and tensile strength improvements align with Panchal & Mathew (2015), who found that quarry dust enhances concrete strength. These studies emphasise the effectiveness of quarry dust when used in specific proportions, as noted by Rahim et al. (2020), who found that quarry dust could partially replace cement while maintaining concrete quality.

Soil Stabilisation

The Sridharan et al. (2006) findings about quarry dust improving shear strength in clayey soils resonate with the work of Karim, Samueel, and Jassem (2020), who explored the role of quarry dust in soil stabilisation. This supports the idea that quarry dust can be used in applications beyond concrete, contributing to infrastructure development, such as road construction and embankments.

Cost-Effectiveness and Sustainability

Studies like Febin et al. (2019) and Rahim et al. (2020) indicate that quarry dust is an economically viable and environmentally sustainable alternative. These findings align with Prakash (2017), who suggested that quarry dust offers a cost-effective and eco-friendly solution to address material shortages, reduce waste, and lower carbon footprints in construction.

Material Variability

Silver et al. (2022) found that quarry dust's characteristics depend on its origin, highlighting the importance of material testing. This aligns with Chakraborty & Elzarka (2019), who emphasised the need for standardising quarry dust properties to ensure consistent performance in construction applications.

Specialised Applications

Febin et al. (2019) demonstrated quarry dust's role in concrete block production, offering an alternative to traditional materials. This extends the idea explored by Prakash (2017) and Sarvade & Nayak (2014), who noted the material's utility in both niche and mainstream construction applications.

4.3. *Implications of the Findings for practice and policy in South Africa*

The findings suggest that quarry dust can contribute to more sustainable and cost-effective construction in South Africa by reducing the environmental impact of cement and sand. Its use should be guided by local material testing to ensure quality, as its properties vary by origin. South African building codes could incorporate optimal replacement levels (20-30%) for strength and durability, especially in non-load-bearing applications. Quarry dust's cost-saving potential supports affordable housing projects, and its integration

aligns with circular economy goals by reducing waste. Policymakers should promote education and training on proper quarry dust use to maximise benefits in construction. Table 1 (Appendix 1) summarises the systematic synthesis of the literature.

Table 1 shows the systematic synthesis revealing that quarry dust plays a pivotal role in enhancing environmental sustainability, economic feasibility, mechanical properties, and material performance in the South African construction industry. Key strategies for adoption include research & development, technical training, policy frameworks, and local testing to ensure successful integration. These findings align with previous studies and offer practical recommendations for stakeholders in the South African construction sector.

5. Discussion of Findings

This study reviews quarry dust's effectiveness in concrete, road construction, and other applications, addressing factors enabling its use in the South African construction industry. It highlights the need for a multi-stakeholder approach, involving government, industry, and academia, to overcome challenges such as limited awareness, technical expertise, and logistical barriers like supply consistency.

Key findings include optimal replacement levels for performance: up to 50% for fine aggregates (Ajamu et al., 2020) and 25% for cement (Rahim et al., 2020). The study also identifies workability challenges due to quarry dust, necessitating adjustments in mix design and water-cement ratios. Quarry dust's potential in soil stabilisation and road construction is highlighted, alongside its environmental and economic benefits, such as waste reduction and carbon emission lowering. However, variability in its properties based on origin requires local material testing and certification to ensure quality.

To fully utilise quarry dust in South Africa, the study recommends:

- Standardising guidelines and protocols.
- Conducting region-specific material characterisation studies.
- Enhancing technical capacity through training.
- Promoting policies and incentives that prioritise sustainable materials.
- These strategies will support the widespread and reliable use of quarry dust, advancing both economic and environmental goals in South Africa's construction sector.

5.1. *Contribution to knowledge*

This study enhances the body of knowledge by providing evidence on optimal quarry dust replacement levels (20-30%) for improving strength and durability

in concrete and sandcrete blocks. It highlights the need for local material testing due to variability in quarry dust properties, addressing gaps in current practices. The study also reinforces the environmental and cost benefits of quarry dust, supporting sustainable construction practices and resource efficiency. Additionally, it offers insights for updating policies and building codes to incorporate quarry dust safely, contributing to the broader push for sustainable construction and circular economy practices.

6. Conclusion

This literature review provides a comprehensive overview of quarry dust's effectiveness, applications, and enabling factors in the South African construction industry. Continued research and engagement with local stakeholders are crucial for maximising the potential of quarry dust and promoting its adoption as a sustainable construction material. Future studies should focus on creating standardised testing methods, assessing long-term material performance, and fostering awareness among construction professionals to encourage more widespread integration of quarry dust in various applications. However, the main objective of this review is to provide a comprehensive summary of the complexities associated with the use of quarry dust in the South African construction industry. The authors systematically reviewed 11 articles on the use of quarry dust in the South African construction industry. They classified the articles based on the main component, which is the research question: What strategies should be implemented to fully utilise the

potential of quarry dust in the SA construction industry?

Furthermore, the systematic review highlights that while the technical and economic viability of quarry dust is established, its full utilisation in South Africa depends on targeted adoption strategies. These include R&D investments, supportive policies, capacity building, public awareness, supply chain optimisation, and alignment with sustainability frameworks. Implementing these strategies requires:

- Strong leadership and collaboration among policymakers, industry players, and researchers.
- Comprehensive performance validation and standardisation to ensure consistent material quality.
- Greater investment in supply chain infrastructure to ensure accessibility.

Future efforts should focus on scaling up successful pilot projects, addressing logistical challenges, and integrating quarry dust into national construction policies. These steps will contribute to sustainable and cost-effective construction practices across South Africa.

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Appendix 1

Table 1: Summary of the systematic synthesis

Theme	Study Reference	Key Findings	Adoption Strategy/Enabling Factor	Relation to Existing Literature
Environmental Sustainability & Economic Feasibility	Febin et al., 2019; Rahim et al., 2020	Quarry dust reduces cement use, cutting carbon emissions and enhancing durability. It also reduces production costs and environmental impact in concrete block production.	Environmental Sustainability Framework; Economic Feasibility	Aligns with Prakash (2017) on quarry dust reducing carbon emissions and material costs. Supports Ismail et al. (2017) 's broader sustainability goals.
Mechanical Properties & Performance	Ajamu et al., 2020; Rahim et al., 2020	Quarry dust enhances compressive and tensile strength in concrete when used at optimal levels (25-30%). Excessive replacement (50%) reduces workability.	Research & Development Investment; Technical Training	Supports Panchal & Mathew (2015) on strength enhancement, and Rahim et al. (2020) on maintaining concrete quality with partial cement replacement.
Material Variability & Local Adaptation	Silver et al., 2022; Sridharan et al., 2006	Quarry dust's properties vary by source (granite, limestone, marble), impacting its effectiveness in construction and soil stabilisation.	Supply Chain & Logistics Optimization; Local Material Testing	Confirms Chakraborty & Elzarka (2019) on material variability, emphasising the need for local sourcing and testing.
Soil Stabilisation & Infrastructure Development	Sridharan et al., 2006; Corroborates Karim, Samueel, and Jassem, 2020	Quarry dust significantly improves shear strength in clayey soils, supporting road construction and infrastructure.	Policy & Regulatory Framework; Public Awareness & Advocacy	Corroborates Karim, Samueel, and Jassem (2020) on soil stabilisation and Sridharan et al. (2006) on infrastructure applications.
Specialised Applications & Sustainability	Febin et al., 2019 (additional study); Nayak, Sarvade, Patel & Yadav (2019)	Quarry dust is effective for niche applications like building blocks, offering economic and environmental benefits.	Specialised Applications; Public Awareness & Advocacy	Supports Panchal & Mathew (2015) and Nayak, Sarvade, Patel & Yadav (2019) on quarry dust's role in specialised construction applications.

Source: Authors 2025