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A Review on Feasibility Study on The Use of Iron Ore Tailings as a Fine Aggregates with Glass Fiber in Concrete

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ABSTRACT:
Concrete, a fundamental construction material, forms the basis for infrastructure projects globally. The environmental impact of concrete is influenced by factors such as the type of concrete and the quantity of cement used. Cement, a key component of concrete, has diverse effects on the environment. Additionally, the surge in concrete demand necessitates vast amounts of natural river sand, a crucial fine aggregate in concrete production. This heightened demand leads to adverse effects on river ecosystems, including increased riverbed distance, lower water tables, exposure of bridge substructures, and substantial impacts on rivers, deltas, coasts, and marine environments. The scarcity of natural river sand elevates its cost, underscoring the necessity for affordable raw materials. To address the need for cost-effective alternatives, attention turns to iron ore tailings (IOT), a byproduct from the iron concentrates beneficiation process. Combining IOT with glass fiber in concrete emerges as a strategy to enhance its properties. This overview discusses research conducted on the utilization of iron ore and glass fiber as partial replacements for fine aggregates, examining their impacts on the workability, durability, and mechanical properties of concrete.

INTRODUCTION

Concrete, a composite material comprising cement, fine aggregate, coarse aggregate, water, and potential admixtures, is integral to global construction activities. The surge in construction demands has led to heightened requirements and costs for materials like natural river sand, obtained through various methods, thereby impacting the environment. Global aggregate consumption or extraction estimates range between 32 and 50 billion tons annually, with sand being a critical component. This escalating demand, driven by construction activities, carries environmental repercussions affecting sectors like tourism, fishery, insurance, and beyond.

The extraction of sand from pits, riverbeds, lakes, or seabeds has multifaceted consequences. It results in land loss due to river or coastal erosion, lowers the water table, diminishes sediment supply, increases flood frequency and intensity, exacerbates drought occurrences, contributes to greenhouse gas emissions, and poses threats to species' survival. As construction activities continue to rise, the environmental impact of sand extraction becomes a growing concern.

Concurrently, the growing need for natural resources and rising living standards have caused an increase in the generation of industrial waste. As a result, recycling waste products into secondary resources becomes a practical tactic for easing environmental restrictions and promoting sustainability. Significantly, millions of tons of industrial byproducts—some of which contain hazardous materials—have been absorbed by the concrete industry. China, a prominent player in the iron and steel industry, has created a substantial amount of industrial waste as a result of its rapid economic growth over the past three decades. Slag and other leftovers are valuable in the manufacturing of cement, but dangerous materials like iron ore tailings are frequently thrown out with the trash, which degrades the environment. Just 7% of China's 0.6 billion tons annual discharge of iron ore tailings were recycled into new resources in 2008, underscoring the need for more sustainable waste management practices.

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This review aims to shed light on previous research involving the incorporation of iron ore and glass fiber into concrete, offering an alternative low-cost raw material to mitigate the environmental impact of natural river sand extraction. The detrimental effects of iron ore on the environment, water resources, and human safety are acknowledged, prompting the exploration of viable alternatives.

Examining the ratios and percentages of iron ore in conjunction with concrete, the review explores the advantages of incorporating glass fiber and identifies optimum replacement percentages to minimize costs and environmental impact. Various tests, including compression tests, tensile strength tests, flexural tests, and assessments of durability and workability, are employed to evaluate the properties of these concrete alternatives. By providing a comprehensive overview of previous work, this review serves as a valuable resource for researchers and practitioners seeking sustainable solutions in concrete production.

In conclusion, the escalating demand for construction materials, particularly natural river sand, necessitates a re-evaluation of the industry's practices to address environmental concerns. Utilizing industrial byproducts, such as iron ore and glass fiber, as alternative materials in concrete production represent a step toward sustainability. This review underscores the importance of optimizing replacement percentages and conducting thorough property assessments to pave the way for environmentally friendly and cost-effective alternatives in the construction industry.

LITERATURE REVIEW

1. Mohamed Moafak Arbili, Muwaffaq Alqurashi, Ali Majdi, Jawad Ahmad and Ahmed Farouk Deifalla (2022)

Conducted research on incorporating iron ore tailings (IOT) as a fine aggregate in concrete, aiming to advance sustainable construction practices. The investigation revealed distinctive physical properties of IOT particles, characterized by their rough and angular nature, potentially impacting the flowability of concrete. Chemical composition and XRD analysis indicated that IOT possesses binding capabilities, positioning it as a viable component in concrete formulations.

Analysis of fresh concrete properties, including slump flow and compactability, demonstrated a decrease with the addition of IOT. However, a promising finding emerged as concrete maintained satisfactory flowability and compactability with up to a 40% substitution of IOT. Beyond this threshold, it is recommended to incorporate a plasticizer to optimize properties. Remarkably, the research identified a positive correlation between mechanical strength and IOT substitution, attributed to micro filling voids and pozzolanic reactions. Optimal doses varied among researchers, but a consensus suggests a typical range of 30% to 40%. Nevertheless, caution is advised, as a higher dose of IOT exceeding 40% adversely impacts concrete's mechanical strength.

The compressive strength of concrete exhibited a noteworthy improvement of 14% with a 20% substitution of IOT compared to reference concrete. Notably, water absorption, chloride ion penetration, and dry shrinkage experienced significant reductions with increasing levels of IOT substitution. Scanning electron microscopy (SEM) results provided visual evidence of improved Interfacial Transition Zone (ITZ), indicating enhanced crack resistance due to void filling and pozzolanic reactions.

In summary, the comprehensive studies advocate the credible utilization of up to 40% IOT in concrete formulations without compromising strength and durability properties. This research contributes to the evolving landscape of sustainable concrete practices, offering insights into optimal substitution percentages and affirming the positive impact of IOT on various performance parameters.

2. Abdulaziz Alhassan, Kudirat O. Yusuf, Adavi Aliyu Abdulazeez and Salihu Usman (2022)

In a recent investigation, the utilization of iron ore tailings (IOT) as a partial substitute for fine aggregate in concrete production garnered considerable attention. Existing literature reveals that certain IOTs exhibit oxide compositions characterized by elevated levels of silica and iron oxide. Researchers have conducted experiments on IOT-infused concrete, comparing it with standard concrete, and varying the replacement percentages of natural river sand with IOT.

The findings suggest that the inclusion of IOT as a partial replacement for fine aggregate in concrete leads to a

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reduction in workability as the percentage of IOT replacement increases. Despite the decrease in workability, the use of IOT contributes to an enhancement in compressive strength, along with other strength parameters. The optimal replacement percentage, however, does not exceed 40% of the weight of sand in concrete.

Concrete incorporating IOT exhibits commendable resistance to carbonation in comparison to standard concrete. Interestingly, water absorption rates and chloride penetration in the concrete tend to increase with higher percentages of IOT replacement. Notably, the weight of IOT decreases more than that of the control concrete after exposure to an acid solution.

The literature review strongly suggests that IOT holds significant potential as a material for concrete production, particularly for fine aggregate replacement. This application of IOT not only aids in the conservation of natural resources but also supports mining companies in the sustainable management of waste disposal.

While the current studies provide valuable insights, there is a recognized need for further research, specifically on the long-term effects of incorporating IOT as a replacement for fine aggregate (normal river sand) on the durability properties of concrete. Such investigations will contribute to a more comprehensive understanding of the viability and sustainability of utilizing IOT in concrete production, guiding future practices and decision-making in the construction industry

3. Jesús Suárez González, Iñigo Lopez Boadell, Fernando López Gayarre, Carlos López-Colina Pérez, Miguel Serrano López and Flavio Stochino (2020)

Two significant findings have been made in the study of using mining waste to produce ultra-high-performance fiber-reinforced concrete (UHPFRC), which provide insight into the results of laboratory experiments. First off, the mixtures' grading curves show a more in line range of particle sizes, improving packaging effectiveness and requiring less water. The quality of mining sand, which has 10% CaO, is somewhat lower than that of natural sand, which is mostly made up of about 100% SiO2, according to the second the end. As a result, better packaging results in an important boost in mechanical qualities. However, this benefit only lasts for about 70% of replacement before the inferior quality of leftover mining sand negates the benefits of improved packaging.

Fresh UHPFRC is more stable when waste mining sand (WMS) is added. This is probably because WMS's smaller particle size allows for a lubricating action inside the mixture. Surprisingly, UHPFRC with WMS displays a density that is almost exactly the same as the control concrete, with very little variation—all under 2.5%—across various substitution percentages.

Because of its smaller particle size and greater consistency, fresh UHPFRC with WMS encourages concrete compactness, which raises compressive strength by about 11% across all substitution percentages. Even after 100% substitution with WMS, the modulus of elasticity fell somewhat, staying below 6%, however the impact on the elasticity of UHPFRC is considered inconsequential.

On the other hand, there appeared to be substantial discrepancy in the flexural and tensile strength data, which might be caused by an ineffective dispersion of short steel fibers in these concretes. However, the differences are negligible up to a 70% substitution; only at 100% substitution are notable losses noted, with flexural and tensile properties values rising to 17% and 20%, respectively.

The study concludes that, given its negligible impact on mechanical qualities, it is feasible to manufacture UHPFRC by substituting up to 70% of waste mining sand for natural sand. On the other hand, a 100% substitution causes a significant decrease in tensile and flexural strengths of more than 15%, making this substitution percentage unfavorable for the best UHPFRC performance.

4. Yunqi Zhao, Xiaowei Gu, Jingping Qiu, Weifeng Zhang and Xiaohui Li (2021)

In the investigation that was carried out, iron tailings were used to create ultra-high-performance concrete (UHPC). specific findings emerged regarding fresh properties and compressive behaviors. As the content of iron tailings (TS) in UHPC increased, there was a noticeable decline in workability accompanied by a corresponding increase in air content. .. This behavior was explained by the fact that, during the mixing process, TS exhibited better shear resistance and higher water absorption than ordinary sand (RS).

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Despite the diminishing workability, the compressive strengths of UHPC exhibited a decline with increasing TS content, yet still achieved an impressive 120 MPa with a 50% TS content. This correlation was found to be closely linked to the workability of the slurry. Consequently, to maintain both workability and mechanical strength in UHPC, it was determined that the TS content should be limited to 50% or less.

An adverse impact on the internal pore structure of UHPC was observed with the addition of TS. The angular nature of TS particles resulted in loose contact between them, leading to increased internal porosity, influencing both fresh and mechanical behaviors of the concrete.

The study also found that, while it stayed below 10%, the autogenous shrinkage of UHPC increased with the addition of TS. The effect was ascribed to TS's finer equivalent particle size and increased water absorption. Subsequent investigations will concentrate on methods to reduce autogenous shrinkage in UHPC and improve its general characteristics.

5. Kai Liu, Zhi Wang, Can Jin, Fang Wang, Xueyuan Lu (2015)

The thermal conductivity of iron ore sand (IOS) cement mortar was examined experimentally in this study, taking into account five important factors that have a major impact on thermal conductivities. The precedence relationship between these elements influencing thermal conductivity was ascertained using SPSS partial correlation analysis, resulting in the following order of importance: temperature, density, R/I ratio, W/C ratio, and S/C ratio.

It was discovered that raising the water-to-cement (W/C) ratio raised the mortar's pore percentage and decreased its heat conductivity. On the other hand, a rise in the IOS proportion and an increase in the specimen's thermal conductivity were caused by a decrease in the R/I ratio and an increase in the S/C ratio.

The results of the investigation showed that a rise in thermal resistance and a corresponding decrease in thermal conductivity were caused by temperature increases. It's interesting to see that density had little effect on the specimen's heat conductivity.

A suggested formulation showed a significant correlation with test findings, indicating a sample correlation coefficient of 0.99, based on the test results from these five criteria. The empirical formula was found to be more appropriate for determining the thermal conductivity of the IOS cement mortar since it seemed to be closer to the measured value and provided a more straightforward calculation method.

Notably, the IOS cement mortar demonstrated both cost-effective qualities and high-performance heat conductivity. The development of this novel thermal conductive material creates opportunities for use in a variety of settings, including the deicing and melting of snow, heating, petroleum pipelines, and the chemical industries.

6. Buthainah Nawaf AL-Kharabsheh, Mohamed Moafak Arbili, Ahmed Farouk Deifalla, Ali Majdi, A. Hakamy and Hasan Majed Alqawasmeh, Jawad Ahmad (2022)

The research conducted on the feasibility of using quarry dust (QD) in concrete production addresses the significant environmental challenge posed by the substantial generation of QD from quarries and aggregates. The potential positive impacts of incorporating these materials into building construction are explored in this study, considering both environmental and economic aspects. Recent research efforts have investigated the utilization of these by-products as aggregates or cement replacement materials in cement-based building materials, as outlined in this paper. The key findings and conclusions drawn from the analysis are summarized as follows.

The substitution of QD in concrete resulted in a decrease in flowability, attributed to the rough surface texture and higher water absorption of QD. Despite this reduction, the mechanical performance of concrete, including compressive strength (CS), flexural strength (FS), and tensile strength (TS), demonstrated improvement with the incorporation of QD. However, the optimal dosage is crucial, as higher doses negatively impact concrete strength due to compromised flowability. The recommended optimum dose of QD ranges from 40% to 50%.

The density of concrete exhibited an increase with the addition of QD, attributed to the filling of voids by QD. This density increment not only reduces water absorption but also diminishes chloride ion penetration. Moreover,

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scanning electron microscopy (SEM) results indicated a significant enhancement in the interfacial transition zone with the substitution of QD.

In conclusion, the comprehensive review suggests that the incorporation of QD up to 40% in concrete is viable without inducing adverse effects on strength and durability properties. This finding opens avenues for sustainable construction practices by utilizing QD as a potential resource in concrete production.

7. Kangning Liu, Sheliang Wang, Xiaoyi Quan, Jing Wu, Jin Xu, Nan Zhao and Bo Liu (2023)

The study concentrated on creating ecologically friendly aggregates called Iron Ore Tailings (IOTs) for use in Engineered Cementitious Composites (ECCs). The physical and chemical characteristics of IOTs confirmed that IOT-ECCs could be made, with IOTs serving as fine aggregates instead of traditional sand (S). Up to 80% IOT incorporation was shown to result in significant improvements in mechanical properties; the ECC variation with 40% IOTs (called IOT40-P2.0) had the best mechanical performance.

Upon subjecting the IOT-ECCs to Freeze-Thaw (F-T) cycles, the mass loss and Relative Dynamic Elastic Modulus (RDEM) initially increased before decreasing rapidly, while the compressive strength (fcu) exhibited a decline. Notably, the IOT ECC with 40% IOTs showcased the least F-T damage, reflecting superior reliability. Nuclear Magnetic Resonance (NMR) results indicated that replacing S with 20–80% IOTs had a positive impact on optimizing the internal pore structure of IOT-ECCs, particularly evident at the 40% IOT replacement ratio. However, as F-T cycles increased, the pore structure gradually deteriorated, with notable degradation after 100 F-T cycles.

Results from scanning electron microscopy (SEM) showed that adding 40% more IOTs significantly improved the compactness of IOT-ECCs. The size of the pores and fissures, as well as the bonding interface between the Polymer Fibers (PF) and the matrix, showed notable degradation during 100 F-T cycles. Overall, macroscopic and microscopic analyses showed that IOTs replaced 40% of S in the creation of IOT-ECCs, which produced better mechanical qualities and durability than regular ECCs. This novel material may find use in real-world construction projects like masonry building strengthening, seismic walls, beams, and columns with energy-dissipating joints. The building sector has a chance to progress toward sustainable growth through the effective use of industrial by-product IOTs as environmentally acceptable materials. More investigation into structural members (beams, joints, and walls) is advised in order to have a more thorough grasp of the possible uses of IOT-ECCs.

8. Paweł Walczaka, Jan Małolepszy, Manuela Reben, Paweł Szymański, KarolRzepa (2015)

The research conducted on the utilization of waste glass in autoclaved aerated concrete (AAC) has demonstrated the feasibility of incorporating glass additives in the production process. The study leads to the following conclusions:

Autoclaved aerated concrete can be successfully produced by incorporating various types of glass cullet.

The compressive strength of autoclaved aerated concrete, enriched with additives like Cathode Ray Tube (CRT) glass and cullet, closely resembles that of the reference sample. The enhanced pozzolanic characteristics of glass powder are identified as a potential factor contributing to the improvement in compressive strength.

The introduction of glass powder into the mix does not adversely affect the qualitative hydration products of AAC. Additionally, X-ray diffraction analysis reveals the absence of harmful compounds resulting from the incorporation of glass.

The utilization of glass in AAC production stands as an effective means of waste utilization, offering a sustainable approach to managing and repurposing glass waste.

In summary, the research findings highlight the positive aspects of incorporating glass additives in autoclaved aerated concrete, showcasing its potential as a valuable method for the efficient utilization of waste glass in the construction industry.

9. Sujing Zhao, Junjiang Fan, Wei Sun (2014)

The study on the use of iron ore tailings as a fine aggregate in ultra-high-performance concrete (UHPC) found that the material's workability and compressive strength significantly decreased when the tailings were used in place of natural aggregate.

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However, for specimens that underwent a conventional 90-day curing period, the mechanical performance of the tailings mixes showed comparability with the control mix when the replacement level was restricted to 40%. Furthermore, specimens that underwent a two-day steam curing process showed an increase in flexural strength of up to 8% and a loss in compressive strengths of less than 11% relative to the control mix.

The examination of pore structure revealed that the micro-pore structure coarsened as the tailing content increased, indicating a significant relationship between the porosities and compressive strength of the UHPC matrices. Images of the microstructure also showed what may be a poor interfacial zone surrounding some tailings particles.

In summary, the research findings indicate that controlled replacement levels of natural aggregate with iron ore tailings in UHPC can lead to comparable mechanical performance under specific curing conditions. The observed changes in pore structure and microstructure suggest a nuanced relationship between tailings content and the overall properties of ultra-high-performance concrete.

10. Wu Ruidong, Shen Yu, Liu Juanhong, Cheng Linian, Zhang Guangtian, and Zhang Yueyue (2021)

The following conclusions were drawn from the study on the effects of slag powder and iron tailings on the mechanical qualities and workability of concrete:

Concrete performance was positively impacted by the prudent inclusion of iron tailings powder, which successfully reduced time-related reductions in fluidity.

With compressive strengths of 50.3 and 80.7 MPa, the mechanical properties of the concrete were similar to those of concrete that only included slag powder when the iron tailings powder concentration in the compound admixture was kept at 50% or less.

A relative strength and age prediction model for iron tailing powder concrete was developed, building on the 28-day compressive strength. With an error rate of less than 1%, the computation and experimental findings showed how accurate the model is at forecasting long-term compressive strength.

In summary, the research underscores the positive influence of incorporating iron tailings powder in concrete, enhancing both workability and mechanical properties. The established prediction model provides a reliable tool for foreseeing long-term compressive strength in concrete formulations containing iron tailings powder.

11. P. Dhanabal, K.S Sushmita (2021)

The following results were obtained from the investigation into the effects of glass powder (GP) and iron ore tailing (IOT) on the characteristics of concrete:

The concrete that had 30% fly ash and 0% glass trash as cement showed the largest slump (43mm) when it came to workability, as determined by the slump cone test. The findings imply that a decrease in slump value was caused by a rise in the glass waste replacement percentage with 30% IOT.

According to a concrete density analysis, the mix including 30% IOT as fine aggregate and 20% glass powder as cement had a density of 2604 kg/m³, which was 6% higher than the density of conventional concrete, which was 2456 kg/m³. The results indicate that a higher percentage of glass powder with 30% IOT was associated with an increase in concrete density.

Results for compressive strength at 7, 14, and 28 days indicated that using 30% IOT in place of glass powder increased strength in all combinations. At the ages of 7, 14, and 28 days, respectively, concrete containing 10% glass powder and 30% IOT showed 54% (39.5 N/mm²), 39% (43.70 N/mm²), and 20% (52.11 N/mm²) higher strength. At 28 days, the compressive strength of concrete containing 20% and 30% glass powder was 10% (47 N/mm²) and 21% (43.33 N/mm²) lower than that of concrete containing 10% glass powder and 30% IOT.

When compared to concrete containing 10% glass powder and 30% IOT (4.48 N/mm²), conventional concrete's split tensile strength at 28 days was 2.78 N/mm², 61% less. The findings showed that replacing glass powder with 30% IOT increased tensile strength; however, replacing glass powder with more than 10% IOT decreased tensile strength. In order to obtain high tensile strength, 10% glass powder waste is recommended as a notional replacement percentage.

In conclusion, the study suggests the ideal mix percentages to incorporate iron ore tailing and glass powder into concrete in order to attain the required

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qualities in terms of workability, density, compressive strength, and tensile strength.

12. Sushmitha K.S, Dhanabal P. (2021)

The following important conclusions from the investigation into the characteristics of concrete including glass waste and iron ore tailing (IOT) were made:

Concrete's compressive strength, split tensile strength, flexural strength, and modulus of elasticity all showed remarkable performance when 10% glass waste powder (GP) and 30% iron ore tailing (IOT) were substituted as fine aggregate and cement, respectively.

Even if the strength attributes of the concrete improved, the combined effect of IOT and glass waste did not significantly improve the concrete's workability or flowability, according to the research.

In terms of durability, adding more glass waste powder resulted in a notable decrease in water absorption, especially when 30% IOT was added as a fine aggregate. This may indicate improved durability qualities in the concrete mixture.

All things considered, the study found that IOT and glass waste, more especially at the ideal replacement proportion of 10% GP and 30% IOT, worked well together and could be applied in the building sector. This combination reduced the need for conventional cement and river sand, supporting sustainable building practices, in addition to showing favorable benefits on a number of strength metrics.

13. Xiaoyan Huang, Ravi Ranade, Qian Zhang, Wen Ni, Victor C. Li (2013)

In this research focused on the mechanical and thermal properties of green lightweight engineered cementitious composites (GLECC), notable achievements were realized. GLECC, characterized by densities ranging from 1649 to 1820 kg/m3, exhibited impressive tensile ductility surpassing 3.4%. The development of GLECC was successful, with a substantial portion—82-89%—of the total solid matrix material by volume comprised of industrial wastes.

Notable were the developed GLECC's key mechanical qualities at day 28. The ultimate tensile strength and compressive strength were measured at 25 to 47.6 MPa, whereas the tensile first cracking strength varied from 2.5 to 3.6 MPa. By using spherical fine aggregate concrete (FAC) instead of irregular iron ore tailings (IOTs) aggregates in GLECC, the study improved tensile ductility and reduced fracture width. This performance improvement was made with only a slight loss in compressive strength.

Moreover, the efficient lowering of the material's thermal conductivity was proved by the addition of hollow FAC as a lightweight filler in GLECC. This reduction has encouraging ramifications for GLECC-built buildings' energy efficiency. All things considered, the study effectively demonstrated the feasibility of GLECC with significant contributions from industrial waste materials, showcasing its potential for sustainable and high-performance applications in the construction industry.

CONCLUSION

The review paper underscores the imperative for a construction material that is not only environmentally friendly but also readily available and cost-effective. Numerous research papers have been explored, leading to the conclusion that the inclusion of iron ore tailings (IOTs) in concrete can significantly enhance mechanical properties, particularly compressive strength. IOTs demonstrate promise as eco-friendly aggregates, aligning with sustainable construction practices. The identified optimum replacement percentages for fine aggregates with IOTs range from 30% to 40%.

However, challenges have been observed in the utilization of IOTs in concrete mixtures. Workability tends to decrease as the percentage of IOT in the concrete increases, and there is evidence of pore structure deterioration and reduced modulus of elasticity, affecting durability. The long-term effects on concrete durability necessitate further research.

Turning to the effects of glass fiber on concrete, it has been observed that the addition of glass fibers can enhance compressive strength without detrimental effects. Glass fibers exhibit pozzolanic characteristics, contributing to the improvement of strength. Challenges in using glass fibers include potential reductions in the workability and flowability of concrete, as well as potential negative impacts on tensile and flexural strength, especially when glass waste is used in isolation.

An identified research gap is the absence of studies exploring the combined use of iron ore tailings and glass fiber in concrete. The collective findings suggest the importance of striking a balance when incorporating these alternative materials into concrete mixtures. While they offer sustainability benefits and certain mechanical improvements, careful consideration is essential to address challenges such as workability, durability, and the impact on specific strength parameters. Further research, especially investigating the synergies and potential limitations of the combined use of iron ore tailings and glass waste in concrete, is recommended.

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