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Effect of Replacement of Fine Aggregate with Dune Sand in Concrete

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ABSTRACT

This study investigates the feasibility of using desert dune sand as a replacement for conventional fine aggregates in concrete. With increasing environmental concerns surrounding the depletion of natural sand resources, dune sand, which is abundant in desert regions, presents a promising alternative. The research focuses on evaluating the impact of dune sand on the Physical, mechanical and durability properties of concrete. Various tests, including workability, compressive strength, tensile strength, flexural strength, water absorption were conducted to assess the performance of concrete with dune sand. The results indicate that dune sand can be a viable replacement, offering improvements in specific properties and contributing to more sustainable construction practices.

KEYWORDS: *dune sand, concrete properties, sustainability, mechanical strength, durability*

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1. INTRODUCTION

The construction industry is increasingly seeking sustainable alternatives to traditional materials, particularly river sand, which poses significant environmental risks through its extraction. Dune sand from desert regions emerges as a promising substitute for fine aggregates in concrete mixes. Its fine, uniform particles can enhance concrete properties like workability and durability while providing a locally sourced solution that mitigates ecological impacts.

This research aims to explore the effects of dune sand on the mechanical and durability characteristics of concrete, assessing its viability as an eco-friendly building material. By investigating the unique properties of dune sand, this study seeks to contribute valuable insights into its integration into conventional construction practices. As the industry prioritizes sustainability, leveraging dune sand could significantly reduce the environmental footprint of concrete production, making it an essential focus for future developments in construction technology.

2. Sand Dune Concrete

Sand dune concrete utilizes dune sand as a substitute for conventional fine aggregates, such as river sand, offering a sustainable alternative that addresses environmental concerns related to sand mining. Dune sand, found in abundance in desert regions, consists of fine, uniformly graded particles that differ significantly from the angular, irregular particles of river sand. This unique particle shape influences the workability and compaction of concrete mixes, necessitating careful adjustments to optimize performance. The chemical composition of dune sand is predominantly silica, with quartz and feldspar being the primary constituents, making it suitable for concrete applications. Its physical properties, including grain size distribution and specific gravity, play a critical role in determining how the concrete mix behaves under different conditions. Understanding these characteristics is essential for producing high-quality concrete that meets stringent

structural requirements, especially in demanding applications.

Previous research, including studies has investigated the feasibility of incorporating dune sand into concrete formulations. Ahmad et al. found that while dune sand can enhance workability due to its fine nature, careful mix design is essential because of its high fineness modulus, which can affect the balance of water and cement in the mix. Similarly, Luo et al. observed that the fine particles of dune sand improve compaction and density but may lead to increased water demand, posing challenges for achieving optimal strength and durability. These studies underscore the importance of optimized mix proportions and the potential use of admixtures to fully leverage the benefits of dune sand while mitigating any drawbacks. In conclusion, sand dune concrete presents a promising solution for sustainable construction by utilizing abundant desert sand, with research indicating its favorable effects on workability, strength, and durability. As ongoing studies continue to refine our understanding of its properties and applications, sand dune concrete has the potential to significantly reduce reliance on conventional river sand, thereby minimizing environmental impacts and promoting more eco-friendly construction practices.

2.1. Benefits of Sand Dune Concrete

Sand dune concrete presents a range of environmental and economic benefits that position it as a sustainable alternative in construction practices. Environmentally, the use of dune sand helps mitigate the depletion of river sand—a finite resource whose extraction often leads to ecological harm, including riverbed degradation and habitat destruction. By substituting river sand with dune sand, pressure on river ecosystems is alleviated, which supports biodiversity and helps maintain natural water cycles. Dune sand is abundantly available in desert regions, making it a sustainable resource that minimizes the environmental impact associated with long-distance sand extraction and transportation. This local sourcing not only reduces greenhouse gas emissions but also aligns with sustainable development principles by utilizing readily available resources. Economically, the adoption of dune sand can lead to cost savings by decreasing traditional sand mining and transportation expenses. By sourcing locally, concrete production becomes more cost-effective, stimulating regional economies, creating job opportunities, and supporting local businesses, particularly in rural and desert communities. From a technical standpoint, research indicates that incorporating dune sand enhances concrete properties, improving workability and compaction, which in turn leads to better density and structural integrity. The fine particles of dune sand also reduce porosity, increasing durability, especially in harsh environmental conditions. In summary, sand dune concrete offers substantial environmental, economic, and technical advantages, making it a promising alternative for sustainable construction practices that reduce reliance on river sand and foster regional development.

3. Mix Proportion

For the preparation of concrete Grade M20, as per standard ratio of cement, Fine aggregate & Coarse aggregate is taken 1:1.5:3. According to IS 10262:2009 various proportions used for preparation of concrete grade M20.

A. Design Stipulation:

Grade of concrete = M20

Characteristics Strength (f_{ck}) = 20 N/mm^2

Type of cement = 43 Grade OPC

Maximum size of aggregates = 20 mm

Density of material

- Cement = 1440 Kg/m^3
- Fine aggregate (FA) = 1645 Kg/m^3
- Coarse aggregate (CA) = 1520 Kg/m^3
- Dune Sand (DS) = 1510 Kg/m^3

1 m^3 wet concrete = 1.54 m^3 dry concrete

Volume of material

$= \frac{ratio\ of\ material}{Sum\ of\ ratio}$ x Dry vol. of material

Weight of material =

Volume of material x Density of material

- For mix ratio M20 where cement, Fine Aggregate & Coarse aggregate is used in proportion of 1:1.5:3, it defines by mix ID S1.

Volume of cement= $\frac{1}{(1+1.5+3)}$ x1.54 = 0.28m^3

Wt. of cement = 0.28 x 1440 = 403.2 Kg/m^3

Volume of Fine Aggregate

= $\frac{1.5}{(1+1.5+3)}$ x1.54 = 0.42 m^3

Wt. of cement = 0.42 x 1520 = 638.4 Kg/m^3

Volume of Coarse aggregate

= $\frac{3}{(1+1.5+3)}$ x 1.54 = 0.28 m^3

Wt. of cement = 0.84 x 1645 = 1381.8 Kg/m^3

Water cement ratio: -

As per table 2 (Size of maximum aggregate is 20 mm) then water content is taken 186 Kg

W/C ratio = $\frac{weight\ of\ water}{weight\ of\ cement}$

$= \frac{186}{403.20} = .046$

adopt 0.50

Therefore, the mix proportion of M20 concrete is given by below table 7 as follows for preparation of test sample.

Mix Proportion

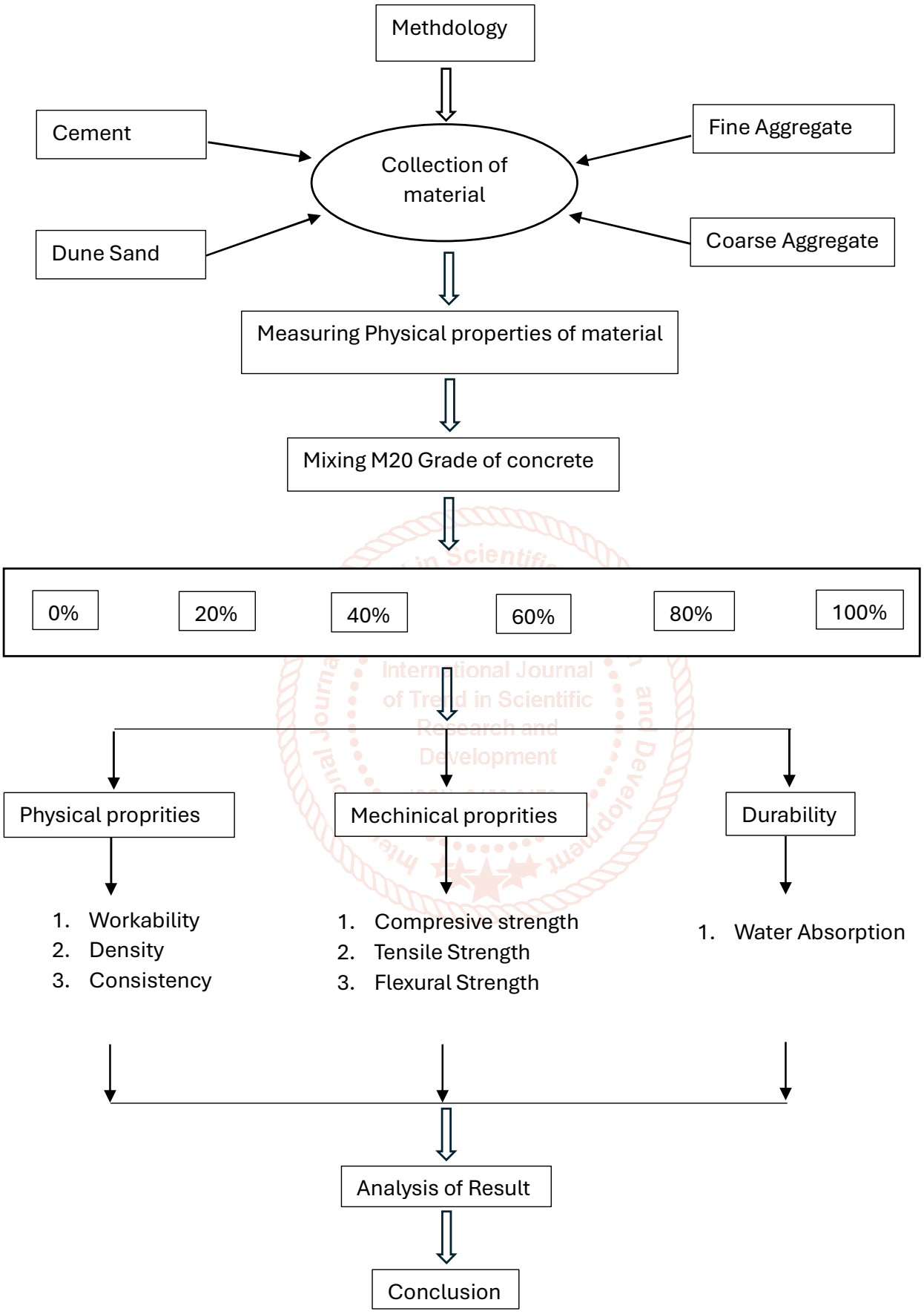
Mix ID	Ratio % (FA:DS)	Cement (Kg/m^3)	Fine Aggregate (Kg/m^3)	Dune Sand (Kg/m^3)	Coarse Aggregate (Kg/m^3)
S1	100:0	403.20	638.40	0.00	1381.80
S2	80:20	403.20	510.72	126.84	1381.80
S3	60:40	403.20	383.04	253.68	1381.80
S4	40:60	403.20	255.36	380.52	1381.80
S5	20:80	403.20	127.68	507.36	1381.80
S6	0:100	403.20	0.00	634.20	1381.80

4. Methodology

The methodology for investigating the effect of dune sand as a fine aggregate replacement in concrete involves several key steps. Initially, dune sand samples are collected from a designated desert region, ensuring they are free from organic matter and contaminants. Alongside the dune sand, standard Portland cement and conventional coarse aggregates are selected for the mix. A thorough characterization of the materials is conducted, including physical properties such as particle size distribution, shape, specific gravity, and fineness modulus through standard sieve analysis and sedimentation techniques. Chemical composition is analyzed to assess the silica content and other relevant minerals.

Subsequently, a range of concrete mix designs is developed, varying the percentage of dune sand replacing conventional fine aggregate (0%, 20%, 40%, 60%, 80%, and 100%), while maintaining a consistent water-cement ratio. The mixing procedure involves batching the materials according to the designed proportions, thoroughly mixing them, and using a mechanical mixer to achieve uniformity. Specimens for testing—cubes for compressive strength, beams for flexural strength, and cylinders for tensile strength—are cast in molds, compacted to eliminate air voids, and cured in a controlled environment for specified periods.

Testing involves measuring physical properties such as workability via the slump test and determining density through mass-volume measurements. Mechanical properties are assessed by conducting compressive strength tests on cubes, flexural strength tests on beams, and tensile strength tests using split-cylinder methods. Durability properties are evaluated through water absorption tests. Data analysis compiles and statistically evaluates test results, comparing them against control mixes to determine optimal dune sand replacement levels. The study ultimately aims to provide insights into the viability of dune sand as a sustainable alternative in concrete production, contributing to the field of sustainable construction practices.



5. Results:

The results of the study on the effect of dune sand as a fine aggregate replacement in concrete indicate that optimal replacement at 40% enhances physical mechanical and durability properties. As shown in

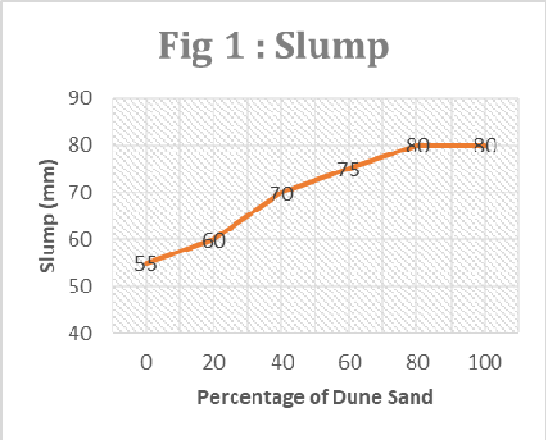


Figure 1, slump tests revealed a Increase in workability with increased dune sand content.

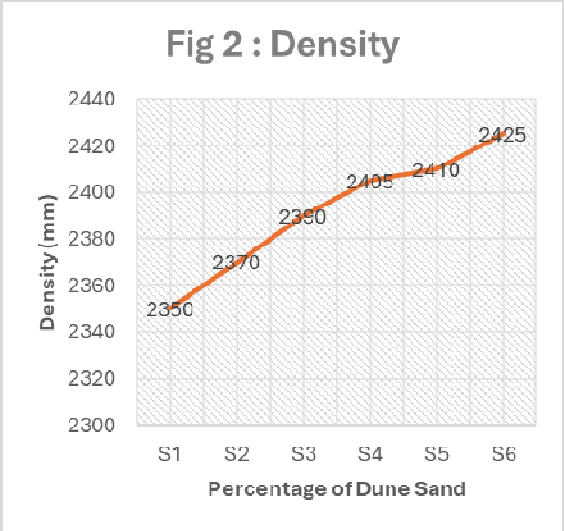


Figure 2, slump tests revealed a decrease in workability with increased dune sand content, with notable reductions at higher percentages.

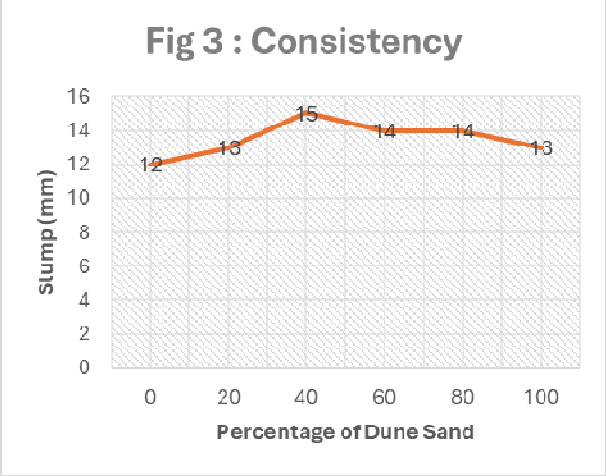


Figure 3, slump tests revealed a decrease in workability with increased dune sand content, with notable reductions at higher percentages.

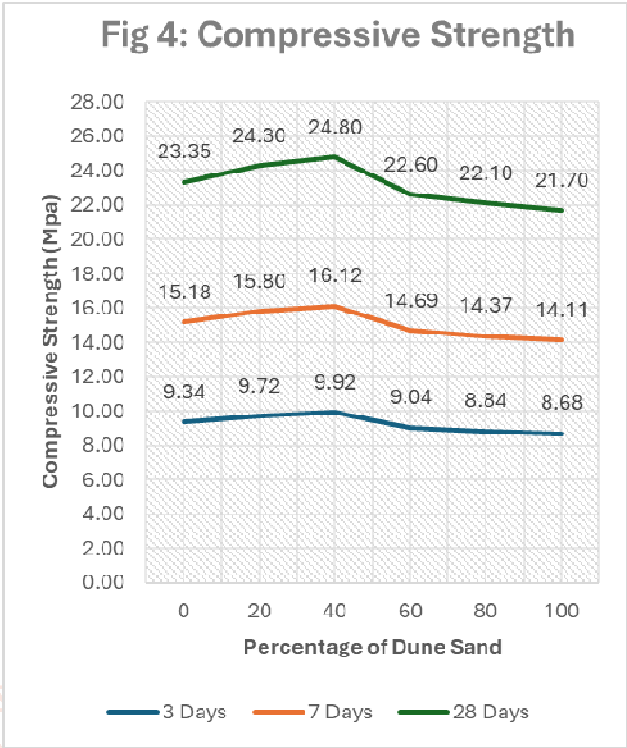


Figure 4 illustrates that compressive and flexural strengths peaked at 40% replacement, while higher percentages led to a decline in performance.

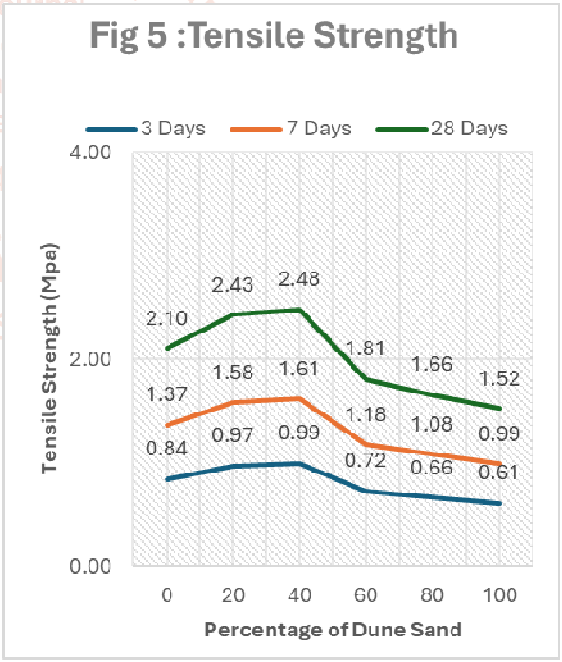


Figure 5 illustrates that compressive and flexural strengths peaked at 40% replacement, while higher percentages led to a decline in performance.

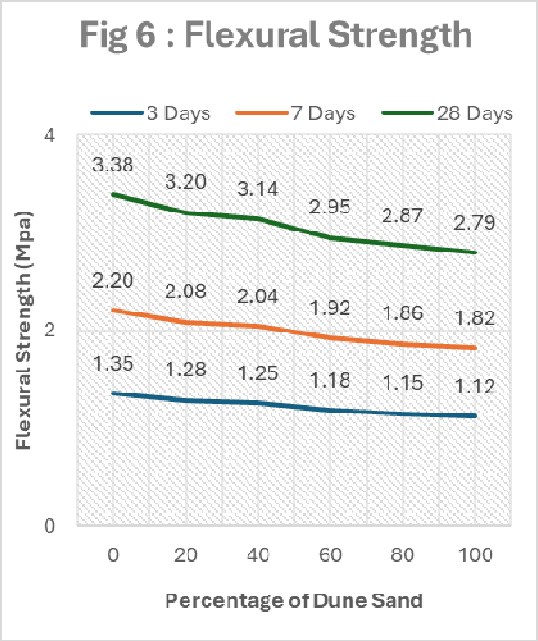


Figure 6 illustrates that flexural strengths is decreased continuously when increasing the percentage of dune sand.

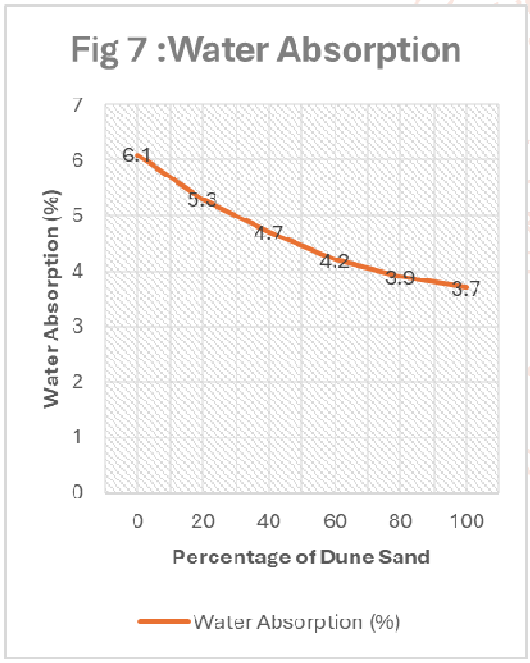


Figure 7 indicates that concrete with dune sand exhibited lower water absorption when increasing the percentage of dune sand.

Dune sand can be a sustainable alternative without compromising concrete quality. These findings highlight the potential of dune sand to contribute positively to concrete properties when used judiciously.

6. Conclusions

The utilization of dune sand as a substitute for fine aggregates in concrete mixtures reveals promising potential for enhancing specific properties of concrete while promoting environmentally responsible building practices. This study demonstrates that incorporating dune sand, up to a certain percentage, can significantly improve Physical, mechanical and durability characteristics. However, an increase in the percentage of dune sand leads to a increase in workability, as shown by slump test results. The fine, rounded particles of dune sand decrease internal friction within the concrete, increasing its fluidity. Nonetheless, the mixes remain workable for practical applications when the replacement percentage is carefully controlled.

The slight increase in density observed with higher dune sand percentages is primarily attributed to the uniformity and packing efficiency of the sand particles, which effectively fill voids within the concrete mix, resulting in a denser, more compact matrix that enhances overall strength. Consistency tests indicate that dune sand contributes to the homogeneity of the concrete, ensuring even distribution of aggregates and binding materials essential for maintaining structural integrity. A significant relationship exists between dune sand content and mechanical properties, with notable improvements in compressive and tensile strengths observed up to a 40% replacement level. This enhancement is due to the fine particles of dune sand, which contribute to a denser matrix that reduces voids and improves load-bearing capacity.

However, beyond this optimal replacement level, the strengths begin to decline, suggesting that excessive dune sand may compromise concrete's structural integrity. Additionally, increased dune sand content correlates with reduced flexural strength due to decreased bond strength between fine aggregates and the cement matrix. Despite the reduction in workability. This is particularly crucial for structures exposed to harsh conditions, as improved durability extends service life and reduces maintenance costs. Overall, dune sand is a viable alternative to conventional fine aggregates, particularly at a 40% replacement level, offering increased strength, durability, and sustainability, provided that mix design is carefully optimized to ensure optimal performance.

7. Future Scope

To fully understand the potential of dune sand in concrete applications, several areas warrant further investigation. First, long-term performance evaluations should be conducted under diverse environmental conditions, including freeze-thaw cycles, coastal exposure, and high sulfate content, to assess the durability and strength of dune sand concrete. Additionally, the development of specific admixtures tailored to enhance workability and

setting time without compromising strength is crucial. Research should also focus on the feasibility of using dune sand in high-performance concrete applications, particularly in mass concreting, precast elements, and other specialized uses. Furthermore, environmental impact studies are essential to analyze the ecological benefits of dune sand compared to traditional fine aggregates, emphasizing reductions in carbon footprints and resource conservation. Lastly, given that dune sand properties vary regionally, comprehensive studies are needed to evaluate its applicability on a global scale. This could lead to the establishment of standardized guidelines for its use in construction. Together, these research initiatives will contribute to a deeper understanding of dune sand's benefits and limitations, paving the way for its sustainable integration into the construction industry.

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