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Strength Behaviour of Concrete Incorporating Washed Marine Sand as a Partial Substitute

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Abstract

The increasing scarcity of river sand and the environmental concerns associated with its extraction have necessitated the development of sustainable alternative fine aggregates for concrete production. This study evaluates the mechanical performance of cement mortar and M25 grade concrete incorporating washed marine sand (MS) as a partial replacement for manufactured sand (M-Sand). Washed marine sand was used at replacement levels of 20%, 40%, 60%, 80%, and 100%. The mechanical properties were assessed through compressive strength, split tensile strength, and flexural strength tests in accordance with relevant Indian Standards. The experimental results indicate that partial replacement of M-Sand with washed marine sand significantly enhances the strength characteristics of concrete. Among the replacement levels investigated, 60% marine sand exhibited the optimum performance, producing higher compressive, split tensile, and flexural strengths than the control mix. The improved mechanical properties are attributed to the finer particle size and better particle packing of marine sand, which enhance the bond between the cement matrix and aggregates. These findings demonstrate that washed marine sand is a sustainable and technically viable alternative fine aggregate for structural concrete applications.

Keywords: Concrete, Compressive strength, Strength, M sand, Aggreagate

1. Introduction

The Concrete is the most extensively used construction material worldwide because of its excellent strength, durability, versatility, and cost-effectiveness. It is composed primarily of cement, coarse aggregate, fine aggregate, and water, with fine aggregate accounting for approximately 30–35% of the total concrete volume. The rapid growth of urbanization, industrialization, and infrastructure development has significantly increased the demand for concrete, leading to excessive consumption of natural resources, particularly river sand used as fine aggregate [1,2]. Global construction activities continue to expand,

resulting in a substantial increase in the extraction of natural aggregates and raising serious environmental concerns.

River sand has traditionally been the preferred fine aggregate for concrete due to its favorable grading and engineering properties. However, uncontrolled mining of river sand has caused riverbank erosion, lowering of groundwater tables, destruction of aquatic ecosystems, and loss of biodiversity [3,4]. Increasing restrictions imposed by environmental agencies and the depletion of natural sand resources have resulted in shortages and escalating construction costs. Consequently, the construction industry has shifted toward the use of manufactured sand (M-Sand), which is produced by crushing hard rock under controlled conditions. Although M-Sand has become an accepted substitute for river sand, its large-scale production also requires quarrying operations that consume natural rock resources and energy [5].

The search for sustainable alternative fine aggregates has therefore become an important research area in concrete technology. Among the various alternatives, marine sand has gained considerable attention because of its abundant availability in coastal regions. Marine sand deposits represent an enormous natural resource that can potentially reduce dependence on river sand while supporting sustainable infrastructure development [6]. Nevertheless, untreated marine sand contains significant quantities of chloride salts, sulphates, shell fragments, and organic impurities that may adversely affect concrete durability and reinforce steel corrosion. Washing marine sand effectively removes most soluble salts and improves its suitability for construction applications [7].

Several researchers have investigated the performance of washed marine sand in cementitious materials. Previous studies have reported that appropriate washing significantly reduces chloride content and enhances the physical characteristics of marine sand, making it suitable for partial replacement of conventional fine aggregate [8]. The finer particle size and improved grading of washed marine sand contribute to better particle packing, reduced voids, and improved interfacial bonding between cement paste and aggregates, which can enhance the mechanical performance of concrete [9].

Mechanical properties such as compressive strength, split tensile strength, and flexural strength are fundamental parameters governing the structural performance of concrete. Compressive strength determines the load-carrying capacity of concrete, whereas split tensile and flexural strengths indicate its resistance to cracking and tensile stresses. Evaluating these properties is essential before recommending any alternative fine aggregate for structural applications. Although several investigations have examined marine sand as a substitute for river sand, limited research has focused on the mechanical behaviour of concrete using washed marine sand as a partial replacement for manufactured sand, particularly under Indian conditions [10].

The present study aims to investigate the influence of washed marine sand on the mechanical properties of M25 grade concrete. Washed marine sand is used as a partial replacement for M-Sand at replacement levels of 20%, 40%, 60%, 80%, and 100%. The performance of the concrete is evaluated through compressive strength, split tensile strength, and flexural strength tests conducted in accordance with relevant Indian Standards. The outcomes of this research are expected to establish an optimum replacement level of washed marine sand and promote its use as a sustainable alternative fine aggregate for concrete production, thereby reducing dependence on natural river sand and supporting environmentally responsible construction practices.

2. Literature Review

The growing scarcity of natural river sand and increasing environmental concerns associated with excessive

mining have encouraged researchers to explore alternative fine aggregates for concrete production. Among the available alternatives, washed marine sand has emerged as a promising material because of its widespread availability in coastal regions and its potential to reduce dependence on river sand. Numerous studies have investigated the influence of marine sand on the mechanical properties of concrete, including compressive strength, split tensile strength, and flexural strength.

Tam et al. [11] reported that marine sand can be effectively utilized as a fine aggregate after proper washing to remove chloride salts and organic impurities. Their findings indicated that the physical properties of washed marine sand are comparable to those of conventional fine aggregates, making it suitable for concrete production. Similarly, Karthick et al. [12] demonstrated that chloride removal through washing significantly improves the durability and mechanical performance of marine sand concrete, thereby minimizing the risk of reinforcement corrosion.

Yang et al. [13] investigated the effect of seawater and marine sand on concrete properties and observed that properly treated marine sand produced satisfactory compressive strength comparable to conventional concrete. The study concluded that the reduced chloride content after washing played a significant role in maintaining concrete quality. Li et al. [14] reviewed the engineering properties of marine sand concrete and reported that optimized replacement levels improve particle packing, reduce voids, and enhance the bond between cement paste and aggregates, resulting in improved mechanical performance.

Researchers have also examined the influence of marine sand on compressive strength. Xiao et al. [15] observed that concrete incorporating up to 60% washed marine sand exhibited compressive strength comparable to or slightly higher than conventional concrete because of the filler effect of finer particles. Similar findings were reported by Wang et al. [16], who concluded that well-graded marine sand contributes to a denser concrete matrix, thereby increasing compressive strength while maintaining workability.

Split tensile strength is another important parameter for evaluating the cracking resistance of concrete. Zhang et al. [17] reported that partial replacement of conventional fine aggregate with washed marine sand improved tensile strength due to better aggregate interlocking and enhanced interfacial transition zones. Their experimental investigation showed that replacement levels up to 60% produced optimum tensile strength without adversely affecting concrete quality.

Flexural strength has also been extensively investigated because it directly influences the structural behaviour of concrete members subjected to bending. Kumar et al. [18] evaluated reinforced concrete specimens prepared with washed marine sand and observed improvements in flexural strength at moderate replacement levels. The enhanced flexural performance was attributed to improved particle grading and stronger bonding between the cement matrix and aggregates. Similar conclusions were presented by Singh and Sharma [19], who reported that marine sand concrete exhibited comparable crack resistance and load-carrying capacity to conventional concrete when appropriate washing procedures were adopted.

Although previous studies have demonstrated the feasibility of using washed marine sand as a sustainable fine aggregate, variations in material properties, geographical origin, washing techniques, and replacement percentages have resulted in inconsistent recommendations regarding the optimum replacement level. Furthermore, relatively few investigations have simultaneously evaluated compressive strength, split tensile strength, and flexural strength using manufactured sand as the primary fine aggregate replacement under Indian conditions [20]. Therefore, a comprehensive experimental investigation is required to establish the optimum proportion of washed marine sand for structural concrete applications.

The present study addresses this research gap by investigating the mechanical properties of M25 grade concrete containing 20%, 40%, 60%, 80%, and 100% replacement of manufactured sand with washed

marine sand. The findings are expected to provide reliable experimental evidence supporting the sustainable utilization of marine sand as an alternative fine aggregate while maintaining the required structural performance.

3. Materials and Method

Ordinary Portland Cement (OPC) of 53-grade conforming to IS: 12269-1987 was used as the primary binder, Potable water was used for mixing and curing. All specimens were demolded after 24 hours and transferred to a water-curing tank maintained at 27°±2°C until testing. Curing was conducted for 7 and 28 days in accordance with standard practices. The materials used in the present investigation were selected in accordance with the relevant Indian Standards to produce M25 grade concrete. Ordinary Portland Cement (OPC), manufactured sand (M-Sand), washed marine sand (MS), coarse aggregate, potable water, and a superplasticizer were used throughout the experimental programme. Marine sand was collected from a nearby coastal region and subjected to a thorough washing process to remove chlorides, sulphates, shell fragments, and other soluble impurities. After washing, the sand was air dried and sieved before use. Manufactured sand (M-Sand), conforming to IS 383:2016, was used as the control fine aggregate.

4. Result

The mechanical properties of concrete containing washed marine sand (MS) as a partial replacement for M-Sand were evaluated through compressive strength, split tensile strength, and flexural strength tests at 7 and 28 days. The results show that partial replacement of M-Sand with washed marine sand improved the strength characteristics up to a replacement level of 60%. At 28 days, the compressive strength increased from 26.0 MPa for the control mix (M100) to 28.0 MPa for MS60, while the split tensile strength increased from 3.0 MPa to 3.4 MPa, and the flexural strength increased from 3.4 MPa to 3.6 MPa. The improvement in strength is attributed to the finer particle size and better grading of washed marine sand, which enhanced particle packing, reduced internal voids, and improved the bond between the cement matrix and aggregates.

However, replacement levels beyond 60% (MS80 and MS100) resulted in a decline in all mechanical properties due to reduced aggregate interlocking and increased porosity. The combined results indicate that MS60 exhibited the best overall mechanical performance, providing approximately 7.7% higher compressive strength, 13.3% higher split tensile strength, and 5.9% higher flexural strength than the control mix at 28 days. Therefore, replacing 60% of M-Sand with washed marine sand can be recommended for producing concrete with improved mechanical performance while promoting the sustainable utilization of marine sand as an alternative fine aggregate.

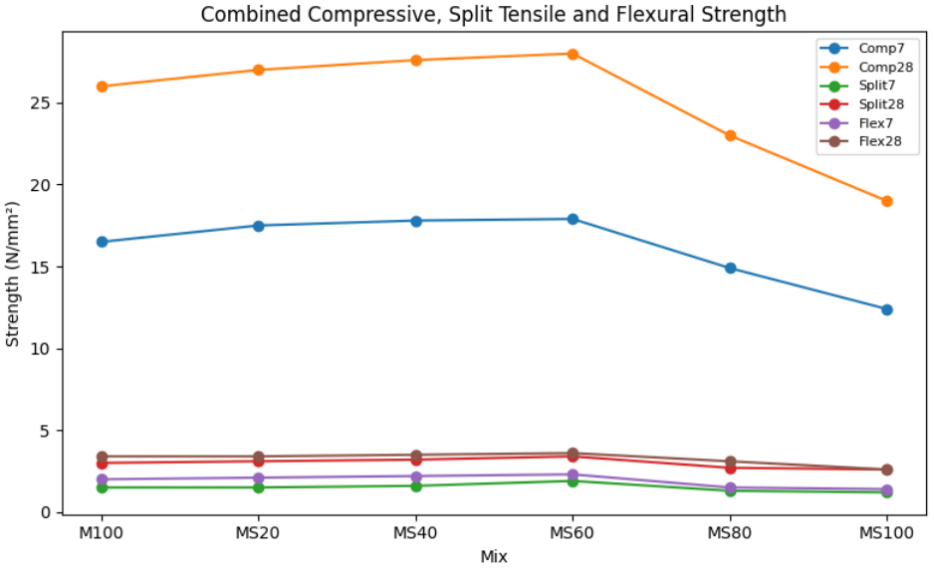

Fig. 1 - Strength Results for 7 and 28 days

5. Conclusion

The Based on the experimental results, the following conclusions are drawn:

1. Partial replacement of M-Sand with washed marine sand improved the mechanical properties of concrete up to a replacement level of 60%.
2. The MS60 mix exhibited the highest mechanical performance, achieving a 28-day compressive strength of 28.0 MPa, split tensile strength of 3.4 MPa, and flexural strength of 3.6 MPa, outperforming the control mix.
3. The improvement in strength is attributed to the finer particle size and better gradation of washed marine sand, which enhanced particle packing, reduced voids, and improved the bond between the cement matrix and aggregate

Declaration of Conflicting Interests

The authors declare no potential conflicts of interest with respect to the research, authorship and publication of this article.

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