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Effect of Sea Sand Substitution on the Strength and Durability Characteristics of Epoxy Modified Cement Concrete

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ABSTRACT

This study explores the integration of sea sand as a substitute for conventional fine aggregates in epoxy polymer concrete. The research addresses the pressing environmental concerns associated with the overreliance on river sand, offering a sustainable alternative. The investigation evaluates the unique combination of epoxy resin and sea sand, examining their synergistic impacts on the mechanical strength and durability of the concrete. The study's objectives encompass material property analysis, mix proportion determination using IS Code, workability assessment, and comprehensive evaluation of mechanical and durability properties. Environmental benefits include minimized river sand usage, reduced quarrying, and the utilization of sea sand as an abundant alternative. However, limitations include the need for desalting procedures for sea sand and the associated high costs, as well as the absence of suitable desalting technologies. This research contributes valuable insights into eco-friendly concrete production and proposes an innovative approach to enhance the durability of polymer concrete.

In a comprehensive exploration of epoxy-sea sand concrete, incorporating varying sea sand and epoxy resin proportions, significant findings emerged. Workability, assessed through the slump test, improved with higher sea sand substitution, compensating for epoxy's cohesion. All sea sand mixes exceeded control concrete in slump values, with pronounced enhancements at higher sea sand ratios. Sea sand acted as a lubricant, counteracting epoxy's workability reduction. Compressive strength varied, decreasing with epoxy substitution but increasing with sea sand, especially under water curing. Flexural strength consistently surpassed normal concrete, peaking with 20% sea sand in water-cured epoxy concrete. Splitting tensile strength excelled in epoxy-sea sand mixes, up to a threshold, revealing a complex interplay of sea sand and epoxy. Bond strength was notably higher in sea sand epoxy concrete, improved by epoxy's adhesive and sea sand's shear capabilities. Impact strength increased with sea sand, showcasing its potential for enhancing concrete durability. This study unravels the intricate dynamics between sea sand and epoxy resin, shedding light on their roles in various concrete aspects under diverse curing conditions.

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1. INTRODUCTION

Concrete stands out as the predominant construction material in contemporary infrastructure, finding application in diverse settings such as offices, schools, roads, railways, dams, and homes. Its ubiquitous presence reflects the indispensable role it plays in a world marked by rapid urbanization, with an estimated production of several billion tonnes annually. The adaptability of concrete arises from its moldable nature and favorable engineering attributes. Despite its numerous desirable properties, the inherent brittleness of concrete renders it unsuitable for heavy load-bearing applications.

Concrete, which is made up of a mixture of cement, fine and coarse aggregates, and water, is primarily dependent on sand and is the second most utilized material worldwide. Depending on the use, different admixtures and additions improve the characteristics of concrete even more. Because of its unmatched adaptability, concrete is the material of choice when fire resistance, abrasion resistance, strength, performance, durability, and impermeability are required. Because of its great compressive strength, moldability, and improvements in prestressing and reinforcing procedures, it is now widely used as a necessary component of daily life for people all over the world.

While strength and durability are paramount considerations in concrete structure design, challenges arise due to its brittleness, especially under normal stresses and impact loads. Many existing structures fall short of current design standards, posing concerns for public safety. With a growing population and increased purchasing power, the demand for raw materials for structural strengthening is escalating.

Concrete made with Portland cement exhibits strength in compression but weakness in tension, making it brittle. Conventional rod reinforcement and the incorporation of fibers partially address this weakness. The introduction of fibers enhances flexural and tensile strength, providing a novel binding agent for cement matrices.

Concrete's prevalence extends to India and other countries, solidifying its status as the construction material of choice. Extensive global research focuses on enhancing concrete properties, particularly in aggressive environments. The incorporation of supplementary cementing materials or mineral admixtures, derived from industrial wastes, presents an eco-friendly approach. These materials, exhibiting pozzolanic characteristics, contribute to cementing properties, conserve resources, and improve strength and durability.

In the field of civil engineering, concrete reigns supreme, offering better strength, flexural structure, workability, and durability. Its composition involves binding material, fine and coarse aggregates, water, and admixtures in specific proportions. The chemical process of hydration, where water reacts with cement, solidifies the mixture into a stone-like material. Despite its advantages, the increasing demand for concrete raises concerns about the rising costs of cement and depletion of natural aggregate sources.

2. OBJECTIVE OF THE STUDY

This investigation aims to assess the viability of substituting sea sand for fine aggregate in epoxy-blended cement concrete. The uniqueness of this study lies in the comprehensive examination of the synergistic impacts of epoxy resin and sea sand on the mechanical strength and durability of the concrete. The ultimate objective of this research can be outlined as follows:

1. To investigate the physical, chemical and engineering properties of the materials used for the production of concrete.
2. To arrive with the mix proportions using IS Code to produce epoxy polymer sea sand concrete by varying the proportions of sea sand as fine aggregate replacements.
3. To determine the workability of the fresh state concrete.
4. To determine the properties of hardened concrete such as mechanical and durability properties.

3. LITERATUREREVIEW

B. M. Sindhurashmi et at., 2024 in their research concluded that the rising need for river sand, spurred by infrastructure growth, presents environmental concerns. This study aims to tackle river sand depletion by incorporating sea sand as a fine aggregate in Self-Compacting Concrete (SCC), as evidenced through a Systematic Literature Review. Additionally, it conducts a comprehensive bibliographic analysis utilizing VOSviewer to visualize author-co-citation networks and country-wise citations. The article proposes various sustainable solutions to mitigate environmental impacts while fulfilling infrastructure requirements. It emphasizes evaluating the durability of SCC with sea sand through real-time monitoring using the Internet of Things (IoT) and employing artificial intelligence techniques like PointRend and neural networks to analyze SCC properties with sea sand. Furthermore, the study underscores the necessity of addressing river sand shortages in infrastructure development and provides insights for further research to enhance SCC properties with sea sand.

Wang F et al., 2023, discussed in length through experimental investigations the potential of seasand in construction. The mix design was conducted in accordance with IS 10262–2019, and the specimens were cast following IS standards. The results demonstrated that replacing fine aggregate with sea sand up to 100% led to enhanced split tensile strength and compressive strength in the developed concrete due to pore refinement by finer particles of the sea sand. Moreover, the mechanical properties of concrete produced using untreated sea sand outperformed those of concrete made with desalinated sea sand, regardless of curing duration, FA or BFS substitution, or carbonation effects. Sea Sand Concrete (SSC) and seawater concrete exhibited a compressive strength of 50.90 MPa, while plain concrete had a compressive strength of 49.34 MPa.

Zhou L et al., 2022, explored through their detailed investigation that the primary constraint in concrete structures constructed using sea sand and and seawater is the corrosion of steel bars. The lifespan of concrete structures will be threatened by too many active ions like Na+, Cl−, SO2− 4 , Ca+ 2 , and Mg+ 2. In this context, Fiber Reinforced Polymer (FRP) bars have gained much importance to overcome corrosion and to reduce the cost

Bhatawdekar RM et al., 2021 studied the adverse effects of excessive river mining. The escalating extraction of river sand induces changes in the flow dynamics of rivers, leading to the formation of new catchment areas. Such modifications bear the risk of causing flooding and disrupting the natural conveyance of water, thereby disturbing the hydrological equilibrium of the river system. This phenomenon highlights the intricate interplay between human activities and environmental processes, underscoring the importance of sustainable resource management practices to mitigate adverse consequences on river ecosystems.

Du Pan et al., 2021 summed up their research as infrastructural construction expands globally, the scarcity of river sand and freshwater poses challenges, particularly in coastal areas. To address this issue, researchers have explored the feasibility of using seawater and sea sand as substitutes. This study presents findings from a comprehensive investigation into the mechanical and microstructural characteristics of concrete made with seawater and sea sand. Three concrete types were examined: seawater and sea sand concrete (SSC), sea sand concrete (SC), and ordinary concrete (OC), each prepared with two different water/binder ratios. Compressive strength, flexural strength, dynamic modulus of elasticity, stress-strain relationship, and microstructural features were analyzed for all concrete variants. Results indicated that early-age compressive strength increased with the use of seawater and sea sand, albeit with a slight decrease in strength at 28 days. Additionally, flexural strength of SSC and SC surpassed that of OC at 28 days. The dynamic modulus of elasticity notably improved in concrete incorporating seawater and sea sand, particularly in early stages. X-ray diffraction pattern (XRD) and scanning electron microscopy (SEM) analyses confirmed distinctive surface morphology in sea sand and seawater concrete, characterized by a prevalence of ettringite phase crystals with fibrous shapes. This morphology contributed to a denser, less porous structure, enhancing mechanical properties compared to ordinary concrete.

Gavril et al., 2018 concluded in their research that polymer concrete has embraced sustainable practices by incorporating recyclable resin and aggregate components in recent decades. Researchers have explored various avenues to ensure sustainability, with some focusing on the applications of recyclable resins or liquid polymers, while others have sought sustainability through the utilization of waste materials.

As per studies of Giovanni et al., 2019 industrial by-products has potential to be used as fillers in polymer concrete. Investigations have been conducted using waste materials such as expanded Polystyrene and Polyethylene, as well as the use of fly ash as a filling material in polymer concrete. Notably, fly ash demonstrated no degradation in mechanical strength over a seven-year period when combined with vinyl ester resin, suggesting its potential as a substitute material for aggregates in polymer concrete.

Guo Li et al., 2019 studied in length in their research on polymer concrete. To enhance concrete strength, researchers have incorporated nano materials and micro-scale materials into polymer concrete. Nano powder dispersion in polymer concrete has shown a significant improvement in strength, while the addition of micro steel and synthetic fibers displayed no notable strength contribution. The increased surface area of nano materials is believed to contribute to strength improvement. Unlike micro materials, nano materials not only function as fillers but also actively react with polymers, forming a new nano polymer composite. The strength increment and properties of nano-modified polymer concrete depend on dispersion techniques, emphasizing the need for high-quality adoption of suitable polymer concretes. Dispersion techniques are chosen based on the geometry of the nano material, and modifying surface functional groups enhances the dispersing ability and reactivity of nano materials with polymers. The incorporation of aluminum nano particles and carbon nano tubes has been shown to improve the ductility and toughness characteristics of polymer concrete, respectively.

4. MATERIALUSED

The components employed in the manufacturing of epoxy-sea sand concrete comprise cement, epoxy resin, river sand, and sea sand as the fine aggregate, along with water and a water-reducing agent.

Cement

Ordinary Portland cement grade 53 is employed in the formulation of concrete mixes. To safeguard against dampness, the cement bags are meticulously stored in a dry environment.

Epoxy Resin

Polymeric materials, specifically epoxy resins, are commonly employed from both monomeric and oligomeric families. Upon solidification, these resins can transform into materials with a high level of resistance to both chemical exposure and impact. Additionally, epoxy resins exhibit favorable flexibility and electrical properties. In the ongoing study, the epoxy resin employed was obtained from ASTRAA Chemicals located in Tamil Nadu, India. Generally, epoxy resin is composed of a two-part polymer-based mixture, including epoxy resin (derived from Epichlorohydrin) and a hardener (based on Bisphenol A). The curing procedure for the epoxy resin in this research occurred at ambient temperature, and the weight ratio of hardener to epoxy resin was maintained at 1:1 during the mixing process.

Fine Aggregate

The fine aggregate used in the present study includes the natural river and sea sand subjected to water washing for a period of three hours to drain the unwanted impurities.

River sand

The study utilized fine aggregate composed of river sand that adheres to zone II grading, in accordance with the Indian Standard BIS: 383-1970. Fine aggregate sourced locally from natural river sand was employed in this investigation. The river sand aggregates met the prescribed standards outlined in IS 383-1989. The relevant physical and chemical characteristics of the utilized river sand aggregates are presented in Table .

Table Physical properties of river sand (as per IS 383-1970)

S. No.	Properties	River Sand
1.	Maximum size (mm)	4.75
2.	Water absorption	1.3
3.	Fineness modulus	2.28
4.	Specific gravity	2.61
5.	Shell thickness (mm)	-
6.	Void ratio	0.472
7.	Bulk density (g/cc)	-
8.	Moisture content (%)	-
9.	Abrasion value (%)	-
10.	Crushing value (%)	-
11.	Impact value (%)	-

The chemical composition of sand clearly shows silica (SiO_2), usually in the form of quartz as the most common constituent of sand which contributes to its chemical inertness, considerable hardness and resistance toweathering.

Table Chemical composition of river sand (as per IS 383-1970)

Chemical oxide	Content (%)
SiO_2	95.86
Al_2O_3	1.24
Fe_2O_3	0.65
CaO	-
MgO	-
K_2O	0.35
LOI	1.9

Sea sand

Sea sand was acquired using India Mart's internet platform. The sea sand was examined using the Indian standard IS-2386:1997, and the IS-383:1970 guidelines were also compared to the specifications.

Table Physical properties of sea sand

S. No.	Properties	Sea sand
1.	Particle shape, size	Rounded, 4.75 mm
2.	Fineness modulus	1.98
3.	Specific gravity	2.69
4.	Silt / Dust content	2.2%
5.	Surface moisture	Nil
6.	Water absorption	1.8%

Table Chemical composition of sea sand

Chemical oxide	Content (%)
SiO_2	52.16
Al_2O_3	18.40
Fe_2O_3	4.20
CaO	2.56
MgO	2.06
LOI	20.61

Water

Water is a crucial component in the creation of concrete. The water content affects how quickly cement hydrates and how evenly the binder is distributed throughout the concrete in general. Care must be taken when fixing the water content, as adding too much water can cause an increase in pore reaction from evaporation. Since the chemical characteristics of water also affect the qualities of concrete, drinkable water devoid of oil, acid, and other organic contaminants is used in this investigation.

Superplasticizer

The superplasticizer component has a significant control over the fresh qualities of concrete. The superplasticizer chemical additive disperses the components of the concrete, making it extremely workable. Superplasticizers, however, do not interact with cements in any way. In the current investigation, a commercially available superplasticizer called Viscocrete, a SIKA product, is utilized as a water-reducing agent. The superplasticizers' characteristics are listed in Table 3.11 of the manufacturer's data sheet.

5. RESULTS AND DISCUSSIONS

WORKABILITY

The workability of epoxy-modified concrete mixes, incorporating varying percentages of sea sand aggregates, is depicted in Figure based on slump test results. Notably, the slump values of the concrete mixes demonstrated an increase with higher ratios of sea sand substitution. The workability of the epoxy-substituted concrete mix (PC) was comparatively lower than that of the control concrete (CM) due to the cohesive nature of epoxy resin. The conventional concrete mix (CM) exhibited a higher slump value of 68 mm compared to the polymer concrete mix (PC). All other mixes containing sea sand aggregates showcased higher slump values than the standard concrete mix.

Minor fluctuations were observed in the slump values of sea sand epoxy concrete containing sea sand aggregates below 15%. However, a significant enhancement in slump values was evident at higher concentrations of sea sand substitution. This underscores the substantial influence of sea sand aggregate proportions on concrete workability. The outcomes indicate that variations in the workability of epoxy concrete are attributed to the grading and shape of sea sand used as fine aggregate in the epoxy concrete.

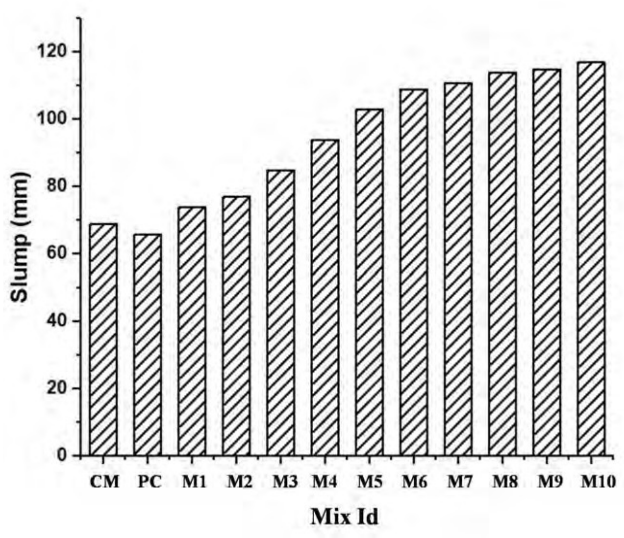

Figure Workability results of epoxy-sea sand concrete

COMPRESSIVE STRENGTH

The examination of compressive strength in epoxy polymer concrete mixes, incorporating sea sand as a partial replacement for fine aggregate and subjected to both ambient and water curing, unveils intricate details, as portrayed in Figures . A discernible trend emerges, showcasing a substantial decline in compressive strength of polymer concrete compared to the conventional concrete mix (CM) during later stages. This concurs with well-established studies that consistently report a decrease in compressive strength during later ages owing to epoxy substitution.

The extent of the reduction in compressive strength due to epoxy substitution in the polymer concrete (PC) is noteworthy, registering 5.3% and 4.6% lower values than the control concrete (CM) at the 28-day mark under ambient and water curing conditions, respectively. This underlines the material impact of epoxy resin on the compressive strength properties of the concrete mixes.

The compressive strength characteristics of sea sand-containing polymer mixes, meticulously detailed in Figures , reveal a compelling disparity between water-cured and ambient-cured concrete. The former consistently exhibits higher compressive strength than the latter, pointing to the pivotal role of curing conditions in influencing the concrete's mechanical properties. Notably, the 28-day compressive strength of concrete incorporating 25% sea sand as aggregate demonstrates a remarkable enhancement—approximately 24.32% and 25.89% higher than the polymer concrete mix (PC) under ambient and water curing conditions, respectively.

Diving deeper into the data, it becomes apparent that the optimal replacement percentage of fine aggregate with sea sand, ensuring maximum compressive strength, is determined to be 20% when subjected to water curing. This nuanced finding underscores the significance of the interplay between sea sand substitution ratios and curing conditions in shaping the mechanical performance of the concrete.

An intriguing anomaly surfaces in the study: contrary to the expected trend where concrete strength diminishes with sea sand substitution, the compressive strength of concrete is found to increase with rising sea sand content. This unexpected outcome is attributed to the synergistic action of sea sand and epoxy resin. Finer sea sands act as effective fillers, reinforcing the epoxy matrix and contributing to the overall strength of the concrete. This revelation challenges conventional assumptions about the impact of sea sand on concrete strength.

Results from the water-cured sea sand polymer concrete series indicate a substantial improvement in compressive strength—approximately 15% higher—when 40% sea sand is utilized as a fine aggregate replacement in concrete. This noteworthy enhancement is linked to the finer and more angular nature of sea sand aggregates, fostering incompressibility and increased packing density in the aggregate phase of the concrete.

The filling of micro voids and pores by sea sand further corroborates the increase in compressive strength. This intricate interplay of sea sand characteristics and its interaction with the epoxy matrix underscores the multifaceted nature of the factors influencing concrete strength.

An aspect emphasized in the study is the meticulous attention given to the mixing process of epoxy resins to ensure a homogeneous distribution within the matrix. The compressive strength of concrete, as indicated by the findings, is predominantly influenced by aggregate phases rather than binder phases, emphasizing the pivotal role of sea sand substitution over epoxy substitution in shaping compressive strength.

Examining the relative values of compressive strength for polymer concrete mixes compared to the conventional concrete mix (CM) provides additional insights. Beyond a 15% substitution level, the compressive strength of all concrete mixes consistently surpasses that of the control concrete, up to a certain threshold. This nuanced observation suggests a complex relationship between substitution levels and compressive strength, emphasizing the need for a nuanced understanding of the factors at play.

The sea sand concrete mixes, as detailed in Table 5.3 and 5.4, demonstrate their ability to attain a significant percentage—97%—of the 28 days strength of the concrete at an early age of 14 days under ambient curing. This underscores the rapid development of strength in these concrete mixes, influenced by the unique interplay between sea sand and curing conditions. Additionally, around 85% of the 28 days strength of concrete is achieved at 14 days under water curing, further highlighting the influence of curing conditions on early-age strength attainment.

Intriguingly, a negative influence on compressive strength beyond a 40% replacement level in the sea sand substituted concrete water-cured series is discerned. This suggests a threshold beyond which the strength is adversely affected, underscoring the need for caution in the extent of sea sand substitution. The study posits that the improved denseness of the concrete mixes, coupled with the pore-filling property of sea sand, significantly contributes to the observed improvement in strength.

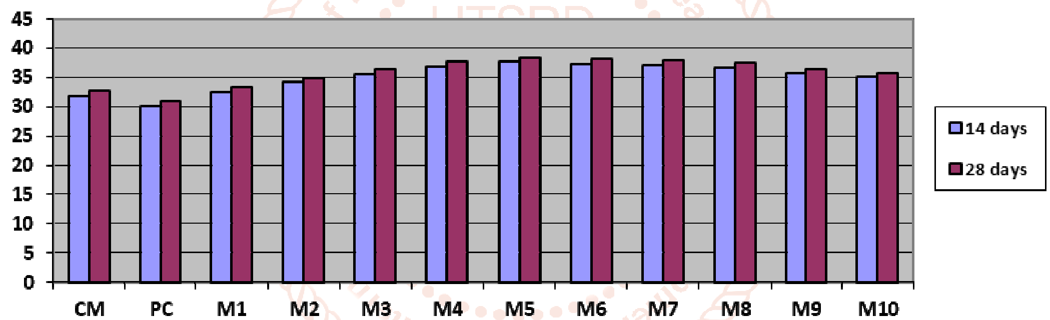

Figure Compressive strength values of epoxy concrete mixes inambient curing

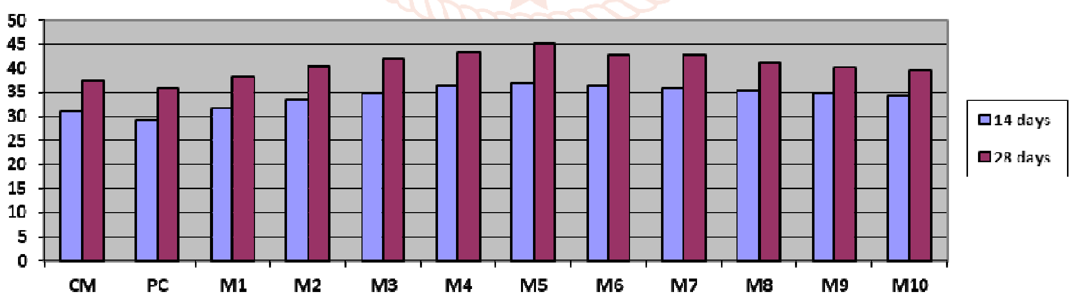

Figure Compressive strength values of epoxy concrete mixes inwater curing

FLEXURAL STRENGTH

The fluctuation in the flexural strength of polymer concrete mixes across various ages under ambient and water curing conditions is illustrated in Figures The incorporation of sea sand as fine aggregate and epoxy resin as a cement replacement has shown consistent enhancements in the flexural strength of concrete at all stages of development. The pinnacle of flexural strength was achieved in the water-cured epoxy concrete mix containing 20% sea sand as a fine aggregate replacement, exhibiting a strength approximately 40% higher than that of the standard concrete mix (CM). This notable improvement is attributed to a synergistic effect, involving both epoxy resin and sea sand, coupled with the compaction of the cement-aggregate matrix.

The intricate mechanisms at play include the adhesive function of epoxy resin, effectively bonding loose sea sand aggregates and thereby augmenting the flexural performance of the concrete. The refinement in the fineness of sea sand further contributes to the densification of the cement-aggregate matrix, ultimately enhancing flexural strength. A discernible compounding effect of epoxy resin is noted in the early-age improvement of flexural strength. However, it is observed that the flexural strength experiences only marginal improvement beyond 15% of sea sand aggregate.

Beyond a certain threshold of sea sand addition in concrete, there is a decline in flexural strength due to increased fineness, leading to a higher powder content in the concrete and, consequently, a reduction in flexural strength. For instance, the 28 days flexural strength of polymer concrete containing 20% sea sand was found to be 46% and 40% higher, respectively, than the standard concrete mix (CM) for ambient curing and water curing.

The findings reveal that approximately 88% of the 28 days strength of the concrete was achieved at 14 days when 50% sea sand was used as fine aggregate in epoxy concrete, subjected to both ambient and water curing. This underscores the significant contribution of epoxy resin in enhancing the early-age strength of concrete, a key factor influencing the overall performance of the material.

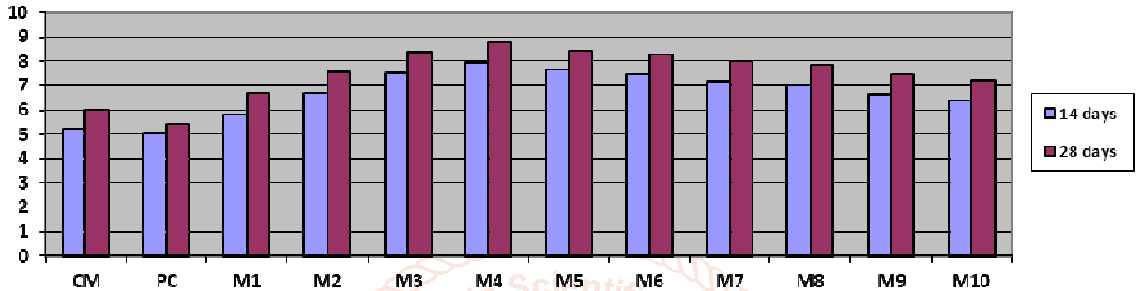

Figure Flexural strength values of epoxy concrete mixes in ambientcuring

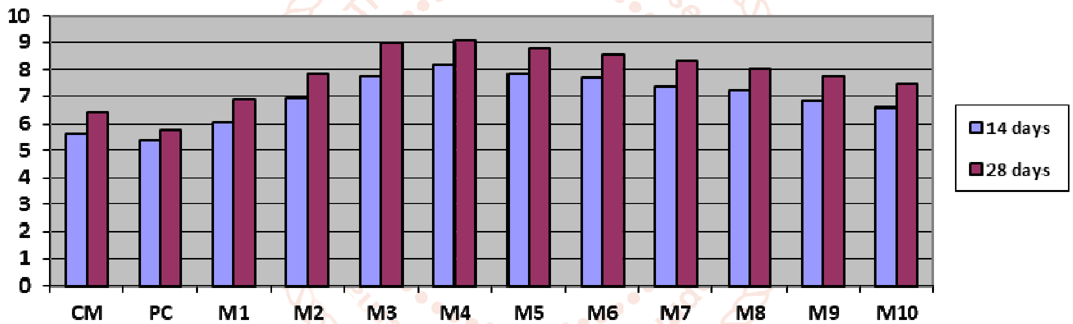

Figure Flexural strength values of epoxy concrete mixes in watercuring

IMPACT STRENGTH

The impact strength analysis of polymer concrete incorporating sea sand aggregates is depicted in Figure . Evidently, there is a noticeable increase in the impact strength of the concrete as the fine aggregate is replaced by sea sand aggregate. Conversely, the polymer concrete mix (PC) exhibits a lower impact strength value compared to the standard concrete mix. The decrease in impact strength in the concrete mix containing epoxy resin (PC) is measured at 6.15% and 5.73% lower than the control mix (CM) under ambient and water curing conditions, respectively. This signifies that epoxy resin does not contribute to the enhancement of concrete impact strength.

However, when sea sand aggregates are introduced, the impact strength of the concrete slightly surpasses that of the control concrete (CM). Consequently, it can be deduced that the combined effect of epoxy resin and sea sand aggregates contributes to an increased resistance to crack propagation in the concrete. Notably, the highest impact strength is observed in the concrete mix containing 20% sea sand aggregate, demonstrating an increment of about 70.77% and 64.45% higher than the control concrete mix under ambient and water curing conditions, respectively. This underscores the substantial influence of sea sand in improving the impact strength of concrete.

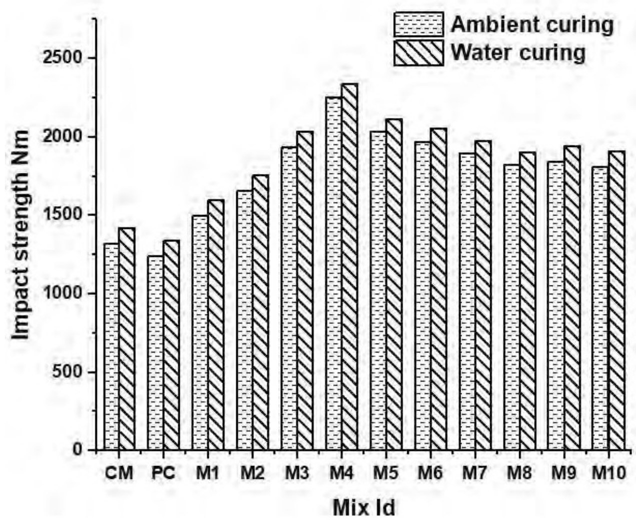

Figure Impact strength values of epoxy concrete mixes undervarious curing conditions

6. Conclusion

General

In summary, the extensive experiments conducted on epoxy sea sand concrete, incorporating varying levels of sea sand replacement and 12% epoxy resin cement replacements, have provided significant insights into the multifaceted aspects of these concrete mixes.

The results from the slump test revealed a noteworthy improvement in the workability of the concrete as the percentage of sea sand substitution increased. However, it was observed that the workability of the epoxy-substituted concrete mix (PC) was slightly lower than that of the control concrete (CM) due to the cohesive nature of epoxy resin. Interestingly, all concrete mixes containing sea sand aggregates exhibited higher slump values than the control concrete. The most substantial improvements in workability were evident at higher concentrations of sea sand substitution, emphasizing the pronounced influence of sea sand aggregate proportions on concrete workability. These variations were attributed to the grading and shape of the sea sand used as a fine aggregate in the epoxy concrete.

The reduction in workability caused by epoxy resin substitution was effectively counteracted by the presence of sea sand aggregates, which acted as a lubricant to minimize functional forces between the cement paste and fine aggregates. This underscores the crucial role of sea sand in enhancing the overall workability of epoxy-modified concrete.

Moving on to compressive strength, the study on epoxy polymer concrete mixes with sea sand as a partial fine aggregate replacement demonstrated nuanced effects. Compressive strength decreased compared to conventional concrete at later ages due to epoxy substitution, but water curing had a positive impact on strength. Interestingly, sea sand substitution contributed to increased compressive strength, potentially owing to its fine, angular nature that filled voids and enhanced binding. Overall, this study highlights the intricate interplay between sea sand and epoxy resin, showcasing their distinct roles in various stages of concrete development and curing conditions.

The examination of flexural strength further demonstrated consistent improvements with the combination of sea sand and epoxy resin, surpassing the strength of normal concrete. The highest strength was achieved with the water-cured epoxy concrete mix containing 20% sea sand replacement, indicating notable early-age strength benefits. The bonding effect of epoxy and the finesse of sea sand played pivotal roles in enhancing flexural strength.

In the context of splitting tensile strength tests, epoxy-sea sand modified concrete consistently outperformed unmodified plain concrete. This increase in splitting tensile strength was attributed to the reinforcing effect resulting from the substitution of epoxy resin. However, sea sand substitution exhibited positive effects on splitting tensile strength up to a certain threshold, with the magnitude of improvement influenced by aggregate type and cement matrix quality. Beyond this threshold, excessive fine aggregate substitution had an adverse effect on splitting tensile strength, revealing a complex relationship between sea sand content and concrete strength.

The bond strength of sea sand epoxy polymer concrete was notably higher than that of the normal control concrete mix. Epoxy resin incorporation significantly improved bond strength, with the high shear capability of sea sand aggregates further contributing to this enhancement. However, the improvement in bond strength declined with increasing sea sand content, particularly in ambient-cured concrete. This phenomenon could be attributed to the lubricating nature of round sea sand aggregates. Nevertheless, epoxy resin played a crucial role in balancing this negative effect, forming a robust adhesive layer around fine aggregates and the cement matrix, ultimately strengthening the interfacial transition zone (ITZ) within the concrete.

In terms of impact strength, the combined effect of epoxy resin and sea sand aggregates increased the energy required to induce cracks in the concrete. While epoxy resin alone had no significant impact on impact strength, sea sand aggregates, when used, led to a slight improvement compared to the control concrete. The concrete mix with 20% sea sand aggregate exhibited the highest impact strength, demonstrating a substantial increase compared to the control mix under both ambient and water curing conditions. This emphasizes the positive influence of sea sand on enhancing concrete's impact resistance, showcasing the potential of sea sand in contributing to the overall durability and resilience of the concrete.

7. CONCLUSION

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