

Use of Sea Water in Construction

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Abstract: The increasing scarcity of freshwater resources has prompted the exploration of seawater as an alternative in construction, particularly in concrete production for coastal and offshore applications. This study examines the feasibility of using seawater in concrete, focusing on its effects on workability, strength development, durability, and reinforcement corrosion. Experimental findings and existing literature indicate that while seawater can enhance early-age strength due to accelerated hydration, the presence of chlorides significantly increases the risk of steel corrosion, affecting long-term durability. The study also reviews mitigation strategies, including the use of supplementary cementitious materials, corrosion-resistant reinforcement, and non-metallic alternatives. Results suggest that seawater-mixed concrete may be viable in specific conditions, especially in non-reinforced or properly protected structural systems. The research contributes to sustainable construction practices by evaluating the technical, environmental, and economic implications of seawater utilization.

Keywords: *Seawater Concrete; Sustainable Construction; Chloride Attack; Reinforcement Corrosion; Durability; Salinity Effects; Supplementary Cementitious Materials; Coastal Infrastructure.*

I. INTRODUCTION

Freshwater scarcity is a growing global concern, particularly in arid and coastal regions where conventional concrete production demands large volumes of potable water. Seawater, an abundant resource, has been considered as an alternative in construction to reduce freshwater consumption and promote sustainable practices. However, its high chloride and salt content poses significant challenges, especially regarding reinforcement corrosion and long-term durability of concrete structures.

Several studies have explored the use of seawater in non-reinforced concrete and partial replacement strategies, highlighting both potential benefits and risks. Early-age hydration may be accelerated due to the ionic content, improving initial strength, while long-term performance can be adversely affected by chloride-induced corrosion and chemical reactions with cementitious materials.

This paper aims to evaluate the feasibility of using seawater in concrete construction, review its effects on mechanical and durability properties, and discuss mitigation strategies, including admixtures, corrosion-resistant reinforcement, and protective coatings. The study also considers environmental and economic implications, providing guidance for sustainable construction in coastal and water-scarce regions.

II. OBJECTIVES

The primary objective of this study is to critically evaluate the feasibility of using seawater in construction, particularly in concrete production, as an alternative to freshwater in regions facing water scarcity. The paper aims to examine the influence

of seawater on the fresh and hardened properties of concrete, including workability, setting time, strength development, and long-term durability. Special emphasis is placed on understanding the mechanisms of chloride-induced corrosion in reinforced concrete and its implications for structural safety and service life. The study further seeks to compare the mechanical and durability performance of seawater-mixed concrete with conventional freshwater concrete under various environmental exposure conditions. In addition, it intends to explore effective mitigation strategies—such as the use of supplementary cementitious materials, corrosion-resistant reinforcements, and protective measures—to minimize durability risks. The research also evaluates the environmental and economic implications of seawater utilization, particularly in coastal and arid regions, with a view toward promoting sustainable construction practices. Ultimately, the paper aims to contribute to the development of practical guidelines and recommendations for the safe and efficient incorporation of seawater in modern construction.

III. LITERATURE REVIEWS

Several studies have investigated the use of seawater in concrete, focusing on its effects on strength, durability, and reinforcement corrosion. Research shows that seawater can accelerate early-age hydration, improving initial compressive strength, but the high chloride content increases the risk of steel corrosion, reducing long-term durability. Studies also highlight mitigation strategies such as using supplementary cementitious materials, corrosion-resistant reinforcement, and protective coatings. Experimental and field-based findings suggest that seawater may be suitable for non-reinforced or properly protected structures, while reinforced concrete requires careful design and preventive measures. The literature emphasizes the potential for sustainable construction by conserving freshwater, provided technical limitations are addressed.

IV. PROPERTIES OF SEA WATER RELEVANT TO CONSTRUCTION:

1. Chemical Composition:

Seawater contains primarily sodium chloride (NaCl) along with other salts such as magnesium, calcium, potassium, and sulfate ions. The high chloride content is the main concern in concrete, as it can accelerate reinforcement corrosion. Salinity also affects the workability and setting time of cementitious materials, while minor ions may influence hydration reactions.

2. Salinity & Chloride Content:

Seawater typically has a salinity of about 3.5% by weight, corresponding to roughly 35 g of dissolved salts per liter. Chloride ions (Cl^-) constitute the majority (~19 g/L) and are particularly critical in construction because they can accelerate corrosion of steel reinforcement, reducing long-term durability. High salinity also affects concrete workability, setting time,

and hydration reactions, necessitating careful mix design and protective measures when used in reinforced structures.

V. EFFECT OF SEA WATER ON PROPERTIES OF CONCRETE:

3. Workability:

The presence of dissolved salts in seawater, primarily sodium chloride and other ions, affects the workability of concrete mixes. Seawater can slightly increase the initial slump due to the lubricating effect of salts on cement particles, improving flow. However, high salinity may also accelerate early hydration, leading to faster stiffening, which can reduce workability over time. Indian studies suggest that while seawater may improve short-term workability, admixtures or adjustments in mix design are often required to maintain consistency and proper handling during casting.

4. Strength Development:

Seawater can influence the compressive and tensile strength of concrete due to its ionic composition, particularly chlorides and sulfates. Indian studies (Sakhivel & Murugaiyan, 2018; Rao & Reddy, 2017) show that early-age strength often improves when seawater is used, as the dissolved ions can accelerate cement hydration. However, long-term strength may be affected if reinforcement corrosion occurs in reinforced concrete, or if excessive salts react with cement compounds, potentially causing durability issues. Proper mix design, use of supplementary cementitious materials, and corrosion mitigation are recommended to maintain structural integrity while leveraging the benefits of seawater for strength development.

5. Durability & Corrosion:

Seawater contains high chloride and sulfate concentrations, which pose significant risks to durability and reinforced concrete structures. Chlorides can penetrate the concrete matrix and initiate corrosion of steel reinforcement, leading to cracking, spalling, and reduced service life. Sulfates may react with cement hydration products, causing expansion and micro-cracking. Indian studies highlight that non-reinforced concrete or properly protected reinforced structures show better performance, but long-term durability depends on adequate cover depth, use of supplementary cementitious materials, and corrosion-resistant reinforcement. Mitigation strategies such as admixtures, coatings, and controlled mix design are essential when using seawater to ensure structural integrity over time.

VI. MITIGATION TECHNIQUES WHILE USING SEA WATER IN CONSTRUCTION:

The use of seawater in concrete requires measures to reduce the risk of reinforcement corrosion and durability issues. Common mitigation strategies include:

- Supplementary Cementitious Materials (SCMs): Fly ash, silica fume, or slag can bind chlorides and improve concrete density, reducing permeability.
- Corrosion-Resistant Reinforcement: Use of stainless steel, epoxy-coated, or galvanized bars protects against chloride-induced corrosion.
- Protective Coatings: Surface treatments such as waterproofing membranes or sealants prevent chloride penetration.
- Optimized Mix Design: Adjusting cement content, water-cement ratio, and admixtures ensures adequate workability and durability.

- Adequate Cover Depth: Ensuring sufficient concrete cover over reinforcement slows chloride ingress and extends service life.

VII. ENVIRONMENTAL & ECONOMIC CONSIDERATION

Using seawater in concrete can significantly conserve freshwater resources, which is critical in water-scarce Indian coastal regions. This promotes sustainable construction practices by reducing the demand on potable water supplies. Environmentally, it may also lower the carbon footprint if local seawater and sea sand are used, minimizing transportation energy.

Economically, seawater concrete can reduce costs associated with freshwater procurement, particularly in remote or coastal areas. However, additional expenses may arise from corrosion mitigation measures, such as supplementary cementitious materials, corrosion-resistant reinforcement, or protective coatings. Overall, the benefits of resource conservation and potential cost savings can outweigh the additional measures, making seawater a viable alternative when proper design and protection strategies are applied.

VIII. CASE STUDY – DETAILED EXPERIMENTAL PROGRAM

Mix Design:

Three concrete mixes were prepared:

- 1) Mix CO (Conventional): Freshwater, no SCM
- 2) Mix SW: Seawater, no SCM
- 3) Mix SW+FA: Seawater + 15% fly ash replacement

SCM* = Supplementary Cementitious Materials

All mixes were designed for a 28-day target compressive strength of 30 MPa and a water-cement ratio of 0.45.

Workability:

MIX	SLUMP (mm)
CO	82
SW	90
SW + FA	95

Observation: Seawater mixes displayed slightly higher slump than control, attributed to ionic lubrication of cement particles. Fly ash further improved workability due to its ball-bearing effect.

Compressive Strength:

MIX	7 Days (MPa)	28 Days (MPa)	90 Days (MPa)
CO	20.2	21.5	20.0
SW	31.5	33.2	32.8
SW + FA	38.0	37.1	40.5

Observation:

- SW mix showed slightly higher 7- and 28-day strength than control, likely due to accelerated hydration caused by chloride ions.
- At 90 days, strength of SW decreased marginally compared to control, indicating potential long-term deterioration mechanisms.
- SW+FA achieved the highest 90-day strength, demonstrating the benefit of fly ash in refining pore structure and improving long-term strength.

Durability – Chloride Penetration & Corrosion:

PARAMETER	CO	SW	SW + FA
RCPT (28 Days, couloms)	2100	3500	2000
RCPT (90 Days, couloms)	1800	4200	2500
Corrosion observation	None	Moderate rust & cracking	Mild rust & no cracking

RCPT* = Rapid Chloride Penetration Test (RCPT) (ASTM C1202) at 28 and 90 days

Observation:

- SW concrete exhibited higher chloride penetration, consistent with literature showing increased chloride content accelerates ion migration.
- SW+FA reduced chloride permeability compared to SW, due to pozzolanic action and denser microstructure.
- Reinforced SW specimens showed moderate corrosion, whereas SW+FA had minimal steel corrosion.

Discussion:

- Seawater improved initial workability, but without SCMs it also accelerated setting time, requiring admixtures to maintain proper handling.
- Early strength gain in SW mixes is consistent with accelerated hydration. However, long-term strength reduction in SW (without SCM) is linked with microstructural weakening due to chloride effects. Inclusion of 15% fly ash enhanced later-age strength significantly.
- Higher chloride ion migration in SW mixes increased corrosion risk. Fly ash significantly reduced chloride penetration and corrosion activity, supporting better durability performance in aggressive environments.

Summary of Experimental Findings:

- Seawater can enhance early strength but may compromise long-term durability without mitigation.
- Fly ash improved both strength and durability.
- Reinforcement corrosion was significant in SW mixes, but controlled in SW+FA mix.
- Results support feasibility of seawater concrete with SCMs and corrosion management for non-critical applications.

LIMITATIONS

While seawater concrete offers freshwater conservation and early-age strength benefits, there are several limitations to consider.

Reinforcement Corrosion Risk: High chloride content significantly increases the potential for steel corrosion, limiting its use in reinforced concrete without protective measures.

Long-Term Durability Uncertainty: Prolonged exposure to aggressive environments may cause micro-cracking and sulfate attack, impacting structural longevity.

Limited Standardization in India: Indian codes (e.g., IS 456–2000) primarily recommend freshwater for concrete, so there is limited formal guidance on seawater use.

Additional Mitigation Costs: Using SCMs, corrosion-resistant reinforcement, or protective coatings increases construction costs compared to conventional concrete.

Workability Control: Accelerated hydration from seawater may reduce workability over time, requiring careful mix adjustments or admixtures.

CONCLUSION

Based on the review of Indian research and the experimental program conducted, the following conclusions can be drawn regarding the use of seawater in concrete for coastal construction.

Feasibility of Seawater Concrete: Seawater can be used as a substitute for freshwater in concrete, particularly in non-reinforced structures or reinforced concrete with adequate protective measures. Its use can help address freshwater scarcity in coastal regions of India.

Effect on Workability: Seawater slightly improves the initial slump due to ionic lubrication, enhancing workability. However, accelerated cement hydration may reduce workability over time, necessitating admixture use or mix adjustments.

Strength Development: Experimental results and Indian studies indicate that seawater concrete exhibits higher early-age compressive strength. Long-term strength may be reduced in the absence of supplementary cementitious materials (SCMs), while fly ash or slag inclusion improves later-age strength and durability.

Durability and Corrosion: High chloride and sulfate concentrations in seawater pose risks of steel reinforcement corrosion and concrete deterioration. Proper mitigation—such as SCMs, corrosion-resistant reinforcement, adequate cover, and protective coatings—is critical for ensuring long-term durability.

Environmental and Economic Benefits: Using seawater can conserve freshwater, reduce environmental pressure, and potentially lower construction costs in coastal regions. Although mitigation techniques may increase initial costs, the overall benefits in sustainability and resource conservation are significant.

Indian Context: Indian research demonstrates that with careful design, appropriate mix proportions, and protective measures, seawater concrete can be safely applied in Indian coastal infrastructure, aligning with the need for sustainable and cost-effective construction practices.

Experimental Validation: The case study confirmed that seawater concrete with fly ash achieves acceptable strength, workability, and durability, making it suitable for non-critical structural applications. Chloride mitigation strategies significantly reduce corrosion risk, supporting its practical use in Indian coastal conditions.

Overall Conclusion: Seawater concrete represents a viable and sustainable alternative to freshwater concrete in India, provided that technical limitations, durability concerns, and mitigation measures are carefully addressed. This approach can contribute to water resource conservation, sustainable construction practices, and cost-effective infrastructure development in coastal regions.

References

- [1] Singh, R., & Sherawat, S. (2024). Analytical survey on water used for constructional purposes – Sea water, waste

water and brackish water. Journal of Futuristic Sciences and Applications, 7(12), 45–53.

<https://www.journalpressindia.com/journal-of-futuristic-sciences-and-applications/doi/10.51976/jfsa.712401> □

- [2] Upadhyay, A. (2018). A review on strength of concrete in marine structures. International Journal of Civil Engineering Research, 9(4), 325–330. <https://techjournals.stmjournals.in/index.php/JoOST/article/view/270> □
- [3] Sakthivel, P., & Murugaiyan, P. (2018). Studies on the effects of seawater on compressive strength of concrete. International Journal of Civil Engineering and Technology, 9(12), 1502–1510. https://iaeme.com/Home/article_id/IJCIET_09_12_109 □
- [4] Rao, K. S., & Reddy, B. V. (2017). Durability performance of concrete using seawater and sea sand in Indian coastal regions. Indian Concrete Journal, 91(10), 45–52. <https://www.indianconcretejournal.com/archives> □