Strengthening Techniques for Transparent Reinforcement Concrete Cover in Marine Structures

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Abstract- **Marine structures, often subjected to corrosive seawater and challenging environmental conditions, demand robust solutions for maintaining structural integrity while preserving transparency. This study investigates the efficacy of stainless-steel wire mesh reinforcement within clear cover layers of transparent reinforcement concrete (TRC) to enhance durability in marine environments. Experimental investigations are conducted to assess the performance of TRC covers with stainless steel wire mesh under various loading and environmental conditions. The study evaluates parameters such as corrosion resistance, mechanical properties, and long-term durability to quantify the effectiveness of the proposed reinforcement technique. Results indicate that the incorporation of stainless steel wire mesh within the clear cover layer significantly improves the resistance of TRC to corrosion and mechanical damage. The wire mesh acts as a protective barrier, providing enhanced structural support while maintaining transparency. Furthermore, advanced monitoring techniques are employed to analyze the performance of the strengthened TRC covers over extended periods in simulated marine conditions. This research contributes valuable insights into the development of sustainable solutions for strengthening TRC covers in marine structures. By utilizing stainless steel wire mesh reinforcement, engineers can extend the service life of marine infrastructure, ensuring both structural reliability and aesthetic appeal in underwater environments.**

Index Terms **- Transparent reinforcement concrete, marine structures, stainless steel wire mesh, durability, corrosion resistance.**

I INTRODUCTION

Reinforced concrete is one of the most widely used construction materials due to its versatility, strength, and durability. However, one of the main challenges facing reinforced concrete structures is the corrosion of steel reinforcement, particularly in aggressive environments such as coastal regions, industrial areas, and structures exposed to de-icing salts on roads. Corrosion not only compromises the structural integrity of the concrete but also leads to costly maintenance and repair efforts. In recent years, there has been growing interest in developing innovative techniques to enhance the durability of reinforced concrete structures and mitigate the effects of corrosion. One promising approach is the incorporation of stainless steel mesh in the cover zone of reinforced concrete elements. Unlike conventional carbon steel reinforcement, stainless steel offers superior corrosion resistance, making it an attractive option for improving the longevity of concrete structures. The cover zone of reinforced concrete plays a critical role in protecting the embedded steel reinforcement from corrosive agents present in the surrounding environment. By adding a layer of stainless-steel mesh in this zone, the ingress of moisture, chlorides, and other aggressive substances can be effectively mitigated, thereby extending the service life of reinforced concrete beams. This study aims to investigate the performance and longevity of reinforced concrete beams with enhanced durability through the incorporation of stainless steel mesh in the cover zone. By conducting experimental tests under various environmental conditions and loading scenarios, the effectiveness of stainless-steel mesh in improving the corrosion resistance and overall durability of reinforced concrete beams will be evaluated. Stainless-steel wire mesh reinforces concrete columns, enhancing load capacity and durability. Research suggests its potential for marine structures, improving longevity and structural integrity in harsh environments.[1] Study explores cover spalling in concrete due to bond or internal pressure, revealing increased brittleness and abrupt crack propagation. Proposes stainless steel incorporation to enhance ductility and prevent failures. [2] Corner spalling in concrete was identified via parallel longitudinal and transverse cracks. Negative correlations observed between spalling bending moments and crack widths. Analytical model established with the strong agreement, applicable for rectangular sections. Proposed spalling prediction criterion considers cracks and corrosion layer thickness [3] This journal extensively investigates how water-to-cement ratio, concrete cover thickness, and water saturation affect the corrosion rate of reinforcing steel in concrete structures. Findings contribute to understanding corrosion mechanisms and inform strategies for enhancing the durability and longevity of reinforced concrete infrastructure.[4] The literature comprehensively explores methods to predict the probability and severity of reinforced concrete corrosion-induced cracking. Understanding these mechanisms aids in developing proactive maintenance strategies to mitigate structural deterioration and ensure the longevity of concrete infrastructure.[5] This literature review delves into stiffness degradation and time to cracking of cover concrete in reinforced concrete structures affected by corrosion. Insights aid in understanding structural behavior, informing maintenance practices, and enhancing the durability of corroded concrete infrastructure.[6] This journal investigates the phenomenon of cracking in reinforced concrete beams caused by steel corrosion. The study offers insights into corrosion-induced structural deterioration, informing mitigation strategies for enhancing the durability of reinforced concrete infrastructure.[7] The reliability of concrete cover for buried structures is assessed from the perspective of chloride-induced corrosion. The study provides valuable insights into the durability of buried concrete infrastructure, informing design and maintenance practices for enhanced reliability.[8] The primary objective is to reinforce effective cover in offshore structures, enhancing their structural integrity and resilience against harsh marine conditions. This involves improving rebar durability through the strategic placement of transparent reinforcement within the cover of structural elements, mitigating corrosion risks. Additionally, measures are implemented to prevent concrete cover impaling, ensuring long-term stability and safety of offshore installations. The outcomes of this research have significant implications for the design, construction, and maintenance of reinforced concrete structures, especially in corrosive environments. If proven successful, the use of stainless-steel mesh in the cover zone could lead to more sustainable and resilient infrastructure solutions, reducing life cycle costs and enhancing the overall reliability of reinforced concrete construction.

II. MATERIAL INVESTIGATION

A. MATERIALS

Utilized PPC Cement fly ash-based variant for enhanced durability and workability. The specific gravity of 2.88 in cement determines mix proportions and ensures structural integrity. Fine aggregate with specific gravity 2.67 and fineness modulus 2.76 influences concrete properties. Coarse aggregate with specific gravity 2.67 and fineness modulus 7.56 impacts workability and texture. Water-cement ratio crucial for strength and durability. High-performance admixture improves workability, strength, and resistance to environmental conditions.

Steel for Reinforcement

Main bars and distribution bars have a diameter of 12mm, while stirrups are 8mm in diameter. They are spaced at 150mm c/c distances. This configuration ensures structural strength and stability in concrete elements, such as beams and columns, by providing adequate reinforcement.

Stainless steel 304 Wire Mesh:

Stainless steel wire mesh in concrete zones improves durability by inhibiting corrosion of embedded reinforcement. Its properties include high corrosion resistance, durability, and strength, ensuring long-term structural integrity. The mesh effectively prevents ingress of moisture and aggressive substances, extending the service life of reinforced concrete structures. The stainless-steel material offers excellent corrosion resistance, ensuring that the reinforcement remains effective and intact over time, even in harsh environments. This helps to maintain the structural performance and durability of the concrete structure, particularly in marine or coastal applications where exposure to saltwater and moisture can lead to corrosion of traditional reinforcement materials. The use of stainless-steel mesh in concrete also enhances the tensile strength of the material, providing additional support for load-bearing elements such as beams and columns. This helps to improve the overall stability and load-carrying capacity of the concrete structure.

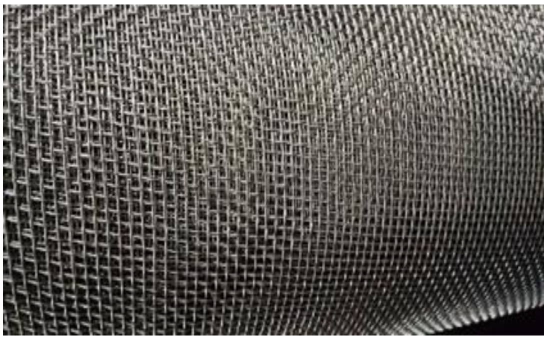
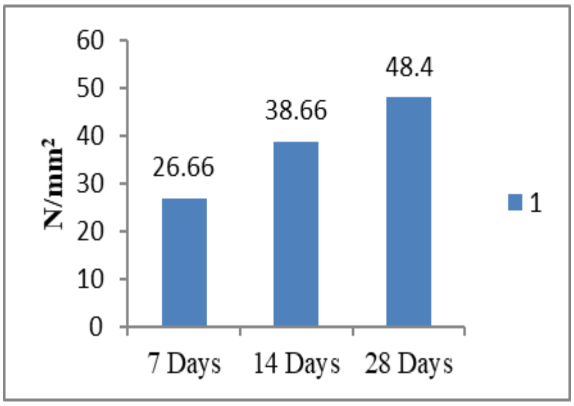


Fig1 Stainless steel wire mesh (SSWM)

Table 1 Physical properties of SSWM

PROPERTIES	VALUE
Thickness	1 mm
Hole shape	Square
Diameter of hole	1.2 mm

B. MIX PROPORTION



In accordance with IS 10262:2019 and IS 456:2000 code books, designing concrete for M40 grade entails meticulous mix proportioning. Using a ratio of 1:1.79:2.8 for cement, fine aggregate, and coarse aggregate respectively, the first step is determining the required strength for cubes, cylinders, and beams. Subsequently, calculate the quantities of materials and ensure thorough mixing to achieve uniform consistency. The mix is then poured into moulds, with cubes and cylinders typically cast in 150mm moulds and beams in 100mm x 100mm x 1700mm moulds. Finally, cure the samples under controlled conditions, typically moist curing for 28 days, to achieve optimal strength and durability.

Table 2 Mix Ratio for M40

	C	FA	CA	W	Admixture
For 1 m^3 of Concrete	41 2	739	1166	144	6.12
Mix Ratio	1	1.79	2.8	0.35	0.015

III. EXPERIMENTAL PROGRAM

The experimental initiative is directed towards enhancing the longevity of transparent reinforced concrete covers in marine structures.M40 grade concrete cubes and cylinders are subjected to compression and split tests to evaluate their strength and structural integrity. These tests provide essential data on the material's performance under axial loading. Beams are reinforced with wire mesh and subjected to flexural tests to assess their bending strength and resistance to cracking. The wire mesh reinforcement enhances the structural integrity and durability of the concrete beams.

Concrete specimens containing wire mesh reinforcement undergo durability tests, including acid resistance and RCPT (Rapid Chloride Penetration Test). These tests evaluate the ability of the concrete to withstand harsh environmental conditions, such as exposure to acids and chloride ions, commonly found in marine environments.

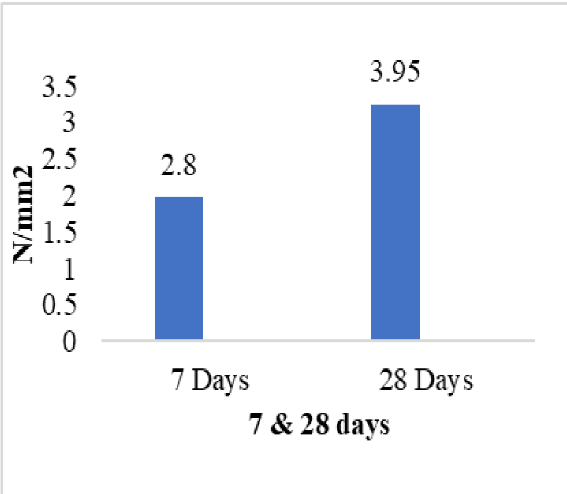
TEST RESULTS

Compression test:

CTM tests 9 concrete cubes, each sized 150×150×150 mm. Evaluates compressive strength, crucial for structural integrity assessment and material suitability. At 7 days, the concrete cube achieved 56% of the target mean strength; at 14 days, it reached 80%, and at 28 days, it nearly met the target mean strength, achieving 99% of it.

As the cement was replaced with fly ash, the reduction in compressive strength of concrete was higher at the age of 7 days as compared to 28 days. This occurs as the secondary hydration due to pozzolanic action is slower at initial stages for fly ash concrete. [9]

Split tensile test:



The split tensile strength of the concrete cylinder reached 4% of the target mean strength at 7 days and increased to 7% at 28 days.

Flexural test: In a flexural test, beams are reinforced with stainless steel wire mesh covers to evaluate their bending strength and crack resistance. The beams are subjected to load until failure while being monitored by LVDT (Linear Variable Differential Transformer) testing machines. This method assesses the effectiveness of wire mesh covers in enhancing the flexural performance and durability of concrete beams.

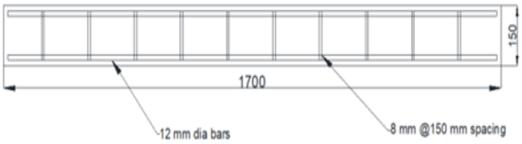


Fig 2 Reinforcement detail of beam

Fig 3 Reinforcement rebar with Mesh

Fig 4 Test setup

Fig 5 Crack in beam

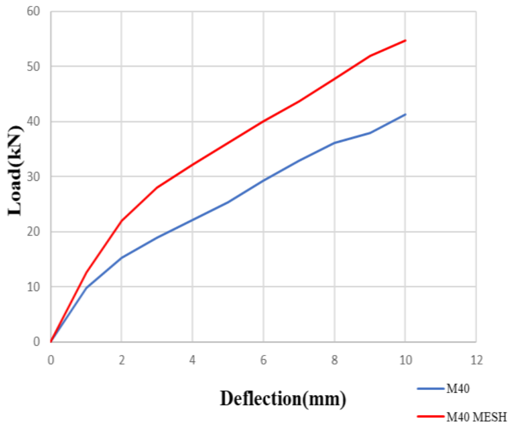


Fig 6 Comparison of Load and Deflection

In comparing flexural load and deflection between control concrete and transparent reinforced concrete beams, the control beam sustains 41 KN load with 10 mm deflection, while the TRC beam endures 55 KN load with 10 mm deflection. This represents an approximately 34% increase in load-bearing capacity and achieve in same deflection for the TRC beam, showcasing its superior performance.

Both conventional (CC) and transparent reinforced concrete (TRC) beams Fig 5 showed crack behavior, differing in cracking patterns. Failure in all beams occurred due to flexure, with tension failure characterized by longitudinal steel yielding followed by concrete crushing. The utilization of stainless-steel wire mesh (SSWM) within the bottom side of transparent reinforced concrete (TRC) beam covers serves to effectively reduce crack width, particularly in areas where cracks are prone to initiation, such as near the midspan. Under maximum loading conditions acting upon the beam, crack width tends to manifest predominantly towards the top of the cover. This strategic placement of SSWM contributes significantly to the structural integrity of the beam, as it reinforces the underside, where tensile stresses are most prevalent. By minimizing crack width and strategically positioning the reinforcement, the TRC beam is fortified against the detrimental effects of loading, ensuring enhanced durability and performance over time.

Crack pattern

The crack pattern observed in the study likely follows typical patterns observed in reinforced concrete beams subjected to flexural loading. In the control concrete beam, cracks may appear predominantly along the tension side, starting near the mid-span and propagating towards the supports. These cracks may extend diagonally and intersect the neutral axis, indicating tension failure. This crack is flexural crack.

In the transparent reinforced concrete (TRC) beam, the crack pattern may be similar but potentially less extensive or narrower due to the presence of the stainless-steel wire mesh reinforcement. The mesh helps distribute and limit crack propagation, resulting in a more controlled and localized cracking pattern. Cracks may still occur but could be shorter in length and exhibit reduced width compared to the control beam.

Additionally, the crack pattern in the TRC beam may show fewer instances of crack widening or spalling, indicating improved crack resistance and durability. Overall, the crack pattern observed in the TRC beam should demonstrate the effectiveness of the stainless-steel wire mesh reinforcement in enhancing the structural performance and mitigating crack formation in the transparent concrete cover.

Rapid Chloride Penetration Test (RCPT) test: The Rapid Chloride Permeability Test (RCPT) swiftly measures chloride ion transport in concrete. Disc specimens, 100mm in diameter and 50mm thick, are cast with and without SSWM. ASTM C1202 standardizes the test. The setup, shown in Figure 4.3, correlates chloride penetration rate with the charge passed in coulombs, facilitating concrete durability assessment.

Fig 7 RCPT Specimen

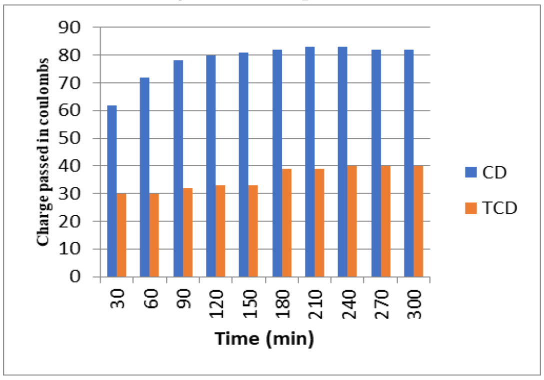


Fig 8 Comparison of Chloride Diffusion

The RCPT test results reveal a substantial difference between the control concrete and transparent reinforced concrete, indicating higher charge passage in the former. This underscores the necessity of selecting suitable materials to boost durability and resist electrical conductivity. It highlights transparent reinforced concrete's potential in reducing conductivity, urging further exploration for optimal construction performance.

Table 3 Results for RCPT

Specimen	Charge passed (Coloumbs)	Chloride Diffusion
Control concrete Disc	1286.1	Moderate
Transparent Reinforced concrete Disc	720.2	Very low

CONCLUSION

- The results of the experimental investigation indicate the efficacy of incorporating stainless steel wire mesh within TRC covers to enhance the durability and mechanical properties of reinforced concrete beams in marine environments.
- The concrete cubes exhibit a gradual increase in strength over time, reaching 99% of the target mean strength at 28 days. This suggests favorable concrete maturity and potential for robust structural performance.
- The observed increase in flexural strength demonstrates the beneficial effect of wire mesh reinforcement in mitigating cracking and improving the load-bearing capacity of the concrete beams.
- The flexural strength increased by approximately 34% compared to the control beams without wire mesh reinforcement. This improvement in flexural strength highlights the effectiveness of stainless-steel wire mesh in providing additional support and resistance to cracking.
- This enhancement is attributed to the protective barrier provided by the wire mesh, which inhibits the ingress of moisture, chlorides, and other corrosive substances, thereby reducing the likelihood of corrosion-induced damage.
- RCPT test shows higher charge passage in control concrete than transparent reinforced concrete, emphasizing material selection for

durability and conductivity resistance. TRC holds promise for reducing conductivity, warranting further investigation for construction optimization.

- Furthermore, the compatibility of stainless-steel wire mesh with the transparent nature of TRC covers ensures that the structural support is achieved without compromising transparency, which is crucial for maintaining aesthetic appeal in marine structures.
- Overall, the findings suggest that the proposed reinforcement technique offers a promising solution for extending the service life of marine infrastructure while ensuring both structural reliability and visual attractiveness.
- Further research and validation are recommended to confirm the long-term durability and performance of TRC covers reinforced with stainless steel wire mesh in practical marine applications.

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