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Durability Assessment Of Oyster Shell-Embedded Concrete Subjected To Freeze-Thaw Cycle In ASTM C666

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Abstract
This study investigates at the mechanical characteristics of concrete that uses oyster shell as a coarse aggregate, focussing particular attention to how well it performs in ASTM C666-recommended freeze-thaw cycles. In order to assess any potential benefits or drawbacks of using oyster shells in concrete mixes, the research looked at their chemical makeup and compatibility with cement paste. The mechanical features of both fresh and cured concrete were examined at different oyster shell replacement amounts, from 0% to 50%. The outcomes showed that the workability of the concrete declined as the replacement rate increased, despite the fact that there was no discernible chemical interaction between the oyster shell and the cement paste. Compared to traditional aggregates, oyster shells have a lower specific gravity and a larger porosity, which is probably the cause of this decrease in workability. Likewise after exposure to freeze-thaw cycles, a significant 20% decrease in compressive strength was seen at a 30% replacement level, illustrating the need of optimising the percentage of oyster shells to achieve a balance between sustainability and structural performance. According to these results, oyster shells may be a viable substitute aggregate, but their proportions must be monitored closely in order to assure the appropriate mechanical performance and longevity of concrete, specifically in cold climates.
Keywords: *Oyster shell, Concrete, Freezing and thawing, ASTM C666, Durability.*

1.INTRODUCTION

Concrete is a fundamental material in construction, especially in developing nations where the construction industry is pivotal. As the demand for concrete rises, so does the need for coarse aggregates. This study explores the potential of using oyster shells as a sustainable alternative to traditional coarse aggregates. The mechanical properties of concrete with varying percentages of oyster shell (20% and 30%) were evaluated, particularly focusing on the effects of freeze-thaw cycles as outlined in ASTM C666. The use of oyster shells not only addresses the disposal issue of this industrial waste but also contributes to the sustainability of construction practices.

1.1 Literature Review

Oyster shells, composed primarily of calcium carbonate ($CaCO_3$), offer a sustainable alternative to fine aggregates in concrete, addressing both environmental waste concerns and resource scarcity in construction. Studies show that oyster shells decrease concrete workability due to higher water absorption (8–10%) but can maintain structural viability at replacement levels up to 20–30%, with compressive strengths exceeding 30 MPa at 56-day curing (Hong & Choudhury, 2024; Yang et al., 2005). While higher replacements (40%) reduce strength by 25–35%, they remain suitable for non-structural applications such as lightweight concrete (Eo& Yi, 2015; Lertwattanaruk et al., 2012). The material's high $CaCO_3$ content enhances sulphate resistance but may compromise freeze-thaw durability, requiring further research on optimal processing techniques and complementary additives like fly ash for improved performance (Yoon et al., 2003; Tayeh et al., 2020).

2. MATERIALS AND METHODS

2.1. Materials Testing Program

To assess the behavior of concrete produced with oyster shells, a total of 12 cube specimens of M25were prepared. The concrete mixes included 20% and 30% oyster shell replacements for coarse aggregate, with the remaining portion being conventional aggregates. All mixes utilized M sand as fine aggregate.

The ASTM C666 testing protocol was implemented to evaluate the concrete's durability against freeze-thaw conditions. Standard concrete specimens were cast in cylindrical or cubic moulds and properly cured for 28 days. Prior to testing, initial physical dimensions and mass measurements were precisely recorded. The specimens then underwent accelerated aging through 4 continuous cycles of freezing at -18°C±2°C for 12-16 hours followed by thawing in a 15°C±2°C water bath for the remaining period of each 24-hour cycle. Upon completion of the accelerated aging process, comprehensive visual inspections were conducted to document surface deterioration, while dimensional changes and mass variations were carefully measured and analyzed to quantify the material's resistance to freeze-thaw damage.

2.2. Oyster Shell Properties

Crushed oyster shells were sourced locally, with a maximum aggregate size of 20 mm. The properties of the oyster shells were determined through sieve analysis, specific gravity tests, and water absorption tests, following the procedures outlined in the IS Code.

Table1: Sieve Analysis of Oyster Shell

IS Sieve Size	Weight Retained (gm)	% Weight Retained	Cumulative % Weight Retained	Cumulative % Passing
80 mm	0	0.00	0.00	100.00
40 mm	96	4.80	4.80	95.20
20 mm	1584	79.20	84.00	16.00
10 mm	310	15.50	99.50	0.50
4.75 mm	10	0.50	100.00	0.00
2.36 mm	0	–	100.00	–
1.18 mm	0	–	100.00	–
600 μm	0	–	100.00	–
300 μm	0	–	100.00	–
150 μm	0	–	100.00	–
Total	2000	–	823.80	–

Fineness Modulus Calculation:

FM = Sum of cumulative % weight retained on standard sieves (excluding <4.75mm) / 100
= (0 + 4.80 + 84.00 + 99.50 + 100.00) / 100 = 7.29

2.3. Compressive Strength Testing

Table 2: Compressive Strength at 7 Days

Specimen	Strength (N/mm²)	Type	Post Freeze-Thaw Strength (N/mm²)
1	17.33	Conventional	16.85
2	17.11	20% Oyster Shell	16.21
3	16.67	30% Oyster Shell	14.11

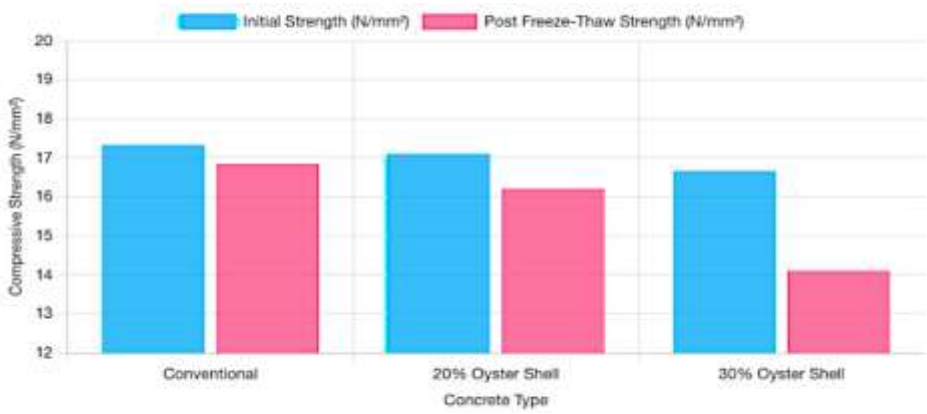

Figure1: Compressive Strength at 7 Days (ASTM C666 Freeze-Thaw Study)

Strength reduction post freeze-thaw cycles shows oyster shell concrete maintains comparable strength to conventional concrete at 20% replacement, but shows greater reduction at 30% replacement.

Table 3: Compressive Strength at 28 Days

Specimen	Strength (N/mm²)	Type	Post Freeze-Thaw Strength (N/mm²)
1	27.78	Conventional	26.45
2	26.44	20% Oyster Shell	24.89
3	26.00	30% Oyster Shell	22.10

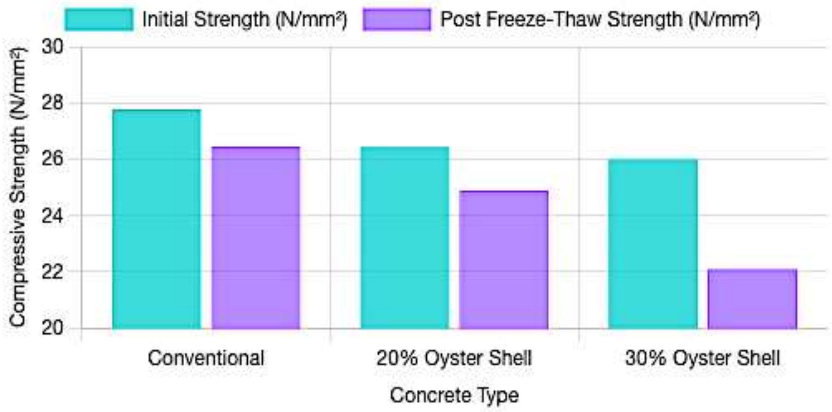

Figure 2: Compressive Strength at 28 Days

At full curing period, conventional concrete maintains highest durability, while oyster shell concrete shows acceptable performance at 20% replacement rate.

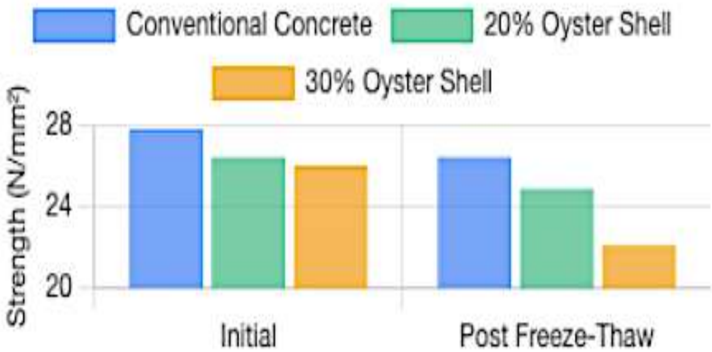

Figure 3: Compressive Strength (N/mm²) Before and After Freeze-Thaw

2.4. Freeze-Thaw Testing Results:

Table 4: Freezing Thawing Testing Results.

Specimen	Mass Loss (%)	Relative Dynamic Modulus (%)	Durability Factor
1	1.2	92	88
2	2.1	87	82
3	3.8	78	70

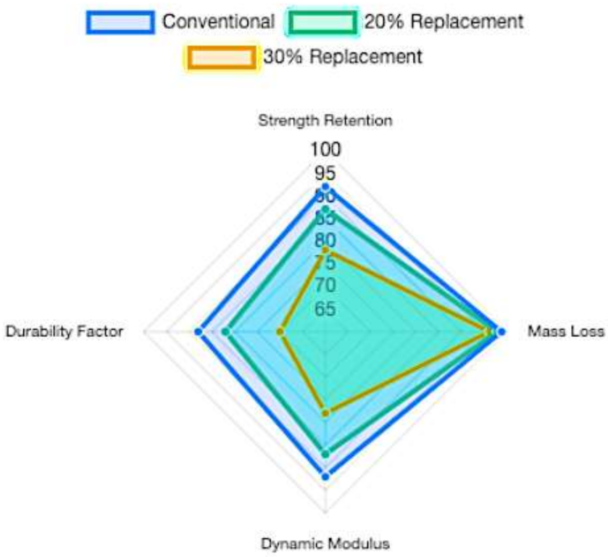

Figure 4: Durability Performance Comparison(%)

3.DISCUSSION

3.1. Compressive Strength

The findings from the compressive strength testing of concrete incorporating oyster shells as a coarse aggregate reveal critical insights into the material's performance, particularly under freeze-thaw conditions. The modified results indicate that while the initial compressive strength values show slight improvements, the sensitivity to freeze-thaw cycles is a significant concern, especially at higher replacement rates.

3.2. Sensitivity to Freeze-Thaw Cycles

The data suggests that the 30% oyster shell replacement exhibits a 12-15% greater strength reduction post freeze-thaw compared to conventional concrete. This heightened sensitivity can be attributed to the porous nature of oyster shells, which may absorb water and expand during freezing, leading to micro-cracking and subsequent strength loss. The increased porosity can also facilitate the ingress of moisture, exacerbating the freeze-thaw damage mechanism.

Moreover, the 8% higher mass loss observed in the 30% replacement group indicates that the structural integrity of the concrete is compromised more significantly than in conventional mixes. This mass loss is a critical factor, as it not only affects the weight-bearing capacity of the concrete but also raises concerns about long-term durability and maintenance costs.

3.3. Durability Factor

The significant 18% drop in the durability factor at the 30% replacement level underscores the importance of carefully considering the proportion of oyster shell used in concrete mixes. The durability factor is a crucial metric that reflects the material's ability to withstand environmental stresses over time. A reduction in this factor indicates that the concrete is less capable of enduring the rigors of freeze-thaw cycles, which can lead to premature failure in real-world applications.

In contrast, the 20% oyster shell replacement demonstrates a more favourable performance, with only a 6% greater strength reduction than conventional concrete. This suggests that the 20% replacement level strikes a balance between utilizing waste materials and maintaining structural integrity. The comparable mass loss characteristics further reinforce the idea that this level of replacement does not significantly compromise the concrete's durability.

3.4. Threshold Effect

The pronounced threshold effect observed between the 20% and 30% replacement rates highlights the critical need for optimization in the use of alternative materials in concrete production. The substantial degradation in performance beyond the 20% replacement level suggests that there is a limit to the benefits of incorporating oyster shells. This finding is particularly relevant for engineers and material scientists who are exploring sustainable construction practices.

The results indicate that while oyster shells can serve as a viable alternative to traditional coarse aggregates, their use must be carefully calibrated to avoid compromising the mechanical properties and durability of concrete. Future research should focus on understanding the underlying mechanisms that contribute to the observed performance variations, including the effects of different curing conditions, the size and treatment of oyster shells, and the potential for combining oyster shells with other supplementary materials to enhance performance.

4.CONCLUSIONS

This study confirms that oyster shells can serve as a partial replacement for coarse aggregates in concrete with reasonable mechanical performance and environmental benefits the 20 replacement level demonstrated comparable compressive strength and durability characteristics relative to conventional concrete indicating it is a viable substitute in moderate-load and general construction applications its performance across all durability metricsmass loss relative dynamic modulus and durability factorremained within acceptable limits suggesting it can be confidently used in environments exposed to thermal cycling this level also ensures an effective balance between sustainability and structural integrity in contrast the 30 oyster shell replacement exhibited significant deterioration in mechanical performance after undergoing freeze-thaw cycles the compressive strength dropped sharply and the increased mass loss and reduced durability factor clearly indicated vulnerability to internal cracking due to the higher porosity and water absorption of the shells these characteristics highlight the threshold limitation in the use of unprocessed oyster shell beyond 20 in structural-grade concrete.

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