INVESTIGATING THE EFFECT OF CARBONATION CURING ON THE STRENGTH, DURABILITY, AND PERFORMANCE ENHANCEMENT OF FOAM CONCRETE

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Introduction:

Foam concrete, a lightweight and sustainable material, reduces weight and enhances thermal insulation, making it an eco-friendly alternative in construction. Research in Cement and Concrete Research, Construction and Building Materials, and Materials Science and Engineering: A highlights its strength, durability, and environmental benefits. Journal of Cleaner Production emphasizes foam concrete's role in sustainable building practices.

Carbonation curing, which incorporates CO_2 into the curing process, further enhances foam concrete's properties. This technique improves compressive strength, durability, and resistance to environmental factors, while also sequestering CO_2. Combined with foam concrete, carbonation curing offers a sustainable solution for creating durable, energy-efficient structures.

Objectives:

1. To determine the optimum foam concentration by varying the weight of foam in water, in order to achieve the ideal balance of density and strength properties

for high-quality foam concrete, with up to 30% cement replacement using fly ash.

2. To study the impact of carbonation curing using dry ice on the initial strength development of foam concrete, accelerating the curing process and enhancing early- age strength gain.
3. To compare the performance of foam concrete cured with dry ice (carbonation curing) with conventional curing methods, focusing on improvements in compressive strength, durability, and resistance to cracking.
4. To evaluate the long-term effects of carbonation curing on the durability, strength, and structural integrity of foam concrete, ensuring that it meets the required standards for use in construction projects.

Methodology:

Preparation of Foam Concrete Mixes:

Foam concrete will be prepared by varying the foam-to-water ratio to determine the optimum percentage of foam that balances density and strength, properties. In addition, up to 30% of cement will be replaced with fly ash to evaluate its impact on the mix's performance. Once the optimal foam concentration is identified, these proportions will be used consistently in the subsequent experiments.

Curing Methods:

Foam concrete samples will be cured using two methods: conventional water curing and carbonation curing with dry ice. The identified optimum foam concentration will be applied to both curing methods to compare their effectiveness.

Early-Age Strength Testing:

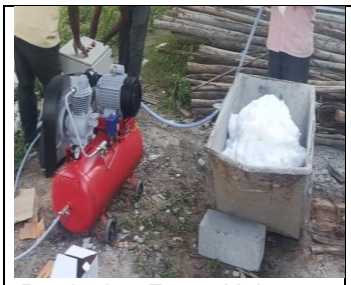
The compressive strength of foam concrete with the optimum foam percentage will be tested at 1, 3, 7, and 28 days of curing. The strength development of carbonation-cured samples will be compared with those cured by water curing.

Physical and Mechanical Properties Evaluation:

The workability, density and mechanical properties (compressive strength) of foam concrete with the optimum foam percentage will be measured. This will assess the impact of curing method on the overall performance of the foam concrete.

Long-Term Durability Testing:

The durability of foam concrete with the optimum foam concentration will be evaluated under sulphate attack, chloride attack, and alternate wet and dry cycles. The performance of carbonation-cured samples will be compared with water- cured samples to assess long-term durability.



Producing Foam Using an Air Compressor

Foam Concrete cubes

Foam Concrete Blocks

Result and Conclusion:

The table 1 summarizes the performance of foam concrete mixes with varying oven-dry densities ranging from 400 kg/m³ to 1600 kg/m³.

Oven-Density in	KG/m3	400	600	800	1000	1200	1400	1600
Sand	(Kg)	0	220	500	600	750	950	1100
Cement	(Kg)	300	300	250	320	360	380	400
Water in Mortar (Kg)		110	120	140	160	180	200	220
Quantity of Foam (Ltrs)		1.3	1.3	1.1	1.1	1	1	0.9
Water in Foam (Kg)		25	25	22.5	22.5	20	20	15
Wet Density		480	700	900	1100	1300	1500	1700
Maximum Compressive Strength N/mm2		1	2	3	4	8	12	18

Table 1: FOAM CONCRETE MIX DESIGN USING FINED SAND TO PRODUCE 1m3

Comparative Study of Compressive Strength of Foam Concrete (Optimized for 8 MPa) with Different Curing Techniques

Curing Method	1 Day	3 Days	7 Days	28 Days
Conventional Water Curing	1.5	2.8	4.9	8.1
Carbonation Curing (Isolated Chamber for 96 hours)	2.2	4.0	6.4	8.6
Carbonation Curing (1% Crushed Dry Ice by weight added during casting)	2.0	3.7	6.5	8.9

Durability Test Results – Conventional vs Carbonation Curing of Foam Concrete

Curing Method	Sulphate Attack (% weight loss after 28 days)	Chloride Attack (% weight loss)	Alternate Wet & Dry (% weight loss)
Conventional Water Curing	3.8%	3.2%	2.9%
Carbonation Curing (96 hrs)	2.1%	1.8%	1.6%
Crushed Dry Ice (1% by wt) Method	1.9%	1.5%	1.4%

In conclusion,

1. Carbonation curing using dry ice showed a moderate increase in early compressive strength of foam concrete compared to conventional water curing, with up to 12–15% improvement at 28 days in optimized mixes.
2. Incorporation of **1% dry ice during casting enhanced uniform carbonation**, leading to slightly better strength development than chamber carbonation curing alone.
3. **Durability results under sulphate and chloride attack** indicate that carbonation-cured samples experienced **lower weight loss and chloride penetration**, showing better resistance than water-cured counterparts.
4. **Alternate wet and dry cycles** revealed that carbonation curing improved structural integrity under cyclic environmental exposure, contributing to **better long-term durability**.

5. The study demonstrates that **carbonation curing is a promising technique** for enhancing both early strength and durability, making it suitable for eco-friendly and sustainable building materials.

Project Outcome & Industry Relevance

Project Outcome:

The project demonstrates that carbonation curing with dry ice improves the early compressive strength and long-term durability of foam concrete, offering an efficient and eco-friendly alternative to conventional water curing. The incorporation of dry ice results in better carbonation uniformity, enhanced resistance to sulfate and chloride attack, and improved structural integrity under environmental exposure.

Industry Relevance:

This study highlights the potential of carbonation curing as a sustainable method for producing high-performance concrete in the construction industry, contributing to eco-friendly building materials and enhancing the durability of structures under challenging environmental conditions.

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Working Model vs. Simulation/Study:

The project involved the development of a physical working model where foam concrete samples were prepared using specific mix proportions, incorporating dry ice for carbonation curing. These samples were subjected to curing and tested for compressive strength and durability, including resistance to sulfate and chloride attack.

Project Outcomes and Learnings:

The project demonstrated that carbonation curing with dry ice improved foam concrete's compressive strength by 12-15% and enhanced its durability, showing better resistance to sulfate and chloride attacks. It also improved structural integrity under alternate wet and dry cycles. These findings highlight carbonation curing as an eco-friendly, sustainable alternative for concrete curing, offering both environmental and performance benefits.

Future Scope:

For future studies, a comparison can be made between carbonation curing using dry ice and carbonation curing in a carbonation chamber. Additionally, varying the percentages of dry ice used in the curing process could help optimize the mix for better strength and durability outcomes. This would provide a more comprehensive understanding of the best practices for carbonation curing under different conditions.