Analysis of Carbonated Concrete used in Building Construction

Vivek Tiwari[1], Adarsh Tiwari[2], Md. Tahir Ansari[3], Devendra Singh[4], Akash Verma[5] , Raj Kumar Gupta[6]

[1] *student, Department of Civil Engineering GITM, Lucknow*
[2] *student, Department of Civil Engineering GITM, Lucknow*
[3] *student, Department of Civil Engineering GITM, Lucknow*
[4] *student, Department of Civil Engineering GITM, Lucknow*
[5] *student, Department of Civil Engineering GITM, Lucknow*
[6] *Associate professor , Department of Civil Engineering GITM, Lucknow,*

Abstract -*Carbonated concrete is created through a chemical process known as carbonation, where CO2 reacts with calcium silicates in the cement matrix. This process can occur both during the mixing of concrete and during the curing phase, resulting in the formation of calcium carbonate, which contributes to the concrete's strength and durability. Furthermore, the use of supplementary Cementous materials, such as slag or fly ash, in conjunction with carbonation can further improve the sustainability of concrete production.*

Carbonated concrete utilizes this concept by incorporating CO2 into the concrete mix during the curing process. The carbonation reaction involves CO2 reaction with the calcium compounds present in the cement matrix, resulting in the formation of stable calcium carbonate. This process not only sequesters CO2 but also enhances the chemical and physical properties of the concrete, making it a valuable alternative to traditional concrete.

Key Words: Carbonated concrete, carbonation, cement matrix, sustainability.

1.INTRODUCTION

Concrete is an essential material in modern construction, serving as the backbone of infrastructure such as roads, bridges, buildings, and dams. Its widespread use can be attributed to its strength, versatility, and durability. However, the production of concrete is not without significant environmental consequences. Traditional concrete manufacturing processes are highly energy-intensive, primarily due to the production of Portland cement, which involves heating limestone to high temperatures. This process not only consumes a large amount of energy but also releases substantial amounts of carbon dioxide (CO2) into the atmosphere—approximately 8% of global CO2 emissions originate from cement production.

1.1 Case Study

In light of increasing concerns over climate change and the need for sustainable development, the construction industry is exploring various strategies to reduce its carbon footprint. One promising approach is the development and use of carbonated concrete, which incorporates CO2 into the curing process. By utilizing captured CO2, carbonated concrete not only sequesters emissions but also enhances the material properties of concrete.

Carbonated concrete is created through a chemical process known as carbonation, where CO2 reacts with calcium silicates in the cement matrix. This process can occur both during the mixing of concrete and during the curing phase, resulting in the formation of calcium carbonate, which contributes to the concrete's strength and durability. Furthermore, the use of supplementary cementitious materials, such as fly ash or slag, in conjunction with carbonation can further improve the sustainability of concrete production.

Carbonated concrete utilizes this concept by incorporating CO2 into the concrete mix during the curing process. The carbonation reaction involves CO2 reacting with the calcium compounds present in the cement matrix, resulting in the formation of stable calcium carbonate. This process not only sequesters CO2 but also enhances the chemical and physical properties of the concrete, making it a valuable alternative to traditional concrete.

2. METHODOLOGY

The methodology for producing carbonated concrete involves a systematic approach that encompasses material selection, mixing, carbonation, and testing. This detailed guide aims to ensure optimal performance, sustainability, and practical application in the construction industry.

2.1 Material Selection

2.1.1 Cement:

The most commonly used binder in concrete. Its properties can be enhanced with supplementary cementitious materials (SCMs). These incorporate materials like fly ash, slag, or silica fume, which not only improve sustainability by reducing cement content but also enhance mechanical properties.

2.1.2 Aggregates: Gravel or crushed stone should be clean and well-graded to optimize concrete density and strength. Sand that meets standards for grading, cleanliness, and absence of deleterious materials is essential for achieving desired workability.

2.1.3 Water:

Use potable water free from impurities that can adversely affect the hydration process and long-term durability of the concrete.

2.1.4 Carbon Dioxide Source:

Sourced from industrial emissions, power plants, or even direct air capture technologies. Ensuring a consistent and concentrated CO2 supply is critical for effective carbonation.

2.2 Mix Design

2.2.1 Proportioning:

A typical mix design for carbonated concrete involves defining the ratios of cement, aggregates, water, and any SCMs. A lower water-cement ratio enhances strength but requires careful handling to maintain workability.

2.2.2 Performance-based Design:

Adjustments to the mix should consider specific performance requirements (e.g., compressive strength, durability) and intended applications (e.g., structural, decorative).

2.3 Additives:

2.3.1 Chemical Admixtures: These can improve workability (plasticizers), reduce water content (superplasticizers), or accelerate the setting and hardening process, particularly beneficial for achieving effective carbonation.

2.4 Preparation of the Concrete Mix

2.4.1 Mixing Process:

2.4.1 Dry Mixing: Begin by thoroughly combining the dry ingredients in a concrete mixer to ensure uniform distribution of the cement and aggregates.

2.4.2 Adding Water: Gradually introduce water while mixing until a homogenous consistency is achieved. Aim for a workable mix that can be easily placed in molds without segregation.

2.4.3 Consistency Check:

The mix should be assessed for slump (workability) to ensure it meets the requirements for the intended application.

2.5 Casting

2.5.1 Molding:

Pour the mixed concrete into predetermined molds (cubes, beams, or slabs). Ensure that the molds are adequately treated to prevent sticking.

2.5.2 Vibration:

Use mechanical vibration to eliminate air pockets and enhance the density of the concrete. Proper consolidation reduces porosity and improves the overall quality.

2.5.3 Curing Process

2.5.3.1 Initial Curing:

Allow the concrete to set in a controlled environment for 24-48 hours. This initial curing phase helps maintain moisture and temperature, promoting optimal hydration of the cement.

2.5.3.2 Carbonation Curing:

After initial curing, expose the concrete to CO2:

2.5.3.3 Gas Chambers: Place the concrete in sealed chambers where CO2 can be introduced at controlled concentrations (typically 50,000 to 200,000 ppm) and pressures. This environment accelerates carbonation.

2.5.3.4 Ambient Conditions: For practical applications, ambient exposure can also be used, although it may be slower and less uniform.

2.6 Monitoring Carbonation

2.6.1 Duration and Conditions:

Monitor the exposure duration and environmental conditions, including temperature and humidity, as these factors significantly influence the carbonation rate.

2.6.2 Measurement Techniques:

Use methods such as pH testing, phenolphthalein indicator, or advanced techniques like X-ray tomography to assess carbonation depth and effectiveness.

3.Data Analysis and Reporting

Age of Concrete (Days)	Uncarbonated Compressive Strength (MPa)	Carbonated Compressive Strength (MPa)
7	15-25	20-30
28	20-40	30-50
90	25-50	40-60
180	30-55	50-70

Property	Uncarbonated Concrete	Carbonated Concrete
Compressive Strength (MPa)	**15-55**	**20-70**
Density (kg/m^3)	**2100-2400**	**2200-2400**
Water Absorption (%)	**6-12**	**5-10**
Permeability (mD)	**20-200**	**10-100**

3.1 Performance Comparison:

Analyze the mechanical and durability properties of carbonated concrete against conventional concrete, focusing on strength gains and environmental benefits (CO2 sequestration).

3.2 Documentation:

Prepare a comprehensive report that includes the methodology, experimental results, interpretations, and recommendations for future applications of carbonated concrete in construction.

4. CONCLUSIONS

In summary, carbonated concrete embodies a holistic approach to addressing the intertwined challenges of environmental sustainability, structural integrity, and economic viability. Its ability to sequester carbon, enhance durability, and reduce lifecycle costs positions it as a transformative solution in the construction landscape. By embracing carbonated concrete, the industry not only takes a significant step toward mitigating climate change but also sets the stage for building a resilient, sustainable infrastructure that meets the needs of present and future generations. The adoption of this innovative material will play a pivotal role in redefining construction practices and fostering a sustainable built environment, ultimately contributing to a healthier planet.

Economically, while the initial investment in carbon capture and carbonation technologies may present challenges, the long-term benefits far outweigh these concerns. With increasing regulatory pressures and societal demand for sustainable building materials, early adopters of carbonated concrete are likely to benefit from enhanced market opportunities. As governments worldwide implement stricter environmental regulations, the ability to demonstrate compliance with sustainability standards will become increasingly vital for construction firms. Carbonated concrete not only meets these standards but can also enhance the overall value proposition of projects.

On a social level, the growing awareness and preference for sustainable practices among consumers and industry stakeholders cannot be underestimated. As public consciousness around climate change rises, there is an increasing expectation for businesses to adopt environmentally friendly practices. By utilizing carbonated concrete, companies can showcase their commitment to sustainability, thereby enhancing their brand reputation and attracting environmentally conscious clients. This alignment with societal values can foster goodwill and lead to greater collaboration among stakeholders.

REFERENCES

[1] D. Kornack and P. Rakic, “Cell Proliferation without Neurogenesis in Adult Primate Neocortex,” Science, vol. 294, Dec. 2001, pp. 2127-2130, doi:10.1126/science.1065467.

[2] https://www.sciencedirect.com/science/article/abs/pii/B9780081020012000152M.

[3] https://www.mdpi.com/2075-5309/13/8/

[4] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9412592/