

Sustainable Concrete Strategies

Introduction

Concrete is one of the most versatile and widely used construction building materials due to its strength, durability, and flexibility in design. Its fire resistance, vibration-dampening characteristics, and other properties make concrete a good choice for the design of research buildings, including on the NIH campus. This article therefore focuses on the implementation of sustainable strategies that can significantly reduce the environmental impact of concrete.

Limitations of Conventional Concrete

The environmental impact of building construction faces more scrutiny than in previous years due to zero-carbon mandates and other green initiatives. Despite its many advantages, concrete's contribution to environmental degradation and CO₂ production is significant and must be recognized. Issues include:

- **CO₂ Generation:** Concrete is estimated to account for 8% of global CO₂ production.¹ Raw materials (chiefly limestone) are heated in kilns, which are traditionally fed with fossil fuel, releasing CO₂. This process (calcination) converts limestone to calcium oxide, releasing additional CO₂.²
- **Land Degradation:** Aggregate, traditionally sand and gravel, is extracted from the ground. The extraction, processing, and transportation of aggregate result in land degradation, habitat loss, water pollution, and CO₂ production.
- **Water Use:** Concrete production consumes large amounts of water, contributing to runoff and pollution. The concrete industry is among the top water-consuming sectors, requiring approximately 150 liters of freshwater per cubic meter of concrete.³

Environmental Benefits of Sustainable Concrete

The negative environmental impacts of concrete can be reduced by incorporating sustainable strategies which utilize the advantageous properties of concrete while reducing carbon production and water use. These strategies include:

- Implementing cement production techniques using renewable energy, biofuels, or other alternatives to fossil fuels.
- Reducing cement content by using supplementary cementitious material (fly ash, slag, silica fume) in concrete mixes. Supplementary cementitious materials (SCMs) are industrial by-products used as partial replacements of clinker in cements or Portland cement in concrete mixtures that provide strength and durability to cement applications.
- Reducing 'virgin' aggregate extraction with suitable locally-sourced recycled material, including recycled concrete aggregate, to conserve resources and reduce pollution from aggregate production.
- Reducing freshwater use via grey or recycled water and admixtures, which improves workability and reduces water demand to curtail the burden on our water supply.
- Implementing innovative structural design building systems that use less structural concrete, which may reduce as much as 40% of the total CO₂ emissions created during construction.

Future Advancements in Concrete

Concrete uses approximately 7-15% cement by weight, varying by performance requirements. Numerous promising advances are being developed which are expected to further reduce negative environmental impact, as well as the percent of CO₂ produced during manufacturing,² including:

- **Carbon Capture:** Carbon capture involves capturing emissions from concrete production before they enter the earth's atmosphere and storing the CO₂ either in the concrete or in geologic reservoirs.
- **Ultra High-Performance Concrete:** Ultra high-performance concrete adds fibers to the concrete mixture to improve strength, resulting in designs utilizing less volume of concrete.
- **Carbon Sink Additives:** Concrete admixtures in development will increase the atmospheric carbon absorbed in concrete.³
- **Artificial Intelligence Modeling:** Artificial intelligence (AI) is utilized to develop low-CO₂ concrete mixes. An AI model generates and analyzes various concrete formulas much faster than traditional methods. Adjustments are made in the model for variables such as local material availability and cold-weather conditions.⁴

Conclusion

Concrete will continue to be essential to structures that support our daily lives, so it is critical to mitigate its environmental impact. Innovative methods for reducing CO₂ production, such as carbon capture that turns carbon emissions into solid mineral for use in concrete, will help ensure that concrete remains a viable construction material. In order to increase the widespread adoption of sustainable concrete, proponents must seek to raise awareness of its environmental benefits and how they are worth initial higher costs, and the industry must continue to develop additional eco-friendly materials and production techniques.⁵ We remain optimistic for the future of sustainable concrete as experts in the concrete industry are working toward energy-efficient cement production facilities, transportation systems, and construction methods.

References

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