The Path To What's Next

Craig W. Hargis, Fortera, shows how performance-based standards and carbon mineralisation technology are enabling low-carbon cement to move from innovation to large-scale commercial deployment.

As global demand for infrastructure accelerates, the cement industry faces increasing pressure to reduce its carbon footprint without compromising performance, cost, or scale. While a range of low-carbon cement technologies has emerged, widespread adoption has been constrained by limitations in standardisation, infrastructure compatibility, and real-world validation. This article examines the role of performance-based specifications, carbon mineralisation pathways, and operational deployment in advancing low-carbon cement technologies. A case study of Fortera's ReAct® cement, certified to meet all six categories of ASTM C1157, is presented as an example of how emerging systems can align with existing industry requirements while enabling meaningful emissions reductions. The discussion highlights best practices for adoption and outlines how the industry can transition from pilot-scale innovation to full commercial deployment.

The imperative to decarbonise cement

Cement production contributes approximately 7% of global CO_2 emissions, making it one of the most carbon-intensive industrial sectors. Emissions arise from two primary sources: the calcination of limestone and the high-thermal energy required for clinker production. Efforts to decarbonise cement have focused on several strategies: clinker substitution using supplementary cementitious materials (SCMs), alternative fuels, electrification, carbon capture, utilisation, and storage (CCUS), and the development of alternative cement chemistries.

While these approaches offer incremental progress, each presents limitations in scalability, availability, or compatibility with existing systems. The next phase of industry transformation requires solutions that integrate with current infrastructure while delivering measurable performance and emissions reductions.

Performance-based standards as a catalyst for innovation

A critical enabler for low-carbon cement adoption is the transition from prescriptive to performance-based standards. ASTM International specification C1157 evaluates cement based on performance outcomes rather than chemical composition. The standard assesses key properties, including compressive strength, set time, heat of hydration, sulfate resistance, expansion characteristics, air content, density, and chemical composition. ASTM C1157 defines six performance categories: General Use (GU), High Early Strength (HE), Moderate Sulfate Resistance (MS), High Sulfate Resistance (HS), Moderate Heat of Hydration (MH), and Low Heat of Hydration (LH).

Historically, achieving these categories has required multiple cement formulations, increasing complexity in procurement, mix design, and field application. Performance-based standards, however, enable innovative materials to compete on outcomes, opening the door for advanced cement systems to enter the market.

Table 1. Standard physical properties of ReAct Cement compared to ASTM requirements.

Parameter	ReAct® cement	C1157 requirement
Fineness		
Blaine, C204 (m²/kg)	523	Report
45 µm (No. 325) sieve, C430 (passing %)	100	Report
Density, C188 (g/cm³)	2.54	Report
Heat of hydration, C1702 (kJ/kg)		
3 days	22.1	≤ 200
7 days	22.1	≤ 225
Time of setting, C191 (min)		
Initial	320	≥ 45 & ≤ 420
Air content of mortar volume, C185 (%)	5.2	≤ 12
Compressive strength, C109 (MPa)		
1 day	24.5	12
3 days	27.4	13
7 days	26.7	20
28 days	29	28
Mortar bar expansion at 14 days, C1038 (%)	0.004	≤ 0.020
Sulfate expansion, C1012 (%)		
6 months	0.02	0.05
12 months	0.02	0.10

Carbon mineralisation and next-generation cement production

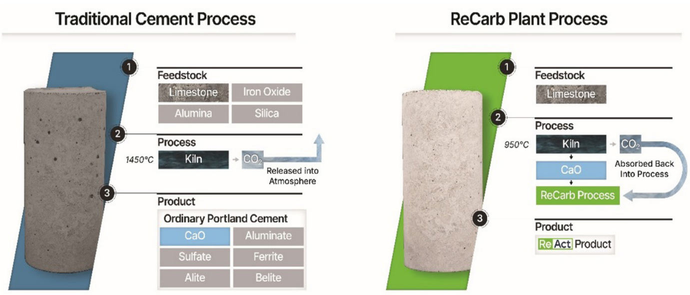
Carbon mineralisation represents a promising pathway for reducing emissions in cement production. Unlike traditional clinker-based processes, mineralisation converts CO_2 into mineral phases that can be used directly in cementitious systems. In these systems, calcium-bearing materials are reacted with CO_2, CO_2, is mineralised into calcium carbonate structures, and the resulting material contributes to strength development and durability.

Fortera has developed a commercial approach through its ReCarb® process, which integrates with existing cement and lime plants to transform industrial CO_2 emissions into a usable cementitious material. Key characteristics of this approach include: operation at lower temperatures than conventional cement kilns, which eases the pathway to process electrification, and utilisation of CO_2 as a feedstock rather than a byproduct. Integration with existing infrastructure enables a more practical pathway to scale compared to technologies requiring entirely new production systems.

Case study: a multi-category cement

A recent advancement in low-carbon cement technology is the development of a single cement formulation that is capable of meeting all six ASTM C1157 performance categories simultaneously. Fortera's ReAct Cement has been independently validated to meet all performance and compositional requirements defined by ASTM C1157. Testing confirmed compliance across compressive strength development, setting time, heat of hydration, sulfate resistance, dimensional stability, and durability metrics (Table 1). This represents a notable departure from traditional portland cement systems, which typically require multiple formulations to meet these diverse performance requirements.

Scaling up ReAct Cement testing.



Traditional cement production process compared to the ReCarb Plant Process.

Performance characteristics

ReAct Cement has accelerated strength development. It achieves compressive strength comparable to 28-day portland cement strengths within approximately 2 days. This rapid strength gain can reduce formwork cycles, accelerate construction schedules, and improve project efficiency.

In addition to rapid strength development, ReAct Cement has superior chemical durability because it is the first hydraulic cement to be thermodynamically stable after hardening. This translates to the cement demonstrating resistance to chemical attacks by chlorides and sulfates and other degradation mechanisms, supporting long-term infrastructure performance. Due to its different pore structure, ReAct Cement has greater dimensional stability. Its low drying shrinkage reduces cracking potential, enhancing structural durability over time.

ReAct Cement makes thermal control plans a thing of the past. The cement releases approximately 22 kJ/kg, which is over 10x less heat evolved than portland cement. This gives it the ability to meet both moderate and low heat of hydration requirements, enabling the same cement to be used across a wide range of applications, including mass concrete and structural elements.

Operational and commercial implications

The ability to deploy a single cement across multiple performance categories reduces inventory complexity, risk of specification errors, and variability in mix design. For contractors and ready-mix producers, this translates into more efficient operations and greater consistency in field performance.

A key barrier to adoption for many low-carbon technologies is the requirement for new manufacturing infrastructure. In contrast, Fortera's ReCarb process is designed to integrate with existing plants, allowing producers to retain current kilns and assets, utilise existing limestone sources, and leverage established distribution networks. This compatibility reduces capital investment requirements and accelerates the timeline for commercial deployment.

Low-carbon cement systems based on carbon mineralisation can achieve emissions reductions of up to 70%

compared to portland cement. These reductions are driven by lower process temperatures, reduced calcination requirements, and conversion of CO_2 into stable mineral forms. When combined with renewable energy or carbon capture systems, these technologies offer a pathway toward near-zero or net-zero cement production.

Best practices for industry adoption

Robust quality systems are essential for scaling new cement technologies. Fortera supports deployment through ISO 9001:2015 certification and AASHTO-accredited laboratory testing. These certifications ensure consistency, reliability, and alignment with industry expectations.

To accelerate the adoption of low-carbon cement technologies, several best practices have emerged. Specifiers should adopt performance-based specifications and leverage standards such as ASTM C1157 to enable material innovation. During preconstruction, it is critical to align engineers, contractors, and producers during project planning. Engage key stakeholders early and often.

Novel cement technologies need to utilise pilot projects to demonstrate performance through real-world placements. Additionally, technology providers must provide training and support to their customers and contractors. Educating field teams on material placement, finishing, and proper curing procedures is critical to achieve the desired performance characteristics.

From innovation to deployment: building what's next

The cement industry is entering a critical phase in its evolution. The focus is shifting from pilot-scale innovation to large-scale deployment, where performance, cost, and scalability must align. Technologies that integrate with existing infrastructure, meet established standards, and demonstrate field performance are positioned to lead this transition. For Fortera, this transition is encapsulated in a simple principle, 'Build What's Next'. In practice, this means: advancing solutions that work within today's construction ecosystem, delivering measurable emissions reductions without trade-offs, and enabling the industry to scale low-carbon materials globally.

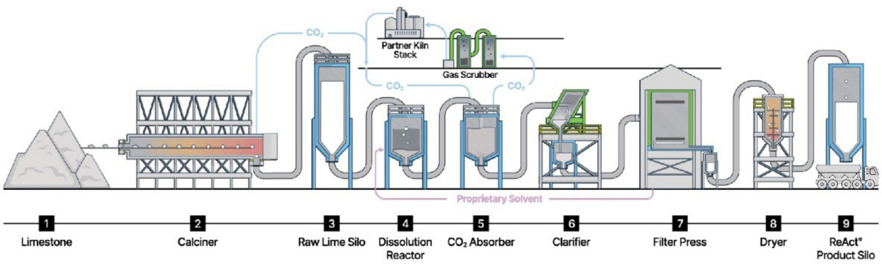
Conclusion

Decarbonising cement requires more than innovation; it requires alignment with the realities of how the industry builds. Performance-based standards such as ASTM C1157 provide a pathway for new materials to compete on measurable outcomes. Carbon mineralisation technologies offer a scalable approach to reducing emissions while maintaining compatibility with existing infrastructure.

The emergence of cement systems capable of meeting all performance categories within a single formulation represents a meaningful step forward. As these technologies continue to be validated in real-world applications, the industry moves closer to achieving its decarbonisation goals.

The challenge ahead is not only to develop new materials, but to deploy them at scale. The next era of cement will be defined not by what is possible in the lab, but by what is proven in the field. The proof is in and on the ground. The scale of success is performance. ■

Fortera ReCarb Plant in Redding California, US.



ReCarb plant process.