Policy Brief

Using carbon-reactive aggregates to reduce emissions in concrete infrastructure

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About the Hub

The Queensland Decarbonisation Hub brings together knowledge, people and innovation to co-create solutions to accelerate Queensland's clean growth future. We connect Queensland universities, industry, communities, First Nations people and government to build and share the knowledge needed to reduce emissions. The Hub's vision is for Queensland to become a leading decarbonised economy in which communities, industry and the environment thrive.

About this policy brief

In 2024, the Queensland Decarbonisation Hub initiated a funded research stream, inviting proposals for research that could contribute to understanding and supporting Queensland's decarbonisation transition. The Hub's Advisory Committee, which brings together representatives from industry and other sectors, helped inform the selection process by identifying areas where research could add value to emerging policy and practice. Eight projects were selected across a diverse range of topics, including the research featured in this brief.

Each project has produced a detailed technical report, which is undergoing review prior to publication. Alongside these reports, the Hub has worked with the research teams to consider a different question: what does the research mean for policy and practice?

This question was explored through a series of workshops and the Hub's Research Showcase, where researchers presented their findings to an audience drawn from government, industry, research and the wider community. These policy briefs build on that process. They are intended as short, accessible companions to the technical reports, highlighting the findings that matter most beyond the research itself and the questions and opportunities they raise for Queensland and Australia more broadly.

About this research

Much of the discussion about decarbonising infrastructure focuses on reducing emissions from energy use, industrial production and construction processes. This research considers a different opportunity by examining whether the materials used to build infrastructure can also contribute to emissions reduction. It explores how incorporating naturally occurring ultramafic minerals into concrete production could increase carbon sequestration while maintaining the engineering performance required for construction.

The study suggests that this approach can be achieved without fundamentally changing established construction practices. Concrete containing dunite minerals performed comparably with conventional mixes while increasing the amount of carbon dioxide stored within the material. This indicates that lower-carbon construction may be supported through improvements to materials that are already widely used across the infrastructure sector.

While further validation under operational conditions will be required, the research broadens the range of options available for reducing emissions from infrastructure. It suggests that construction materials can make a greater contribution to decarbonisation than has traditionally been recognised and provides an evidence base for considering how material innovation could be incorporated into future infrastructure standards, procurement and investment decisions.

Dr Liz Young

Research Director, Queensland Decarbonisation Hub

From the Showcase Session Facilitator

What interested me about this research is that it builds on materials and construction practices that the industry already knows. If replacing a proportion of conventional aggregate in concrete or shotcrete with dunite minerals can reduce emissions without compromising performance, it offers a practical pathway for lower-carbon infrastructure, complementary to other research in low-carbon cement. The next step is demonstrating these benefits through more infrastructure projects that build industry confidence to adopt the approach.

Andrew Chamberlin

Project Manager, Energy, Queensland Farmers' Federation

1. Why this research matters

Concrete and shotcrete are fundamental materials to modern infrastructure worldwide, underpinning tunnelling, mining, transport, and urban development systems. However, these materials are also a major contributor to global greenhouse gas (GHG) emissions, with cement production alone responsible for approximately 7-8% of global CO_2 emissions. As global infrastructure demand continues to rise, reducing the carbon footprint of construction materials has become a pressing challenge for governments, industry, and international climate policy frameworks.

Despite growing interest in low-carbon construction, current approaches to emissions reduction in concrete production remain limited in scale and effectiveness. While concrete can gradually absorb CO_2 through natural carbonation, this process is slow and highly constrained in many engineered environments, particularly underground structures where exposure to atmospheric CO_2 is minimal. At the same time, infrastructure delivery requires materials that meet strict standards for strength, durability, and cost-effectiveness, which limits the practical uptake of many alternative binders and novel formulations. These challenges create a clear global gap between climate ambitions and deployable construction technologies.

This research addresses this gap by investigating whether widely available ultramafic minerals, such as dunite, can be used to transform concrete from a predominantly carbon-emitting material into one that actively sequesters carbon. Dunite is an igneous rock, predominantly composed of the mineral olivine, and is commonly found in the Earth's upper mantle. Given the global distribution of ultramafic resources and the widespread reliance on concrete infrastructure, this approach has the potential for broad international applicability. The project aims to develop a practical pathway for integrating carbon sequestration directly into construction materials, aligning infrastructure development with global decarbonisation objectives while maintaining required engineering performance standards.

2. Key findings

The study shows that replacing up to 50% of conventional aggregate with dunite minerals produces concrete and shotcrete that perform at least as well as standard mixes. Strength at later ages (upwards of 28 days) is slightly higher, while tensile performance, durability, and workability remain stable, indicating that this approach can be adopted without compromising engineering construction requirements.

A clear outcome from the study is that dunite-containing mixes absorb more CO_2 than conventional materials, particularly in the early stages of exposure. Measurements indicate up to 35-40% greater CO_2 penetration at early ages, demonstrating that the material actively enhances carbon uptake rather than relying only on natural slow carbonation.

Importantly, this additional carbon capture occurs not only at the surface but also within the material at the micro-scale. Analysis of the internal structure confirms a higher carbon content in the cement matrix when dunite is used, meaning CO_2 is chemically stored within the material rather than simply passing through it.

The results also indicate that using dunite does not introduce major durability risks under normal conditions. Key indicators such as shrinkage, creep, permeability, and resistance to chemical attack remain comparable to those of standard concrete, with only minor increases in reactivity that remain within accepted limits.

Overall, the findings demonstrate that it is possible to turn a widely used construction material into a functional carbon sink while maintaining performance. This opportunity shifts concrete from being solely a source of emissions to a material that can contribute to emissions reduction over its service life.

3. Why the findings matter in practice

These findings demonstrate that lower-carbon infrastructure can be achieved by adapting existing construction materials and practices rather than relying on disruptive new technologies. For policymakers and infrastructure agencies, this provides a practical pathway to reduce emissions through procurement, design standards, and material specifications. For the industry, it offers an opportunity to deploy materials that meet performance requirements while contributing to decarbonisation objectives.

The broader implication of this study is that construction materials can play an active role in climate mitigation strategies. Applications such as shotcrete, pavements and other non-structural elements could be designed not only to deliver engineering performance, but also to capture and store CO_2 over their service life, helping to reduce the overall carbon footprint of infrastructure development.

4. Who should pay attention

The findings are relevant to **governments and policymakers** because they identify a practical pathway to reduce emissions from infrastructure using existing construction materials and practices. The research can inform procurement policies, emissions reduction strategies, and material standards aimed at accelerating the uptake of low-carbon construction strategies.

Infrastructure owners and delivery agencies in sectors such as transport, mining, energy, and water can use these findings to reduce the carbon footprint of infrastructure projects while maintaining required performance and durability. The approach is particularly relevant for tunnels, underground works, and other applications where shotcrete is widely used.

The **construction and materials industry**—including contractors, engineers, and suppliers—should take note that carbon-reactive aggregates can potentially be incorporated into existing mix designs and construction workflows with limited disruption, creating opportunities for near-term emissions reductions. The research is also relevant to regions with access to ultramafic mineral resources, where new supply chains and economic opportunities could emerge alongside decarbonisation benefits.

Finally, **standard bodies and regulators** play an important role in supporting adoption through the development of guidance, testing protocols, and specifications that enable the safe and effective use of carbon-reactive materials in construction.

5. What could happen next

The next step priority is to move from laboratory validation to pilot and demonstration projects in real infrastructure settings. Field trials in applications such as tunnelling, mining, and other shotcrete-intensive environments would provide critical evidence on performance, durability, and carbon sequestration under operational conditions, helping to build confidence among asset owners, contractors, and regulators.

There is also a need to develop practical guidance, standards and specifications to support safe and effective deployment. This includes identifying suitable applications, establishing performance requirements, and integrating carbon-reactive materials into existing design, procurement and regulatory frameworks. Such measures would enable governments and infrastructure agencies to begin incorporating these materials into low-carbon construction strategies.

Further research should focus on long-term durability, fire performance, reinforced concrete applications, and behaviour under a range of environmental conditions. Expanding testing across different aggregate sources, mix designs and construction scenarios will strengthen the evidence base and support broader adoption.

Achieving large-scale impact will require collaboration between governments, industry, infrastructure owners, and research organisations. Coordinated efforts across material supply chains, construction practice, standards development, and decarbonisation policy can accelerate the transition from promising research outcomes to practical low-carbon infrastructure solutions.

6. Points to note

These findings demonstrate strong potential but should be interpreted within the scope of the study. Results are based on laboratory-scale testing under controlled conditions, and performance will require validation under real-world construction, curing and exposure environments. While enhanced CO_2 uptake has been demonstrated, the full life-cycle carbon benefits have not yet been quantified. Further research is also needed to assess long-term performance in reinforced concrete applications, including potential implications for steel corrosion. Finally, broader testing across different aggregate sources, mix designs and operating conditions will be required to confirm the scalability and general applicability of the approach.

7. Contact

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