permacast

Pathways to Low-Carbon,
High-Performance Green Concrete

# Implementing Circular Economy Principles in WA Concrete Production


**Corresponding Author**

Colin Davies General Manager of Sustainability & ESG

ReGen Strategic Level 3, 34 Parliament Place, West Perth 6005 Australia

colin@regenstrategic.com.au

Written on behalf of Permacast (394 Robertson Rd, Cardup WA 6123)



## Abstract

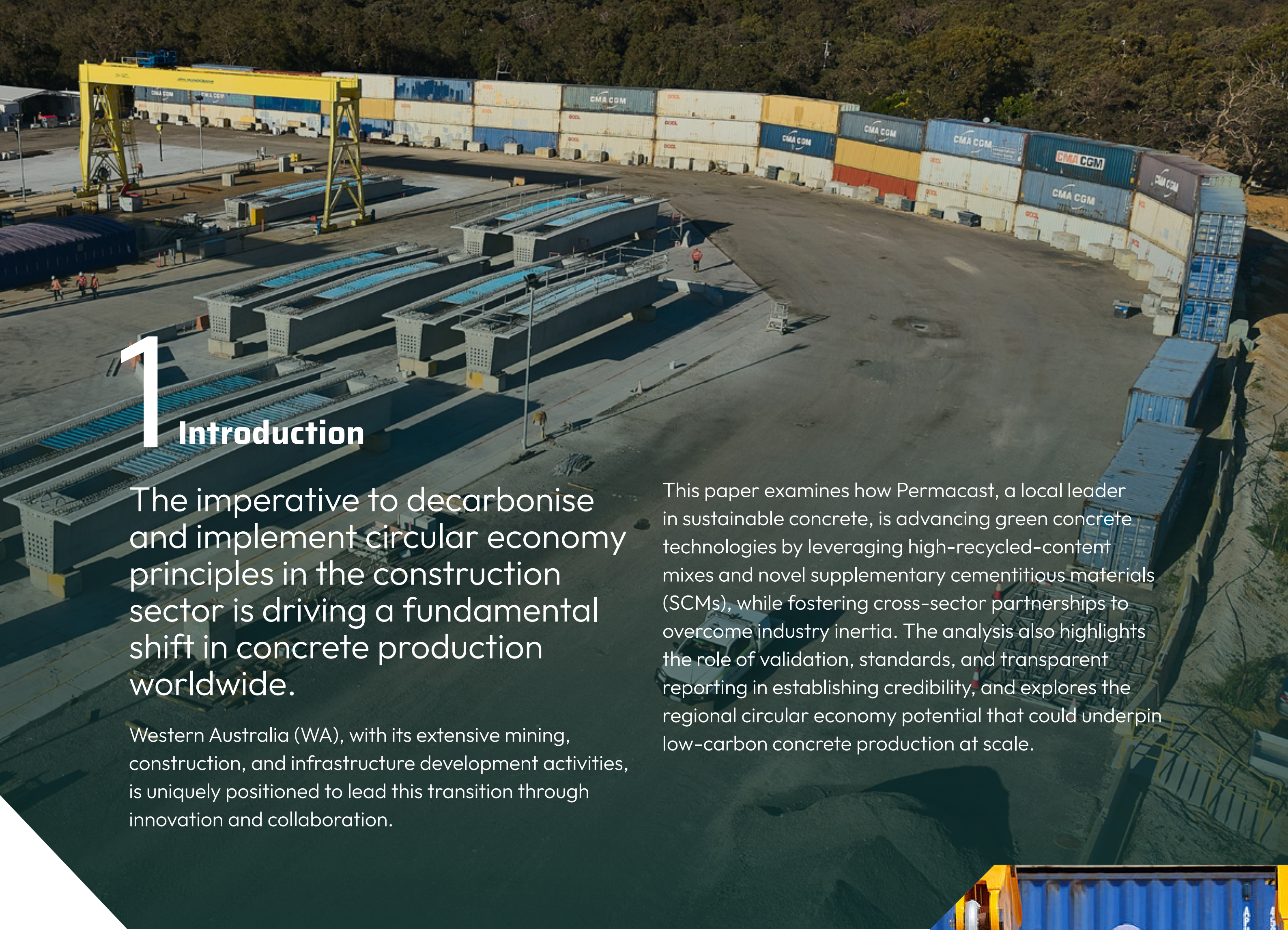
This paper explores the advancement of sustainable concrete production in Western Australia, focusing on the innovation, collaboration, and circular economy potential necessary to decarbonise the construction sector. With concrete responsible for a significant share of embodied carbon emissions, transitioning to low-carbon alternatives is imperative. Permacast, a regional industry leader, has pioneered high-recycled-content concrete mixes utilising locally sourced industrial by-products, including delithiated beta spodumene (DBS), to reduce clinker dependency and associated emissions.

Through rigorous testing, adherence to national and international standards, and cross-sector collaboration with academia, government, and industry partners, these innovations demonstrate technical feasibility and economic viability. This paper highlights the challenges of industry inertia and policy gaps in Western Australia, advocating for enhanced validation protocols, transparent reporting, and policy support to accelerate adoption. Emphasising the region's abundant waste streams, it articulates the transformative potential of a circular economy approach that fosters local resource utilisation, reduces environmental impact, and strengthens supply chains. Ultimately, this paper underscores that integrated innovation and leadership, underpinned by collaborative ecosystems and systemic change, are essential to achieve sustainable, low-carbon concrete production that aligns with Western Australia's (WA) climate and economic goals.



## Keywords

- Low carbon concrete
- Decarbonisation
- Circular economy
- Embodied carbon emissions
- Recycled materials
- Geo-polymer concrete
- Green concrete



# 1 Introduction

## The imperative to decarbonise and implement circular economy principles in the construction sector is driving a fundamental shift in concrete production worldwide.

Western Australia (WA), with its extensive mining, construction, and infrastructure development activities, is uniquely positioned to lead this transition through innovation and collaboration.

This paper examines how Permacast, a local leader in sustainable concrete, is advancing green concrete technologies by leveraging high-recycled-content mixes and novel supplementary cementitious materials (SCMs), while fostering cross-sector partnerships to overcome industry inertia. The analysis also highlights the role of validation, standards, and transparent reporting in establishing credibility, and explores the regional circular economy potential that could underpin low-carbon concrete production at scale.

# 2 Context and Challenges in Western Australia's Concrete Sector

The traditional concrete industry remains heavily reliant on Portland cement, which accounts for the majority of concrete's embodied carbon emission – approximately 0.9 tonnes of $CO_2$ per tonne of cement produced (Gursel et al., 2014; Scrivener et al., 2018). Despite strategic policy frameworks such as the Waste Avoidance and Resource Recovery Strategy 2030 (WARRS, 2030), enforceable mandates to incentivise or require low-carbon concrete alternatives are currently lacking in WA (Waste Authority WA, 2024). This regulatory gap, coupled with the construction sector's conservative culture and risk aversion, hinders widespread adoption of greener mixes.

Concurrently, WA generates significant volumes of industrial and construction waste, presenting an untapped resource pool for circular economy initiatives (Maruthupandian & Kanellopoulos, 2023). However, paradoxical practices such as exporting and importing waste-derived materials contribute to inefficiencies and missed opportunities to reduce emissions and foster local economic development.

# 3 Innovation and First-Mover Advantage

The pursuit of low-carbon and circular concrete solutions requires practical, large-scale innovation. Permacast has positioned itself as a pioneer by developing concrete mixes incorporating up to 40% recycled materials, despite the absence of strong government mandates in WA.

## Technical Innovation in High-Recycled Concrete Mixes

To reduce clinker dependency and associated emissions, alternative raw materials are being explored. Wollastonite ($CaSiO_3$), a calcium silicate mineral, offers potential as a clinker substitute without $CO_2$ release during calcination; however, its limited availability in Australia restricts its applicability.

Instead, Permacast focuses on replacing clinker with SCMs derived from recycled aggregates, industrial by-products such as fly ash and delithiated beta spodumene (DBS), mining tailings, and construction demolition waste (CDW) aggregates. These components reduce carbon footprint while diverting waste from landfill or export. Traditional SCMs such as fly ash and slag have proven effective but face supply constraints due to coal plant closures and limited slag availability (Khan et al., 2020).

Permacast is developing two parallel concrete types: geopolymer concretes using locally sourced precursors, and low-carbon concretes partially replacing clinker with new SCMs from industrial by-products. Notably, WA's lithium industry is projected to produce ~3.5 million tonnes per annum of DBS by 2035, offering a promising locally available SCM (Permacast, 2025). Experimental mixes containing 30–40% DBS combined with limestone fillers have demonstrated comparable strength and durability to conventional concrete and have been formally recognised under AS 3582.4:2022 – Manufactured Pozzolans.

## Overcoming Industry Inertia

Construction's conservative nature, driven by regulatory compliance and liability concerns, often impedes innovation adoption. Permacast addresses this by rigorously benchmarking recycled-content mixes against established standards and project criteria, investing heavily in testing protocols to build stakeholder confidence.

By demonstrating both technical feasibility and economic viability, Permacast's leadership fosters momentum for policy evolution, encouraging a shift from prescriptive specifications to performance-based outcomes favouring greener alternatives.

## Technical Protocols and Validation

Extensive laboratory and precast scale testing confirm the promising performance of Permacast's mixes, benchmarked against GP/GB concretes using AS 1012 test methods for slump, compressive strength, and workability. Early-age strength, setting time, and finish quality have met or exceeded requirements, supporting practical application in precast elements such as noise walls and barriers.

Carbonation testing indicates stable alkalinity levels (>12.3 pH) in specimens over 90 days old, while further durability assessments (chloride ingress, sulfate resistance, shrinkage, corrosion) are underway. Independent research and Cement Australia testing corroborate the durability of lithium by-product SCMs. International studies show mechanically activated tailings with finer particle size enhance pozzolanic reactivity, informing Permacast's material processing strategies (Ramanathan et al., 2021).

## Benefits of Being First

Permacast's first-mover status delivers reputational, strategic, and operational advantages. Early adoption strengthens supply chains, testing infrastructure, and certification pathways, enabling collaboration with academia and certification bodies to refine standards and pursue eco-labelling.

This leadership role supports systemic change, helping to shift industry norms and expectations toward sustainable concrete adoption across WA.

# 4 Cross-Sector Collaboration for Sustainable Concrete

## Achieving a sustainable concrete sector requires coordinated efforts spanning academia, industry, government, and standards bodies.

Academic research at institutions including Murdoch and RMIT universities complements Permacast's innovation by investigating pozzolanic reactivity of mining tailings, blend optimisation, and long-term durability under real-world conditions. This scientific foundation validates structural and environmental performance of high-recycled-content concrete.

Private contractors, material suppliers, and public agencies such as the Department of Transport collaborate in pilot deployments and field testing, facilitating practical scale-up. Regulatory and certification bodies like Good Environmental Choice Australia (GECA) play a critical role in ensuring environmental and performance standards through Environmental Product Declarations (EPDs) and Life Cycle Assessments (LCAs). An example of this is the joint venture partnership between Permacast and Green360 Technologies who have collaborated to successfully produce a low carbon concrete noise panel wall.

The low carbon noise wall panel was designed to reduce GHG emissions from large-scale civil infrastructure. The panel incorporates a proprietary blend that replaces 35% of traditional Portland cement with an industrial by-product. Taking the panel's sustainability credentials even further, Permacast also sequestered captured carbon within mix. This was made possible through a partnership with KAPTURE, whose novel carbon capture technology extracted CO2 emissions directly from diesel generator exhausts and converted them into stable sediment and incorporated into the mix, locking it away. The mix targeted a design strength of 40 megapascals (MPa) but exceeded expectations, delivering 64MPa after 28 days of curing proving it to be a commercially viable, high-performance product ready for large scale deployment.

Veteran industry leaders, such as Peter Trinder, contribute valuable expertise, supporting sustainable practices integration into education, policy, and norms. Local councils and procurement agencies, including Serpentine-Jarrahdale, help validate green concrete through early demonstration projects, generating data and demand to influence broader procurement specifications.

Together, this collaborative ecosystem enables co-design, testing, validation, and monitoring necessary to transition green concrete from concept to widespread practice. Permacast's leadership in convening this network ensures sustainable materials are both scientifically sound and economically viable for WA infrastructure.

# 5 Policy, Risk, and Industry Leadership

In WA's current regulatory landscape, industry leadership is pivotal given the absence of binding sustainability mandates. While the Waste Avoidance and Resource Recovery Strategy 2030 (WARRS, 2030) outlines strategic waste reduction goals, its voluntary nature reduces uptake (Waste Authority WA, 2024).

Voluntary initiatives exemplified by the joint venture between Suvo Strategic Minerals and Permacast however, accelerate geopolymer concrete commercialisation. This partnership includes deploying low-carbon concrete in foundation works for 500 wind turbines, generating critical validation at scale and building technical and economic confidence (Concrete Institute of Australia, 2024; The West Australian, 2025).

Systemic change also requires policy evolution - mandating EPDs, lifecycle carbon thresholds in public contracts, and financial incentives for supply chain innovation would hasten adoption. Concurrently, ongoing leadership demonstrating cost-effective, reliable green concrete through transparent pilots and third-party validation remains essential.

The interplay of voluntary leadership and policy alignment offers the most viable pathway. Industry pioneers such as Permacast demonstrate potential; coordinated public-private actions can establish these approaches as new norms.

# 6 Validation, Standards, and Transparency

Credible validation, rigorous standards, and transparent reporting underpin trust and widespread adoption of low-carbon concrete. Without independent benchmarks, sustainability claims risk 'greenwashing', undermining confidence.

Permacast targets compliance with standards including AS 1379 - Specification and supply of concrete, Main Roads WA Specification 820 - Concrete for structures, and PTA Specification 8880-450-021 - Concrete durability. EPDs and LCAs remain indispensable for distinguishing genuinely low-carbon products by providing third-party verified environmental impact data (GECA, 2023).

International emissions intensity targets for "green" cement vary from 0.437 $tCO_2e/t$ under the Climate Bonds Initiative to more ambitious thresholds (0.04–0.125 $tCO_2e/t$) proposed by the IEA and Industrial Deep Decarbonisation Initiative (IEA & IDDI, 2023). The US Buy Clean Colorado standard allows up to 1.11 $tCO_2e/t$, illustrating jurisdictional variation (US GSA, 2024).

Australia trails behind global best practices, with voluntary and unevenly adopted certifications creating a patchwork lacking comparability and transparency (GECA, 2023). To address this, green concrete leaders must make performance visible and verifiable through product-specific EPDs, third-party audits, and documented materials provenance.

Permacast is advancing verified carbon declarations based on actual supply chain data, aligning with international calls for science-based, technology-neutral methodologies (WTO, 2022). This transparency positions early adopters to benefit from emerging carbon credit markets, green procurement, and climate-linked financing.

Ultimately, technical innovation must be matched by rigorous validation to build trust among regulators, clients, and the public, enabling confident decarbonisation progress.

# 7 Local Impact and Circular Economy Potential in Western Australia

WA's abundant industrial waste streams and expanding infrastructure pipeline create a compelling opportunity to lead circular, low-carbon concrete development. Present practices of exporting and importing waste-derived construction materials introduce inefficiencies and missed economic and environmental benefits.

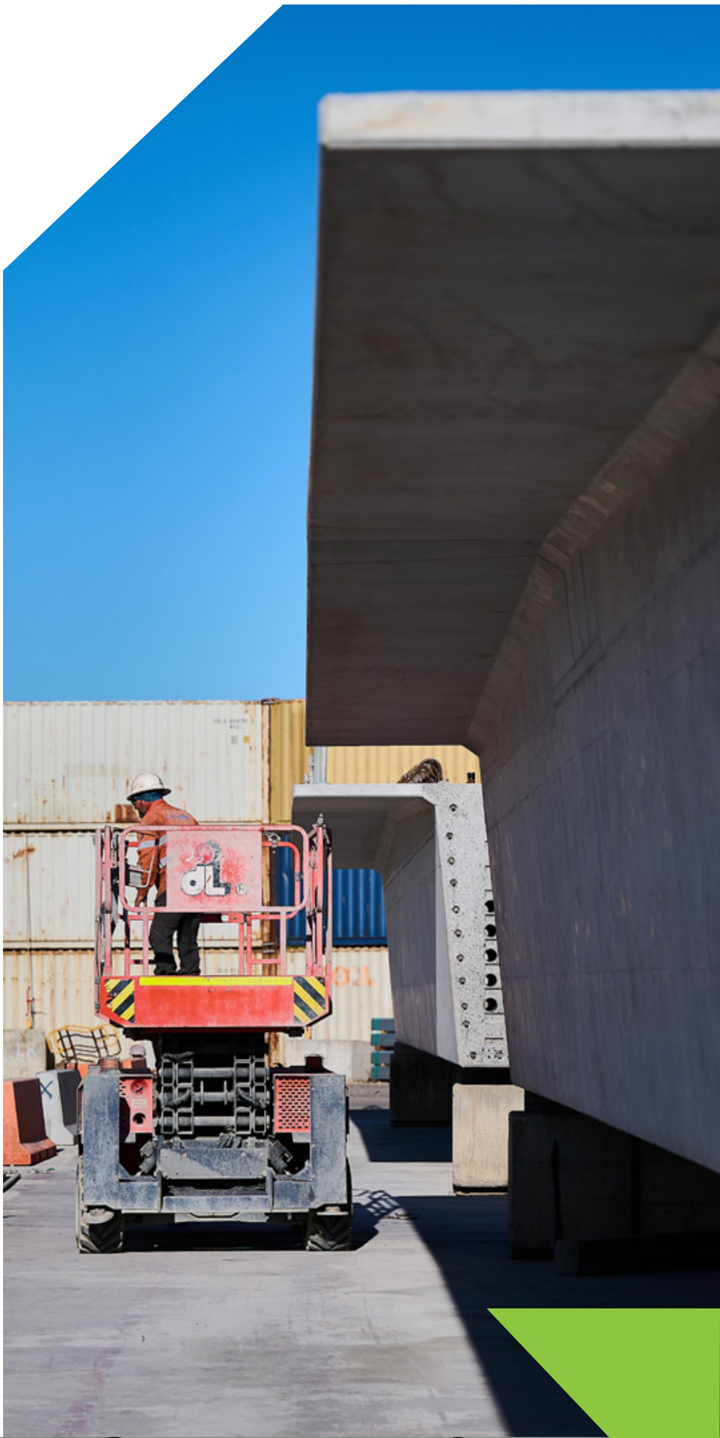
The cement industry's heavy reliance on Portland cement drives significant emissions, estimated at nearly 8% of global $CO_2$ output (Gursel et al., 2014; Scrivener et al., 2018). Substituting cement with local industrial by-products like DBS offers a pathway to substantial emissions reduction and regional self-sufficiency. Preliminary estimates indicate Permacast's mixes with ~30% DBS substitution can achieve 20–25% embodied carbon reductions, pending verification against industry baselines.

A circular concrete economy would also reduce transportation emissions and costs, create markets for previously wasted materials, and relieve environmental pressures on natural resources such as river sand and limestone. Permacast's high-replacement mixes, informed by scientific research and local resource mapping, provide a model for state-wide and national replication.

Public agencies including Main Roads WA, Department of Transport, and Public Transport Authority stand to gain from adopting regionally optimised, low-carbon products, which offer competitive advantages under evolving sustainability procurement requirements.

Aligned with the "Use WA" ethos, this approach champions full lifecycle value creation beyond procurement, emphasising sustainability and regional identity. Leveraging waste as resource enables a transition from linear to circular models, reducing emissions, cutting costs, and strengthening local industry resilience.

Realising this potential requires deliberate collaboration, supportive policies, and leadership. The technical capability and materials exist - the challenge is cultivating the collective will to act.



# 8 Conclusion

The journey toward a sustainable, low-carbon concrete industry in Western Australia is both a technical and systemic challenge that demands innovation, collaboration, and leadership. As demonstrated throughout this paper, Permacast's pioneering efforts in developing high-recycled-content concrete mixes, utilising locally sourced industrial by-products such as DBS, and advancing geopolymer technologies have established a strong foundation for transforming the sector. These innovations not only reduce embodied carbon significantly but also offer practical, scalable solutions aligned with regional resource availability and infrastructure needs.

Technical innovation alone is insufficient. The transition to sustainable concrete requires a cohesive ecosystem involving academia, industry practitioners, government agencies, and regulatory bodies to validate, standardise, and promote green concrete technologies. Through rigorous testing, adherence to recognised standards, transparent reporting, and third-party certification, stakeholders can build the trust necessary to overcome industry inertia and integrate low-carbon materials into mainstream construction practices.

Moreover, proactive industry leadership, exemplified by strategic partnerships and voluntary initiatives, is crucial in the current policy environment where binding mandates remain limited. By setting precedents in performance, economic viability, and environmental stewardship, early adopters like Permacast pave the way for broader regulatory evolution and market transformation.

Western Australia's abundant waste streams and industrial by-products present a unique opportunity to pioneer a circular economy within the concrete sector. By closing material loops and reducing reliance on virgin resources, the region can achieve significant environmental benefits while stimulating local economic growth. The "Use WA" philosophy embodies this vision by encouraging full lifecycle value creation and regional resilience.

In conclusion, the path to decarbonising concrete production in WA is clear but requires collective will and coordinated action. The technical capability and resource inputs exist; the imperative now is for sustained commitment from all stakeholders to realise the full potential of green concrete, thereby contributing meaningfully to climate goals and sustainable infrastructure development.

## References


Adeed Khan, M., Fahim, S., Ahmad, F., & Ullah, R., 2020. A comprehensive review on the development of green concrete. Materials Today: *Proceedings*, 28, pp.1925-1930.

Concrete Institute of Australia, 2024. *Sustainability in Concrete Construction*. Canberra: Concrete Institute of Australia.

Ellen MacArthur Foundation, 2019. *Completing the Picture*: *How the Circular Economy Tackles Climate Change*. Cowes: Ellen MacArthur Foundation.

Geissdoerfer, M., Savaget, P., Bocken, N.M.P., & Hultink, E.J., 2017. The Circular Economy – A new sustainability paradigm? *Journal of Cleaner Production*, 143, pp.757-768.

GECA, 2023. *Environmental Certification for Building Materials*. Melbourne: Good Environmental Choice Australia.

Gursel, A.P., Masanet, E., Horvath, A., & Stadel, A., 2014. Life-cycle inventory analysis of concrete production: A critical review. *Cement and Concrete Composites*, 51, pp.38-48.

Habert, G., & Roussel, N., 2019. A scientific and technical review of greener concrete and its application in practice. *Green Materials*, 7(1), pp.1-19.

IEA & IDDI, 2023. *Low Carbon Cement and Concrete Roadmap*. Paris: International Energy Agency & Industrial Deep Decarbonisation Initiative.

Khan, A., et al., 2020. Environmental impact of concrete production and recent innovations in sustainability. *Journal of Sustainable Construction*, 12(3), pp.45-58.

Kumar, R., & Kumar, N., 2020. Utilization of industrial waste in green concrete: A review. *Construction and Building Materials,* 230, 117019.

Maruthupandian, A., & Kanellopoulos, A., 2023. Advances in circular economy practices in the concrete industry. *Resources, Conservation and Recycling*, 186, 106590.

Mylapilli, R., & Venkatesan, S., 2021. Green concrete: A sustainable material for the future. *International Journal of Environmental Science and Technology*, 18, pp.123-136.

Permacast internal brief, 2025. *Sustainable Concrete Production in Western Australia.* Perth: Permacast.

Ramanathan, S., Kumaravel, V., & Rajendran, S., 2021. Enhancing durability and sustainability of green concrete: A comprehensive review. *Construction and Building Materials,* 276, 122235.

Siddique, R., 2011. Utilisation of industrial by-products in concrete. *Resources, Conservation and Recycling,* 55(11), pp.923-932.

Sureshkumar, P., Ashok, B., & Subramanian, A., 2019. Barriers and opportunities for green concrete in India. *Journal of Cleaner Production*, 234, pp.1403-1411.

The West Australian, 2025. *Local Innovation in Sustainable Concrete.* Perth: The West Australian.

UNEP, 2021. *Global Status Report for Buildings and Construction.* Nairobi: United Nations Environment Programme.

WARRS, 2030. *Waste Avoidance and Resource Recovery Strategy.* Perth: Government of Western Australia.

Waste Authority WA, 2024. *Waste Material Management in Western Australia.* Perth: Waste Authority WA.

WTO, 2022. *Global Trade and Sustainable Practices Report.* Geneva: World Trade Organization.

US GSA, 2024. *Buy Clean Initiative: Low-Carbon Concrete Standards.* Washington, D.C.: U.S. General Services Administration.


permacast