Low-carbon engineered concretes

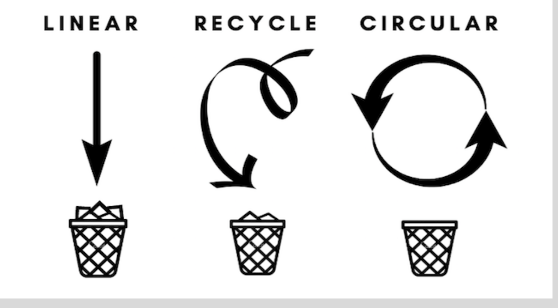
Product information

THE UNIVERSITY OF SYDNEY

Transitioning local councils to the circular economy

Local councils have the opportunity to utilise recycled materials in their roads and pavements, as part of the transition to the circular economy.

This is achieved through the application of the principle of "designing out waste" and maximising material resource value while in use (Ellen MacArthur Foundation, 2013).



Depiction of a linear, recycling and circular economy
image source: lowwastewellness.com)

In doing so, councils will contribute to various United Nations Sustainable Development Goals and align with the principles of the 2018 National Waste Policy.

The growing circular solution, despite its multi-faceted complexities, will create new circular businesses in NSW impacting positively on the future of waste in NSW.

To help guide decision making in the transition to a circular economy, the NSW government has developed:

- "Too Good to Waste", a discussion paper on a circular economy approach for NSW (NSW EPA, Oct 2018); and
- NSW Circular Economy Policy Statement paper (NSW EPA, Feb 2019)

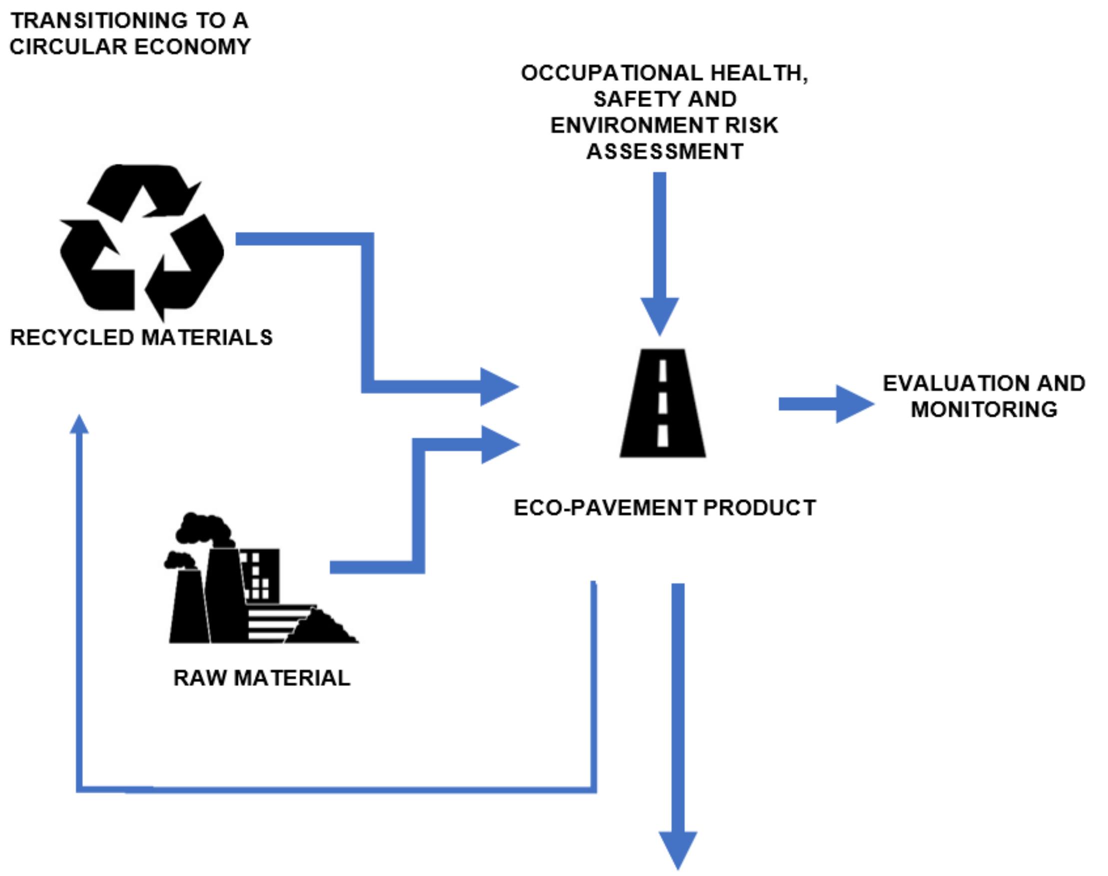
The circular economy life cycle
(image source: Too Good to waste discussion paper, pg. 15 (NSW EPA, Oct 2018))

Advanced low-carbon engineered concretes

Recycled materials in roads and pavements

Objectives

To increase the use of recycled materials by local councils and promote good practice in the specification and application of material reuse in roads and pavements by local council engineers.



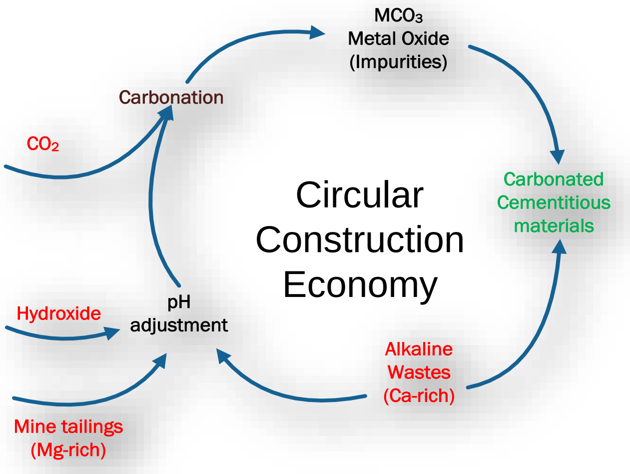
Advanced low-carbon engineered concretes

Recycled materials in roads and pavements

A preview of our product

Our product combines fly ash and waste glass to replace cement, sand and coarse aggregates. Our products upcycle these materials in concrete creating an environmentally friendly product range with low-carbon footprint, without sacrificing strength.

A key innovation is to also incorporate CO2 into the concrete mix, which locks away carbon dioxide into a stable mineral form, before otherwise entering the atmosphere.



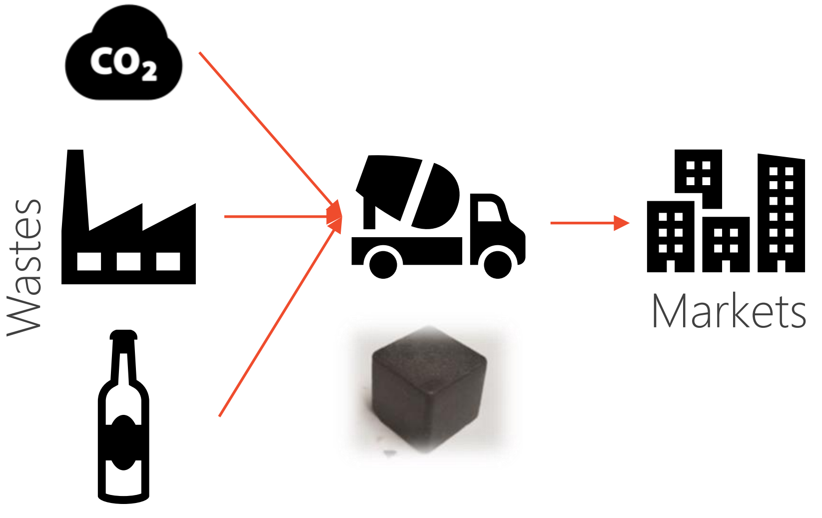
A preview of our product

Application: small- or large-scale concrete pavements for footpaths (light or heavy load)

Mix ingredients: Sand, cement, fly ash, glass, carbonated compound, water, plasticier

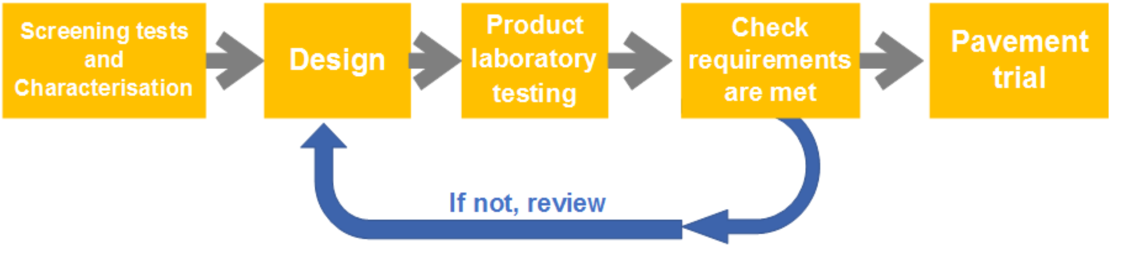
Recycled Materials used:
Carbonated fly ash, mixed Ground Waste Glass (GWG)

- Utilises fly ash and waste glass as replacements of cement and fine aggregate, and optimises compositions to maximise waste incorporation whilst maintaining adequate strength.
- To develop eco-pavements suitable for foot or heavy load traffic.



Design Requirements

- a minimum concrete design strength of 20MPa at 28 days (AS 2870);
- concrete with ability to flow under its weight and adequately fill the formwork;
- Utilises fly ash and waste glass in the replacement of OPC and other aggregate material;
- Utilises carbon dioxide as carbonated material to further reduce carbon footprint
- No leaching of cement stabilised waste.



Design Process & Methodology

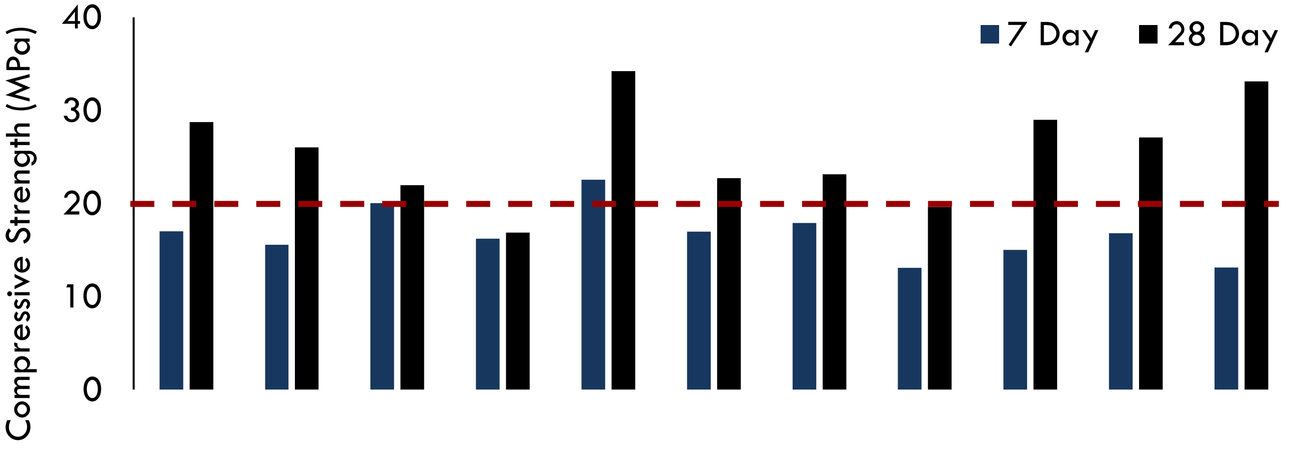
A preview of our product

Material Characterisation

- X-Ray Fluorescence (XRF) values
  - Portland Cement: calcium oxide (64%) and silicate (20%)
  - Fly Ash: silicate (58%) and aluminate (26%)
  - GWG: silicate (70%) and calcium oxide (11%)

Laboratory Product Testing

Ultimate Compressive Strength: The final product with fly ash replacing up to 60% portland cement exceeded minimum strength criteria (i.e. greater than 20MPa at 28 days).



A preview of our product

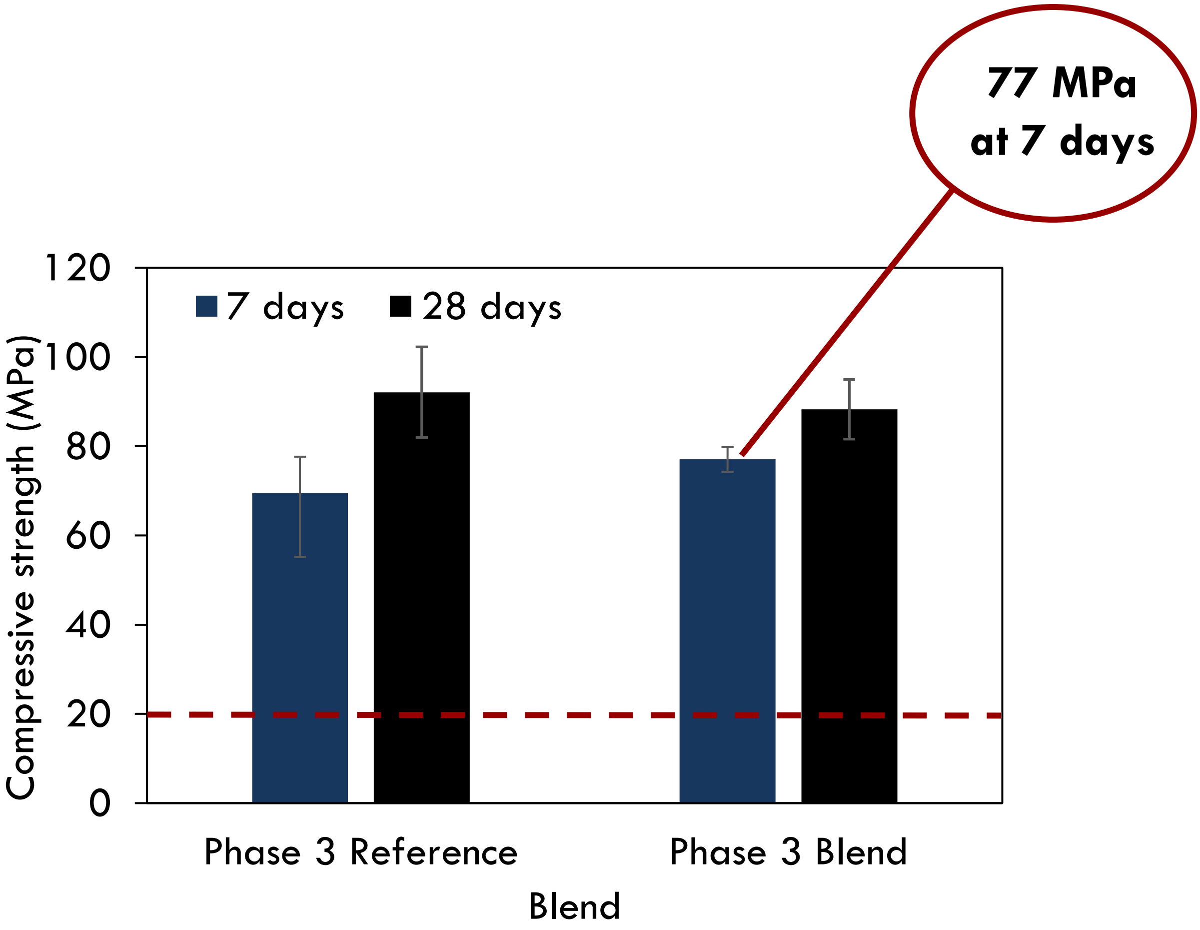
A high-strength low-carbon concrete

Ultimate Compressive Strength: The final product withstood greater than:

- 75 MPa at 7 days
- 80 Mpa at 28 days

Applications beyond pavements in vertical and load bearing infrastructure

Photograph of an eco-concrete sample, after 7 days compressive strength testing



A preview of our product

Relevant standards

Our eco-pavement products are designed and constructed in accordance with Australian Standards for general concrete blends and pavements. The standards used are:

- AS 1012:2014 Methods of testing concrete:
  - Method 8.1: Method for making and curing concrete- compressive and indirect tensile test specimens
  - Method 9: Compressive strength tests – concrete, mortar and grout specimens
  - Method 18: Determination of setting time of fresh concrete, mortar and grout by penetration resistance
  - Method 21: Methods of testing concrete determination of water absorption and apparent volume of permeable voids in hardened concrete
- AS 1141.5-2000 Methods for sampling and testing aggregates particle density and water absorption of fine aggregate
- AS 1141.60.1:2014 Methods for sampling and testing aggregates Potential alkali-silica reactivity - Accelerated mortar bar method
- AS/NZS 2350.4:2006 Methods of testing portland, blended and masonry cements Setting time
- AS 2758.1 Aggregates and rocks for engineering purposes - Concrete aggregates
- AS 2870-2011 Residential slabs and footings
- AS 3600-2018 Concrete structure
- AS 3727.1:2016 Pavements residential
- AS 3972-2010 General-purpose and blended cements
- AS 4439.3-1997 Wastes, sediments and contaminated soils preparation of leachates - bottle leaching procedures
- ASTM C109/C109M - 16a Standard Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or [50-mm] Cube Specimens)

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Eco-pavement trials

Eco-pavement trials are currently being conducted on selected areas of the university campus.

These trials use laboratory tested low-carbon engineered eco-pavement concrete products.

Carbonated fly ash and mixed ground waste glass were incorporated into concrete, with the final product exceeding the minimum compressive strength criteria for footpath applications (i.e. greater than 20MPa at 28 days).

In order to use the laboratory product as a pavement trial, considerations of scale up were made by accounting for material quantities and environmental performance.

The recycled materials incorporated into our eco-pavement products comply with the relevant legislations governing material reuse. The key legislative documents for the regulation of waste in NSW are the Protection of the Environment Operations Act 1997 (POEO Act) and the Protection of the Environment Operations (Waste) Regulation 2014 (Waste Regulation) (NSW EPA, 2017a).

- One pavement trial installed and monitoring underway.
- Two further trials in preparation on campus
- Two trials in preparation at local councils

A preview of our product

Eco-pavement trials
Results from our first ecopavement trial have so far demonstrated the quality and durability of the eco-pavement concrete product under field conditions.






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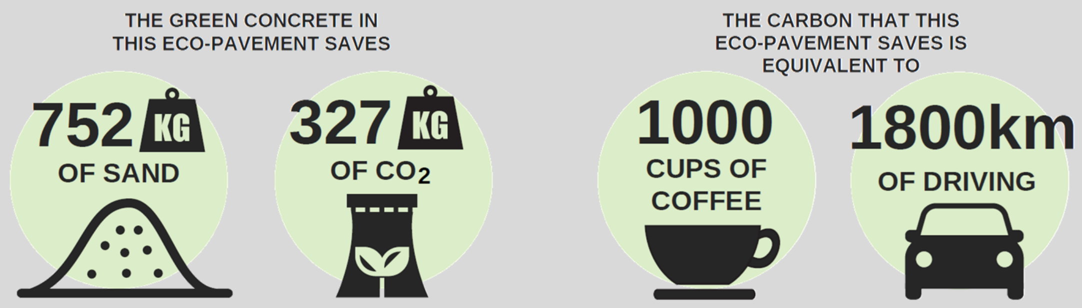
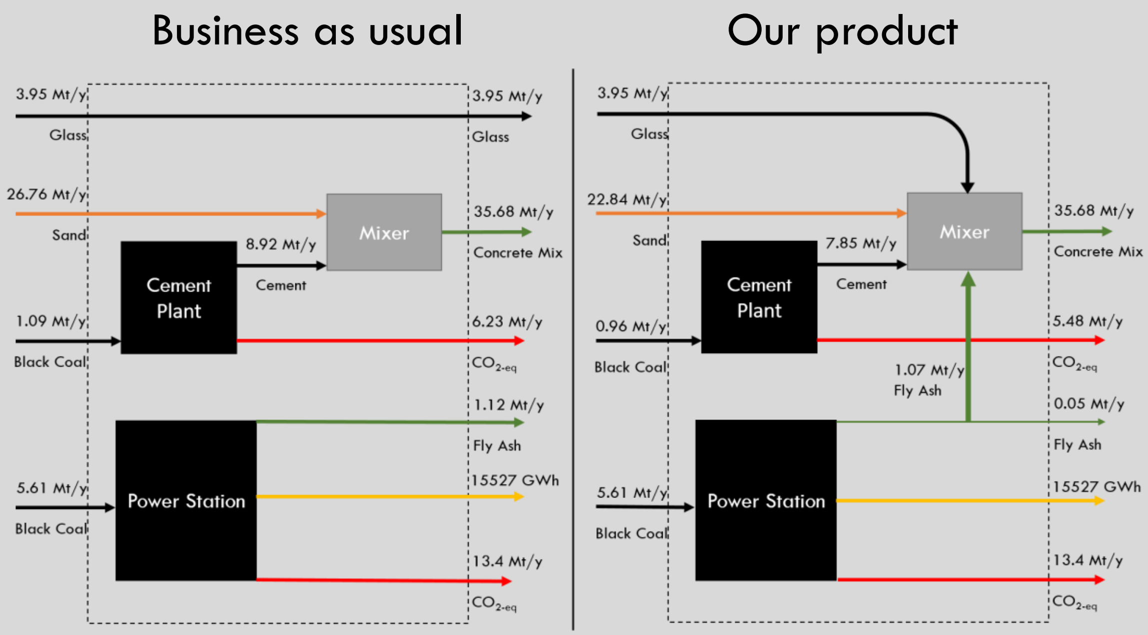
Environmental performance





Beyond the eco-pavement trials:

The technical success of our products so far is being tested for scale-up, environmental and economic performance. The eco-pavement trials will ascertain:

- Environmental footprint
- Life cycle assessment (LCA) of our product providing cradle-to-cradle evaluation
- Economics of our production pathway and ultimately its cost advantage
- Certification of our product for council applications
- Certification of our product with authorities Transport for NSW
- Scale-up through technology transfer agreement to a local trusted civil engineering company to deliver our product to market, and in partnership with local councils.

Engineered and backed by world class research

WASTE TRANSFORMATION RESEARCH HUB

The Waste Transformation Research Hub at the University of Sydney

The Waste Transformation Research Hub (WTRH) was formalised in 2016 within the School of Chemical and Biomolecular Engineering at USYD with the aim to build research capacity at the University and beyond in transformative waste research and innovations. The WTRH provides consulting services to various industries including those in the waste, energy, water, foods and minerals sectors.

A key thrust of the WTRH activities is its industry engagement and partnerships with more than 60 companies within its network, with several multi-national companies. The WTRH fosters relationships with NSW Government organisations including with the Office of the Chief Scientist and Engineer, the Office of Environment and Heritage, the NSW EPA, LGNSW and local councils.

Expertise in process industries: Industrial plant operators have benefited from our research and detailed investigations into improving process efficiencies and materials recoveries, as well as understanding process carbon emissions and life cycle environmental impacts. Hundreds of thousands of dollars in savings have been captured by our industry clients/partners through our engagements in the waste, paper, power, renewable energy, pharmaceutical and chemicals industries.

The Faculty of Engineering and Information Technologies

The University of Sydney’s Faculty of Engineering and Information Technologies is ranked first in Australia and top 100 in the world for Chemical Engineering in the QS World University Rankings. The University also placed first in Australia and fourth in the world for graduate employability.

School of Chemical and Biomolecular Engineering

The School of Chemical and Biomolecular Engineering was the first to offer a tertiary chemical engineering program in Australia. It is committed to excellence in teaching and research in chemical engineering, biochemical engineering and biotechnology, energy and environment, green product and process design, minerals processing, process systems engineering, and sustainability.

With a focus on food, energy, health, water and the environment, the School engages with industry, government and the community to support researchers and educate aspiring engineers as they endeavour to solve today’s pressing issues.

The WTRH at the University of Sydney is building research capacity critical to advancing new circular economy solutions in engineering that impacts population sustainability, food use and production, healthcare, and our understanding of climate change.

Engineered and backed by world class research

Academic profile: Associate Professor Ali Abbas

Director of the Laboratory for Multiscale Systems
Director of the Waste Transformation Research Hub
School of Chemical and Biomolecular Engineering

"I am very passionate about applying science and engineering to solving challenging sustainability problems that make impact on communities and peoples' lives.

Traditional concrete production is energy and resource intensive, yet is one of the most common materials used by the construction industry. Our R&D aims at developing a less energy-intensive solution that would have less impact on the environment using carbon-capture and beneficially reusing materials that would otherwise end up in landfill."

An ideal ecosystem for success

As director of the Waste Transformation Research Hub, Professor Abbas brings together expertise from industry, researchers and leading academics to jointly contribute to transforming Australia's waste industry.

Professor Abbas leads a team of researchers and students to develop new technologies that transform waste materials into energy and other high-value products. Using a whole-systems approach, Professor Abbas aims to understand the causes and effects of interactions between resource extraction, materials production, and product processing in conjunction with minimal waste. This effort and concerted activity sets Professor Abbas as a leading authority in the implementation of the circular economy in Australia.

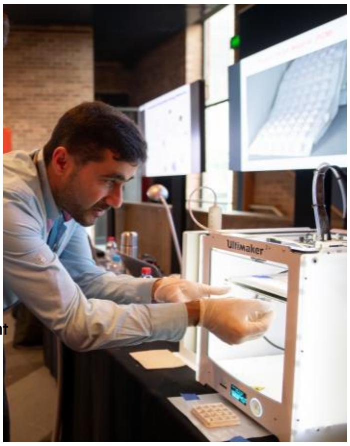
Industrial waste

Associate Professor Abbas's team are processing waste products from one or more industries (power generation, mining, steel, glass, aluminum, agricultural) into various useful materials such as construction industry products. The goal of this research is to identify novel and large-scale circular routes for converting carbonated blends of industrial waste, and novel product formulations of construction materials with targeted specially properties.

Impact of research in society

Our research is translating the circular economy into practice through the development of core technology for future sustainable development, while continuing to deal with existing waste and pollution challenges.

Being able to reprocess industrial waste products into useful products such as building materials is an important area of waste minimisation. Our research is directly impacting our society's grand waste problems by developing novel and large-scale waste recovery options. This positively impacts our health and environment through the removal of contaminants and the reduction of greenhouse gas emissions.



Professor Abbas has developed processes to transform fly-ash into a new cement blend (above), utilising fly ash, carbon dioxide and glass wastes to produce future eco-pavement products and sustainable construction materials. Using advanced manufacturing techniques (3D printing) (right)

For more information
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