CONCRETE FUTURES

Futurebuild 2023

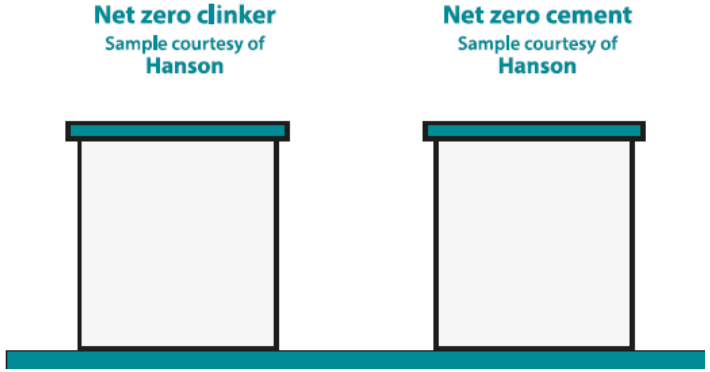
Innovative and low carbon concrete display

ACTUAL DISPLAY

WALL DISPLAY

WALL DISPLAY – and related samples

Samples on wall



Project to establish potential of producing low carbon cements using waste-derived clays in the UK

Project partners: MPA, Hanson, Imerys, Tarmac, University College London, University of Dundee and Forterra Building Products.

The project is part-funded under the UKRI's Industrial Strategy Challenge Fund, sponsored by Innovate UK.

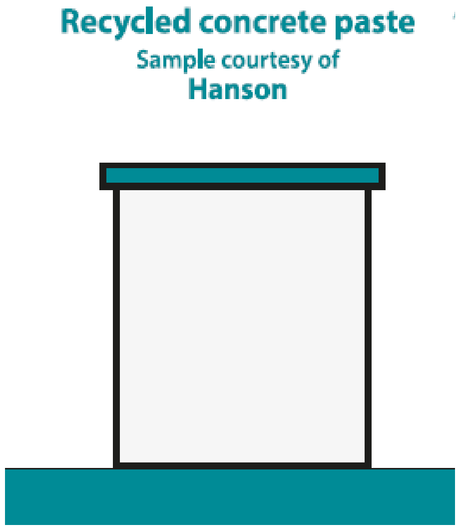
Samples on wall

Calcined clay from ground waste brick
Sample courtesy of
Forterra

UK-sourced ground clays prior to calcination
Samples courtesy of
Imreys, Hanson and Tarmac and Dundee University

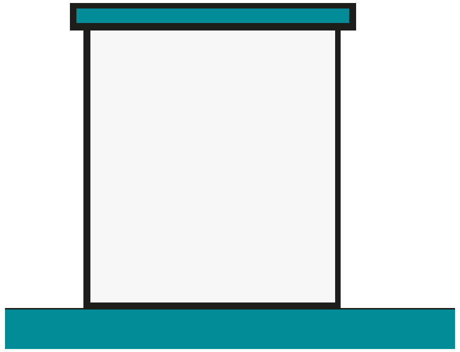
Coal derived fly ash
Sample courtesy of
UKQAA/University of Dundee

Sample on wall



Sample on wall

100% recycled clinker
Sample courtesy of
Aggregate Industries/Holcim



Samples on Innovation table

Carbonation

The speed of carbonation depends on multiple factors, such as the concrete strength, porosity, and exposure.

Mortar, precast concrete blocks and foamed concrete carbonate rapidly, whereas reinforced concrete structures are typically designed to carbonate slowly, to protect the steel rebar.

At the end of life, crushing increases the exposed surface area of the concrete, so carbonation speeds up.

Laboratory testing can show how carbonation progresses over time using a pink dye. The dye becomes colourless if the concrete has already carbonated. Concrete that has not yet carbonated remains pink.

Foamed concrete – fully carbonated within months *Sample courtesy of University of Dundee*

28 year old concrete – partially carbonated *Sample courtesy of University of Dundee*

Samples

No sample available
as sections are very large!

Is an illustration of innovation taking place within industry and supported by industry to provide lower carbon concrete products.

Many other examples included in the display.

Eg:

'Circular' lightweight aggregate

Manufactured using waste materials and by-products.

Block pavers made using this aggregate was a finalist of the Earthshot Prize 2022.

Sample Courtesy of Low Carbon Materials & Aggregate Industries

On the wall and / or innovation table

Recycled tyres

Otherwise hard to recycle, tyres, tyre chips and tyre fluff are all used as alternative fuels. The waste steel within the tyres is upcycled, contributing useful iron content for cement manufacture.

Sample courtesy of Tarmac

Refuse derived fuels (RDF)

This non-recyclable household and business waste is diverted from landfill and processed to produce a clean, non-hazardous alternative fuel that is used at every UK cement plant.

Sample courtesy of ClimaFuel

Pelletised sewage

This renewable energy source is a biofuel, produced from sewage sludge. It is already used at several UK cement plants as a fossil fuel replacement.

Sample courtesy of Tarmac

Meat and bone meal (MBM)

This 100% carbon neutral fuel has a significant calorific value. It was recently used alongside glycerin and hydrogen in a world-first demonstration of a cement kiln main burner successfully using a 100% net zero fuel mix.

Sample courtesy of Hanson

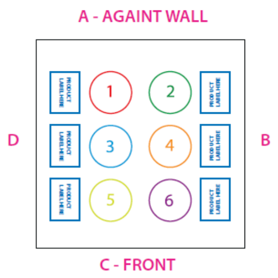
Glycerin

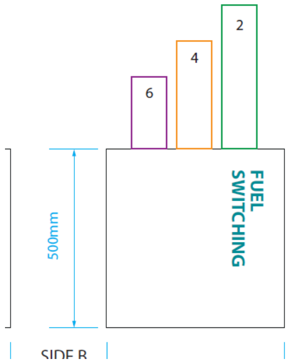
A by-product of the bio-diesel industry, this 100% carbon neutral, alternative fuel was used alongside meat and bone meal and hydrogen in a world-first demonstration of a cement kiln main burner operating using 100% net zero fuel.

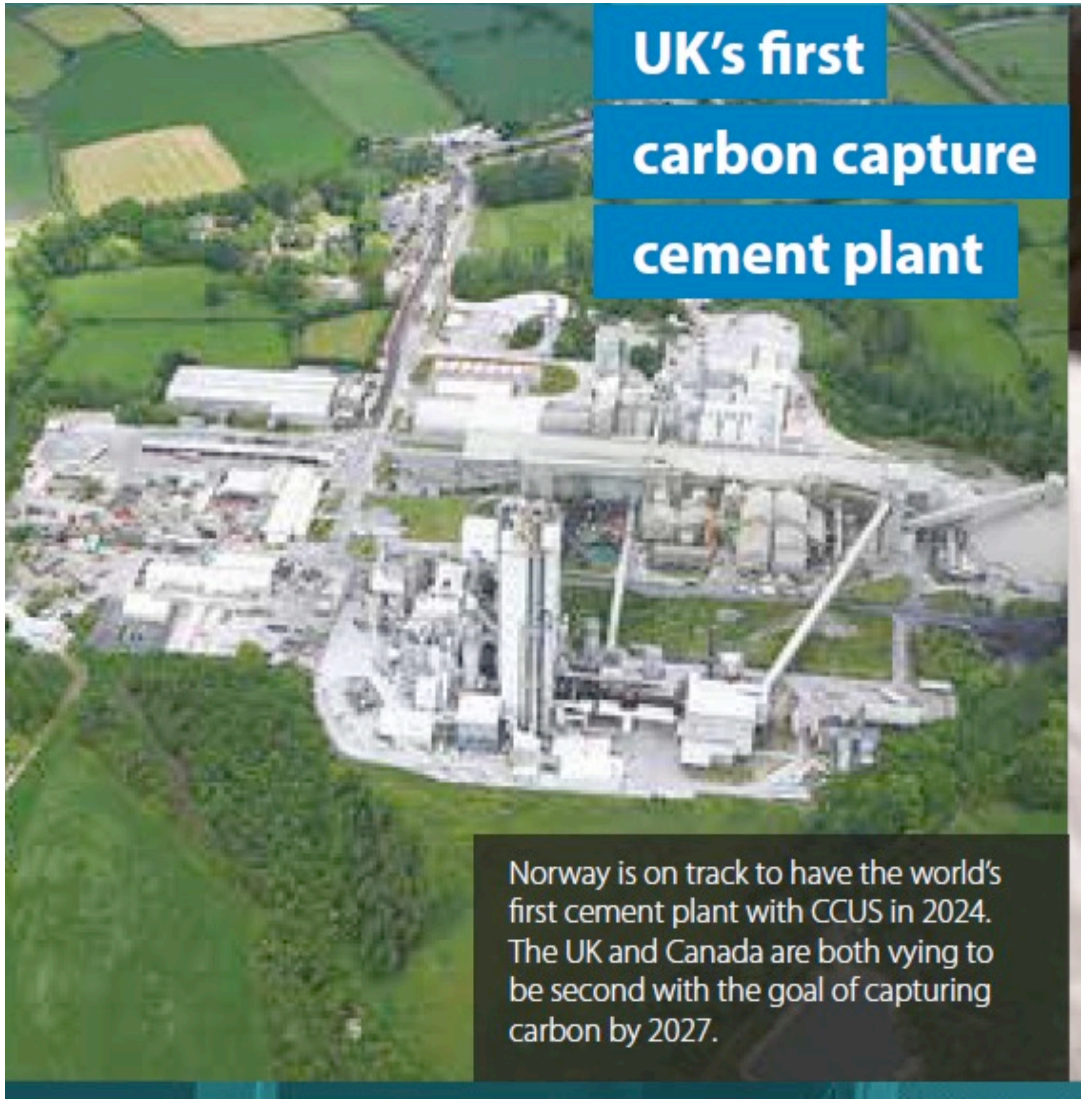
Polyurethane (PUR)

Waste rigid polyurethane foam containing impurities is recycled through co-processing into cement.

Sample courtesy of Breedon







Main article in Magazine

Carbon utilisation samples on Innovation table

INNOVATION TABLE

Carbon storage using concrete

The research and development of new uses and methods for storing carbon dioxide, captured from cement manufacture, includes using concrete itself as a permanent carbon sink.

The process of carbonation can be accelerated and enhanced, enabling more CO_2 to be absorbed into the concrete earlier, as part of new or adapted manufacturing process.

Carbon mineralisation is the process of combining waste products with captured CO_2 to create carbon-negative aggregates and is another example of the permanent storage of carbon in concrete.

INNOVATION TABLE

Carbon storage using concrete

Carbon capture

Low carbon concrete containing aggregate manufactured from cement residues that permanently capture CO_2 from the cement plant's flue gas.

Sample courtesy of Carbon8 Systems

Carbon sequestering aggregate

An innovative lightweight aggregate for use in concrete blocks, created from waste materials and CO_2.

Sample courtesy of O.C.O Technology Limited and Carbon8 Systems

CO_2 utilisation in ready-mixed concrete

Ready-mixed concrete using minerals manufactured by combining CO_2 and reclaimed residues from wash out water.

Sample courtesy of CarbonCure

Carbon negative concrete using biochar

Achieved using a biochar-CEM I composite that sequesters carbon. Sometimes known as Char-crete.

Sample courtesy, CREST, South West College, Enniskillen, N.I

Carbon capturing SCM

Concrete made using an innovative SCM that captures CO2 in the process of manufacture.

Samples courtesy of Karbonite ®

Carbon capturing precast concrete

Precast concrete that has been factory cured with CO_2. The cement uses less energy to manufacture than conventional Portland Cement.

Sample courtesy of Solidia

Carbon capturing cementitious material

Concrete made using a carbon capturing cement based on olivine and bio-waste.

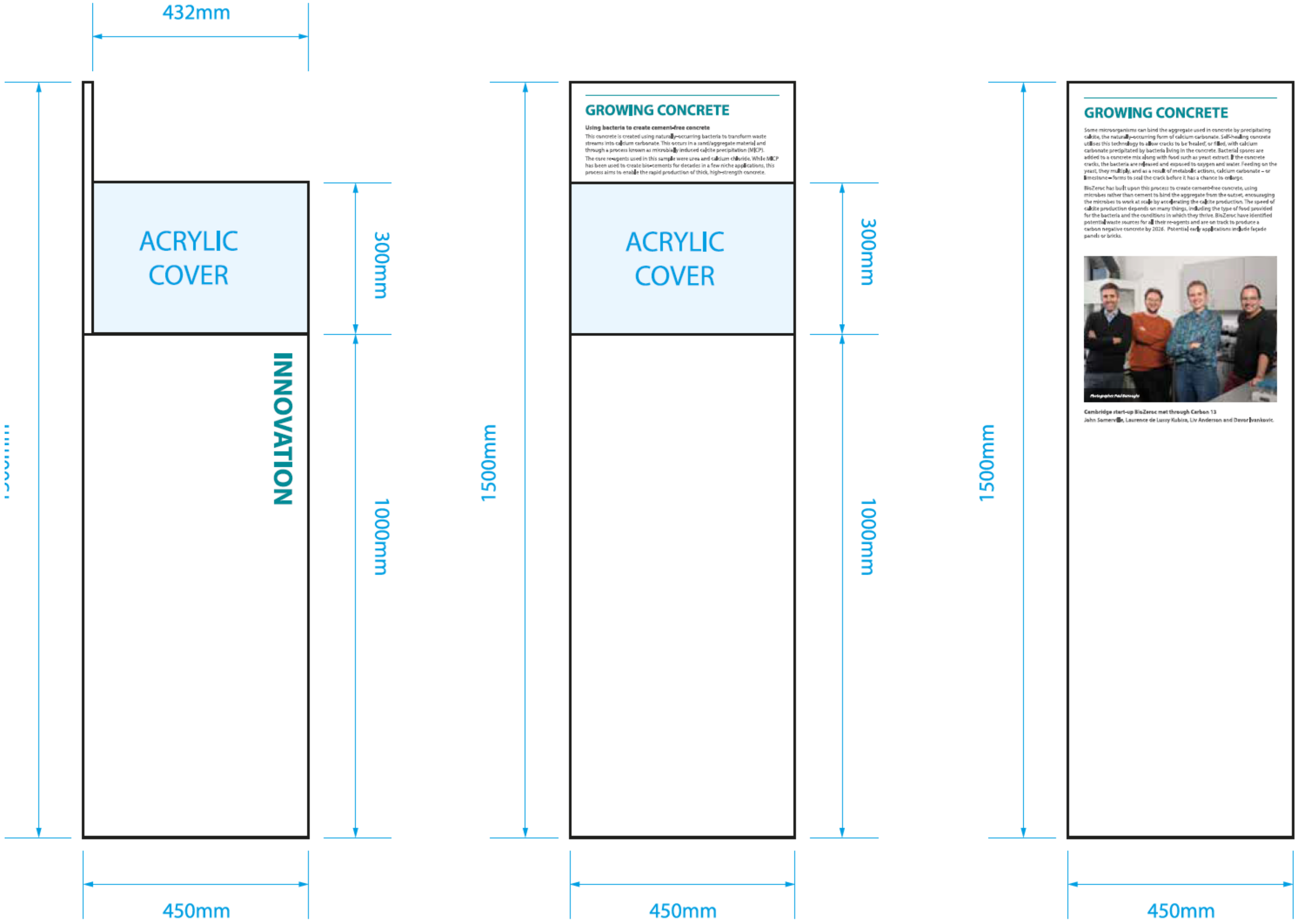
Samples courtesy of Karbonite ®

Carbon sequestering concrete

A 60MPa strength concrete made using a developing technology that sequesters CO_2 as part of the manufacturing process.

Sample courtesy of Concrete4Change Ltd. (C4C)

Illuminated plinths: INNOVATION



GROWING CONCRETE

Using bacteria to create cement-free concrete

This concrete is created using naturally-occurring bacteria to transform waste streams into calcium carbonate. This occurs in a sand/aggregate material and through a process known as microbially induced calcite precipitation (MICP).

The core re-agents used in this sample were urea and calcium chloride. While MICP has been used to create bio-cements for decades in a few niche applications, this process aims to enable the rapid production of thick, high-strength concrete.

Samples

Display key:

1 Grown concrete

2 Re-agents urea and calcium chloride

3 Base aggregates
Samples courtesy of BioZeroc

GROWING CONCRETE

Some microorganisms can bind the aggregate used in concrete by precipitating calcite, the naturally-occurring form of calcium carbonate. Self-healing concrete utilises this technology to allow cracks to be 'healed', or filled, with calcium carbonate precipitated by bacteria living in the concrete. Bacterial spores are added to a concrete mix along with food such as yeast extract. If the concrete cracks, the bacteria are released and exposed to oxygen and water. Feeding on the yeast, they multiply, and as a result of metabolic actions, calcium carbonate – or limestone – forms to seal the crack before it has a chance to enlarge.

BioZeroc has built upon this process to create cement-free concrete, using microbes rather than cement to bind the aggregate from the outset, encouraging the microbes to work at scale by accelerating the calcite production. The speed of calcite production depends on many things, including the type of food provided for the bacteria and the conditions in which they thrive. BioZeroc have identified potential waste sources for all their re-agents and are on track to produce a carbon negative concrete by 2026. Potential early applications include façade panels or bricks.

Photographer: Paul Burroughs

Cambridge start-up BioZeroc met through Carbon 13
John Somerville, Laurence de Lussy Kubisa, Liv Anderson and Davor Ivankovic.

CEMENT FROM CONCRETE DEMOLITION WASTE

Recycling concrete to produce a new cement with no process emissions

A new way of manufacturing cement has been created using concrete waste from the demolition of old buildings. 'Used cement' powder is separated from the concrete's aggregates through crushing. Its chemistry is very close to that of the lime-flux used in conventional steel recycling processes. The results are both recycled steel and a liquid slag that can be rapidly air-cooled and ground into a powder for use as a cement.

Samples

Display key:

1 Recycled crushed concrete aggregate, sourced from construction and demolition waste

2 'Used cement' powder, produced through the separation process

3 Recycled concrete aggregate, a by-product of the separation process

4 New 'Electric' slag

5 New 'Electric' cement

6 Concrete made using the new 'Electric' cement

Samples courtesy of Cambridge Electric Cement

CEMENT FROM CONCRETE DEMOLITION WASTE

This new manufacturing technique combines steel and cement recycling processes and has been patented by three engineers based at Cambridge University. Their small scale trials have demonstrated that that the chemical composition of the resultant clinker is virtually identical to the clinker used to create Portland Cement.

The new cement, called Cambridge Electric Cement, could therefore be made in a virtuous recycling loop, and using renewable energy for the manufacture, could eliminate the emissions almost entirely. The process also saves raw materials and reduces the emissions required in making the lime-flux for steel recycling.

Innovate UK funding has been awarded to trial the product at industry scale. This Cement 2 Zero project will investigate both the technical and commercial aspects of upscaling Cambridge Electric Cement production to produce 20 tonnes of zero-emissions cement. The project is supported by the Materials Processing Institute, The University of Cambridge and key supply chain partners: Tarmac, CELSA, Balfour Beatty, Atkins, Brewster Brothers and Day Aggregates.

Celsa's Electric Arc Furnace facility, Cardiff
Photographer: Dr Pippa Horton

Cambridge Electric Cement was developed by Cambridge University based engineers Dr Cyrille Dunant, Dr Pippa Horton and Professor Julian Allwood.

CARBON NEUTRAL CONCRETE

Olivine based carbon-negative supplementary cementitious material (SCM)

New technology has been developed that utilises captured industrial carbon dioxide emissions to produce a carbon-negative SCM and magnesium carbonate compound, also for use in construction products. The engineered pozzolan, or silica powder, can be added to concrete as an SCM to produce a carbon-neutral, or potentially even carbon-negative concrete. The base material is olivine - an abundant mineral known in its purest crystalline form as peridot - a natural form of magnesium silicate.

Samples

Display key:

1 Olivine powder

2 Engineered silica SCM

3 Magnesium carbonate

4 Brick made from magnesium carbonate

5 Concrete using Seratech SCM

Samples courtesy of Seratech

CARBON NEUTRAL CONCRETE

Replacing cementitious materials with a carbon-negative alternative could enable carbon-neutral concrete without making any changes to the construction process. The innovative technology developed by Seratech includes a carbon mineralisation process offering a safe and permanent form of carbon storage.

Replacing about 35% of the Portland Cement with this carbon-negative, engineered pozzolan could achieve carbon-neutral concrete. No adjustment to plant or machinery should be needed for its use in precast or in-situ concrete and laboratory tests indicate that curing times and strengths are similar to a standard concrete.

The Seratech technology has been in development since late 2020, established by staff and researchers based at Imperial College London. The team has since been accepted into the climate-tech accelerator, The Greenhouse, founded by The Centre for Climate Change Innovation and The Royal Institution, and has been awarded grants to assist the development of the process and products.

Photographer: Paul Burroughs

Seratech evolved from research at Imperial College London

Sam Draper and Barney Shanks.

SUPPORTING BIODIVERSITY

Attracting sea life to concrete

This low carbon, ultra-high-performance concrete is shaped to encourage natural shore life and support marine biodiversity.

The Mumbles Sea-Hive features 13 flexible formwork textures used to cast the 50% GGBS concrete, including two tailor-made oyster shell textures. After six months, periwinkles, limpets and up to 1,000 barnacles had colonised individual hexagons. The project was developed with residents and is part of the SEACAMS2 and ECOSTRUCTURE research projects to develop sea defences for Swansea Bay, Wales and beyond.

Sample courtesy of BlueMarine Cube Ltd

(Left) Recently installed.
(Right) Eight months after installation.
Images courtesy of Ruth Callaway

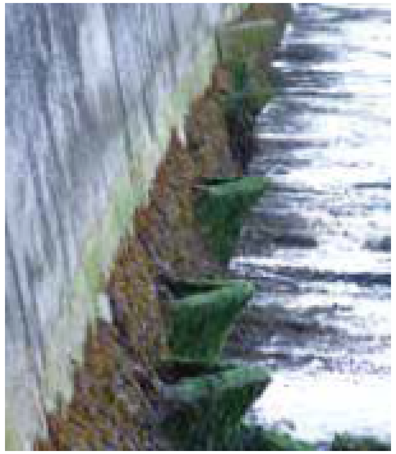
Sample

Enhancing river flood defences

These 'NatureBricks™' are individually crafted using low carbon concrete to provide a variety of resources for different plants and insects linked to local ecology.

They have been successfully used to form part of the new vertical flood defences on the River Lugg, providing holes for invertebrates, texture for mosses and lichens and cavities for plants and vertebrates. The bricks with fossils demonstrate the potential for place-based designs, incorporating local themes and heritage.

Samples courtesy of Artecology



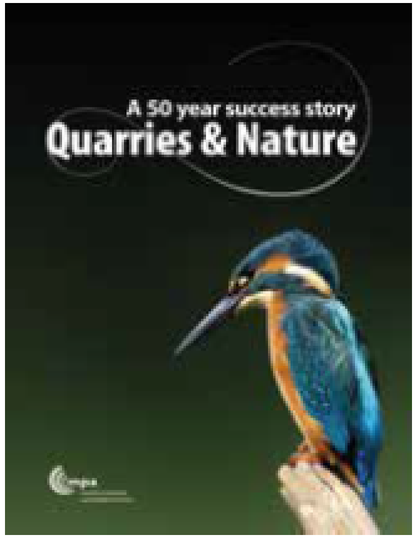
Images courtesy of Artecology

Samples

Quarries and Nature

The UK concrete industry makes a significant contribution to biodiversity and nature conservation through the management and restoration of sites of mineral extraction.

Over 8,000 hectares of priority habitat has been created to date on restored quarry sites in the UK; and a further 11,000 hectares is planned, helped through collaboration with stakeholders such as the RSPB and Natural England.



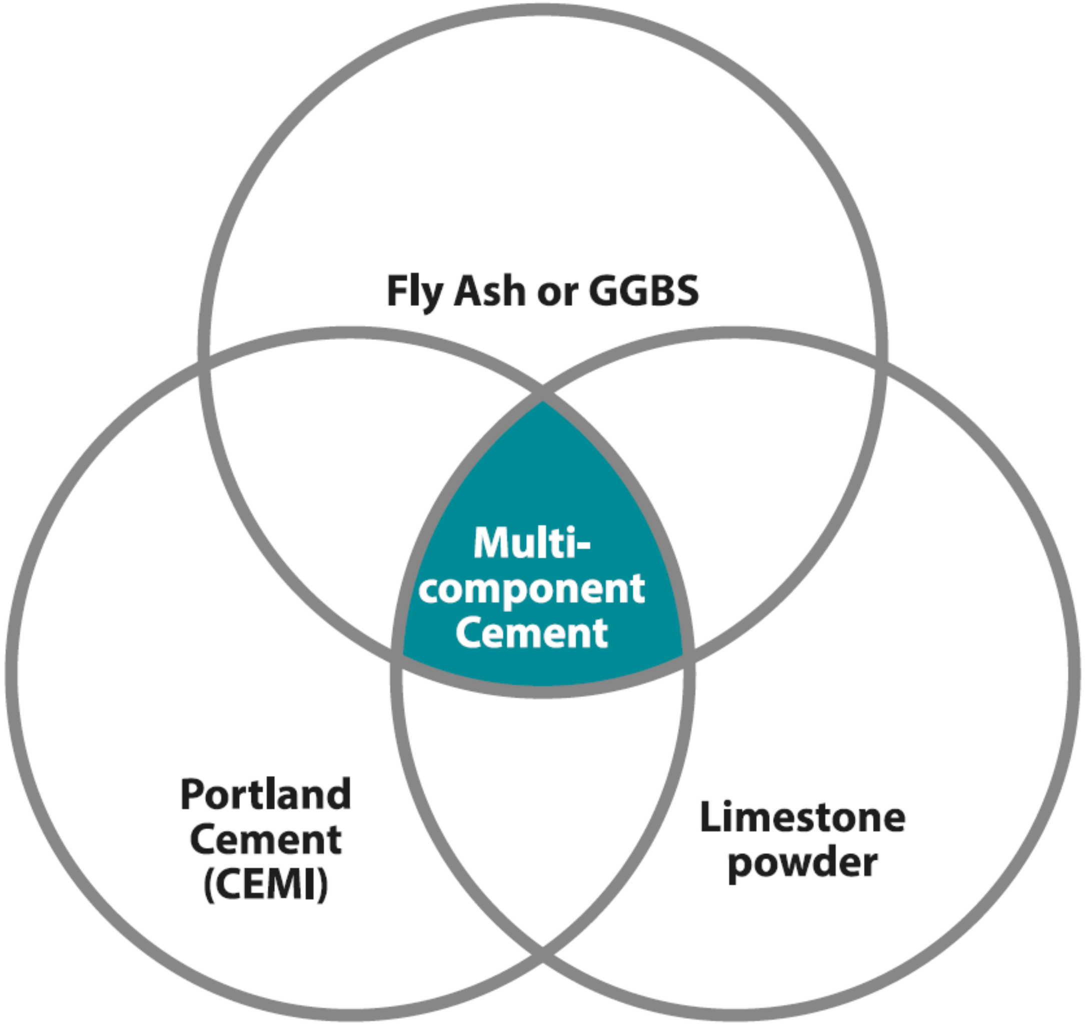
LOW CARBON SUPPLEMENTARY CEMENTITIOUS MATERIALS (SCMS)

SCMs are an established method of reducing the upfront embodied carbon of concrete, but are also used to enhance the properties of concrete. In the UK, commonly-used SCMs are ground granulated blast-furnace slag (GGBS), fly ash and powdered limestone. Other materials are also permissible in BS 8500.

All have a lower embodied carbon than Portland Cement (CEM I) and are used in combination with CEM I in varying proportions. Other sources of SCMs for use with CEM I are being developed, including recovered fly ash, calcined clays, and recycled concrete fines.

The forthcoming amendment to BS 8500 will include the use of Multi-Component Cements, where more than one SCM can be combined with CEM I. Multi-component cements are formed when CEM I is combined with powdered limestone and then GGBS or fly ash. BS 8500 will allow these SCMs to make up 65% of the binder content.

LOW CARBON SUPPLEMENTARY CEMENTITIOUS MATERIALS (SCMS)



MULTI-COMPONENT CEMENTS

Limestone powder is abundant in the UK. However, due to its limited chemical activity it is used to substitute clinker in lower quantities than fly ash or GGBS. Research by the MPA demonstrated that this issue can be overcome by using limestone powder alongside other, more reactive, constituents.

Samples:

Concrete made using low carbon multi-component cements

1 CEM II/C-M (S-L) – 30% GGBS, 15% limestone powder, 55% CEM I

2 CEM II/C-M (V-L) - 30% fly ash, 15% limestone powder, 55% CEM I

3 CEM VI (S-L) - 50% GGBS, 15% limestone powder, 35% CEM I

Sample courtesy of MPA

LOW CARBON SUPPLEMENTARY CEMENTITIOUS MATERIALS (SCMS)

Samples

Concrete using silica fume

Silica fume (also known as micro silica) is a well-established SCM adding durability and strength to concrete.

Sample courtesy of Ferroglobe

SCM based on natural pozzolana (volcanic material)

Sample courtesy of EMC cement BV

Concrete using volcanic ash

The concrete contains 70% SCM, based on mechanically activated naturally abundant volcanic material.

Sample courtesy of EMC cement BV

Concrete made using low carbon multi-component cements

1 CEM II/C-M (S-L) – 30% GGBS, 15% limestone powder, 55% CEM I

2 CEM II/C-M (V-L) - 30% fly ash, 15% limestone powder, 55% CEM I

3 CEM VI (S-L) - 50% GGBS, 15% limestone powder, 35% CEM I

Sample courtesy of MPA

Concrete with 70% GGBS

Sample courtesy of Tarmac

Concrete using calcined clay as SCM

Sample Courtesy of Banahcem

Concrete with 25% fly ash

Sample courtesy of CEMEX

LOW CARBON CONCRETE

The range and availability of low carbon concretes and concrete products continues to increase, based on Portland Cements and alternative binder chemistry.

These include those created using Alkali Activated Cementitious Materials (AACMs) and geopolymers, with guidance provided by PAS 8820:2016.

Other low carbon concrete technologies include concrete made using graphene-enhanced admixtures and carbon mineralisation (storage) in aggregates or concrete manufacture.

A project is under way to create a BSi Flex Standard for performance-based specification that would be applicable for all cements and binders, whatever the chemistry.

LOW CARBON CONCRETE

Samples

Low carbon concrete made using AACM

1 Sample courtesy of ECOPACT ®
London Concrete/Aggregate Industries

2 Sample courtesy of Vertua ®
CEMEX

3 Sample courtesy of Earth Friendly Concrete®
Capital Concrete

4 Sample courtesy of CemFree ®
part of DB Group (Holdings) Limited

Low carbon mortar made using AACM

Sample courtesy of CemFree ®
part of DB Group (Holdings) Limited

Ultra-low carbon concrete blocks

These high density, load bearing blocks are manufactured using AACMs in the concrete mix, replacing Portland cement. They are available for different applications including paint-grade, medium density and lightweight blocks.

Sample courtesy of Greenbloc®/CCP

CO_2 utilisation in ready-mixed concrete

Ready-mixed concrete using minerals manufactured by combining CO_2 and reclaimed residues from wash out water.

Sample courtesy of CarbonCure

Graphene-enhanced concrete

Using a graphene-enhanced admixture has been demonstrated to significantly reduce the depth of a ground-bearing floor slab without the need for any reinforcement.

Sample courtesy of Concretene

Low carbon concrete brick utilising waste CO_2

'CarbonCure' technology injects waste CO_2 into the concrete during manufacture, to be stored there permanently.

Sample courtesy of Marshalls

INNOVATION TABLE

Alternative reinforcement

Steel reinforcement contributes approximately 25% of the embodied carbon of a concrete structural floor – a proportion that will become even more significant as the embodied carbon of concrete continues to fall.

Most UK reinforcement uses recycled steel and is manufactured using an electric arc furnace (EAF) which emits less CO_2 than other steel manufacturing processes.

Focusing on the detailed design of reinforcement, modifying material factors and avoiding over-rationalisation all provide opportunities for carbon savings.

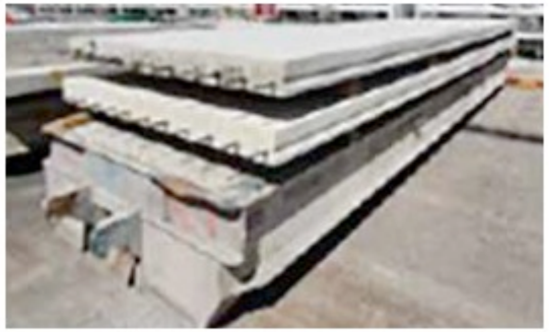
Alternatives to conventional steel reinforcement can offer lower embodied CO_2 and reduced concrete cover.

Samples

Basalt fibre reinforced polymer (BFRP)

Laing O'Rourke has trialled the use of BFRP in precast concrete slabs and beams, saving around 70% of the reinforcement's embodied carbon.

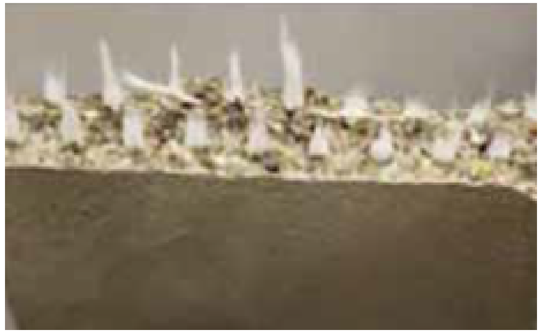
Samples courtesy of Bastech & LOR



Glass-fibre textile mesh reinforcement

Flexible, non-corrosive mesh reinforcement was used to create a novel, thin-shell vaulted concrete flooring system. This system reduces material usage and embodied carbon compared to traditional slabs and beams.

Sample courtesy of Solidian & Bath University



Glass-fibre reinforcement

Corrosion-resistant glass fibres bonded with resin, offering durability, high tensile strength and less weight.

Sample courtesy of Schöck

Automated knitted reinforcement

Prototype fibre-reinforced polymer reinforcement, wound or knitted automatically into a bespoke cage to achieve highly-efficient forms.

Sample courtesy of Cambridge University

INNOVATION TABLE

Recycled Materials

Most concrete contains some recycled content.

Each of concrete's main constituents provides an opportunity to use recycled materials and by-products from other industrial processes. The type and amount depend on the application of the concrete.

Concrete is itself recyclable at the end of its serviceable life.

Innovative new processes are expanding the opportunities for use of recycled concrete.

Recycled Materials

Concrete made using recycled brick

Visual concrete for non-structural applications.

Sample courtesy of VICO

‘Circular’ lightweight aggregate

Manufactured using waste materials and by-products.

Block pavers made using this aggregate was a finalist of the Earthshot Prize 2022.

Sample Courtesy of Low Carbon Materials & Aggregate Industries

Recycled steel reinforcement

Most steel reinforcement used in the UK is made using recycled steel.

Sample courtesy of Celsa Steel and BRC

Pigmented concrete using reclaimed ink toner

An innovative solution to creating coloured concrete.

Sample courtesy of University of Dundee

INNOVATION TABLE

Permeable paving

Permeable concrete can be used as part of a Sustainable Drainage System (SuDs) to reduce the risk of surface water flooding and contribute to groundwater recharge.

Solutions include pervious, ready-mixed concrete for continuous paving and permeable concrete block paving.

Samples

Innovative permeable paving

Using innovative permanent formwork made from recycled plastic to facilitate water flow.

Sample courtesy of Kiacrete / Permia

Permeable concrete

Pervious concrete for outdoor, continuous paving that drains water and can reduce the risk of flooding.

Samples courtesy of Aggregate Industries, CEMEX and Hanson

INNOVATION TABLE

Sample

Concrete made using cement containing calcined clay and limestone (LC3)

Sample courtesy of EPFL, Laboratory of Construction Materials (LMC)

3D Printed concrete

This table base was printed using a low carbon, graphene-enhanced mortar.

Design: Ben Harries

Design and manufacture: Versarien PLC

Photo courtesy of: Versarien PLC

Other Samples on reception desk:

1) White architectural precast
Courtesy of Techcrete

With QR code to TCC website

2) Flexible formliner and concrete
Courtesy of Reckliw