THIS IS **NOT THE END**

Circular economy thinking has enormous potential to reduce the carbon impact of the built environment, by keeping valuable resources in use at their highest value for as long as possible.

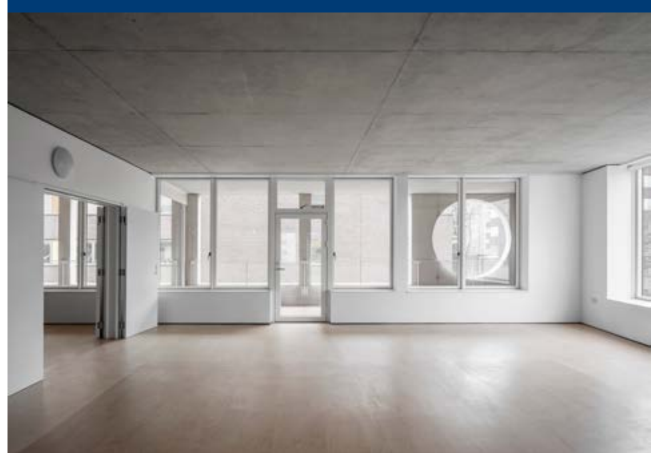
This is at the heart of the transition away from a linear "take-make-dispose" approach, and towards a model where consumption of raw materials is greatly reduced and waste is eliminated. In this world, designing concrete buildings becomes a balance between efficiency and flexibility. It means using the minimum amount of materials to achieve the desired goal, while looking towards the second, third or fourth lives of a structural frame and ensuring that it can be readily repurposed to fulfil new uses and shelter future generations. Through a net-zero lens, obsolete buildings are no longer problems to solve, but low-carbon resources, full of potential.

Elsewhere in this magazine, we've looked at how the concrete industry is lowering the embodied carbon of its products (pages 4-9), and supporting its customers to make the most carbon-efficient choices (10-13). This article is about how we keep those resources in circulation for as long as possible, and how we can derive the greatest value from them when they finally reach the end of their lives.

RETAIN

Designing for longevity

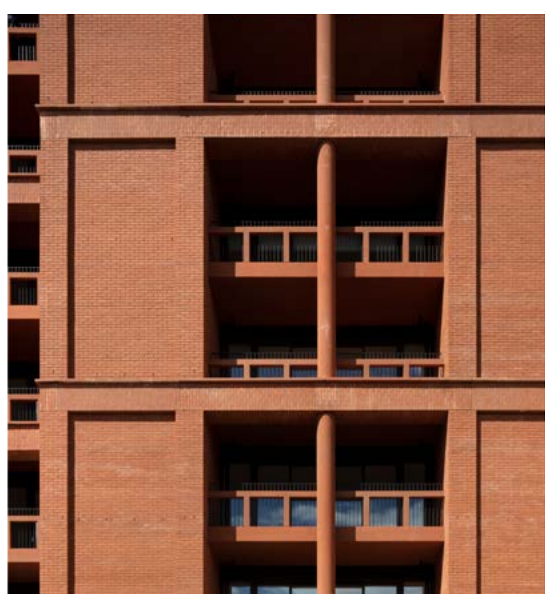
The best way to keep a concrete structure at its highest value is to reuse it. Designers can facilitate this by thinking about the future lives of their buildings when they are designing their first iterations, and making them adaptable for other uses. This might mean considering optimal spans, loads, grids and floor-to-ceiling heights, and making partitions removable so that internal layouts can be reconfigured. Creating an as-built digital twin will also be invaluable for future designers.

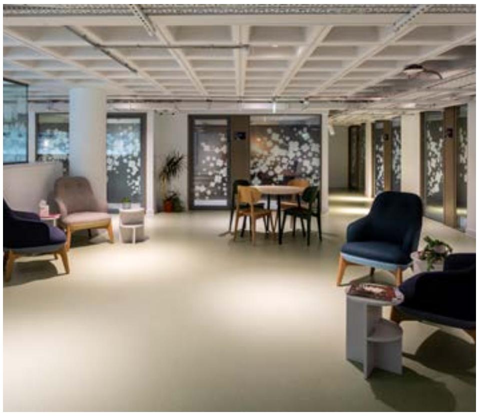


Photos: Johan Dehlin (left); Laing O'Rourke (below)

Right At Apparata Architects' A House for Artists, soft spots in party walls and external circulation allow flats to be completely reconfigured
Below right The deep facade of Henley Halebrown's 100 Kingsland Road helps to conceal the residential function, improving future flexibility
Below Lifschutz Davidson Sandilands' Hoxton Southwark features long spans and open spaces, enabling it to switch between hotel, residential and office functions

Photos: Paul Riddle (right); Nick Kane (far right)





Right Page/Park's Health Centre at the University of Edinburgh. Original 1970s features, such as the coffered slabs, have been exposed and celebrated

Designing for disassembly

Disassembly offers an alternative route for keeping structural elements in use for as long as possible. For some types of building, precast systems that are designed to be demountable will enable the components to be reused again when they have fulfilled their first function. Another route to circularity is to retain the building structure, but design all the layers attached to it so that they can be disassembled, replaced and potentially used elsewhere.

Below Laing O'Rourke recently trialled its M Frame system as part of a kit of parts for housing and schools. The floor slabs require no structural topping and connections are made with steel bolts and removable low-strength grout

Renewing and adapting

Reusing existing buildings is not only extremely efficient in terms of embodied carbon, it also preserves their social and cultural value, as well as the fabric of our towns and cities. Existing buildings may have been designed for a lifespan as short as 25 years. But concrete structures can last for well over a century, and they may be able to support much greater loads than originally intended.

Structures may be renewed and reused for the same purpose – with shorter lifespan elements such as facades, building systems and internal finishes upgraded to meet modern performance standards. Or the original structure and foundations can become the base for a larger building – with the benefit of today's digital tools, designers are identifying spare load-bearing capacity that can help to meet higher demand in growing cities, without expending new resources.

RECYCLE

End of life

At the end of its serviceable life, concrete can be recycled ad infinitum as a low-carbon resource. In the UK, virtually all concrete from demolished buildings is recycled – whether as aggregate within new concrete or hardcore for load-bearing surfaces, it goes on to have a second useful life often even longer than the first.

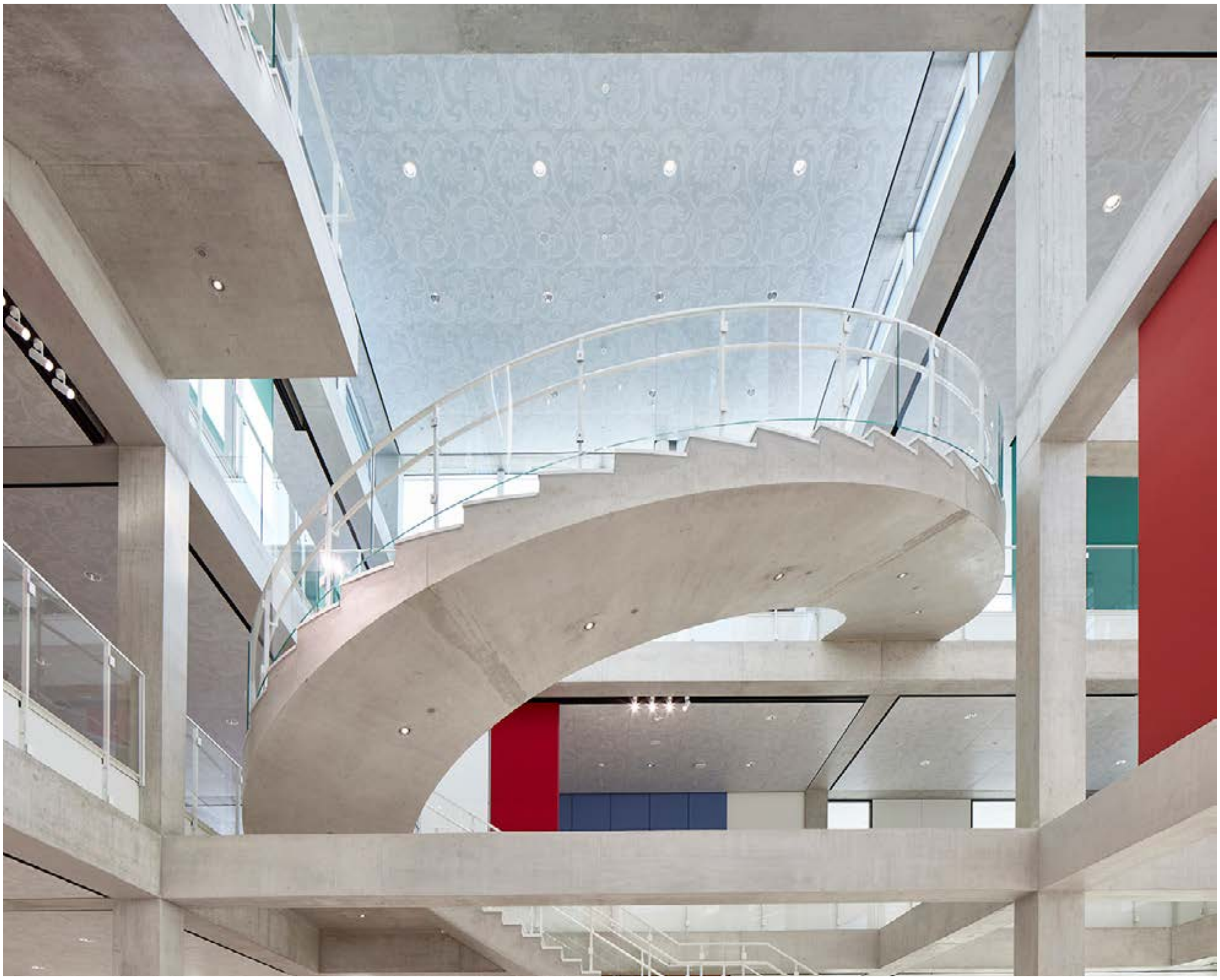
Crushing concrete also increases the rate of carbonation – the absorption of CO_2 from the air over time. Research is underway to maximise this carbon-sequestration potential in both new products and in recycled concrete.

Perhaps the most exciting change is taking place in technologies for reprocessing concrete. Recycled concrete can now be used to make enhanced aggregate, new concrete products, secondary cementitious material – or even new cement.

"The need to decarbonise construction is encouraging the creation of more value from demolition waste, and this is driving significant innovation in this sector," says Dr Pippa Horton, business manager with Cambridge University. "Recent years have seen a surge of new ideas and the development of a range of higher value products. This is currently a really exciting space in which we expect to see continued rapid progress over the next few years."

To showcase progress in the sector, in November 2023, Horton and Elaine Toogood, director of architecture and sustainable design at The Concrete Centre, co-hosted a conference – Making Better Use of Recycled Concrete Demolition Waste. The event brought together 14 speakers from some of the leading organisations active in this field. Overleaf, we explore some of the innovations they highlighted, and consider how they could transform our built environment.

Above left The Hylo Building, where structural engineer AKT II added 15 storeys to a 1960s office block, reusing much of the existing concrete structure



CLOSING THE LOOP

New technologies hold the promise of transforming waste concrete into a wider range of low-carbon materials. **Tony Whitehead** reports

While almost all waste concrete is already recycled, its processing has recently become more sophisticated. Traditionally, it has been simply crushed to various sizes for use as hardcore, or to partially replace virgin aggregate in some applications. New processes, however, are now able to more effectively separate aggregate from concrete paste – the component including some residual cementitious properties.

"It's about getting the cement paste away from the aggregate as effectively as possible," says Adam Day, contracts director at London-based Day Aggregates. "So we use three different crushing procedures in conjunction with air separators which remove the finer powders."

The result is that waste concrete could now provide a wider range of higher-quality components, from "cleaner" aggregate to recycled concrete paste (RCP) – and all these resources are now attracting attention from innovators.

Paste pioneers

Heidelberg Materials (HM) was behind one of the first plants to separate aggregate from concrete paste on an industrial scale. Now it is developing a process to produce supplementary cementitious material (SCM) by mineralising CO_2 in the paste. HM has already run trials at two plants – Ribblesdale in the UK, and Brevik in Norway – and is now ready to begin industrial-scale pilots.

"The process starts as normal, by crushing concrete from demolition," says Nina Cardinal, national technical manager with HM in the UK, "but this is then followed by soft mechanical treatment which effectively separates the fines from the aggregate. "If we expose those fines to CO_2, it reacts with them to create a new SCM."

The process works with the levels of CO_2 found in cement plant exhaust flue gases: "So it doesn't require carbon capture technology. We use flue gases direct from our plants, but you could use any similar industrial source of CO_2."

Cardinal adds that the process supports both carbon reduction and circular economics: "As well as storing the CO_2 in a permanent chemical bond, the process reduces the call on natural resources because the RCP is being reused as a reactive SCM and the separated aggregates are also clean and reusable in concrete."

Meanwhile, the production of a new form of Portland cement from recycled concrete is under development by Cambridge Electric Cement. This process involves replacing the lime flux used in steel recycling with RCP.

"We found that if you put hydrated recycled cement paste into molten steel, what you get is reactivated cement," says Cyrille Dunant, founder and principal research associate with Cambridge Electric Cement. "The steel becomes a working clinkering medium – and because the temperatures involved are higher than in a normal cement kiln, problematic impurities like sulphur and chloride tend to evaporate."

The technique raises the exciting possibility of creating near zero-carbon cement, as there are none of the process emissions associated with clinkering limestone and, potentially, none from the running of the electric arc furnaces used to recycle steel. "These furnaces would be operating anyway," says Dunant, "and as the grid decarbonises, the total carbon involved becomes very small indeed."

Enhanced aggregate

Day Aggregates supplied the RCP used in the first Cambridge Electric Cement industrial trials. Contracts director Adam Day points out that, in concrete terms, the benefits of the separation process are twofold: "We get high-quality RCP that we can send to be reactivated in Celsa's furnace [for steel reinforcement production] in South Wales. But we have also removed so much of the cement that the remaining aggregate is much better quality."

Technology is also being applied to more conventionally recycled concrete aggregate. For example, Fast Carb, a publicly-funded French research project, has developed a technique that improves the quality of simply crushed concrete aggregate while allowing it to store significant amounts of CO_2.

"FastCarb puts RCA together with CO_2 from untreated cement plant exhaust gases so that the CO_2 becomes part of the mineral," says Jesus Subero of Holcim, one of the cement producers that took part in the project. "The carbon becomes fixed in the aggregate as calcium carbonate. It is a chemical bond, so the aggregate becomes a permanent carbon sink and we expect this to soon be recognised as such by the European Carbon Trading Scheme."

> "WE FOUND THAT IF YOU PUT HYDRATED RECYCLED CEMENT PASTE INTO MOLTEN STEEL, WHAT YOU GET IS REACTIVATED CEMENT"

Pilot schemes have been encouraging: "For every tonne of recycled aggregate, we store 30kg of CO_2," says Subero. "That translates to at least 60kg per m^3 of concrete – and that is without optimising the process by, for example, selecting the finer fractions of recycled concrete. If you use 100% FastCarb recycled aggregate, a 20-25% reduction in the carbon footprint of concrete should be possible."

He adds that the process adheres to another key circular principle. As the RCA absorbs CO_2, limestone forms on the surface which is beneficial when using it as an aggregate in concrete, since the amount of cement required is reduced. "So you are adding value and improving the product – upcycling rather than downcycling."

Alternative raw material

Another use for concrete fines, along with other mineral waste from construction and demolition, is as an alternative raw material (ARM) in cement manufacture, added as part of the raw mix before the kiln stage and becoming part

Right Day Aggregates takes in 600,000 tonnes of CDW per year, of which only 0.2% ends up in landfill. "What we are trying to do now," says contracts director Adam Day, "is make it more useful – to uplift where it goes and what it is used for"

Opposite The concrete used at Sou Fujimoto's The Square in St Gallen, Switzerland contains cement made with up to 20% CDW, as well as local recycled aggregates of the clinker. Research carried out by Holcim has identified the chemical composition of a variety of waste streams and assessed their usefulness as ARM. "Concrete fines have the highest compatibility with the raw mix, but other waste streams each have different properties which can be useful in different situations," says Lilia Caragacean, R&D lead engineer with Holcim Innovation Centre. "For example, bricks and tiles can be a great source of alumina, and gypsum from plasterboard can be a source of sulphate." She adds that a Holcim cement plant in France is already routinely using a raw mix comprising 12% CDW, while another in Spain uses up to 15%.

In Europe, a new cement standard, BS EN 197-6, has been introduced to allow the use of recycled concrete fines (RCF) and other building waste materials as a cement constituent in the manufacture of concrete. "The evidence is that RCF, which is largely inert, behaves in a similar way to limestone when used as a cement substitute," says Colum McCague, technical manager with MPA Cement.

The standard permits up to 35% of cement to be replaced with RCF, which it defines as 90% concrete fines. It also sets limits for impurities such as glass or bituminous material both of which must be below 1%.

At the moment, RCF is not recognised as a cement substitute by the British Standard BS 8500: "But there is new standard under development, BS Flex 350," says McCague. "This takes a performance-based approach, and may provide an earlier route to deploying RCF cements in the UK."

Urban quarrying

Circular economy thinking encourages a new approach in which buildings and structures are no longer viewed simply as waste disposal problems. Increasingly they are now seen as a resource, or "urban quarries" . This approach is already well established as a source of recycled aggregates in the UK, accounting for around one-third of all aggregate use here.

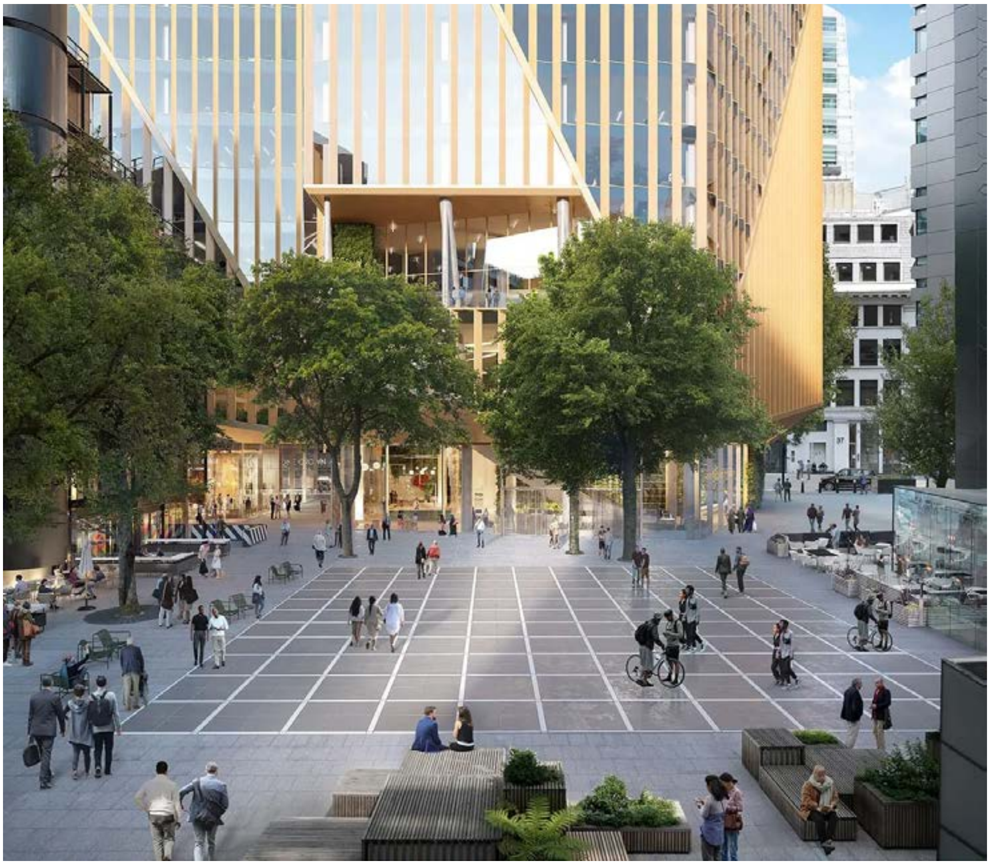
As alternative uses of recycled concrete aggregate (RCA) become more widespread, several demolition companies have now started their own off-site crushing and cleaning facilities to enable the sale of aggregate for reuse in concrete and other applications. "It's a significant development," says Howard Button, of the National Federation of Demolition Contractors (NFDC): "It shows our members are interested in helping to recycle concrete at a higher value."

To maximise such opportunities, says Button, it would help to know more precisely what a structure contained before its demolition: "We would support the introduction of more pre-demolition audits (PDAs). These would help us identify contaminants in advance, and also flag up opportunities for reuse of materials."

PDAs have been carried out since at least the 1990s, and are becoming more popular as their role in making the best use of construction waste becomes more appreciated. They have been part of the BREEAM standard for about a decade and, following the Greater London Authority's Circular Economy Statement, are mandatory within London for referable projects.

"PDAs help focus on the potential for reuse and in facilitating higher value recycling of material," says Gilli Hobbs, director of Re-usefully – an organisation that has carried out more than 70 PDAs. "If you know what's available from demolition, it can also help you meet requirements for the incorporation of reused products and recycled material in your new building. Such targets are increasingly being set by planning authorities and clients."

The incorporation of PDAs into standard construction processes is far from complete, however. "There is a lack of standardisation," says Hobbs. "And we need better systems for ensuring compliance with the reuse and recycling opportunities PDAs reveal. The development of material passports might help with that important flow of data."



Right National infrastructure projects such as the £8bn Lower Thames Crossing can help to develop the market for recycled concrete products

Opposite Reusefully undertook a PDA for architect 3XN's proposed redevelopment of 2-3 Finsbury Avenue, London. A reuse strategy was produced which provided details of elements that could be reused or repurposed in the new development

Keep it close

Another important factor in smoothing the path from demolition to recycling is logistics. "If you have to move material very far, then it's not going to work," says Ian Riley, co-founder of Xeroc, a company that seeks to return waste concrete back to developers as useable ingredients, including RCP, virgin-quality aggregate, or CO_2-enhanced aggregate.

The beauty of reusing high-quality crushed concrete aggregate (CCA), points out Day Aggregates' Adam Day, is that it can take transport out of the equation. "In London, virgin aggregate tends to be brought in from outside. Reusing clean CCA keeps the material within London, though you do need suitable places to store it before and after processing."

This point is highlighted by Aggregate Industries' work on a new development at Canary Wharf, which has involved the demolition of a 10,000m^3 concrete marine quay. "The quay is 110 years old, but core samples confirmed the concrete was of good quality," says Cassandre Le Galliard, product manager for sustainable ready-mixed concretes at Aggregate Industries. "We looked at how it could be reused, and an early requirement was for storage space. Fortunately, there was a recycling facility with room to store it quite close by, at Greenwich, and that was key to making our project work." Having been screened and crushed in Greenwich, the concrete is ready to be used in floor slabs and a replacement quay at the new development.

Creating a market

Ultimately, a circular economy requires economic forces to support it, and the market for recycled building materials is still developing. It looks set to be boosted, however, by new carbon intensity targets being applied to major projects and infrastructure.

A good example is the £8bn Lower Thames Crossing (LTC). "At tender stage, we asked contractors to demonstrate a carbon reduction of at least 30% from the norm," says Andrew Kidd, LTC director of environmental sustainability. "They came back with around 50% – and that's with design and technology available today."

"WE ARE PREPARED TO INVEST AND COMMIT TO GET THE KIND OF MATERIALS WE WANT ON OUR PROJECT"

Once in contract, LTC plans to make further inroads on the carbon intensity of materials. "What technologies can we bring forward? What can we scale up? We are prepared to invest and commit to get the kind of materials we want on our project – and I think that is very much part of creating the kind of market that supports circularity and carbon reduction through new technologies."

LTC is far from alone in its search for low-carbon solutions: "Companies like Land Securities, Berkeley Group and Grosvenor have all set ambitious targets for carbon reductions in their business and their buildings, says Miles Watkins, Riley's fellow Xeroc co-founder.

If, as seems likely, the approach taken by these organisations becomes the norm for major projects, they will provide consistent and increasing demand for low-carbon concrete solutions. Happily there is no shortage of innovators striving to develop exactly that.

This is an edited version of a report from the Making Better Use of Recycled Concrete Demolition Waste conference held by the University of Cambridge and The Concrete Centre in November 2023. To read the full article, go to concretecentre.com