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The Concrete Centre

CONCRETE FUTURES

REMIXED

How concrete is evolving for a net-zero built environment

WHOLE-LIFE THINKING: HOW TO BALANCE EMBODIED AND OPERATIONAL CARBON

THE RISE OF REUSE UNLEASHES A WAVE OF BRILLIANT BUILDINGS

CONTENTS

mpa The Concrete Centre

The Concrete Centre provides design guidance, seminars, courses, online resources and industry research to the design community. Our aim is to enable all those involved in the design, use and performance of concrete to realise the potential of the material.

The Concrete Centre is supported by industry to inform, educate and inspire. Our members are Aggregate Industries, Allen Newport, Breedon Aggregates, Brett Group, Britannia Aggregates, British Precast, Cemex Materials, Deme Building, FM Conway, Gallagher Aggregates, GRS Roadstone, Grundon Waste M'ment, Hanson Aggregates, Harleyford Aggregates, HH and HE Drew, Hills Minerals, Ingrebourne Valley Aggregates, J & J Franks, J Clubb, Marshalls Group, Moorhouse Sand & Gravel Pits, Moreton C Cullimore, Morris & Perry, Myers Group, Quattro UK, Rotherham Sand & Gravel, Sea Aggregates, Smith & Sons, Springfield Farm, Tarmac, Tudor Griffiths, Volker Dredging.

The Concrete Centre is part of the Mineral Products Association, the trade association for the aggregates, asphalt, cement, concrete, dimension stone, lime, mortar and silica sand industries.

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Cover: Bioreceptive facade panel at The Bartlett School of Architecture, by Richard Beckett, Marcos Cruz and Javier Ruiz. Photo: Sarah Lever

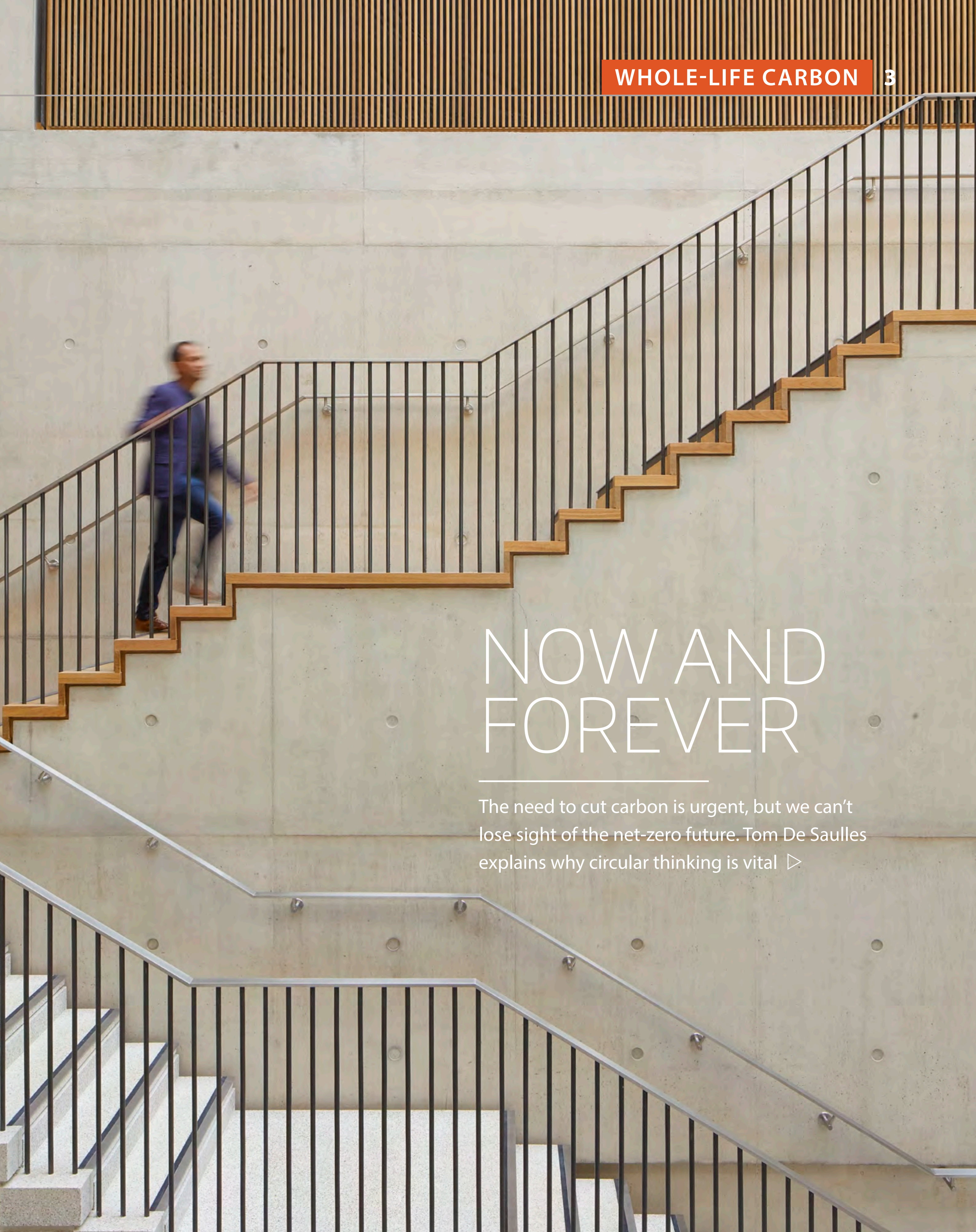
WELCOME

Designers understandably have questions for the concrete industry about what it is doing to minimise or eliminate its contribution to climate change. We welcome these questions: since 2008 we have been publishing detailed information about our sustainability targets, on materials, carbon, waste, biodiversity, water and wellbeing, and our progress towards them. The 12th annual performance report on the Concrete Industry Sustainable Construction Strategy, based on data up to 2018, shows that the embodied carbon of a standardised mix of concrete is 30% lower than in 1990.

With most of our 2020 targets met, the industry is preparing to publish a new strategy to take us further towards net-zero carbon, without relying on offsetting. There's much that we can and are doing in terms of fuel switching, investing in technologies such as carbon capture, use and storage, and developing low-carbon cements (see page 20). There is also much that can be done to reduce carbon in the way our products are used – for example, by project teams specifying low-carbon concrete and designing material-efficient structures that can be delivered. One problem is that sustainable choices are often stripped out before projects get to site. Contractors are driven by economics – understandably, given the number of firms that fail – so clients and investors must make sure that sustainability is economically viable for every link in the chain.

The Concrete Centre was established to be the bridge between materials suppliers and the designers and contractors who rely on their products. We want to facilitate the conversations and collaborations that are essential to reaching a net-zero carbon built environment. We can't do it alone – but I'm confident that we can do it together.
Claire Ackerman, director, The Concrete Centre

THE INDUSTRY IS PREPARING TO PUBLISH A NEW STRATEGY TO TAKE US FURTHER TOWARDS NET-ZERO, WITHOUT RELYING ON OFFSETTING



NOW AND FOREVER

The need to cut carbon is urgent, but we can't lose sight of the net-zero future. Tom De Saulles explains why circular thinking is vital ▷

The UN declaration made last year that only 11 years remain to limit catastrophic climate change is a warning that seems to have resonated more than any other with the design community. Organisations such as the RIBA and RICS have announced net-zero carbon initiatives with ambitious timelines – initiatives that also place a strong emphasis on "saving carbon now" in respect of the embodied impact of building materials and construction activities. This can seem at odds with the principles of a whole-life approach, also widely promoted and largely focusing on longer-term carbon performance. So, do they conflict? At what stage in a building's life cycle should the greatest emphasis be placed on saving carbon?

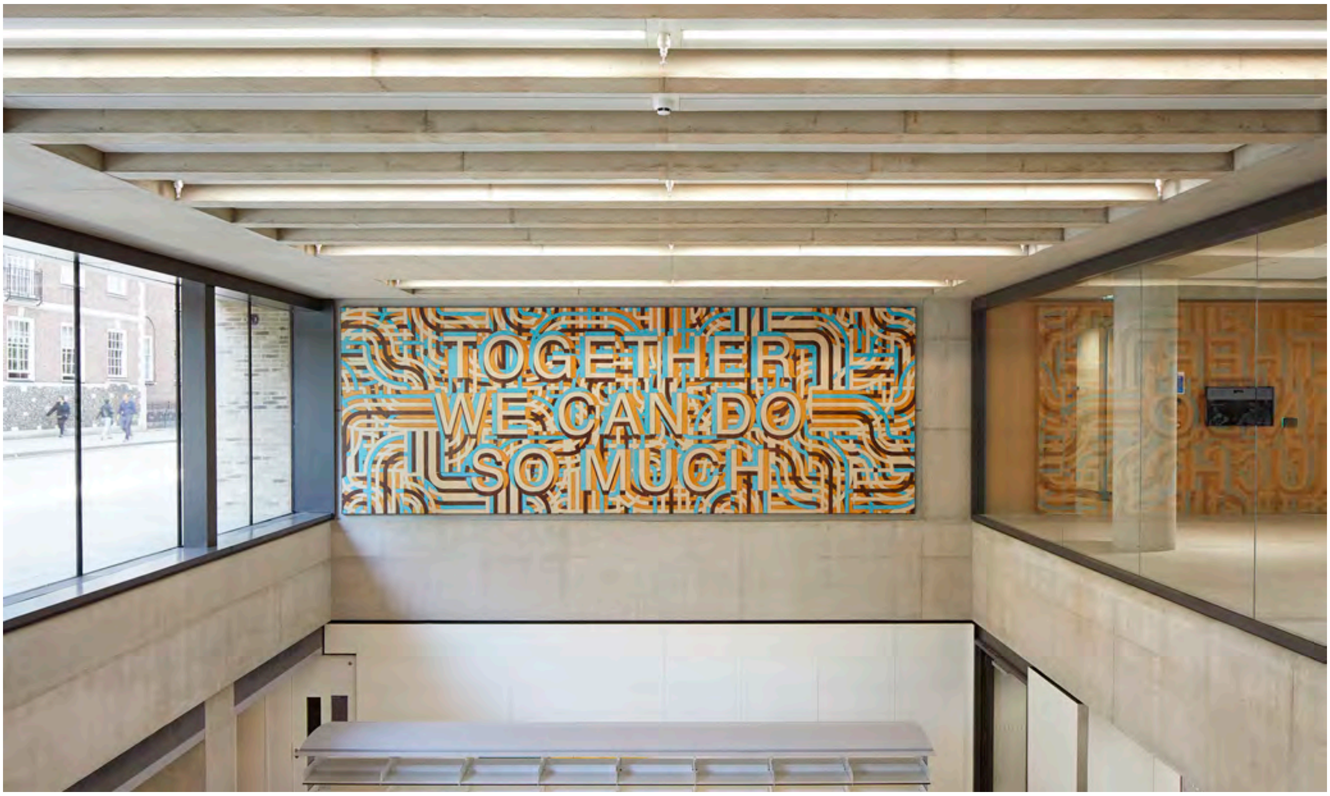
Views may have polarised somewhat between whole-life and upfront carbon reductions, but a more pragmatic way forward combines both approaches as far as practicable. This is perhaps best summarised in the World Green Building Council's definition of net-zero carbon, published in August 2019 in Bringing Embodied Carbon Upfront, which acknowledges the immediacy of the UN declaration by encouraging designs that reduce initial carbon impacts as far as possible, with the balance offset over a building's life through operational savings and efficiencies.

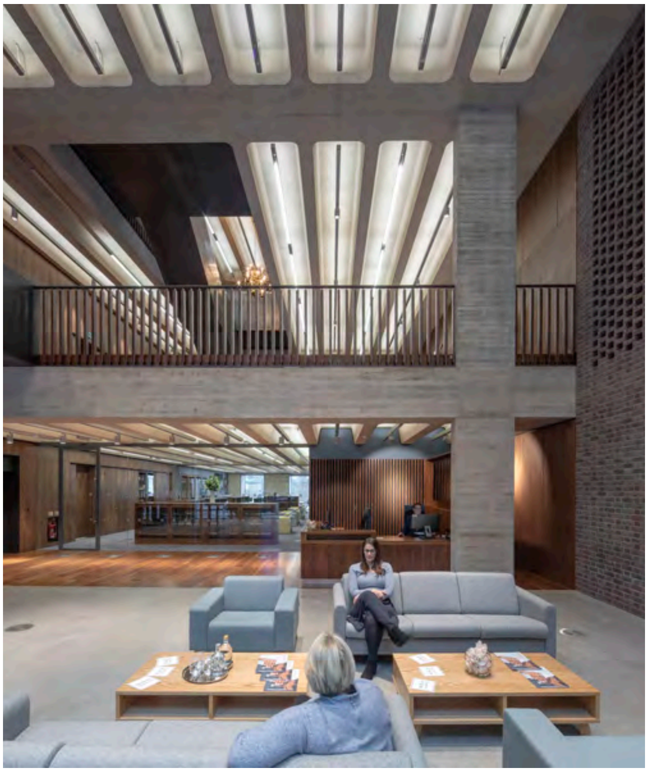
This approach also broadly aligns with the principles of a circular economy, in which the design stage is the entry point to a continuous cycle of more sustainable construction. This is predicated on selecting and using materials with their embodied carbon in mind, both at the outset and in their ability to ensure the building remains energy efficient and in use for as long as possible, allowing maximum value to be extracted before they are repaired, repurposed and ultimately recycled.

So where does that leave concrete? As a material, it has several qualities that sit well with the principles of a circular economy, provided they are actively used in the design and operation of buildings. These include its longevity and ability to help meet multiple design needs, namely structural, aesthetic, acoustic, fire and thermal, without reliance on additional materials and treatments. A further characteristic of many existing concrete buildings is the long-term serviceability of the frame and foundations, which often makes reuse a viable option (see page 10).

IN A CIRCULAR ECONOMY, THE DESIGN STAGE IS THE ENTRY POINT TO A CONTINUOUS CYCLE OF MORE SUSTAINABLE CONSTRUCTION

Below and previous page: The Zayed Centre for Research into Rare Disease in Children, London. The exposed concrete frame reduces heating and cooling needs
Right: The coffered ceiling at Bannetts Associates' Royal College of Pathologists HQ in London minimises the weight of concrete while maximising thermal mass





Concrete can also contain recycled content and itself be recycled.

There remains the question of upfront embodied carbon impacts, and what the cement and concrete industries are doing today to help meet the net-zero carbon challenge. Cutting carbon has been, and continues to be, an ongoing activity for the UK concrete sector, which to date has reduced its emissions by 30% against a 1990 baseline.

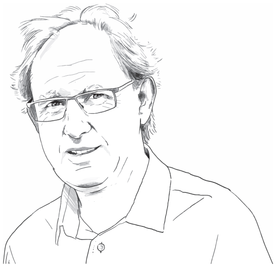
Reaching the ambition of net-zero production by 2050 will involve incremental cuts as cement production methods are reshaped, entailing technological challenges that will take time to develop and implement commercially. The cement sector is actively focusing on fuel switching to zero-carbon fuels, including increased use of biomass for cement production, on capturing the CO_2 released from the cement manufacturing process, and on reducing the clinker content in cement with low-carbon cement formulations (see page 20). Progress towards net-zero carbon will continue to be reported in the concrete industry's annual sustainability performance report, first published in 2009.

Using environmental product declarations

At a more technical level, carbon reductions will also be reflected in future updates to the sector's environmental product declarations (EPDs) for concrete products, which now cover a range of generic ready-mixed and precast concrete products. The environmental information provided in these independently verified EPDs offers a good starting point for early-stage design. For example, the generic ready-mixed concrete EPD is based on the commonly used mix strength (C30/37), making it suitable for all foundations, floors and most ▶

VIEWPOINT: SIMON STURGIS

"Everyone has to up their game on whole-life carbon"



Everyone wants to know what they need to do about whole-life carbon and how they can do it, and I'm having a lot of conversations with architects who recognise that now is a key moment. Investors are recognising that whole life carbon is a business issue, and are asking developers and clients the difficult questions. It took us 45 years to get our act together on operational energy. We have to do rather better with whole-life.

Architects have an opportunity to reverse their marginalisation in the construction process by becoming the focal point for carbon assessment. To tackle whole-life carbon, architects and designers need to do the carbon assessments on their designs – there really is no substitute. But everyone needs to be on the same page. One of the problems is that different software gives different answers, so various organisations have put out target figures, and they are all different. I'm working with Cundall on guidance for whole-life carbon assessment for the GLA's draft London Plan. This will hopefully provide a way forward by being more specific about what's required in a carbon assessment.

There is a parallel problem to do with professional indemnity insurance. Most buildings are significantly over-designed in structural terms since structural engineers are concerned, not unreasonably, about safety. Without this over-design, it could be possible to make savings in embodied carbon of as much as 20%.

Concrete has been fingered as a material of concern, and it does start at a disadvantage because of the carbon-intensive digging and heating involved in making cement. If you can use cement substitutes that helps, along with sourcing locally to reduce transportation. The industry also needs to make the case for the whole-life benefits of thermal mass, longevity and ease of maintenance, and to address its suitability to the circular economy – precast flooring planks and other elements have the potential to be re-used, but standardised sizes would make this easier.

It's easy to be glib about which materials are better for embodied carbon, but the truth is that manufacturers in every sector have to work harder, and architects need to know more about these materials and how to reduce carbon. Whatever the structure, you still have to get everything right when you build a building to benefit in carbon terms. Everyone has to look at the core of what they're doing in order to up their game.

Simon Sturgis is an expert on low-carbon design. He is the author of Targeting Zero: Embodied and Whole Life Carbon Explained

Photos: Hufton + Crow; Peter Cook. Potrait illustrations: Ben Southan building structures. It contains a level of cementitious additions (ground granulated blast-furnace slag (GGBS) and fly ash) that reflects the current UK average.

Product-specific EPDs from manufacturers and suppliers can be used later in the design process, when more specific concrete performance requirements are known and there has been discussion with the concrete supply chain. These can offer opportunities to further reduce embodied carbon through a greater use of cementitious additions and other manufacturing efficiencies. Generic and product-specific concrete EPDs are free to download from:

- ibu-epd.com/en/published-epds
- greenbooklive.com
- concretecentre.com/EPD

Building-level carbon assessment

It is tempting to use EPDs as a standalone shortcut to material selection, but their intended purpose is to inform a more comprehensive environmental assessment at the building level, which looks at the collective life-cycle performance of the structure, materials and building systems. The established method for undertaking this type of analysis is set out in BS EN 15978: Sustainability of construction works – Assessment of environmental performance of buildings.

Unsurprisingly, the European technical committee behind this standard is also responsible for the development of the EPD scheme that underpins it. The standard brings together all the elements needed for life-cycle assessment (LCA), enabling each aspect of a material's whole-life carbon performance to be properly evaluated at the building level, where it matters most.

This is especially important for concrete, which increasingly fulfils multiple design functions that can help maximise the return on the carbon investment. It also ensures construction materials, systems and products are assessed in the round, with the ability to explore design synergies and trade-offs.

LCA tools such as One Click, which is BS EN 15978 compliant, help to make this possible and are increasingly used by engineers and designers throughout the construction sector.

Looking specifically at concrete in LCA terms, it can offer a number of building-level carbon efficiencies. Some of these are summarised below, along with an indication of the carbon savings they offer.

Material-efficient structural design

The upfront embodied carbon of a concrete frame can be reduced not only through consideration of the credentials of the concrete itself, but the volume of concrete used. Structural design and different framing solutions therefore have a role to play. For example, ribbed slabs can provide long spans while using less concrete, while pre- and post-tensioning reduce structural depths. The Concrete Centre's tool, Concept, offers a simple means of assessing and comparing structural solutions.

DESIGNING OUT SUSPENDED CEILINGS CAN SAVE UP TO SIX TONNES OF MATERIALS PER 1,000M^2

Designing out finishes

Where practicable, designing out suspended ceilings and floor finishes, through the use of visual concrete for soffits and polished concrete floors, can save around 10 and 20kgCO_2/m^2 respectively, according to research by WRAP. Additional longer-term savings from avoided maintenance and replacement of finishing materials are likely to be even more significant, as carpet has a typical life span of only 15 years and suspended ceilings 24 years.

Designing out suspended ceilings can also provide a number of indirect savings:

- Up to six tonnes of materials saved per 1,000m^2
- Net saving per storey height of around 250mm
- Improved effectiveness of natural ventilation from increased slab-to-slab height
- Greater building adaptability from increased slab-to-slab height
- Up to 5% less floor area needed for plant
- Around 50kgCO_2/m^2 saving if air-conditioning plant can be designed out completely (see overleaf). ▶

Left: At the Bullring shopping centre in Birmingham, a demand-side response system and thermal mass have combined to cut operating costs by £23,000 over a six-week trial period

Opposite: At Sevenoaks School Science & Technology Centre, concrete soffits are integral to heating and cooling the naturally ventilated spaces

VIEWPOINT: HERO BENNETT

"Clients should ask for a whole-life assessment at the start"

Embodied carbon thinking is rapidly changing. Last year we had four times as much interest from architects and clients as the year before. There is certainly an increased appetite for carbon literacy, which is important because without that designers can't interrogate the data and critique what they're being told.

But the industry has a long way to go and quite frankly, people still aren't looking at whole-life emissions nearly enough. We are going through a period of transition, just as we did 12 or so years ago with operational carbon.

At Max Fordham, we've been shifting our thinking to whole-life-carbon assessment for some time. And while traditionally this is done over a 60-year period, we are increasingly focusing more on the next 10-20 years in recognition of the fact that if we don't address carbon reduction in that time, we'll miss longer-term targets. This focus raises the importance of reducing embodied carbon in the creation of the building as this represents a bigger proportion of the calculation.

Clients have an important role to play in setting the brief and asking for a whole-life assessment at the start so that there is no dispute about the necessity, who will do it and how its paid for.

We should be optimising carbon, by refining the embodied carbon assessment regularly over a project rather than just through rigid optioneering as required by BREEAM. Even small changes to finishes and metal supports, for example, can have an impact. Clients should understand that it takes time for designers to analyse the options and find the right solution, and they need to allow for that.

The starting point has to be use of low-carbon materials but there isn't just one design solution, or one right structural or material approach. We need to always strive for better and think beyond standard solutions. If we use a concrete structure, for example, how can that be optimised? There are ways to slash the amount of concrete in a floor slab, for example, by using hollowcore. Also with concrete, we need to stop patting ourselves on the back for using 50% GGBS cement replacement – we should be looking at how we can go further. In terms of structure, the most important thing is to ensure that the floor-to-ceiling heights are of the right generosity to allow a second life in a different use. If you get that right, you can be less concerned with being able to take the structure apart, and more about the elements that need to regularly refitted such as facades and finishes.

We're on the cusp of real change. Currently there isn't enough incentive to optimise design in whole-life terms. But with investors seeking clearer standards in relation to climate resilience for financial reporting, this will, hopefully, rapidly start to happen.

Hero Bennett is principal sustainability consultant and partner at Max Fordham

Photos: Hélène Binet; Hammerson

Left: Lifschutz Davidson Sandilands' Hoxton Southwark hotel and office building in London is designed for future flexibility. The concrete frame enables clear spans and adaptable floorplates, so hotel floors can become offices and vice versa
Opposite: For the refurbishment of the Bartlett in London, Hawkins\Brown convinced the client to retain the concrete frame because of the whole-life benefits

Reducing energy demand

A visual concrete soffit unlocks the thermal mass provided by the slab, enabling it to form a key element in the cooling strategy by using its passive performance to help reduce or avoid the need for air-conditioning. For office environments, this can cut the average cooling load by 40-70% (based on the typical cooling output of an exposed concrete soffit as a percentage of the average office cooling load, cited in BSRIA's 2011 Rules of Thumb guide), which over time will deliver sizeable savings. As the grid continues to decarbonise, this saving will gradually switch from carbon to energy – a commodity that will be subject to increasing demand and cost as fossil-fuel use declines. For designers and architects unfamiliar with the use of exposed concrete soffits for cooling, refer to The Concrete Centre's Concrete Floor Solutions for Passive and Active Cooling.

Demand-side response

Looking to the future, thermal mass is also set to form a key element in demand-side response (DSR) control systems, which smooth out power use in buildings to counter the intermittency of renewables supplying the national grid. DSR can be configured to use thermal mass for storing and later releasing heat or coolth produced by heat pumps or chillers at times of low grid demand, when power is cheap and renewable energy would otherwise not be fully used. In addition to lower running costs, this approach enhances the carbon efficiency of grid-supplied power.

An example of the use of DSR and thermal mass to cut operating costs is the Bullring shopping centre in Birmingham, which delivered savings of £23,000 over a six-week trial period, according to owner Hammerson. The use of DSR in this manner represents a significant development for the future use of heavyweight materials, even if it is something that LCA tools cannot necessarily take account of at present.

What is old is new again

Building refurbishment in preference to new-build has become an increasingly pragmatic option, driven in part by the principals of a circular economy and carbon considerations. Reuse can be the largest single means of maximising whole-life carbon performance. The savings realised from extending a building's life are of course largely project-specific, but for concrete essentially equate to that of a new concrete frame. As an indication of the upfront embodied savings that can be achieved, the initial embodied carbon in the concrete superstructure of an office is generally around 200-250kgCO_2/ m^2, according to research by Arup (see Whole-life Carbon and Buildings, published by The Concrete Centre, for more details) and provides a design life of 100 years or more.

A "long life, loose fit" approach, combining the use of durable materials and a format that is not tailored too tightly to the building's primary function, aligns well with circular-economy thinking. Designing in this way today provides valuable low-carbon resources for future buildings.

End-of-life and beyond

Moving finally to the end-of-life stage, it is a little known fact that the demolition and crushing of concrete results in a surprising amount of CO_2 being absorbed into the newly formed concrete aggregate due to carbonation. This naturally occurring process is purposefully limited during the in-use phase of the building to prevent corrosion of any embedded steel reinforcement. There is, however, a much greater degree of carbonation during the end-of-life stage, when crushing greatly increases the concrete's surface area, thereby enabling much more rapid CO_2 absorption. Ultimately, the combination of carbonation during the building life cycle and during its secondary life as a recycled aggregate can reduce its initial carbon footprint by around a third, as outlined in BS EN 16757:2017, Sustainability of construction works.

The need to save carbon now and achieve net zero in our built environment is a challenge that the concrete sector takes seriously, with work underway to produce a roadmap for production, supply and use, building on the 30% cut in emissions that has already been achieved. In the meantime, there continues to be much that a whole-life approach to design can do to demonstrate the contribution concrete makes over its life cycle, including the aspiration of making a circular economy a reality. ●

VIEWPOINT: JAKE ATTWOOD-HARRIS

"You can't just look at materials in isolation"

At Hawkins\Brown, we're very much in favour of the whole-life carbon approach to carbon calculations. By 2030, we want every one of our projects to have the capability to be zero carbon.

We're moving towards that target using our open-source H\B:ERT tool, which we've developed with University College London. It calculates the embodied carbon using the volume of modelled construction materials and components in Revit. We are further developing it to include energy in use to allow us to assess whole-life carbon per square metre across all types of projects, balancing the contribution of each component. This fundamentally changes how we design, which is exciting, and allows us to value the retention of heritage buildings as well as take new design approaches.

It's difficult to measure carbon in buildings. The industry has historically focused entirely on energy in use, since operational carbon used to be the major part of a building's impact. But as energy efficiency improves, in many building types the embodied carbon is now the largest component.

The problem is that the more you focus on operational carbon and ignore embodied carbon, you end up with what we call "spaceship"-type buildings. While many are incredibly well-sealed and insulated, this can come at considerable embodied carbon cost, since this is achieved with aluminium, steel, plastic insulation materials and a large amount of mastic.

Working with H\B:ERT and our project engineers, we now calculate whole-life carbon figures for every new project. We're also going through our back catalogue to learn from measured energy data. This knowledge is key during the briefing process, where we look at the largest embodied carbon impacts, which tend to be the structure and facade.

H\B:ERT has produced surprising results, and that's exactly why we need it. Broadly, metals and plastics have the largest carbon impacts. A basic principle is that if a material is mined or smelted, its embodied carbon will be huge due to high-temperature manufacturing processes – and will account for a lot more than involved in transportation. This includes recycled steel and aluminium. There are some high-performing wonder materials: earth-based materials like terracotta bricks; natural materials that have good thermal properties and can be net biogenic carbon stores such as hemp-lime; cement fibreboard. But you can't just look at materials in isolation. A building with a timber or stone facade looks promising but it's the substructure supporting it that has the highest carbon load.

Sometimes thermal mass is more useful than insulation, especially with rising temperatures. When we refurbished Wates House for the Bartlett, for example, we convinced the client to retrofit by retaining the concrete frame rather than rebuilding – not only is the thermal mass useful (and beautiful) but it saved the energy of demolition.

We see it as inevitable that the industry will move to using whole-life carbon calculations, leading to a fundamental reassessment of how we practise architecture.

Jake Attwood-Harris is sustainable design advisor at Hawkins\Brown

Photos: Hawkins\Brown; Paul Riddle

A LIFE LESS ORDINARY

Architects and engineers are showing how utilitarian structures can be reimagined as inspiring, future-flexible spaces. Nick Jones reports

This page: Architecture Initiative's Northampton International Academy – a derelict Royal Mail sorting office reborn as a 2,200-pupil school

To the casual observer, last year's Architects Declare manifesto appeared to offer the unusual spectacle of an entire profession shooting itself in the foot. The commitments contained in the headline-grabbing document – signed by many of the UK's leading practices – sought to address the construction industry's contribution to climate change: awkward truths such as that it produces about 40% of the UK's total carbon emissions and uses 295 million tonnes of virgin materials per year. Among the architects' pledges was a vow to "upgrade existing buildings for extended use as a more carbon efficient alternative to demolition and new build whenever there is a viable choice". The fact that construction and disposal contribute about half of a typical new building's lifetime carbon emissions can no longer be ignored: increasingly, we're going to have to make do with the built environment we have.

"The reuse of our existing building stock is key to maximising the carbon we've already spent, and fundamental if we're ever going to get near to carbon neutral as an industry," says Paul Hutter, a director at engineering consultant AKT II, which has helped to revitalise a series of existing buildings, from an 18th-century flax mill in Shrewsbury to the South Bank Tower, once the tallest building in south London. In pursuit of this goal, architects and engineers are showing that building types previously dismissed as inflexible – from 1970s office blocks to multistorey car parks – can be put to a range of new uses, sustainably, economically and to stunning effect. Far from sounding the death knell of the architectural profession, the rise of reuse could be its most exciting chapter yet.

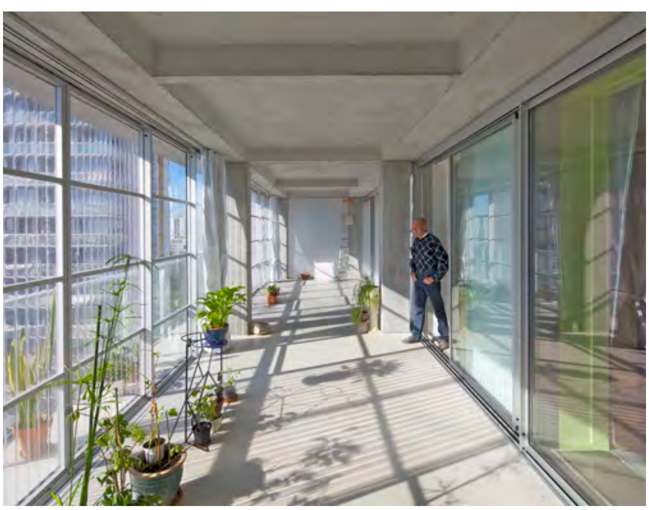
Serious structure

Adapting existing buildings is as old as construction itself, but it has been enjoying much greater prestige in recent years. The last two winners of the Mies van der Rohe Award, the EU's top prize for contemporary architecture, have involved the radical overhaul of postwar buildings: Lacaton & Vassal's transformation of a 530-unit housing block in Bordeaux and NL Architects and XVW's reboot of Amsterdam's brutalist Kleiburg development. Meanwhile, architects are discovering possibilities in existing utilitarian structures that would be inconceivable if built from scratch: at the Zeitz MOCAA art gallery in Cape Town, Thomas Heatherwick carved and sliced an old grain silo into one of the most instagrammable buildings in the world; in London, Herzog & de Meuron recast the brooding oil tanks beneath Tate Modern as one of the capital's leading cultural attractions, without even having to clean the oil stains from the walls.

It is no coincidence that these buildings all have a reinforced concrete structure. Concrete, perhaps more than any other material, is ripe for adaptation. "Longevity has no chance without serious Structure," wrote the architectural theorist Stewart Brand, who in the 1970s did much to popularise the idea of designing long-life, loose-fit buildings capable of adapting to new uses. Given that the predicted life of contemporary reinforced or prestressed concrete structural elements in an internal environment is 100 years, there is usually plenty of scope for a second lease of life.

It takes a lot to make an existing concrete structure unviable. Architecture Initiative's Northampton International Academy project, for example, began with a derelict former ▶

Photo: Will Scott



Photos: Mike O'Dwyer; Philippe Ruault;

Royal Mail sorting office that was little more than a frame blackened by arson attacks – an inauspicious starting point for a school. But the material was in a surprisingly good condition, says design director Lee Mainwaring. "All of the concrete was covered in soot, but we gave it a sandblast, which brought up the nice raw finish, and that was basically it in terms of the structure." The fair-faced concrete is now one of the defining features of the interior (see box, opposite).

It may sound obvious, but giving concrete a good clean can be revelatory. On London's Euston Road, Camden's unloved, brutalist former town hall annexe has been reborn as the very hip Standard hotel, but the precast concrete facade is essentially the same. It has just been carefully cleaned with a mild water-pressure-based abrasive system, revealing its near-white aggregate from beneath 45 years of London pollution. The intervention could barely be more light touch, but it has been vital to the building's reinvention.

It's also striking how little work is often needed to make a concrete structure fit for a completely different use. A Royal Mail sorting office is starkly different in terms of function to a school: deep-plan with very little daylight, the Northampton building was built for storage and logistics rather than the shaping of young minds. Mainwaring says that it would almost certainly have been torn down if the local property market had been more buoyant. But they still tried to do as little as possible: "Every insertion is

Above left: AKT II's forensic analysis of the 30-storey South Bank Tower in London allowed Kohn Pedersen Fox's design to extend the existing structure by 11 floors
Left: Lacaton & Vassal transformed three social housing blocks in Bordeaux by adding a 3m-deep structural facade

"WE NEED TO MAKE SURE WE GIVE THIS GIFT OF DATA TO THE NEXT GENERATION. NOT THE SAME DATA WE'VE USED – WE NEED TO GIVE THEM MORE"
PAUL HUTTER, AKT II

obviously a massive amount of effort and money and time and craftsmanship. So we just cut these two long slots down the length of the building, with the primary school arranged around one and the secondary school around the other. It was very simple."

The 3.6m-wide voids were created between the main 10m x 10m structural grid lines on all three floors by breaking through the slabs with jack hammers. The rebar caging was then reset and the in-situ concrete recast around the edge of the slots. Daylight now washes through the spaces, enhanced by 6.5m ceiling heights and the liberal use of white, glazed and reflective surfaces.

Featherstone Young's recent award-winning conversion of the lower levels of a Wrexham car park into an arts centre and community space also involved less of a structural overhaul than might be imagined. "There was a lot of discussion about how we could work around what was already there, and make smaller rather than wholesale changes – partly because that's more sustainable, but partly because it's more economical as well," says architect Sarah Featherstone. "Externally, the brick facing and blue-painted ironwork weren't the most attractive, but inside it was actually a very beautiful precast concrete structure. It has these prestressed

T-beams which curve so you can see where the ramps lead up – it's not just a flat ceiling."

Again, the main structural interventions involved drawing more light into the deep-plan building: larger openings were made on the south and east elevations and two deep voids were created by removing several 10m-long concrete beams from the first-floor slab. "We decided to take them out in their entirety rather than try to cut them, which might have disturbed the structure's integrity," says Featherstone. On the floor above the voids, 30cm-wide slots were cut between the prestressed beams of the roof slab – the thin openings a necessary strategy to avoid severing crucial tendons. Each pair of slots is straddled by a rooflight, casting light deep down into this previously back-of-house area, now transformed into a gallery space and open "people's square" (see box, overleaf).

Added space

Another advantage of concrete structures is that they are often strong enough to accommodate extra space, either in new storeys on top or new elements hung from them. For example, Lacaton & Vassal reinvigorated its Bordeaux housing block by adding a 3m-deep structural facade that provides generous winter gardens to all the flats.

Structural engineer AKT II has taken this search for spare capacity to new levels. At the South Bank Tower in London, it collaborated with architect Kohn Pedersen Fox on a first-of-a-kind refurbishment, adding a further 11 storeys to a 30-storey building. It is now repeating the trick a couple of miles north in Islington, working with Horden Cherry Lee to add 12 new levels to Richard Seifert's 16-storey Finsbury Tower.

Both projects hinged on forensic analysis of the original 1960s structural drawings, both to understand the structure and to identify any spare capacity. "We wanted to understand every single bit of rebar and why it was there, what the original designer was thinking. You have to start by putting their hat on," says AKT II's Paul Hutter. The drawings were the most important thing on the job, he adds: "If anyone went to draw on my existing drawings I slapped their hand away and told them to get off. They were precious to me – that pack of drawings drove the project, drove the architecture, drove the structure, drove the programme. It enabled us to work out where the opportunity was and say 'let's not just push it two or three floors, let's go all the way'."

Combining the drawings with technology unavailable to the original engineers, AKT II modelled the entire history of the concrete frame to understand the distribution of load, both as materials aged and floors were added. On Finsbury Tower, they constructed finite element models, with over 200 construction stages, spanning from the 1960s through to 2050. They also conducted extensive geothermal analysis, identifying the unused capacity of the piled foundations. "The ▶

"THE CONCRETE WAS COVERED IN SOOT, BUT WE GAVE IT A SANDBLAST, WHICH BROUGHT UP THE NICE RAW FINISH, AND THAT WAS BASICALLY IT"

LEE MAINWARING, ARCHITECTURE INITIATIVE

IN PRACTICE

Northampton International Academy

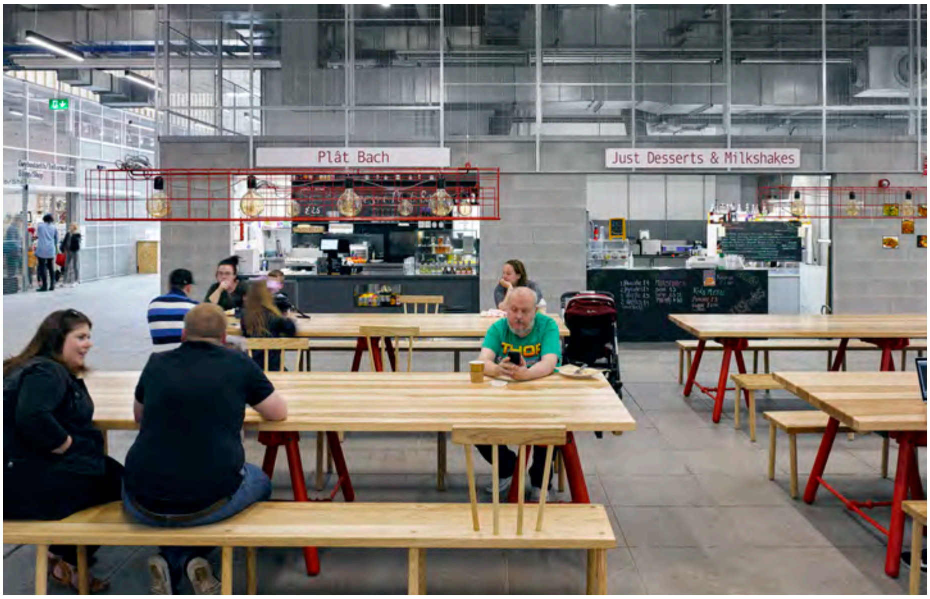
Four years ago, it would have been hard to imagine the abandoned Royal Mail sorting office on Barrack Road as the sort of place you would happily send your children on a daily basis. The near-windowless 1970s utilitarian structure had been vandalised, broken into, set on fire. "It had almost become a beacon of bad news. The only reason it hadn't been demolished was that it would have been too expensive," says Architecture Initiative design director Lee Mainwaring.

Thanks to the practice, the sorting office is no longer an eyesore – and it's turned out to be the answer to Northampton's secondary school crisis too. With minimal interventions in the existing structure (see main story), the building has been reborn as a 2,200-pupil school, covering primary to sixth-form. Two long voids cut into the floor plates of the two-storey, double-height building wash the deep-plan interiors with daylight. In a nod to the building's history, the concrete has been left exposed, with lighting and other services suspended from the 6m-high soffits.

Basing the spatial arrangement on the 900mm x 900mm waffle slab structure, Architecture Initiative placed the classrooms around the building perimeter in a mezzanine level suspended via a system of steel clamps from the concrete coffers. The teaching rooms are allowed maximum access to natural light through new window openings punctured through the existing external walls. More specialist areas such as science labs and music and drama facilities are placed in the heart of the structure.

Mainwaring argues that in some ways it is better than a new-build school. At 22,250m^2, it has a greater ratio of space to pupils than the Department for Education would normally budget for. "There was no point demolishing or not using part of the building, so we made the school more generous, and made use of these double-height spaces." The thermal mass of the concrete structure also prevents overheating, he adds, and those mighty floor slabs mean Northampton can teach subjects not normally on the curriculum: "On one side you can drive a car in, so they offer automotive engineering – not many schools can do that."

Photo: Will Scott



IN PRACTICE

Ty Pawb, Wrexham

At Ty Pawb art centre, Featherstone Young has shown how the reuse of an existing building can give an architect the freedom to think about a traditional function in an entirely new light, and offer something that a new-build can't. Within a 1990s multistorey car park and market hall, Featherstone Young has inserted art galleries, market stalls, performance space, a learning centre, cafes and bars. And in doing so, it has radically reimagined what an arts centre can bring to a community.

The brief for the £4.5m project was originally to provide three gallery spaces for local arts organisation Oriel Wrecsam, but Featherstone Young successfully argued for a single dedicated gallery surrounded by looser, indeterminate spaces, which would be more welcoming than typical "white cube" art centres. "These spaces can lend themselves to a whole range of different activities – workshops, concerts, recitals, open mics. It resolved some of the tensions between the art centre and the market hall: instead of the two never meeting, there's this area where quite different activities might come together."

In keeping with this "baggy space" concept, Featherstone Young conceived the building as a continuation of the street, reusing the existing concrete flagstones and employing a palette of utilitarian, everyday materials such as plywood and exposed blockwork. The council client team were initially nervous about the aesthetic: "Celebrating the concrete paved floor, exposing the concrete roof, using materials that were quite rough was difficult for them. But I think they supported it in the end because of the concept of the streetscape."

A light touch was taken with the structure (see main story), with voids cut into the prestressed roof and first-floor slab to bring light into the eastern side of the deep-plan building, and openings cut into the east and south elevations. This turned the former "back" of the building into a welcoming new frontage, emphasising the building's role as a shortcut from the edge of town to the centre. Where the new rooflights have claimed space from the top-level parking, there is now a bee garden – an example of user-led "baggy space" in action, says Featherstone.

With cities including York and Birmingham considering a car-free future, could Ty Pawb provide a template for the future of our parking infrastructure? "We have had quite a few people ring up now with multistorey car parks they want to transform," says Featherstone. "As soon as you take cars out of the equation, you have all this space you can potentially turn into public realm."

"AS ARCHITECTS, YOU HAVE TO CREATE A CLEAR FRAMEWORK, BUT YOU DO AS LITTLE AS YOU NEED TO DO"

SARAH FEATHERSTONE, FEATHERSTONE YOUNG

advance in that type of analysis in the past 5-10 years has been quite profound, and it's allowing us to push the boundaries more and more," says Hutter.

The upshot is that two tired London office buildings have become desirable mixed-use developments: on the South Bank Tower, the new storeys cantilever from the core adding 67,000m^2 of floor space; at Finsbury Tower, the new scheme adds 100% more area within the footprint, replacing the core but reusing the existing foundations and basement. It is the dramatic expansion of usable area, says Hutter, that makes such schemes commercially attractive. "It's more complicated work than new-build, and you need a good contractor, but the savings on programme mean the construction cost is substantially reduced."

But more needs to be done to build the commercial case for refurbishment. As the government's Building Better, Building Beautiful commission highlighted in its final report in January, new-build construction is zero-rated for VAT, but renovation is taxed at 20%. The reason often cited for this anomaly is that the construction industry, which constitutes more than 6% of the UK economy and 7% of its jobs, relies on the "planned obsolescence" of buildings to keep the wheels turning. Such a position looks increasingly untenable in the light of challenging emissions targets.

Planning regulations could also be more pragmatic, says Hutter, pointing out that any unused capacity in existing structures is a wasted resource. "We need planning authorities to perhaps break their own rules and allow the correct amount of mass to be added. With the South Bank Tower, we argued we weren't maximising the building, so they allowed us to go to 11 storeys. The construction industry needs to put these arguments forward before a new-build is on the table."

An adaptable future

Recent conversions hold valuable insights for the design of new buildings – what could we do now to encourage future reuse? For Hutter, the key lesson is to share drawings and data forward. "We need to make sure we give this gift of data to the next generation. It's not just about giving them the same data that we've used – we need to give them more, so they can understand the buildings better than we do now. Then, in 50 years' time when they hopefully have more technology, they can push the boundaries yet again."

A flexible, loose-fit approach often seems to characterise the new-build work of many architects who've undertaken major refurbishments. Jean-Philippe Vassal, the architect behind the Bordeaux housing project, intends that every one of the practice's new projects should contain equal amounts of programmed space and "undefined space".

Similarly, Sarah Featherstone is a proponent of what she calls "baggy space": "It is about exploring how much we as architects need to do, before other people can come in so it can grow and adapt. You have to create a clear framework but you do as little as you need to do."

Right: The facade of the Standard hotel in London was carefully cleaned with a mild water-pressure-based abrasive system
Below right: At the Zeitz MOCAA gallery in Cape Town, Heatherwick Studio carved a stunning atrium from a grain silo

Her practice recently completed Bay 20, a community centre and boxing club under the Westway in London: "It's a shared space for two different activities, with the community centre as loose as possible and this in-between space between the two buildings, which people can spill into and use in different ways."

The distinction between new-build and refurbishment may become increasingly blurred. Building elements are already being designed to be demounted for reassembly elsewhere: the precast-concrete top tiers of the 2012 Olympic Stadium, for example. This semi-permanent approach to construction could be coupled with material passports, now being pioneered in the Netherlands by an organisation called Madaster that logs data on all the materials in its library of buildings. In the near future, a Madaster-registered building scheduled for disassembly or demolition could be scanned by project teams for parts to be reused elsewhere.

The industry has a long way to go if it is to make more than a token dent in the 295 million tonnes of virgin materials it consumes every year. But architects and engineers are already coming up with ingenious responses, using the rich history of buildings and their component materials to create new and reimagined spaces. The Building Better, Building Beautiful commission may well be right when it says: "The beautiful building is one that outlives its original use." ●

Photos: James Morris; Tim Soar; Iwan Baan

WELCOME HOME

Concrete can support plant and animal life in surprising and often beautiful ways, finds Tony Whitehead

Since 1950 the UK hedgehog population has shrunk by 96%. Tree sparrow numbers are down 95%. Many other birds, including starlings, swifts and songthrushes have also suffered depressing declines, along with bees, butterflies and even earthworms.

All of this adds up to a steep decrease in Britain's biodiversity. Everything from climate change to wind farms to modern farming practice has been blamed, and insensitive building too has played its part. From later this year, however, the construction sector will, by law, become part of the solution. With few exceptions, planning permission will be withheld from all development in England that cannot demonstrate a 10% net gain in biodiversity. The new regulations are set to become law this autumn and will apply fully by 2022 (see box, overleaf).

Many planning authorities already impose net gain conditions on schemes, so the new rules should not prove too much of a hardship for developers who have adopted advanced environmental policies. But the changes will certainly serve to raise the profile of urban wildlife, not least as a focus for innovation in construction materials and techniques. Beyond biodiversity, the myriad benefits of nature in cities are well rehearsed and often intuitive. From mitigating air pollution, overheating and flooding to improving psychological wellbeing, we clearly stand to gain a lot by welcoming in the wild.

It turns out that concrete can be a very good way to do this. Far from being grey and inert, it can support plant and animal life in surprising and often beautiful ways. Researchers are using it as durable substrate, robust shelter, even a source of nutrients for many different creatures from the smallest to the most useful to the most endangered.

Take the work of concrete scientist Dr Elizabeth Gilligan. Her company, Material Evolution, is developing concrete panels that are specially adapted to host sedums, the low-maintenance succulent plants used extensively on green roofs. "The panels have deep indents in which sedums can take root," she explains. "This happens with the panels horizontal, but after a few days, when the plants are established, the panels can be made vertical to form a building facade."

Much of Gilligan's research has focused on developing a plant-friendly concrete mix. "It's a hyper-porous concrete with a very open cell structure to allow for plant and water ingression," she says. "It holds water like a sponge, so its qualities are exactly what most precast panel manufacturers would try to avoid. However, the concrete still forms a protection for waterproof membranes and insulation behind it."

The mix comprises 90% recycled material, as well as nutrients for the plants, along with elastic fibres which help the concrete cross-knit back together if it starts to crack under the influence of roots. The exact details remain secret, pending patent approval, but Gilligan says it can be adapted to recycle local waste streams: "For example, a lot of seafood gets eaten in the San Francisco area. We have done some experimental work there using crushed oyster shells as a nutrient source."

Opposite: Green and Blue's bee homes are all made from concrete with a 70% recycled mix using local china clay waste
Right: Material Evolution's concrete mix contains 90% recycled material as well as nutrients for the plants

A test wall of Gilligan's panels is already in place at Queen's University, Belfast and performing well: "The bees, butterflies and other bugs love it." But the panels do more than just support local biodiversity: "The concrete carbonates, reabsorbing CO_2 relatively quickly. The sedums also absorb CO_2 and are good at trapping pollution particulates. They could be particularly effective lining an urban canyon – we have measured local improvements in air quality of up to 60%."

The panels must be irrigated to protect the plants from drought, and grey water can be used for this: "The panels can form part of a filtration system, cleaning the water and then returning it to the building."

Of course, not all green walls require specialist concrete. Precast panels are routinely shaped to hold various systems of planters, with the concrete simply providing a tough, root-resistant background against which plants can thrive. Dr Eleanor Atkins, lead researcher at Staffordshire University's Green Walls Centre, addresses the potential concern that plants will damage a building: "Plants can damage buildings, but roots tend to find existing cracks – so if the facade is new and sound, it shouldn't be a problem."

In fact, a covering of plants can be a shield against local environmental conditions: "As well as boosting biodiversity, green walls can protect a building by providing insulation and reducing weathering, including frost shattering. They can also keep a building cool in summer by providing shade, and if the plants are deciduous, this shade will be reduced in winter to let the sun through – particularly useful for seasonal window shading."

Atkins advises that green walls should be selectively placed

"IT'S A HYPER-POROUS CONCRETE WITH A VERY OPEN CELL STRUCTURE TO ALLOW FOR PLANT AND WATER INGRESSION. IT HOLDS WATER LIKE A SPONGE"
DR ELIZABETH GILLIGAN, MATERIAL EVOLUTION

where they can do most good, as they can be relatively expensive and may require some irrigation and maintenance. If that puts off some building owners, they might prefer a new sort of concrete panel created by two academics at the Bartlett School of Architecture at University College London.

Professor Marcos Cruz and lecturer Richard Beckett have been researching how concrete can be made more bioreceptive, and have developed facade panels specially designed to encourage the growth of cryptogams – organisms such

Photos: Green and Blue; Elizabeth Gilligan / Material Evolution

as moss, algae and lichens – which require no irrigation.

The aesthetic effect has been a major focus of their work, says Beckett. "After all, a green stain on a white building can look terrible. It often marks some point of failure like a leak. So we have experimented with ways to encourage mosses and lichens to grow in a way that is pleasing to the eye as well as beneficial to the environment." This has involved designing a range of mixes – most of which result in a slightly porous concrete that allows the rhizoids (root structures) to get a foothold. "We have also altered the pH so that it is more conducive to the plants," says Beckett. "The concrete is perhaps a little weaker than standard mixes, but we are proposing it for facade panels rather than structural purposes."

The surface can either be "seeded" with spores, or cultivated cryptogams can be transplanted onto the panels. "Alternatively you can just wait and see what develops. This gives you plants that are well adapted to the location, but obviously takes longer and gives less control over aesthetics."

The panels' benefits are wide ranging: mosses and lichens absorb CO_2 and punch above their weight when it comes to purifying air by trapping particulates. They also provide a habitat for micro fauna and small insects on which birds can feed.

None of these benefits will be realised, however, unless the panels look attractive enough to be specified. "We have tried various patterns and the ones with more flowing shapes tend to look best," says Beckett. He points out that lichen-covered statues in churchyards develop a pleasingly romantic aspect: "You'll often pay more at auction for a garden statue with patina than for a new, unweathered one."

There are plans to install the panels at two sites in London – a school and an underground station. Meanwhile, Beckett has turned his attention to the role of biodiversity in improving the indoor micro biome. "This is the population of bacteria that inhabit your building," he says. "The more cleaned and sealed our buildings become, the less diverse the bacteria. You end up with too many human-related bacteria, which can be unhealthy."

A rich diversity of plant and animal life outside a building can improve the bacterial diversity

> "WE ENCOURAGE MOSSES AND LICHENS TO GROW IN A WAY THAT IS PLEASING TO THE EYE AS WELL AS BENEFICIAL TO THE ENVIRONMENT"
> RICHARD BECKETT, THE BARTLETT

Photos: Sarah Lever; Richard Beckett, Marcos Cruz and Javier Ruiz

Opposite: The Bartlett's facade panels are specially designed to encourage the growth of organisms such as moss and lichens
Right: Green and Blue's bee homes can be built into the fabric of a house without compromising its structure

inside, says Beckett. He is looking to boost this further – again by using concrete. "We have found that by seeding specially adapted concrete with healthy bacillus we can encourage good bacteria at the expense of the bad, and end up with panels that are resistant to MRSA, the bacteria that causes infections in hospitals."

Working on an altogether larger scale, a company in Cornwall is using concrete to provide builders with an easy way of making their developments more friendly to local fauna. Green and Blue's range of small animal homes are all made from concrete with a 70% recycled mix using local china clay waste.

"We chose concrete because it is a material builders are familiar with," says founder Gavin Christman. "It's long-lasting and structural, so our homes for bats, swifts and bees can be built into the fabric of a house without compromising its structure. And being integral to the building, they are there for good, whereas wooden boxes can decay over time through lack of maintenance."

Initially interest in the products came mainly from developers specialising in building with nature, but Christman says that it is receiving more enquiries from mainstream companies, thanks to the biodiversity net gain rules. Formalising biodiversity requirements within the planning system also chimes with a wider change in public awareness, he suggests: "We have ambitious housebuilding targets in the UK, so I think there is an understanding that the more we build, the more important it is that every house gives something back to nature."

Photo: Green and Blue

Biodiversity net gain explained

The requirement for developers to achieve a biodiversity net gain of 10% is expected to become law in autumn this year, which will mark the start of a two-year transition period. To begin with, biodiversity will probably be measured using the Biodiversity Metric, an online tool published by Natural England. Developers will comply first by minimising any destruction of habitat and then by adding improvements.

"Currently different local planning authorities use different metrics and require different levels of mitigation or improvement," says Dr Nick White, Natural England's principal net gain adviser. "The new rules should make it easier for developers to know where they stand."

The metric includes a range of things that could count as a credit, such as green roofs, green walls or urban trees. "What's required will vary according to what you start with," says White. "If you are building on an relatively uninteresting brownfield site, then an area of community grassland or a sustainable drainage scheme may be all you need to do to achieve a 10% gain. But if you are building in an area rich in wildlife you will have to do more and possibly add off-site improvements."

While in most cases it is best to achieve the net gain on the site concerned, where this proves impossible developers can offset by improving nearby sites or purchasing sites that have been improved by others. "For example, we have worked closely with the Mineral Products Association as their members are typically good at achieving net gain from quarries that have stopped operating. Many of them restore sites to a standard beyond what is required, and this gives them the potential to make surplus gain available to others. This would in effect create a market in biodiversity."

To avoid having to purchase off-site improvements, White recommends architects and developers consider the biodiversity target at an early stage. "Too often the site is designed, and then handed to ecologists to green," he says. "It is much easier and better to look to integrate green infrastructure early on. Ideally this can be done in a way that delivers wider functional benefits such as mitigating flood risk and improving air quality."

NO OFFSETS REQUIRED

The concrete industry is developing a roadmap to net-zero carbon – and there will be no grey areas, writes Claire Ackerman

Decarbonising concrete has been a focus of the industry for 30 years. It has been reporting on its efforts since the Kyoto protocol in 1990 – which is why 1990 is the benchmark for the carbon indicators in the Concrete Industry Sustainable Construction Strategy. First launched in 2008, the strategy represents a commitment from 10 different sub-sectors to work to an agreed reporting framework. The latest report, the 12th, is based on performance data from 2008 to 2018 and the headline statistic is that the embodied carbon of a standardised mix of concrete is now 72kg per tonne, a reduction of 30% from the 1990 baseline.

The original strategy set a range of targets for 2012, which were subsequently updated with new ones for 2020. As we reach that milestone, the concrete industry will set out a revised strategy for beyond 2020, with the aim of achieving net-zero carbon. At The Concrete Centre, we want to make the journey as easy as possible for designers, but – let's be honest – it is complex. So the next four pages don't contain all the answers, but they do explain some of the key components of the solution.

The first challenge in reaching net-zero carbon is to understand what puzzle you are trying to solve. Are you looking at carbon at a product level, or carbon at a building or structure level? They obviously work together, but the levers for change are very different, so they are best explained separately. Then there is the carbon comparison for the first life of a building versus its many potential uses over a whole lifetime, which is covered on pages 3-9.

Decarbonising cement and concrete

The majority of the embodied carbon in concrete comes from cement, an ingredient that plays an important role in properties such as fire resistance and durability. For over 20 years, the UK cement industry has been replacing fossil fuels with renewable, low-carbon sources. Through fuel switching and the use of by-products from other industries, carbon dioxide emissions per tonne of cement have fallen by 29% since 1990.

A 2019 study by the University of Cambridge Institute for Sustainability Leadership (CISL), ▶

INNOVATION IN ACTION

Low-carbon cements

In 2018, the Mineral Products Association (MPA) initiated a project to develop new low-carbon multi-component cements for UK concrete applications, forming a partnership with Hanson, BRE and Bison Precast with the aim of saving carbon through the increased and more efficient use of low-carbon cement. Recent research has shown that materials such as ground granulated blast-furnace slag (GGBS), fly ash, calcined clay and powdered limestone can work together effectively in a multi-component cement. Combinations such as cement-GGBS-limestone, cement-fly ash-limestone and cement-calcined clay-limestone potentially enable greater rates of cement replacement – in current tests, 65% has been achieved. The project is testing the performance of a range of concretes (22 new cements in 50 concrete mixes) and the results will be used to support standardisation of low-carbon multi-component cements in British standard BS 8500. The project is due to be completed in 2021 with the new materials available to the market soon after. The research and demonstration are part-funded by the government under the Department for Business, Energy and Industrial Strategy's (BEIS) £9.2m Industrial Energy Efficiency Accelerator programme, which is managed by the Carbon Trust assisted by Jacobs.

Industrial fuel switching

Switching from fossil fuels to hydrogen and plasma energy could also reduce carbon emissions in cement and lime production. In 2019, a BEIS-funded feasibility study found that a combination of 70% biomass, 20% hydrogen and 10% plasma energy could eliminate fossil fuel CO_2 emissions from cement manufacturing. Now BEIS has awarded £6.2m to the MPA to test that theory. The groundbreaking project will involve trials at sites operated by Tarmac and Hanson Cement, one focusing on electrical plasma energy with biomass, the other on hydrogen and biomass.

Carbon capture

"Direct separation" is a new type of carbon-capture technology, in which the pure CO_2 released from limestone as it is heated is collected separately from the furnace exhaust gases. In a five-year, EU-funded programme that began in 2016, the LEILAC (Low Emissions Intensity Lime And Cement) project has been testing its application to the cement and lime industries at the HeidelbergCement plant in Lixhe, Belgium. The pilot unit has undergone two years of extensive testing in a standard operational environment, in order to demonstrate that the technology can work at scale across the industry. LEILAC will also deliver a techno-economic roadmap for implementation and share knowledge with industry partners.

LEFT All of the in-situ concrete at Nicholas Hare Architects' University College London Student Centre includes 50% GGBS

Photo: Alan Williams

published by Material Economics, found that it was possible for the cement sector to be net-zero carbon by 2050, although it also estimated that zero-carbon production will cost more than current practice.

The report identifies four routes for cement and concrete to decarbonise:

- Materials efficiency and circular business models
- Materials recirculation and substitution
- New low-emissions processes
- Carbon capture and storage/use.

Not all of these activities are related to cement and concrete production – some fall under the scope of the designer.

Cement and concrete production

The simplest place to start is with energy use and indirect emissions. As the electricity grid decarbonises, the energy used to produce materials will be less carbon-intensive, reducing the embodied carbon of cement and concrete. The decarbonisation of delivery transport will also have an impact. Concrete is a local material so the overall travel distances are small. As the automotive industry deploys low-carbon vehicles, the costs and emissions profiles for transport will change.

The next energy use category is direct emissions, the energy use that is in the control of the cement and concrete manufacturer – combustion and process emissions. A cement kiln reaches high temperatures, and that requires energy. Here fuel switching is one answer: the industry has already replaced 34% of its fossil fuel use with renewable, low-carbon sources, which include biomass as well as materials from other industries and processes that could otherwise go to landfill. But to reach net zero, a zero-carbon fuel mix is needed, and this will require new technologies. The cement sector has recently been awarded funding by the Department for Business, Energy and Industrial Strategy to test emerging technologies such as hydrogen-based fuels (see box, page 21).

Some emissions are difficult to abate, and this is true of the process

Sustainable concrete: Progress to 2020 targets based on 2018 performance data

The graph below summarises the 12th progress report on the Concrete Industry Sustainable Construction Strategy. The strategy is underpinned by the international standards ISO 14001 on environmental management and ISO 9001 for quality and performance, and the industry has met its target on both of these, with 100% of sites now certified. It also uses the responsible sourcing standard BES 6001, to which 96% of concrete is certified. The concrete industry is a net user of waste and by-products from other industries, using 271 times more than it produces. The graph is based on a 2008 baseline year for all targets, other than carbon targets, which are based on a 1990 baseline year. For the latest updates on the data, visit sustainableconcrete.org.uk

ABOVE The LEILAC project has been testing the application of "direct separation" technology to the cement and lime industries at the HeidelbergCement plant in Lixhe, Belgium

Photo: Carbon Trust

emissions related to the physical transformation of limestone to Portland cement. One option is lower-carbon clinkers – already other minerals are added to reduce the use of Portland cement clinker and produce lower-carbon cements. New technologies are also in development.

Alternative clinkers can help to reduce process emissions, but adoption of carbon capture, use and storage (CCUS) is needed to eliminate them entirely. CCUS will enable the transition to net-zero carbon of not only the cement and concrete industry, but the steel industry too. For the cement and lime sectors, there is a live demonstration project in Belgium (see box, page 21). There are obviously considerable costs associated with such transformative technology, and collaborative European projects are currently leading the way. The UK cement sector is encouraging the government to support similar projects for the local manufacture of net-zero carbon cement.

The cement and concrete industry is developing a roadmap to net-zero carbon, which will include the potential application and associated costs of a number of enabling technologies. Implementation of these technologies is not all within the control of the industry, though we want to collaborate to accelerate progress. One thing that the industry can control is the first principle of the roadmap: it will not rely on offsetting.

Concrete and carbon in the built environment

The other group of enablers that are vital to achieving net-zero carbon concrete and a net-zero carbon built environment are designers and the wider construction industry, through material specification, design, use and reuse of buildings. The construction industry represents 7% of the UK's economy yet 10% of its CO_2 emissions, and it directly influences 47% of the total when the operational emissions from the built environment are included. If buildings were designed to use less material, be more energy-efficient in use, last longer, be more easily repurposed, and then were recycled at end of life, the UK could reduce its carbon emissions considerably. There are many ways in which this can be tackled using concrete.

Designers can use concrete in myriad ways in the built environment, and each application can be specified with a different balance between performance and carbon. There are material-efficient design solutions, there are energy strategies that can use concrete's thermal mass, and there are flexible design choices that enable buildings to be used and adapted in many ways over their lifetime, to make the most of concrete's durability.

Guidance from The Concrete Centre is available to enable designers to:

- specify low-carbon concrete
- design using material-efficient design solutions such as post-tensioned concrete, ribbed slabs and offsite construction
- use the thermal mass of concrete to save energy
- optimise the whole-life carbon investment of concrete buildings.

THROUGH FUEL SWITCHING AND THE USE OF BY-PRODUCTS FROM OTHER INDUSTRIES, CO_2 EMISSIONS PER TONNE OF UK CEMENT HAVE FALLEN BY 29% SINCE 1990

We are also working to share lessons learned and new innovations on:

- reuse and refurbishment of existing structures
- new cements
- carbonation, the process by which concrete absorbs carbon naturally, and new carbon-cured products in which this natural process is accelerated.

It should not be forgotten that this is just part of the story. No other product offers so much in terms of strength, durability, thermal mass, fire resistance and resilience, all of which will be essential for adapting to the climate change that is already unavoidable. The Concrete Centre is committed to working with industry, designers, contractors and clients to achieve the best carbon result now and to support investment in new technologies to deliver a carbon-negative future. ●

More information about the Concrete Industry Sustainable Construction Strategy is available at sustainableconcrete.org.uk. A range of guidance documents on low-carbon design published by The Concrete Centre can be downloaded from concretecentre.com/publications