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The Concrete Centre

CONCRETE QUARTERLY

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Director, architecture
and sustainable
design, The Concrete
Centre

Thirst for knowledge

It's great to see so much cross-industry discussion and acitivity about developing the targets we need to deliver a zero-carbon built environment, from a net-zero standard to a new Part Z of the Building Regulations.

But I've noticed that they very often come up against the same problem: a lack of data about the whole-life carbon of the buildings we are completing today. We find this as we compile Concrete Quarterly: detailed information just isn't available, especially for projects that might have taken four or five years to come to fruition due to the disruption caused by Covid.

Targets are essential for setting the direction of travel and aligning a fragmented industry towards a common goal – but only if they are appropriate. We need to set them at a level that encourages rather than stymies knowledge-sharing, and ensures that neither success nor failure acts as a disincentive to further progress. We don't want to create the impression that the job is done as soon as the boxes are ticked, or conversely that there's no point trying if a project can't tick them all.

In particular, we should be wary of setting benchmarks based on limited data. The projects where information is already available on embodied and whole-life carbon are typically the early adopters. We should admire and learn from their passion, while recognising that we cannot necessarily extrapolate their experiences to produce a realistic picture of where the wider industry is at. The sample may be skewed towards certain building types for which solutions are more readily applicable, for example,

Net-zero is a journey, and we don't yet have a complete map. Early data is based on assumptions that will continue to be refined or challenged by further analysis, especially as our understanding of the problem and potential solutions is evolving so rapidly. Data from previous projects is also unlikely to reflect the best possible practice today, and certainly not tomorrow. As the UK concrete sector continues to decarbonise and with a steady stream of new technologies becoming available, the solutions we use today to lower the embodied carbon of a structure will not be the best ones in ten, five or even two years' time.

At a recent hackathon organised by LETI, Circuit and the Interdisciplinary Circular Economy Centre for Mineral-based Construction Materials, there was a fascinating debate about different potential metrics, which threw up some fundamental questions that still need to be resolved. For example, how do we actually quantify the materials in a building: by weight, by volume, by value, or by carbon? Only through concerted industry-wide recording and reporting will we be able to determine the most effective strategy.

This work of evidence-gathering seems to me to be as important as setting the targets themselves – and perhaps even more so at this crucial stage of the journey. One of the most valuable things that teams can do today is to share their progress and learning on reducing whole-life carbon, helping to amass the detailed evidence base to support realistic but stretching targets, and ultimately getting the built environment to where it needs to be. ■

> THIS WORK OF EVIDENCE-GATHERING SEEMS TO ME TO BE AS IMPORTANT AS SETTING THE TARGETS THEMSELVES

CONCRETE QUARTERLY

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Photos: Paul Burroughs

INNOVATION

BIOZEROC

A CAMBRIDGE START-UP IS USING BACTERIA TO CREATE CEMENT-FREE CONCRETE. NOW THEY JUST HAVE TO PROVE THAT THESE TINY MICROBES CAN WORK AT SCALE …

ABOVE
BioZeroc's John Somerville, Laurence de Lussy Kubisa, Liv Andersson and Davor Ivankovic

The drive to decarbonise concrete is progressing on several fronts, each with exciting potential. One of the most intriguing areas of research focuses on replacing cement with bacteria. Unlikely as it sounds, some microorganisms can bind the aggregate used in concrete by precipitating calcite, the naturally occurring form of calcium carbonate. BioZeroc, a Cambridge-based start-up, is using this capacity to create cement-free concrete.

Co-founder Liv Andersson, a former sustainability professional with qualifications in architecture, engineering and ecology, explains: "In my old job, I worked to reduce the carbon embodied in new buildings and, sure, good design can significantly reduce a carbon footprint. But for me, in the end, it was not enough. We need new approaches – new materials – if we are to go further and get to a zero-carbon construction industry."

Andersson became fascinated by the use of calcite-precipitating bacteria to stabilise soils, and in self-healing concrete (see CQ 270, winter 2019). "I thought, suppose you could scale up this process to create larger, more solid material? Suppose you could make concrete this way? If you use microbes rather than cement to bind aggregate, that alone cuts concrete's carbon footprint by about 85%."

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IF YOU USE MICROBES RATHER THAN CEMENT TO BIND AGGREGATE, THAT ALONE CUTS THE CARBON FOOTPRINT OF CONCRETE BY ABOUT 85%

Andersson met scientist John Somerville through Carbon13, a Cambridge-based organisation that brings together entrepreneurs and scientists. For the past year, together with experimental biologist Davor Ivankovic and microbiologist Laurence de Lussy Kubisa, they have been exploring how to encourage their microbes to work at scale: "Our unofficial motto is from the Daft Punk track: harder, better, faster, stronger!" says Andersson. "The speed of calcite production depends on many things, including the food you give the bacteria, and the conditions in which they thrive. Our process control has succeeded in greatly accelerating calcite production. This is where the gold in our technology lies." The latest samples (see below) are about four times thicker than the previous batch.

Andersson can say little about how they have achieved what she calls "the magic". This is still very new and patents are pending. But on her desk are two small pieces of concrete: "This one is made with cement," she says, "while this one has the same aggregate, but no cement at all. I can't say exactly how we do it, but the ingredients are inexpensive and widely available. And, if we succeed in sourcing feedstock chemicals from waste sources, the resulting concrete could be carbon-negative."

The BioZeroc concrete is whiter than its cement-based equivalent and has a fine texture. "It is in some ways like marble – smoother and less porous than standard concrete – but these are properties that we should be able to control as we refine our processes."

Facade panels are one potential application, as are bricks – as smaller, repeatable elements, they enable faster iteration. BioZeroc expects to create its first full-size brick early in 2023 and to exhibit a larger structure later in the year. "There is an eagerness to use the product, but we have to be patient. Right now our concrete is made with a lot of love in a lab. We need to get it to the point where it can be reliably produced at scale in a factory. So, yes, if you like, harder, better, faster stronger!" ■

Interview by Tony Whitehead

BELOW
The latest samples are about 2cm in diameter and 8cm thick – four times the thickness of the previous batch

LASTING IMPRESSION

JULIAN GITSHAM

FROM HIGH-SPEED HOUSEBUILDING VICTORIAN-STYLE TO BEAUTIFUL BLOCKWORK, VIA A GRAVEYARD OF ASTRONOMICAL WONDERS

Five St John's Row in Long Wittenham, Oxfordshire, was the first house I bought, and must be one of the first concrete houses in the UK. It dates from the late 1800s and has cast concrete walls 1.5ft thick with no foundations at all. The land was owned by St John's College in Oxford, which set up a competition between two local builders to see who could build a row of terraces fastest. They just chucked everything they could find into the mix and whacked them up. As we were exposing the concrete, we found bits of rubbish and old newspaper. The first row, which won the competition, was rendered with a rough pebbledash. The second, where we lived, was rendered smooth with lines to make it look like stone. It was a great house to live in. Structurally, we were able to do what we wanted with the internal walls, and it had incredible thermal mass, so it was warm in winter and cool in summer. Even though it was a terrace, you couldn't hear the neighbours at all.

I've lived in Oxfordshire ever since I went to Oxford Poly when I was 18. But I was brought up in Cheshire, just a few miles away from Jodrell

Photos: Julian Gitsham; St John's Row photo courtesy of Long Wittenham History Group

ABOVE
St John's Row, Long Wittenham, Oxfordshire, late 1800s. No 5 is at the right-hand end of the far terrace

LEFT
Telescope base structure, Jodrell Bank, Cheshire

Bank, where I was later involved in masterplanning, and where Hassell has just completed the First Light Pavilion (CQ 279, summer 2022). It's a goldmine of experimentation, where science, art and culture come together. The site is littered with the detritus of old experiments, where scientists have built something and dismantled it or it's just been left to rot. You have these high-tech telescopes, anchored to the ground by extraordinary cast concrete bases. I love that relationship between the earth, the sky, and the brutalness of the concrete and how it has aged.

The building that has probably influenced my career most is very different. Peter Aldington is one of the great romantic modernists of the 1960s and 70s, a landscape architect who then trained as an architect. I worked for him part-time while I was studying and then for a few years in the practice, which were incredibly formative. At Turn End (1968), he built three houses and an amazing garden with his wife Margaret, just white painted concrete blocks with beautiful Douglas Fir timber structures. The concrete block was the core of everything he did, and everything we drew was coordinated to a block dimension. He taught me the craft of how to put buildings together. Peter is 85 and still lives in one of the houses. We've created the Turn End Trust to educate and inspire the wider public. Our vision is that it will become a studio where students can live and work, a bit like Frank Lloyd Wright's Taliesin. ■

Julian Gitsham is a principal at Hassell and chair of trustees at the Turn End Trust

BELOW
Turn End in Haddenham, Buckinghamshire, by Peter Aldington, 1968

Photo: Turn End Trust

FROM THE ARCHIVE: WINTER 1966

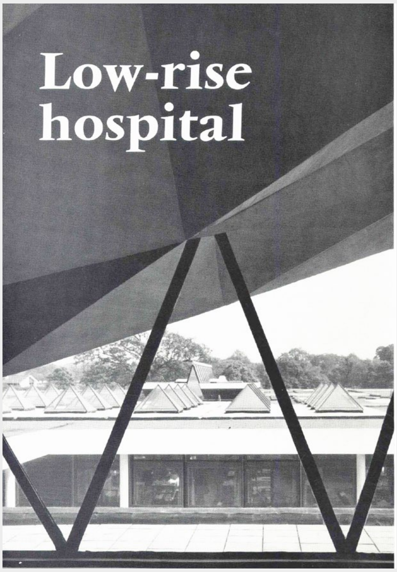
IN NEED OF TREATMENT

A recent Twitter thread by Tim O'Callaghan, director of nimtim architects, has highlighted the plight of Wexham Park Hospital in Slough – described by architectural historian Elaine Harwood as the "most admired and imitated post-war hospital in Britain". O'Callaghan, whose father has been receiving care at the hospital, lamented the "mess" that had been made of Powell & Moya's pioneering 1966 building. The main tower, "beautifully sculptural … with articulated levels and setbacks", is unused and covered in phone antennae, while the celebrated entrance foyer, with its faceted concrete structure (once likened to a pineapple skin), is also hidden from view.

It is a far cry from the futuristic vision that greeted CQ in the winter of 1966. Then, the entrance hall was "a fascinating study in the plasticity of concrete construction", with the tower above "all lightness, springing in to the air like a fountain from four tapering columns". The whole campus was underpinned by the architects' belief in the importance of daylight and nature, the wards arranged in low-rise blocks with large windows overlooking courtyard gardens. "It makes you feel," wrote CQ, "if not exactly welcome, at least at home directly you pass through the gates. No white tiles and whiff of formaldehyde here …"

Added to this was an inherent flexibility in the design approach. Powell & Moya saw the hospital as "a village or small town which can grow and where each sector, while being unmistakably part of the same organism, has its own individual character. The result is a criss-cross of covered, enclosed walkways." As he looked around the hospital half a century on, O'Callaghan reflected that "it must have been an amazing place to recuperate, with views of what was at the time a semi-rural landscape". Or as CQ put it, "Somehow, one could be doing with more hospitals of this kind …" ■

Explore the CQ archive at concretecentre.com/cqarchive



Photos and drawing: Jan Friedlein, AKT II

ORIGIN STORY

HYLO TOWER

ALBERT WILLIAMSON-TAYLOR EXPLAINS HOW AKT II CHANGED THE RULES ON RETROFITS AND ADDED 13 FLOORS TO A 15-STOREY TOWER

This story really begins about 15 years ago, with the South Bank Tower. That project broke the mould in terms of intense analysis of buildings and how we understand towers. People said that there was no way you could repurpose and add to towers. We showed that you can.

I was on the Southwark Design Review Panel at the time. George Kyriakou from the developer CIT approached me and asked me to look at this brutalist concrete tower [the 30-storey IPC Tower on the South Bank of the Thames, designed by Richard Seifert and completed in 1972]. There was a pre-planning scheme in place that proposed demolishing the building and replacing it with four 24-storey towers. The original engineers

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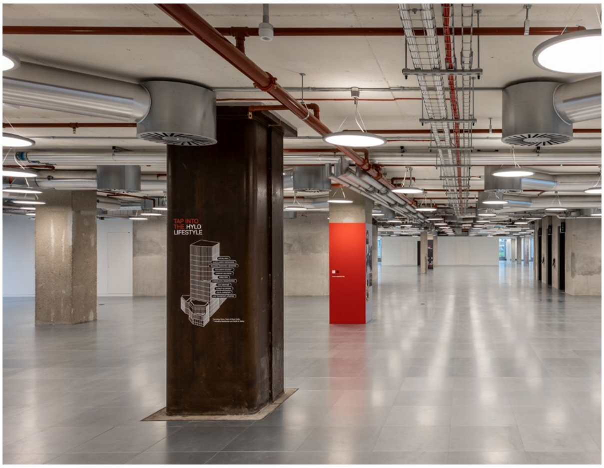
had also done due diligence and calculated that no more than four storeys could be added to the top. George asked me what I thought.

I had a quick look and said, "You don't have to knock it down. I'm sure we could add at least eight storeys. Let me do some numbers." We spent three months analysing everything from scratch, learning how the building actually worked rather than how it was designed to work. We developed our own bioclimatic CFD [computer fluid dynamics] tool that could take raw wind data and impose it on any kind of structure. We put anemometers on top of the building to see how much it swayed.

In the end, we added 11 floors to the tower and three floors to the six-storey podium – everything above the ninth floor was essentially new space. We strengthened the core by about 7% and redirected the load path of the structure over the podium. But we didn't need to strengthen the foundations. When I was called in to the planning department to present the scheme, I had to tell them that it wasn't a joke. Engineering is not just about following the codes: if we want to progress, we need to go back to first principles and challenge the thinking behind them.

A few years later, George phoned me again because CIT was about to buy a 15-storey exchange tower near Old Street – another concrete building designed by Seifert for British Telecom in the 1960s. They thought they could add eight storeys to it. When we looked at the numbers, we worked out that we could actually add 13 – making it 75% taller. We would have to strengthen the columns at the top, as they weren't designed to support additional load, but our geotechnical and stress analysis indicated that the foundations were fine.

Then the architect, Stephen Cherry at HCL, said that the floorplates wouldn't work for modern office space, and that the core, which was on the north-east corner of the plan, would have to be removed



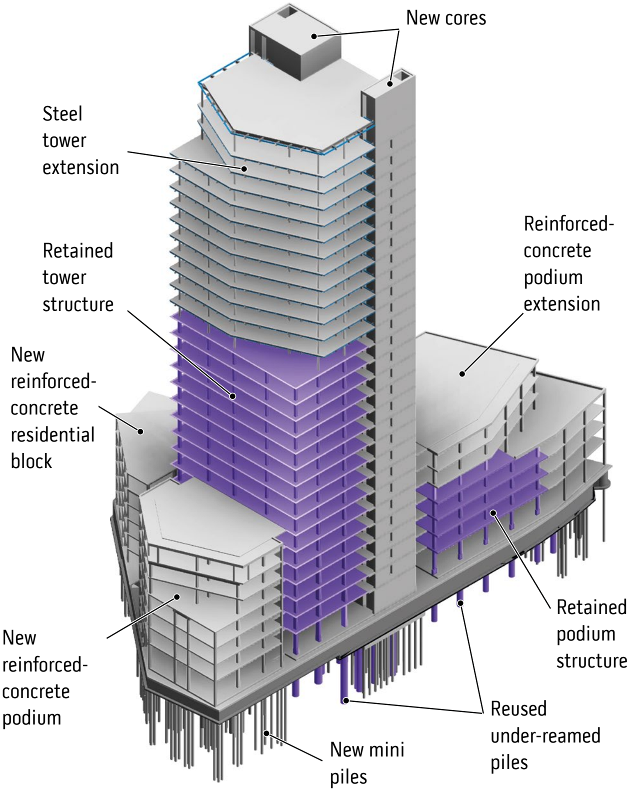
ABOVE
The interior design celebrates the original structure – offering one of the few clues that this is not an entirely new building

and replaced. We calculated that we could demolish the core and the existing structure would remain stable without the need for external bracing. The cladding was stripped off and diagonal bracing was placed between the floor slabs, and then the core could be taken out – we were monitoring closely the whole time for any movement.

When we got to the substructure, some additional foundations were needed for the new cores, so we threaded a series of mini-piles between the existing, under-reamed piles. The cores, on the northern corners of the tower, were then slip-formed to the new height. To minimise loads, the new structure on the top is a steel and composite frame. The brick-slip cladding is also lightweight: fixed to an ultra high-strength precast-concrete panel which is just 75mm thick, about half that of a standard panel.

As with the South Bank Tower, we have also expanded the podium. The existing structure has been extended by 50% to six storeys and a new reinforced-concrete residential block added. An underused site on the edge of Silicon Roundabout now contains double the floor space, with state-of-the-art offices, retail and 25 social-rent homes. We've done this while using all of the existing foundations and most of the frame of the original – saving 35% of the embodied carbon of an equivalent new-build. HCL has done such a great job that everybody thinks that it's a brand-new tower! ■

Albert Williamson-Taylor is co-founder and design director of AKT II. Interview by Nick Jones



ABOVE
New elements include 13 storeys on top of the original tower, two new cores on the northern corners, an extended podium, new podium and a residential block

RIGHT
The original 16-storey Finsbury Tower, designed by Richard Seifert as a telephone exchange

Photo: Thilo Ross © AS+P Albert Speer + Partner GmbH

TRICKS OF THE TRADE

Heidelberg Materials' new HQ is a trove of concrete excellence, from the air-cleaning facade to precision-cast feature columns. And it's just been awarded Germany's top sustainability rating. Tony Whitehead reports


Photo: Thilo Ross © AS+P Albert Speer + Partner GmbH

The Neuenheim district of Heidelberg is filled with large buildings: university departments, research institutes and company head offices. They look solid, imposing, and rather dour. Heidelberg Materials' recently opened headquarters is the new kid on this block, and it could hardly be more different.

ABOVE
The facades were assembled from approximately 1,000 precast concrete panels, most weighing around three tonnes

Though itself a fairly massive 50,000m², its fluid lines impart an admirable lightness. And the facade shines, not just architecturally, but actually: it is made from sparkling white concrete.

Attracting attention is the aim here, for while the building had to provide a modern, high-performing environment in which to gather some 1,000 of Heidelberg Materials' staff, it also stands as an unashamed advertisement for concrete. As the company (known until recently as Heidelberg Cement) puts it: "It is a sample project for sustainability, and demonstrates what concrete is capable of nowadays, both technically and aesthetically."

"Yes, we are absolutely trying to show what concrete can do," agrees Kathrin Gallus, associate partner at architect and general planner Albert Speer + Partner (AS+P). "To demonstrate how it can be shaped, and how it can be part of a building that performs extremely well environmentally."

IT IS A SAMPLE PROJECT FOR SUSTAINABILITY, AND DEMONSTRATES WHAT CONCRETE IS CAPABLE OF NOWADAYS

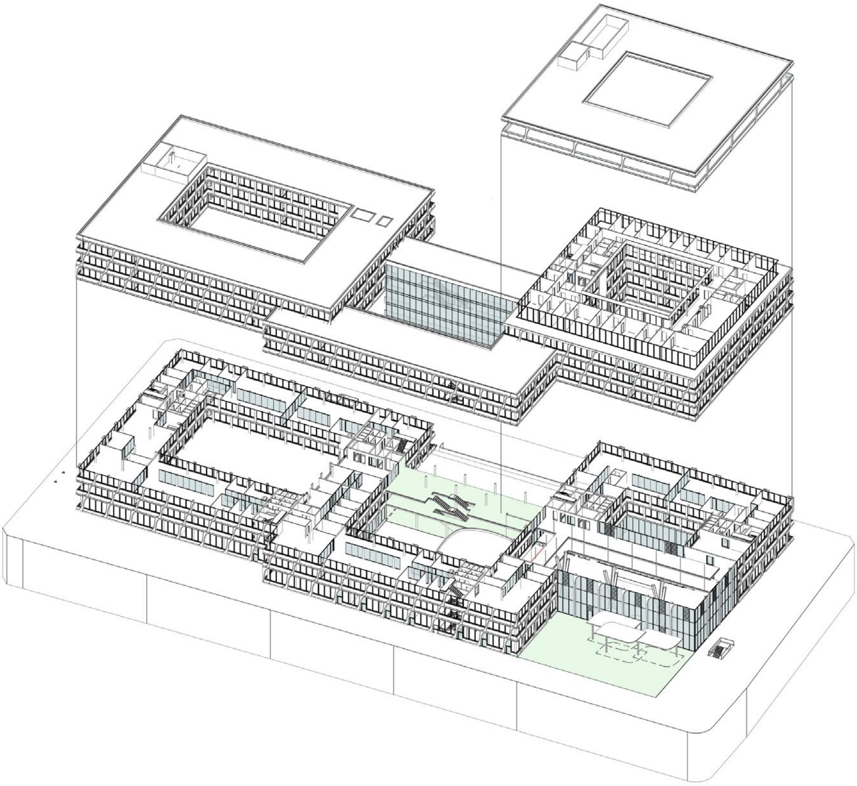
BELOW
The triple-height reception area features three impressive "trees" – actually nine tall columns supporting an 880m² ceiling

Photo: Thilo Ross © AS+P Albert Speer + Partner GmbH

Photo: Thilo Ross © AS+P Albert Speer + Partner GmbH

Heidelberg Materials' new HQ does this in a number of ways. Its stunning white facades, for example, are made from concrete containing a proprietary additive that removes pollution from the air it comes into contact with. The building is powered by solar panels that cover approximately 1,000m^2 of the roof, and heated and cooled by a ground-source heat pump sunk into the earth below. These and other measures, such as 28 electric car charging points, enabled it to achieve the DNGB Platinum standard – the German Sustainable Building Council's highest rating. (It also won the innovative architecture category at the German Design Council's 2022 Iconic Awards.)

ABOVE
The in-situ concrete restaurant ceiling was created by pouring reinforced beams around 64 large diamond-shaped formers



Drawing: © AS+P Albert Speer + Partner GmbH

ABOVE
The building, which houses 1,000 Heidelberg Materials employees, comprises three connected blocks, of between five and seven storeys, arranged around courtyards

Comprising three connected blocks arranged around courtyards, the building's in-situ concrete frame sits on a 0.8m-thick foundation slab, with 250mm-deep floor slabs. "Energy from the heat pump and the thermal mass effect of all the exposed concrete is a great combination," says Gallus. "The concrete floors are actively heated and cooled by warm or cold water from the ground, run through pipes set in the slabs." This works in conjunction with the passive effect of the exposed concrete soffits, which absorb excess heat in summer and store it in winter.

"There is also local control, so users can still open windows if they want. For all this to work, of course, the concrete must be exposed to the air inside the building. But that's great for us because we want people to see the concrete anyway."

And it is the visuals that really set this building apart – notably its astonishing facades (see box, right), assembled from some 1,000 precast concrete panels, most weighing around three tonnes. "We have taken inspiration from nature, which is present all around us, even in a city," says Gallus. "The site is close to the river Neckar, and that is reflected in the moulded lines of the facade."

Ensuring that the panels would achieve the desired "sparkling wave" effect involved some serious research and preparation, however. "It was challenging," concedes Gallus. "We worked hard to achieve the surface – so that it would look right, and also not be too porous, so it would perform well against pollution.

"We made sample blocks, to help us choose the finish and the type of whiteness. Then we made whole panels and left them exposed outside for a year to verify the durability."

In this, the facade is helped by a specialist cement containing titanium dioxide, which reacts with sunlight to remove nitrogen oxide from air. "It not only cleans the air, the photocatalytic effect also helps a little to keep the surfaces clean," says Gallus.

Once completed, the precast elements required special measures to ensure the bright finish was not compromised: "We wanted them

Mighty white: the precast facade

Approximately 1,000 precast elements make up the building's facades, and they needed to be as homogenous and dense as possible, says Koen van Tartwijk, head of projects for Byldis, the Eindhoven-based manufacturer. "This meant as few pores as possible in the concrete, so we thought carefully about the interplay between water, cement and additives. We found the right balance by lowering the water-cement factor, and achieved better workability by using additives. The bright white colour comes from white cement and Norwegian White gravel aggregate, which we used in sizes up to 15mm."

Because elements made months apart might end up next to each other on the facade, quality control was paramount: "It was agreed with the client that the clarity of the concrete surface would not drop below a set value. This was checked by measuring the surface clarity after an element had dried, using a specialist camera."

The moulds for the facade elements were precision-made from 3,800m^2 of ply boards using a combination of CNC routing and traditional joinery. To ensure a smooth finish, the sanded and oiled internal surfaces were protected with foil until the moment the concrete was poured.

Most of the exterior facade panels were identical: 3.5m high, 5.8m long, and weighing

Photo: Thilo Ross © AS+P Albert Speer + Partner GmbH

to stay really white," says Koen van Tartwijk of Eindhoven-based manufacturer Byldis. "So we literally handled them with white gloves and there were notices saying 'Ornamental Concrete. Do not touch' all over the yard."

Inside the building, more concrete spectacles await. In particular, the triple-height reception area features three impressive "trees" – actually nine tall columns supporting an 880m^2 ceiling. "To support this ceiling traditionally would have involved many columns or very thick columns," says Gallus. "There is a lot of weight above, as the building is at its highest point here, with four storeys above the reception area.

3.13 tonnes. Similar panels, but with straight rather than curving verticals, were made for the internal courtyard facades. "So around 40% were identical exterior panels, 30% identical courtyard panels and for the rest, smaller numbers of corner elements and the slightly different panels below roof level," says van Tartwijk. "All were made from precision, heavy-duty plywood moulds which yielded up to 70 uses each. We considered making them from other materials, such as fibreglass, but timber gave us the finish we wanted."

He adds that although the Byldis factory is highly automated, most of the reinforcement had to be made by hand: "So while we can easily make a rectangular cage automatically, these delicate, curved shapes were quite labour-intensive."

Most challenging of all were the three, curving canopies that grace the building's entrance: "These were massive, 9m x 4.7m elements, each weighing 29 tonnes. The reinforcement was so complex that we found we couldn't print a drawing that the rebar workers could make sense of. In the end they worked directly from 3D computer models – a technique born out of necessity, but one we have taken forward since."

BELOW
The roofs contain landscaped areas, as well as approximately 1,000m^2 of solar panels

Photo: Thilo Ross © AS+P Albert Speer + Partner GmbH

Photo: Thilo Ross © AS+P Albert Speer + Partner GmbH

ABOVE
The foyer's triple-height feature wall consists of several prefabricated concrete elements mounted to the in-situ concrete wall

"So again we are taking inspiration from the nature around us to find a more refined solution. There are trees outside, lining Berliner Strasse and the parks by the Neckar, so we have arranged nine columns in three 'trees', each comprising three angled concrete 'trunks'. The result is more elegant and interesting than just thick vertical columns."

Each of the nine tree columns is 500mm square, 11m high and, although made from similar pale concrete to the facade, was constructed in situ (see box, next page). "Because the columns are set at an angle, and connect about a third of the way up, this was very challenging – both for the engineer to calculate and for the contractor to construct. The connection plates with the floor are quite complex, there is a lot of reinforcement, and the finish had to be perfect."

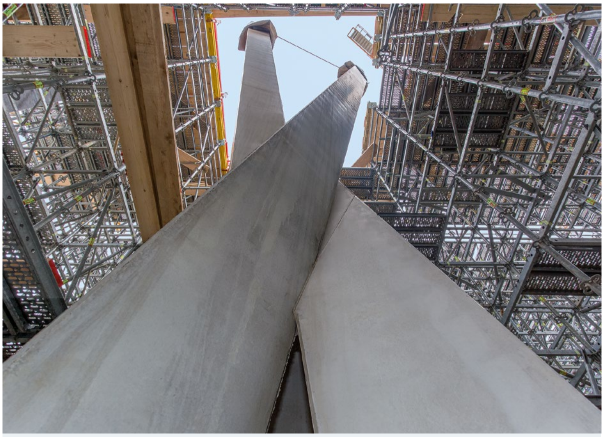
Also in the foyer is a stunning triple-height feature wall. Slim white precast panels have been attached to the in-situ wall, each with a unique cast-in geometric pattern, echoing the lines of the angled tree columns. "We considered making this feature in-situ," says Gallus. "But precast was best to achieve the precision and finish we wanted over that kind of height."

There is more to admire elsewhere in the building too. In the staff restaurant, for example, the ceiling has been created from in-situ concrete by pouring reinforced beams around 64 large diamond-shaped formers. Each beam is 300mm across and 500mm deep, creating a deeply textured and eye-catching diamond pattern.

Like the facade and the foyer, it serves to remind diners and their guests of the artistry that can be wrought with concrete. ■

PROJECT TEAM

Architect and general planner Albert Speer + Partner
Structural engineer Wulle Lichti Walz
Main contractor and in-situ concrete Diringer & Scheidel
Precast supplier Byldis
Formwork contractors PERI Germany, Westag & Getalit



Casting the twisted 'trees'

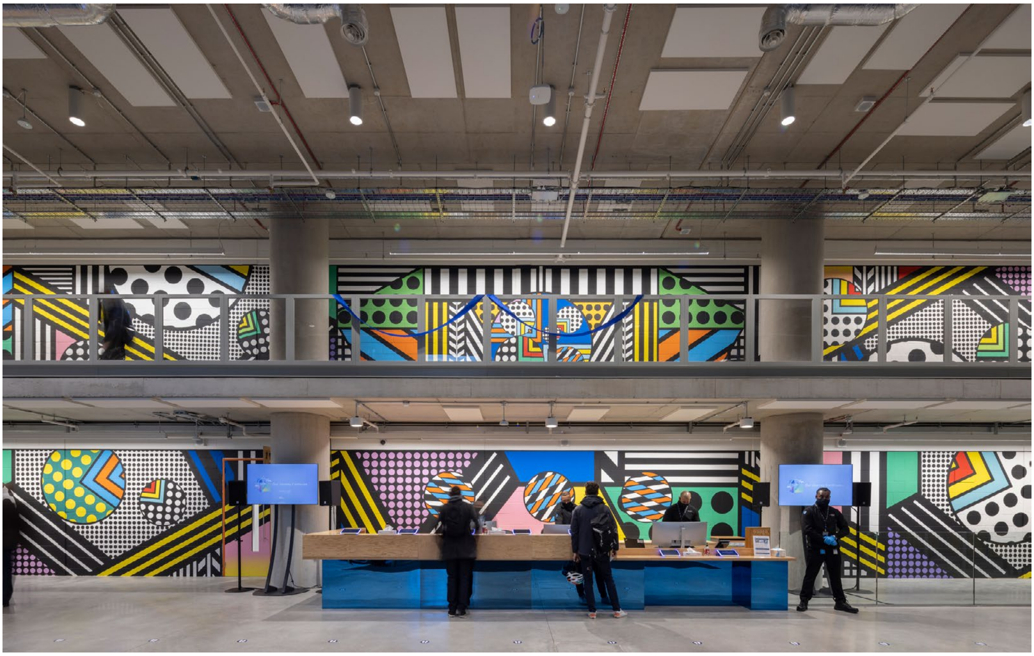
Probably the most technically demanding part of the building to construct were the three in-situ concrete "trees" that adorn its 10.5m-high foyer. Reflecting Heidelberg Materials' desire to show concrete at its very best, these elements had to be as visually perfect as possible – resulting in the columns being "poured" from below to help ensure a smooth, blemish-free, almost glassy finish.

This unusual process involved injecting concrete into the (non-visual) base of the heavily reinforced column forms from the basement floor below. A self-compacting SB4 fine mix with a maximum aggregate size of 8mm was used. In order to rise 10.5m, the fresh concrete needed to be pumped at pressures of up to 200kN.

To withstand this, bespoke steel moulds were built. These comprised 63 individual parts that could be assembled on site as a plug-in system to avoid time-consuming welding. A 150mm-deep steel honeycomb structure on the exterior lent extra strength to the moulds, which were also lined with a 5mm-thick steel formlining.

For each tree, concrete was injected into all three columns simultaneously. To guard against blockages or formwork deformation, the pour pressure was monitored in real time via embedded sensors and a mobile phone app.

Photo: PERI Germany



Photos: Hufton + Crow, John Sturrock, Matt Livey / Meta

BIGGER LEANER META

The first thing to note about the Meta HQ is its sheer size. By far the largest completed office building at King's Cross Central, it varies between 10 and 12 storeys and, at 180m, is as long as the Gherkin is tall. Even its address stretches from 11 to 21 Canal Reach. "It has the floor area and more of a skyscraper, but lying on its side," says Simon Banfield, director at Ramboll, the structural engineer on the project. This vast footprint accommodates more than 4,000 employees on 37,000m^2 of large, open floorplates. Above it all, the roof has enough space for a 3,900m^2 park, complete with trees and beds of wildflowers.

What it doesn't have is a basement. This was an early decision, as the scale of the site meant that sufficient floor space could be provided without one. "This sounds quite simple, but it makes a huge difference," says Banfield. Plant has instead been mainly housed at the back of the building.

Meanwhile, the use of post-tensioning has restricted slab depths by about 100mm, lowering the amount of concrete needed by 20-25%, as well as minimising the need for reinforcement.

This was partly the result of a design process in which – unusually for a scheme that began life back in 2015 – embodied carbon was measured and monitored from the outset. "It was before everyone became carbon literate," says Banfield, "but [developer] Argent wanted to push it forward."

The final as-built upfront total of 705kgCO_2e/m^2 is about 25% lower than a "current average design" for a speculative office of the same scale, according to the LETI embodied carbon rating system. Bennetts also calculates that the material-efficient design saved 10,564 tonnes of CO_2. ■

READ THE FULL STORY
concretecentre.com/cq

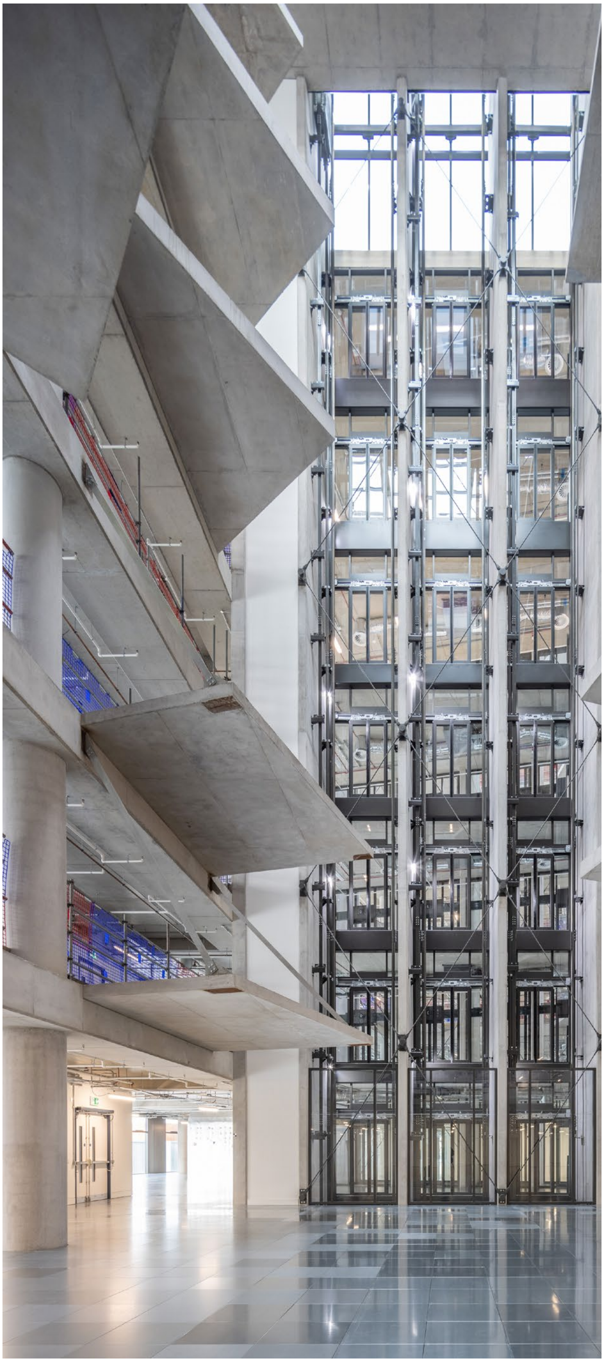


Photo: Daniel Hopkinson

COLLEGE MATERIAL

FCB Studios partner Hugo Marrack describes the Catalyst Building at Staffordshire University as inviting the "unknown brief" of the 21st century. "We wanted to develop what we called a framework building: as open-plan as possible, with as few columns as possible, long spans, concrete frame, exposed soffits, and all the services in raised access floors."

Today, the ground floor is a largely double-height zone with a foyer, cafes, gallery and a mezzanine at the back containing smaller meeting rooms. The upper two levels house quieter study spaces, offices and more specialised areas. But in the future, that can all change. "It's nice knowing that you're designing a building that, in theory, has 100-plus years of life in its frame," says Marrack. "It can be reused, knocked about, moved about. You can start imagining it having three or four lives."

The frame may be robust enough to survive a knockabout, but it's also lean. Post-tensioning has reduced the depth of the subtly coffered slabs by up to 250mm, to as little as 275mm. ■

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NEPTUNE RISING

"It's a proper piece of city," says Graham Haworth, of Fish Island Village. On the furthest fringes of the Olympic Park, Haworth Tompkins, together with fellow architects Lyndon Goode and Pitman Tozer, have taken 2.2ha of wasteland and warehouses and, over the course of eight years, turned it into a bustling neighbourhood.

By far the biggest element of the scheme is Haworth Tompkins' Neptune Wharf, an ensemble of 17 blocks containing 501 homes and, intriguingly, a campus of low-cost fashion studios. The first Neptune Wharf blocks, flanking one side of Fish Island's main square, act as an entrance to the campus and are defined by grid-like concrete facades.

Haworth describes these concrete-framed, double-height spaces as "very robust architectural containers" and sees them as crucial to the spirit of Fish Island. "As a practice, we like the idea of buildings that can take knocks and can also accommodate other people's voices." For the fashion campus, interior architect Bureau de Change has inserted mezzanines into the concrete framework to make a variety of social and studio spaces. ■

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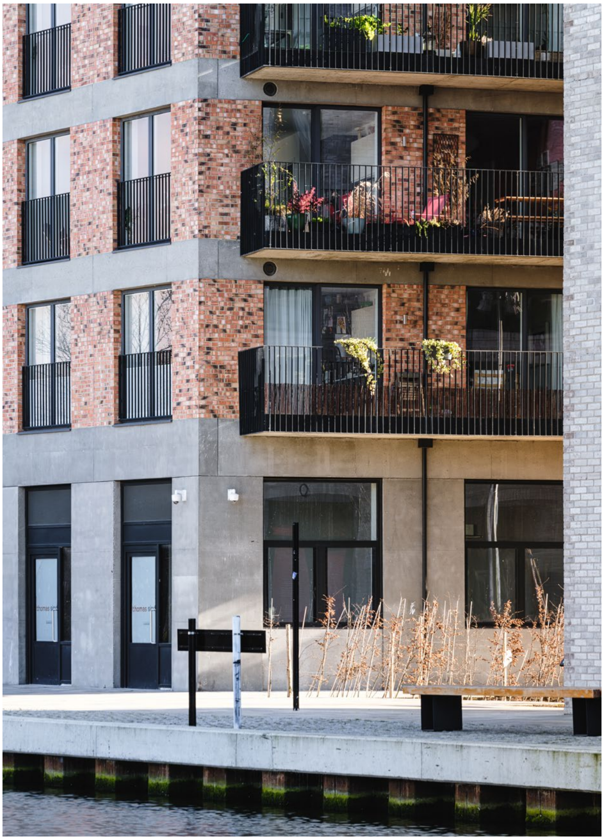

Photos: Fred Howarth

ABOVE Designed by Henn Architecture, the Cube at the Technical University of Dresden in Germany is the first concrete building to be reinforced with carbon fibre mesh instead of steel

Photo: Stefan Gröschel

How to cut carbon in reinforcement

Steel contributes around a quarter of a concrete slab's embodied carbon. Fortunately, there is much designers can do to reduce this often overlooked environmental impact, says Emily Halliwell

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As the construction industry seeks solutions for reducing the embodied carbon of concrete buildings, much of the focus has been on the concrete itself – on alternative cements and cement replacements, and on more material-efficient floor systems that use less concrete.

But we can't afford to ignore the reinforcement within the concrete. This contributes approximately 25% of the embodied carbon of a structural floor – a proportion that will become even more significant as the embodied carbon of concrete continues to fall.

This article will look at some of the opportunities to design out carbon from this often overlooked element. As with all carbon assessments, selecting the right data is essential, particularly with large variations in carbon factors due to different steel production routes. Additionally, designers have many options for both refining their designs to minimise material use and for specifying alternatives that can offer savings in reinforcement, concrete or both.

Understanding embodied carbon in reinforcement

When calculating the embodied carbon in a structure, it is important to use appropriate carbon factors from reliable sources. It is recommended to refer to environmental product declarations (EPDs), standardised documents that provide performance data for a given product or material. As there are many EPDs available, selecting the right one is important.

Reinforcement is mainly manufactured either using an electric arc furnace (EAF), which often recycles scrap steel, or a basic oxygen furnace (BOF), which creates new or "virgin" steel. An EAF is powered by electricity whereas a BOF is generally fossil-fuel-fired. As such, reinforcement produced by EAF typically has much lower embodied carbon, and this may fall further as the grid decarbonises. In Europe, the majority is produced in this way, but this is not necessarily the case elsewhere in the world. So, given the large variations in embodied carbon associated with different production methods, it is vital to understand where reinforcement is sourced from and to obtain EPDs from suppliers and manufacturers.

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Table 1: Rebar carbon factor (A1-A3) value based on rebar source

	Rebar sourced from UK mill	Rebar imported to the UK	Rebar source unknown
Carbon factor (kgCO$_2$e/tonne)	Celsa: 647 Liberty Steel: 1,180	784.1	742.1
	2019-21 mean value 800.08kgCO$_2$e/tonne		

Where information is not available, or during the early stages of a project, guidance on embodied carbon factors for use in carbon calculations (such as Table 1, above) can be found in the reinforcement appendix to Specifying Sustainable Concrete, published by The Concrete Centre.

Modifying material factors

Embodied carbon is determined not only by the choice of materials in a building, but the quantity. There are many measures we can take to reduce the amount of reinforcement in a concrete structure.

To calculate the design strength of a material, the characteristic strength is divided by a material partial factor – so the lower the partial factor, the higher the design strength. For reinforced concrete structures, the relevant partial factors are set out in Eurocode 2 (EN 1992-1-1). These account for variability in the properties of concrete and reinforcing steel and for geometrical deviations in the structure. By applying a reduced partial factor for reinforcing

Photo: Lily Maggs

ABOVE
At House on the End in south-east London by 1200 Works, a proprietary fibre-reinforced concrete, which derives its flexural strength from strands of polypropylene and steel, reduced embodied carbon by cutting the amount of both steel and concrete cover. The slabs only needed to be 180mm thick and the walls 150mm

steel, engineers can reduce the quantity of reinforcement without any impact on performance, lowering both the cost and embodied carbon of the structure.

When calculating the capacity of concrete structures in normal design situations, the recommended partial factor for reinforcing steel, γ_s, is 1.15 (from EN 1992-1-1 Table 2.1N). However, this is a Nationally Determined Parameter, allowing different countries to specify their own value, and a reliability study using UK CARES reinforcement data has shown that it is feasible to reduce the partial factor for reinforcing steel to 1.05 for bending. This potentially reduces the area of steel

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BELOW
The BREEAM Excellent University of Warwick Arts Faculty, designed by FCB Studios and completed in 2022. The structural design, by Buro Happold and Arup, includes post-tensioned transfer beams and slabs, which Arup estimates saved 1,085m^3 of concrete and 115 tonnes of steel, equating to 425 tonnes of embodied carbon

Photo: Daniel Hopkinson for Feilden Clegg Bradley Studios required by 9.5%, although this may also be affected by other demands such as robustness or serviceability. More guidance on using a reducing partial factor can be found in Reducing Carbon and Cost of Reinforcement from The Concrete Centre.

Saving through reinforcement detailing

Reinforcement detailing is a key process in the design of concrete structures. This involves taking the output from the structural design and turning it into an arrangement of bars that works with the geometry of the structure.

There are practical limits on the length of reinforcement bars, both for delivery and installation, and so "laps" (or overlaps) are used to transfer bar forces in locations where it is not possible to use a continuous bar. Additionally, in some locations reinforcing bars are required to transfer forces directly into the concrete, which means they must be anchored. The required reinforcement length for transferring forces between bars (lap length) or into the concrete (anchorage length) depends on the forces in the bars, as well as geometric parameters such as cover to reinforcement, whether there is a bend in the bar, and the arrangement of adjacent bars.

As the lap and anchorage lengths depend on many factors, conservative assumptions are typically made to simplify the process and avoid having to calculate lengths for each individual bar. This can, however, lead to more steel being used than is required, increasing the associated embodied carbon.

One common assumption is that a bar

Photo: Expedition Engineering

Case study: Network Rail

Network Rail has worked with suppliers to reduce the embodied carbon of precast concrete planks used to refurbish station platforms by 64%.

The greatest contribution came from substituting 80% of the Portland cement in the mix with GGBS, but the team also made a number of improvements to the reinforcement. This included reducing the partial factor for steel reinforcement from 1.15 to 1.05, and developing the arrangement to increase utilisation and optimise the layout.

Where non-corrodible reinforcement is required, stainless steel was replaced by basalt-fibre reinforcement. Load testing also demonstrated that in some of the precast units, loose bar or mesh reinforcement could be replaced by fibre reinforcement.

Expedition Engineering was innovation partner on the 18-month project, working with structural engineer Studio One, concrete consultant AMCRETE UK, contractor G-Tech Copers and precast supplier Anderton Concrete.

is carrying the maximum force for a bar of its size, rather than using the actual calculated force. This presents an opportunity to refine the design to reduce lap and anchorage lengths.

As an alternative, couplers may be used in place of lap lengths to provide continuity, which can result in material savings, particularly for larger diameter bars. It is important that lap and anchorage lengths are communicated clearly on drawings so that detailers and installers understand the requirements, especially if these vary for different elements.

Avoid over-rationalising

Rationalising reinforcement layouts typically involves grouping elements, such as beams, and only designing for the worst case, such as the maximum load or longest span. This design is then used to develop reinforcement details for the whole group of elements. Rationalising reinforcement layouts is common practice because it simplifies design, checking and installation.

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BELOW
The First Light Pavilion at Jodrell Bank in Cheshire, designed by Hassell (see CQ 279, Summer 2022). To realise this 50m-diameter concrete roof, structural engineers Atelier One and Roscoe used 3D modelling software to analyse the loads and develop a refined, more material-efficient reinforcement design. The dome comprises a 200mm-thick slab with eight discrete zones of rebar, which curves in both radial and circumferential directions

Photo: Kier Construction

However, it can lead to the use of significantly more material than a structural design requires. There is a balance to be struck between ensuring reinforcement can be installed efficiently and accurately and avoiding unnecessary embodied carbon. A variety of tools are available to designers to assist with this, including in-built carbon calculators in structural modelling software and parametric design tools. Early discussions between the structural engineer and concrete contractor can assist with developing designs that are practical to install while offering embodied carbon savings.

Using alternative reinforcement types

So far we have focused on standard carbon steel reinforcement, but there are alternatives that offer potential carbon savings. One of the main concerns with standard reinforcement is its durability: it can corrode if the cover distance from the surface of the concrete to the surface of the bar is insufficient for the environment the concrete is used in.

Alternative reinforcement materials such as stainless steel, fibre-reinforced polymer (FRP) and basalt fibre offer improved resistance to corrosion and may either be used to prolong service life or reduce maintenance, both of which result in carbon savings over the whole life of a structure.

Additionally, there may be scope to reduce concrete cover to the reinforcement. Cover is driven by a number of requirements including fire protection, bond and durability. For aggressive environments where durability often drives the cover

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Case study: Laing O'Rourke

Laing O'Rourke has trialled the use of basalt fibre reinforced polymer (BFRP) in two structural systems as part of its Decarbonising Precast Concrete Manufacturing project.

Megaplank (below) is a one-way spanning precast concrete slab. Two units were produced, reinforced with BFRP meshes, using geopolymer concrete and AACM concrete. The use of BFRP saved 67% of the reinforcement's embodied carbon, and 22% across the overall unit.

Meanwhile, the Arup Vault prototype is a lightweight compression shell-based reinforced-concrete floor system, including a perimeter tension beam ring. Two tie-beam units were manufactured using geopolymer concrete and BFRP cages (above). The use of BFRP saved an estimated 72% of the reinforcement's embodied carbon, and 45% overall.

Further testing of the beam units is planned.

requirement, using corrosion-resistant reinforcement may offer an opportunity to reduce cover and therefore the volume of concrete required. For more information, refer to The Concrete Society's Concrete Advice 64: Cover to stainless steel reinforcement.

Neither are designers limited to using reinforcement in bar form. A wide range of fibres may be used, including steel and synthetic fibres, potentially enhancing the properties of the concrete. This can reduce the requirement for standard reinforcement – for example, in ground-bearing structures where fibres are often used to control cracking – and also offer programme savings by reducing time needed to fix the reinforcement.

Post-tensioning tendons are another alternative that can offer carbon savings compared to a typical reinforced concrete system. While there is limited information on the embodied carbon of post-tensioning systems themselves, they can significantly reduce the amount of steel required, as well as allowing thinner structural elements, reducing the quantity of concrete in a design.

The available information about alternatives to reinforcement has been limited up to now, but this is set to change with the increased focus on embodied carbon and material efficiency. Eurocode 2 is currently under revision, and it is expected that the new version will provide information on stainless steel reinforcement, steel fibre reinforced concrete and embedded FRP reinforcement, which should assist designers considering their use to reduce embodied carbon. ■

Emily Halliwell is senior structural engineer at The Concrete Centre

Photo: Skanska

Case study: National Highways

Skanska has used basalt fibre reinforcement as part of a trial of low-carbon concrete on the National Highways M42 Junction 6 improvement scheme. Working with Tarmac and Basalt Technologies, it cast four different reinforced concrete slabs as part of a temporary haul road and monitored their performance and durability.

Two of the slabs contained steel reinforcement and two contained basalt fibre with a polymer binding, which is non-corrodible and between four and five times lighter than steel. Each reinforcement material was combined with both conventional concrete and a low-carbon alkali activated cementitious material (AACM).

Results show that the basalt fibre solution reduced carbon by more than 50%. It proved equally resilient when compared to conventional reinforced concrete using steel.

Skanska is now working with National Highways and High Speed 2 on the next phase, which will trial the low-carbon combination on a permanent road. The ultimate aim is to roll out the solution across the UK's strategic road network.

FINAL FRAME: IQON, QUITO

Bjarke Ingels Group has completed the tallest building in the Ecuadorian capital, Quito. IQON is a 133m-high apartment building and “urban tree farm” structured around rectilinear concrete frames that project and rotate to give a pixelated appearance. To celebrate Ecuador’s rich biodiversity, the balconies house a selection of native mid-size trees and shrubs. These are grown in large sculptural planters that reach down a full storey into the apartments below.

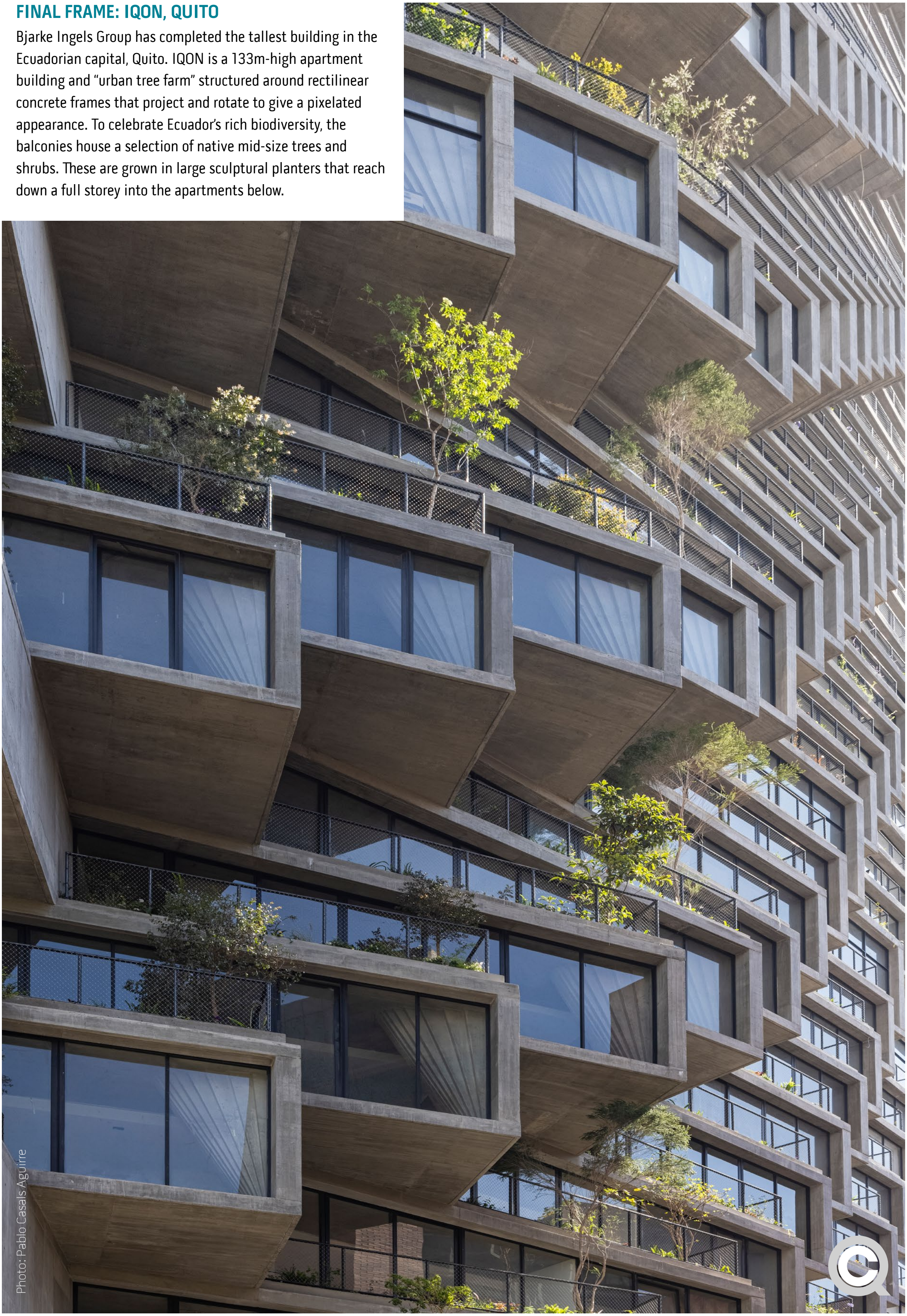

Photo: Pablo Casals Aguirre