CONCRETE QUARTERLY

The Concrete Centre

SPRING 2023 | ISSUE NUMBER 282

WHITE COLLAR KID →
What Derwent's latest loose-fit office learnt from the Factory next door

PUMPED UP →
How recycled concrete is being turned into 'fly ash on steroids'

SLIMMED WASTE →
Why it's time to update the way wastage rates are calculated

In the shadow of Belval's blast furnace, Foster + Partners has delivered the biophilic ICÔNE building

P29→

Elaine Toogood
Director, architecture and sustainable design, The Concrete Centre

Innovation unleashed

The level of innovation under way in concrete right now is unlike anything I've experienced during my career as an architect. There has always been research and development, but what feels different is the appetite to take it to the next level, from early stage work in universities right through to real-world projects.

This is being driven by an absolute recognition of the urgency of the climate challenge, and the pressing need for both mitigation and adaptation. It's about many things coming together: the UK government's legally binding net-zero target, the ESG commitments made by businesses, burgeoning market demand, and perhaps also the knowledge-sharing that digital technology has driven. All of this has not only increased the funding available to help decarbonise an essential building material, it is also focusing minds and creating more opportunities for bringing people together, so that promising research no longer languishes in silos.

Carbon capture is a major focus, as a key part of the UK's 2030 decarbonisation strategy – the sheer number of pilot projects aimed at extracting process emissions at source is really impressive. There have also been considerable advances on alternative cementitious materials. Heidelberg Materials' recycled concrete paste on page 6 is a very promising development on both counts.

Research is also ongoing into using concrete more efficiently, and into the associated innovations that will enable new types of mix to be deployed – such as digital sensors that measure curing temperatures.

Innovation is the subject of the Fresh Concrete series of online talks that we're curating this summer, in partnership with The Building Centre, now in its second year. Showcasing new ideas can be a double-edged sword – I love the enthusiasm they generate, but it is often accompanied by a frustration among specifiers that they can't always make use of them on projects now. This is a perennial tension. The construction industry has sometimes been perceived as stymying innovation, and wanting to stick to established processes, but it is reliant on the development of robust standards and performance specifications. Fortunately, there is also a concerted effort to speed up the rigorous behind-the-scenes testing that is less eye-catching but no less necessary to ensure new technologies can be deployed appropriately and safely. There is already a variety of cementitious materials with a different chemistry which can be trialled on non-critical structures, under the PAS 2080 guidance, while we assess their full potential. Work is also under way on a BSI Flex Standard to allow specification by performance, which should provide a framework for the design of future concretes.

SOME INNOVATIONS MAY RESULT IN WHOLESALE CHANGE, WITH US FOR THE LONG TERM. OTHERS MAY BE STEPPING STONES

Right now, research and development is taking place on many scales and at every stage in the manufacturing and construction process. Some of these innovations may result in dramatic, wholesale change, with us for the long term. Others may be stepping stones while more permanent technologies are proven. There are many possibilities, but perhaps the only certainty is that we won't know where they lead unless we all work together to develop them. ■

CONCRETE QUARTERLY

Concrete Quarterly is published by The Concrete Centre, part of the Mineral Products Association. mineralproducts.org

Editing and production: Wordmule

Design: Nick Watts Design

On the cover: The Featherstone Building by Morris+Company. Photo by Jack Hobhouse

Photo: Chris Underwood

INNOVATION

RECYCLED CONCRETE PASTE

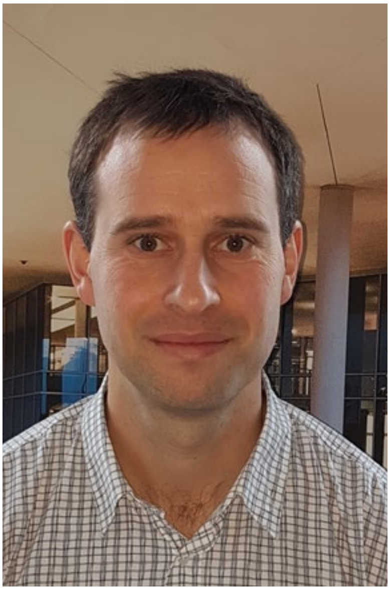
HEIDELBERG MATERIALS HAS DEVELOPED A PROCESS FOR BREAKING DOWN OLD CONCRETE SO THAT IT CAN ABSORB THE CARBON EMISSIONS FROM CEMENT PRODUCTION, USING A FRACTION OF THE ENERGY OF TRADITIONAL CARBON CAPTURE. THE POTENTIAL IS ENORMOUS

ABOVE
At Hanson's Ribblesdale plant, 15 tonnes of RCP captured 1.5 tonnes of CO_2 in just 20 minutes

A remarkable new technology being developed by Heidelberg Materials has the potential to greatly enhance the value of recycled concrete, while simultaneously capturing significant amounts of CO_2. At a trial in Ribblesdale, Lancashire, the company used 15 tonnes of recycled concrete paste (RCP) to capture 1.5 tonnes of CO_2 in just 20 minutes.

The project is led by R&D programme manager Dr Jan Skocek. "Although this technology can only capture around 10% of flue-gas CO_2, it is cheap and efficient, so can become a useful part of any carbon capture system," he says. "Better still, the RCP that has been through this process is a highly reactive material that can be used to make new concrete. It's like fly ash on steroids."

The process begins with a new mechanical technology that can "unmake" concrete, partly restoring it to its constituent parts of sand, cement and aggregate. "Usually, when concrete is recycled, it is almost always simply crushed," Skocek says. "Some is used as filler in new concrete, but the majority becomes rubble and has a low-value future as road base or backfill. We have developed a new process, selective separation, which uses rubbing and shearing motions to separate old concrete." The result is RCP – a fine powder comprising



THE RCP THAT HAS BEEN THROUGH THIS PROCESS IS A HIGHLY REACTIVE MATERIAL THAT CAN BE USED TO MAKE NEW CONCRETE. IT'S LIKE FLY ASH ON STEROIDS

ABOVE
The project is led by Heidelberg Materials' R&D programme manager Dr Jan Skocek

60% cement and 40% very fine sand and aggregate.

The remaining larger particles of sand and aggregate can simply be reused as if they were new material, says Skocek. For the RCP, there are three options. "The easiest is to use it as a filler, adding it to cement in the same way limestone is sometimes used. It is not reactive, so 15% is about the highest proportion. Or you can use it to replace some limestone in the production of clinker. This saves raw material and some carbon emissions. But the most exciting way is to get it to absorb CO_2 – a process that mineralises the CO_2, storing it forever within the chemical structure of the RCP."

At Heidelberg Materials' Hanson plant in Ribblesdale, the RCP powder was mixed with water to form a slurry, then sprayed into the scrubber that cleans exhaust gases from cement production. "Normally the scrubber absorbs mainly sulphur oxides to prevent atmospheric pollution – it is not designed to capture CO_2. But the RCP slurry captures both, absorbing CO_2 quickly, and in the process becoming a new and, we think, very useful material."

When the RCP binds with CO_2 it becomes carbonated, while other elements in the mix form a new phase known as alumina silica gel. "It is then a highly reactive material that can be used as a cement substitute, and one that can be used to create very strong concrete with rapid strength gain – much faster than fly ash, for example."

To take the technology forward, Heidelberg Materials' will this year commission its first full-scale selective separation plant in Poland – able to process 150 tonnes of old concrete per hour. Next year, RCP from this plant will be used in a new, specially designed cement-works scrubber, also in Poland. This pilot plant will continually mineralise around 100kg of CO_2 per hour, and because it is a mechanical process, requiring little heat, it uses about a tenth of the energy of traditional carbon capture. "The pilot will enable us to finetune the process and learn how best to scale it up," says Skocek. "At the same time we will continue our research into the properties of carbonated RCP and how to maximise its potential."

He has been involved in various stages of developing RCP since joining the company as a scientist in 2012: "But now I am also handling business development. It is time to make this science work in the market." ■

Interview by Tony Whitehead

LASTING IMPRESSION

LUKE TOZER

TWO EARLY EXAMPLES OF TADAO ANDO'S VIRTUOSIC CONTROL OF CONCRETE: A MOUNTAINSIDE HOUSING COMPLEX AND A MYSTERIOUS WINDOWLESS BOX ...

I remember seeing Tadao Ando's Rokko Housing I (1981-83) in a book when I was a student. It's a complex of about 50 homes that steps up the side of Mount Rokko in Kansai, western Japan. It struck me as being an incredibly clever use of a steep site and a single material: cast concrete. The stepped section has echoes of postwar British housing such as Neave Brown's Alexandra Road, and means that all of the homes enjoy beautiful views across the bay towards Osaka.

I spent a year in Japan after university, and I was surprised to find that this building was just a few hundred metres down the road from where I lived. I had the pleasure of walking past it most days. What is notable when you look around is the consistency and technical accomplishment of the construction. The surface has an almost marble-like quality and there's a real rigour to the details, particularly the indented bolt holes. There is a simple clarity to the layout with the organisation of flats either side of a central external staircase. And it doesn't seem to have suffered the ravages of ageing

Photo: John Barr / RIBA Collections

ABOVE
Rokko Housing I in Kobe, by Tadao Ando, 1981-83

RIGHT AND BELOW
Azuma House, Osaka, by Tadao Ando, 1976

Photos: Hiromitsu Miromoto

that exposed concrete sometimes does, even though it endures a harsh climate, with plenty of rain, snow and hot summers.

Reducing architectural language to a single monolithic material is something that Ando is amazingly good at. The Azuma House in Osaka (1976) is on a very different scale to the Rokko Housing but shares the same idiom of carefully conceived and executed concrete. This private house was one of Ando's first works, and occupies a very narrow but long site squeezed between two party walls. It was a source of inspiration when we were designing Gap House [winner of the 2009 RIBA Manser Medal], which is just 2.3m wide.

The Azuma House's street elevation is just a blank concrete facade without windows – a very laconic sculptural edifice. It has an unassuming solidity at odds with the turmoil of the street, a typical Osaka scene of messy high-level cabling and chaotic urban planning. You step through the doorway into another world. The elongated house is divided into three equal parts, with the living accommodation and bedroom separated by a beautiful external courtyard. It's like a riad in Morocco: a tranquil, peaceful environment that completely rejects the street outside. And it's achieved by reducing the house to three simple components: concrete, glass and light. ■

Luke Tozer is director of Pitman Tozer Architects

FROM THE ARCHIVE: SUMMER 1980

SOMETHING BREWING ON BRICK LANE

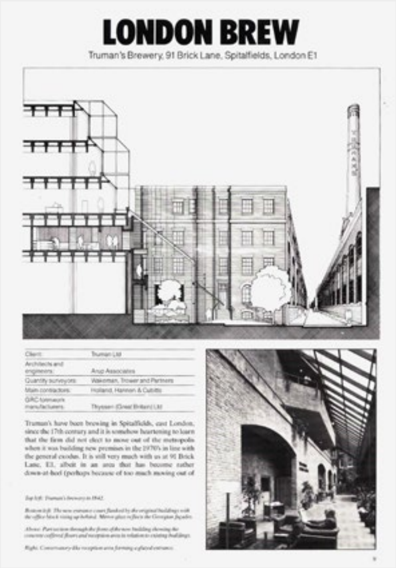
The Truman Brewery in Brick Lane, east London, dates back to the Great Plague and was once the largest beer maker in the world. But in the late 1970s, its premises also became a landmark in the evolution of both the modern office and the adaptive reuse of historic buildings. Having moved its factory to a new site, Truman commissioned Arup Associates to design an office, store and mixed-use space in the heart of its mainly Georgian complex – at the time, as CQ noted, "a rare linking of new and old".

The architects chose two defiantly modern materials to perform this mediating role. A five-storey reinforced-concrete structure, faced with mirrored glass, was inserted between the old Brewers' and Director's Houses. London buff brick, reclaimed from demolition sites, clad the lower floors. "The most satisfying parts of the building are perhaps around the edges where the juxtaposition of concrete and brick becomes apparent," wrote CQ.

The three open-plan office floors were treated with "consistent simplicity", the most dominant feature being the coffered reinforced concrete floor slabs. Here, Arup Associates' fusion of architecture and engineering came to the fore: the deep coffers discreetly house lights, air extractors and diffusers, and help to reduce the overall building height. The slabs were cast in permanent formwork of smooth, light-reflecting glass-reinforced concrete – "a new and interesting use of the material".

CQ was particularly impressed by the mixed-use space – a foretaste of offices to come. "[It] is exceptional both in the astonishingly high standard and range of amenities which it offers, including a coffee bar, dining area, pub, shop, social club and games room, and in the fact that the amenities are used by all grades of staff." Arup Associates had not only adapted a historic building using modern architectural principles, but also created a new type of hybrid space – one that has brought countless events, exhibitions (and beer drinkers) to Brick Lane over the past 40 years. ■

Explore the CQ archive at concretecentre.com/cqarchive



LONDON BREW

Truman's Brewery, 91 Brick Lane, Spitalfields, London E1

Client:	Truman Ltd
Architects and engineers:	Arup Associates
Quantity surveyors:	Wakeman, Trower and Partners
Main contractors:	Holland, Hannen & Cubitts
GRC formwork manufacturers:	Thyssen (Great Britain) Ltd

Truman's have been brewing in Spitalfields, east London, since the 17th century and it is somehow heartening to learn that the firm did not elect to move out of the metropolis when it was building new premises in the 1970's in line with the general exodus. It is still very much with us at 91 Brick Lane, E1, albeit in an area that has become rather down-at-heel (perhaps because of too much moving out of

Top left: Truman's brewery in 1842.

Bottom left: The new entrance court flanked by the original buildings with the office block rising up behind. Mirror glass reflects the Georgian façades.

Above: Part section through the front of the new building showing the concrete coffered floors and reception area in relation to existing buildings.

Right: Conservatory-like reception area forming a glazed entrance.

Photos: Brigida González

ORIGIN STORY

BUNDES-SCHULE VISITOR CENTRE

STEIMLE ARCHITEKTEN PAYS TRIBUTE TO THE BAUHAUS' CONFLICTING IDENTITIES WITH A LEAN STRUCTURE OF BEAUTIFULLY CRAFTED CONCRETE

When Steimle Architekten won the competition in 2017 to build a visitor centre at a Bauhaus Unesco World Heritage site, it found itself engaging in a conversation that had started in 1928. That was the year that Hannes Meyer became director of the Bauhaus, a brief interlude between the movement's more celebrated figureheads, Walter Gropius and Ludwig Mies van der Rohe.

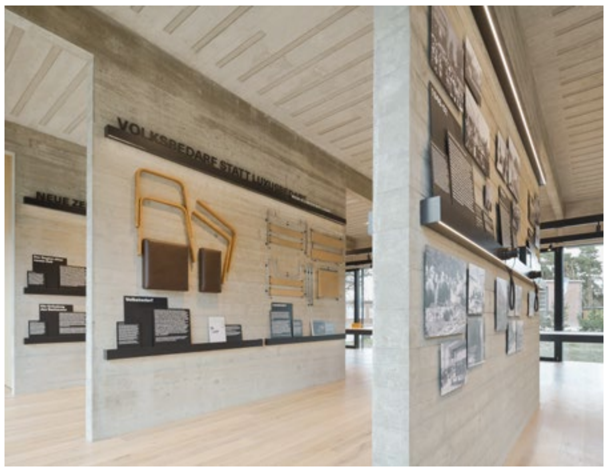
Meyer's short reign was responsible for the Bauhaus' second largest project, after the school's own Dessau complex: the Bundesschule (trade union school) in Bernau, 30 miles north of Berlin. The Bundesschule hasn't always enjoyed the same renown as the other Bauhaus sites. This is partly due to the all-engulfing tides of German history: completed in 1930, it enjoyed less than three years as a campus for continuing education before being repurposed as a Nazi management training centre.

It is also perhaps due to its architectural character: modest brick buildings that don't quite fit the heroic image conjured by the white curves and thrusting cantilevers at Dessau. Meyer, an avowed functionalist, saw architecture not as an art but as an objective tool for organising society, based on scientific principles. Such views alienated many at the Bauhaus, while his communist politics set him on a collision course with the Dessau city authorities. In 1930 he was ousted from the school and emigrated to the Soviet Union, while the Bundesschule was consigned to the footnotes of history.

Its fortunes began to change in 2017, when Unesco gave it World Heritage status, and the city launched a competition for the first new building on the site in over 90 years. The challenges echoed the tensions in Dessau nearly a century earlier. The visitor centre had to speak to competing ideas of what the Bauhaus was, while also, as architect Thomas Steimle puts it, "transforming them into the present".

Steimle's single-storey concrete and glass building plays with Bauhaus themes such as the celebration of craftmanship and expressive use of modern materials, but with added functionalist rigour. "The requirement to limit the building to what is actually necessary and to dispense with non-essential accessories pays respect to the Unesco site, and also contributes to sustainability and economic efficiency," he says.

The structure is unadorned: the internal arrangement of beams and supporting walls is clearly visible through the glass and follows a logical, regular sequence. One half of the 11m-deep plan is open and column-free, for use as a flexible



TOP
Timber formwork was trialled from different saw mills to achieve the desired board marking

ABOVE
The soffits have grooves cast in for inlaid acoustic materials and recessed lighting

Photo: Florian Monheim

TOP
The roof slab cantilevers 6m to create an entrance canopy

ABOVE
Meyer's functionalist Bundesschule buildings were the Bauhaus' second largest project

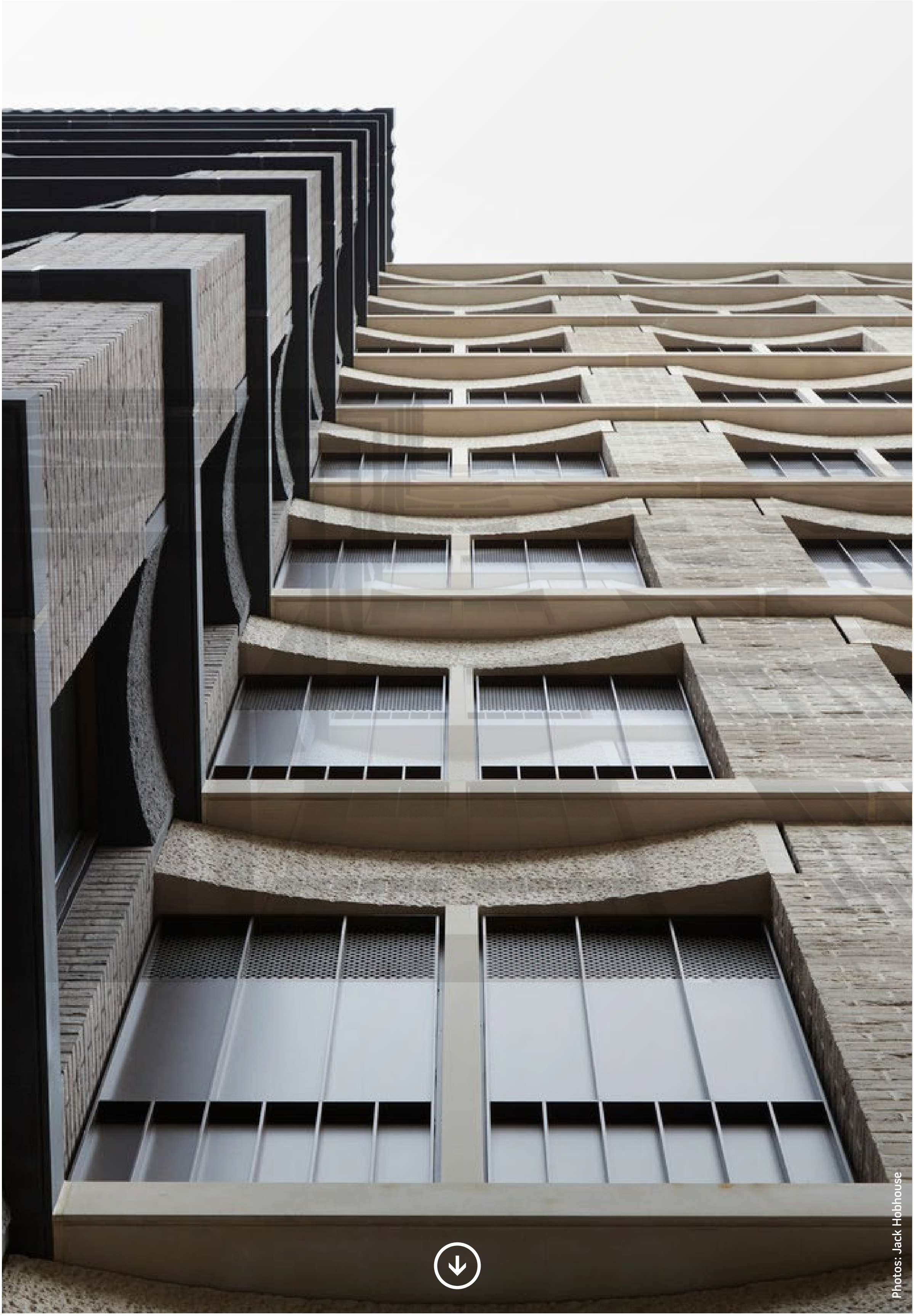
exhibition space. The other half has a series of walls at 3m intervals, which act as columns to support the roof as well as display surfaces.

The structure is deceptively lean, "reduced to the absolute minimum", says Steimle. The internal supporting walls are 140mm thick and the roof slab just 120mm deep. Expanded clay beads were incorporated into the proprietary mix to improve the concrete's thermal properties, making the structure work even harder.

Several sample walls were produced in order to test the mix, including the aggregates for the desired colour, and also the formwork. The pattern of the shuttering required detailed drawings and trials on the sample walls, using different joints and boards from several saw mills. Eventually, tongue-and-groove boards were specified from the mill with the most loosely tensioned saw band. "This ensured the desired surface structure, with a vertical strike in the wood," explains Steimle. The soffits are also exposed, with grooves cast in for inlaid acoustic materials and recessed lighting.

Such fine attention to detail seems a far cry from Meyer's anti-aesthetic manifesto. But it helps visitors to connect Bernau to the wider Bauhaus movement. Perhaps nothing does this more overtly than the building form itself, embracing what Gropius termed "the aesthetic of the horizontal". Above the glass facade, the monolithic concrete roof extends the full 42m length of the building, projecting a further 6m at one end to create a canopy over the entrance.

The effect of a solid roof plane seemingly floating above the glazed space is reminiscent of Mies' Neues Nationalgalerie in Berlin. But it is a sleight of hand – a 2m-deep perimeter beam conceals the slender roof slab behind. One wonders whether Meyer would have entirely approved – but then, this building is far more than a simple tribute. ■



Photos: Jack Hobhouse

FAMILY VALUES

Derwent has delivered a 'little sister' to its pioneering White Collar Factory, reprising the thermally active slabs and exposed concrete finishes while finding inspiration in Old Street's Victorian heritage. By Nick Jones

When the White Collar Factory was completed in 2017, it offered a glimpse of the future of office working: a model low-carbon workplace in the heart of London's Old Street tech district that mixed smart building systems with old-school warehouse elements. Now developer Derwent has evolved the model with another BREEAM Outstanding, LEED Platinum, concrete-framed office, just a few doors down.

ABOVE
The building is articulated as distinct volumes, ranging from five to 11 storeys

ITS EMBODIED CARBON OF 496KGCO_2/M^2 FROM STAGES A1 TO A5 IS THE LOWEST OF ALL DERWENT'S NEW-BUILD PROJECTS TO DATE

Designed by Morris+Company, the Featherstone Building incorporates five more years of collective knowledge and understanding of material-efficient design and intelligent systems. Its embodied carbon of 496kgCO_2e/m^2 from stages A1 to A5 is the lowest of all Derwent's new-build projects to date. Designed in 2016-17, it beats LETI's 2020 target, and represents a 380kgCO_2e/m^2 reduction on the White Collar Factory's footprint over the same stages.

The Featherstone also appears on first glance to take a different approach to workplace aesthetic. Whereas the AHMM-designed White Collar Factory rises 17 storeys from a small, irregular-shaped site, the Featherstone is an 80m-long block, articulated as four roughly square volumes, two of five storeys, one of 10 and one of 11. And whereas the White Collar Factory is sheathed in sleek glass and hole-punched aluminium, the facades of the Featherstone pay homage to the area's Victorian warehouses, with broad piers of dark-grey and buff

ABOVE
Full-height windows look out over the green space of Bunhill Fields at the back of the building

ABOVE
The ground floor includes a cafe. Shared space plays an important role in Derwent's approach to workplace design

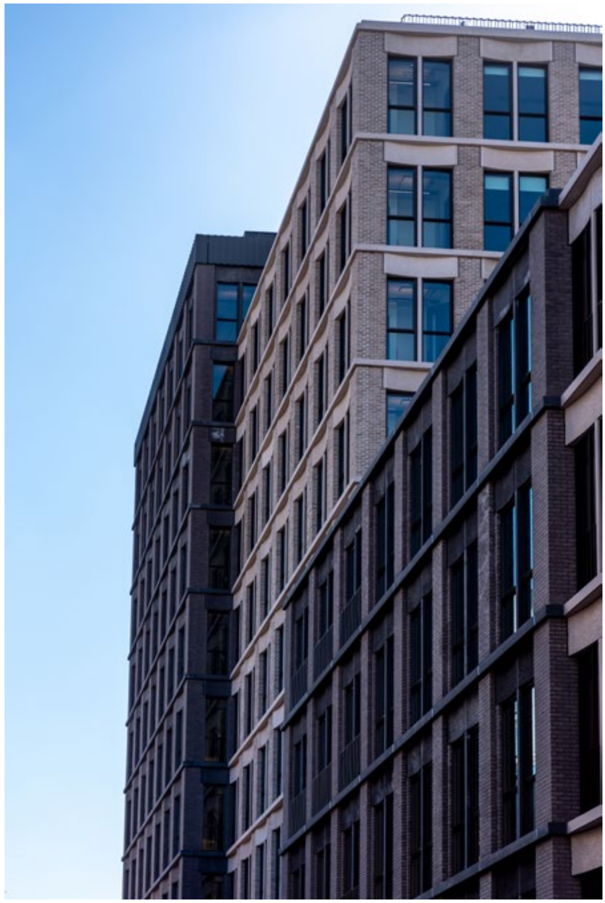
brickwork and scalloped, rough-textured concrete lintels.

Yet both buildings are born out of the same philosophy: a "long-life, loose-fit, low-carbon" approach developed over many years by Derwent in collaboration with its different design partners. Morris+Company fondly refers to the Featherstone as the White Collar Factory's little sister, and the two buildings share the Derwent hallmarks of high ceilings, large-span spaces, exposed finishes, generous outdoor areas and large, openable windows. Both buildings also have an in-situ reinforced-concrete frame, made to work as hard as possible – not just as structure and finish but also an integral part of the heating and cooling system.

Design work on the Featherstone was just getting under way as the White Collar Factory was completed, and Derwent was keen to adopt many of the same sustainable technologies. This included "activating" the slabs by casting in a network of plastic pipes, through which chilled or heated water can flow, supercharging the concrete's thermal mass. Sensors monitor the slab temperature and air humidity and feed this data back to the building management system, which controls the water temperature.

It is easy to see why thermally active slabs appeal to Derwent. They are both sustainable and unobtrusive, leaving expanses of clear soffits while lowering operational energy use – by a claimed 25% at the Featherstone. They enhance the building's stripped-back aesthetic and accentuate the 3.125m floor-to-ceiling heights.

BELOW
The column-free reception has a 7.5m floor-to-ceiling height, made possible by a large transfer structure that oversails the entrance



But this apparently simple passive solution took a lot of very active structural engineering to achieve. As with the White Collar Factory, the grid has to be organised in a way that balanced the requirements for large spans and a lean structure, while still being able to incorporate the pipework. And as with the previous project, they had to work within awkward local constraints, the footprint of the building exceeding the space available for foundations.

The Northern Line and Network Rail Northern City Line tunnels run adjacent to the entrance facade. With a 3m exclusion zone around the tunnels, structural engineer Heyne Tillett Steel needed to set back the piles from the perimeter, effectively cantilevering the whole building. HTS's solution was to use the basement slab as a transfer structure, increasing its depth to 1.5m. "We looked at different options, but actually doing everything below ground was the most efficient way without compromising the internal layouts," says Robert Mills, senior associate at HTS.

Above ground, the challenge was to create column-free spaces without increasing the depth of the slabs. The four interconnected volumes are about 21m x 21m, which would have lent itself to 10.5m spans. Post-tensioning was ruled out as a means of providing a leaner structural solution – with 60km of pipework needing to be embedded in the structure already, a traditional approach to reinforcement reduced the perception of

ABOVE
The bricks and concrete alternate from dark grey to a lighter buff between the different volumes

risk. Instead, HTS refined the design, adjusting column positions, analysing stresses and modelling deflections to create a 9m x 9m grid, with some variations. "That still gives a big, open, flexible space," says Mills, "but it meant we were able to engineer the slabs so they are only 325mm deep."

The pipework has been designed to avoid the most heavily stressed areas of the structure, such as around column heads, as well as built-in "soft spots" to enable future flexibility. It was laid between two mats of reinforcement and fully tested before the slab was poured. (Main contractor Skanska issued follow-on trades with short 19mm drill bits to make sure that no one accidentally penetrated the pipes.)

The soffits have a matt finish from the paper-faced MDO formwork, and were also "sanded" to remove blemishes. The mix contained 30% GGBS, although higher proportions were used elsewhere, including 50% in the columns, 70% in the piles and 75% in the pile caps, where it helped to slow the curing of the thicker concrete elements, reducing the need for anti-crack rebar.

There is a 15m x 9m core on the east side of the

BELOW
A 20mm shadow gap separates the textured GRC spandrels and brick-clad piers

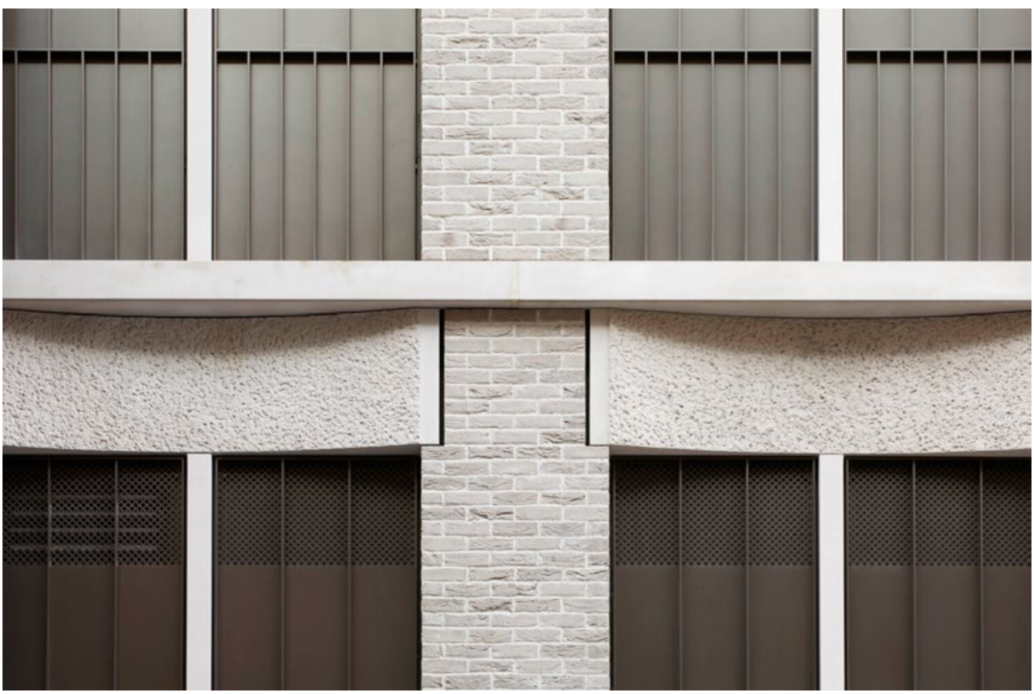



Photo: Skanska

ABOVE
Tie bolt holes from the jump-form system are a recurring motif throughout the circulation areas

building and a smaller 9m x 9m core on the west side, both of which provide further expanses of exposed concrete. The mix here contains 20% GGBS but also includes a 2.5% addition of silica fume, a by-product of the computing industry. This helped to give the walls a slightly darker tone.

Each jump-formed floor was cast in a single pour, partly due to programme constraints but also to avoid day joints in the exposed surfaces. "Because it was all visual concrete, the pour had to be continuous, well vibrated and controlled," says Steve Arthrell, project director at Skanska. "It would take a whole day." The team spent a lot of time testing the mix, he adds, as the balance between the silica fume, which is an accelerator, and the GGBS, a retardant, was critical to both the initial setting and curing times. They also had to take the location of the tie-holes into account and keep them in alignment: these are a recurring motif.

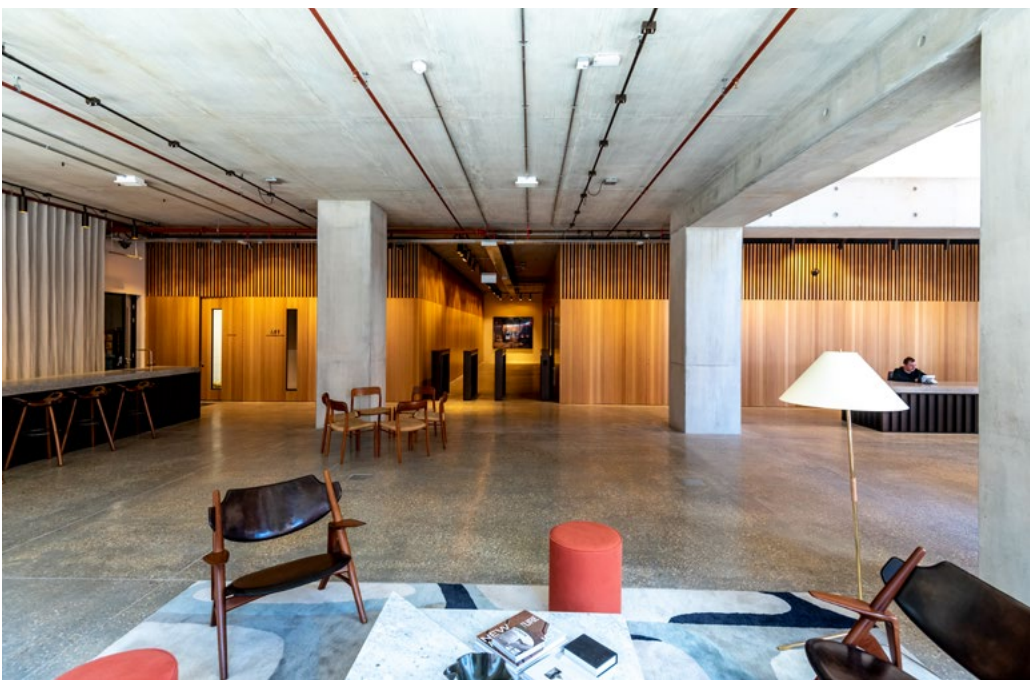
The cores were cast using phenolic ply formwork. Although this leaves a shinier finish than MDO, it can be reused more times.

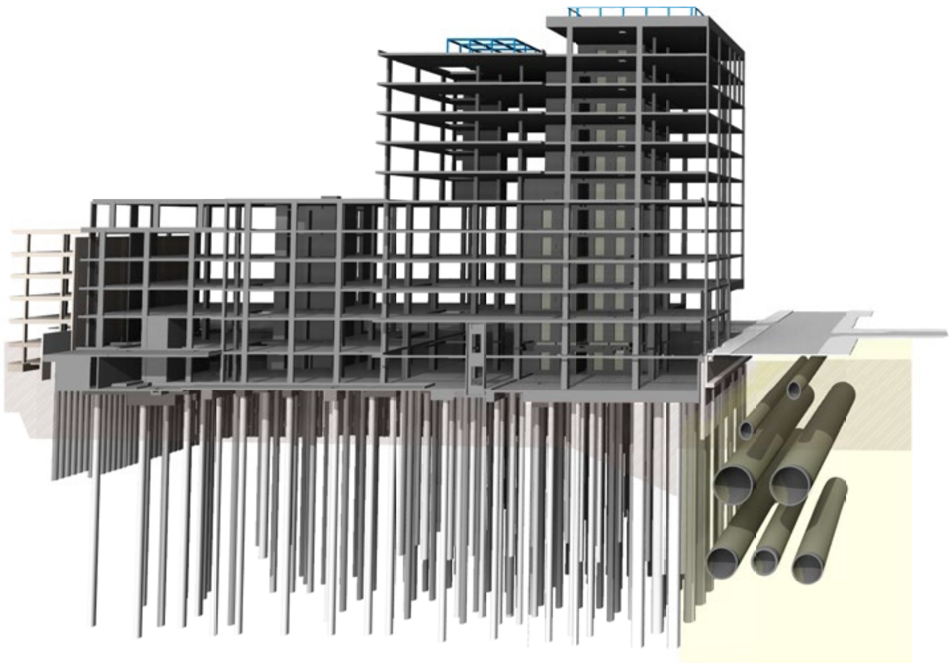
The exterior, on the other hand, shows very few signs of its construction method. The masonry facades may look traditional but are actually supported between perimeter columns like a curtain wall. This lightweight unitised system is made from glass-reinforced concrete (GRC), albeit with high-quality material finishes instilling a strong sense of depth and solidity.

Facade engineer Eckersley O'Callaghan had explored a number of options, including handlaid brickwork with precast lintels and fully brick-faced precast panels. However, the constrained inner-city site presented a logistical headache, with little room to install scaffolding or to manoeuvre the large elements that would be needed to work with the 9m grid and 3.8m floor-to-floor heights. The lean in-situ frame was another factor: "The slabs were as thin as they could be," says Arthrell. "Their dead and live load deflections were quite high, which is always a sign that it's designed as efficiently as possible."

Skanska was also keen to explore the efficiencies of design for manufacture and assembly (DfMA), which led the team to consider GRC panels, fixed to the frame using a cassette system. This had the added benefits of being fully demountable at the end of its life and potentially reducing the facade's whole-life carbon (see box). "It was quite bespoke at the time," says Arthrell. "Together with the manufacturer, we worked up a design that made the facade work and the client loved the idea." A 1:1 mock-up demonstrated that

BELOW
The active slabs result in expansive exposed soffits free from ventilation ductwork





the GRC system could deliver the required architectural quality. There were three main elements to the system: the piers, made with half bricks on 82mm-thick GRC panels; openable aluminium windows; and a T-shaped unit comprising a slender GRC mullion and the scalloped lintel. Variations include the use of a double scallop on the upper level to define the crown of the building.

The scallops were cast with a Reckli mould to create a hammered effect – a faint echo perhaps of the White Collar Factory interiors, which also use a flexible form liner to recreate a traditional effect, in that case timber board marking. It's as if both buildings are paying their respects to a shared heritage, before striking out on their own. ■

ABOVE
The piles were set back from the perimeter, effectively cantilevering the whole building, due to a 3m exclusion zone around the rail tunnels

PROJECT TEAM

Architects Morris + Company, Veretec
Structural engineer Heyne Tillett Steel
Facade engineer Eckersley O'Callaghan
Main contractor Skanska
In-situ concrete contractor Mitchellson
Facade supplier Skonto Plan

Face off: comparing the carbon of two facades

At the time that the Featherstone Building was being designed, there was no standardised methodology for calculating the embodied carbon of different facade options. But Eckersley O'Callaghan (EOC) found itself in a unique position to do some numbers of its own. Having already worked up a detailed design in precast concrete and brickwork before switching to unitised glass-reinforced concrete (see main copy), the engineer realised it was able to carry out a detailed comparison.

"When the project finished, we thought it would be great to compare both options over a lifespan of 60 years and see whether or not we made the right choice," says Florence Li, senior engineer at EOC. "We felt that the embodied carbon in offsite assembly is not well documented."

Using product data from the supply chain as well as a breakdown of energy use in production and installation, the team initially expected the GRC option to involve more upfront carbon. "You've effectively got a panel with another layer of cladding on top, and there are also a lot more metal components. The bricks came from Belgium and had to be shipped to the manufacturer in Poland," Li explains.

Yet one surprising result was that the unitised solution involved less embodied carbon from stages A1 to A5 (extraction, manufacture and installation), estimated at 95kgCO_2e/m^2 compared with 104kgCO_2e/m^2 for the brick laid on site. This was partly because the impact of site waste for the bricks was greater than the transport involved in the GRC panels.

But where it gets really interesting is when carbon emissions are extrapolated over a 60-year life. The unitised solution has a shorter lifespan, with the gasketry needing to be inspected and potentially replaced after 30 years. "We assumed that the whole facade would be dismantled to allow us to replace the gaskets, install new glazed units and then reinstall it all on site," says Li. With the brick, on the other hand, EOC assumed that the punched window elements could just be reinstalled, which meant a lot less activity during the life of the building.

Factoring in the shorter lifespan, the unitised solution was now calculated to be slightly more carbon-intensive: 140kgCO_2e/m^2 compared with 130kgCO_2e/m^2. The D module for recovery and reuse also favoured the precast option in purely carbon terms, although Li points out that the metal unitised components are directly reusable. It's also easy to envisage a future where shorter-term facade options play a role in the expanding retrofit market, with property owners simply switching building skins every few decades to refresh their offer.

So did EOC make the right choice? "It was nice, in a way. We landed in a place where both solutions were roughly the same – we went full circle." ■

Photos: Keith Hunter Photography

COFFER REMEDY

When the University of Edinburgh began updating its central campus, 7 Bristo Square's days looked to be numbered. This unloved 1970s refectory bore many of the failings of architecture from that era: inaccessible, poorly lit and forbidding, its apparent lack of charm further marred by a series of pragmatic but ill-advised additions.

Which makes its new role as the university's Health and Wellbeing Centre, bringing together counselling and disability services, pharmacy and health facilities, something of a Lazarus-like recovery. Architect Page\Park has achieved this not with a radical overhaul, but by reinstating many of the original modernist qualities.

Suspended ceilings have been removed throughout, exposing the in-situ coffered slabs, which were in a good condition. In some areas, the grid of downstands has been used to route services; in others, lights drop down from the centre of the coffers. Towards the back of the building, four circular voids have been cut into the coffers to create lightwells.

A key move has been to open up a pyramidal lightwell that had been concealed by the lecture theatre soffit – a later addition. "They had put a sort of lid over that just killed the natural light coming in," says project architect Jamie Hamilton. "It was a very odd space. I don't think we were really aware that the rooflight was such an amazing feature until we squeezed our heads up above the soffit and got to dig around a bit more. It just opens the heart of the building back up."

Page\Park estimates that 75% of the embodied carbon of an equivalent new building was saved by retaining the substructure, structure and facades. ■

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WALL GAMES

XO Apartments is an all-electric residential block in north London, designed by Dowen Farmer. The interlocking, double-walled exterior is a means of containing and organising a geometric puzzle of a building. "There were transfer structures at every level," says Sean Martin of Dowen Farmer. "The whole reinforced-concrete frame was a series of steps and pushes and pulls. For a scheme of a relatively small size, it was exceedingly complex for the structural engineering team." ■

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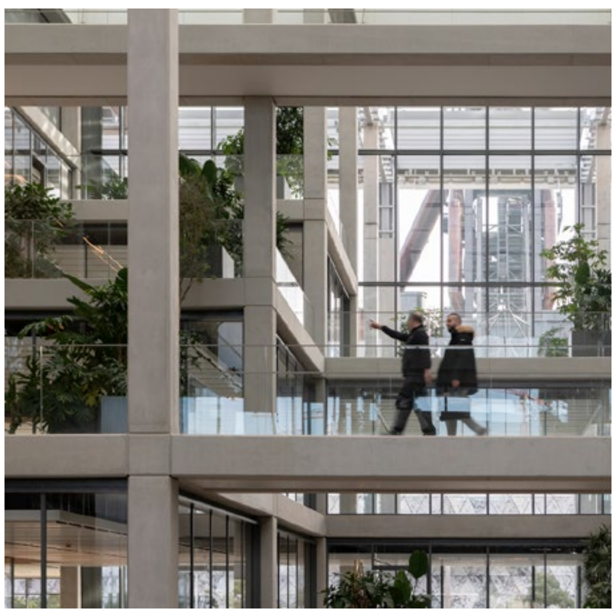
Photos: Richard Fraser, Roberto Garagaza

OPEN FOR BUSINESS

ICÔNE, a new office in Luxembourg, offers a dramatic example of the changing nature of speculative development. The 24m-wide atrium, animated by small trees, terraces and bridges, is the main space; the 16m office wings subordinate to it. Beams trace the outline of where one might expect a floorplate to be, while columns rise unrestricted through all four levels. "The structure is the architecture," says Darren Haylock, partner at architect Foster + Partners. "Where we don't need material, we haven't used it." ■



Photos: Nigel Young

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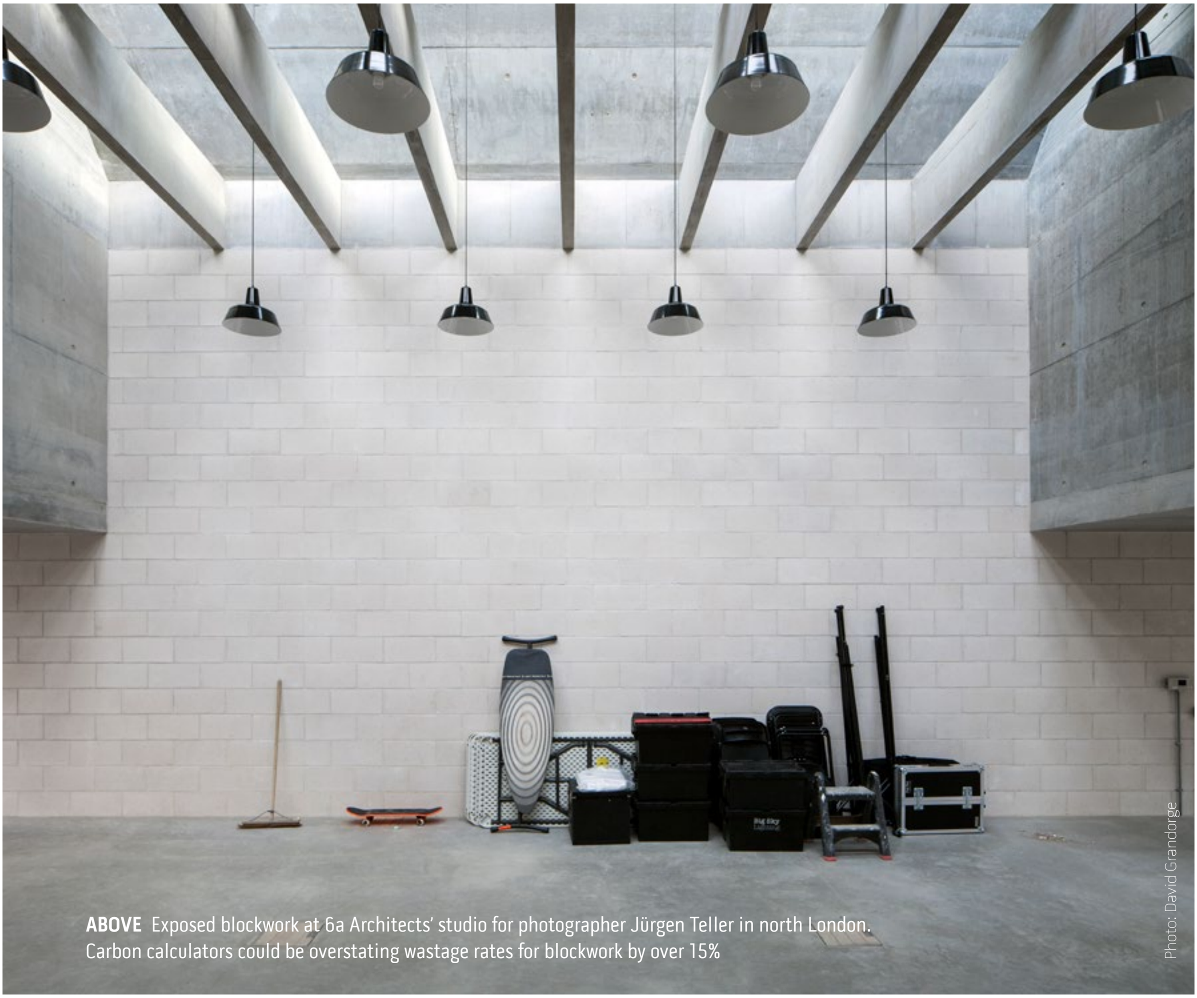

ABOVE Exposed blockwork at 6a Architects' studio for photographer Jürgen Teller in north London. Carbon calculators could be overstating wastage rates for blockwork by over 15%

Reassessing concrete wastage rates

The amount of material wasted on site is an important factor in whole-life carbon calculations, but the rates used in most methodologies are out of date. Hafiz Elhag reports

↓

Recent years have seen dramatic changes in the way that concrete is used, accounted for and disposed of. Technologies such as post-tensioning continue to reduce the quantities needed in structures, while developers are increasingly looking to reuse rather than demolish existing frames. And the UK concrete sector's approach to manufacturing waste gets ever more miserly: in 2020, it sent 100g per tonne of production output to landfill compared with 5kg in 2008. Driven by sector-specific Resource Efficiency Action Plans, developed in 2012 with the Waste and Resources Action Programme (WRAP), use of both precast and ready-mixed concrete is more tightly managed, with improved ordering processes and waste reused as fill material on site.

Yet despite this backdrop of improving resource efficiency, the concrete wastage rates used in construction industry guidance have remained unchanged for 15 years. Most carbon tools and guidance specify data from either the BRE's Green Guide to Specification or WRAP's NetWaste tool, both published in 2008 and including rates that vary by as much as 15% (see table 1 overleaf).

In 2017, the RICS proposed the use of the NetWaste baseline figures – 20% and 5% for blocks and ready-mixed concrete respectively – to account for impacts at the A5 (construction) life cycle stage in its Whole-Life Carbon Professional Statement. The RICS guidance is considered by many as the UK's principal methodology for assessing building emissions, and since then, several other guidance documents and carbon calculators, including the IStructE's "How to Calculate Embodied Carbon", have adopted the same data. According to some estimates, this could be inflating the A5 upfront carbon of blocks and ready-mixed concrete by about 25% and 6% respectively.

The RICS has recently consulted on a revision to its guidance. With this in mind, and in the context of a focus on reducing waste across the sector, MPA Masonry and the British Ready-mixed Concrete Association commissioned circular economy consultant Reusefully to examine the existing rates and propose updates. These could then be used to inform environmental product declarations (EPDs) and future waste strategies, as well as the RICS consultation.

Understanding existing rates

The study involved three main activities: a desktop review of the existing literature, including relevant EPDs for blocks and ready-mixed concrete; a survey of contractors and suppliers to compile site waste and product takeback data; and interviews to gain further insights into the causes of waste and the best ways of eliminating it.

But it started by examining the existing rates in the Green Guide to Specification and the WRAP NetWaste tool. The WRAP tool included "baseline" (standard) and "good" wastage rates for 6,000 construction products. For in-situ concrete, the rates were 2.5% and 5%, based on research projects and trials, although it is not clear how many sites this data is derived from. The rates proposed for blocks, meanwhile, diverged dramatically, from 5% to 20%. The baseline 20% figure comprised 5% on-site waste and 15-16% waste during transportation. Again, it is not clear how many sites this data was taken from.

The Green Guide, by contrast, suggested a 5% wastage rate for blockwork and 2.5-7.5% for in-situ concrete.

Reusefully also reviewed 43 EPDs, which indicated UK average wastage rates for blocks and ready-mixed concrete of 5% and 3% respectively, as well as pricing books and European embodied carbon databases.

Finally, it looked at previous studies on the topic. A 2008 study by the Construction and Waste Resources Platform, for example, directly collected data from three construction sites and recorded concrete block wastage rates ranging between 5.7% and 7.3%, largely corresponding with data reported in

Table 1: Wastage rates used in Green Guide to Specification and WRAP Net Waste Tool

Product	Green Guide to Specification wastage rate (%)	WRAP NetWaste tool wastage rate, baseline (%)	WRAP NetWaste tool wastage rate, good (%)
	2008	2008	2008
Dense concrete blocks	5	20	5
Lightweight concrete blocks	5	20	5
In-situ concrete	2.5 / 5 / 7.5	5	2.5

Table 2: Rates proposed by 2023 Reusefully study

Product	Proposed wastage rate (%)
Concrete blocks	3-5
In-situ concrete	1-2

EPDs and European embodied carbon databases. On the other hand, a 2011 study by WRAP showed significantly high wastage allowances reported in three construction sites, exceeding 20% for concrete blocks in at least two sites. The report notes that the contractors made high allowances in these projects due to concerns over material availability and design variations, and that they had a take-back clause for unused products.

The range detected for ready-mixed concrete was significantly tighter, usually between 1% and 5%, with very few reports and a single paper suggesting wastage rates above 5%.

Survey and interview findings

Reusefully then organised both an online survey and a series of interviews to test the findings of the desktop study. A general theme to emerge was the limited availability of data. This is due to a number of factors:

- Waste data is commonly collected but this is rarely related to actual deliveries of product
- Materials that have not been installed can be recycled on

BELOW
Light-pigmented blockwork at King's Grove, south London, by Al-Jawad Pike

Photo: Ståle Eriksen

site, which is not included in waste generation data

- Products are reused for other purposes – for example, blocks used to keep pallets off the ground.

This situation may improve over the next two to three years. Most developers and contractors see resource efficiency and waste reduction as a priority, which is leading to internal projects to better understand the amount and causes of waste, and to the development of reduction measures.

Findings: blockwork

The wastage rate proposed for concrete blocks by nearly all respondents was around 5%. However, some respondents suggested rates as low as 3% could be achieved in cases where good design, quality, procurement and site management practices were in place. This 3-5% range is significantly lower than the 20% rate used in carbon assessments over the last five years, and would indicate that the upfront carbon of blockwork has been systematically overestimated by 14-18%.

Respondents suggested that the lower end of the range could be achieved by adopting the following approaches:

- Design: Standard designs can lead to less waste. For housebuilding, there is not much variation in the block types used, so unused products can be transferred to other sites. Conversely, changes to designs and varying features will have the opposite effect. It can also be quite wasteful if openings need to be made after blockwork has been installed.
- Quality: Given the less visible nature of blocks, aesthetic quality is less of an issue, but it can impact waste

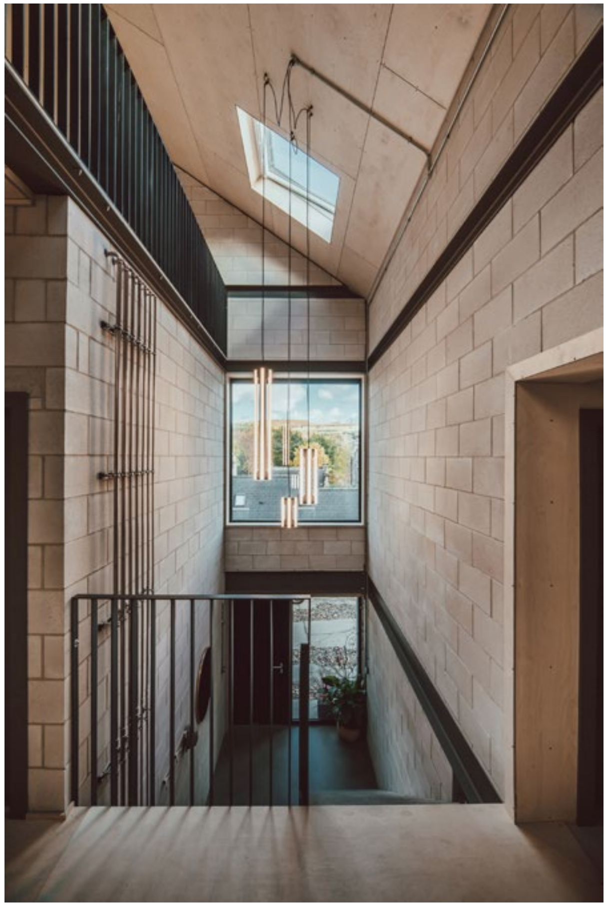

Photo: Tom Kahler

ABOVE
Twin-build by CODA Bespoke in Sheffield

generation if a batch is delivered with quality issues.

- Procurement: Wastage is thought to be lower when the product has been bought by the company installing the blockwork. "Free issue" to subcontractors, on the other hand, is considered to contribute to higher wastage rates. Where there is a double charge to return unused products, this acts as a financial disincentive to do so. In these cases, unused products tend to go to other sites, be sold to third parties at large discounts, or get crushed for fill material on site. Greater flexibility from suppliers was proposed, in terms of reducing or redirecting orders, and allowing part-loads to be returned.
- Site management: Engaged site managers can have a significant impact on the efficient use of materials such as blocks, for example by promoting reuse of offcuts, flagging up quality issues and ensuring the accuracy of orders.

Findings: Ready-mixed concrete

All interviewees suggested that the wastage rates for ready-mixed concrete were low, and falling. It is understood that there is now better estimation of the quantities needed and therefore ordering is more accurate. The improvement in control, planning and management of ready-mixed concrete is mainly driven by cost savings.

Often, smaller areas make use of ready-mixed concrete left over from bigger pours. If this is not possible, waste concrete is often crushed and used as fill material around the site.

Interviewees typically proposed a 1-2% wastage rate. One supplier suggested a return rate of no more than 1.25%.

What next?

The study proposed that wastage rates of 1-2% for ready-mixed concrete and 3-5% for blockwork would lend greater accuracy to carbon calculation tools. It also suggested that better data, collected and reported using an established method, is needed to further reduce wastage levels. Opportunities to gather data are likely to increase as housebuilders and contractors focus on reducing waste to lower the material costs and meet targets linked to the government's Zero Avoidable Waste strategy.

MPA Masonry is using the updated data in its EPDs and recommending that the RICS includes it in the update to its Professional Statement. It is also exploring further research opportunities on data collection, and continues to develop its REAP work and tools to help with quantity estimation. ■

ALL INTERVIEWEES SUGGESTED THAT THE WASTAGE RATES FOR RMC WERE LOW, AND FALLING. THERE IS NOW BETTER ESTIMATION OF THE QUANTITIES NEEDED AND THEREFORE ORDERING IS MORE ACCURATE

FINAL FRAME: CHAPEL OF SOUND, CHENGDE

OPEN Architecture has created a boulder-like concert venue in the shadow of the Great Wall of China. In-situ concrete provides the structure, finish and – unusually – the acoustics. Arup used parametric software to rationalise the amorphous double-shell structure, then OPEN translated the 3D coordinates into 2D drawings, to be incorporated into the structural sets. From these, the local contractor created a skeleton of reinforcement out of vertical and horizontal elements, which acted as a guide for the traditionally constructed timber formwork.

Photo: Jonathan Leijonhufvud