CONCRETE QUARTERLY

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Elaine Toogood
Senior director, MPA Concrete
& The Concrete Centre

Navigation skills

Of all the questions The Concrete Centre receives from architects, the majority concern how to specify low-carbon without having to go in-depth on concrete technology or supply chain dynamics. Designers are keen to move beyond business as usual, but they're struggling to know what good actually looks like.

There are a number of reasons for this. First, as our collective knowledge and proficiency increases, we start to look more closely, find more carbon and understand the implications of the design decisions and specifications we make. Secondly, the data available to us is increasing in quantity, granularity and, hopefully, accuracy. EPDs are updated as a minimum every five years, reflecting the changing performance of products, as well as refinements in the rules to calculate emissions. Finally, the solutions themselves are evolving, with new multicomponent cements (page 34) and various innovations at different stages of development.

Against this backdrop, designers could be forgiven for throwing their hands up in defeat. Not so fast. There are some simple rules of thumb that will continue to hold true.

The first is not to get bogged down in the concrete composition. Specify a carbon aspiration and a performance category, but not particular constituents. There are many possible ways to achieve the desired end result, and the right one will depend on many factors – from construction conditions to local supply chains – that are outside the designer's control or knowledge. Well-intentioned targets or limits can easily backfire, forcing a specification that's higher carbon than necessary. Designers' most important role is to establish the carbon aspiration at the outset and thus not hinder the adoption of an innovative, or particularly appropriate alternative solution.

The next rule of thumb is not to miss carbon-reduction opportunities that are within your grasp. The amount of concrete that is used is just as significant as what's in it – and material efficiency sits squarely with the designer. With our free Concept structural comparison tool, you can see how even small changes can add up to massive reductions (see CQ 289).

DESIGNERS' MOST IMPORTANT ROLE IS TO ESTABLISH THE CARBON ASPIRATION AT THE OUTSET, SO THAT THIS INFORMS ALL FUTURE DECISIONS

Our feature on 3 Chamberlain Square (page 16) shows this approach in action. By shrinking the grid from 9m to 7.5m, structural engineer Cundall reduced the amount of concrete required by 25%. When it came to the concrete specification, it set a strict limit for embodied carbon and a stretch target, leaving the contractor to determine how best to meet it. In the end, it beat the target by 5%.

But how to set project goals? The third rule of thumb is to lean on established standards and benchmarks. The Embodied Carbon Market benchmark from the Low Carbon Concrete Group in the UK and the Global Cement and Concrete Association's Global Low Carbon ratings system enable specifiers to see what current practice looks like, and set targets for their project, whether that's a slight improvement or a deep green exemplar.

An enormous amount of work has already gone into agreeing how to measure whole-life carbon – we're not in the Wild West anymore. Today's standards and benchmarks will inevitably change. But that's what progress looks like. ■

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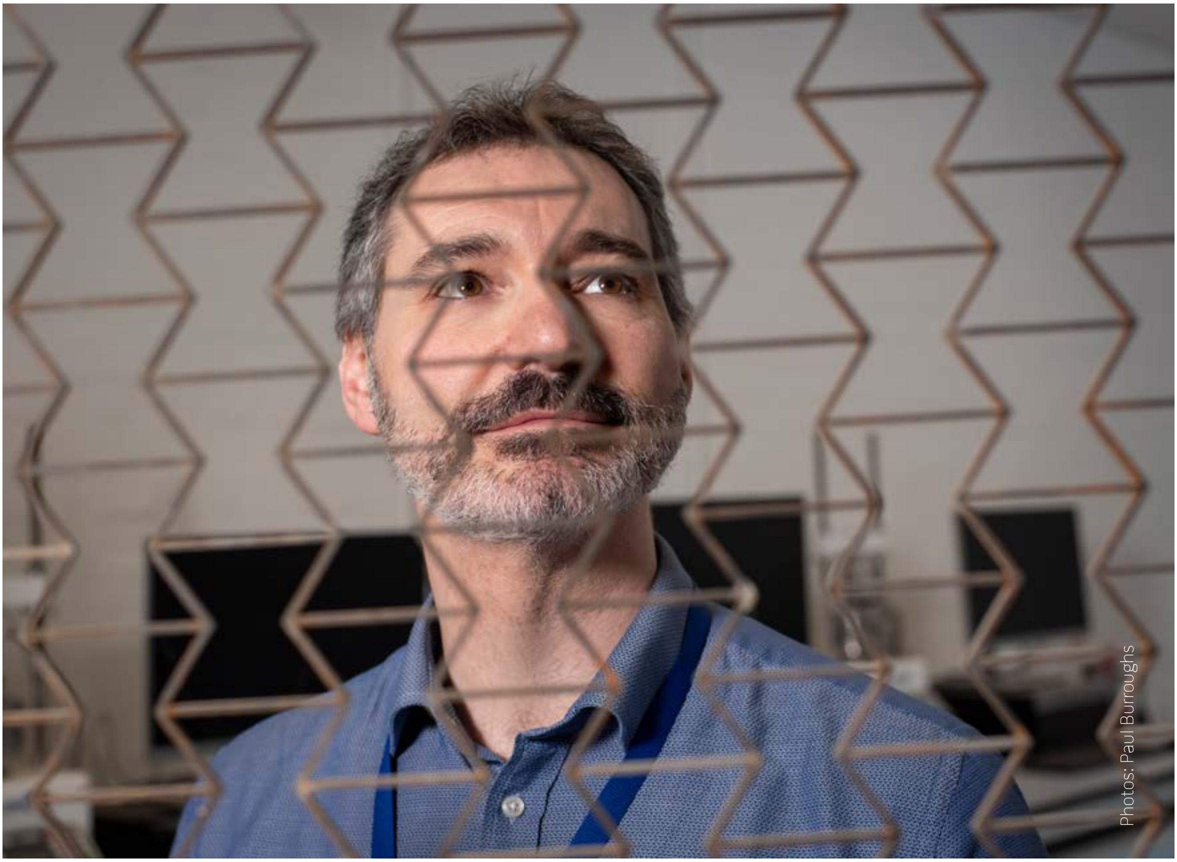

Photos: Paul Burroughs

INNOVATION

AUXETIC FORMWORK

RESEARCHERS AT THE UNIVERSITY OF EXETER ARE USING GRIDS WITH UNIQUE PROPERTIES TO CREATE STRUCTURALLY EFFICIENT CONCRETE DOMES

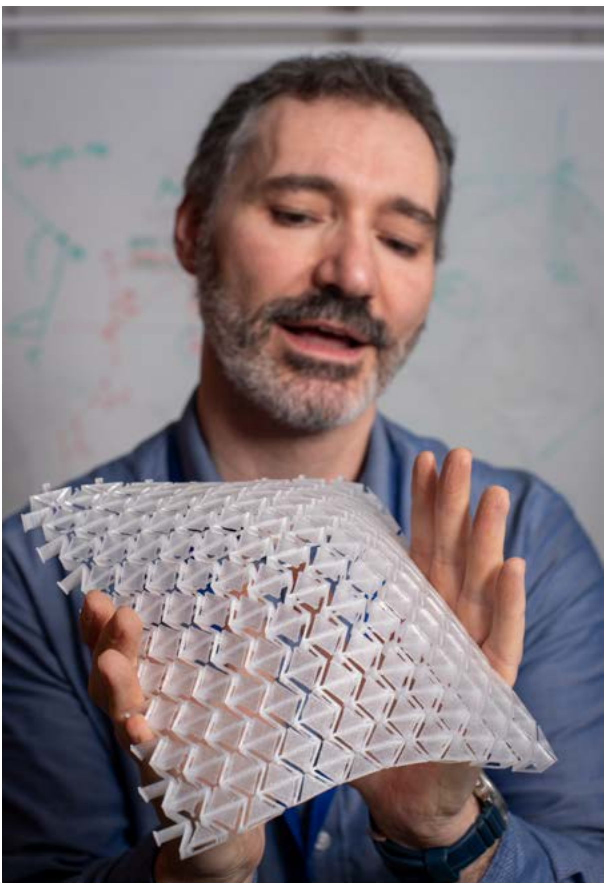
Imagine a garden trellis. Pull the ends apart to stretch it, and the grid's squares will turn to diamonds, making the trellis longer and thinner. This seems natural: after all, if you stretch dough or melted mozzarella, it too becomes thinner.

But not everything becomes slimmer when stretched. Replace the squares of the trellis with a grid formed from tessellated bow-tie shapes, for example, and something unexpected happens. The shape thickens when stretched, and becomes thinner when compressed. Grids or meshes with geometries that exhibit this effect are described as "auxetic".

"Of course compression is a key part of how concrete works in structures," says Dr Raffaele Vinai at

“IF YOU BEND AN AUXETIC GRID ONE WAY, THE GRID WILL AUTOMATICALLY CURVE IN ALL OTHER DIRECTIONS. SO A FLAT SQUARE BECOMES A PERFECT DOME”

BELOW
Vinai demonstrates how an auxetic grid curves into a dome when bent in just one direction, using a 3D-printed prototype



the University of Exeter. “So, a few years ago, we started to think about whether we could use the extra confinement coming from auxetics to make concrete structures that are stronger, or more efficient in terms of material and carbon usage.”

A project funded by the UK Engineering and Physical Science Research Council gave the research team – made up of Dr Vinai, Dr Prakash Kripakaran and Prof Ken Evans at the University of Exeter, and Prof John Orr at Cambridge University – the opportunity to explore these concepts.

Vinai’s first experiments concerned embedded auxetic reinforcement grids: “But we found that concrete is too brittle to allow the grid to move sufficiently to have an auxetic effect. Interestingly, though, we found that if we used Miscrete [a building material developed by Dr Vinai and his colleagues using miscanthus fibres and lime-based binder] its extra squeezability meant that auxetic reinforcement doubled the load-bearing capacity of bow-tie-shaped blocks compared with standard prismatic blocks.”

But bio-fibre blocks, like Miscrete or Hempcrete, are not structural materials, and are used mainly as an eco-friendly form of insulation. “So we looked at other ways we could use auxetics,” says Vinai, “particularly in formwork.”

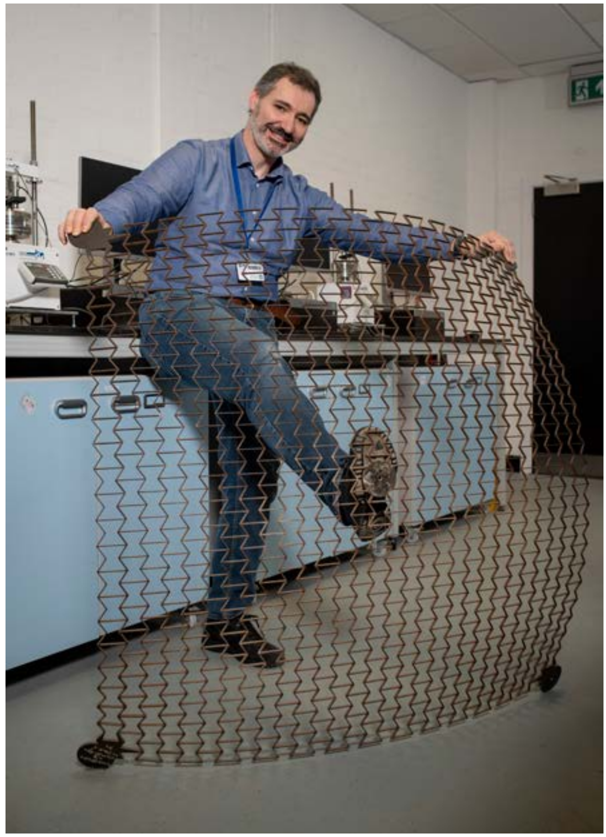
In addition to becoming thinner when compressed, auxetic grids have another unique feature: “If you bend an auxetic grid one way, say north-south, the grid will automatically curve in all other directions. So a flat square becomes a perfect dome.

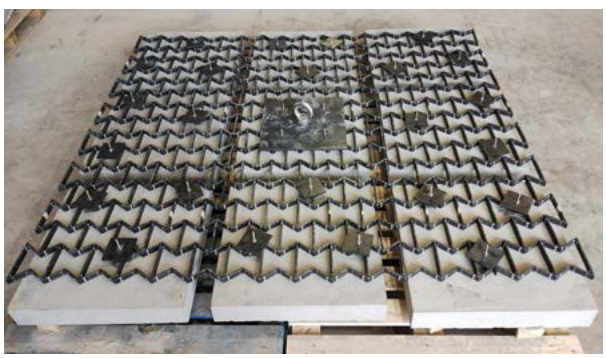
Domes are structurally very efficient, but are seldom constructed because they are very labour-intensive. Making formwork for concrete domes is challenging, but because auxetic grids bend synclastically – identically in all directions at once – they can form them easily. Our goal now is to use auxetics to develop deployable supporting structures for domes."

Vinai's team have already proved it can be done using an auxetic steel grid that had been water-cut from a solid steel sheet. But this is inefficient in terms of wasted steel. So their first full-scale steel grid is made with thousands of individual components that can be assembled like Meccano, resulting in cells about 150mm long. "At 25mm thick, and 2m square, we think it might be the world's largest-ever auxetic grid."

The team carried out a major test at FP McCann's R&D facility in Knockloughrim, Northern Ireland, where they deformed the 120kg grid by hanging 800kg worth of concrete slabs from it. "The grid bent into the expected shallow dome, although we observed that the joint design and load repartition need further development to fully deliver the concept we envisage in a structurally sound way."

What can you do with a $2m^2$ dome? "Domes work under static compression, so can support far more load per tonne than a rectangular slab or beam, and could ideally work without steel reinforcement. This significantly reduces the material needed. We use prismatic beams and slabs because they are cheap to





ABOVE
A $1.2m^2$ steel grid in the lab at Exeter, and the $2m^2$ test grid at FP McCann's R&D facility in Knockloughrim, believed to be the largest ever produced

produce, not because they are efficient."

Domes could be used structurally for material-efficient flooring or roofing systems, or naturally self-shading facade panels, he suggests. "But there are many possibilities."

Auxetic grid formwork, says Vinai, could do more than create simple dome shapes. The team is now working on the prototype of a complex-shape casting bed: "By connecting several servo motors to an auxetic grid, it could be deformed into all kinds of interesting shapes by pushing and pulling at various points. So one casting bed could produce infinitely variable curved shapes. Combine this with 3D printing, and the potential for automation is quite exciting."

Designing complex, curving elements has become relatively straightforward, he adds. The hard part is making them. "Auxetics is still a fairly niche area of research – but we hope it could be the answer to making complex concrete shapes efficiently and economically." ■

Interview by Tony Whitehead

BELOW
A prototype dome made from a tetra-chiral auxetic geometry, using a 3D-printed polymeric mesh combined with mortar

LASTING IMPRESSION

KWAMENA BEECHAM

THE +TWOTHREETHREE FOUNDER PICKS THREE BUILDINGS THAT DEFINE A TIME AND PLACE: COOL SIXTIES BERLIN, UTOPIAN SEVENTIES BARCELONA, AND BOOMING NINETIES ACCRA

The National Theatre of Ghana in Accra is a building that's really close to my heart. It's become a real linchpin of Ghanaian culture. I remember being quite surprised when I found out the architects were Chinese – it's so in tune with the city and its lifestyle that it never feels like an implant. Accra is an old fishing town, and the way the building curves and billows is almost like a sail itself.

The expressive use of brick and concrete clearly relates to the city's postcolonial heritage, but it also points towards something new – it's like the middle of a Venn diagram of modern Ghanaian architecture. As with much of Africa, independence (in 1957) coincided with brutalism, and for the next 30 years the new national identity was entwined with this very expressive type of modernism. Then in the 1990s, foreign investment started to come in, and you began to see more international influences. There is also a renaissance in traditional design influences being respected, revisited and celebrated.

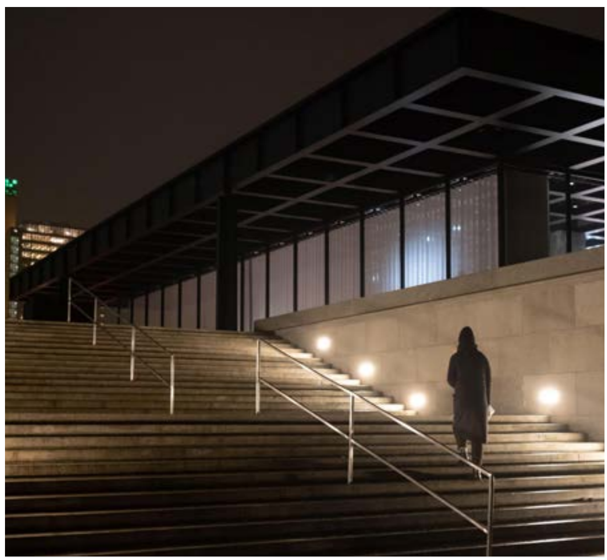
Ricardo Bofill's Walden 7 outside Barcelona is a very different type of

BELOW
The National Theatre of Ghana in Accra, designed by Cheng Taining and Ye Xianghan, completed in 1992

Photo: Martin Barlow / Art Directors / Alamy Stock Photo urban landmark. This is architecture that comes out of nowhere, like an alien ship, and I love it. It's funny how the city has grown around it – there's a McDonald's, a school, a car dealership, and then this big red housing block sitting in the middle of it all. It reminds me of an MC Escher painting. You look at one door and you think, where does that lead? How does it connect with those balconies? It's organised around different configurations of 30m^2 units, and I find that modular way of thinking fascinating. You could almost move in as a young couple, buy the flat next door and knock through to make a family home. Bofill envisaged it as a self-contained city, and you can imagine it evolving with its residents. The other side of that is that it feels very closed off, which is definitely not how you would approach social housing design today. The only time I've glimpsed inside is when someone opened the front door.

My final choice is almost the anti-Walden 7. There is nothing shouty about Mies van der Rohe's Neue Nationalgalerie in Berlin. I love how everything about it is so precise: just enough steel, just enough glass, just enough concrete, and no more. Its entrance pavilion is so pristine and poised. The Neue Nationalgalerie is often thought of as Mies' hymn to glass and steel, but you cannot have the delicacy of that pavilion without the heft and strength of the concrete base. It's beautifully engineered, and somehow very German.

Kwamena Beecham is founder of architectural practice +TwoThreeThree



Photos: Agencja Fotograficzna Caro / Alamy Stock Photo, Viennaslide / Alamy Stock Photo

TOP
The Walden 7 apartment building in Sant Just Desvern near Barcelona, designed by Ricardo Bofill Taller de Arquitectura, completed in 1975

ABOVE
Neue Nationalgalerie in Berlin, designed by Mies van der Rohe, completed in 1968

Photo: Gustav Willeit

ORIGIN STORY

MOTHER OF PEARL MUSEUM

A SMALL SOUTH-EAST GERMAN TOWN CELEBRATES ITS SHELLFISHING HERITAGE WITH A MUSEUM ENTRANCE THAT DOUBLE-CURVES LIKE A MUSSEL AND GLISTENS UNDER A CONSTANT FLOW OF FRESH WATER

Adorf, a small town close to the Czech border, shares the same problems as many rural areas in the former East Germany: an ageing and shrinking population, unemployment and economic decline. At one time, however, it was a major centre of freshwater pearl mussel fishing. The pearls – found in only one out of every two thousand mussels – were highly prized, while the shells were used to craft a variety of artisanal objects including purses, clocks and jewellery boxes.

In an effort to reverse the town's fortunes, Adorf recently opened a museum celebrating this cultural heritage. But the shell that has caught the most attention is the building itself: a carapace of boardmarked concrete wedged between two half-timbered buildings on a formerly vacant site in front of the medieval city wall.

"The facade represents a transformation of a seashell," explains Ansgar Schulz, director of Leipzig-based architect Schulz und Schulz. "Both seashells and concrete shells are created through mineralisation – through a biological process in the case of the shell, and through a chemical-technical process in the case of the building envelope, namely the hydration of cement."

Schulz has reinterpreted the curved mussel shell as a warping, windowless front wall. A fold in the roofline corresponds to the eaves of the neighbouring buildings. From here, the wall descends three storeys to the first-floor level, where it is pulled outwards at one corner. This creates an overhang to the entrance below and twists the whole wall into a double curve.

The concrete wall suggests a mussel shell in other ways too. Anthracite pigments give a dark grey tone, while the narrow horizontal lines of the timber formwork evoke the crustacean's annual growth rings. Water flows continuously over the rough surface of the wall, "symbolising the basis for life of mussels", says Schulz. Individually adjustable nozzles on the roof, usually used in agriculture, ensure the facade is evenly wetted. The water is then collected in a concrete gutter on the edge of the entrance canopy. "Our roofer constructed a small pouring aid, similar to that used when pouring wine from a bottle, which allows the water to drain off precisely." From here, it is funnelled into a well before being pumped back to the top of the building in a solar-powered loop.

The wall comprises an inner and outer leaf of 250mm-thick in-situ concrete, filled with 200mm of

BELOW
Water flows continuously over the facade before being funnelled via a concrete gutter into a well. A solar-powered system then pumps it back up to the roof

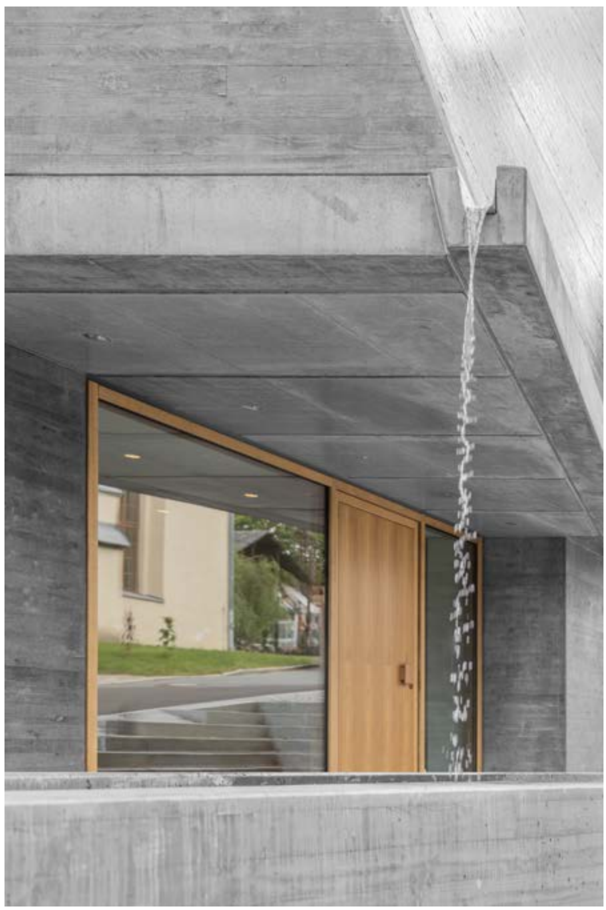


Photo: Gustav Willeit

XPS insulation. The inner leaf is a loadbearing part of the structure, tied into the slabs, and has a "very slight" curvature. "For this reason, the formwork elements were as narrow as possible and only clamped at the top and bottom, and at the floor slabs," says Schulz. Bespoke anchors were embedded into the shell to connect to the outer shell.

The asymmetric outer layer was initially given shape in the workshop of André Schürer, master carpenter at contractor SP Bau Lengenfeld. He created a non-scale model to illustrate the curves, before applying the hyperbolic paraboloid form to the actual dimensions of the roof ridges and eaves. At the same time, the architects and contractor were making mock-ups to explore colouring, board sizes and finishes. To create the crustacean-like texture, they chose thin strips of open-pored timber, "flamed but not charred".

The boards were laid on large panels, flexible enough to be twisted into shape. These were then placed in the formwork system, which was tied into the structural wall with anchor beams and individually adjusted spacers. Electronic sensors measured the concrete strength as it cured, enabling the formwork to be struck after three days.

Despite the windowless concrete wall, the glazed entrance offers passers-by tantalising glimpses of the museum inside. Here, smooth white surfaces frame a section of the historic city wall, naturally lit from above. Just like the pearl mussel, a rough shell washed by water encloses a precious, shimmering interior. ■

Photos: Albrecht Voss

ABOVE
The narrow horizontal lines of the timber formwork evoke the mussel's annual growth rings

From the archive: Spring 1967 / Autumn 1968
THE COMPLEX COMPLEX

In February, the South Bank Arts Centre in London was finally awarded a grade II listing, 35 years after it was first recommended by English Heritage. Designed by the London County Council architects' department under the leadership of Norman Engleback, the complex has long been viewed as either the apotheosis or nadir of British brutalism, depending on your sensibilities. Perhaps unsurprisingly, CQ was among its early champions (while acknowledging that "it will not be everyone's cup of tea".)

"Sincerity is the quality that stamps the whole concept – with a concentration of purpose and a clarity in the use of materials to serve that purpose," wrote then-editor George Perkin, on first visiting the centre's two auditoriums – the Queen Elizabeth Hall and Purcell Room – in 1967. The foyer, with its "randomly placed" mushroom columns, pyramidal acoutic panels and glazed walls "must be one of the most exciting concourses anywhere", its palette of concrete, white marble and black leather seats "an ideal background for the colour and movement of a concert-going throng".

Perkin was particularly impressed by the distinctly un-British levels of concrete craftsmanship, the result of "an extensive tour of European countries" undertaken by the architects. "When the scheme went out to tender, contractors were invited to inspect a sample panel … with formwork of rip-sawn Baltic pine, which was found to have the most satisfactory grain structure … The contractor was obliged to construct a similar sample panel, designed to meet all likely contingencies in the structure."

A year later, Perkin was back to look around the newly opened third wing, the Hayward art gallery. Despite some mild navigational difficulties ("The word complex seems purpose-made. It is rather difficult to find your way in …"), he again admired the accomplished use of concrete, with "jutting balconies, terraces and linking walkways – all piling up like a cubist painting by Braque". The centre as a whole, he concluded, was "neither trivial, nor transient, nor even fashionable" but "a serious, honest and lasting accompaniment to music and painting".

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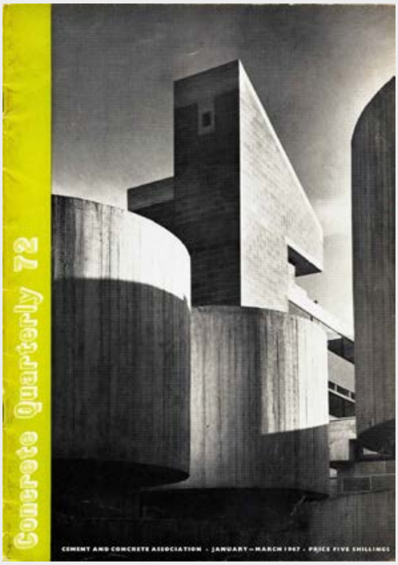
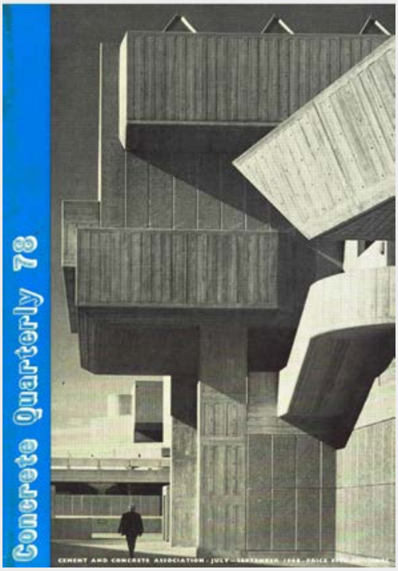




Photos: Andy Stagg

WORKING OVERTIME

Three Chamberlain Square is Birmingham's first BREEAM Outstanding office. Nick Jones learns how FCB Studios and Cundall challenged conventional wisdom about the workplace to deliver its super-efficient structure

Even as it was rising from the ground, Three Chamberlain Square was turning heads. This wasn't just because of its plum location, next to the grade I-listed Birmingham Town Hall. "As the building was going up," recalls Tim Stidwill, partner at structural and services engineer Cundall, "people were looking at the slabs and saying, how is that possible? How are you making them so thin?"

↓

ABOVE
The 10m-high reception is framed by full-height circular columns and transfer beams that carry the second-floor slab to the perimeter

Designed by Feilden Clegg Bradley Studios, Three Chamberlain Square is a blast of colour amid the Victorian gothic and 1960s brutalism of central Birmingham. The ten-storey office block, the fourth commercial building in MEPC's Paradise devlopment, is framed by orange terracotta fins and deep-red aluminium spandrel panels. Ornate ogee arches wrap around the double-height ground level and the top two storeys, which slant inwards like a mansard roof. "You find these forms and motifs all around Birmingham and it's been fun to reinterpret them," says Alina White, partner at FCBS. "It was important to be different because this is a new kind of building for Birmingham."

Three Chamberlain Square is the first to earn BREEAM Outstanding and the first NABERS 5-star base building in the West Midlands, hosting 17,500m^2 of all-electric, grade A office space, equipped to be net-zero carbon in operation. The structure's upfront embodied carbon represents a 100% improvement on the UK Net Zero Carbon Buildings Standard target for 2030, and achieved a B rating under the SCORS scheme, which focuses on the carbon footprint of the primary structure for lifecycle stages A1-A5 (cradle to completion).

This is where the slabs come in. The frame is an extremely lean assembly of in-situ reinforced concrete, comprising post-tensioned (PT) slabs, just 215mm thick, on a tight 7.5m structural grid, the whole assembly borne on a raft foundation without piles. The PT slabs are visible as exposed flat soffits and there are as many as 22 exposed concrete columns on a typical 2,100m^2 floorplate, with a line of six separating the 16m-deep zone between the lift lobby and the front of the building.

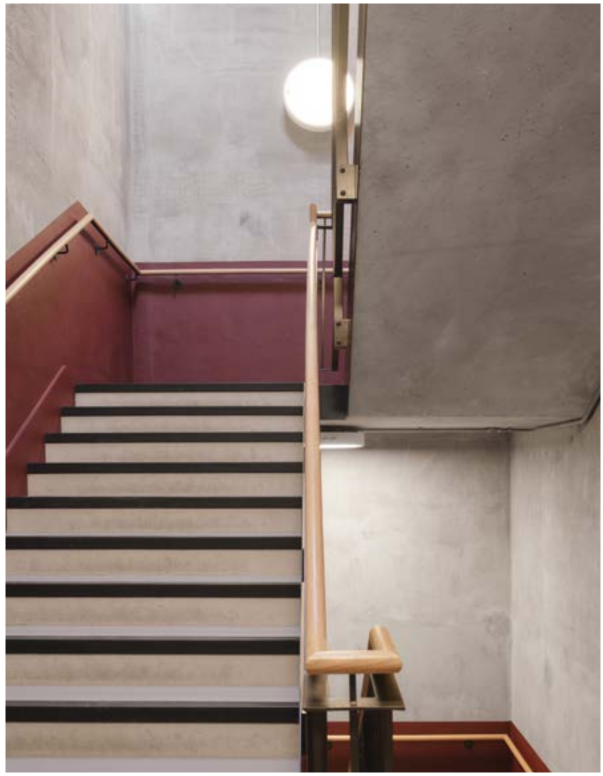
This runs counter to commercial development lore, in which open, column-free floorplates have almost become a defining characteristic of grade A space. The rationale is that this offers tenants a blank canvas to divide up and fit out however they wish, as well as longer-term flexibility to accommodate more radical

PEOPLE WERE LOOKING AT THE SLABS AND SAYING, 'HOW IS THAT POSSIBLE? HOW ARE YOU MAKING THEM SO THIN?'

change. When the design process for Three Chamberlain Square began, guidance from the British Council of Offices advised that columns should be no closer than 9m apart.

However, the early stages of the project also coincided with Covid, which suddenly called into question all aspects of workplace design. Cundall took the opportunity to talk to property agents, who agreed that more columns would have little impact on commercial viability.

They do, on the other hand, have a significant impact on carbon. Longer spans typically need deeper slabs: a conventionally reinforced concrete flat slab with columns 9m apart tends to be 300mm. By reducing the grid to 7.5m, Cundall's analysis suggested that this could be slimmed to 225mm, a 25% reduction in material. Post-tensioning would cut the steel content in the slabs by 45-50%.



ABOVE
Concrete in the stairwells was cast in-situ and left as struck to minimise additional finishes

"You could easily have made this structure completely column-free from the core to the perimeter," says Stidwill. "But having the extra columns allows everything to be kept as light and thin as possible. You're using less material, you're putting less weight into the building, so the columns don't need to be so big, and the foundations don't need to be so big either. These benefits go all the way down through the building."

Cundall initially assessed six frame options, using its in-house embodied carbon measurement tool, which follows the RICS and IStructE methodology. Two bays of the structure were analysed over the full height of the building, with options including cross-laminated timber and CLT-steel hybrids. The best-performing solution, however, was a concrete frame based on 225mm-deep PT slabs, with a 50% GGBS mix used throughout. This came out with an

ABOVE
The office floorplates are based on a 7.5m grid. Each floor is supported on up to 22 internal concrete columns

A1-A5 embodied carbon value of 131kgCO_2/m^2, equivalent to a SCORS A rating.

In the event, the contractor was concerned that the slow early strength gain of a GGBS mix would delay the stressing of the tendons in the PT slab, particularly in colder weather. It therefore opted for a CEM I mix, partially compensating for the additional carbon by reducing the slab thickness by a further 10mm. This resulted in an embodied carbon value of 175kgCO_2/m^2 for the completed frame.

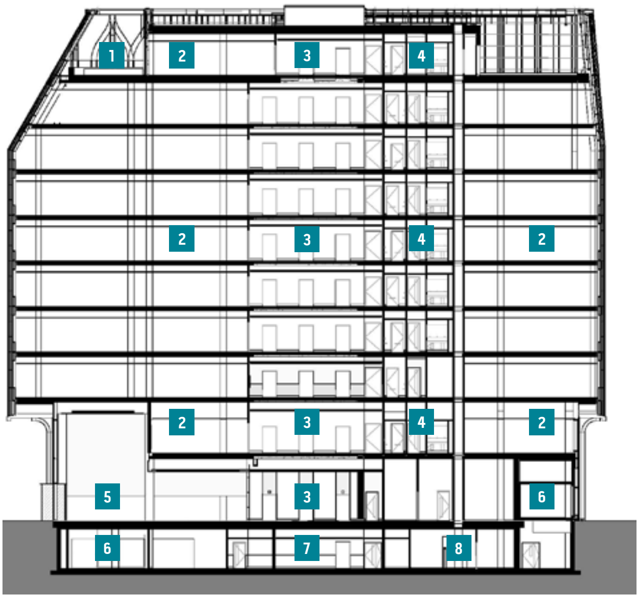
Giving the contractor this flexibility was an important part of the sustainability strategy, designed to avoid unintended consequences. The client chose not to impose specific carbon limits for different building elements. Instead, it wrote a strict limit into the design-and-build contract of 600kgCO_2/m^2 for the whole building, as well as setting a stretch target of 475kgCO_2/m^2.

ABOVE
The exposed concrete columns in the reception echo the colonnade of the neoclassical Town Hall opposite

"Sometimes, if you set a limit, it restricts how the contractor can do the work," says Stidwill. "This way, there was really good collaboration between the client, consultants and contractor on monitoring carbon performance throughout the project. There could be flexibility on some elements, but everyone knew that lower carbon solutions would be needed somewhere else to meet the project requirements."

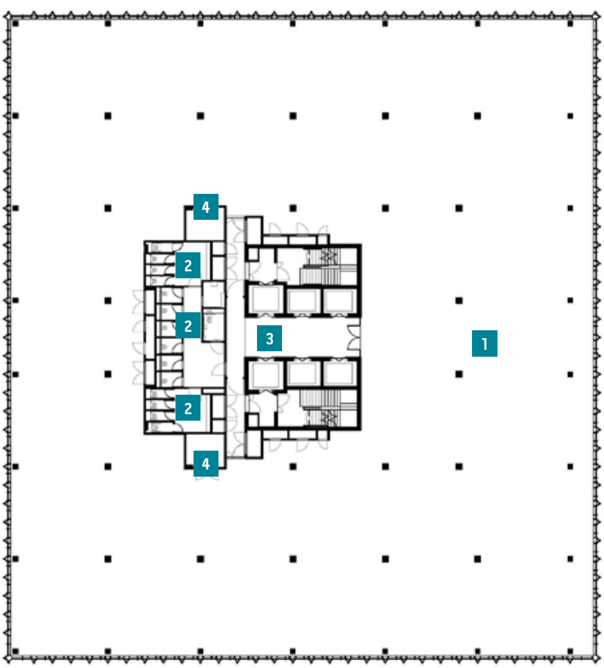
A key move was to specify double rather than triple glazing, because the combined upfront and whole-building operational carbon emissions were lower for double glazing. Expendable finishes are also kept to a minimum, with exposed soffits and columns in the offices, as well as low embodied carbon raised floors. The public-facing areas have a warmer, richer palette, made almost entirely from low-carbon, natural materials. These include mycelium wall panels,

EAST-WEST SECTION



1 Terrace
2 Office space
3 Lift lobby
4 WCs
5 Reception
6 MEP plant / riser
7 Bike store
8 Changing rooms

TYPICAL FLOOR PLAN



1 Office space
2 WCs
3 Lift lobby
4 MEP plant / riser

grown in moulds to the specified shape, and wood-fibre acoustic baffles, which add texture to the smooth, exposed concrete frame.

The flexible, holistic approach to embodied carbon meant that, even without GGBS in the slabs, the whole-building value came to 449kgCO_2/m^2.

For Stidwill, the use of CEM I suggests that further savings should be easily attainable on future projects. "There's definitely scope for having a range of mixes at different times of year. If even a quarter of those slabs were 50% GGBS, it would bring the structure closer to SCORS A. While we need to keep some flexibility in the contract, as consultants we can definitely push a bit harder."

The services design takes a similarly lean approach. "From the outset, the fundamental strategy was to achieve realistic and reasonable

ABOVE
Three Chamberlain Square is the fourth office building completed as part of the £1.2bn Paradise regeneration in central Birmingham. To its right are Two and One Chamberlain Square, by Howells and Eric Parry Architects respectively. The darker building behind the square is Howells' One Centenary Way. The tower on the right is the recently completed 49-storey Octagon residential, also by Howells and the tallest building in the city

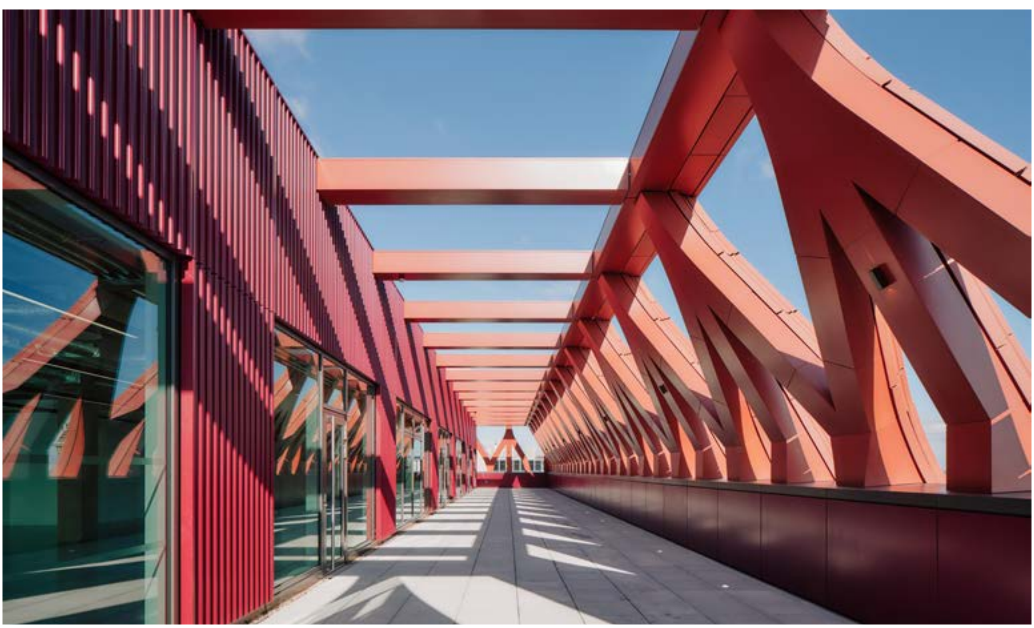
operating loads for the average occupier, rather than designing for peak loads that might only apply for one or two days of the year," says Mike Gosling, partner at Cundall, which also oversaw the services design. "Generally, flexibility can add quite a lot of carbon, as you end up oversizing systems. We went down more of an adaptability route, with roof space for an additional air source heat pump if needed, and capacity for tenants to move their electrical load between different floors."

It is often argued that a "loose fit" helps buildings to evolve to changing needs, reducing the risk of demolition and redevelopment. At Three Chamberlain Square, FCBS and Cundall have taken a slightly different approach. The building's future is instead tied more to the strength of its identity, particularly those brilliant red ogee arches that rise above the Town Hall on the Birmingham skyline. It already feels like an indelible part of the city, says FCBS's White. "When the sun shines through the rooftop arches, and they cast their shadow on the Town Hall, that's a special moment."

PROJECT TEAM

Architect Feilden Clegg Bradley Studios
Structural and services engineer Cundall
Main contractor Sir Robert McAlpine
In-situ concrete contractor MPB Structures

BELOW
The top floor opens out onto a terrace framed by a terracotta and aluminium pergola, overlooking central Birmingham



ABOVE
The grid offers space for banks of eight desks, as well as the option to partition off individual offices or larger conference rooms

THE RETURN OF THE COLUMN

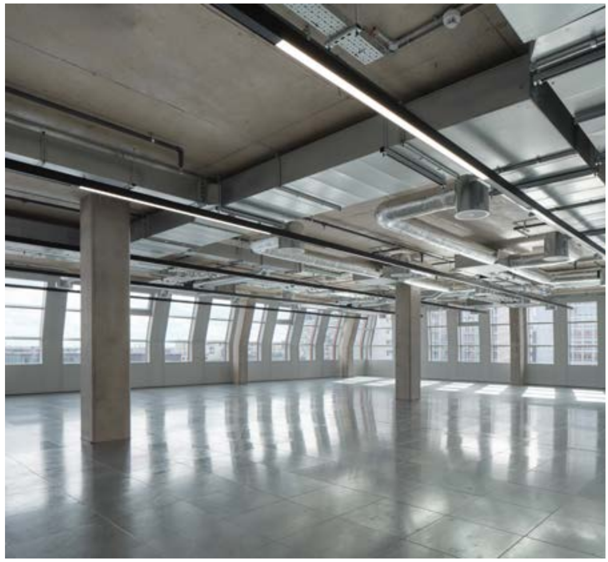
Is this the workplace of the future?

Embracing the column has brought down Three Chamberlain Square's embodied carbon. The big question is whether it can create spaces where people actually want to work. The initial evidence suggests it does, with the building already fully let to blue-chip companies Ernst & Young, Eversheds Sutherland, CBRE and Forvis Mazars.

FCBS has made most of the building's location to give the offices a definite wow factor. Despite a strict glazing ratio of 40% to control solar gain, windows stretch between desk and ceiling height, framing views of the Town Hall, and drawing daylight through to the lift core on all sides. The upper floors follow the pitch of the mansard-style roof to create more intimate loft-like spaces behind slanted perimeter columns. The top floor opens out onto a terrace framed by a terracotta and aluminium pergola, which looks down on the square and beyond to central Birmingham.

The additional columns don't really inhibit flexibility, says Alina White, partner at FCBS. "It's become accepted wisdom that if you want a flexible space you need 15m, but you don't." The 7.5m grid offers space for banks of eight desks, as well as the option to partition off individual offices or larger conference rooms.

Nothing feels restrictive: the thinness of the PT slabs helps to maximise floor-to-ceiling heights, as do the exposed services, suspended below the soffits in a rationalised, uncluttered layout. Some of the windows are openable, allowing tenants to let in fresh air and connect to the street life below. And if future tenants need to expand, soft spots have been included in the slabs, so that stairs can be added between floors.



ABOVE
Services are exposed in a rationalised layout on the flat soffits

BELOW
The reception provides a range of spaces for more informal working

ABOVE
The basement includes parking for 220 bikes, as well as 27 showers and drying rooms

CITY OF ROCK

Why Birmingham is built for raft foundations

Another advantage of a smaller grid is that it spreads loads more evenly across the building footprint. This made it possible to found the structure on a raft rather than deep bored piles, saving huge amounts of material and time. "If we'd had a longer span, I don't think the raft foundation would have worked," says Cundall's Tim Stidwill. "It would have placed too much stress on the ground."

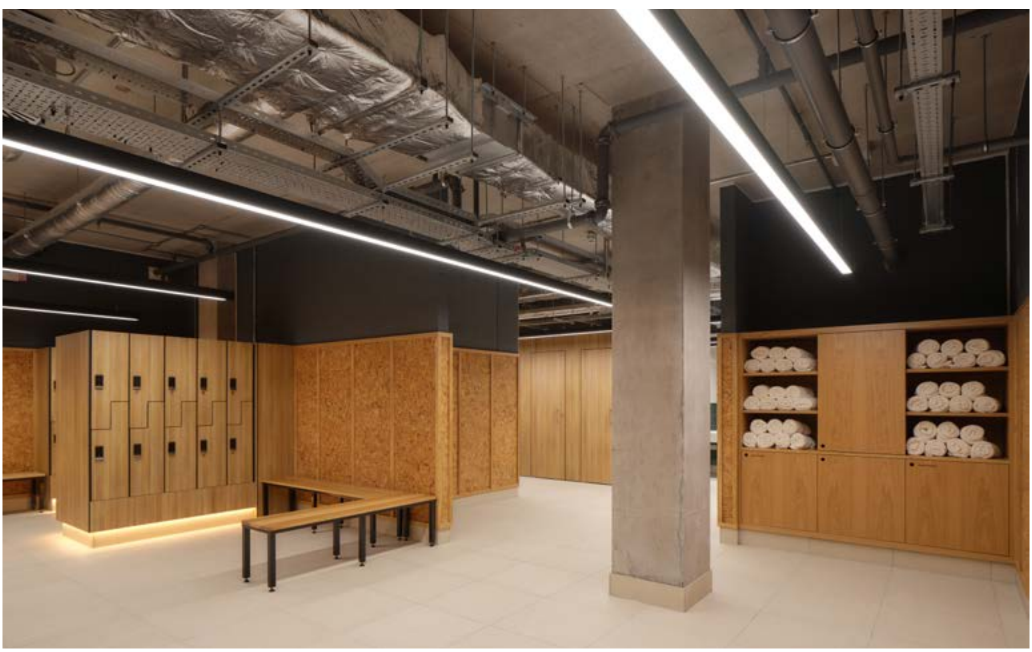
The site also had the geological advantage of a stable bedrock, little more than a metre below the city. "There's a sandstone ridge that runs through the centre of Birmingham, which you can read in the historic cityscape. It's a really good material to build onto and it's also an aquifer, so it attracted a lot of industry."

The west side of Chamberlain Square is raised a little higher, above a disused pedestrian tunnel from the 1960s ring road development. This was removed and the whole footprint excavated to the sandstone bedrock, a depth of 4m. The raft was then cast in-situ to depths of between 300mm and 1m. "A pure raft would have a constant depth but we have made it work more efficiently with localised thickenings under the columns," says Stidwill.

The raft solution also left space for a basement that covers the whole footprint – the original design had tried to minimise excavation with a far smaller underground level. This cavernous space has become an impressively provisioned facility for the building's cyclists, with 220 bike racks, 27 showers and generous cork-lined changing rooms. ■

BASEMENT PLAN

1 MEP plant / riser
2 Bike store
3 Changing rooms
4 Lift lobby
5 Refuse and recycling



TURNING POINT

Designed by architect The Harris Partnership and structural engineer Renaissance, Stockport Interchange is a mainly single-storey bus station, with a passenger concourse at one end, and a vehicular entrance and back-of-house spaces at the other. Between the two is a large oval-shaped opening, or oculus, where the buses turn and park.

The roof doubles as a 2-acre park, combining grass areas with play zones, spacious paths and cycle lanes. There are 95 trees, large boulders for climbing, seating areas,

Photos: Heiss Rourke Photography; Anthony Dewar

and rain gardens designed to reduce runoff and increase biodiversity.

The concrete structure has to support all of this activity while also carving out plenty of room for buses to manoeuvre. Radial beams fan out from the edge of the oculus to the building perimeter. These are up to 2.2m deep and span up to 22m between two rings of circular columns. Above this sits a 250mm-deep slab, which extends 1.2m beyond the inner ring of columns. Here, it is stiffened with a 2.5m-high ring beam, framing the oculus in a loop of pale fair-faced concrete.

READ THE FULL STORY
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COSMIC RESET

Zodiac House in Croydon is probably best known as home to the characters Mark and Jez in Channel 4 sitcom Peep Show. Until recently, the reality was even more depressing. Built in the 1960s, the four-storey office block had been vacant for half its life.

"There was evidence of water leakage, stalactite formation and heavy corrosion where openings had been made in the slabs," says Ella Flint, architectural lead at Shedkm. "But generally the size of the floor plates was really good."

Working with developer Common Projects, Shedkm has restored the complex – highlighting the best features of its brutalist design – and adapted it into temporary council housing for homeless families.

Ella Flint spoke about Zodiac as part of the Concrete Centre's Sustainability Series of webinars. Watch back at: **concretecentre.com/CPD-Events.aspx**

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Photo: Agnese Sanvito

Photos: Homi Hormasji; Robert Landau / Alamy Stock Photo

ROAD SHOW

Designed by Swiss architect Peter Zumthor, the David Geffen Galleries for the Los Angeles County Museum of Art is a reinforced-concrete structure supported on seven 10m-high pavilions. Its main exhibition space is 300m long and spans 50m across the four-lane Wilshire Boulevard – its contractor described the structural design as "more akin to a box girder bridge system than a typical building".

READ THE FULL STORY
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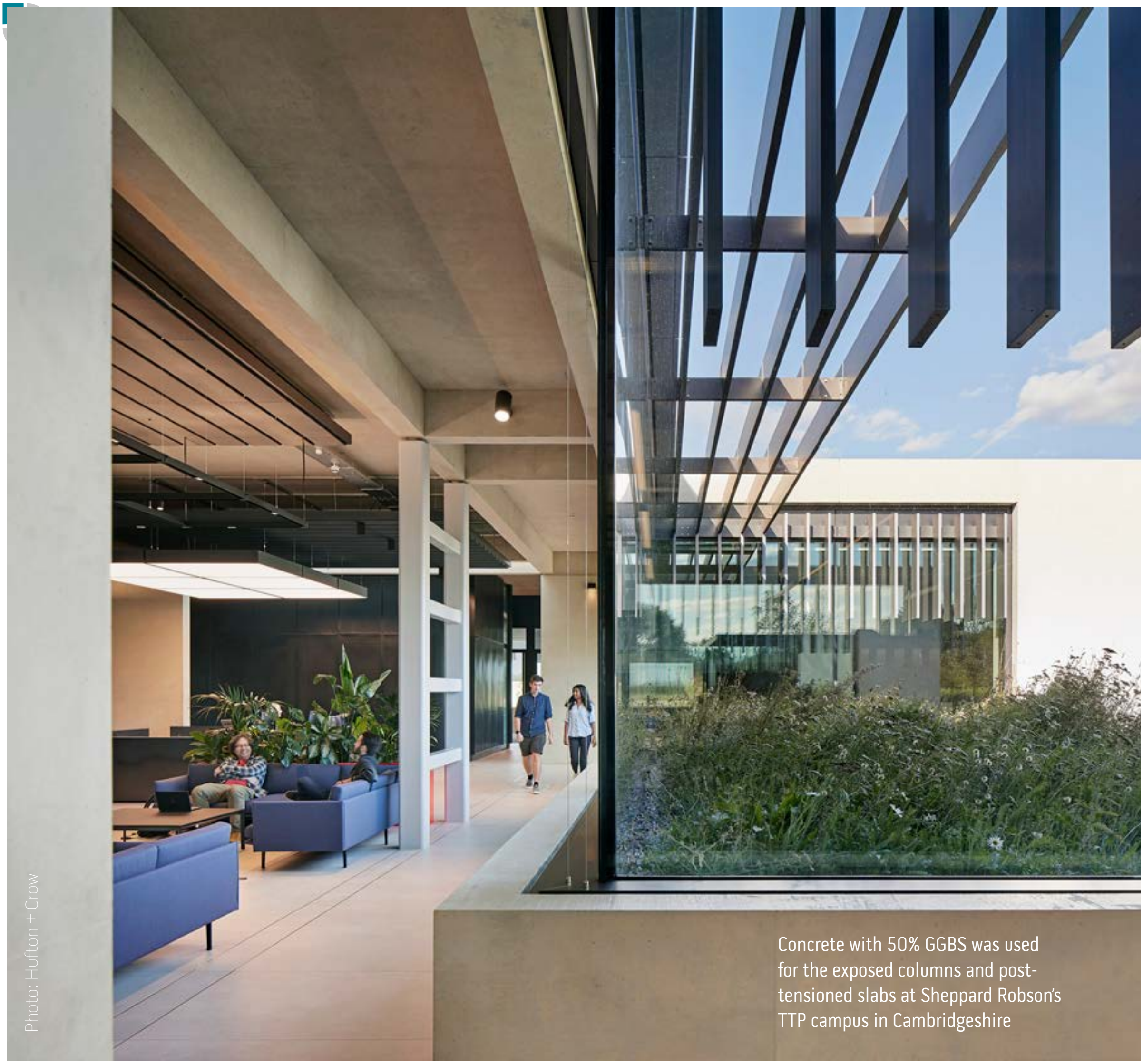

Photo: Hufton + Crow

Concrete with 50% GGBS was used for the exposed columns and post-tensioned slabs at Sheppard Robson's TTP campus in Cambridgeshire

Efficient use of GGBS in concrete

Informed specification can help to maximise the value of this low-carbon cementitious material, ensuring that it is used where it delivers the greatest benefit, writes Noushin Khosravi

Ground granulated blast furnace slag (GGBS) is a well-established constituent of concrete in the UK. This is due to its ability to enhance durability and long-term performance, and to significantly reduce embodied carbon through the partial replacement of Portland cement.

Like all construction resources, GGBS should be used efficiently, and where it can deliver the greatest technical and environmental benefit. Specifiers can achieve this by engaging with concrete suppliers early in the design process, setting clear performance and carbon objectives, and allowing flexibility in how those objectives are met.

What is GGBS?

Blast furnace slag is a co-product of the ironmaking stage of steel production. Smelting iron ore produces molten pig iron, which is used to make steel, and molten slag. Cooling this slag rapidly produces a glassy, granular material. When this granulated slag is dried and ground into a fine powder, it becomes reactive and it can be used in concrete, in combination with cement.

GGBS has been used as a supplementary cementitious material (SCM) for decades in the UK. In concrete, it brings a number of performance benefits, including:

- lower early-age temperature rise, reducing the risk of thermal cracking in large pours
- minimising the risk of damaging internal reactions, such as alkali silica reaction and delayed ettringite formation
- high resistance to chloride ingress, reducing the risk of steel reinforcement corrosion
- high resistance to attack by sulfates and other chemicals
- an attractive pale, off-white colour.

GGBS and embodied carbon

In comparison to Portland cement, the manufacturing of GGBS emits less carbon dioxide. This is partly due to reduced energy requirements, since it is a co-product of steelmaking, and partly because CO_2 is not released during its formation, unlike Portland cement production.

Calculating the cradle-to-gate embodied carbon of GGBS includes emissions from:

- the electricity used to granulate the slag at the steelworks
- transporting the slag from the steel works to the grinding site
- drying and grinding it to produce GGBS
- a proportion of the emissions associated with steelmaking, based on an economic allocation.

The most recent industry data for the embodied carbon of UK cements, contained in MPA Fact Sheet 18, shows an indicative value for GGBS of 155kgCO_2e/t, compared to 840kgCO_2e/t for Portland cement (CEM I).

Supplies of GGBS

The 2024 closure of the blast furnaces at Port Talbot, the UK's largest steelworks, has prompted concern about whether there is enough GGBS to meet demand. These are unfounded: historically, some GGBS was sourced from within in the UK, but it has always been a globally traded resource and industry feedback indicates this will continue.

Getting a clear picture of global availability is challenging, due to international trade policies and varying levels of domestic use, but annual GGBS production is estimated to be within the range of 330-407 million tonnes.

The UK uses a very small proportion of this: according to the latest MPA data, approximately 2.5m tonnes of GGBS and fly ash were incorporated into UK concrete production in 2024. (The industry does not measure them separately.) This means that UK use of GGBS represents less than 0.6-0.7% of global output. As such, variations in

BELOW
At Reiach and Hall's Inverness Justice Centre, replacing 70% of the cement with GGBS saved around 360 tonnes of CO_2 compared with a traditional CEM I mix

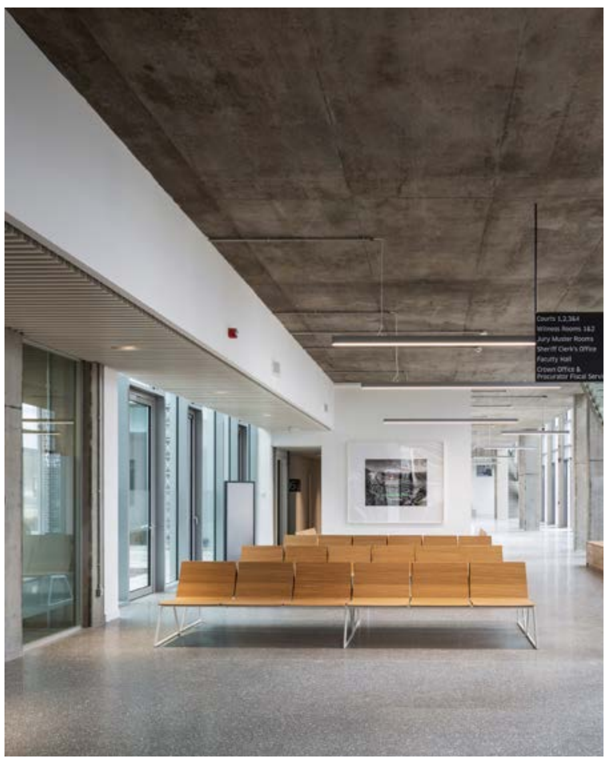

Photo: Keith Hunter

UK demand for GGBS are not expected to have a significant influence on international supply dynamics or market stability.

If all blast furnaces are phased out in favour of less carbon-intensive methods of steel production, then GGBS production will eventually cease. But for now, it remains a valuable resource for lowering the embodied carbon of concrete. The immediate challenge is not one of scarcity, but of ensuring that GGBS is used efficiently and where it delivers the greatest benefit: technically, environmentally and economically.

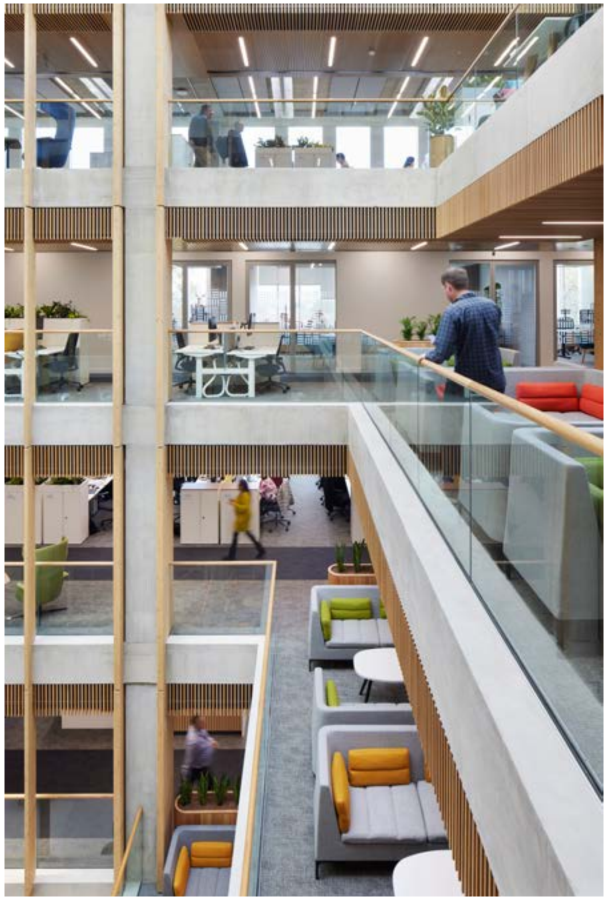

Photo: Jack Hobhouse

ABOVE
At the Salvation Army HQ in south London by Tatehindle, all of the concrete contained 50% GGBS. The contractor split each floor into six pours rather than the planned four, to help maintain progress on site

Using GGBS efficiently

In combination with other cement replacements

GGBS is just one of a growing range of constituents that can be used to produce lower-carbon concretes. There is currently no direct replacement for GGBS that results in the same performance, with the same carbon reduction. But SCMs should be viewed as complementary materials. Under current standards it is possible to combine several to deliver comparable strength, durability and carbon performance, while reducing reliance on any single resource.

The use of multicomponent cements and combinations in concrete was established in the 2023 version of BS 8500, the British standard for concrete. This allows up to 65% Portland cement replacement by up to two SCMs, which means that GGBS can be combined with other materials such limestone fines, fly ash or pozzolans such as calcined clay.

Specify using combined performance categories

BS 8500 sets out five standard specification methods: designed concretes, designated concretes, prescribed concretes, standardized prescribed concretes and proprietary concretes.

Of these methods, designed concretes offer the greatest flexibility. The designer specifies the required performance and sustainability characteristics, leaving the concrete producer to decide the best way to achieve them. This allows it to supply whichever lower-carbon cements or combinations will create a concrete with the lowest possible embodied carbon for a specific application and location.

Specifiers should avoid requesting particular cement combinations, because availability varies depending on the local market and the supplier. Instead, they should use the combined performance categories (CPCs) set out in BS 8500-1. These group cement combinations according to their ability to resist sulfate and chloride attack, their durability and suitability for different exposure classes.

For detailed guidance, refer to The Concrete Centre document, How to design concrete structures using Eurocode 2: BS 8500 for building and civil structures. The Concrete Centre has also published a free, spreadsheet-based tool to help specifiers identify CPCs for a particular application.

BELOW
Allies and Morrison's London College of Fashion. A 50% GGBS mix was used in the foundations and between 30-40% in the superstructure, where setting times were more critical to the programme

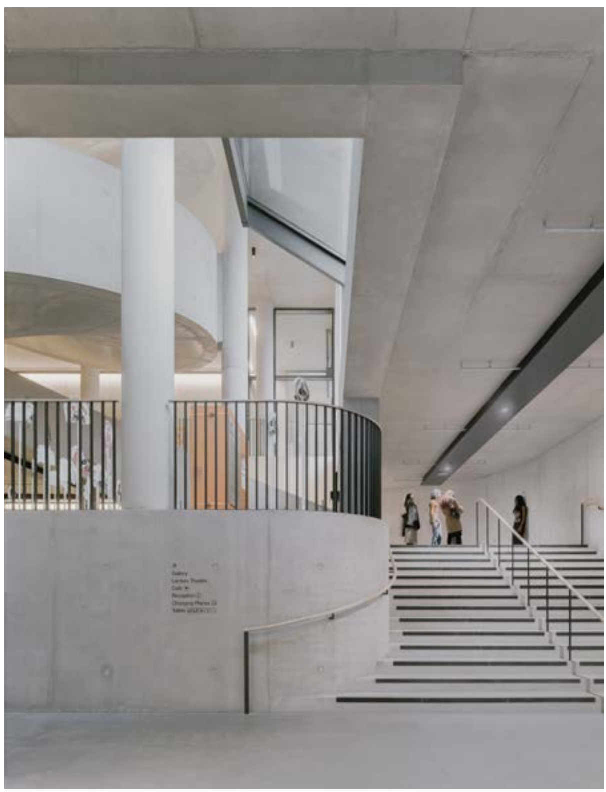

Photo: Simon Menges

Specify using carbon rating systems

Carbon assessment and reduction should always be based on a whole-life, whole-project approach, not on a single material or performance characteristic. Typically, the biggest carbon savings can be made through early optioneering. But to ensure that design aspirations are carried through to delivery, carbon performance can be included in the concrete specification.

To facilitate low-carbon procurement, the concrete industry has developed product carbon classifications. Project teams can use static classification systems such as the GCCA Global Definitions for Low Carbon and Near Zero Concrete to set an appropriate target – from "better than average" to "market leading". The actual concrete composition is left up to the supplier, enabling them to use the most efficient route to achieve it.

The latest version of the National Structural Concrete Specification (NSCS) also provides guidance on specifying carbon targets in a way that encourages innovation in mix design and avoids overreliance on any single constituent.

What not to do: setting minimum or maximum GGBS content

As well as not specifying particular constituents or combinations, designers should not prescribe minimum or maximum GGBS content.

This is because setting a minimum GGBS content risks driving up its use where it will offer limited benefit, and could conflict with other project requirements. Limiting the maximum GGBS content, meanwhile, can hinder the supplier in providing the optimal concrete to deliver the required performance, and may result in a higher embodied carbon.

From a technical perspective, GGBS typically delivers performance benefits at replacement levels of around 35-55%, so restrictions outside of this range are likely to result in an inefficient use of the material. At low levels of replacement, other SCMs such as fly ash, calcined clay or silica fume provide better durability. Multicomponent cements incorporating up to 20% limestone fines can be extremely effective for achieving a specified carbon performance.

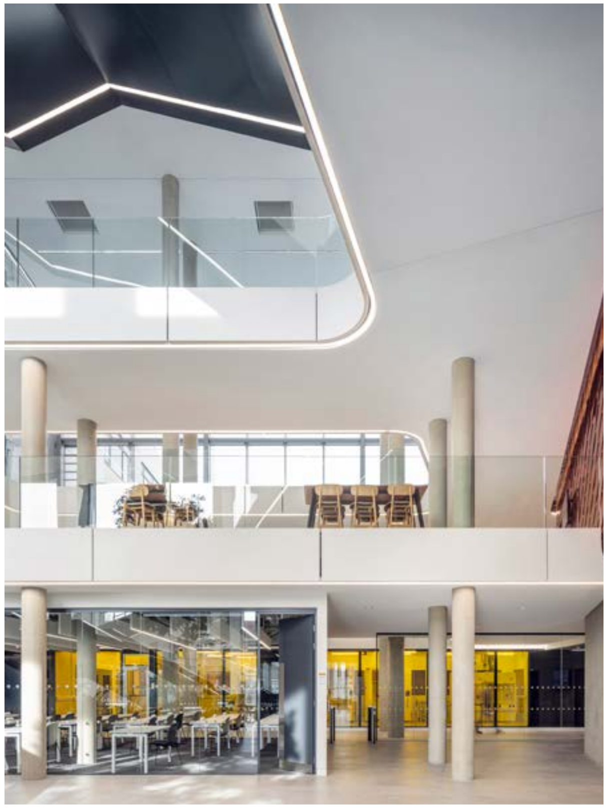

Photo: Kilian O'Sullivan

ABOVE
At the Ray Dolby Centre in Cambridge by Jestico + Whiles, 50% GGBS concrete was used in the slabs and 70% GGBS in the substructure

Collaboration is key

As with all concrete, the final specification should be developed collaboratively between the specifier, contractor and concrete producer, with consideration given to construction programme, placement and curing conditions, long-term performance requirements and sustainability.

By focusing on performance, and specifying carbon outcomes rather than material proportions, designers and specifiers can ensure that GGBS continues to deliver the maximum benefit technically, environmentally and economically, now and in the future. ■

Noushin Khosravi is head of sustainability at UK Concrete

Photo: Rafael Gamo

FINAL FRAME: CASA WABI, MEXICO

Dutch architect OMA has completed a concrete dome for farming mushrooms at the Casa Wabi arts campus in Oaxaca, Mexico. The monolithic concrete panels were cast in situ using formwork faced with hessian. The rough surface is intended to retain the iron-rich rainwater that falls in the region. Over time, this will leave a distinctive patina in the concrete.