CONCRETE QUARTERLY

SUMMER 2023 | ISSUE NUMBER 283

TWO TERMS EARLY →
Sheppard Robson turns to MMC to beat York University's deadline

ELECTRIC DREAMS →
Meet the Cambridge scientists making new cement from old concrete

MANHATTAN MYSTERY →
How Arup built a $465m cast-concrete museum without formwork

Clinical finish: the new precast facade at Hawkins\Brown's Royal College of Surgeons in London

P31→

CONTENTS

CASTING OFF

INSPIRATION

APPLICATION

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

The end of which life?

When I was an architecture student, I used to make my models out of recycled Weetabix packets. It was only partly thriftiness – I also enjoyed the different qualities they could bring, which you just didn't get using white Kapa board. Today, I'm still more excited about working with the layers of history and materials that an existing building presents than a greenfield site.

So I'm very excited to see the greater focus on circular economy principles, and treating our existing built environment as a resource that can be harvested for new construction. This will make an important contribution to reaching net-zero, as we retain the embodied carbon in the structures we already have, but it also has the potential to transform every aspect of how we create places. In this issue alone, we highlight three major projects that have revitalised outdated or unused spaces, as well as Cement2Zero's ongoing industrial trials of a process that reactivates recovered cement paste.

We talk about "end of life", but in the case of concrete, a key question is: the end of which life? When we do a life-cycle analysis of a building, there's an understanding that we're looking at a period of 60 years – although we know that a concrete structure can retain its integrity and its usefulness for much, much longer. After that, in the UK today the vast majority of concrete from demolished buildings is recycled, whether as aggregate or hardcore, and it goes on to have a second useful life at least as long as the first. Innovations such as the Cement2Zero project could provide an additional second life use.

Different strategies will work for different parts of a building. Materials are produced via myriad different processes – so why would we assume that they should all end their life in a similar way? Instead, we need to play to their potential. While designing for disassembly and reuse elsewhere might be the best route for a steel structure, for concrete it's probably better to adopt the milk bottle strategy: reusing the structure as it is, keeping it at its highest value for longer and expending less carbon in the process. This is not a new idea but it would be further facilitated if all of the layers attached to it – facades, services, fit-outs – were designed for disassembly.

MATERIALS ARE PRODUCED VIA MYRIAD DIFFERENT PROCESSES – SO WHY WOULD WE ASSUME THAT THEY SHOULD END THEIR LIFE IN A SIMILAR WAY?

Working out the best end-of-life strategy for each building component may need case-by-case assessment, as new technologies evolve and market factors change. Better as-built data will undoubtedly help – we can only derive value from resources if we know they're there.

A circular approach that prioritises reuse preserves not only the financial and carbon value in a building, but its social and cultural value too. I'll be particularly interested to see how it might influence aesthetics – rather than coming up with a design and then choosing the materials to suit it, a more sustainable approach might be to base the design on the resources available. That's perhaps the ultimate creativity, and it adds another level of problem-solving. As a former remodeller of Weetabix packets, I know that the possibilities are endless – and exciting! ■

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:
Campus East Gateway, University of York by Sheppard Robson.
Photo by Jack Hobhouse

Photos: Paul Burroughs

INNOVATION

CAMBRIDGE ELECTRIC CEMENT

A CAMBRIDGE UNIVERSITY SPIN-OUT HAS DEVELOPED A WAY TO PRODUCE NEW, POTENTIALLY EMISSIONS-FREE CEMENT FROM RECYCLED CONCRETE

ABOVE
The Cambridge Electric Cement team: founder Dr Cyrille Dunant, research associates Dr Rohit Prajapati and Dr Shiju Joseph, research lab technician Ricardo Osuna Perdomo and senior project manager Patricio Burdiles

A process that can produce cement from recycled concrete is to be trialled by a Cambridge firm this summer. If successful the technology, from Cambridge Electric Cement (CEC), could prove revolutionary – enabling waste concrete from demolition to be transformed into new, potentially zero-carbon cement.

"The process involves replacing the lime flux used in steel recycling with recovered cement paste (RCP)," explains CEC's senior project manager Patricio Burdiles. "Most steel is recycled in electric arc furnaces (EAFs), but the lime traditionally used to remove impurities from the scrap steel results in a slag that is non-

AT SOME POINT, OUT OF SLIGHT FRUSTRATION, I SAID 'WE'VE KNOWN HOW TO RECYCLE CEMENT SINCE WE INVENTED IT. IT'S NOT DIFFICULT – IF YOU REHEAT CEMENT, IT RECLINKERS'

cementitious and of little value."

But, if RCP is used instead of lime, the cement is reactivated by the heat in the EAF. "So the slag that comes out is very similar to the clinker for Portland cement (PC). Add gypsum and you have PC."

CEC's product is distinct from ground granulated blast-furnace slag (GGBS), which results from slag processed in coke-fired steel blast furnaces. "We are not producing a cement supplement or substitute," stresses Burdiles. "We are taking deactivated cement and reactivating it to produce actual cement."

The CEC team is led by Dr Cyrille Dunant of the University of Cambridge. He says that the idea arose during Covid, when the Use Less Research group led by Professor Julian Allwood was kicking around ideas for how we might build in a zero-emissions world. "At some point, out of slight frustration, I said 'we've known how to recycle cement since we invented it. It's not difficult – if you reheat cement, it reclinkers. In fact, I bet you could even recycle it electrically in an EAF because the chemistry is about right.' Julian said, 'That's perfect – let's try it!'"

Until recently, concrete recycling has involved simply crushing old concrete and using it as rubble in lower value applications such as road-base or backfill. Now, though, techniques are being developed to "unmake" concrete, restoring it to its constituent parts of sand, aggregate and deactivated cement powder (see CQ Spring 2023).

"Only 18 months ago, there was no interest in obtaining cement paste

THE ELECTRICITY TO POWER THIS COULD POTENTIALLY COME FROM GREEN, RENEWABLE SOURCES. IF THAT'S THE CASE, THEN OUR REACTIVATED CEMENT IS CARBON-NEUTRAL

from recycled concrete, as it was considered waste," says Burdiles. "But now we are aware of a number of companies developing technology to produce high-quality aggregates and sand, with high-quality RCP as a by-product. As more becomes available, techniques like ours are set to make a big difference to the carbon footprint of cement and concrete."

RCP can already be reactivated in a cement kiln, but this leaves sulphur impurities that can spoil the quality of the cement, so it can only be used in small quantities. This method also requires considerable amounts of energy from fuel to heat the kiln. "With our process, the

ABOVE
Cement and concrete made using the Cambridge Electric Cement process

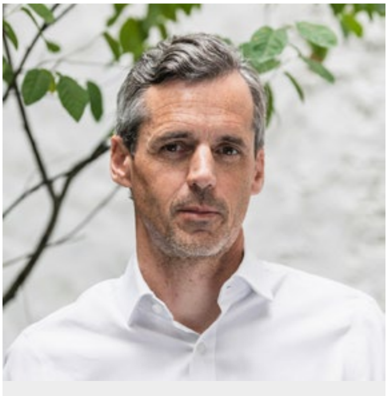
sulphur problem is avoided and the heat has to be generated anyway as part of the steel recycling process," he says. "Furthermore, because steel is recycled in EAFs, the electricity to power these could potentially come from green, renewable sources. If that's the case, then our reactivated PC is carbon-neutral since there are no process emissions, none from the burning of fuel and, potentially, not even any from the running of the EAF, beyond those already involved in recycling steel."

CEC's technology has produced PC with very similar properties to that made in a normal cement kiln: "The strength, and strength gain, are much the same – as we would expect from a material whose chemical composition is essentially the same as PC."

So far, it has only been produced in a laboratory, however. The team is now in the middle of a two-year industrial trial, the Cement2Zero project. This will first involve a small test EAF, able to produce about seven tonnes of steel. "This is the exciting part," says Burdiles. "If that's successful, we will scale up the testing to a commercial-sized EAF."

Cambridge Electric Cement is a collaboration between the Universities of Cambridge, Warwick and Imperial College London and is funded by EPSRC. Cement2Zero is a collaboration between the Materials Processing Institute, the University of Cambridge, Atkins, Balfour Beatty, Celsa, Day Group and Tarmac, and is supported by Innovate UK funding. ■

Interview by Tony Whitehead



LASTING IMPRESSION

JASON PARKER

THE ADAPTIVE REUSE OF CAR PARKS, INDUSTRIAL BUILDINGS, EVEN MILITARY FORTS IS TESTAMENT TO THE ENDURING NATURE OF CONCRETE, AND ITS CAPACITY FOR REINVENTION

I always think of concrete as a Cinderella material: mostly ignored, only allowed out every now and again, but usually doing all the hard work. My recent experience of using concrete is in high-rise, where it does the heavy lifting – cores, basements – then gets hidden away.

At the same time, it shaped so much of the world I grew up in. I come from Bristol, which was a very concrete urban environment, with all these forms driven largely by post-war industry. One building that definitely left an impression was the Rupert Street car park (designed by R. Jelinek-Karl, 1959-60), which is currently facing demolition. This was the first of its kind in the UK to feature a continuous spiral ramp.

As transport patterns change, structures such as Rupert Street are increasingly seen as obsolete, but the irony is that they are all the more greatly prized as architectural assets. A friend of mine parks at the Golden Lane estate (Chamberlin, Powell and Bon, 1951-62), and people are always doing photo shoots there because the large circular rooflights create a really cool lighting effect.

Drawing: Know Your Place Bristol; Photo: Joe Dunckley / Alamy Stock Photo

ABOVE
The Rupert Street car park in Bristol, designed by R. Jelinek-Karl, 1959-60

At Make, we retrofitted an NCP car park to be our own office. That wasn't the original plan – we stumbled across it and fell in love with it. We've turned the columns into a positive feature, wrapping our desks around them. And the ramp is the best space in the building – it's the heart of the arrival experience and we also use it for exhibitions.

Since then, we've been asked to reconfigure other car parks, and they are usually quite exciting spaces: you can knock through, make them double-height. Rupert Street would be a challenge – its continuous ramp would be tricky to adapt into a workplace, although there have been suggestions that it could become an electric vehicle charging station.

Of course, concrete buildings have always found new uses. When I was a student in Portsmouth, we would have our summer balls on one of the Solent forts. These were built in the 19th century in response to the threat of a French invasion. Stone blocks were lowered onto the seabed for the foundations and then the walls were constructed from concrete blocks, transported by barge. They were built as defensive shields; now they're used as party venues and luxury hotels. One is even a private island.

This is perhaps the more eye-catching end of reuse. But it needs to become the norm as concrete becomes less a utilitarian material and more a resource to be prized. Concrete's enduring appeal is that, like Cinderella and her pumpkin carriage, it can be reclothed, regenerated and transformed. ■

Jason Parker is a director at Make Architects

BELOW
Car park, Golden Lane estate, London, designed by Chamberlin, Powell and Bon, 1951-62

BOTTOM
Spit Bank Fort in the Solent, built in the 19th century to defend Portsmouth harbour, and subsequently used as a pub and an unusual holiday home

Photos: Paweop / Alamy Stock Photo; Roger Bamber / Alamy Stock Photo

From the archive: Winter 2008

NOZZLES AND NATURAL HISTORY

Studio Gang's Gilder Center in New York (see pages 28-29) is not the first time that a Natural History Museum has used sprayed concrete to dramatic effect. In 2008, London's venerable institution gained a mysterious pod – at eight storeys high and 65m long, Europe's largest sprayed concrete structure.

This was the £78m Darwin Centre, an exhibition space, archive and laboratory for the museum's collection of insects and plants, designed by CF Møller. In-situ concrete, steel and precast concrete were all considered for the amorphous form, but the most economic method of construction was found to be sprayed concrete, wrote CQ.

The wall was set out by marking 3D coordinates generated by Rhino software onto scaffolding. These were then used to locate vertical reinforcement bars, sized so that they could be curved on site rather than be pre-bent. Horizontal bars were positioned in front, with an expanded mesh behind the vertical bars to give a keying surface.

Structural engineer Ed Newman-Sanders of Arup told CQ that the main challenge was trying to construct all the internal floors before the wall was sprayed. Originally, the contractor suggested heavy steel props but Arup proposed casting temporary raking columns which could be cut out once the wall was in place.

To fine tune the shape, a top layer of concrete was dry-sprayed, then hand-trowelled to give a smooth finish. Dry-spraying means that water was only added to the mix at the nozzle, allowing the operator to control how much time was available to work the surface. Fifty millimetres of polystyrene insulation was mechanically fixed and bonded to the concrete surface, and an anti-crack base coat of render applied over that with plastic mesh reinforcement.

The surface was finished with a polished plaster made from aged lime putty and Bianco Carrara marble. This had "a tone and lustre similar to that of the cobalt blue terracotta bands in the [19th-century] facades". ■

Explore the CQ archive at concretecentre.com/cqarchive

CF Møller | Darwin Centre

Venturing into the cocoon

Danish architect CF Møller's stunning sprayed concrete pod will protect the Natural History Museum's 17 million dry insect and plant specimens

By Graham Bizley

Since it opened in 1881, London's Natural History Museum has been synonymous with Alfred Waterhouse's magnificent byzantine-gothic palace, its intricate terracotta facades inhabited with sculptures of exotic plants and animals that express the diversity of the collections inside. For the latest addition to the complex, phase two of the Darwin Centre, Danish architect CF Møller has employed a very different concept that expresses its function in a more metaphorical way.

The winner of an architectural competition in 2001, the £78 million building is both archive and laboratory for the museum's dry collection of insects and plants, a counterpart to phase one, completed in 2002 by HOK, which houses bottled samples. At its centre is a glazed atrium filled by a vast, curving, grey "cocoon" that almost touches the walls, reminiscent of the blue whale or the *Diplodocus* in nearby galleries. The cocoon is a concrete structure insulated on the outside to provide a controlled storage environment and finished with lustrous polished plaster. Eight storeys high and 65m long, it is Europe's largest sprayed concrete structure.

Most of the building is supported by a conventional concrete frame save the complex curved wall of the cocoon.

12 | CQ | Winter 2008

In-situ concrete, steel and precast concrete were all considered for the amorphous form, but the most economic method of construction was found to be sprayed concrete. The wall was set out by marking 3D co-ordinates generated by Rhino computer software onto scaffolding. These were then used to locate vertical reinforcement bars. For economy, the bars were sized so that they could be curved on site rather than be pre-bent. Horizontal bars were positioned in front and an expanded metal mesh behind the vertical bars gave a keying surface for the concrete.

Structural engineer Ed Newman-Sanders of Arup described the main challenge as trying to construct all the internal floors before the wall was sprayed, which had to be done by a specialist contractor. "Originally, the contractor suggested heavy steel props but Arup proposed casting temporary raking columns which could be cut out once the wall was in place."

To fine tune the shape, a top layer of concrete was dry-sprayed, then hand-trowelled to give a smooth finish. Dry-spraying means that water was only added to the mix at the nozzle, allowing the operator to control how much time was available to work the surface.

Fifty millimetres of polystyrene insulation was mechanically fixed and bonded to the concrete surface, and an anti-crack base coat of render applied over that with plastic mesh reinforcement. The final finish is Armuralia, a polished plaster made by Armourcoat from aged lime putty and Bianco Carrara marble. The surface has a tone and lustre similar to that of the cobalt blue terracotta bands in the Waterhouse's facades. Expansion joints were required across the 3,500sq m surface, so these have been carefully set out as recessed channels which look like threads wrapping round the cocoon.

When it opens in September 2009, a route will bring visitors from the adjacent dinosaur galleries into the atrium to a lift that goes up to the cocoon entrance on the eighth floor (see Detail, pages 14-15). An exhibition will occupy the cave-like space, with a ramp winding down through three floors. Exhibition designer At Large liked the texture of the concrete so much that it is being left exposed and finished with Keim mineral paint.

Believe it or not, the biggest threat to the collection comes from the aptly named museum beetle (*Anthrenus museorum*), which has a penchant for dried specimens and textiles. Concrete was chosen for the structure because it can be cast with a smooth surface that offers no nooks and crannies where the beetles might thrive. For the same reason, services have been left exposed in the labs and stores rather than run in concealed ducts.

Most of floor area is taken up with movable storage racks, 3.3km of them, to house 17 million specimens. The thermal mass of the concrete and 50mm of insulation help moderate the internal environment to below 17°C and at a relative humidity of 45%.

As well as helping control environmental conditions, the atrium is a public space, glazed on three sides so visitors can observe scientists at work in the laboratories above. The scale of the cocoon is such that it cannot be seen in its entirety from any one position, giving the visitor a sense of the scale of the collection. This intriguing form may well be the sort of gesture required to lure visitors.

Opposite The cocoon is the largest sprayed concrete structure in Europe. **Above left** The new building links to the 1870s Waterhouse building. **Above right** Recessed expansion joints run across the surface like silk threads. **Below** Concrete's thermal mass will help maintain a stable internal environment.

PROJECT TEAM
Architect: CF Møller
Client: Natural History Museum
Structural engineer: Arup
Main contractor: HBG
Sprayed concrete: Shotcrete
Concrete frame: Getjar
Plaster: Armourcoat
Curtain walling: Permasteelisa

Winter 2008 | CQ | 13

Photos: Ben Dale

ORIGIN STORY

BERMONDSEY SPA STUDENT HOUSING

DUNCAN GREENAWAY GETS TO REALISE HIS CORBUSIAN DREAM WITH A DOM-INO INSPIRED STUDENT BUILDING

I've always been fascinated by the Dom-Ino House, the prototype for mass-produced housing that Le Corbusier designed in 1914. It is pure system: a structure that just carries the floors and staircase, with no loadbearing walls, allowing you to arrange the internal space in any way you want. When I began studying architecture, I thought it was the cleanest thing I'd seen.

Bermondsey Spa, a seven-storey student housing development in south London, is our subtle homage to Dom-Ino. In particular, the way that the concrete floor slabs are expressed on the facade – a strong, straight edge sitting between an angled wall line of hand-laid brick. It was important to us that this 276mm band wasn't precast cladding, but an actual continuation of the slab. I'm really pleased that we managed to maintain that concept through to the finished article.

The slab design was complex: the exterior element needed a 25mm fall to avoid standing water, while the brick wall concertinas in and out, which changes the thermal line. We did a lot of research, and at one point it looked like precast cladding would be the only affordable option. However, we found a German product, Max Frank, that connects rebar through a continuous insulating layer, and that enabled us to cast the exposed slab edge in situ.

It's a low-rise area, so the local authority stipulated that it would only approve a seven-storey scheme if it was a "piece of architecture", which helped us because the building is quite sculptural. The elevation makes a play of light and shade, as well as generating more interesting interiors, with oblique views over the park. And the structure cantilevers dramatically over the building corners. This allowed us to incorporate column-free, dual-aspect glazing, and further emphasises the horizontal slabs. We could only really achieve those properties using reinforced concrete – it would have been impractical in any other material.

The concrete frame brought a number of other advantages. The

TOP
The structure has been left exposed for aesthetic and durability reasons

ABOVE
The slab design had to take account of the concertina-like thermal line

slabs are just 225mmm thick, which again helped to keep the building to an acceptable height for the planners. It's a wonderful material for student buildings. There's no sound travel between rooms, and it's really durable: students can't accidentally make a hole in a concrete column.

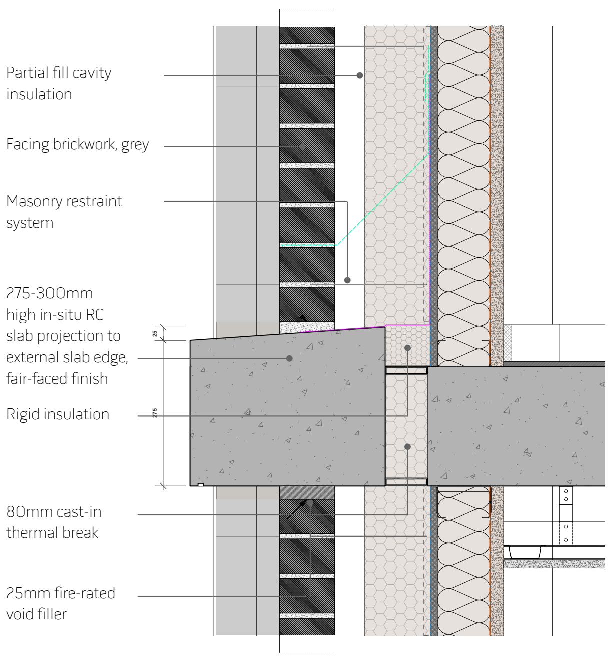
We left as much of the structure exposed internally as possible. Again, it was about standing up to hard use – other student schemes have to be painted every summer.

We gave a lot of thought to the finish. We did various sample panels that were too smooth and looked like plastic, and others that were too rough and looked like a car park. Ultimately, we used a standard mix and ply formwork, which gave the sort of "perfect imperfection" we were aiming for.

It was also about giving the students something that belongs to them. It's London, it's urban, it's honest, it's their era. The basement common room has an almost nightclub feel to it in the evenings, while light comes in from the south-facing courtyard garden above during the day.

The building offers future flexibility too. The frame allowed us to have 5.5m spans between columns, so it could easily be adapted to flats or offices. It comes back to the Dom-Ino House again, and that ability to rearrange internal space. Le Corbusier's system could be a house, two flats, an office and a flat, a factory … The point is that the only certainty in life is change. ■

Duncan Greenaway is founder of Greenaway Architecture



TOP
Cantilevered corners enable the use of column-free, dual-aspect glazing

ABOVE
Cill and head detail, third floor

Photos: Jack Hobhouse

FAST LEARNERS

Sheppard Robson turned to an innovative crosswall precast system to cope with the post-pandemic rush of students to its new University of York campus. By Tony Whitehead

In 2021, British universities were faced with an accommodation crisis. Because of the Covid pandemic, adjustments had been made to the A-level marking system and many more candidates than usual attained their grades. Universities were obliged to honour their offers — but where to put the extra students?

ABOVE
The use of concrete and brick echoes the more brutalist character of York's 1960s-built Campus West

The University of York was already building the £130m Campus East Gateway – a set of 18 three and four-storey blocks, which would provide 1,480 rooms. Was there any way, wondered York, of delivering some of that accommodation early?

In the midst of the pandemic, with sites and factories closed or struggling to maintain interrupted schedules, this may have seemed a forlorn hope. Nevertheless, it is exactly what has been achieved by the team building Campus East Gateway: a partnership between funder Equitix and design-and-build contractor Graham, with architect Sheppard Robson and precast supplier FP McCann.

"This was – is – a design, build, finance and operate contract," says Neil McFarlane, special projects director for Graham. "If anything went wrong with quality or programme, it would be us who would suffer. So when we looked at the various construction methods and materials we could use, we were thinking about the tight programme, and about risk. And the more we thought

WHEN WE LOOKED AT THE VARIOUS METHODS AND MATERIALS WE COULD USE, WE WERE THINKING ABOUT THE TIGHT PROGRAMME, AND ABOUT RISK

BELOW
The 18 three and four-storey blocks at the lakeside campus provide 1,480 student rooms

ABOVE
The reintroduction of native planting was central to the sustainable landscaping strategy

about the speed of construction, cost certainty, quality control, compliance, and low ongoing maintenance, the more obvious it became that MMC [modern methods of construction] using precast was the way to go."

Of course, back when the project was in the planning stages, Covid was not one of the risks that McFarlane envisaged: "But the precast solution turned out to be a hidden gem in our risk management strategy," he says. "The system of off-site prefabrication and rapid assembly proved extremely resilient. We barely stopped."

In practice, this meant McCann delivering panels on a just-in-time basis to be lifted into position by one of the two cranes on site. "Each crane had a team of just ten men and, being crawler cranes, they could work on more than one block at once," says McFarlane. "It took around eight weeks to complete a block and we were working on up to four blocks at a time. It was so fast we were completing the enclosure of each room in an average of 1.9 hours." This pace allowed the team to deliver 300 rooms a full two terms ahead of schedule.

Situated in a peaceful lakeside location, Campus East Gateway is today a calm and stylish neighbourhood, the first phase of which has just been recognised with a 2023 RIBA Yorkshire Award. The materials palette includes brick and steel, but concrete is predominant, echoing the more brutalist character of York's 1960s-built Campus West.

"Part of the brief was to create 'Yorkness'," says Natalia Maximova, associate partner with Sheppard Robson, and RIBA Yorkshire Project Architect of the Year. "By this, the client was not talking about old York, rather the character of the existing York campus. So while programme and risk were deciding factors for Graham, the decision to go with concrete was a great opportunity for us to replicate some of the design language of Campus West." This included its panels of concrete artwork by artist Fred Millett.

Each block at East Gateway is constructed almost entirely from FP McCann's precast panels (see box, page 26). The facades are made from insulated 465mm-thick sandwich panels, while slimmer 160-180mm panels form the internal walls. Each room is completed with a 175mm-thick precast slab or "lid" which

BELOW
Covered walkways further enhance the connection to the outdoors


Photo: FP McCann

ABOVE
Most of the internal walls are plasterboard-free and the rooms have no false floors or ceilings

cantilevers beyond the room perimeter to form half the ceiling for the internal corridor. The wall panels for the room above are attached directly to this slab. "Being a crosswall system, the walls are part of the structure," explains Maximova. "FP McCann joined the team very early in the process, and it helped that we could design from the start with the manufacturer's systems in mind. Having substantial concrete walls to every room means that they perform very well acoustically – you really can't hear much from next door. It also meant that we exceeded the requirements for fire rating."

Although the rooms do feature some plasterboard around the en-suite bathrooms, most of the walls are plasterboard-free and the rooms have no false floors or ceilings. "The concrete wall and ceiling panels are so smooth that they just need painting," she says. "This keeps things simple. Risk is reduced by having fewer materials and fewer trades on site – and that really helped during the pandemic."

This approach did mean that services conduits had to be carefully worked out early in the design process, and cast into the panels. ""The rooms are arranged so the student desks are situated symmetrically on either side of dividing walls," says Maximova. "We discovered that the panels could not accommodate conduits for two desks, if arranged directly opposite, and the acoustic performance was compromised, so we changed the layout to offset the services. You only find out these things by doing them."

The slim structure delivered a further important benefit: although the floor-to-ceiling height is 2,525mm, the lack of false floors or ceilings means the floor-to-floor height is only 2,700mm. "Planning restrictions limited the height we could build to, but this system allowed us to fit four floors in more of the blocks and provide over 200 rooms more than were envisaged in the original brief."

An additional advantage to this "structure-as-finish" approach is that it helps to regulate internal temperatures. "It's not that unusual these days to have an exposed concrete soffit to benefit from the thermal mass of concrete," says Maximova. "But our blocks have exposed walls as well – lots of them – so the thermal mass effect is especially significant."

BELOW
The facades are made from insulated 465mm-thick sandwich panels

ABOVE
Natalia Maximova's panel designs were inspired by artist Fred Millett's work on the 1960s Campus West

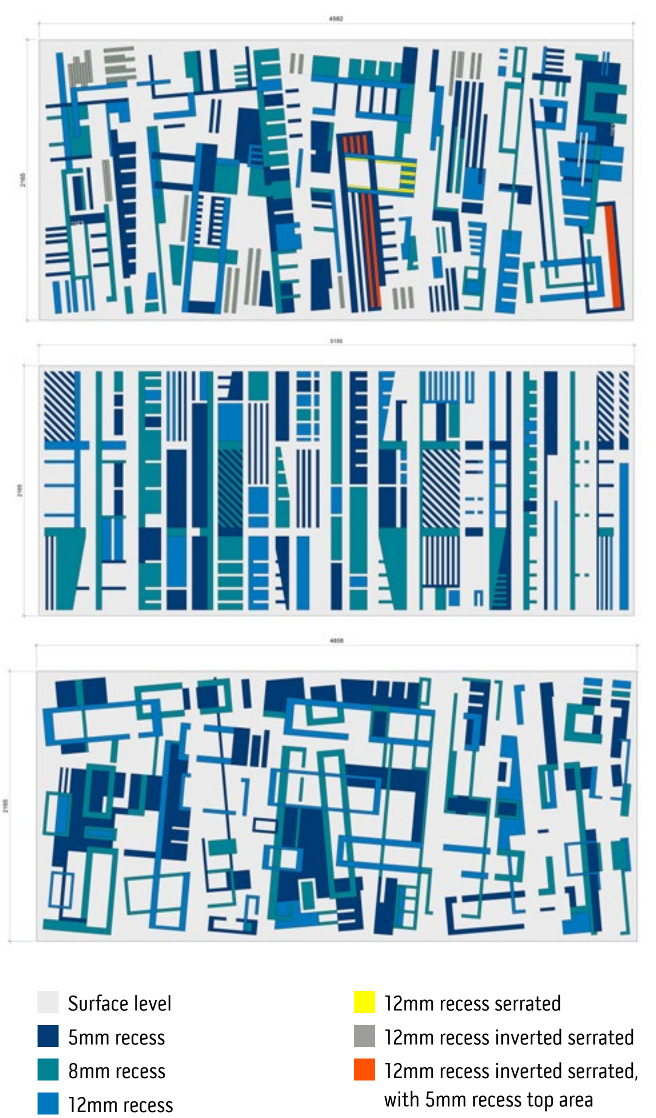
The buildings are naturally ventilated with user-operated windows that open inwards to allow a considerable flow of air. In summer, this allows the concrete to cool overnight, ready to absorb heat from the spaces the following day. Conversely, in winter with the windows shut, the concrete becomes a store of warmth, thus reducing the need for heating.

The blocks also benefit from a high degree of airtightness, due to the fine tolerances to which the precast panels are manufactured, and the close fit that results. This helps preserve the "storage-heater" effect of the concrete's thermal mass. "We were achieving close to Passivhaus. Combined with a considerable thermal mass, it resulted in energy-efficient sustainable buildings: after the first year of use, the energy use is significantly lower than the predicted level."

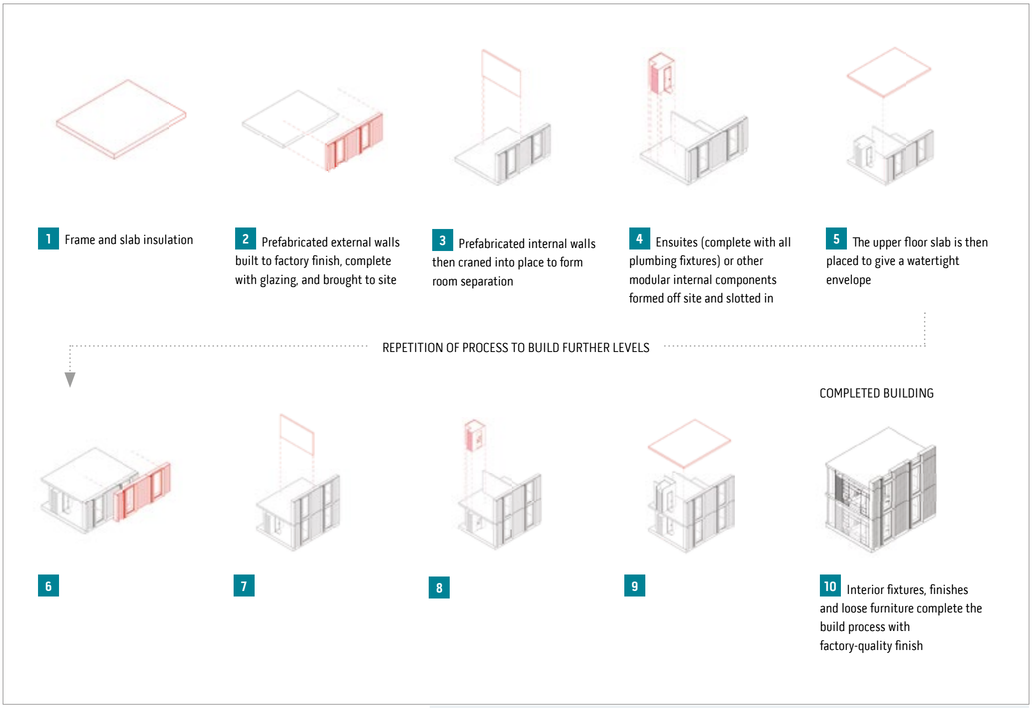
The passive temperature control offered by the thermal mass means each room has just a small electric heater, and the blocks need no active air-conditioning or mechanical air supply. "This cut down the M&E services – again keeping things quick, simple, and reducing the need for labour on site."

Outside, the architectural dialogue with the original 1960s campus is clear to see. A typical facade sandwich panel, for example, comes complete with windows, brick panelling and, above the brickwork, what appears to be a concrete crossbeam. Rows of such panels, one on top of another, give the impression of exposed concrete beams or floor slabs, though the concrete in question is entirely non-structural, being merely part of the external skin of the sandwich panel.

But perhaps the most significant nod to the original mid-century styling are the patterned precast art panels that Maximova designed herself. An artist as well as an architect, Maximova became fascinated by the history behind the Fred Millett panels which can still be seen in Campus West. "Fred died in 1980, but I became so interested in his work. I was able to contact his daughter who remembers the moulds for the York panels being constructed in the family's garden. The precast company that made them, Evans Bros [now Evans Concrete], is still operating."



ABOVE
The three facade panel designs by Maximova, with the different depths and textures highlighted. The patterns were cast using bespoke flexible formliners



ABOVE
Diagram showing the sequence of the concrete MMC assembly. In total, FP McCann provided over 7,000 individual precast concrete units

A key difference between Millett's work and the new designs is that while he made a few one-offs, Maximova had to design for mass production. "There are three different designs: one quite placid, inspired by the stillness of the lake, one more active, like the light filtering through moving leaves, and a third featuring sawtooth designs. Each design includes three depths – 50mm, 80mm and 120mm – not as deep as Fred's, but enough to cast distinctive shadows. Any deeper would risk water retention and excessive staining."

These panels, a floor high and up to 5m in length, were manufactured

'The key to efficiency is repetition'

To create the 18 accommodation blocks at York, FP McCann provided 7,177 individual precast units including walls, floor slabs and external architectural sandwich panels. Because of the scale of the contract, panels were supplied from three facilities: Byley, Littleport and Grantham.

"We had to be careful to maintain a consistent colour and appearance across the three sites ," says Gavin Lowe, structural and architectural precast manager with FP McCann. "But we batch our own concrete and this was a fairly standard mix, so we had few problems with that."

The mix contained about 30% pulverised fly ash (PFA) to lower the carbon content: "It also helps provide the smooth, consistent appearance required when the panels are simply going to be painted as an internal finish. It helps too that our mix is self-compacting."

by FP McCann using a proprietary "architectural mix" and bespoke flexible form liners. "The trick was to stop the design becoming boring through repetition, so roughly half the panels are cast with the form liner rotated 180°," says Maximova. "The patterns looks quite different that way. We also needed different sizes, so each design has a place where the panel can be safely cut without eating into the indented designs and creating fragile edges."

Changing the size, orientation and using the three different designs in different ways throughout the blocks creates a surprising amount of variety from just three mould shapes: "People tend to think there are more than just three designs."

So did the MMC approach work for the architect? "It does mean a longer upfront preparation period to sort out the design in detail," she says. "But once on site it's exceptionally quick and reliable. As for crosswall construction, you couldn't use it everywhere – we looked at it for a hospital, but the length and variety of spans involved made it unsuitable. But for projects like student accommodation, or hotels, it's a very practical, high-quality solution." ■

PROJECT TEAM

Architect Sheppard Robson
Structural engineer Cundall
Contractor Graham Group
Precast supplier FP McCann
Precast installer McVey Stone

The larger facade elements weigh 10 tonnes and are 2.7m high and two rooms long – or just over 6m. These insulated sandwich panels comprise a 150mm-thick structural concrete inner skin designed to carry its own dead loading and that of the external skin. Added to this is a 200mm layer of insulation and a 115mm outer cladding of concrete, in many cases with cast-in brick panels.

"These are made on steel tables onto which we place a CNC-cut timber form with precision-cut indents for the position of each brick," explains Lowe. "Most of the bricks are cut in half, and we use both halves, placing them face down in the mould. Some designs featured projecting bricks and so, for those, we used whole bricks. We then place removable strips between the bricks and cover with a little dry sand to prevent concrete leaking through to the visible brick faces."

The bricks are covered with steel mesh before the first layer of concrete was poured. Then, while the concrete is still soft, the insulation is added on top and fibre-reinforced resin pins with low thermal conductivity are pushed through to bond it to the cladding. Some of each pin is left projecting – so when the rebar and concrete is added to form the structural inner layer, this too is bonded to the insulation. Once de-moulded these external panels are finished with a light acid etch.

Simpler to make were the uninsulated internal panels, typically weighing seven tonnes. The ceiling slabs were simply cast flat, and with most spans only 3m long, or the width of a room, there was no need to prestress them. The internal wall panels were made in the same way. "With a job like this, the key to efficiency is repetition," says Lowe. "So we worked hard on the design of the wall panels to ensure that, as far as possible, they all had the same conduit set cast in."

FP McCann also supplied precast pillars to support the blocks' overhang "porches", and precast staircases. In all, the contract lasted 56 weeks – a significant time saving on the original estimate of 18 months.

BIG SHOT

In CQ online, we explore three major projects that use concrete structures to breathe new life into heritage buildings on complex sites – starting with Studio Gang's shotcrete Gilder Center

Shotcrete has very rarely been used architecturally, and certainly not on anything as high-profile as a $465m extension to a much-loved national institution. It is typically used in tunnel linings, which are structural but tend to follow a regular geometry, and theme parks or zoos, for more sculptural, non-structural applications.

But at the Gilder Center – Studio Gang's $465m extension to the American Museum of Natural History in New York – it has provided a spectacular but pragmatic solution. The designers needed to stitch together the institution's patchwork of existing buildings, built over the past 150 years. In all, the extension includes 33 connections to 10 other buildings within the complex.

Photos: Iwan Baan

"The idea emerged of these flowing walls that guide people and create a sense of flow that had never been there in the past," says Matt Jackson, associate principal at structural engineer Arup. The geometry was also influenced by constraints on where foundations could be placed. "There's a lot of existing infrastructure, which had to remain operational throughout the project, so we knew we had to land in certain places. This led to a system of arches and walls, forming the canyon look.

"Once we had that concept, the question was, how do we build it and get the aesthetic we want?"

READ THE FULL STORY
concretecentre.com/cq

WINDING DOWN

Architect Hall McKnight has retrofitted a constrained basement beneath the quadrangle at King's College London, inserting a number of new-build elements to create workspaces for the Department of Engineering while rejuvenating the space above as a pedestrian square.

At the heart of the facility is an in-situ concrete spiral stair beneath a precast-clad oculus, drawing light into the centre of the plan and giving a focal point to the newly landscaped quad.

The stair required extensive 3D modelling with Revit software. Executive architect Rock Townsend used this to define reinforcement and cable routes as well as every day joint and shutter joint, producing a set of colour-coded pour sequence drawings for the stair contractor. "It was quite an interesting approach – we'd never done that before," says Richard Sharp, partner at Rock Townsend. The bepoke welded formwork was made from fair-faced ply in order to leave a matt finish.

The pour itself provided another challenge: the quad's original deck could take a maximum load of only 1 tonne, so concrete had to be pumped from up to 80m away.

READ THE FULL STORY
concretecentre.com/cq

Photos: Johan Dehlin Photography

KEYHOLE SURGERY

The reopening of the Hunterian Museum earlier this summer marked the final piece in Hawkins\Brown's extensive remodelling of the grade II*-listed Royal College of Surgeons on Lincoln's Inn Fields in London.

The design approach has been to establish "a dramatic threshold between old and new", restoring and updating historic elements such as the original north facade while removing postwar additions and inserting a publicly accessible, concrete-framed atrium.

While the main structure was cast in situ, the new south facade is made from loadbearing precast concrete panels, with a fluted motif that echoes the Charles Barry entrance facade. Precast panels were also used for the side elevations, to facilitate construction on a site constrained not just by the heritage structure in front but the live construction site of Grafton Architects' Marshall Building immediately next door.

The project was measured using Hawkins\Brown's H\B:ERT emission reduction tool. The estimated carbon saved by retaining the original building structure was 130kgCO_2e/m^2.

READ THE FULL STORY
concretecentre.com/cq

Photos: Jack Hobhouse

ABOVE Adrian Corrigall's Concrete House in East Sussex uses fibre-reinforced concrete for the walls and floor slabs. Codification of such alternative reinforcement methods should lead to wider adoption

Introducing Second Generation Eurocode 2

The revised design code could usher in a new generation of more efficient structures and lower-carbon concrete and reinforcement. Tony Jones outlines what to expect, and when

A new suite of Eurocodes, branded the "Second Generation Eurocodes", is in the process of being introduced across Europe. For concrete, the requirements for the vast majority of structures are contained in Eurocode 2 (see box, next page), which could be published in the UK as early as next year. It is set to have a major influence on the environmental impact of concrete, with significant changes that will encourage the use of a wider range of concretes and reinforcement with lower embodied carbon, as well as recycled aggregates and more efficient designs.

Programme to publication

At the time of writing the Second Generation documents had just passed the Formal Vote stage. Once any editorial comments have been addressed, the documents will be made available to national standards bodies (NSBs). It is then down to NSBs to determine the timing of publication and implementation in their country, but the documents must be published by the end of 2027 and conflicting standards withdrawn in 2028.

For the UK, the British Standards Institution (BSI) is expected to receive the final document in October 2023. For the industry to use the new Eurocodes, National Annexes will also need to be published. These permit each country to adjust key factors that can have a significant impact on the efficiency of the structures produced. As no technical changes are expected prior to the approval of the current version of the document, preparation of the UK National Annexes has already started and it is hoped that a draft of the National Annex, for public comment, will be available soon after BSI receives the final version of the Eurocode. This means that the Second-Generation and its UK National Annex could be available for use as early as summer 2024.

The Eurocodes and the associated product standards provide an interlinked framework of rules. Publishing an update to one part of the framework may cause problems at the interfaces with other documents. For example, the steel and concrete composite part of the Eurocode relies on the current structural concrete Eurocode for many of its provisions. Similarly, precast concrete product standards refer to rules in the current concrete Eurocode. Therefore, there is likely to be a period of coexistence, with both the current Eurocode and the Second Generation being available.

BSI is currently considering what this means contractually, and it is likely that wording in the National Foreword to the Second Generation will state that the existing Eurocodes remain "current" until withdrawn prior to 2028. On the face of it, this would seem to preclude the use of the Second Generation, but the way the UK Building Regulations are implemented means that there is nothing to prevent an engineer using the documents. It may, however, be prudent to agree this on a project basis with your client.

The period of coexistence will also allow supporting resources to be updated. The Eurocodes are detailed and extensive, applicable to a wide range of structures. While early adopters at specialist practices or major consultancies may have the expertise to implement the new standard directly, using the raw document will be a significant burden for many engineers. Experience shows that developing simplified guides, explanations of key changes and principles, and simple software for typical cases all ease the adoption of new codes of practice. MPA The Concrete Centre provides a significant set of resources, including technical guidance documents, webinars, courses and spreadsheets for the current Eurocode. The key resources will be updated before the existing code is formally withdrawn.

A brief guide to Eurocode 2

First published 20 years ago, the Eurocodes are the main design codes for all structural materials in the UK and Europe. The requirements for concrete structures are contained in Eurocode 2, which consists of a number of parts:

- EN 1992-1-1:2004. Eurocode 2: Design of concrete structures – Part 1-1: General rules and rules for buildings
- EN 1992-1-2:2004. Eurocode 2: Design of concrete structures – Part 1-2: General rules – structural fire design
- EN 1992-2:2005. Eurocode 2: Design of concrete structures – Part 2: Concrete bridges – design and detailing rules
- EN 1992-3:2006. Eurocode 2: Design of concrete structures – Part 3: Liquid retaining and containment structures
- EN 1992-4:2018. Eurocode 2: Design of concrete structures – Part 4: Design of fastenings for use in concrete

With the exception of part 4, all of these codes of practice are undergoing a major revision. The most obvious presentational change to Eurocode 2 is that Part 2 and Part 3 will be incorporated into Part 1-1. The revised concrete Eurocodes will therefore consist of:

- EN 1992-1-1:2023. Eurocode 2: Design of concrete structures – Part 1-1: General rules and rules for buildings, bridges and civil engineering structures
- EN 1992-1-2:2023. Eurocode 2: Design of concrete structures – Part 1-2: General rules – structural fire design

The revision of the Eurocodes is being undertaken by the European Committee for Standardization (CEN) Technical Committee 250, and in the case of structural concrete this falls under the remit of Sub-Committee 2.

Key changes to Eurocode 2

It is worth highlighting technical changes that have the greatest potential to impact the industry. New models have been introduced for certain key areas of behaviour. In some cases, these would lead to more conservative designs, and calibration work is ongoing to see if, where justified, this can be addressed in the National Annex. In other cases, models have been introduced that have the potential to enable more efficient design of columns, for example.

Some simplified design methods have been removed – generally where they have proved contentious by reflecting one nation's historic practice above others. National bodies can provide their own simplified methods, as long as they can be shown to be consistent with the more detailed models within the code. These additional methods are referred to as non-contradictory complementary information (NCCI). MPA The Concrete Centre is working with the industry to develop this in parallel with the National Annex and it will be published in due course.

BELOW
The Arup Vault prototype uses geopolymer concrete and basalt-fibre polymer reinforcement to reduce embodied carbon by 45%. The lightweight floor system was trialled as part of Laing O'Rourke's Decarbonising Precast Concrete Manufacturing project. New lower embodied carbon concretes and reinforcement could be introduced more easily under the revised Eurocode 2 (see next page)

Photo: Laing O'Rourke

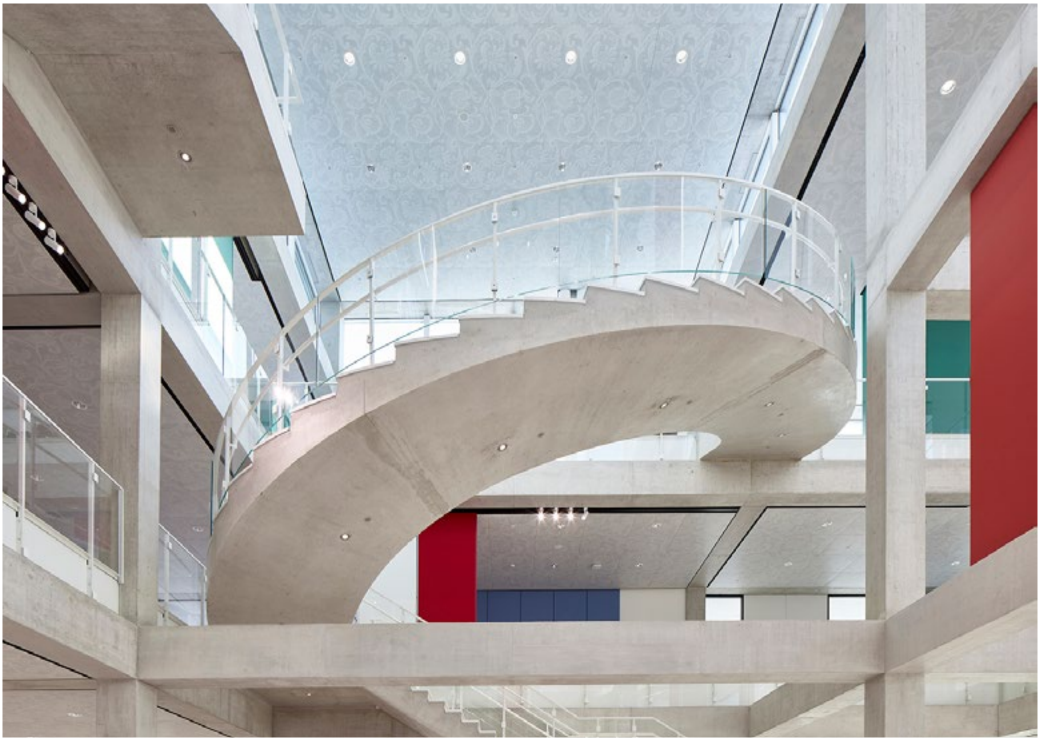


Photo: Chris Mansfield

Completely new areas covered by the Second Generation include:

- Information on the background to the safety factors used. This allows the factors to be reduced, and hence a more efficient design produced, where there is more certainty in the material properties than assumed in the derivation of the default factors.
- Assessment of existing concrete structures, encouraging reuse and adaption and therefore supporting the "long-life" argument for concrete structures.
- Strengthening of structures with carbon-fibre reinforcement polymers. This will likely be used most in conjunction with the assessment of existing structures.
- Structural use of steel fibre reinforced concrete. While already used in basic applications, the codification of these rules will allow wider use of the material where it is the most efficient solution.
- The use of recycled aggregate concrete in structures. This formalises the use of the material and provides guidance on the design implications, which is currently missing.

ABOVE
The concrete used at Sou Fujimoto's The Square in St Gallen, Switzerland uses local recycled aggregates instead of natural gravel, as well as cement made with up to 20% construction and demolition waste . The revised Eurocode 2 will formalise the use of recycled aggregates in structural concrete

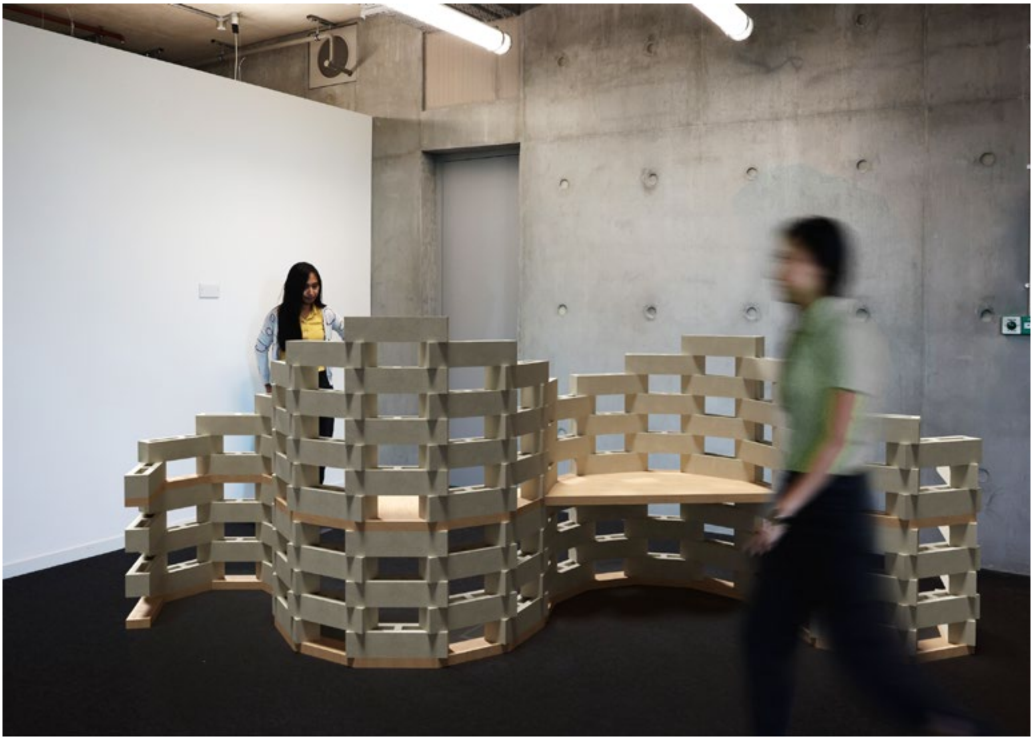


Photo: AKT II

However, practice in Europe varies, so the National Annex will need to ensure that current good practice in the UK is not disadvantaged due to the use of lower quality materials elsewhere.

■ The use of embedded fibre-reinforced polymer reinforcement. This also formalises the growing use of non-metallic reinforcement in specific applications, enabling wider adoption.

■ The use of stainless-steel reinforcement. Guidance on this has existed in the UK for some time but its inclusion in the Eurocode will increase engineers' confidence to use it where appropriate.

■ The use of exposure resistance classes for durability. This has the potential to make the biggest impact. Although the UK National Annex will initially require the durability of concrete structures to be considered as they currently are, as standards are updated there will be a greater opportunity to use a wider range of concretes and demonstrate their performance by testing. This should enable concretes with lower embodied carbon to be introduced more readily. ■

ABOVE
AKT II's Crinkle Crankle Concrete installation at the 2022 London Design Festival uses Seratech's cement-replacement technology, which permanently stores CO_2 within a magnesium carbonate by-product. With the introduction of new exposure classes for durability, such innovations could become more readily introduced

FINAL FRAME: AARE BRIDGE, SWITZERLAND

Swiss architect Christ & Gantenbein has completed a material-efficient 119m-long road, cycle and footbridge for the city of Aarau. The bridge's five arches are of different widths so that they can partially rest on the caissons of the previous 1940s bridge. The foundations, pillars, arches, flanks, roadway and parapets have been designed as a seamless, monolithic structure and all act as loadbearing elements, thereby optimising the use of concrete.

Photo: Stefano Graziani