CONCRETE QUARTERLY

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Brass act: V8 Architects revives a brutalist office in Amsterdam with a facade of inlaid precast concrete

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

Writing on the walls

Right now, there is some exciting experimentation into how concrete structures might be reused, and I've been thinking a lot about how architecture might evolve in a more circular economy. If you're going to adapt or reuse a building or its materials, you need to know what's there in the first place. Recent projects have found useful information in company archives and even back issues of Concrete Quarterly. But how do we communicate more complex data to future project teams – especially when concrete buildings can stand for well over 100 years?

Development of material passports is one area of focus, but we can also think about the role the building itself plays. Should we express the joints between elements to show how they could be taken apart, for example? We already do this to some extent: with a post-tensioned slab, the location of strands is often sprayed onto the soffit before the suspended ceiling goes on, to show where it can be cut.

At the moment, the main way of passing on this kind of information is via a handover report, physical or digital – and easily lost over the long term. We can embed e-tags within the building, but we can't be sure that the technology to scan them will still be around in the distant future. Perhaps there could be an evolution of technical graffiti, with key information written in designated locations, like over the main entrance. But, as we know from material passports, there's an enormous amount of information to communicate. There's also a question about how much people will be prepared to rely on a voice from the past – who would trust that data? Decisions about reuse will always be based on current analysis.

There are a growing number of scanning tools that can identify materials and quantities as part of pre-demolition audits, but the process is greatly facilitated if there are some clues to start with. To me, that makes the architectural expression of a building even more important. After all, aesthetics is essentially a form of communication, data that we can read intuitively.

AESTHETICS IS ESSENTIALLY A FORM OF COMMUNICATION, DATA THAT WE CAN READ INTUITIVELY

Of course, architects have always thought about how to make a building legible to its users, so this is really just a new twist on an old problem. It certainly doesn't mean we need to return to brutalism, which is just one response and a very particular language. As the projects in this issue show, a structure doesn't have to take centre stage to be legible. At Pitman Tozer's Farrimond House in Barking (page 18), the only hint of its hybrid precast and in-situ frame are the panels that encase the stairwells. Stanton Williams' student housing for Emmanuel College, Cambridge (page 26) hides a maze of transfer structures in its basement. At PI59 in Amsterdam (page 32), a 1970s slab block has been glazed and wrapped in a terrazzo-like precast facade. Perhaps in 60 years, this will be replaced and the building reinvented again for another new age.

The interaction of sustainability, circularity and architecture raises so many fascinating questions for design teams to explore. I can't wait to see what answers we'll come up with. ■

CONCRETE QUARTERLY

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Klusterwohnen Wabenhaus in Munich by Peter Haimerl Architects. Photo: Edward Beierle

Photos: Film Infinity

INNOVATION

MINIMASS

STRUCTURAL ENGINEER ANDY COWARD HAS COMBINED 3D PRINTING, POST-TENSIONING AND STANDARD CONCRETE TO DEVELOP A REUSABLE BEAM WITH HALF AS MUCH MATERIAL

ABOVE
Andy Coward and co-founder Sarah Blake enjoy a brew on a minimass beam at their trial project at Constructionarium in Norfolk

A structural engineer with an interest in innovation, Andy Coward became used to sitting in meetings with architects and contractors who wanted to maximise the potential of 3D printing (3DP) with concrete.

"We kept coming back to the difficulties of reinforcing it," he says. "Despite the exciting possibilities of being able to create complex, material-efficient shapes relatively simply, they could not be made strong enough to function as structural elements. We tended to end up with igloos and street furniture – which is fine, but obviously limited."

Coward thought the problem was being approached in the wrong way: "I felt we were missing something:

LEFT
The perimeter of each beam is 3D-printed, on its side, creating 50mm-thick formwork that is filled with standard pumped concrete

essentially that 3DP should be seen as just part of the solution. I began thinking about what geometries 3DP could open up and what other technologies it could be used with."

Determined to test his ideas, he founded his own company, minimass, which has just completed an 11m-long demonstration footbridge in Norfolk. Its slightly curving concrete support beams are recognisably 3D-printed but, as Coward explains, that is only half the story.

"First, we print the sides of the beams in outline, effectively creating 50mm-thick concrete formwork. Then we drop reinforcement inside the forms and fill with standard pumped concrete. Because the beams are printed to exactly the size and shape required, they don't have to be straight, or square in section. That immediately allows us to use less concrete and reduce embodied carbon."

To further minimise the material involved – Coward estimates the Norfolk demonstrator uses 50% less concrete than a standard solution – the elements are also post-tensioned using an innovative external cable system.

"Unusually, we have the cable slung some distance beneath the centre line of the element, and held in the correct position by the 3DP geometry of the beams. We post-tension it using standard PT equipment, but only partially." When loading is applied to the bridge, the forces at play automatically tension the cable further, to around 25% of its capacity, and this increases →

I BEGAN THINKING ABOUT WHAT GEOMETRIES 3D PRINTING COULD OPEN UP AND WHAT OTHER TECHNOLOGIES IT COULD BE USED WITH compression of the concrete element. "It works like a bowstring truss – increasing both tension and compression under loading. You see the technique used sometimes in wider structures but not on single elements like this. The result is a highly efficient, low-mass, structural beam."

The exterior tensioning cables help to make minimass beams reusable, he adds. "Most PT systems have the cables encased in concrete, but our cables can be de-tensioned and removed fairly easily. That's helpful if you want a temporary, reusable structure, or even if you want to disassemble a more permanent structure and reuse the beams elsewhere."

To build the prototype bridge, Coward and co-founder Sarah Blake teamed up with Irish 3DP specialists, Harcourt Technologies. It was assembled on site at Constructionarium in Norfolk, a training facility that also provides a site for experimental technologies. The beams use standard, code-compliant concrete containing 6mm aggregate: "This is important as some printing technologies use low or no-aggregate mixes and this increases the cement and therefore the carbon content," he says. "Our concrete is made 3D-printable by injecting an additive just before it gets to the nozzle. Elements can either be made at a central location or, if the contractor has room, printed on site to minimise transport costs."

Coward believes his design to be the first ever code-compliant structural concrete element to use 3DP. "Our beams do look different," he concedes. "But architects we have spoken to really like having the cable visible. It shows the building's occupants how the structure is functioning."

But could minimass beams ever compete commercially with traditionally produced in-situ or precast elements? "3D printing the permanent forms this way can actually be very cost-effective, especially if you want a range of shapes and sizes. It uses less concrete, less steel and less labour than traditional formwork approaches. We think a three-person team can produce around seven beams a day."

ABOVE
Reinforcement is placed in the 3D-printed formwork before it is filled with a standard concrete mix

ABOVE
The 11m-long footbridge uses an estimated 50% less concrete than a standard solution. The PT cable remains visible beneath the completed bridge

Overseeing the construction of the prototype bridge has involved a steep learning curve: "Sarah and I have been very hands-on. As well as designing the bridge, we had to source materials and organise deliveries." He has clearly found the challenge refreshing, however: "Previously I have worked with Foster + Partners and Danish group BIG. Both practices encouraged creative thinking, but at the same time the reality was it was often not possible to go for the most sustainable solution."

He sees minimass primarily as a product supplier: "I always felt that I could make more of a difference to carbon in construction by developing products than by shaving a few kilos of material here and there on a project-by-project basis."

Coward and Blake are in discussions to provide structural elements for its first commercial project in Ireland: "That would be for a permanent structure," says Coward. "But I think we may also be able to find opportunities, especially initially, to supply structures for temporary works on larger projects." ■

Interview by Tony Whitehead

LASTING IMPRESSION

KEITH WILLIAMS

RACHEL WHITEREAD'S *HOUSE* HIGHLIGHTS CONCRETE'S UNIQUE GIFT OF TURNING SPACE SOLID – A PROCESS THAT ARCHITECTS CAN EXPRESS OR SUBVERT TO EXTRAORDINARY EFFECT

Most buildings are made from positive components – bricks, steel, stone – which are assembled in a given sequence to make the final form. With concrete we do the reverse. We shutter space, making a negative into which the liquid concrete is poured to solidify into a positive: the structure, the form, the architecture.

Rachel Whiteread's *House*, a temporary artwork from 1993-94, viscerally exploited that concept, giving form to the private internal space of an ordinary Victorian house by pumping it full of concrete. She then peeled away the external masonry skin to expose the resultant cast. Humble, domestic space was solidified, and exposed to the city for the first time. Brilliant!

The Capitol Complex at Chandigarh by Le Corbusier is extraordinary. The concrete is rough, raw and heavy but the huge scale and power of the architecture and the drama of the forms in the light of northern Punjab produce the richest of architectural monumentality. I had admired it since my student days, but when I finally got to visit in 2007 I was blown away. It is one of the finest

ABOVE
House, Grove Road, north London, by Rachel Whiteread, 1993-94

RIGHT
Palace of the Assembly, Chandigardh, by Le Corbusier, 1963

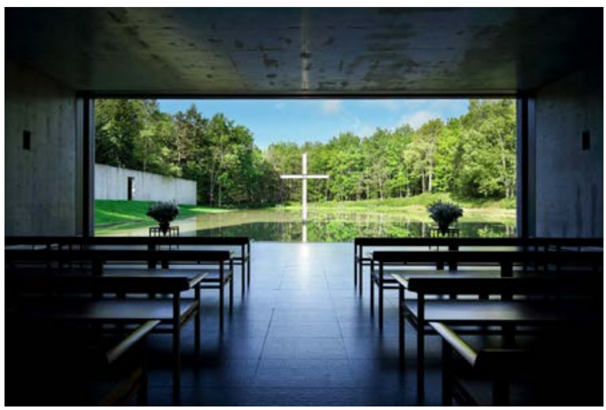
Photos: Alex MacNaughton / Alamy Stock Photo; Keith Williams ensembles of postwar architecture on the planet – an ancient land reinventing itself to take its place in the modern era through radical sculptural architecture in concrete.

Concrete's immense heft can also be subverted to great effect. At the Church of San Giovanni Battista, Campi Bisenzio, Giovanni Michelucci deploys delicate diagonal struts to support the roof, which appears like a curved cloth draped across the space. There's nothing weightless about it – it looks like a very, very heavy cloth. It's remarkable how he's made concrete do that, almost in the way that sculptors like Canova could carve marble into swaths of cloth.

We sometimes forget not just the weight of concrete, but the immense strength needed to hold it while it cures. It's a raw, forceful process – sometimes formwork can simply burst – and it's unusual for concrete to come out looking utterly beautiful. Achieving a fine finish is hard: at the Novium museum in Chichester (CQ 242) we used an aggregate mix rich in quartz to introduce a sparkle into the surfaces, but it involved quite a labour-intensive process of brushing and gently sanding the surface.

This is partly what makes Tadao Ando's work so compelling. At the Church on the Water, exquisitely textured concrete combines with water and light in perfect harmony to create an exquisite numinous ensemble. It is tiny but beautifully ordered in its geometry and craft. ■

Keith Williams is founder and director of design at Keith Williams Architects and chair of trustees of Docomomo UK



Photos: Visit Tuscany; Hirofumi Inaba

TOP
Church of San Giovanni Battista, Campi Bisenzio, by Giovanni Michelucci, 1960-63

ABOVE
Church on the Water, Shimukappu-Mura, Japan, by Tadao Ando, 1988

From the archive: Summer 1947 / Autumn 1948

LIKE NOWHERE ON EARTH

The closure of the Ratcliffe-on-Soar power station in September marked the end of 142 years of coal power in the UK. It also offered a moment to reflect on the passing of one of the icons of the industrial age: the hyperbolic cooling tower. The writer James Graham, creator of the Nottinghamshire-based TV series *Sherwood*, is among those calling for at least some of the 114m-high Ratcliffe towers to be saved. “Some might think they’re ugly,” he wrote on X. “I think they’re majestic. Concrete cathedrals. I got to stand inside one, filming *Sherwood* series two. I’ve never stood anywhere like it on Earth.”

Early issues of Concrete Quarterly were similarly awestruck. Reporting on the opening of Hams Hall B power station in Birmingham in 1948, our writer feared the reader may find the project’s vital statistics “too mighty for meaning”. The four cooling towers – then the largest in the world – each had a capacity of four million gallons and stood 310ft high and 209ft in diameter at the base. “The hourly requirement of water is sixteen million gallons, which has been calculated as being nearly half the whole of the daily domestic consumption of Birmingham.”

A year earlier, in the magazine’s very first issue, an extension to Blackburn power station in Whitebirk had taken centre stage. Increasing its by 70,000kW, the project included two extensions to the turbine house, a new chimney and two new cooling towers – earning it the moniker “the Battersea of the North”. The cooling towers rose to 250ft and each had an hourly capacity of 1,800,000 gallons. A new structural feature was a 10,000-gallon trough near the top of each tower, which caught water as it condensed and stored it for the firefighting system.

The Blackburn Whitebirk power station closed in October 1976, and the cooling towers were demolished in May 1982. Hams Hall closed in 1981 and was demolished in 1985. According to the 20th Century Society, from a peak of 240 towers in the 1960s, just 45 survive. None are listed, and all but one are in the process of decommissioning and demolition.

BLACKBURN **Power** STATION

EXTENSIONS TO THE BLACKBURN power station have increased its capacity by 70,000 kw. and brought it the name of "the Battersea of the North". They were begun in August 1940, and except for some sections of flooring and some inside decorations, have been finished at a cost of £2,000,000. The station is in the Whitebirk district, just outside the eastern boundary of the Borough of Blackburn.

For the two Davenport hyperbolic concrete cooling towers, Mr. R. H. Harral, M.I.E.E., chief electrical engineer and manager of the Blackburn Electricity Undertaking, designed an entirely new structural feature. Within 20 ft. of the top of each tower, on the inside, an annular trough has been constructed to catch the water which condenses on the walls at the tops of the towers and store it for the "Mulsifyre" fire-fighting installation. Each trough holds 10,000 gallons. With this arrangement the fire-fighting system does not need a pump, though a stand-by pump is installed.

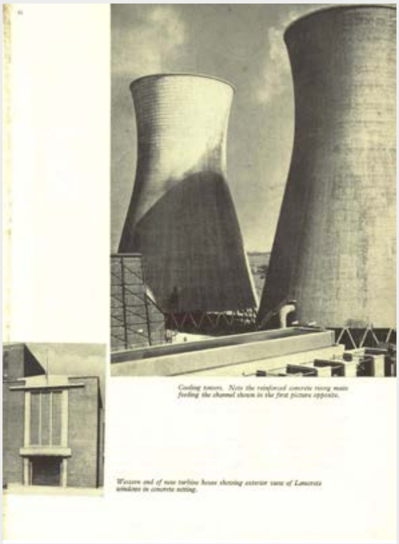
Each of the cooling towers has an hourly capacity of 1,800,000 gallons. The towers are 250 ft. high with a sill diameter of 165 ft. and are equipped with 940 sprayers which receive the returned circulating water direct from the condensers. The circulating water pipes, 48 in. in diameter, are also of reinforced concrete cast on the spot.

Different methods were used in building the two extensions of the turbine house. The first extension is an encased steel frame with brick infilling. In the second there is a reinforced concrete frame with brick panels and a concrete

Interior of cooling tower, showing reinforced concrete distribution channel across the diameter of the tower.

Concrete columns in turbine house, immediately after removal of the shuttering.

Reinforced concrete power house under construction.



Cooling towers. Note the reinforced concrete rising main feeding the channel shown in the first picture opposite.

Western end of new turbine house showing exterior view of Lancrete windows in concrete setting.

Photos: Edward Beierle

ORIGIN STORY

KLUSTERWOHNEN WABENHAUS

GERMAN ARCHITECT PETER HAIMERL THINKS THE HONEYCOMB MAY PROVIDE THE KEY TO HIGH-DENSITY CITY LIVING

What's the most wasted space in any room? Probably the junction between the walls and the ceiling, typically occupied only by spiders and their hapless prey. But what if you could gift that space to another room, and borrow some at a more usable height?

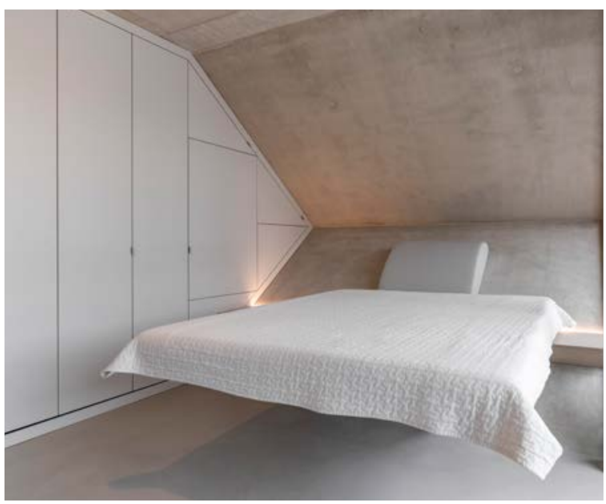
As with many of the best design concepts, nature got there first. This arrangement leads to a honeycomb: a hexagonal shape stacked into a diagonal grid. The idea of breaking out of the four-sided box has long appealed to the German architect Peter Haimerl. "We spend so much of our lives in digital spaces. But ordinary living is more or less the same as it was 50 years ago. The ground is flat, we put a house on it, then we put a chair in it, and so on. I thought, why is it like this? When I was young, I did some research →

about how we could improve life in dense cities. One of the ideas was that we should leave the ground, inhabit higher spaces, like walls – discover this third dimension."

Haimerl has developed these thoughts into a prototype housing development, the Klusterwohnen Wabenhaus – or co-living honeycomb house – in the Reim district of Munich. The Wabenhaus comprises 22 apartments, from $22m^2$ studios to a $106m^2$ four-bed family home – all contained within a diagrid of 17 hexagonal tubes.

A promotional video for the concept shows a small rectilinear living room, 4.5m wide and 2.65m high, slowly morph into a Wabenhaus module. The side walls fold in slightly at the top and bottom, creating a central crease that is then pulled out until the

ABOVE AND BELOW
Haimerl's studio has designed bespoke furniture that fixes to soft spots in the slanted walls



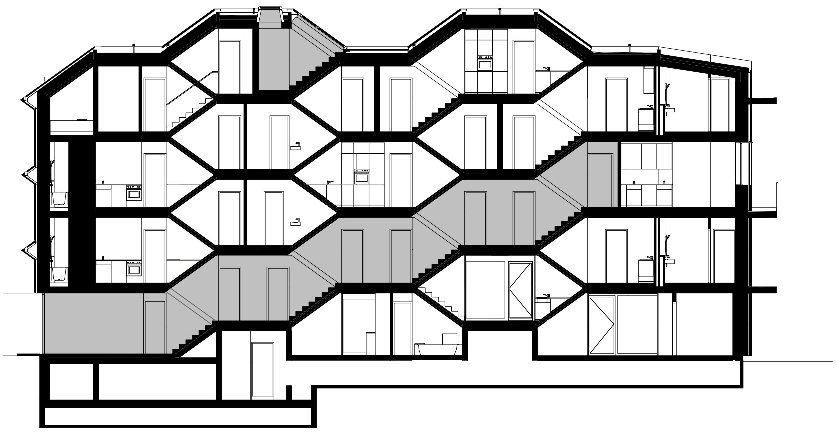
ABOVE
The Wabenhaus comprises 22 apartments, from studios to a four-bed family home

room is 6.6m across the centre. The once-vertical walls slope outwards at a 160˚ angle before doubling back on themselves. Bespoke slanting furniture climbs the walls, effectively extending the floor space. The larger apartments are split, mezzanine-like, over 1.5 levels with openings in the lower wall that step down to the adjoining cell. "You can combine the spaces as you like," says Haimerl.

This creates 1.3 times more space, he adds. "The apartments just look much bigger – you can have two connected spaces, and instead of 9m [with vertical walls] it's 11m wide." Because of the way the modules stretch out and overlap, a 4m by 11m apartment across two units actually generates 50m^2 of living space, rather than 44m^2. Haimerl describes this as "the space miracle".

The Reim Wabenhaus has been built using precast and in-situ concrete in an off-the-shelf twinwall system more commonly found in basement construction. Haimerl, whose previous concrete projects include the Blaibach Concert Hall in Bavaria (CQ 253, Autumn 2015), has embraced the industrial finish of the precast outer leaves, which provide the skewed stage for various everyday activities, from sleeping to working. →

IF WE LIVE IN BOXES, EACH BOX IS SEPARATED FROM THE NEXT. THERE ARE ONLY TWO POSSIBILITIES TO CONNECT THEM. THE HONEYCOMB, ON THE OTHER HAND, IS WOVEN TOGETHER



LEFT AND BELOW
All of the flats open off a "grand staircase" which steps diagonally up the honeycomb structure

The regular cell-like structure lends itself to a manufacturing-and-assembly approach, and Haimerl is now looking to roll out the Wabenhaus as an adaptable modular system for use in different settings. "Sometimes it's even better in small spaces. Because it can connect in four directions, upwards and downwards, we can build over roads and existing structures."

The basic unit of the modular system, known as "the hoodie", comprises the top three sides of the hexagon. Resembling a splayed table, this is precast in one mould from 140mm-deep concrete stiffened with 40mm ribs. The space between the ribs is filled with clay-based natural insulation. The units are stackable, enabling efficient delivery by flat-bed truck, and "click" together on site, a cast-in 160˚ joint slotting the foot of each unit into the outer corner of the hoodie below. "You can easily recycle it – you take off the hoodie, separate the layers and use them again." The

RIGHT
A walkway links the Wabenhaus to a more rectilinear 15-home apartment building

BELOW
The precast system was trialled on the Munich scheme's balcony units

system was trialled on the Munich scheme, forming the building's self-supporting balcony units.

The modular company will also produce the furniture, specifically designed to save space by fixing to, or resting against, the walls. Super-light foam sofas can be arranged in different configurations. Triangular elements, which bolt directly into soft spots in the wall, can be used as shelving or platforms for chairs and desks, and to conceal electric cables. Bathrooms and circulation areas are manufactured as separate rectilinear pods, known as "crates", which form a linear service core at the rear of the building.

It may be a new way of living, but Haimerl hopes the Wabenhaus taps into traditional ideas of community. The Munich co-living scheme includes a shared kitchen and dining area, as well as a bicycle workshop, a grocery store and a rooftop terrace. All of the flats open off a "grand staircase" which steps diagonally up the length of the honeycomb structure. "I wanted a structure which shows community," says Haimerl. "If we live in boxes, each box is separated from the next. There are only two possibilities to connect them. The honeycomb, on the other hand, is woven together."

It offers another, often overlooked advantage too: "Living isn't just rational. We need to live in exciting spaces. They should be fun!" ■

Interview by Nick Jones

Photos: Killian O'Sullivan

HYBRID AND HANDSOME

Part precast, part in-situ concrete, Pitman Tozer's Farrimond House might just provide a template for estate regeneration. Tony Whitehead reports on the latest phase of Barking's Gascoigne estate revamp – and the first to be zero-carbon in operation

ABOVE
The building wraps around a 45m x 30m central courtyard and play area

As it entered the 21st century, the sixties-built Gascoigne East residential estate in Barking was already looking tired – a depressingly familiar mix of deteriorating high-rise towers, anodyne low-rise blocks, and bleak community space. To make matters worse, the area had also been plagued by a series of fires which, particularly after Grenfell, caused increasing concern.

Recent years have seen the start of real transformation. Failing blocks have been demolished, and to date some 1,400 highly efficient and affordable new homes have been delivered. The regeneration arm of the London borough of Barking and Dagenham, Be First, wants the new Gascoigne to be "a model of 21st century urban living", but visiting the estate today it becomes clear that this is no showy silver-monorail vision of the future. There is little in the way of extravagant architecture and, at first glance, some of the developments have a touch of mid-century style about them.

ABOVE
The facade features three different shades of handlaid brick and striking red metal balconies

The Pitman Tozer-designed Farrimond House is a good example. Four-to six storeys high and brick-clad, its 226 new homes are arranged around a central courtyard. Zoom in a little, however, and it quickly becomes apparent that this building offers considerably more than its predecessors.

"It's zero-carbon in operation," says architect Luke Tozer. "It is fed by a district heating system, the roof is covered with PV panels, and it conforms to high standards of insulation and airtightness."

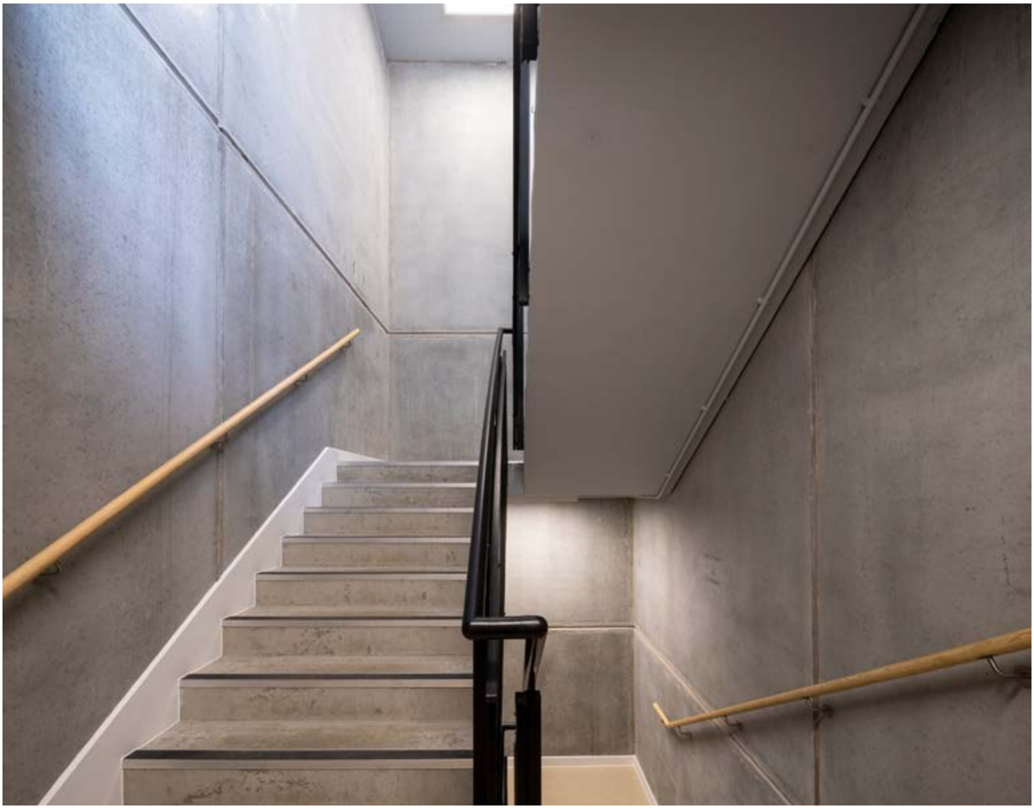
Every home, he adds, is dual aspect, giving residents plenty of light and a variety of views: "This also saves on mechanical air-conditioning, allowing cross-ventilation to keep the flats cool. And vitally, it allows every flat to have two means of escape in the event of fire."

Fire risk was a key factor in choosing concrete for the structure: "For this kind of large-scale, affordable housing project, concrete is a very cost-effective structural solution," says Tozer. "Add to that its inherent resistance to fire, and really concrete is the only material in town for projects like this."

Farrimond House occupies a 73m x 54m footprint with a spacious 45m x 30m central courtyard and play area. This gives "wings" of 14m and 12m in depth, including the walkways, via which the apartments are accessed. It has a hybrid concrete structure, featuring in-situ reinforced concrete floor slabs with precast columns and precast core walls. "Having decided on concrete for the structure, the question was how to make it as sustainable as possible," explains Nathan Fieldsend, associate with structural engineer Elliott Wood.

"In preplanning, we were looking at an all-precast structure: precast load-bearing walls spanned with precast planks. But when we compared that with an in-situ frame, we found the precast option initially came out slightly higher in terms of embodied carbon." →

ADD IN ITS INHERENT RESISTANCE TO FIRE, AND REALLY CONCRETE IS THE ONLY MATERIAL IN TOWN FOR PROJECTS LIKE THIS



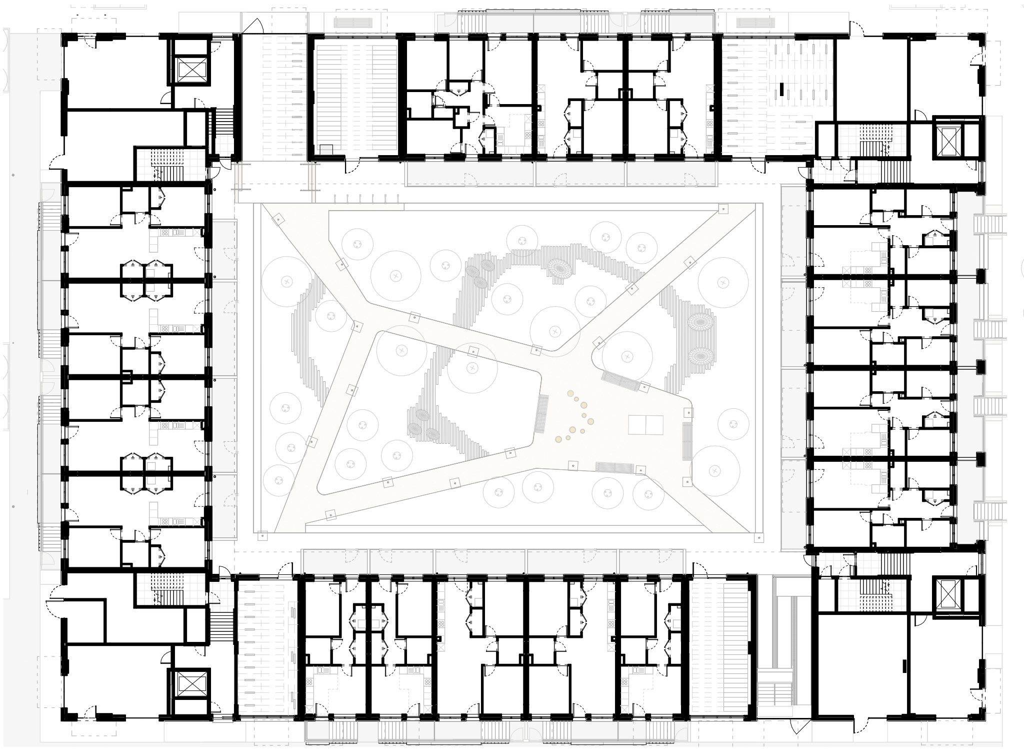
Fieldsend says this was partly due to the concrete mix used to help speed curing and production in the factory. "For example, the columns went from C35/45 in-situ concrete to C40/50. That involves extra cement."

Carbon was not the only factor in the decision, however, and the team wanted to incorporate precast where it brought other benefits. "The client wanted to embrace MMC [modern methods of construction] as far as practicable, and the contractor was keen to use precast, mainly from a programme point of view," says Fieldsend. "Being manufactured offsite in quality-controlled conditions helps maintain that speed of construction."

The challenge was to find a sweet spot between carbon efficiency and buildability. Fieldsend explains that the desire for material-efficient structural simplicity drove the choice of in-situ slabs, rather than the precast planks originally envisaged. "Most precast slab systems span one way," he says. "That would have created some

ABOVE
The building contains 420 precast wall panels, mostly twin wall and typically 4.5m x 3m

GROUND-FLOOR PLAN



difficulties with the column arrangements we have. We would probably have had to introduce beams, with all the extra material and carbon that would have involved. Reinforced concrete flat slabs were a simpler, more efficient option."

Flat slabs made sense architecturally, too. "Beams would have meant downstands," says Tozer. "Not only would that have created issues with our floor-to-ceiling heights, but they would also have got in the way of the MEP [mechanical, electrical and plumbing] services, many of which are carried above false ceilings."

To reduce the carbon content of the slabs, 30% of the cement in the in-situ mix was substituted with GGBS (ground granulated blast-furnace slag), and GGBS replaced 70% of cement in the concrete for the foundations.

The precast concrete elements contained no GGBS, because of the impact on curing times. So the team →

ABOVE
The layout of homes on the ground floor is the same as those above, so they stack from the foundations upwards without the need for transfer structures

instead focused on reducing carbon further by slimming the total amount of concrete in the building.

"A key way we did this was by regularising the layout," says Tozer. "Often, with housing, you find that everything stacks, apart from the ground floor due to the presence of foyers or back-of-house spaces. Here, we've made an effort to avoid that. The homes sit neatly on top of one another all the way down, which enables the loading to go straight down to the foundations. And because everything stacks, there is no need for any transfer structures – strengthened slabs or beams that would have been expensive in terms of material and carbon."

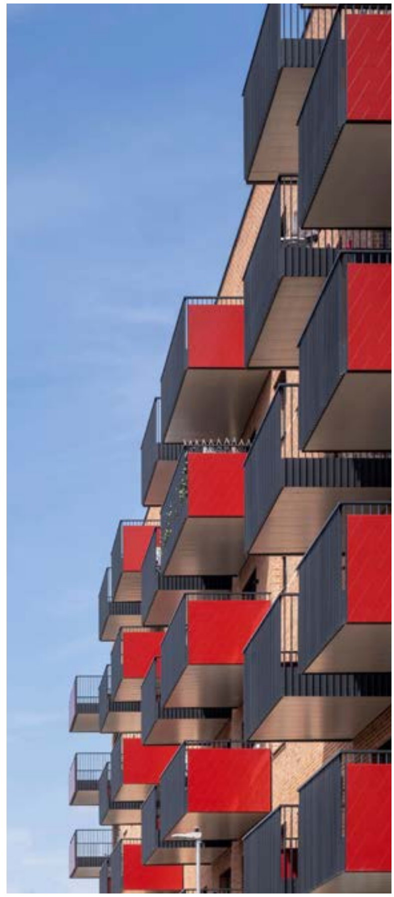
The next step was to remove material from the design. "We were able, for example, to take away some parapet walls – concrete upstands around the deck access. These were replaced with railings. But the main change was to switch from load-bearing walls to columns with stud walls. The columns use less material, and because of this the whole structure could become lighter and less material-intensive."

The 250mm-thick RC slabs are supported by 450 precast blade columns. In section these are mainly 1,000mm x 200mm or 500mm x 300mm – making them slim enough to be concealed within the stud walling which now forms the majority of the partitions between rooms and flats.

The building also contains 420 precast wall panels, used to form cores around lifts and stairwells. Most of these are twin wall, and typically 4.5m x 3m. "Being twin wall, with a cavity between two slim panels, makes the panels lighter," says Fieldsend, "so they are easier to transport and to crane around the site. Once the panels are in place, concrete is pumped into the cavities and this effectively stitches the panels together."

Tozer adds that one advantage of precast wall panels was their factory-controlled appearance. "You don't see much of the concrete in this building, but where you do – around the cores and stairwells – the precast wall units look very neat with a great finish." Where there are openings in the cores, solid panels have been preferred to twin wall to create a visually acceptable cut-edge.

The team is clearly satisfied that the material choices they made back in 2019 have paid off, delivering a smart, practical and very efficient building within a limited budget. "The refinements to the original design reduced embodied carbon by 5-10%," says Fieldsend. "If you think of the construction industry as having a carbon budget, then I would argue that buildings like this are exactly where you should be spending it – using concrete to create long-lasting, affordable and fire-resilient housing." ■



PROJECT TEAM

Architect Pitman Tozer
Structural engineer Elliott Wood
Contractor Willmott Dixon
Precast column supplier FP McCann
Precast wall supplier Oran Kilsaran

Photos: Jack Hobhouse

ORDER IN THE COURT

Stanton Williams' courtyard development at Emmanuel College, Cambridge is a serene composition of spaces underpinned by a furiously hardworking and material-efficient concrete structure. By Nick Jones

ABOVE
The lower ground floor contains a public foyer and exhibition space, and leads out onto the waterfront

Young's Court is the most significant development at Emmanuel College, Cambridge for over a century, and it has been designed to last well beyond the next. The 5,770m^2 scheme comprises three interlinked three-storey blocks of 50 student rooms, forming a courtyard in the south-eastern corner of the college grounds. The facades of warm red brick and precast concrete suggest an air of permanence not dissimilar to the college's 18th-century stone-faced Front Court. Inside the new buildings, this impression is confirmed, with exposed soffits revealing a solid structure of reinforced concrete. "Cambridge colleges build for the long term, which is why we've used robust, long-life materials," says Alex Buckland, →

ABOVE
The precast cladding consists of 900 single-skin, grit-blasted panels with horizontal patterning

senior associate at architect Stanton Williams.

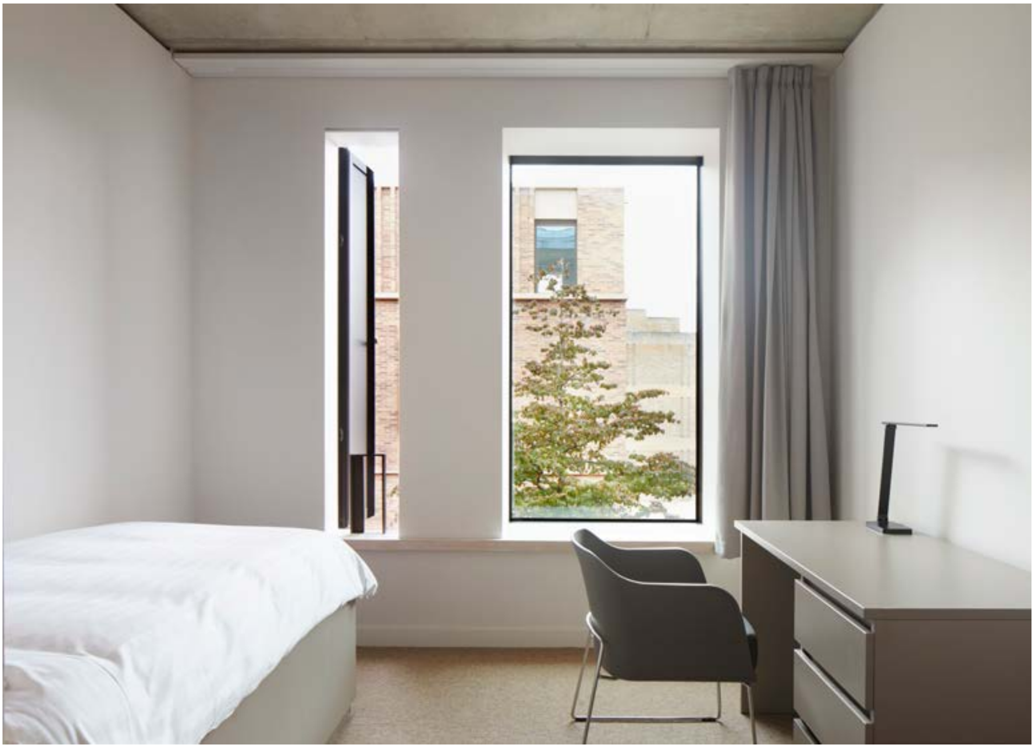
Emmanuel College had ambitious carbon targets for the project, with structural engineer Smith and Wallwork charged with assessing embodied carbon at every RIBA stage. The choice of a reinforced concrete frame was the result of a rigorous analysis of different structural solutions, which considered both embodied and operational carbon. When 2050 and 2080 climate scenarios were factored in, an airtight, thermally massive concrete structure offered the advantage of being able to accommodate rising temperatures without the need for additional mechanical cooling.

The crucial next step for the engineers was to maximise the efficiency of the structure, so that it required as little material as possible. "Material use is one of the big drivers for us, rather than carbon on its own," says Mike White, associate at Smith and Wallwork. "A lot of the carbon data is still quite new, so we generally find it's more reliable to focus on material volumes. If you reduce those, the carbon goes with it."

Because it was responsible for the whole civil and structural design, from the piling to the reinforcement in the precast lintels, the firm could optimise the foundations and superstructure as a single interdependent system. Every column and beam has been exploited to near full capacity, and an innovative raft foundation uses the weight of the concrete frame above to counteract the "heave" of Cambridge's Gault clay soil.

The buildings also have high levels of insulation, supplemented by natural cross-ventilation and shading, and the cooling effect of exposed soffits in the bedrooms and communal kitchens. The facades are self-supporting, reducing the opportunities for thermal bridging to the main frame. Embodied carbon, meanwhile, is further

ABOVE
The stairwells on the new student courts were made from precast concrete. Sections were lowered in from above using a crane stationed in the central court



ABOVE
The bedroom soffits are exposed to maximise the effect of the structure's thermal mass – part of a climate resilience strategy that modelled the building against 2050 and 2080 overheating scenarios

reduced through the use of 50% GGBS in the structural concrete, and was measured at 1,902tCO_2e (A1-A5).

The soffits are part of a restrained interior palette dominated by white painted walls and lye-bleached Douglas fir joinery. The exposed elements had the same specification as the rest of the frame and were cast against phenolic-filmed ply formwork. The thermal mass effect is accentuated through the use of ventilation panels next to the bedroom windows, and low-energy extraction via a bulkhead above the en-suite bathrooms.

Young's Court replaces an expanse of surface parking, which was hidden away behind a 1960s student housing block. Parking spaces have been reduced by more than half and moved underground, on two levels in the 7m-deep basement. The car park has been designed with future adaptation in mind. Access is via two car lifts – which means there are no ramps – floor-to-ceiling heights have been optimised, and soft spots have been considered in the design to enable reconfiguration into workspace. →

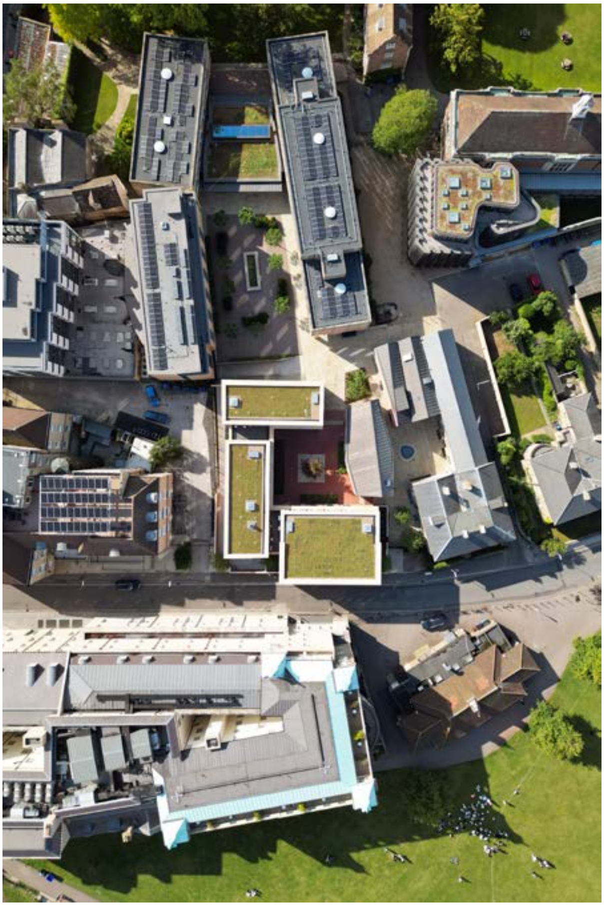
The basement is in many ways the key to the development, stretching all way across the 1,300m^2 site, to within 1m of a grade II-listed Georgian villa, Furness Lodge. The flexible-raft foundation, which requires just perimeter sheet piles, reduces the quantity of concrete in the substructure by about 270m^3, or 25%. Extensive structural modelling indicated that the upward heave of the surrounding clay would remain within acceptable boundaries, with a 25mm swell projected for the centre of the site. "That's actually small-scale – we were comfortable with that," says White. As there are very few case studies of this approach, Smith and Wallwork employed an independent geotechnical expert to conduct a peer review. "That gave us the confidence to go to the client and say, we can save you nearly 300m^3 of concrete, simplify construction and make the dig easier." Real-time remote sensors were installed on the surrounding buildings to monitor ground movements during construction.

The basement soffits reveal an intricate network of transfer structures, which carry the load from the superstructures down to the raft. "A bedroom grid doesn't match a car park grid," points out White. "The buildings all sit on different podiums and at different levels." The basement soffits are a maze of drop slabs, beams that slant downwards mid-span, and cantilevers to the slab edge. Smith and Wallwork spent four months designing these structures alone to work out the most material-efficient solution: "Every beam is at

GROUND-FLOOR PLAN

SECTION

1 South Court
2 Student bedroom
3 Student kitchen
4 Fellow's set and study
5 Vehicle lift
6 Bar lounge
7 College bar
8 Furness Lodge Court
9 Teaching room
10 Seminar room
11 Basement parking
12 Event space



85-100% capacity." The substructure includes 70% GGBS, so slower strength gain also had to be taken into account in the structural calculations.

The architects have taken many of their cues from the historic college, parts of which date back to the 16th century. The Young's Court facades echo the 17th-century Chapman's Garden, with carefully selected red brick, in a narrow format, lent a handcrafted appearance through the use of churn-brushed lime mortar. "Every facade responds differently to its context," says Buckland, adding that they are more strongly articulated on the eastern elevations, which border a bustling side street and the green expanse of Parker's Piece, one of central Cambridge's largest parks. Hit-and-miss brickwork and setback upper floors soften the streetfront, while passers-by are offered glimpses into the landscaped courtyards beyond. Precast concrete lintels and cills evoke the limestone of the Front Court, and angled window reveals frame views out toward the park. In all, the facade comprises more than 300 precast units.

The overall Young's Court development is part new-build, part reuse – an exercise in stitching together some of the more ad-hoc elements of the college. To the north of Young's Court, Furness Lodge has been refurbished and extended on two sides, providing a double-height bar, common room and teaching spaces, as well as forming another courtyard. The 1960s student accommodation has been rejuvenated, with a gravelled courtyard flanked by plane trees. This is enclosed at its western end by a new, fully glazed cafe and informal workspace, which has opened up visual connections between Young's Court and the historic Front Court and Chapman's Gardens. ■

ABOVE
The green-roofed Young's Court is on the eastern edge of the college, bordering the green expanse of Parker's Piece

PROJECT TEAM

Architect Stanton Williams
Structural and civil engineer Smith and Wallwork
M&E engineer Skelly & Couch
Main contractor Gilbert-Ash
Precast concrete Cambridge Architectural Precast

SOFT SCOOP

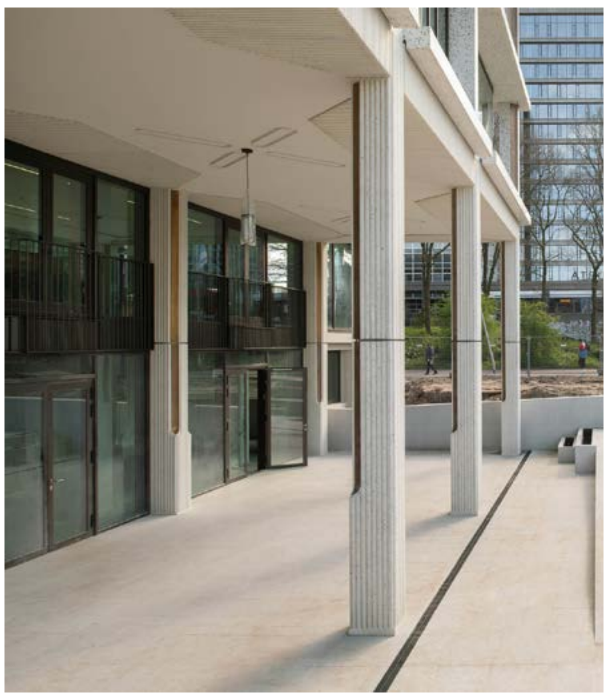
Photos: Aiste Rakauskaite

In Amsterdam, V8 Architects has taken an outside-in approach to revamping a brutalist 1970s office block. Originally wrapped in ribbed brown concrete panels, the fortress-like PI59 has been opened up with a glazed facade framed by terrazzo-like polished concrete and brass.

At ground level, the panels are fluted and acid-etched in an echo of the ribbed 1970s aesthetic. From the first floor up, this gives way to a lighter grid of columns and beams. Blue-grey marble aggregate, in sizes from 25mm to 40mm, creates the terrazzo effect, while one side of each column has been scooped out

and inlaid with brass. "It's really to emphasise the softness," says V8 director Michiel Raaphorst. "You cut out a corner and it's almost like ice cream."

The joints between the column and beam elements are clearly articulated – a way of navigating the deviations in size and varying tolerances of the original frame. "The more components you have, the more chances you have to resolve small differences. Normally architects are a little bit afraid of joints, but here the joints are really designed – almost more than the elements between them."



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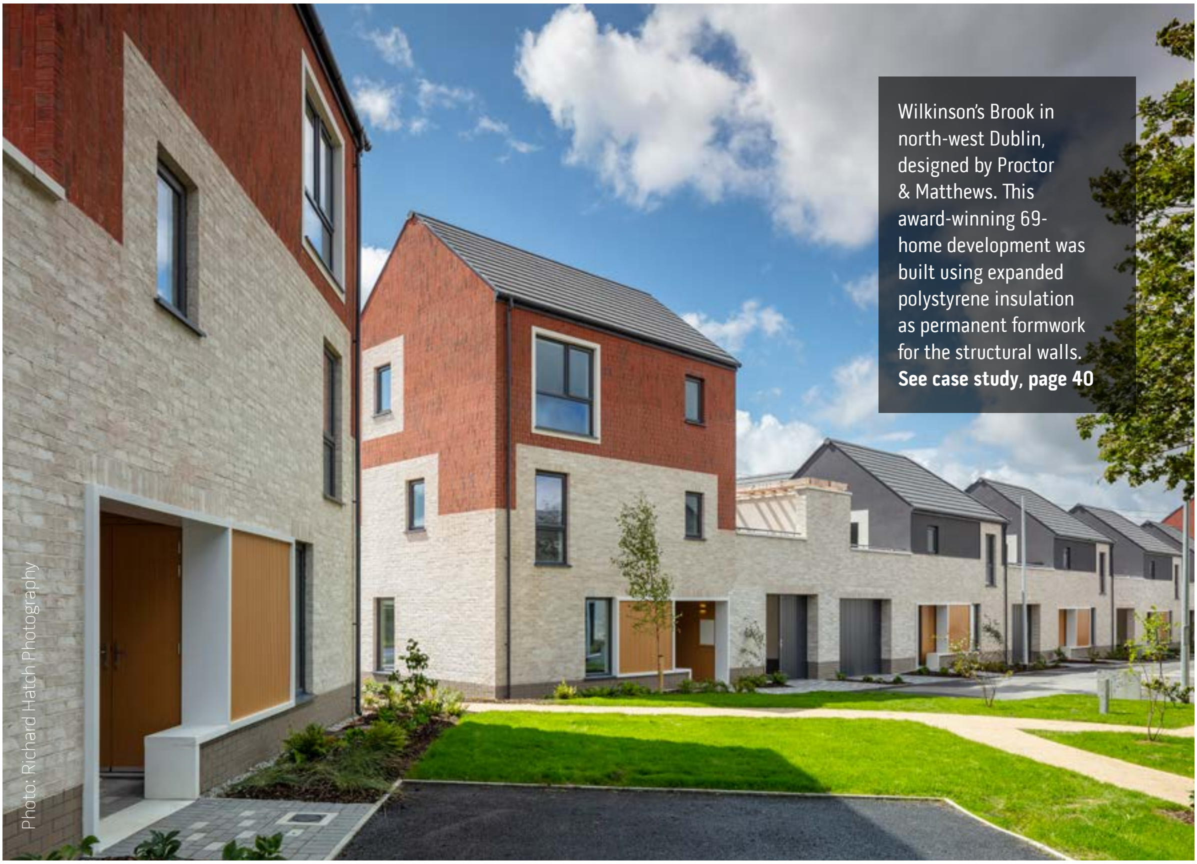

Wilkinson's Brook in north-west Dublin, designed by Proctor & Matthews. This award-winning 69-home development was built using expanded polystyrene insulation as permanent formwork for the structural walls. **See case study, page 40**

Insulating concrete formwork for low-rise housing

ICF is a quick, cost-effective method for constructing watertight, highly insulated building envelopes. Could it be a solution to the government's housing challenge?

The government has committed to building 1.5 million new homes over the lifetime of this parliament. This flagship policy will inevitably focus not just on what we build, but also on how we build it, continuing the drive for modern methods of construction (MMC) to improve efficiency, quality and speed of construction.

In the context of skills shortages, the need to maximise resources and the sheer amount of construction ahead of us, the case for rationalised factory production is compelling. But low-rise family housing also poses a number of challenges for MMC providers. Residential developments need to cater to different markets and usually require a variety of designs specific to local needs, environmental factors and the complexities of a site.

In response, some MMCs incorporate elements of traditional construction, allowing greater design flexibility without compromising build rates. One such method is insulating concrete formwork (ICF), which currently accounts for 2-5% of the UK housing market. ICF systems comprise hollow blocks or panels made of an insulating material. These are produced in a factory before being delivered to site, where they are stacked to form the shape of the building's outer wall. The outer and inner leaves of panels act as a mould for the concrete, which is pumped into the cavity to form the structural element of the wall. If walls have large openings or significant loads applied to them, reinforcement can be added before the concrete is poured.

The blocks or panels remain in place as a permanent part of the wall assembly, and cladding and internal finishes can be applied directly to the insulating material. This allows contractors to quickly achieve a watertight, airtight and highly insulated envelope.

Types of ICF

A wide range of ICF systems are available, but there are two main categories: blocks and panels. In the UK, blocks are usually made of expanded polystyrene (EPS) or woodcrete, a rigid material made from wood fibres bonded with cement. For external walls, woodcrete blocks usually contain a layer of rigid insulation behind the outer face.

All block systems are composed of two leaves of insulation joined together by insulation or a matrix of steel or plastic ties. The ties can also be used to support reinforcing steel, and provide anchor points for the fixing of finishing materials. Blocks are designed with interlocking surfaces, allowing them to be stacked quickly on site.

Unlike blocks, panels don't have to be moulded, which means they can be made from extruded polystyrene (XPS), which has a closed-cell structure. Panel systems are typically connected with metal or plastic rails, requiring a greater degree of assembly on site, but offer the flexibility of being able to change the depth of the wall assembly.

Panels and blocks are light, and therefore easy to handle without mechanical assistance – one reason why the system is often favoured by self-builders.

Photo: BecoWallform

ABOVE
Rosemary Gardens, Park Wood, Kent. This social housing development by Golding Homes was built using interlocking blocks of EPS insulation supplied by BecoWallform

Concrete specification

The consistency of the concrete is important – too dry and it won't flow around the connectors, too wet and it may place too much pressure on the formwork. Widely available designated concretes may be used to achieve the necessary properties – these should be discussed with the designer and concrete supplier. Typically a slump of S2 or S3 and a maximum aggregate size of 10mm is recommended by manufacturers. Mix designs may vary for different applications, and you should check first with your supplier.

The concrete is typically placed by pump, and then vibrated to expel air and increase density. If reinforcement is used, self-compacting concrete should be specified to avoid the need for vibration.

A proprietary support system may be required around openings, corners and cut units to provide additional stability. This is removed once the concrete has set. The formwork may need to be temporarily supported externally during pouring, depending on the height of the pour and concrete consistency.


Photo: BecoWallform

ABOVE
The development at Rosemary Gardens includes 18 bungalows designed for older people. The BecoWallform ICF structures are finished in a mix of brick, render and timber

The permanent formwork offers an additional benefit because the concrete will cure quicker as heat is retained by the surrounding insulation. This is particularly useful for concrete containing high levels of GGBS cement replacement that is being poured in winter. ICF therefore potentially facilitates the use of lower carbon concretes.

Thermal efficiency

Reliable thermal performance is one of the key advantages of ICF. Studies have shown that gaps of as little as 3mm between insulation boards can undermine U-values by up to 0.2W/m^{2}K. For ICF, continuous insulation is one of the system's defining characteristics: if there are any gaps, it will very clearly fail as formwork. There are numerous examples of ICF being used to construct to Passivhaus thermal standards.

As a fully integrated, enclosed system, ICF offers very little opportunity for thermal bridging from connecting ties or elements such as lintels and cills. The fact that the concrete sets in direct contact with the insulation also reduces risk of thermal by-pass and enhances airtightness, preventing any air movement in the assembly. Inherent airtightness and virtual elimination of cold bridges also limit the risk of condensation and mould.

Fire performance

ICF systems typically offer between two and four hours of fire resistance, with greater resistance achieved by walls with wider concrete cores. They should be tested to consider both reaction and resistance to fire in accordance with the relevant EAD standard.

Concrete does not burn, does not emit toxic fumes when exposed to fire, and has a slow rate of heat transfer, ensuring the structural integrity of the building.

Polystyrene, however, is a flammable material so EPS and XPS insulation is treated with a flame-retardant additive to resist ignition for longer. In the event of a fire, the concrete core will help to contain the fire within the room and prevent it spreading.

For woodcrete, the mineralisation process that occurs during manufacture makes the blocks burn-resistant, and can give them a 90-minute fire rating.

BELOW
Nudura's ICF system was used for the walls, floors and roof of the Curly House, an award-winning Passivhaus scheme in West Sussex designed by Ecotecture

Photo: Nudura

Photo: Thermohouse

ABOVE
The cylindrical forms of this contemporary home in east Devon, on the site of a former Victorian water tower, were built using Thermohouse EPS wall blocks

Design considerations

ICF systems can be adapted to a variety of designs, to maintain architectural quality on larger developments with multiple housing types. At Wilkinson's Brook in Dublin, for example, architect Proctor & Matthews originally designed the 69-home scheme for either traditional construction or MMC. Working with developer Glenveagh Homes to assess the potential of different panellised systems, the team found that ICF could be used on all seven housing variants on the masterplan while achieving the architectural vision (see overleaf).

Designers are aided by a wide variety of standard forms, including straight planks or panels, and right-angled, 45° and curved blocks. If needed, these can be cut using standard construction tools. The systems can work with any foundation – including strip, concrete raft and insulated raft – and most common floor and roof types, such as wooden joists, concrete beams and block, and hollowcore planks.

External walls need protection to provide weather resistance, and can be faced with various materials, including render, brick skin, timber and stone. Internally, plasterboard is the most common finish, fixed directly to the walls. The formwork can be chased to accommodate wiring and pipework. ■

Further technicial information is available from the Insulating Concrete Formwork Association (ICFA)

Photo: Richard Hatch Photography

Wilkinson's Brook, Dublin

Case study Proctor & Matthews has revived a traditional form of settlement with a modern method of construction

At Wilkinson's Brook, architect Proctor & Matthews has looked to the past of Irish housing to transform its present. The practice has taken inspiration from *clachans* – traditional settlements clustered around a communal focal point – to create a neighbourhood of "own door" homes centred on green spaces connected by a network of shared-surface streets.

The 69-home development has won plenty of admirers for its compact formal arrangement, which moves cars off the street into integrated carports and provides private outdoor space on generous multi-level terraces. Earlier this year, it won a Royal Institute of the Architects of Ireland Award, with the judges praising it for "enhancing the living experience of its residents".

But it is also notable for the way it was built. The use of insulating concrete formwork (ICF) created a highly efficient thermal envelope, while speeding up the programme, taking watertightness off the critical path and reducing site waste.

The house types – of which there are seven variants across the development – were not specifically designed as ICF structures. "There was a certain flexibility," says Stephen Proctor, founding director of Proctor & Matthews. "We were asked to design something that could be built either traditionally or with MMC [modern methods of construction] –

whether timber, panellised or ICF." The key advantages of the latter system were that it could be supplied locally, built very quickly, and was cost-effective – an important consideration with nearly a quarter of the homes being made available under Ireland's Affordable Purchase Scheme.

The chosen ICF system uses interlocking hollow blocks of graphite-enhanced expanded polystyrene (EPS) insulation, with integrated cross-ties made from recycled polypropylene and spaced 150-200mm vertically. The blocks – castellated top and bottom like Lego – were stacked directly on strip foundations, ready for the concrete to be pumped into the cavity in half-storey pours. The resulting walls are 300mm thick with two 75mm leaves of insulation around a 150mm concrete core.

The proprietary system included a corner block and an insulated rebated window reveal, which simplified detailing around openings, as well as integrated reinforced lintels. This was particularly useful because of the unusual typology, with the setback terraces and parking incorporated within the building footprint. "It could have been a very big, complicated hybrid structure, with lintels and steels to go over the carport," says Proctor. Where additional reinforcement was needed, the system allows for two courses of rebar to be supported on the cross-ties. "It was just very straightforward," adds Eamonn Doran, of executive architect Doran Cray. "A nice, uniform concrete structure. The structural engineers loved it."

Because the structure is completely enclosed in insulation, ICF virtually eliminates thermal bridging. Combined with rooftop photovoltaic panels and air-source heat pumps, the thermally efficient envelope has helped the homes to secure an A1 under Ireland's Building Energy Rating scheme.

The system also offered aesthetic benefits. "It gave us the opportunity to do lots of interesting patterns with brick that would have been more expensive and added time with traditional methods," says Doran. A variety of brick slips, including some striking vertical bonds, and coloured renders were applied directly to the outer layer of formwork.

There was another practical advantage, particularly relevant in the Irish (and British) climate. "The terraces couldn't be waterproofed until the building was nearly fully up, with the roof on," says Doran. "With a timber frame, you would need to tank and seal the terraces, but here there was no water damage to the structure at all. "To me, that's the biggest advantage of ICF with this typology – it can be rained on." ■

PROJECT TEAM

Developer Glenveagh Homes
Lead architect Proctor & Matthews
Contributing architects de Blacam and Meagher, Doran Cray
Civil and structural engineer DBFL

FINAL FRAME: KINDERSPITAL, ZURICH

Designed by Herzog & de Meuron, Zurich's new acute care centre for children is horizontally arranged into "neighbourhoods" connected by streets and courtyards. Its highly flexible design is based on a three-storey reinforced concrete frame wrapped in a self-supporting skeletal facade, into which more lightweight elements can be inserted or removed as departmental needs change. The building has been awarded a platinum rating by the Swiss Sustainable Building Council.

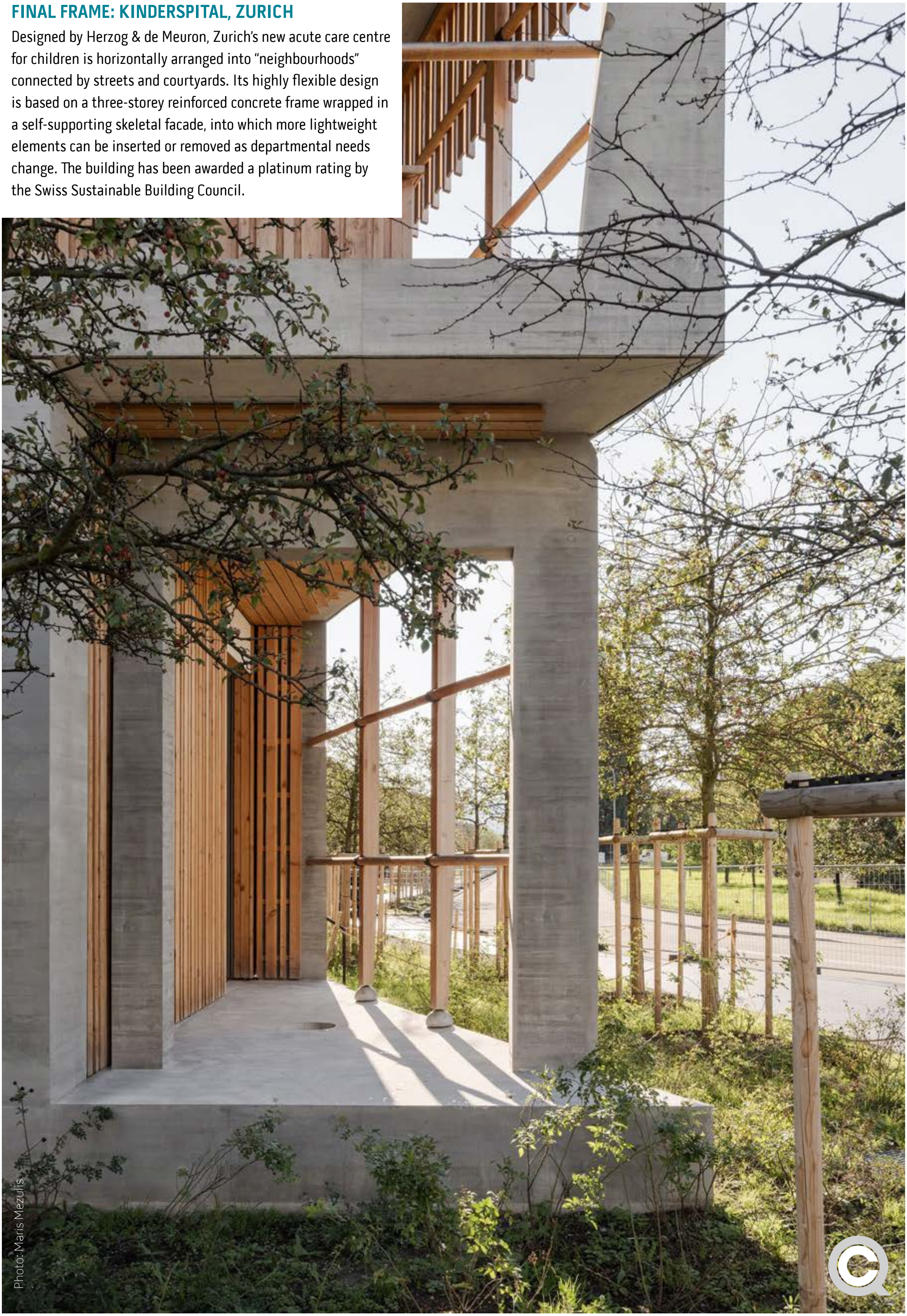

Photo: Maris Mezulis