CONCRETE QUARTERLY

The Concrete Centre

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LAUNCHING IN STYLE
Make reinvents the office – with exposed concrete, woven brick and a Soviet missile

SHAPE-SHIFTER
Herzog & de Meuron lands a mysterious object in the heart of historic Oxford

A MEETING WITH M
Paul Monaghan of Stirling winner AHMM on how the road to success was paved with concrete

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Catch up with the lastest issues of Concrete Quarterly – as well as our archive stretching back to 1947 – at www.concretecentre.com/cq

AGENDA

Guy Thompson
Head of architecture, housing and sustainability, The Concrete Centre

Known unknowns

Of the many specialist disciplines involved in shaping the built environment, one that is sadly lacking is clairvoyance. Sustainable design increasingly encompasses the whole-life impacts of buildings, which presents the impossible challenge of foreseeing what a building may have to contend with over its lifespan, and how it can be designed for a future that may look very different from today while meeting the demands of now.

One answer will surely be greater reuse and refurbishment compared to new build. Buildings do become outdated and replacement is an inevitable part of progress. But the sums are changing. It is far less carbon-intensive to reuse elements of buildings such as structure and foundations than to demolish and start again – a point that enlightened clients are just beginning to take on board. These elements can, in any case, last much longer than the commonly used 60-year study period, raising the question as to whether this remains a valid approach. Yes, 60 years is ambitious for some buildings, but it is far too short for others, especially housing – and half the typical span used for infrastructure such as bridges.

One architect that has successfully challenged perceptions over several decades is AHMM – the practice's Paul Monaghan offers some interesting insights on page 15, and will be speaking at The Concrete Centre's Cafe Concrete event on 18 May (see opposite). Unfortunately few clients can define their requirements as to the lifetime of a building, beyond the short-term or the point of sale. Notable exceptions to short-termism are the hallowed universities of Oxford and Cambridge, whose colleges have always been built not for five or 50 years, but hundreds – the Blavatnik School of Government in Oxford (page 4) exemplifies this continuing approach, a durable concrete shell that provides adaptable spaces within.

YES, 60 YEARS IS AMBITIOUS FOR SOME BUILDINGS, BUT IT IS FAR TOO SHORT FOR OTHERS

As teams wrestle with the problems of reusing building structures, it may cause them to think more seriously about how new buildings can be designed to be repurposed in the future. Answering that question may hold the key to designing truly sustainable buildings – and is perhaps as close to clairvoyance as we can hope to get.

ZAHA HADID: AHEAD OF THE CURVE

Few architects have graced the pages of Concrete Quarterly more often over the past decade than Zaha Hadid, who died suddenly in March. "But then few have done more to push concrete to the limits," writes This is Concrete blogger Nick Jones, "showing what often seemed like wilful disregard for the laws of gravity and the sound sleep of structural engineers." Since the extraordinary Phaeno Science Centre in Germany in issue 208, CQ's writers have struggled to find the words for exhibition spaces that "melted down", components that were both and neither walls and floors, surfaces that curve in two or even three dimensions. There will doubtless be more from ZHA in these pages. "In fact, the new ferry port in Salerno is surely a contender for the next issue …"
Join the debate at www.thisisconcrete.co.uk

On the cover:
Hiscox headquarters in York by Make Architects
Produced by:
Wordmule
Designed by:
Nick Watts Design

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www.mineralproducts.org

Higher and higher

SimpsonHaugh's 50-storey One Blackfriars rises over London's South Bank. The 2016 New London Architecture report on London's towers found 119 new tall buildings planned since spring 2015, bringing the total to 436 – 73% of them residential.

Reputation restored?

Well done to architect Carlos Quevedo, whose restoration of the Castillo de Matrera in southern Spain – much mocked on social media – has been shortlisted for an Architizer A+ award.

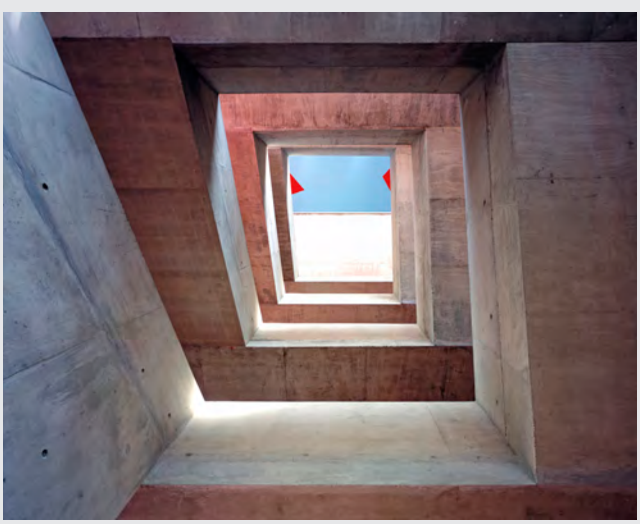
Passive remedy

The Centre for Medicine at the University of Leicester has become the largest non-domestic Passivhaus building in the UK. The centre, designed by Associated Architects, has a concrete frame and precast-concrete cladding.

Curtain up

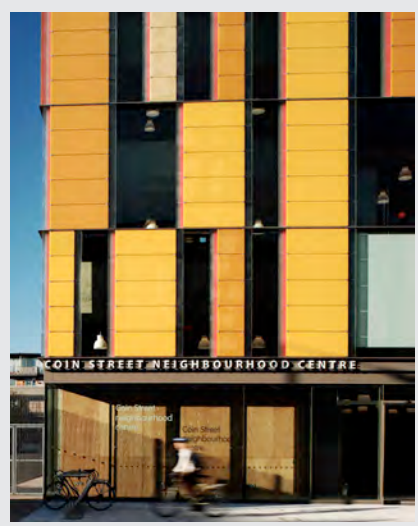
The latest phase of Haworth Tomkins' refurbishment of Denys Lasdun's National Theatre is now open. The Sackler Pavilion houses a bookshop and box office.

Photos: Ben Veasey, Mariano Copete Franco, University of Leicester, Philip Vile



CAFE CONCRETE @ COIN STREET

Haworth Tompkins, AHMM and McLaren Excel will be among the speakers at the first of a series of free "pop-up" events from The Concrete Centre, providing inspiration and guidance on visual concrete. Seminars, samples and expert advice will be on offer at Cafe Concrete, which takes place at the Coin Street Neighbourhood Centre on London's South Bank (pictured) on 18-19 May.
For details, go to www.concretecentre.com/events



Photos: Edmund Sumner, Philip Vile

DREAMING SPIRALS

Herzog and de Meuron has landed an audacious glass shape-shifter in the heart of Oxford, complete with swirling staircases and a dizzying concrete atrium. By Nick Jones

Finally, a landmark building that defies all nicknames. Critics have likened it, variously, to a spaceship, a stack of CDs and a pile of washing-up, but none of these seem likely to stick. At a public meeting in 2013, one Oxford citizen dismissed it as "the concrete marshmallow", but the building has far too many cookie-cutter straight edges. There is a distinct possibility that Herzog & de Meuron's Blavatnik School of Government might go through life simply as the Blavatnik School of Government.

Its form is certainly striking, and surely one of the most startling additions to Oxford's rarefied architectural fabric in the city's long history. On a prominent site directly opposite the neoclassical Oxford University Press, it rises as a stack of five glass drums framed in bands of honey-coloured concrete. These drums are all of different shapes, which creates a series of overhangs, setbacks and terraces. The circular ground floor is topped by a larger horseshoe-shaped volume with a flat facade and a showy "window on the world" – the largest piece of double-glazed plate glass in Europe (see box). Above this, a stretched oval bulges out over the entrance, before the plan reverts to a smaller circle. Only the rotunda-like top two floors stack neatly one on top of the other, even as they push the building up to 22m – 4m above the accepted limit for additions to central Oxford's skyline.

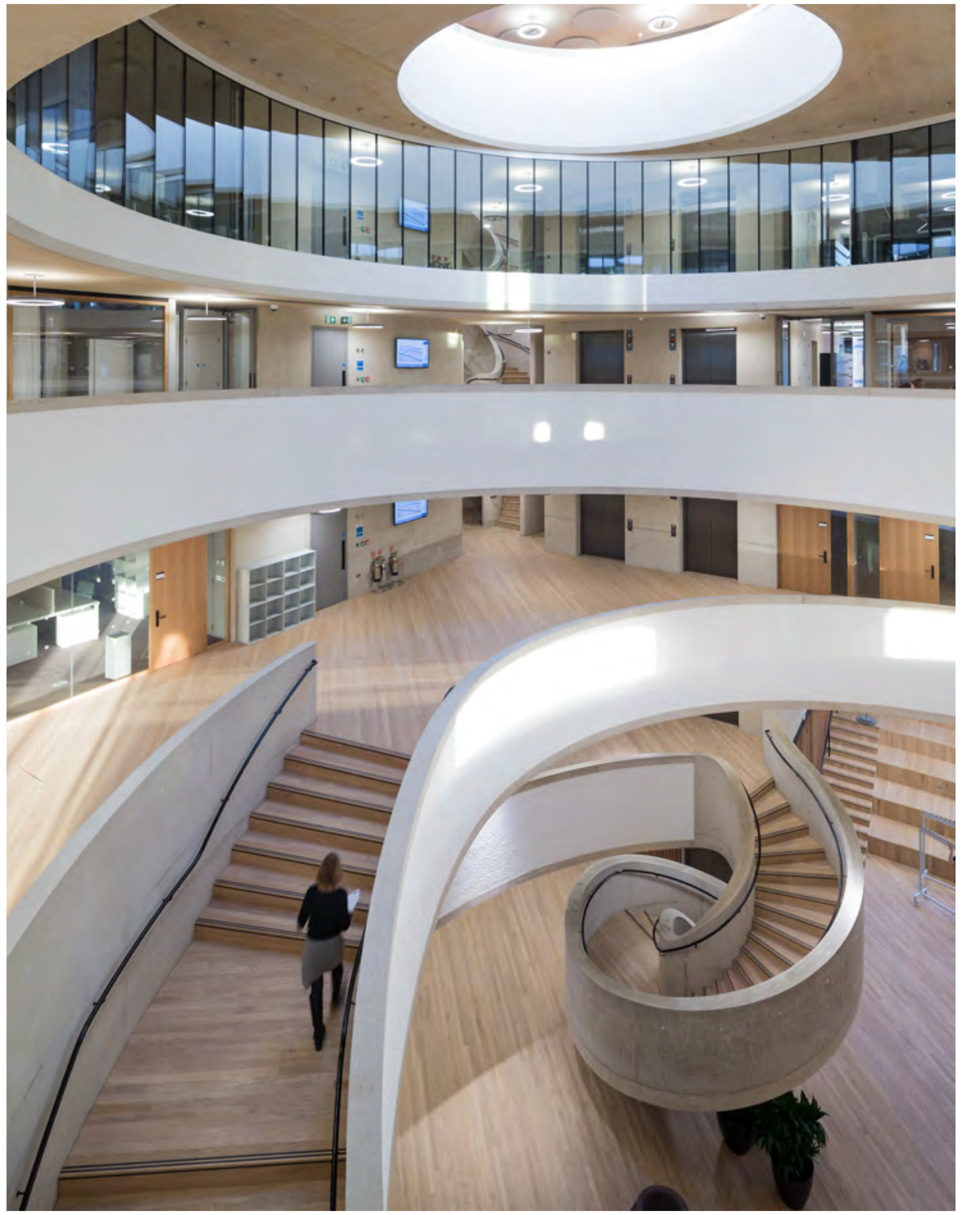
Despite this apparent ostentation, the other striking thing about the School of Government is how well it fits into its context. The rectilinear first-floor facade is a deliberate continuation of the line of the portico of the Greek Revival church next door, and the building tactfully steps back from the main road as it rises. Even the bull-nosed precast-concrete sills and lintels, which support a double-skinned frameless facade, are apparently a reference to the stone architraves on Wren's Sheldonian Theatre a few streets away. Jacques Herzog says that, when faced with the beauty of Oxford's historic buildings, most modernist architects "tried to be modern but nevertheless behave well. And it's very difficult to behave well and do it the right way without losing your own identity". Somehow, it's a trick that the School of Government manages to pull off rather well.

On entering the building, it appears more modern than well-behaved. Passing through the security gates, a sweeping staircase of in-situ concrete draws you down to a basement-level "forum", a space for students to mix and stage events. To look up from here is a slightly dizzying experience. An atrium spirals up the full height of the building, shifting at each level with the irregular plan. The floorplates, wrapped in concrete balustrades, seem to float above the forum, thanks to cantilevers up to 9m deep (see box, overleaf). Coupled with the curving staircase down to the basement, as well as a separate in-situ concrete spiral staircase at the back of the forum, the effect is of unspooling tape. "The building is winding itself up," says Herzog, "so it offers views and perspectives in all directions. People can be on these balconies and overlook this central space, or talk from different levels."

This also means you can get a sense of the building's programme just by standing in the forum: from the ground-floor cafe, past the teaching rooms on the first floor, to the glazed academics' offices on the second and third floors, and even up through the smaller opening in the fourth-floor slab to the common rooms above.

THE BUILDING IS WINDING ITSELF UP, SO IT OFFERS VIEWS AND PERSPECTIVES IN ALL DIRECTIONS. PEOPLE CAN TALK FROM DIFFERENT LEVELS

Photo: Iwan Baan



Photos: Iwan Baan, John Cairns

CLOCKWISE FROM LEFT
An in-situ concrete staircase spirals down to the basement forum; The unusual form changes shape on each level; Likewise, the atrium rises in an irregular plan; The rectilinear first floor cantilevers 4m over the entrance facade

PROJECT TEAM
Architect Herzog & de Meuron
Structural engineer Pell Frischmann
Design-and-build contractor Laing O'Rourke (Expanded Structures)

This may all seem a far cry from the traditional Oxford college, but HdM has included a number of respectful nods. While the rounded shape of the atrium is inspired by the forms of government buildings from around the world, the forum is also a reference to the city's cold, windswept quadrangles. "You are shocked when you see the beauty of these colleges," Herzog says. "Colleges have these open courtyards which we couldn't do, as the programme was so big and the site was very small. But that impulse to make a central space was here at the very beginning." The materials, too, are both resonant of their context and defiantly modern, with oak panelling used in playful riposte to the university's fusty senior common rooms, and walls, soffits and stairs in limestone-hued concrete. As HdM partner Ascan Mergenthaler says: "Limestone is the obvious choice in Oxford, but it would be almost like a cliché. It was important we used today's building materials."

The contractor charged with realising the in-situ concrete was Laing O'Rourke. For a company well known for using off-site manufacture and precast elements wherever possible, this may have seemed a brave move. Not only did the structure appear to defy gravity, but the finishes had to be impeccable – with no scope for second chances. HdM is the sort of architect that likes to express the bones of a building, and doesn't like its concrete to be made good afterwards to hide marks and blowholes. As Tim Rowe, project manager at Laing O'Rourke's specialist concrete division, Expanded Structures, puts it: "What you strike is what you get."

For HdM and Expanded, this meant embarking on an exhaustive testing process with concrete supplier Tarmac. "We did a lot of mock-ups in the beginning to get the right tone, the right methods, and so on," says Mergenthaler. The challenge was compounded not only by the amount of reinforcement demanded by the complex structure, but also the quantity of M&E that had to be cast in – Rowe says that one floor has about 650 containment boxes embedded in the underside of the slab. The workability of the concrete was therefore critical.

The team eventually decided on a high-flow mix with 40% GGBS cement replacement and an added plasticiser. They then cast an exact replica of a two-storey section of wall and, just to be on the safe side, decided to cast all of the concrete to the same high specification, whether it was visible or not. This meant that the plant rooms on the lower basement level could be treated as a final test run.

The result is an impressive exposed finish. The lightening effect of the GGBS has drawn out the honeyish tone of the local limestone aggregate. The soffits are seamless expanses, with the services rising discreetly up through the oak flooring. And the colour is consistent throughout the interior, thanks largely to a contract that insisted the same quarry be used for the whole project.

The real highlights though are the two sculptural spiral staircases – the one rising up from the forum to the ground floor, and another connecting the upper levels above the rear entrance (pictured on the previous spread). The first twists almost organically in two planes, an effect that required meticulous setting out. The moulds were designed in 3D by Loughborough-based Patterns and Moulds, and this model was then used to make the formwork on site, as the shapes simply could not be expressed in 2D drawings. "We were very nervous about it," says Rowe. "We had a full-time land surveyor on site to set out all the curved elements – it was one of the best decisions we made." The moulds were carved out of MDF and then sealed with five coats of varnish.

If anything, the other staircase posed even greater challenges. Because it corkscrews up through an enclosed cylindrical structure, in-situ casting was impossible. The situation seemed tailor-made for Laing O'Rourke's precast capabilities, but the fear was that this would undermine all the work done to achieve a consistent in-situ finish. Fortunately, a third way was found: the staircase was precast – but on site. "We wanted to make sure we had direct control, so that the lay person would see it as an in-situ concrete staircase," says Steve Holland, project manager at Laing O'Rourke. "It was the same concrete that was supplied, same batching plant, same mix, same joiners, same electricians doing the services." Each floor was cast in three sections, two of which were repeated, while the landing segment had to be bespoke as the floor-to-ceiling heights were different on each level. The sections were then lowered by crane through the cylinder. Rowe believes it's the first time such a spiral staircase has been built in precast concrete.

It certainly succeeds in merging seamlessly with the in-situ structure. And it's well worth the climb up to the fourth floor too. Here, you can pass through the rotunda to a large terrace that enjoys a rare view of Oxford. Perpendicular to the High Street, the dreaming spires are laid out as if in a line. It is a vivid reminder that this bold statement of Oxford's future never loses sight of its past.

How to make concrete float

How do you build a structure with thin in-situ concrete elements, several cantilevers, little visible means of support and Europe's largest pane of plate glass? The answer, it seems, is with a lot of 3D modelling, and even more propping.

"Fifteen years ago, if an architect said they wanted to build this, you'd have said it wasn't possible," says Tim Rowe of Expanded Structures. Pell Frischmann's structural design required full 3D modelling of everything from the arrangement of the reinforcement, which varied from floorplate to floorplate, to the temporary propwork. Even the site workers had to be fully trained to read Revit software.

The results are evident as soon as you enter the school. Despite the weight of a concrete frame bearing down on the front of the building, the entrance is column-free, thanks to a vast 1,100mm-deep post-tensioned in-situ concrete beam in the ground-floor slab, which transfers the load via two diagonal shear walls to the basement structure.

The "floating" atrium and the striking cantilevers on the front elevation presented more of a challenge. It was important that the floor slabs looked delicate, but at just 300mm thick, they couldn't support such deep cantilevers. Pell Frischmann solved this by using the walls above the slabs as cantilever beams. The whole thing would then be held together by the fourth floor – a 350mm-thick slab that was post-tensioned to give it sufficient tensile strength to span the atrium.

The problem was that, until the level four slab was cast, the whole structure was inherently unstable. "If we hadn't put in a huge amount of temporary propping, the whole building would have imploded," says Rowe. The area of most concern was the rear entrance, which was also column-free and directly beneath the massive cylindrical drum that houses the precast-concrete spiral staircase. "The propping had to support 600 tonnes of concrete until it was properly tied back at level 4," says Rowe. "We had to put in structural steelwork down through two levels of the basement."

Meanwhile, back at the front of the building, the propwork had another important role to play. The first-floor facade contains a centrepiece window that, at 10.5m x 3.2m, is the largest sheet of double-glazed plate glass ever produced in Europe. It was also £70,000, and Laing O'Rourke had only ordered one of them. Because the load had been transferred away from the edge of the slab, deflection posed a significant challenge, says Rowe – the slightest movement in the structure could have been enough to cause the glass to crack. "The glass had to be manufactured very early on, so we couldn't go, 'sorry, we've made a mess of the slab. Can you cut a piece off the bottom?'" The propping was therefore left in place for 80 days. When it was removed, the slab held firm – much to Rowe's relief.

Photos: Make Architects

MISSION CONTROL

Make's HQ for Hiscox in York rewrites the rulebook for insurers' offices, with swaths of sculptural concrete and, erm, a Soviet missile in the atrium. Tony Whitehead reports

It takes a degree of confidence to specify an as-struck concrete interior to a prestige commercial project like the new £15m headquarters of insurer Hiscox in York. Nor are we talking here about super-smooth self-compacting mixes, or concrete born of specialist steel or fibreglass forms. This is standard, structural concrete poured into timber forms to create an architecturally stunning result.

It is unexpected too. Approaching the 6,300m^2 building, close to York's historic centre, the initial impressions are of glass, steel and brick. It is only once through the doors that it becomes obvious that this is a building that has been poured into existence from bottom to top. The floor is poured resin, the columns and soffits are exposed in-situ concrete, as are the slabs and balconies, visible from the triple-height entrance atrium. In addition, three spectacular concrete staircases wind their way through the atrium. Even the reception desk is a stylish sweep of the same in-situ concrete.

Project architect Jason Parker, of Make, explains that Hiscox initially took a little persuading to accept the concrete plan: "We took the client to other projects where concrete has been used in a similar way," he says. "It was the best way to convey how the materiality of concrete can have a real warmth, and how we can live with the joint lines and embrace concrete's natural variations. For Hiscox it is a means to express their brand values, which are all about integrity and honesty."

"The finished concrete is not perfect and if you looked at bits in isolation you would think it wasn't going to work. But when you look at it in its entirety – the way it works with the geometry, the fluidity of the lines and the way it informs the volumes – it works brilliantly as a material."

Contractor BAM Construct started on site in August 2014 and among its first tasks was to deal with what is, for York, the almost inevitable issue of archaeology. Structural engineer Mark Fyson, from Arup, says: "The project has concrete piled foundations with pile caps and quite a substantial 450mm slab transfer structure which bridges over the site of a medieval graveyard."

SPANNING OVER THE ATRIUM INVOLVED A MONUMENTAL AMOUNT OF PROPPING TO SUPPORT THE SLAB FROM GROUND LEVEL

The building has a single core and 450mm in-situ concrete slabs forming the first and second floors, with a 750mm slab to the third floor. "This top slab stretches over the atrium which involves spans of 16m, whereas the lower floors have maximum spans of 10.5m," says Fyson. "The 750mm thickness gives us the extra strength to do that, even though this slab also has a substantial skylight punched through it. Spanning over the atrium involved a monumental amount of propping to support the slab from ground level until it had cured."

The slabs are supported by in-situ concrete columns which, where visible, are circular and 600mm in diameter. Lighting and acoustic baffles are attached directly to the exposed soffits, which required early coordination of wiring. "In order for the conduits to be cast into the slabs correctly, the contractor had to work out with the client where the lighting had to be nine months in advance of the sparkies actually fitting it," says Parker.

The structure was substantially complete before features such as the concrete reception desk and staircases were built. "It helped to have the props

ABOVE The roof terrace offers views across the city towards York Minster

OPPOSITE The decommisioned Soviet rocket appears poised to launch through the 750mm-thick third-floor slab

PROJECT TEAM
Architect Make
Structural engineer Arup
Main contractor BAM Construct
Concrete contractor GRKC

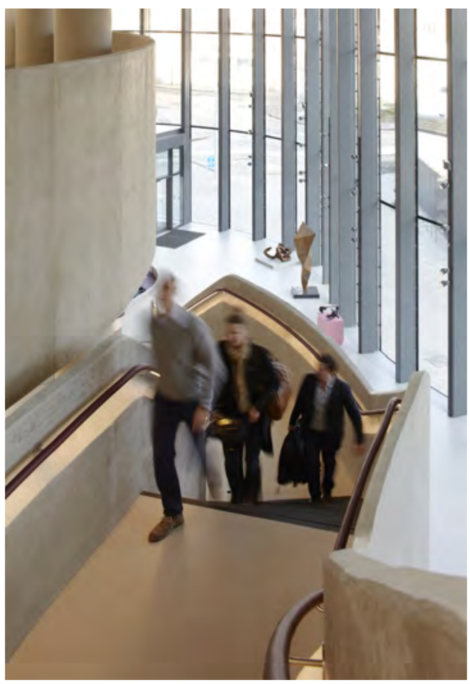
out of the way and a protected environment," says Parker. Like the structure, the staircases were made from timber forms: "We thought about milled forms and glass fibre moulds for some of these elements but having everything made in the same way, with timber, by a bunch of highly skilled chippies, really works texturally. It helps to bring all the elements together and unify the aesthetic."

Parker explains that the staircases were inspired in part by the meandering course traced by York's city walls. They seem almost to defy gravity as they snake unsupported through the atrium area, but despite their impressive appearance their structure is relatively simple, as Fyson explains: "The vertical elements, or walls of the stairs, span from bottom to top, and the steps span side-to-side, so the whole staircase acts like a large U-beam. In fact, the staircases are reinforced quite lightly with small diameter bars at close centres to help control cracking and long-term shrinkage effects."

The real structural gymnastics are in the stair landings. These are supported by 550mm concrete upstand beams that cantilever out from the slabs, hidden in the void beneath the raised floor.

The void also supports the building's displacement ventilation system and this works in tandem with the considerable exposed thermal mass to minimise heating and cooling requirements. The use of the concrete as thermal mass is a major part of the building's environmental strategy and has helped it to achieve a BREEAM rating of Very Good. Parker adds that the concrete contained 40% ground granulated blast-furnace slag (GGBS) as a cement replacement both to lower the building's carbon footprint and to help create the required pale finish.

Dotted throughout the building are a number of large-scale artworks, most notably a decommissioned Soviet missile which seems poised to launch through the atrium skylight. In this context it is a handsome, sculptural object – at once elegantly inspiring and also an impressive grey chunk of heavy technology. It is testimony to Make's vision that it seems to fit perfectly into the beautifully moulded environment around it.



TOP The in-situ concrete staircases and landings are inspired by the city's meandering medieval walls

ABOVE The staircases were made using timber formwork

Weaving with concrete

For a building that contains some 5,000m^3 of in-situ concrete, it is remarkable that very little of it is visible externally. The reception area is defined by glass, with some structural-steel columns supporting part of the third-floor slab, and the other facades appear brick-clad. It is a striking design feature of these elevations that the brickwork seems to weave in and out around the windows – a nod to the fact that the building is located on the site of a former wool market, and that for centuries wool has been a mainstay of the Yorkshire economy. In fact, these elevations are constructed from large precast-concrete elements with brick slips.

"It looks complicated but again it's actually simple," says Mark Fyson, structural engineer with Arup. "It is all post and beam, gravity construction with the precast units restrained to the slab. Every panel is either a post or beam with a bend in it to give the illusion of a weave when they are stacked together."

In all, some 226 of these precast units were used to create the facades. The six-tonne columns were typically 7m x 1.5m while the slightly smaller beams weighed four tonnes and were around 4m x 1.5m.

Made by Dutch firm Hurks, the units were created using handmade timber moulds with raised timber areas inside to create the position of each individual brick slip. "The slips were placed into these spaces like a jigsaw before the concrete was poured," Fyson explains.

VEIN GLORIOUS

ABOVE The veined effect covers all external surfaces, and is reversed in the courtyard

RIGHT AND BELOW Inside, the concrete walls and soffits are left exposed

Photos: Eugeni Pons

Pamela Buxton finds out why a French architect took a splatter gun to the facade of his new music school

For two months, artists Max Coulon and Gabriel Khokha threw paint at the pristine concrete surfaces of the newly completed Henri Dutilleux Conservatoire of Music, Dance and Dramatic Arts in Belfort, north-east France.

This was no act of vandalism. Instead it is an entirely deliberate marbled effect conceived to enhance the monolithic form of the 3,895m^2 building. The conservatoire contains 36 classrooms as well as rehearsal rooms, drama studios, a library, amphitheatre and auditorium.

Architect Dominique Coulon & Associés had the idea for a surface embellishment to the concrete structure quite late in the design process. "The building backs onto woodland, and we felt it was a good idea to offer a texture that reflected that. The veins can be seen as tree branches or the veins found in natural stone," says Dominique Coulon, adding that the design was inspired by the paintings of Jackson Pollock. "We were looking for a texture in keeping with the presence of the concrete which would function as a filter."

The architects wanted the building to appear enigmatic. This explains its largely insular form – only the cantilevered dance room offers extensive views in and addresses the town's monumental Belfort Lion sculpture on the hillside opposite by Statue of Liberty sculptor Frédéric Bartholdi.

The artwork accentuates this sense of otherness, covering all surfaces except those "hollowed out" of the building mass. "We wanted to emphasise the singularity of the building," says Coulon. "This strange texture raises questions. The building takes on an atypical character in relation to its environment."

The artists worked directly onto the concrete structural walls, which were cast in situ using metal formwork panels with lengths of 240cm. It was the first time that they had attempted such a work on a building and, unlike Pollock, they had the added difficulty of working on vertical surfaces and even undersides. They practised the splattered paint effects on derelict industrial buildings and made their own tools in order to achieve the right density of paint. The final work was carried out from a mobile cradle using a light and dark shade of blue, the two lines of paint splatters intertwining to produce a circular movement.

In the courtyard at the heart of the building, the walls were given a "negative drip" of white on a black background. According to the architect, this reversal of the treatment adds drama to the space and is the ultimate expression of density.

Internally, the concrete walls, floor and staircase of the entrance hall and circulation areas are left unadorned due to their "excellent texture", says Coulon, with no treatment other than a dust protection system.

PROJECT TEAM

Architect Dominique Coulon & Associés
Structural engineer Batiserf Ingénierie
Concrete contractor Albizzati Père & Fils

THE ROAD TO BURNTWOOD

Paul Monaghan of AHMM talks to Nick Jones about the ever-evolving role of precast and in-situ concrete in the Stirling-winning practice's work

The journey to the Stirling prize started at a bus station in Walsall. "It was our first key building," says Paul Monaghan in his soft Liverpudlian accent. "Winning that competition changed our lives – after that, we got going."

Monaghan, the first M in AHMM, has invited CQ to his Clerkenwell office to talk about the role of concrete in the practice's work, a theme he will return to later this month at the Cafe Concrete event on London's South Bank (see page 3). What started with the super-thin concrete roof of Walsall Bus Station (2000) has evolved over the past two decades through constant exploration of the material's capabilities and close collaboration with structural engineers and manufacturers. Today the practice has become one of the leading exponents not only of the raw-concrete aesthetic, in projects such as Westminster Academy (2008) and the Angel Building (2010), but also of the beautiful, controlled precast concrete that made the Stirling judges swoon over Burntwood School (2014).

The most striking thing about Walsall Bus Station is how little it has in common with any of these projects. Sixteen years on, it remains the practice's only transport project. The building's most dramatic feature is an elliptical in-situ concrete canopy over the parking bays, from which protrude a series of mighty concrete cowls to draw light in and allow fumes to escape. It is, Monaghan acknowledges, in far more of a "heroic" vein than most of their work.

But this contrast with later work is exactly the

LEFT Dagenham Park School in London. The addition of picture window frames to the precast-concrete panels added depth and shade to the facade

point – one thing that marks AHMM out is a lack of adherence to a dominant style and a willingness to go where the materials take them. "A lot of firms at that time came out of Fosters, Rogers, Stirling. But the four of us hadn't worked with a very famous architect, so we didn't have a master who we were highly influenced by. We didn't have a language – we were making it up as we went along," he smiles.

And indeed their next concrete project took them in a totally different direction. Clearwater Yard in Camden, north London, was a small, speculative office – one of the first in the new century to explore the qualities of exposed in-situ concrete. Here, Monaghan learned a lesson that has stood the practice in good stead. The project had a tight budget of £1.9m, which meant that there was little money to lavish on the concrete specification. There was, however, a graphic treatment painted onto the concrete staircase. "We realised that if you did that you could have quite raw concrete that's not really finished, but you wouldn't notice it."

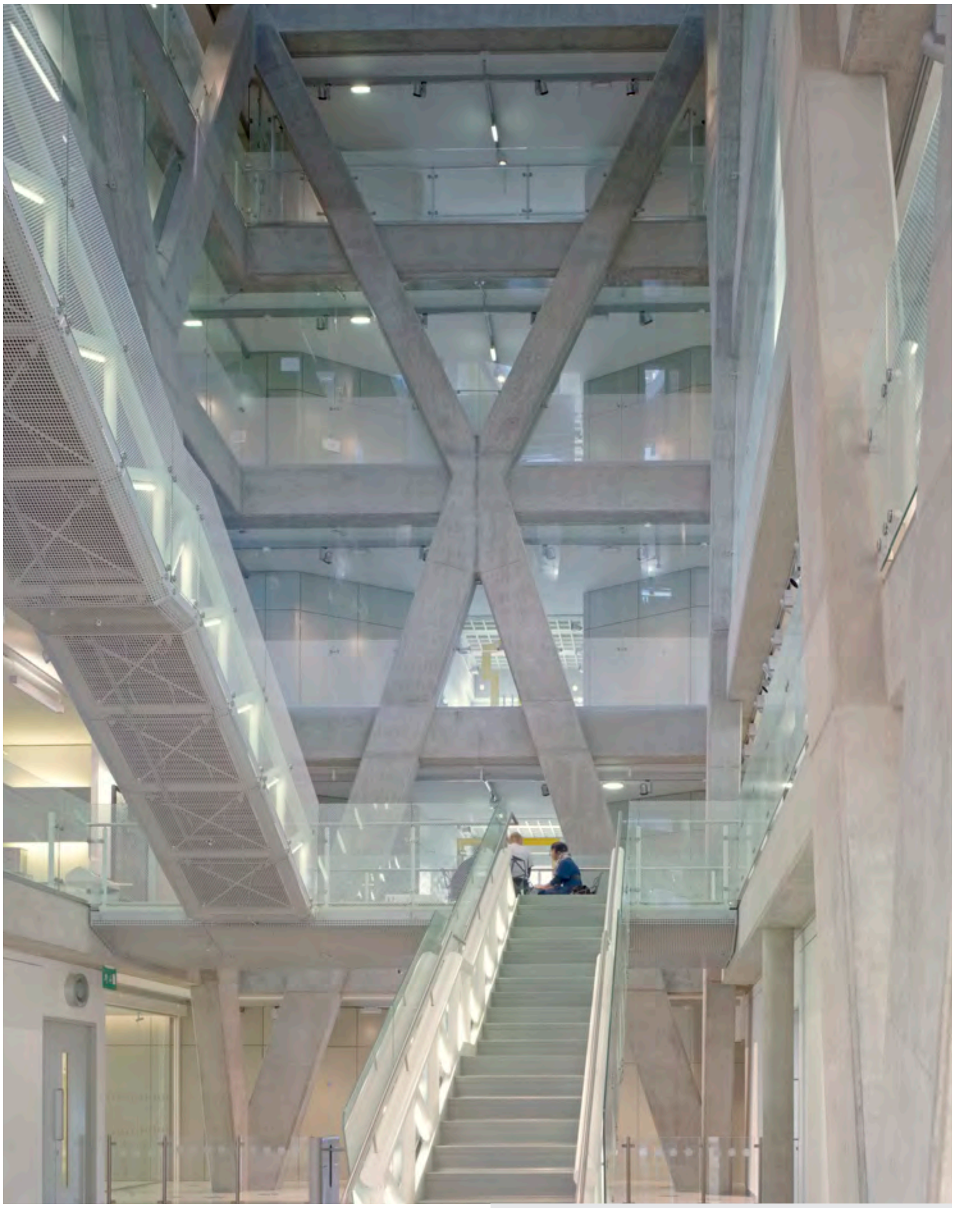
This idea of exposed concrete as a backdrop to different visual layers has become a hallmark of AHMM's work, and was further explored in its next project, at the Barbican. In renovating the centre's art gallery (2003), they stripped it back to the original concrete. "That's the building's statement feature, but they'd hidden it with loads of posters, bad art and these horrible chintzy drapes. We went much more old school, back to what it was like when it was first built." In the process, Monaghan began to think about the power of concrete and how it can be accentuated through layering. "It was all about how we lit it, how we gave it depth, and designed signage that complements it."

An education

By the time it came to the Stirling-shortlisted Westminster Academy (2007), AHMM had this layered approach down to a fine art. As with Clearwater Yard, the budget precluded using a fine grade of concrete, and again AHMM embraced the raw finish: "We had very simple plywood boarding that we'd use three times to save money. We weren't that bothered about the lines." The rough interiors were brought to boisterous life with a sky of coloured acoustic baffles, bold graphics by long-time collaborator Morag Myerscough and inexpensive but innovative lighting. And there was another advantage to this aesthetic: durability. "It looks the same as it did 10 years ago – if the walls had been painted it would look knackered."

It was now the heyday of the Building Schools for the Future programme, and AHMM had become increasingly sought-after as an education architect. Dagenham Park School (2012) soon presented a new challenge: convincing a school community to embrace precast concrete as a facade. Laing O'Rourke was part of the consortium that commissioned AHMM and had already decided to use its Design for Manufacture and Assembly (DfMA) precast factory. The two companies had previously collaborated on 160 Tooley Street (2008), a high-quality, speculative office building that made innovative use of precast concrete both as structure and fair-faced finish. But as Monaghan puts it: "Unless you're in a really sophisticated world, the two words 'prefabricated concrete' don't really work with clients." He set out to show Dagenham Park's headteacher that the repetition inherent in precast construction could, with subtle variation, be a thing of beauty. He clinched the argument with photographs showing "total repetition" – in the form of the Georgian terraces of Bedford Square in central London.

Dagenham Park may not be Georgian but its repeating facade does have a subtle elegance. The rhythm is varied through the use of bright red and orange solar control fins, while depth and shade are provided by a pronounced picture frame cast in



Photos: Timothy Soar

▲ Yellow Building (2008)

Alongside its concrete schools and housing, AHMM has developed a strong reputation for a certain type of refined in-situ concrete aesthetic in the London office market. In recent years, this has included a series of projects for Derwent London, such as the Angel Building, where high-quality concrete and careful detailing of tie holes and joints combined to create a stunning atrium. But first came the Yellow Building in Notting Hill, with its muscular, concrete diagrid. "That was the first version [of an exposed-concrete aesthetic] since Clearwater Yard," says Monaghan. "The whole idea was that the character of the building would be the structure, with cheaper finishes. That then fed into the Angel Building."

Photos: Timothy Soar

WESTMINSTER ACADEMY LOOKS THE SAME AS IT DID 10 YEARS AGO – IF THE WALLS HAD BEEN PAINTED IT WOULD LOOK KNACKERED

concrete around each window. The DfMA modules also integrated the facade with the structure, including precast-concrete columns, walls and soffit panels, which had a huge impact on the programme. "There were literally about 10 people on site as the building went up. It was watertight in six months, which is remarkable ... It was a lesson in working with the manufacturer from day one."

The persuaders

The collaboration with Laing O'Rourke continued in another sector notoriously reluctant to use exposed concrete: housing. At William Street Quarter in Barking (2014), AHMM and the contractor have replaced an unloved 1960s housing estate with a mix of housing types, including a 10-storey concrete tower. "It was quite hard persuading some people at Barking to rebuild a concrete tower," Monaghan says, adding that he uses the term "reconstituted stone" rather than precast concrete "because that's what it is".

As with the schools, the durability and resilience argument proved persuasive, and the team got to work: "In a way, we were doing R&D for Laing O'Rourke," Monaghan says. Again, the concrete is given depth through layering – this time with simple patterns of horizontal lines and perforations around the balconies and corner panels. It is, he says, "proper full-on affordable housing", but through clever detailing it avoids many of the mistakes of its monolithic predecessors.

William Street Quarter and Dagenham Park taught AHMM about the "purity" of designing for precast concrete. Which brings us to Burntwood School. While clearly a close relative of Dagenham Park, the use of relief and expression at Burntwood goes far beyond the window frames – in fact, it defines the whole facade. Here, AHMM was working for a Lend Lease consortium and the manufacturer was Techrete, which the practice had already worked with on Chobham Academy (2012) at the Olympic park. "They are fantastic old-school craftsmen," says Monaghan. "They weren't fazed by the panels. They thought, 'great, we can do this'."

As with Dagenham Park, the beauty of the sculptural elevations stems directly from the repetition and variation found in a palette of just 15 different panels. But unlike the previous project, here the skin supports only itself. "By isolating the facade, we could procure and build the frame

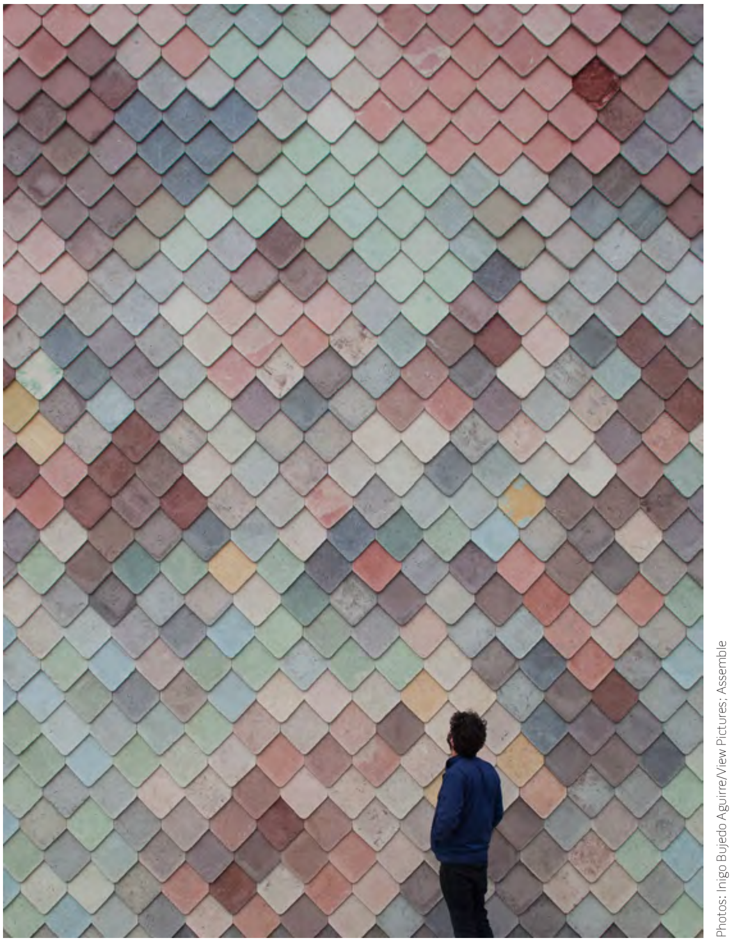
ABOVE LEFT Burntwood School in London. The "corduroy" pattern at the base of the building was added to address the change in ground level

ABOVE RIGHT William Street Quarter in Barking. The precast-concrete facades are enlivened with horizontal lines and a simple perforated pattern

quickly," explains Monaghan – another example of aesthetics and efficiency working in close harmony.

Two decades of concrete exploration is evident in details throughout the school. There are the Myerscough graphics, the "corduroy" pattern, learned from Laing O'Rourke, that gives a strong line to the base of the building despite the changing ground level, and the subtly different treatments of the facade of the sports hall, using both polished and honed black precast panels.

Monaghan often takes visitors to Burntwood – usually architects keen to look around a Stirling winner. But AHMM now has a whole portfolio of projects that have helped to transform the perception of exposed concrete – not just in terms of aesthetics but also durability and sustainability. He is as likely to take clients to Westminster Academy, Tooley Street or even that small first office in Clearwater Yard. "It's 15 years old but it looks brand new," he says. "The more concrete you have in a building, the more it looks the same every time you go to see it."



Photos: Inigo Bujedo Aguirre/View Pictures; Assemble

TRUE COLOURS

Concrete doesn't have to be grey. Elaine Toogood considers ways to achieve concrete of a different hue

ABOVE City of Justice, Barcelona by David Chipperfield Architects

RIGHT Yardhouse workspace in London by Assemble

The colour of concrete is predominantly dictated by the finest particles in the mix, because these migrate to the surface. Cement typically contributes most of the fine content and since most cement is grey, most concrete is also grey. By the same logic, replacements such as ground granulated blast-furnace slag (GGBS) and fly ash can be used to create different tones. Ready-mixed concrete makes use of locally available materials, so there are also regional variations, depending largely upon the strength of colour of the local sand and how fine it is. With paler cements, the colour of the sand will have more impact.

The technique of colouring concrete using natural sands is established practice when making many precast concrete products, such as "architectural precast" or "recon", which is often designed to resemble the colour and texture of natural stone. White cement provides a neutral base, receptive to both coloured sands and pigments, and offers a high degree of control and replication. Pigmented ready-mixed concrete is becoming more available in a range of colours. While pure white concrete is not typically available ready-mixed, a pale cement base using GGBS will provide a brighter colour. Pigments are commonly supplied in granulated form for easy dispersal, pre-measured to suit each load and placed in the back of the concrete truck. They are typically inorganic compounds, which are not affected by UV light, available in earthy tones such as reds and yellows though to browns and blacks, though blues and greens are also possible. White pigment is also used to lighten the tone.

Colour can also be created through the treatment of the concrete surface. Aggregates, normally hidden, can be revealed using surface retarder, mechanical abrasion such as grit and shot blasting, polishing or acid etching. In these circumstances, the colour of the concrete will be a combination of the colour of the aggregate, how much of it is exposed and the base cement or mortar colour. Architectural precast concrete can be created from a large range of coloured aggregates sourced especially to be exposed.

Of course, concrete can also be coloured using an applied coating such as masonry paint or semi-transparent tints, many designed specifically for use on concrete. Stains are also available, although currently less common in the UK. They work by migrating through the upper surface of the concrete and chemically reacting with the lime content to create more permanent colour in the outer surface. Dry shake toppings are a more frequently used application for colouring concrete floors, where pigmented surface hardeners are power-trowelled into the surface of a freshly laid concrete. This achieves a dense, durable, embedded hue, which can be specified to match RAL colours.

The choice of formwork will have an impact upon the colour of as-struck concrete. Linings that absorb water tend to create a darker tone, while timber-based products, if left in contact with the concrete long enough, can impart their tannins into the surface in the form of brown patches.

Other colour variations can be created by localised water or grout loss, and the release agent used. An interesting, but not permanent, phenomenon is the appearance of a blue hue when concrete containing a high percentage of GGBS is cast against an impervious formwork.

Freshly cast concrete will become a few tones lighter during the first few months of exposure, so the colour of new concrete should never be judged just after striking the formwork. This highlights the importance of building sample panels to trial different combinations of mix and formwork construction where colour control is required.

To summarise, colour in concrete can be created through the choice of cement colour and sands, by adding colour to the concrete mix, and by exposing the aggregates – or indeed a combination of all three. And colour can be applied, or incorporated into the surface of concrete. Your choice is likely to be influenced by the intended use of the concrete, its required durability and the method of manufacture. But however you do it, rest assured that it certainly doesn't have to be grey.

Photo: Rory Gardiner

NEXT GENERATION CEMENTS

Colum McCague from MPA Cement discusses the latest developments in novel cements

Designers and specifiers of concrete usually discuss cement in terms of its type and content. But do we need to know anything about the "grey powder" itself? It could be argued that we don't – cement is a standalone product designed to meet strict performance criteria. On the other hand, as Portland cement has the highest embodied CO_2 of all of the materials used to make concrete, we could consider how to further improve this grey powder or replace it with something greener.

The first patent for Portland cement was introduced in 1824, and the concept has remained the same ever since – calcium and silica-bearing minerals are extracted, crushed and burnt, cooled and finely ground to produce a material that sets and hardens in the presence of water. As the process was refined, it was soon discovered that high firing temperatures were necessary to produce a more consistent and versatile material. The demand for rapid-setting and higher-strength cements has meant that the grinding process has become more energy-intensive in order to achieve a finer powder. Grinding now accounts for at least 50% of the electrical energy required to manufacture cement.

In recent years, carbon-emitting fossil fuels such as coal and petroleum coke have been significantly replaced by waste-derived fuels (such as biomass and tyre chips), while by-product materials such as fly ash (FA) and ground granulated blast-furnace slag (GGBS) are used as partial substitutes for the cement itself. Advances in process technology have reduced CO_2 emissions from the UK cement industry by almost 60% compared with 1990 levels.

Limestone (calcium carbonate) remains an essential raw material in Portland cement production. It is both plentiful and locally available, but the release of CO_2 during its decomposition currently accounts for some 60% of the total CO_2 emissions associated with cement manufacture. Developing new cements which require less limestone, or even none at all, offers another way of reducing carbon.

LEFT GGBS replaced 50% of the cement in the concrete mix at The Foundry, Architecture 00's social justice centre in south London

Low-energy cements

Alternative cements may be defined as cementitious materials manufactured using novel, low-carbon processes that offer similar performance to traditional Portland cements. Most react in a familiar way with water, but some react with CO_2 to solidify into a hardened mass. The burning of limestone to make these cements is usually reduced and, in some cases, eliminated. Limestone-free cements can be achieved by chemical activation of by-product materials (such as FA or GGBS) or by producing an array of cementitious compounds based on magnesium. Certain magnesium-based cements (such as Novacem) have "carbon-negative" credentials, though issues such as raw material availability and concerns with technical scale-up have held back research in this area. Only those alternatives showing strong signs of market readiness will be considered here.

Calcium metasilicate cement

In Portland cement manufacture, reducing both the limestone content and the kiln burning temperature to around 1,200°C results in the production of calcium metasilicate compounds. In 2007, researchers at Rutgers University in the US discovered that these react rapidly with CO_2 to form a hardened paste based on calcium carbonate and silica gel.

It is claimed that manufacture of the metasilicates produces 30% less CO_2 than conventional Portland cement, with a potential reduction of a further 40% if CO_2 is fully sequestrated. Hardening is based only on carbonation, and water is used merely to mix the material and is removed later in the process. Rutgers quickly established start-up company Solidia Technologies to develop this cement for commercialisation.

Due to the requirement of a CO_2 chamber, the technology is limited to precast applications. Early demonstration projects carried out with LafargeHolcim have shown that small precast-concrete elements can develop full strength within one day.

The prospect of manufacturing concrete that reacts with CO_2 instead of water is an exciting one. However, the binding of CO_2 causes an associated reduction in the pH of concrete. As alkaline conditions are usually required to protect against steel corrosion, concrete based on calcium metasilicate cements may be limited to non-structural or unreinforced applications.

Calcium hydrosilicate cement

Calcium hydrosilicate cement was invented in the 1990s by researchers at the Karlsruhe Institute for Technology (KIT) in Germany. Like Solidia's cement, the limestone content is reduced but it is burned at an even lower temperature of around 1,000°C to produce lime. The lime is then slaked (mixed with water) and processed with silica under hydrothermal conditions to form partially hydrated calcium silicates. It is claimed that this results in CO_2 savings of up 50%. When fully hydrated, calcium hydrosilicate cement has a chemistry not dissimilar to Portland cement, with calcium silicate hydrate as the main strength-giving phase.

However, it is also less alkaline than Portland cement and this will require further investigation before it can be used with ferrous reinforcement. To aid full-scale implementation, Celitement was set up as a joint venture between KIT and cement manufacturer Schwenk. A bespoke pilot plant was completed in 2011 and currently at least 100kg of Celitement can be produced per day. Research and development is ongoing, with a target of 50,000 tonnes per year set for 2018.

Calcium sulfoaluminate cements

If limestone is partially replaced with sulphur and aluminium-bearing minerals and fired at a lower temperature of around 1,200-1,300°C, various calcium sulfoaluminate cements can be formed. The Aether project, funded by LafargeHolcim, is now well established and full-scale industrial trials recently demonstrated that a variation of this cement can be manufactured using identical kilns to those used for conventional Portland cement with an estimated 25% reduction in CO_2 emissions.

Calcium sulfoaluminate cements have been produced in China for over 40 years with standards already in place. While some of these cements are produced in Europe, manufacture on a large scale may be challenging because an additional source of alumina is required. Researchers are looking at using by-product or waste alumina sources as a substitute.

Alkali-activated materials

Alkali-activated materials (AAMs) are considered to be a special breed of alternative cements as they do not use cement kilns or consume limestone during manufacture. By-product materials such as FA and GGBS that are rich in calcium, silica and alumina are activated using alkaline chemicals, which are generally potassium- or sodium-based. It is claimed that this process reduces CO_2 emissions by as much as 80% compared with Portland cement.

At first glance, AAMs appear to be an excellent alternative as they are considered "cement free", although more lifecycle analysis data is required to understand the CO_2 reductions that can be achieved. As activation chemicals are synthesised using an energy-intensive process, it is important to carefully consider embodied CO_2.

The activation of FA and GGBS can already be achieved with modern Portland cement types (such as CEM II, III and IV). These cements are formed by replacing Portland cement CEM I (an alkaline material) with up to 55% FA or 95% GGBS. In this process, the cementitious elements of FA and GGBS are unlocked by the CEM I component, enabling the manufacture of concrete that is not only lower in carbon, but has a range of improved properties.

As AAMs consist of much higher proportions of FA and GGBS, more energy is required for activation. Therefore, when compared to a typical CEM II cement (such as CEM I with 30% FA), the CO_2 savings may be marginal. For example, AAMs based on FA require heat treatment (up to 200°C) for optimum strength development. AAMs based on GGBS require less energy, which may enable curing at room temperature or the use of lower-energy activators.

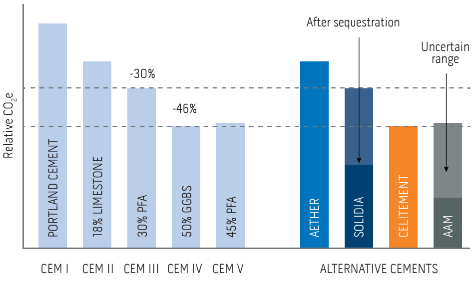
AAMs using FA or other aluminosilicate materials such as metakaolin are sometimes marketed as geopolymer cements. With a reduced calcium content, such cements may yield an additional geopolymerisation reaction process, but this is not always the case. As chemical activation of materials must still take place, AAM is now preferred as a catch-all term to include geopolymer cements.

Comparison

Novel cements are generally marketed by universities and start-up companies with CO_2 reduction figures that make a comparison only with Portland cement (CEM I). As the use of CEM I concrete has diminished significantly in the UK, more realistic comparisons can be made against CEM II, CEM III and CEM IV cement types (figure 1).

For example, calcium sulfoaluminate cement (such as Aether) – which may be the easiest technology to implement – does not measure up particularly well against a typical CEM II/B-V (with 30% FA). While greater reductions with calcium hydrosilicate cement (such as Celitement) would be possible, these will only be of significance if full-scale production plants are developed. From the limestone-based alternatives, calcium metasilicate cement (such as Solidia) has potentially the most significant impact when full CO_2 sequestration is considered. As expected, AAMs demonstrate the highest potential reductions, assuming concretes are manufactured using low-energy activators in conjunction with low-temperature curing.

FIGURE 1: RELATIVE CARBON DIOXIDE EQUIVALENT OF COMMON CEMENTS vs ALTERNATIVE CEMENTS



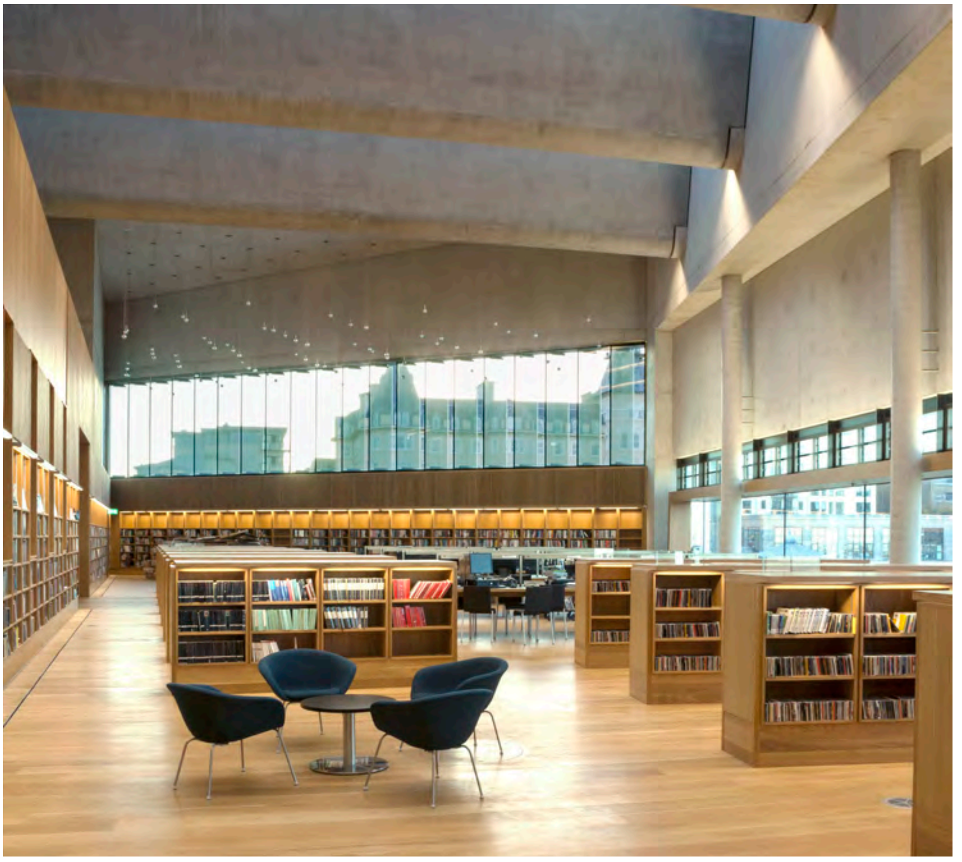


Photo: Alice Clancy

ABOVE The concrete mix used at the DLR Lexicon library in Dún Laoghaire, County Dublin, includes 50% GGBS

Future outlook

The manufacture of limestone-based alternatives is attractive to cement companies due to the abundance of limestone in the UK. Alkali-activated materials will depend on local availability of GGBS and FA, though the recently announced closure of coal-fired power stations and steel plants raises concerns over long-term supply. While vast amounts of stockpiled FA exist in the UK, there is yet to be an effective solution for processing this into a material suitable for use in concrete. Conventional low-carbon concretes are less dependent on these materials, so supply fluctuations are less of a concern. The introduction of new cement types based on tri-blends of CEM I, FA/GGBS and unburnt limestone is one of many long-term solutions being investigated.

So what does this mean for designers and specifiers of concrete? Over the next decade, we will likely see uptake of these materials in low-risk applications such as non-structural paving. For reinforced concrete, durability models and associated test methods will have to be developed and validated before standards can be proposed. In the case of AAMs, we have seen good progress in the UK with the recent development of PAS 8820:2016. While not a product standard, this specification document is a significant step forward in the uptake of novel cement materials in the UK and we can expect to see the use of alkali-activated concrete in low-risk applications very soon. RILEM Technical Committee 224-AAM is currently coordinating university research to support the development of new standards for AAMs.

A draft European standard for calcium sulfoaluminate cements is currently in development and it is expected that a proposal will be put forward to CEN (the European Committee for Standardisation) within the next five years. Such work will rely on the outcome of the Ecobinder project (ecobinder-project.eu) which has been funded by the European Commission as part of its Horizon 2020 initiative. With calcium meta- and hydro-silicate cements a relatively recent development, the drafting of specification documents or standards is in its infancy.

In global terms, the main barriers to uptake of these new cements are raw material availability, speed of production and cost. Around 4 billion tonnes of Portland cement are currently produced annually worldwide and the abundance of limestone in the earth's crust indicates that this will remain the de facto standard for many years to come. Nevertheless, designers and specifiers of concrete must be mindful of alternatives and, when deemed fit for purpose, understand the potential benefits in concrete design.

LASTING IMPRESSION DEBORAH SAUNT

SILOS AND SKATE PARKS SHOWED ME THE WAY HOME

My current favourite building is my house. I wake up to concrete every day and luxuriate in its hand-made, crafted qualities (see CQ 251). I thought there would be more tension between everyday life and this strong armature, but it's rather like living in a beautiful stone villa.

The first concrete environment that I felt exhilarated by was the undercroft of the Queen Elizabeth Hall 1 (1967). I used to hang out in the South Bank skate park and visit the Hayward Gallery, a really good demonstration that concrete can be a foil to both teenage action and high art. I find that kind of concrete underworld fascinating. These spaces have not achieved their potential in modernism. Designers didn't know what to do with them so they became car parks or waste areas, but I think we are entering a period where we appreciate their congregational quality.

I travelled in America as a student and I love the grain silos of the Midwest 2. The power of the monolithic material and form is so expressive in dialogue with the landscape. Then I went to Cambridge for my diploma and learned about architecture in one of the most inspiring brick and concrete buildings, Colin St John Wilson's Scroope Terrace extension 3 (1959). The roof is made of concrete beams, and light filters through so that something very powerful becomes weightless. I teach architecture now and one of my first student trips was to Zaha Hadid's Landscape Formation One 4 (1999) in Weil am Rhine, an incredible sinuous form emerging from the landscape. Skateboarders were using it, people were walking over it – I love that infrastructural quality of concrete, where it has the power to mediate between inside and outside.

As a teenager, I visited the Van Nelle factory 5 (1926) in Rotterdam – an amazing building that captures the heroic scale of concrete. I find it as exciting today as they probably did in 1926. So I'd always wanted to use concrete. Making a building completely out of concrete is a rare treat – that's why I did it with my own house.

Deborah Saunt is director of DSDHA

Photos: 1. Sam Ashley; 2. Fotolia; 3. RIBA Collections; 4. Hélène Binet; 5. Stuart Forster/Alamy

FROM THE ARCHIVE: AUTUMN 1982

A DAISY CHAIN AROUND THE TIGER'S NECK?

When the Barbican Centre finally opened in 1982, CQ editor George Perkins went to see if London's latest brutalist beast was quite as snarling and aggressive as all that. On entering the building, he quickly decided that the most attractive course of action was to head straight back out – to the lakeside terrace. "Here, there is a real suggestion of metropolitan café life," he wrote, before turning his attention to the concrete complex itself. "Seen from this angle, the blocks have a certain dark and brooding majesty. But are they really for people? Beside you, a small tree struggles symbolically upwards in the first years of life. Is it not, you wonder, like hanging a daisy chain around the tiger's neck?"

Venturing inside, Perkins was slightly alarmed by the sheer quantity of bush-hammered concrete surfaces: "Their tactile qualities are not what everyone would call attractive, and the vision persists of a lady – once glimpsed in similar surroundings in far off Montreal – dressed in a backless evening dress, leaning against just such a wall ..." Fortunately, Perkins soon found that the concrete was softened by a palette of rich upholstery and tilted mirrors. Indeed, the cinema interior was so restful as to be "conducive to dozing off". The tiger, it turns out, was really a bit of a pussycat ...

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EVENING AT THE BARBICAN

Barbican Centre for Arts and Conferences, Barbican, London EC2

FINAL FRAME: CROSSED HOUSE, MURCIA

This in-situ concrete house by Clavel Arquitectos makes the most of a stunning view of the Valle del Ricote mountains in southern Spain with an audacious cantilever. The house comprises two volumes, 20m long and 5m deep. The upper level pivots 35 degrees to project 10m out over the ground floor, offering welcome shade for the glazed facade. Sand-blasted pine shuttering gives a rough finish to the exterior, while the internal concrete floors are polished.

Photo: David Frutos (BISimages)