The Concrete Centre

CONCRETE QUARTERLY

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P11 →

CASTING OFF

INSPIRATION

APPLICATION

Jenny Burridge
Head of structural engineering, The Concrete Centre

New powder generation

Specifiers seeking lower-carbon concretes will very soon have a new tool at their disposal, with the addition of multi-component cements to the BS 8500 standard. The 2022 update will permit more "ternary blends" (see page 28), which can contain up to 20% limestone powder as a second cement replacement in addition to GGBS or fly ash. In the UK, limestone is an abundant resource that needs only to be ground up, a process that requires relatively little energy. When it is used in ternary blends, there is no reduction in strength or performance, only embodied carbon.

Portland cement is responsible for the characteristics that make concrete so widely used, but it also accounts for most of its carbon emissions, so the search is on to find cementitious replacements that offer the same benefits with a lower environmental impact. This is bearing fruit in the far greater choice now available to specifiers. There were 15 general purpose cements in the 2006 version of BS 8500 and 16 in the 2015 version. But by the time of the 2019 amendment this had increased three-fold to 48, and in 2022 it is set to more than double again to 112.

The explosion of new cements in the 2022 standard reflects the considerable efforts taking place to decarbonise concrete, but also the long process of testing that the performance, strength and durability of new mixes matches the concretes that we are used to relying on – today's new cement blends have been in development for more than a decade. The Seratech scientists on page 6 represent many, many more working in laboratories across the UK and the world.

SUPPLIERS WILL MOST LIKELY JUST ADD LIMESTONE INTO THEIR PORTLAND CEMENT SILO, AUTOMATICALLY LOWERING THE EMBODIED CARBON

The good news for specifiers scratching their heads over the proliferation of lower-carbon options is that ternary blends will simply become the default within two or three years. Most concrete plants have two silos: one for Portland cement and one for GGBS or fly ash. Rather than investing in a third, suppliers will most likely just add limestone into their Portland cement, automatically lowering the embodied carbon of the concrete they produce. This is already the case in Ireland, where these kinds of ternary blend have been permitted for some years and "limestone cement" has become the default.

This shows the market driving carbon improvements in two ways: one, Portland cement is energy-intensive and therefore expensive to produce, so it makes commercial sense to reduce this component where possible. Two, concrete suppliers are responding to increasing demand for products that have a lower embodied carbon, reflecting the consumer power that specifiers can bring to bear.

So it's well worth becoming familiar with the new standard – even if another update may follow hot on its heels. Because by informing themselves about the options and, crucially, asking for them, specifiers can continue to drive change across the built environment. ■

CONCRETE QUARTERLY

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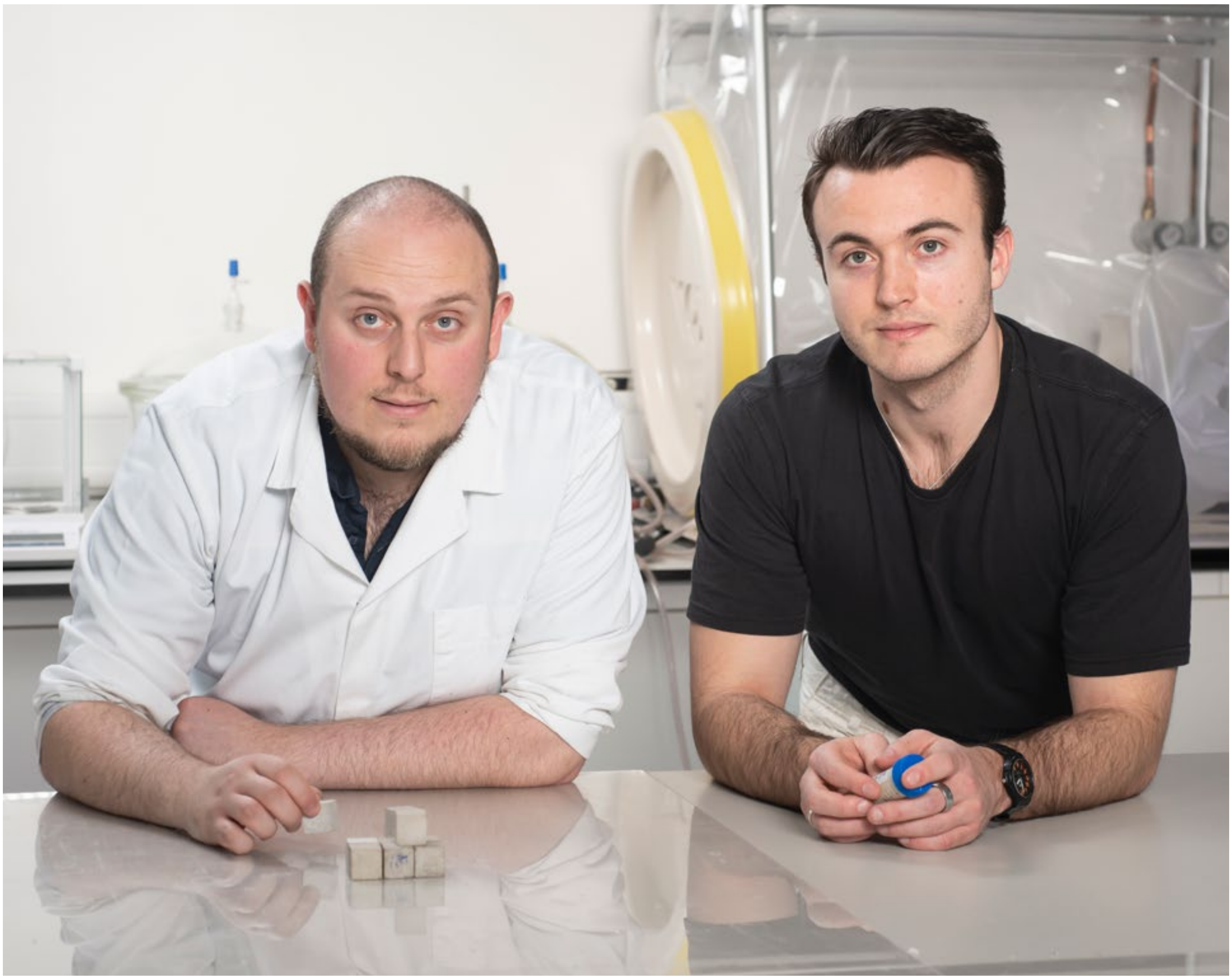
Interdisciplinary Biomedical Research Building, Warwick University by Hawkins\Brown. Photo by Jack Hobhouse



INNOVATION

CARBON NEGATIVE CEMENT

REPLACING CEMENTITIOUS MATERIALS WITH A CARBON-NEGATIVE ALTERNATIVE COULD ENABLE CARBON-NEUTRAL CONCRETE – WITHOUT MAKING ANY CHANGES TO THE CONSTRUCTION PROCESS

In the autumn of 2020, two PhD students from Imperial College London were in a South Kensington pub, talking about concrete. Sam Draper (above left), studying cementitious substitutes, wanted to know: could the silica that Barney Shanks had produced as part of his research into magnesium-based cements be used to make a carbon-neutral cement mix?

"We couldn't see why not, "says Shanks (above right). "I remember it was just before the second lockdown, and so the pub was trying to empty its barrels by selling beer off cheap. It probably helped stimulate our conversation!"

Over the following weeks, the pair refined their thinking and discussed it with senior staff at Imperial. "They told us to patent the idea and go for it," says Shanks. The result is Seratech, founded in July 2021.

ABOVE
Six samples of different concretes, one of which uses the Seratech product. Seratech concrete is visually similar to conventional mixes, as well as having similar curing and strength properties

AS FAR AS THE CONSTRUCTION INDUSTRY IS CONCERNED, THEY DON'T NEED TO DO ANYTHING. THE IDEA IS THAT NOBODY WOULD NOTICE THE DIFFERENCE

Seratech's product is an SCM (supplementary cementitious material) which is added to concrete in a similar fashion to the way GGBS or fly ash are already commonly used. The big difference is that while these SCMs reduce the carbon footprint of concrete by reducing the overall cement content, the Seratech product, being strongly carbon-negative, can produce carbon-neutral, or potentially even carbon-negative concrete. The company is still at the lab-research stage, but hopes to make the first tonne of Seratech concrete in time for the London Festival of Architecture in June.

"You need to replace about 35% of the Portland cement with our product to achieve carbon-neutral concrete," says Draper. "So far we think that there should be little difference between a standard concrete, and that made with our product. Curing times would be similar – as would strength. In fact, as far as the construction industry is concerned, they don't need to do anything. No adjustment to plant or machinery should be needed. The idea is that nobody would notice the difference."

So how does it work? Essentially the process involves crushing and processing olivine – an abundant mineral known in its purest crystalline form as peridot. Olivine is mainly magnesium silicate. But, explains Shanks, by adding CO_2, which could potentially come directly from industrial sources, Seratech's technology produces two compounds. "One is a silica powder, or engineered pozzolan, which can be added to cement, while the CO_2 ends up permanently sequestered within a by-product – magnesium carbonate."

The process is an interesting variation on other new technologies that absorb CO_2 during the concrete's curing process. "What makes our product different," says Shanks, "is that it can be used like ordinary cement – so as part of mixes for precast or in-situ concrete – it makes no difference."

As Shanks and Draper say, it is early days. But chemistry like this really could be a game-changer. ■
Interview by Tony Whitehead

LASTING IMPRESSION

ANDREW TAYLOR

FROM WELSH CASTLES TO VENETIAN TOMBS – VIA THE BUNKERS OF THE KOREAN BORDER

I was born in North Wales, and my dad used to take me to all of the castles along the coast. I think subconsciously they have had a huge influence on the way I think about architecture. They're amazingly simplistic, very pure, with clear diagrams, almost in a modernist way. But what's really compelling about them is the way they grow out of the earth. They're very powerful pieces of the landscape.

At Patel Taylor, much of what we do starts with urban design and landscape. The strong horizontal layers of St George's Bristol (CQ 273), for instance, are a response to the contours of the site, embedding the building into the existing terraces. So I'm fascinated by the way that fortifications sit in the landscape and become part of it. The earth embankments and ravelins of Italian forts are another example of defensive structures that are really tied to the earth.

The plasticity of concrete adds another interesting dimension. About three years ago, I found this

Photos: Andrew Taylor

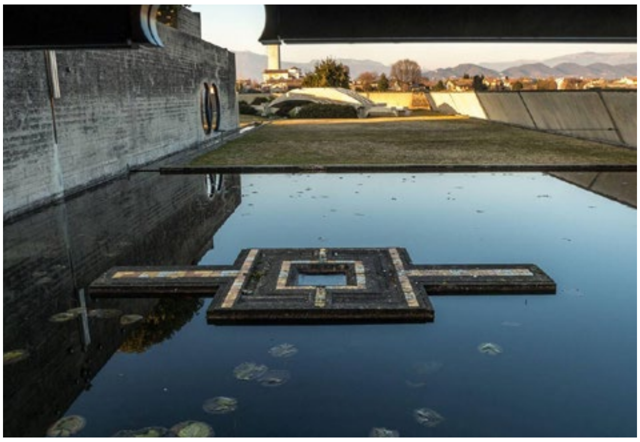
ABOVE
Double-deck pill box, Coalhouse Fort, East Tilbury, Essex

extraordinary pill box in East Tilbury, Essex. It's unlike anything I'd seen before – it's really quite complicated, with a separate turret and gun placement. It's monolithic, it's heavy, but it's also beautiful, like a casting just coming out of the ground. There's a sculptural quality, reminiscent of Rachel Whiteread's House (1993) or Eduardi Chilleda's Monument to Tolerance (2011-) – a carved space inside a mountain on Fuerteventura.

I've spent a lot of time in Korea, and I love creeping around the old bunkers they have near the North Korean border. They're often covered in mesh and have soil poured over them, so again they're merged into the terrain. But what's fascinating is that there is often this incredibly strong relationship between the inside and outside. By their nature, these buildings are usually set in dramatic scenery – on rivers or overlooking valleys – and when you look back from inside, you're drawn into the landscape. There is one extraordinary former anti-tank defence facility about 20 miles north of Seoul that has been turned into a cultural centre by CoRe Architects. The 250m-long blocks of the bunker run along the entire base of a valley like a riverbed.

It's interesting to compare these buildings with something like Carlo Scarpa's Brion Cemetery near Venice (1968-78). This is obviously a more beautiful composition of routes and processions, but the concrete structures are grounded in a similar way. The main mausoleum seems to grow out of the water, and its walls have this pronounced horizontal boardmarking, like sedimentary layers. In his book on Venice, Peter Ackroyd writes about the hazy stratification of the marble, blurring into the rippling water and the sky. You get a similar sense at Brion too. The concrete rises from the ground and where the walls meet the datum, it frames a view of mountain and sky, merging the building into the distant horizon. ■

Andrew Taylor is a director at Patel Taylor



Photos: Andrew Taylor; Luca Lorenzon / Alamy Stock Photo

TOP AND MIDDLE
Bunker overlooking the Imjon River on the border between South and North Korea

BOTTOM
Carlo Scarpa's Brion Cemetery in Treviso, northern Italy (1968-78)

FROM THE ARCHIVE: SUMMER 1965

THE BORDERS SAN SIRO

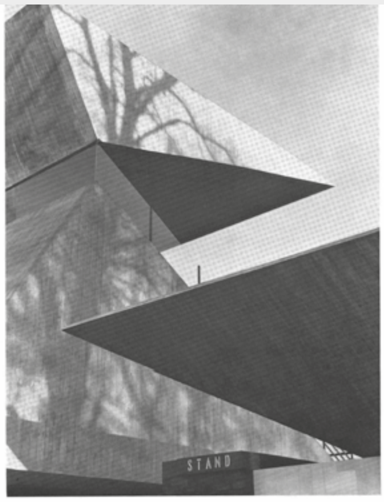
"The sports stadium sweepingly designed in concrete is something we associate with abroad – the great winged canopies of Torroja or Nervi or, more recently, the majestic 'tents' of Tange. Of the same family, but on a much less lavish scale, we now have a small gem of our own."

Gala Fairydean FC in Galashiels, currently nestling in mid-table in the Lowlands League, is not the sort of place you would expect to find an icon of 20th-century architecture. But Concrete Quarterly's reviewer placed its main 620-seat stand, designed by Peter Womersley, alongside the works of renowned stadium designers such as Pier Luigi Nervi, Eduardo Torroja and Kenzo Tange. It remains an astonishing sight as it nears its 60th birthday, and still draws lofty comparisons – locally it is known as the Borders San Siro. Not bad for £25,000.

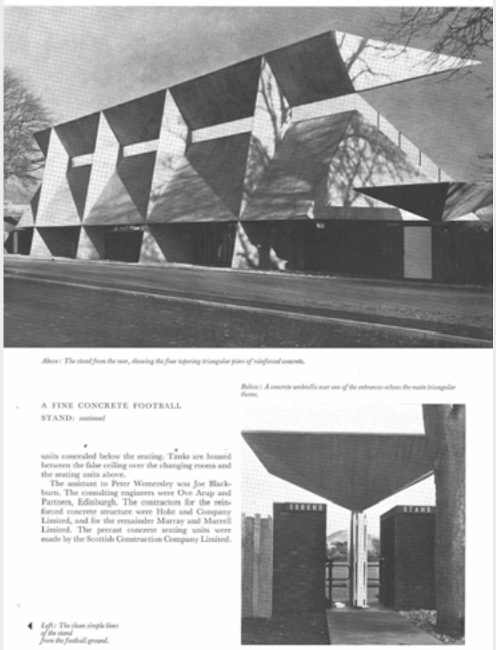
CQ was quick to praise the ingenious concrete geometry, with the whole design based on a module of 5 inches – the width of the Douglas fir boards that comprise the formwork – and on angles of 60˚ and 30˚. The basic structure consists of four tapering triangular piers which support the back wall of the seating and the canopy, a monumental hovering slice of concrete that cantilevers 26ft over the spectators. The turnstiles were a "delightful touch", each with its own concrete umbrella on a single support, sheltering the way through and repeating the triangular theme of the main stand.

The stand has been closed for safety reasons since 2018, but is now being restored by Reiach and Hall. A recent photograph on the architect's Instagram feed showed that advertising boards had been removed from the rear of the seating, allowing the iconic roof to hover in space as originally intended for the first time in 30 years. ■

Explore the full CQ archive at concretecentre.com/cqarchive



VARIATIONS ON A TRIANGLE – *a football stand at Galashiels*



Above: The stand from the rear, showing the four tapering triangular piers of reinforced concrete.

Below: A concrete umbrella over one of the entrances echoes the main triangular theme.

A FINE CONCRETE FOOTBALL STAND: *continued*

units concealed below the seating. Tanks are housed between the false ceiling over the changing rooms and the seating units above.

The assistant to Peter Womersley was Joe Blackburn. The consulting engineers were Ove Arup and Partners, Edinburgh. The contractors for the reinforced concrete structure were Holst and Company Limited, and for the remainder Murray and Murrell Limited. The precast concrete seating units were made by the Scottish Construction Company Limited.

Left: The clean simple lines of the stand from the football ground.

Printed by F. Bussard Ltd., London, E.C.1 CA.5469

ABOVE
The use of local sand has given the fair-faced concrete plinth a pink hue

ORIGIN STORY

EAST QUAY

PIERS TAYLOR'S CULTURAL CENTRE IS A MICROCOSM OF ITS COASTAL SETTING – A SMALL TOWN ON A RUGGED PINK ROCK

In some ways, I was involved in this project before it was a project. A group of local women had set up a grassroots organisation called Onion Collective to explore ways to improve social mobility in Watchet, a coastal town in Somerset. Through conversations with the town's residents, they developed the idea to build a cultural centre, with workshops and a gallery. They gained permission from the council to use the site, but when we undertook the original design, we didn't know if we would ever have the money to build it.

The programme was deliberately quite loose, and we wanted, above all, to make sure something got built. The idea of a concrete plinth emerged from there: we thought we could start with this monolithic structure, with in-situ concrete internal and external walls and slabs, and then add different lightweight elements on top as funds were secured. It would be like Watchet itself – emerging from this strong concrete base just as the town rises from the rugged masonry of the surrounding cliffs. The plinth, with its large spans, would house a gallery, cafe and large workshops, while the ad-hoc assembly of metal-framed pods above would contain artist's studios and accommodation.

The beauty of this approach was that it allowed us to be much looser in terms of where things went. We could have big, open spaces for the gallery and cafe within the plinth, and then we could place these asymmetrical loads on top. If it had been another constructional system, we would have needed intrusive downstand beams and columns. I liked the idea that, on the upper floor, you could move anything anywhere, any time. Again, it would be like the town itself, with courtyards and spaces between buildings that you could infill over time. There's also a walkway across the top of the plinth and a bridge that connects it to the coastal path. It is a major piece of public realm, open 24 hours a day.

Most people were on board with the idea of fair-faced concrete from day one, and I think that was partly because there is a very strong attachment to the geology of the place: the pink rocks of the Triassic coast. The sand in the concrete is local, so has a very rich pink colour, which really does bind it to this

TOP
The industrial material palette reflects the character of the working harbour

ABOVE
A print studio is among the open-plan spaces housed in the concrete volume

part of Somerset. Initially, we designed the concrete with a stratified finish, in reference to the cliffs. But as we cast it, we realised we wanted something more in keeping with the surrounding dock. So we switched to phenolic ply formwork, which still leaves a beautiful finish, but is less overt.

It was really important that this building should age well. This part of the coast is incredibly windy. It's an extreme environment – you can see it in the way the stone harbour walls have eroded. Concrete offered us the promise of something robust, durable and easy to maintain – a vital consideration for a small, local organisation. It could have a lifespan of hundreds of years, and it will undoubtedly change enormously. I like to think future generations will add to it, put another storey on top. Who knows? That's the flexibility that concrete gives you.

The robustness of the structure translates to a very protective, shell-like interior. I've been there on really cold, windy days, and you go in and feel this sense of silence. The thick, thermally massive concrete structure, with the same finishes on the floor, walls and ceiling, has a cathedral-like quality. One of the things that surprises us is how positively people have responded to this space. Concrete is often seen as a hard and cold material, but here it feels warm and friendly. There is a psychological aspect to a material that feels so secure. ■

Piers Taylor is founder of Invisible Studio Architects. Interview by Nick Jones

Photos: Piers Taylor, Jim Stephenson

TOP
The plinth forms a base for lightweight pods and walkways

ABOVE
The monolithic structure includes a single internal column

Photos: Jack Hobhouse

REMOTE CONTROL

An ambitious offsite strategy has helped to deliver Warwick University's sustainable biomedical research building with surgical precision, writes Nick Jones

ABOVE
Concealed cast-in steel fin plates connect the precast-concrete structure to the timber-framed entrance

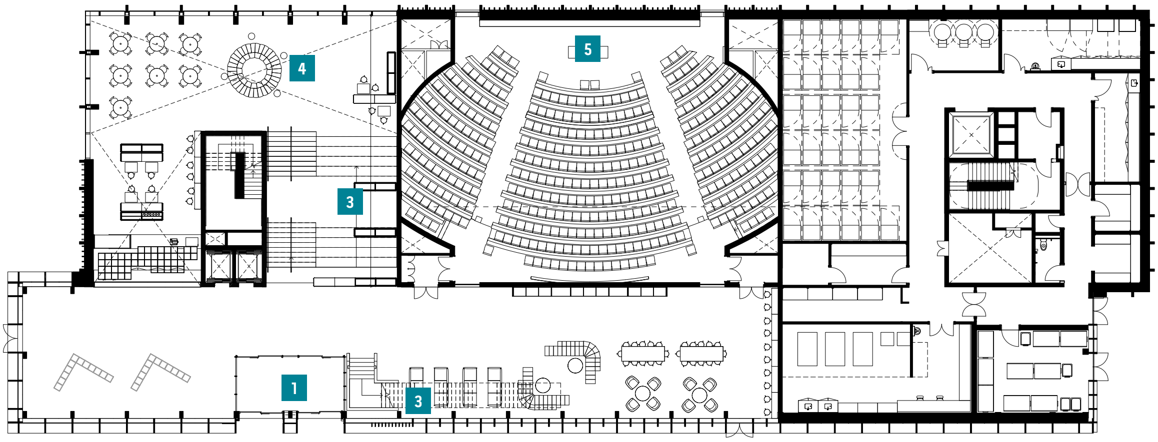
The new Interdisciplinary Biomedical Research Building (IBRB) at the University of Warwick is all about joining things together. It's a gateway building, sitting on the junction between the Gibbets Hill campus and its surrounding woodland. It's a meeting place, with landscaped external seating, open work areas and a welcoming double-height ground-floor cafe. Most importantly, it's a merger of research disciplines, housing both the medicine and life sciences departments, in a move that the university hopes will inspire cross-fertilisation of ideas and research.

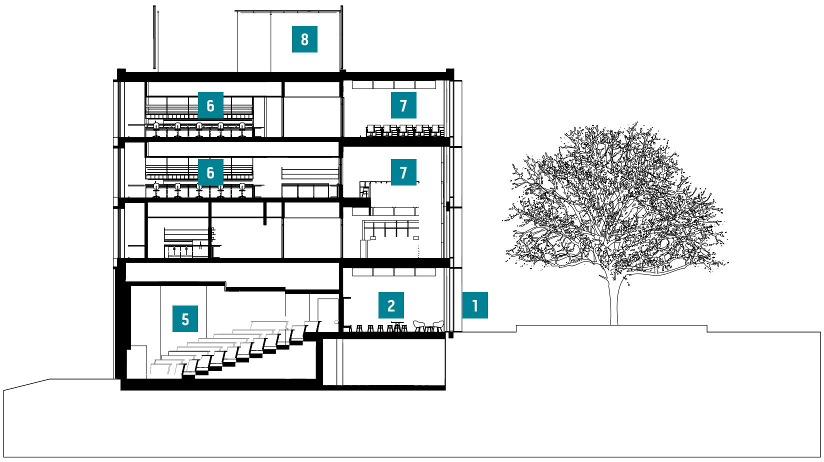
So it's appropriate that the IBRB is a hybrid building, with two distinct but connected structures: an eastern volume clad in anodised aluminium, and a larger western volume wrapped in white precast concrete. The external appearance reflects two different structural systems. The smaller volume is a timber entrance pavilion with a processional staircase and open areas for researchers to write up their experiments. The larger concrete block houses the laboratories, as well as a 400-seat lecture theatre and the cafe. "The concept came from seeing that there are essentially two halves to the building – the wet laboratories and write-up spaces – and that they have quite different requirements," says Jason Martin, partner at architect Hawkins\Brown. "The labs need a very stable environment with large spans and tall spaces because of the amount of servicing." For the write-up spaces, the architects wanted a more relaxed atmosphere and a strong visual contrast, so opted for exposed timber. "We really wanted to express both structural systems as much as possible, and enjoy the different feel of the two spaces."

THE LABS NEED A VERY STABLE ENVIRONMENT WITH LARGE SPANS AND TALL SPACES BECAUSE OF THE AMOUNT OF SERVICING

The concrete structure is almost entirely precast. From the start, Warwick wanted the IBRB to be a flagship sustainable building for the campus. As part of this, it wrote into the brief that at least 50% of the project's value should be constructed from premanufactured components, thereby reducing waste on site and ensuring materials would be used as efficiently as possible. An offsite-manufactured project

ABOVE
The external landscaping includes seating made from precast concrete





GROUND-FLOOR PLAN AND SECTION

1 Entrance
2 Foyer / seating
3 Stairs
4 Cafe
5 Lecture theatre
6 Lab spaces
7 Write-up areas
8 Plant

had the additional advantages of speeding up the construction programme and requiring fewer staff and heavy machines on site – key considerations on a busy university campus.

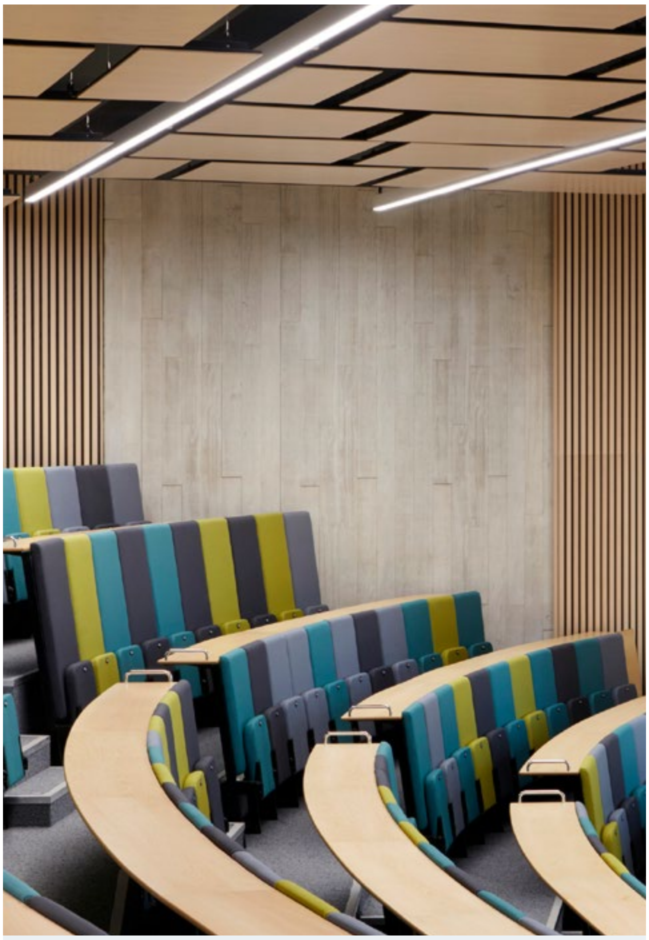
The concrete frame was designed as a kit of more than 1,300 bespoke precast parts. The main vertical elements are storey-height wall panels, 3.6m wide, up to 6m tall and 250mm thick, and weighing as much as 20 tonnes. These meet floor plates constructed of 7m-long, 250mm-deep prestressed hollowcore slabs – a structural solution designed to reduce the load on the transfer beams that stretch 16m over the ground-floor lecture theatre. In-situ reinforced structural toppings, 100mm thick, were also applied to the floor slabs to stiffen the slab, share the distribution of loads and reduce vibrations in the sensitive lab areas. The concrete for the precast frame components contained both a limestone filler replacement and GGBS binder replacement, reducing overall cement content by 35%, while the structural toppings contained up to 50% supplementary cementitious materials in the cement.

The kit of parts proved quick to assemble. In 12 months, an empty site became an almost complete building, with six weeks cut from the programme despite the onset of the Covid-19 pandemic. The contractor, Willmott Dixon, believes there were 100 fewer site deliveries, and the more efficient use of material saved about 850 tonnes of concrete overall.

But it's also clear that this is a highly crafted structure. The main entrance is on the timber-framed side of the building, but visitors are immediately faced with an expansive concrete wall signalling the junction of the two volumes. The concrete has been cast with a corrugated vertical finish, created using Reckli flexible mould liners, which accentuates the contrast with the timber. "Because we had such large areas of concrete, we didn't want it to just have a simple, fair-faced finish," says Martin. "It has an almost curtain-like quality, which gives the impression of something much lighter than it actually is. And you get a beautiful play of light across the surface."

ABOVE
Stairs descend to a lower ground floor cafe. The walls have a discreet joint at 1m, below 8m x 3m corrugated panels

The building follows the natural slope of the site, so stairs from the 6m-high entrance hall lead down to an even taller ground-floor space in the concrete building. The corrugated walls continue along the stairs and into the cathedral-like cafe that occupies this lower space.



LEFT
The walls in the lecture theatre were cast in two halves, with different finishes on each face

The concrete has two faces

The sheer size of the wall panels posed some of the biggest challenges from a precasting point of view – particularly when it came to casting the distinctive textures into the surface. Some of the 8m-tall panels between the lecture theatre, the cafe and the stairwell are double-faced, with the corrugated effect on one side and a boardmarked pattern on the other. "Normally if we are creating two faces we would cast them in a vertical cell, what we call a battery mould, which creates a finish on both sides of the wall,"

At over 9m high, these walls were too big to cast as single panels, so a discreet joint has been placed 1m above the floor, aligning neatly with the high benches that line the space. Views out to the surrounding woodland are framed by full-height columns, just 250mm wide, which stretch up into a 2m-high open service space furnished with neat rows of vertical acoustic baffles.

The cafe leads to the 400-seat lecture theatre, which is embedded into the slope behind a 5m-high in-situ concrete retaining wall. Timber wall cladding is interspersed with further moments of exposed precast concrete, which here has a boardmarked finish, again created using a standard Reckli formliner. What makes this particularly impressive is that the other side of the same wall panel, flanking the staircase, boasts the corrugated finish (see box, left).

Above the ground floor are three levels of category 2 lab spaces, where scientists will explore how cells and tissues perform mechanical functions, with wide-ranging implications for a range of diseases, from cancer to brittle bones and heart conditions. These highly says Simon Harold, development director at concrete contractor PCE. "But because of the size of the panels, we didn't have a mould big enough to do that."

Instead, a complex process was devised, in which the panels would be cast flat on a table in two halves. "We cast half the panel in section, with reinforcement sticking out of it. Then the next day, we turned it over and added another layer of concrete and a mould with the other finish on it. Aligning a geometric pattern, 8m long by 3m wide, was quite tricky."

Transporting the finished panels the 40 miles from factory to site also proved a delicate operation. "You've got to be very, very careful when you're handling the walls. We try to transport them on an edge, but because of their size we had to move them landscape and then spin them upright on site." After the panels had been manoeuvred into position, large props were craned in to support them until they could be stitched together with a vertical joint.

functional spaces benefit from the longer spans and 4.5m floor-to-floor heights of the concrete frame, which accommodates an impressive 1.2m-high servicing void.

The highly complex services are another area that has been almost entirely manufactured off-site. Some 120 horizontal modules slot into the ceiling space and provide all services to the labs. The modules all plug into a 27m-high prefabricated "mega-riser" – claimed to be the largest of its kind to be installed in Europe. The riser has a 5m x 4m footprint and came in six sections, lowered in from above by crane. The installation took four people two days, rather than the 18-week, 10-person job that the contractor had programmed in.

What made this possible was the pinpoint accuracy of the precast frame. "To be able to slot the riser all the way down five storeys, we needed to work to critical tolerances," says Simon Harold, development director at concrete contractor PCE. "If you cast a concrete wall, and it's out, you know you're in big trouble. We were able to build the shaft to within less than 10mm." A number of connections were incorporated into the structure so that the riser could be restrained and fixed into position very quickly. Because no back-propping was needed, work could continue safely in the areas around the riser straight away.

The accuracy of the precast frame was also crucial to connecting the

ABOVE
The facades on the upper levels were cast as double-storey, 9.3m-high panels

two structures. The timber is fixed to the concrete structure with cast-in steel fin plates hidden behind a shadow gap, a gentle illusion that softens the meeting point between the materials. The timber beam fixing position could be adjusted on the fin plate to take up the tolerance deviation and enable the beams to be perfectly aligned. "Again, we were able to design the connections around very tight tolerances," says Harold, "which meant we didn't have to accommodate so much movement and could rationalise those details."

The facade is similarly controlled, with a number of raised vertical details, neatly aligned joints and thoughtful contrasts between smooth, grit-blasted and acid-etched finishes. "We were able to work in that extra level of texture," says Martin, "and also create some quite heavy profiling to highlight areas such as the cafe. That's the sort of detailing you can only really do in precast."

In total, 149 single-skin panels cover more than 2,800m^2 of the facade. The ground-floor units are about 6m high and 3.3m wide, while the upper levels were cast as double-storey, 9.3m-high panels. The glazing was pre-installed, with solid half-panels either side completing the unit. The vertical joints between the units are subtly shaded by 300mm-deep projecting fins, which bring a

PROJECT TEAM

Architect Hawkins\Brown
Delivery architect Fairhurst Design Group
Structural engineer Stantec
Main contractor Willmott Dixon
Offsite concrete frame contractor PCE
Precast cladding contractor Techrete

rhythmic elegance to the ensemble and shield the windows from the afternoon sun.

The precast solution came into its own during the cladding programme, carried out just as the UK was forced into lockdown, as fixing the panels to the structure involved relatively little manual work. "Remarkably, they lost very little time during that period," says Martin, "because they were able to maintain the 2m distance between operatives on site."

In all, a site team of about 20 people and a single tower crane have been able to piece together an impressive piece of architecture. In a building that's all about joining people together, this assemblage of columns, slabs, beams, wall and cladding panels is perhaps the most impressive connecting act of all. ■

LIFE IN A LENS

Photos: Edmund Sumner

Some people like to capture a view by taking a photo. Doug Smith and his wife Wendy decided to build a whole camera. The tp bennett principal director likens the house he has built in the garden of his previous home to a Box Brownie: its central section, glazed at both ends, looks straight down a beautiful Kent valley like a lens trained on the horizon. There are even shutters for each aperture – huge slatted panels of Siberian larch that roll across to provide shade and privacy.

But Haus on the Ridge is about more than a view. The four-bedroom villa has been built to Passivhaus standards, with triple glazing and an insulated in-situ concrete structure. This is shown in all its splendour when the shutters are closed over, and the immaculate fair-faced finish of the two wings is revealed.

Smith has long had a professional interest in Passivhaus, but was never convinced by structural systems that rely on layers of membranes, fixings and "sticky tape". "Unless you get that real attention to detail, and a contractor who is obsessed with making sure it's completely sealed, it's very difficult to achieve the requisite airtight rating." This is one of the reasons he turned to a more monolithic concrete construction system. "You've still got to address junctions with windows and doors, but it lends itself to achieving a good airtightness. When the Passivhaus assessors did the initial air test, they could not believe what the house achieved."

READ THE FULL STORY
concretecentre.com/cq

NEVERENDING STORY

Developed by 3XN, the Circle House research project is billed as Denmark's first circular housing scheme – an alternative way of building with precast concrete that enables the components to be disassembled and reused in new structures. After analysing the different elements of a house and their lifespans, the architects realised that the key to circularity lay in the way the structure was joined together. So instead of using cast-in-place cement-based mortar connections, they modified the beams and slabs so they could be fixed with simple steel plates and bolts. The walls of the 1:1 prototype took just one hour to erect. Crucially, the connections are cast with a lime-based mortar that protects the elements against air, sound and fire but bears no load. This can be pressure-hosed out to enable the system to be unscrewed and reused.

READ THE FULL STORY
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Photos: Tom Jersø; 3XN

Photos: Johan Dehlin; Ståle Erikson

CONCRETE CANVAS

"It's working really, really hard. That's why it's in the building – it's doing so much," says Nicholas Lobo Brennan, co-founder of Apparata Architects, of the concrete that forms the distinctive aesthetic, and so much more, of A House for Artists, its affordable housing development in central Barking, Essex.

Not only is the in-situ concrete both the structure and external skin, it is central to the thermal, acoustic and fire performance of the building, which provides 12 homes for artists and their families. The building's embodied carbon is 470kgCO_2eq/m², over 20% less than that targeted in the RIBA 2030 Climate Challenge. This was achieved by using high rates of cement replacement (50% GGBS above ground and 70% below), keeping build-ups lean and reducing the quantity of walls on plan, as well as minimising the surface area of thermal enclosure to give a very compact heated volume.

READ THE FULL STORY
concretecentre.com/cq

Multi-component mixes for low-carbon cements

ABOVE
Attilio Panzeri's Villa Montagnola in Collina d'Oro, Switzerland derives its black tone from pozzolanic cement

The concrete industry is leaving no stone unturned in its quest for lower-carbon cements. A new set of ternary blends offer specifiers a much greater range of possibilities, says MPA Cement's Colum McCague

Photo: Giorgio Marafioti

Cement is responsible for many of the characteristics that make concrete such a versatile and widely used building material. It gives the material its plasticity when fresh and its strength when hardened, as well as its distinctive appearance. Modern cements are more than just grey powder – they contain other, secondary components which each make their own contribution to the resulting concrete's plasticity, strength and colour. But the grey powder component, known as Portland cement clinker, remains the key ingredient.

Cement is also responsible for by far the greatest proportion of concrete's embodied carbon emissions, which is why it is such a significant focus of the industry's decarbonisation activity. Its relative carbon intensity is due partly to the energy required to operate cement kilns at high temperatures, and there is intensive research and experimentation underway into alternative fuels. Harder to abate will be the process emissions resulting from the chemical reaction taking place inside the kiln, which is why secondary components play another important role by replacing a proportion of clinker to lower the embodied carbon of the mix.

The UK traditionally produces cements with a maximum of one secondary component alongside clinker, with small quantities of gypsum to regulate setting. But research currently underway into lower-carbon formulations has demonstrated the potential benefits of multiple cementitious components, particularly when limestone powder is used in combination with ground granulated blast-furnace slag (GGBS), fly ash or calcined clay.

Fly ash, GGBS and finely ground limestone are already commonly used as secondary components in cement. In

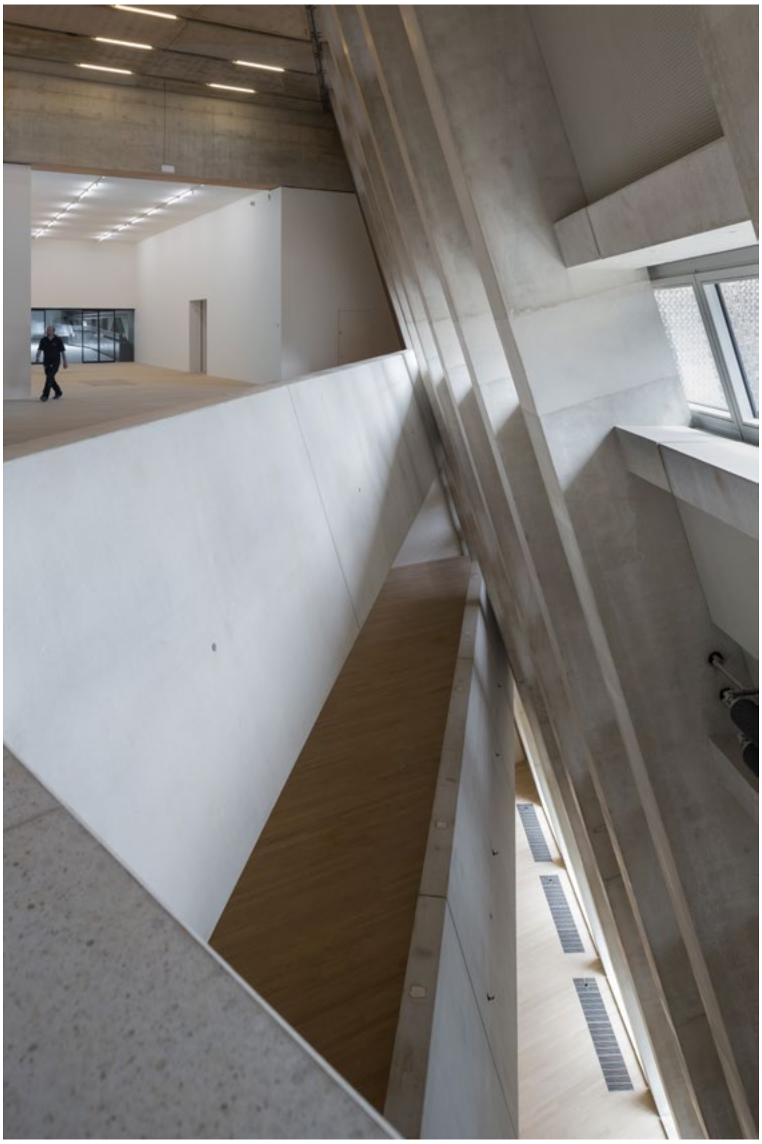

Photo: Iwan Baan

ABOVE
The light-toned walls of the Switch House at Tate Modern by Herzog & de Meuron were created by using a 50% GGBS mix

optimised quantities, each of these can improve concrete's strength while altering its appearance – making it lighter in the case of GGBS and limestone, and darker in the case of fly ash. Concrete that contains cements based on fly ash or GGBS gives off less heat as it sets and is more resistant to chemical attack once hardened. However, as early strengths tend to be lower – particularly at high levels of clinker substitution – it is necessary to strike the right balance for the application.

Limestone with GGBS or fly ash

Limestone powder is abundantly available in the UK but due to its limited chemical activity it is used to substitute clinker in lower quantities than fly ash or GGBS. When used alongside other components, however, it may be a different story. In 2017, the Mineral Products Association conducted a review and found that limestone powder could be better utilised if mixed with other common secondary components such as GGBS or fly ash. In 2018, it formed a research consortium, part-funded by the government under the BEIS Industrial Energy Efficiency Accelerator programme, which is managed by the Carbon Trust and Jacobs, to manufacture, test and demonstrate new multi-component cements containing limestone powder. Hanson Cement manufactured a series of cements that used it in combination with clinker and fly ash, and with clinker and GGBS, at its National Technical Centre

Photo: Colum McCague

ABOVE
A demonstration precast project by the MPA, trialling the use of limestone powder in multi-component cements. The panel on the far left contains a cement comprising 40% clinker, 45% GGBS and 15% limestone powder. The panel on the far right contains a cement with 55% clinker, 30% fly ash and 15% limestone powder

in Scunthorpe, and these were subjected to extensive strength and durability testing by BRE at its Watford laboratory. The project successfully proved that multi-component cements, when optimised, work more efficiently in concrete than their traditional analogues, allowing up to 65% clinker substitution. Each of the low-carbon formulations is covered by the European cement standard, EN 197-5:2021. After completion of the concrete testing in 2021, it was recommended to the British Standards Institution that the new cements be recognised in BS 8500 as general-purpose cements. This will give specifiers more low-carbon cement options, offering savings of up to 60% eCO_2 compared with Portland cement CEM I.

Limestone with calcined clay

Calcined clay refers to clay that is thermally treated to unlock its pozzolanic properties (pozzolanic refers to a material's ability to react with lime and water to produce a hardened cement, with lime arising from the reaction between Portland cement clinker and water). Metakaolin is the most well-known type of calcined clay used in cement. It is produced from kaolin, a high-grade clay, and is generally limited to around 10-15% clinker substitution due to economic cost and workability considerations.

Its use in the UK is however currently limited to specialist applications, as most metakaolin is produced elsewhere in Europe or from Asia and the Americas and local kaolin is predominantly used in the paint, ceramics and paper industries. Lower-grade clays are abundantly available,

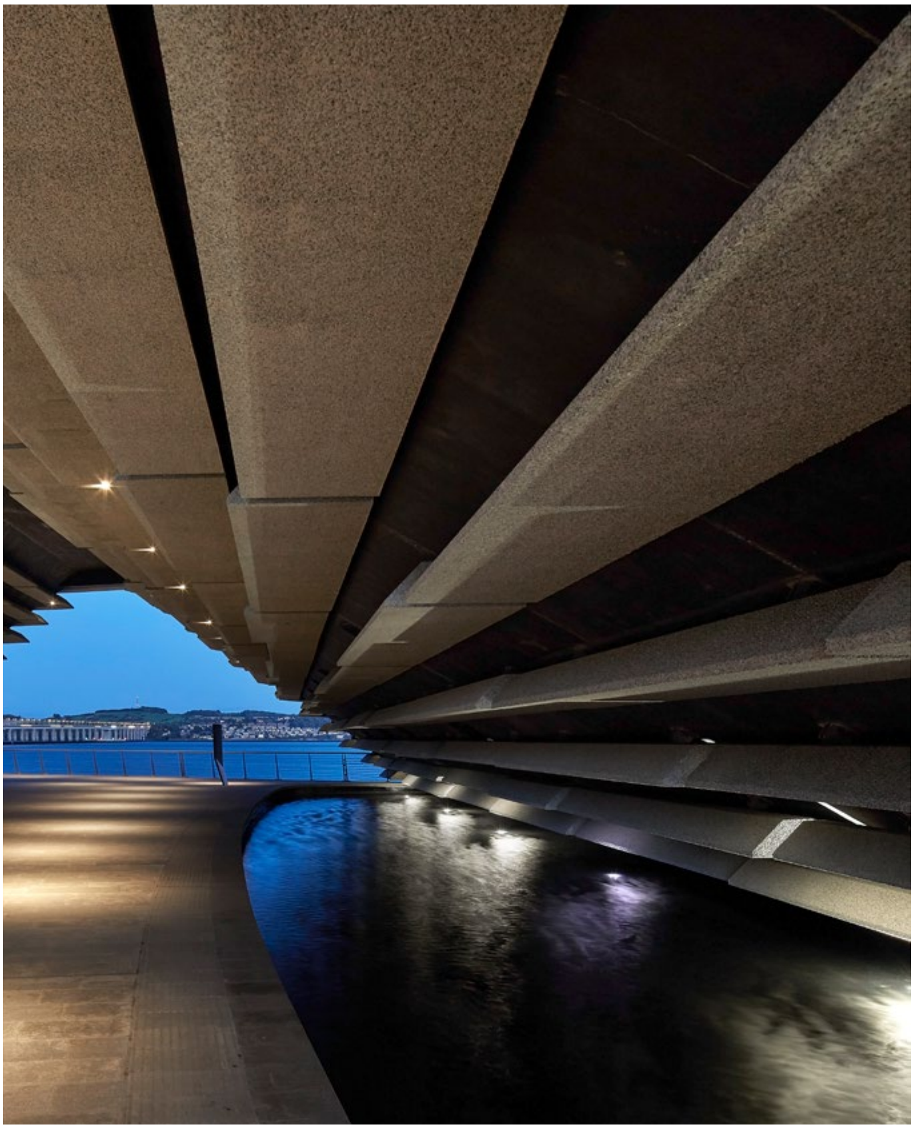

Photo: Hufton + Crow

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The in-situ external walls of the V&A Dundee by Kengo Kuma were cast using a 27% fly ash mix to reduce embodied carbon and darken the tone, contrasting with the lighter precast-concrete panels in front

but they have yet to be tested or trialled in the UK. Experience in other countries shows that the reactivity of calcined lower-grade clays ranges widely from relatively inert to relatively reactive (somewhere between the reactivity of fly ash and metakaolin). This presents a significant challenge to their use, when little is known about the reactivity of low-grade UK clays.

Fly ash and GGBS are by-products of industrial processes that are in decline in the UK – respectively, coal-fired power generation, and the manufacture of iron and steel via the blast furnace route – and this trend may eventually be seen globally. While they will continue to be a viable, proven way to reduce embodied carbon in the short to medium term, they are unlikely to remain the dominant solution in the coming decades. So research is under way into alternatives.

Limestone with calcined clay is one potential alternative. According to BS EN 197-5:2021, it is possible to achieve as high as 50% clinker substitution when limestone powder is added alongside calcined clay in a multi-component cement. An MPA-led consortium, co-funded by the UK's innovation agency, Innovate UK, has begun to investigate the potential

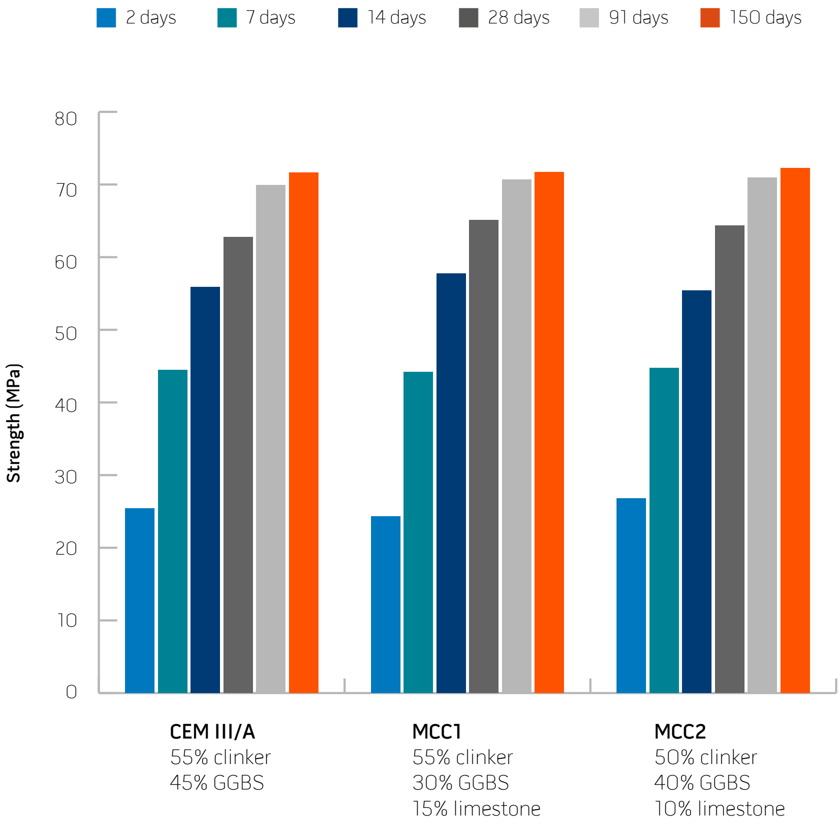

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Chart comparing strength gain of a traditional concrete mix (CEM III/A) with two new multi-component cement concretes (MCC1 and MCC2). The results for MCC1 show that identical performance to CEM III/A is achieved when 15% GGBS is subsituted for limestone powder. MCC2 shows a slight improvement at early age and identical performance at later ages, even with 5% less clinker

of new cements containing UK-sourced calcined clays. The project partners will assess the feasibility of producing calcined clays from lower-grade clays, specifically those reclaimed from extraction or other manufacturing processes. Reclaimed clay sources include waste bricks, which do not require heating as they have already undergone thermal treatment, as well as large reserves of overburden clay materials at quarry sites.

A total of 10 clay sources will be rigorously tested by Imerys Aluminates and University College London, with parameters such as kiln temperature and particle size optimised to allow the highest-possible clinker substitution in cement formulations. Low-carbon multi-component cements will be formulated and tested for conformity against current standards. Following this, the cements will be sent to the University of Dundee for rigorous strength and durability testing in concrete, with the aim of establishing their suitability as general-purpose cements in BS 8500.

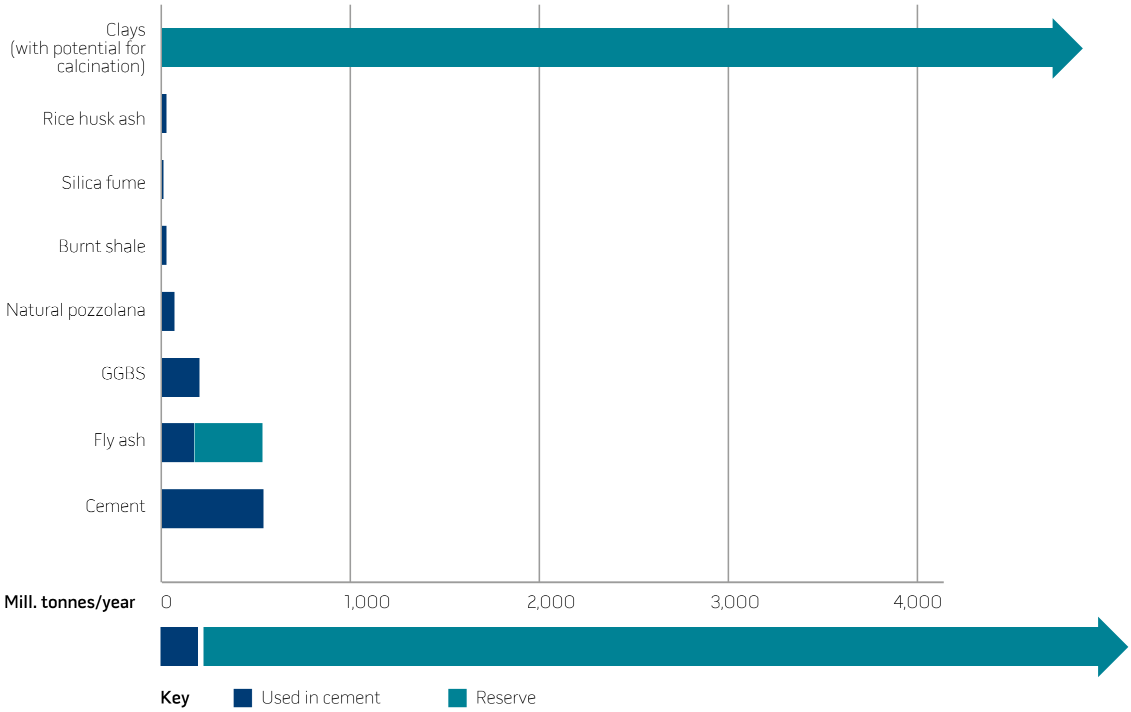
It has been well documented that the reduced workability of concrete containing calcined clays restricts the level of clinker replacement. It is therefore necessary to develop and investigate new water-reducing admixtures which are compatible with calcined clays, and the project will include working closely with the Cement Admixtures Association to achieve this.

Photos: Elaine Toogood

ABOVE
Examples of some of the ground reclaimed clays being tested. Clockwise from top left: raw clay from Imreys, Tarmac and Hanson and brick dust from Forterra

New colours

The evolution of secondary components in cements will likely yield a greater range of options for concrete finishes and colours. Following the update to BS 8500, up to 20% limestone powder will be included in most cements, resulting in concretes of a slightly lighter shade of grey. This is especially the case when used in combination with GGBS, and will also result in the colour of the fine aggregate being more evident in the final concrete. The colour of raw clays vary, ranging from almost white to dark grey, as well as reddish hues. This depends on iron content – with iron-containing minerals causing a darker tone. The thermal treatment of the clays can change their colour, raw grey clay turning to reddish calcined clay for example. This can be controlled depending on the process used. Just as with GGBS and fly ash, concrete using calcined clay based cements will take up some of their colour, the impact depending on amounts used.



Source: Scrivener, Karen et al., Calcined Clay Limestone Cements (LC3), Cement and Concrete Research 114, 2017 (figures from 2013)

ABOVE
Chart showing the global availability of common supplementary cementitious materials

Much greater choice for specifiers

The 2006 version of BS 8500 included a total of 15 general-purpose cements. In the 2015 version, this increased by one to 16. But by the time of the 2019 amendment, there were 48. This reflects demand from specifiers for a greater choice of lower-carbon cements, and the willingness of cement producers and concrete suppliers to respond.

A further update of BS 8500 is planned in 2022. As it stands, the MPA proposal to include the new multi-component cements will more than double the number of general-purpose cements to 112. Multi-component cements will not only be factory-produced in fixed proportions. For example, concrete suppliers will be able to purchase factory-made Portland limestone cement (ie. containing up to 20% limestone powder alongside clinker) and blend additional secondary components in the desired proportions. These changes, with careful consideration of performance aspects of the concrete, such as strength gain or the heat of hydration, will allow much greater optimisation of embodied carbon. ■

Photo: BoysPlayNice

FINAL FRAME: BASE4WORK BRATISLAVA

Once the main heating plant in Bratislava, a functionalist boiler and turbine hall by celebrated Slovak architect Dušan Jurkovic has been converted into a five-storey coworking space by Studio Perspektiv and DF Creative Group. The preservation of the exterior was overseen by national heritage body PAMARCH, and marks a rare example of the adaptive reuse of the city's 20th-century industrial architecture. The massive concrete hoppers, originally used to store coal, still dominate the interiors – two have even been turned into meeting rooms with vertiginous glazed flooring. The restored building forms the centrepiece of a landscaped residential development by Zaha Hadid Architects.