CONCRETE QUARTERLY

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NOCTURNAL ANIMALS
Why Nicholas Hare's UCL Student Centre is the perfect place for a late-night essay crisis

A BAUHAUS MYSTERY
Weimar's new museum offers an enigmatic take on the school's turbulent early years

GETTING OUR GROOVES BACK
Longer spans, less material, lower carbon – why designers are returning to the ribbed slab

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AGENDA

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

How to start a material revolution

It's a truth now universally acknowledged across the construction industry that we need to lower the carbon footprint of the built environment and all the products and processes that go into it. Unfortunately, UK construction is somewhat less united when it comes to collaborating to achieve this.

Savings and efficiencies are best won by cooperation. Take waste and material efficiency. Those supplying raw materials would be able to do so much more efficiently if they knew how much was going to be required and when. Designers could specify far more effectively if they discussed buildability with contractors at an early stage, and contractors could cut waste throughout the supply chain by coordinating with suppliers.

In the UK now, there are probably five or six major infrastructure projects, all seeking the same thing: lower carbon concrete. They will inevitably be managed by different teams in different ways – and yet surely there are efficiencies to be gained through collaboration and knowledge sharing? For projects such as the Thames Tideway tunnel, Heathrow expansion or HS2, further lowering the carbon content of concrete is seen as one of the keys to their overall carbon performance. The embodied carbon of concrete has already reduced by 29% since 1990 – thanks to the combined efforts of 10 concrete industry sub-sectors over the last decade, and particularly those of cement. Research is underway into a whole range of new concrete mixes, in addition to the recent changes to BS 8500, which now permits the use of composite cements. BRE, working with MPA Cement, is already testing 22 separate types with low clinker content.

RESEARCH IS UNDERWAY INTO A WHOLE RANGE OF NEW CONCRETE MIXES

Innovation is an exciting process, but it is also a lengthy and costly one. New cements will undergo years of robust testing, on their own and within the many possible mixes, before they are incorporated into standards, essential if designers are to be confident that they will deliver the required performance over a 120-year lifespan. Of course, new products must then compete on price too, one of the challenges of entering an established, low-cost material base. I can't help thinking that a more collaborative pan-industry approach would help us achieve our goals more quickly – if, say, the clients seeking these products were involved earlier in bringing them to market and at a specification and project level. How do you improve the most used material in infrastructure quickly and cost-efficiently? You do it together.

this is concrete

CALM THINKING IN A CRISIS

As Parliament declares a climate emergency, the UK Green Building Council's framework for net-zero emissions is a progressive step, says This is Concrete blogger Tom De Saulles. "But it does introduce a new challenge – namely the ability to carry out meaningful lifecycle assessments and comparisons." He suggests policymakers refer to a report from the Canada-based International Institute for Sustainable Development highlighting gaps in carbon accounting. "Being equitable and accurate requires proven science and robust environmental performance data. At present, it can be argued that neither has matured sufficiently, so we should perhaps proceed with caution until the actual [picture] is better understood." **Read on at thisisconcrete.co.uk**

CONCRETE QUARTERLY

On the cover:
UCL Student Centre by Nicholas Hare Architects
Photo: Alan Williams Photography
Produced by:
Wordmule
Designed by:
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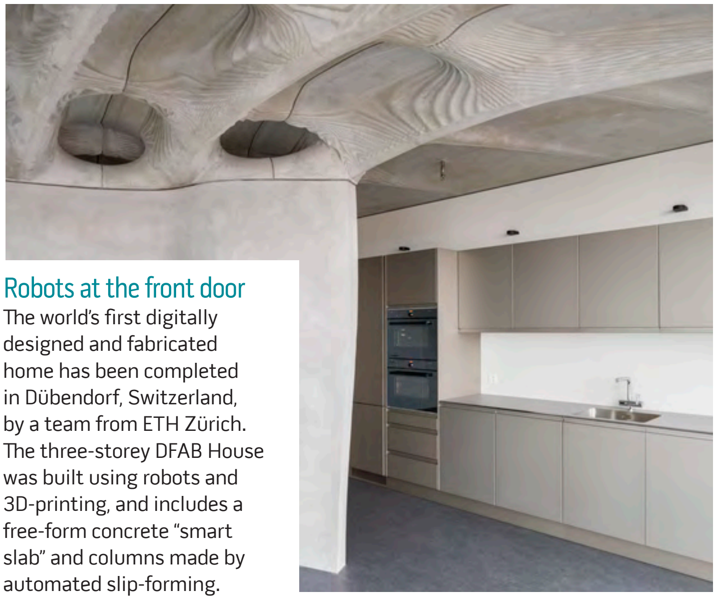
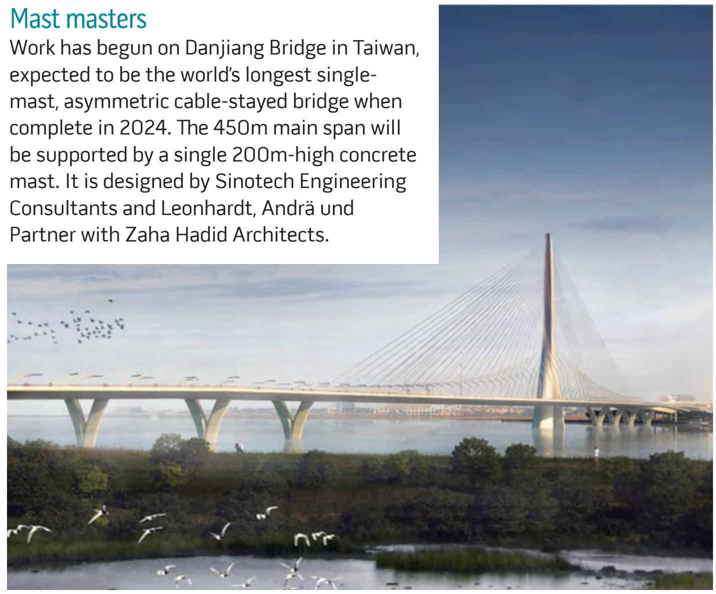


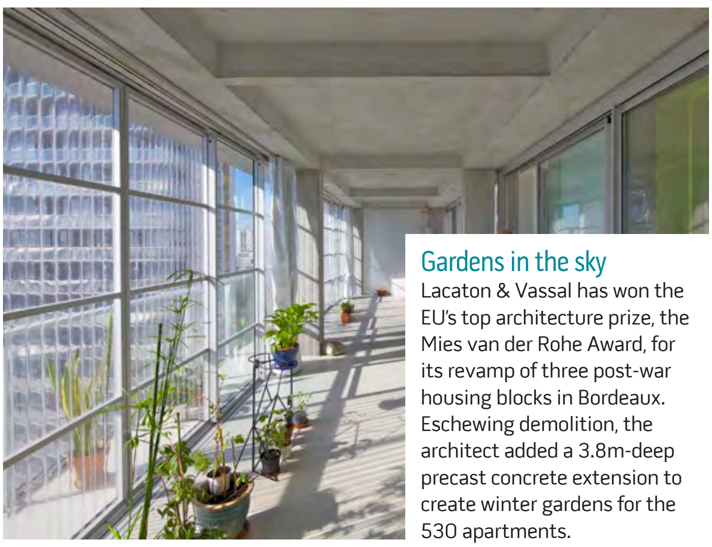
Robots at the front door

The world's first digitally designed and fabricated home has been completed in Dübendorf, Switzerland, by a team from ETH Zürich. The three-storey DFAB House was built using robots and 3D-printing, and includes a free-form concrete "smart slab" and columns made by automated slip-forming.

Mast masters

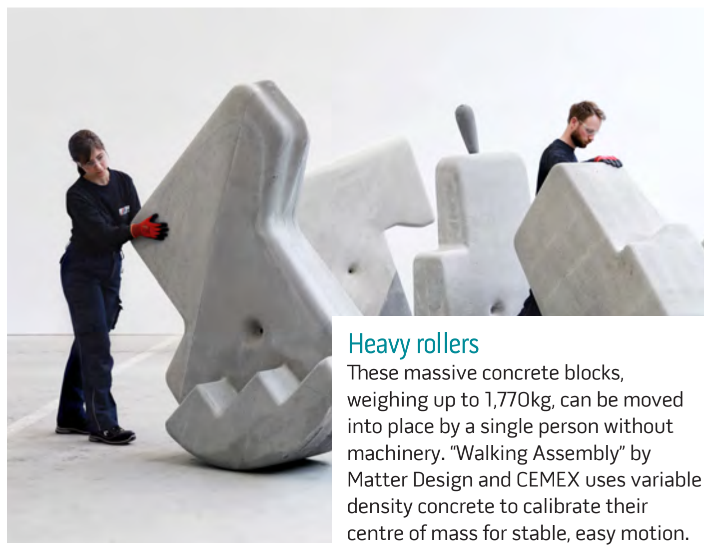
Work has begun on Danjiang Bridge in Taiwan, expected to be the world's longest single-mast, asymmetric cable-stayed bridge when complete in 2024. The 450m main span will be supported by a single 200m-high concrete mast. It is designed by Sinotech Engineering Consultants and Leonhardt, Andrä und Partner with Zaha Hadid Architects.





Gardens in the sky

Lacaton & Vassal has won the EU's top architecture prize, the Mies van der Rohe Award, for its revamp of three post-war housing blocks in Bordeaux. Eschewing demolition, the architect added a 3.8m-deep precast concrete extension to create winter gardens for the 530 apartments.



Heavy rollers

These massive concrete blocks, weighing up to 1,770kg, can be moved into place by a single person without machinery. "Walking Assembly" by Matter Design and CEMEX uses variable density concrete to calibrate their centre of mass for stable, easy motion.

Images: Roman Keller, Zaha Hadid Architects / render by VA, Matter Design, Philippe Ruault

CENTRE STAGE

The recently completed Mountview Academy of Theatre Arts in Peckham, south London, will be one of the projects featured in summer's Concrete Elegance lecture. Of particular interest is the design team's "considered" approach to the standard of concrete surfaces specified. Exposed concrete was chosen as both an aesthetic and cost-efficient solution, bringing character and energy savings over the life of the building.

The lecture takes place on Wednesday 12 June at the Building Centre in London. concretecentre.com/events

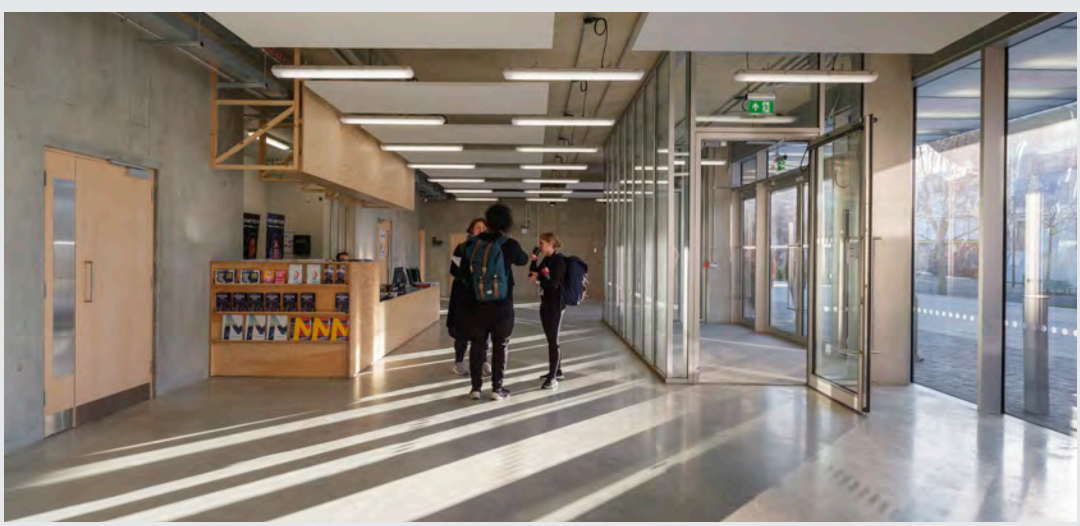


Photo: Tim Crocker

ALL DAY AND ALL OF THE NIGHT

Nicholas Hare's UCL Student Centre shows how exposed concrete's thermal mass can be harnessed even in a hardworking 24-hour environment, writes Tony Whitehead

Using a building's thermal mass to regulate its internal temperature is now a well-established technique, and one for which concrete is ideally suited. Exposed concrete surfaces absorb heat from sunshine, occupants and computers during the day, which is usefully given up later in the day, helping minimise heating requirements during the winter months. In summer, the heat is purged overnight by opening vents so that by morning the concrete is ready to absorb more heat and reduce the need for mechanical air conditioning.

This works because most non-residential premises are occupied only during the day. But what if they are intensely used 24 hours a day, seven days a week? Can thermal mass still play a part in reducing energy needs?

The new seven-storey Student Centre for University College, London (UCL), is proof that it can – albeit with a little help from two bore-holes sunk more than 100m below the building. "The Student Centre is continually used," explains David Tompson, project leader with architect Nicholas Hare. "You have lots of students using loads of IT all through the night – so in summer there is little opportunity for it to lose any heat naturally.

"Our solution has been to supercharge the thermal mass effect by circulating water through 10km of pipes cast into the concrete slabs – water that has been cooled by sending it deep beneath the building into the chalk aquifer below, where the temperature is around 12°C."

If this seems like a lot of trouble to go to, Tompson is quick to explain that concrete was chosen for more than its thermal qualities alone. "We took a fabric-first approach and decided on concrete early on," he says. "This is a highly populated building, designed to last, and we selected materials we thought could last around 200 years. There is a lot of oak, and exposed concrete walls and soffits which are robust enough to withstand heavy traffic over time."

Tompson points out that the fairly regular concrete frame and flat slab construction means the Student Centre will be straightforward to reconfigure should the building's use change, adding that the exposed soffits help to maximise floor-to-ceiling heights, which "lets us use tall windows to allow natural light deep into the building". Concrete's fire-resistant and acoustic properties are also important on this tight city-centre site neighbouring a busy theatre.

Finally, says Tompson, the concrete solved a local geological issue by providing weight as well as mass: "We needed a fairly heavy building to resist hydrostatic pressure from below."

UCL's new Student Centre, which cost £38.5m to construct, is situated on a former bomb site that had never been fully redeveloped. It provides 5,750m^2 of space, mainly comfortable, IT-friendly environments for up to 1,000 students to work – a little like a library without books. It also carves a new route through the campus, connecting Gordon Street to Gower Street via the new building.

Inside, concrete is very much the dominant material. Smooth pale concrete defines the soffits, columns and dramatic flights of stairs. Much less obvious is quite how many different mixes and types of concrete are on display (see box, overleaf).

Most notably, while the foundations and floor slabs are made from in-situ concrete, virtually all the vertical elements, including columns, stair stringers and facade panels, are precast. This, says Tompson, offered practical and programming advantages: "It was a very tight site, so it helped to be able to crane columns and other elements into place. The in-situ slabs had a lot of cast-in services, including electrics and sprinklers.

"There were also the cooling pipes, which sit on a wire grid between the two layers of reinforcement,

WE DECIDED ON CONCRETE EARLY ON. THIS IS A HIGHLY POPULATED BUILDING, DESIGNED TO LAST

Photos: Alan Williams Photography, Richard Chivers so setting that out before pouring the slab was a major undertaking. It made sense for the contractor to be able to work on the slabs without the complication of the formwork and propping that would have been needed for the columns. The precast elements kept it clean and simple."

To create a stable base for the building, a secant piled concrete wall was sunk around the 30m x 30m site perimeter and supporting piles driven 120m below street level. The two boreholes for the water cooling system were also sunk, and the raft slab cast around them some 10m below the street to make space for two basement levels.

Once the slab had reached sufficient strength, precast columns were craned into place, mostly to a 7.2m grid, and connected using column shoes. The columns also feature well voids, holes into which rebar could be grouted at the top of each column. This was then tied into the reinforcement for the next slab up. This being a visual connection, the formwork for the slabs was set 100mm below the top of the columns to allow each column to "bite" neatly into the slab. Most of the columns have a 1,200mm by 300mm section, oriented with the smaller dimension facing the entrances to emphasise the new route through the campus.

Where the Student Centre abuts its neighbours – a Georgian terrace to the left and the brutalist Bloomsbury Theatre to the right – prefabricated insulated concrete sandwich panels were fixed to the adjacent buildings' walls and supported off the slabs. "Each panel is one-storey (3.9m) high, between 2m and 2.8m wide, and 400mm thick, comprising 100mm of concrete abutting the neighbouring building, 100mm of insulation and a 200mm reinforced concrete structural layer which provided the support for the floor slabs at each side of the building," says Tompson. "The structural layer is the one that occupants can see and has the same smooth finish and colour as the columns."

The accommodation is ranged around a full-height atrium spanned by flights of stairs. The airiness of this atrium is vital to the feel of the building – but it did present some structural challenges. "Around the atrium you see a thin slab edge of just 300mm," says Tompson, "but set back from that is a substantial upstand beam, hidden in the raised floor, making the slab 500mm thick."

The staircases are also integral to the structure. "These are made from 200mm-thick precast concrete stringers or balustrades," says Tompson. "Each stringer weighs about 10 tonnes and provides the structural span across the atrium."

Despite their obvious strength, the stairs appear almost to float above the reception areas. It is a neat trick, and emblematic of the clever use of concrete throughout. Nicholas Hare has combined reassuring solidity with the lightest of touches.

IT WAS A VERY TIGHT SITE, SO IT HELPED TO BE ABLE TO CRANE COLUMNS AND OTHER ELEMENTS INTO PLACE

The campus has two faces

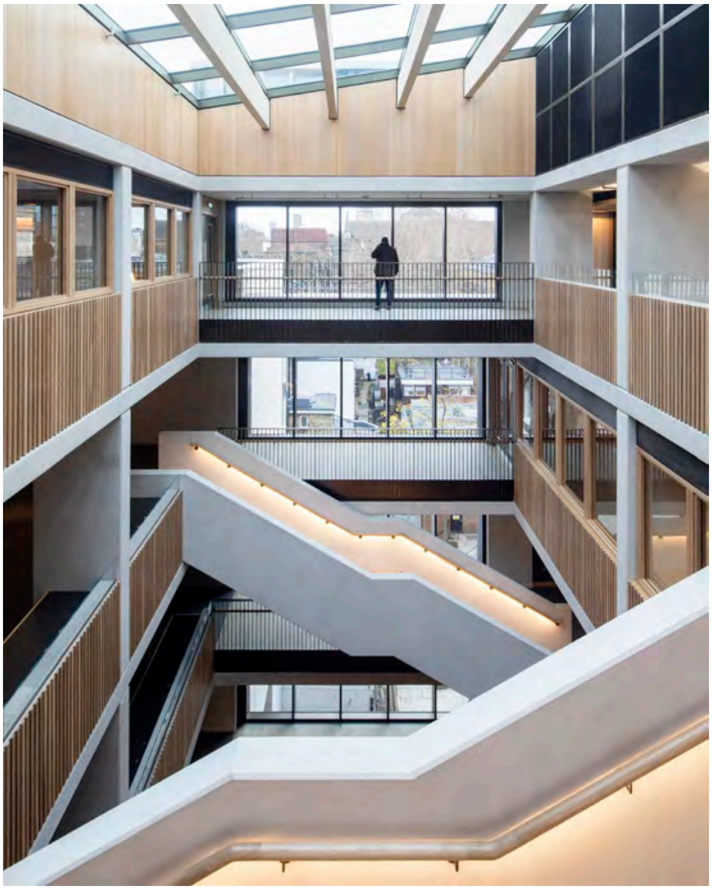
The pale concrete elements framing the doors and windows of the front facade are all precast, though they are supported off the foundations and do not form part of the structural frame. The tall brickwork piers are also precast – the bricks having been sawn in half and set into 12m-high pieces. "If the brickwork had been laid by hand we would have needed long-term scaffolding on Gordon Street," says David Tompson at Nicholas Hare Architects. This way the brickwork was simply craned into place."

For the rear facade the technique was completely different, with the windows formed from rows of large L-shaped precast elements which then had brickwork laid around them by hand. Like all the exterior precast, the colonnade of concrete pillars around the rear entrance has been acid-etched to expose the fines and provide texture. "It also makes it even harder to pick which of the four surfaces is the unformed, trowelled surface," says David Moses at Cornish Concrete.

Finally, at the top of the rear facade is a row of vertical concrete fins, only 100mm wide and chamfered to 60mm at the front. These provide design interest and solar shading to the cafe at the rear of the top storey."Supporting and setting the fins separately on site would have been

expensive and complicated so we made them in units of three fins complete with a coping and parapet all in one [shown above]."

Creating elements so slim required a special approach to reinforcement, Moses adds: "The units were cast with the fins horizontal. They were too slim to use spacer blocks or clips for the reinforcement as these might have been visible on the face of the unit. Instead we suspended the reinforcement from the top of mould and cut away the ties once the concrete had set."



PROJECT TEAM
Architect Nicholas Hare Architects
Structural engineer Curtins
Main contractor Mace
In-situ concrete contractor J Coffey
Precast concrete provider Cornish Concrete

PREVIOUS SPREAD The precast stairs and balustrades closely colour-match the in-situ frame

LEFT The slabs are 500mm thick but are partly concealed where they overlook the atrium

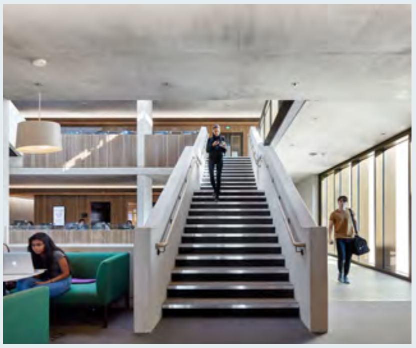
FAR LEFT The door and window frames and brickwork piers of the entrance facade are all precast

BELOW A section showing the new route through the campus from Gordon Street

SECTION

1 Open study space
2 Quiet study space
3 Quiet contemplation room
4 Student enquiries centre
5 Group room
6 Group space
7 Cafe
8 Plant room

Visualisation: Nicholas Hare Architects



The illusion of sameness

As part of the strategy to design the UCL Student Centre to BREEAM Outstanding level, the concrete mixes used include high proportions of cement replacement and recycled aggregate. Combined with the different types of concrete involved in the building and the need for them to match each other visually, this requirement led to some interesting mix choices.

All of the in-situ concrete, for example, features 50% ground granulated blast-furnace slag (GGBS) but the use of recycled aggregate was restricted to non-visual areas, mainly in the basement, as locally supplied recyclate could not easily achieve the fine finishes required.

Once the in-situ contractor, J Coffey, had completed a capping beam on top of the secant piled wall, precast supplier Cornish Concrete produced a number of samples to match its colour. Most of the precast concrete also features a 50% GGBS mix, but uses 100% recycled aggregate – Cornish Concrete's regular supply being stent, a secondary granite aggregate that uses local china clay production waste.

"The only exceptions to this were the stair stringers," says David Moses, Cornish Concrete's product director. "Like the columns and sandwich panels, the stringers were cast flat on their side – so the upper surface, which forms the inner wall of each stringer, had to be trowelled smooth. This is a large and highly visible surface which we needed to get very flat. Power floating was not an option as working the fines that much would darken the concrete. Instead we used a non-GGBS mix which made trowelling it smooth easier. Because GGBS naturally results in pale concrete, we included some white cement in the stringer mix to ensure the colour matched."

Yet another mix was required for the balustrades to the ground floor "grand staircase", which exists to take account of the difference in level between the front and back entrances. "Unlike all the other stairs in the building, this one is made from in-situ concrete," says Tompson. "However because its balustrades naturally have sloping top surfaces, these are made from self-compacting concrete to fill the forms more reliably."

BAUHAUS CUBED

Heike Hanada's Bauhaus Museum Weimar is quietly eloquent about the movement's complex history, writes Nick Jones

CLOCKWISE FROM ABOVE
The double-height foyer with Tomás Saraceno's installation Sundial for Spatial Echoes; LEDs illuminate the facade at night; the minimalist box on its "classical" plinth; services are concealed within the ribbed slabs

The centenary of the Bauhaus is being marked by celebratory events across the world. But in the legendary design school's home town of Weimar, architect Heike Hanada has taken a more reflective approach to its legacy.

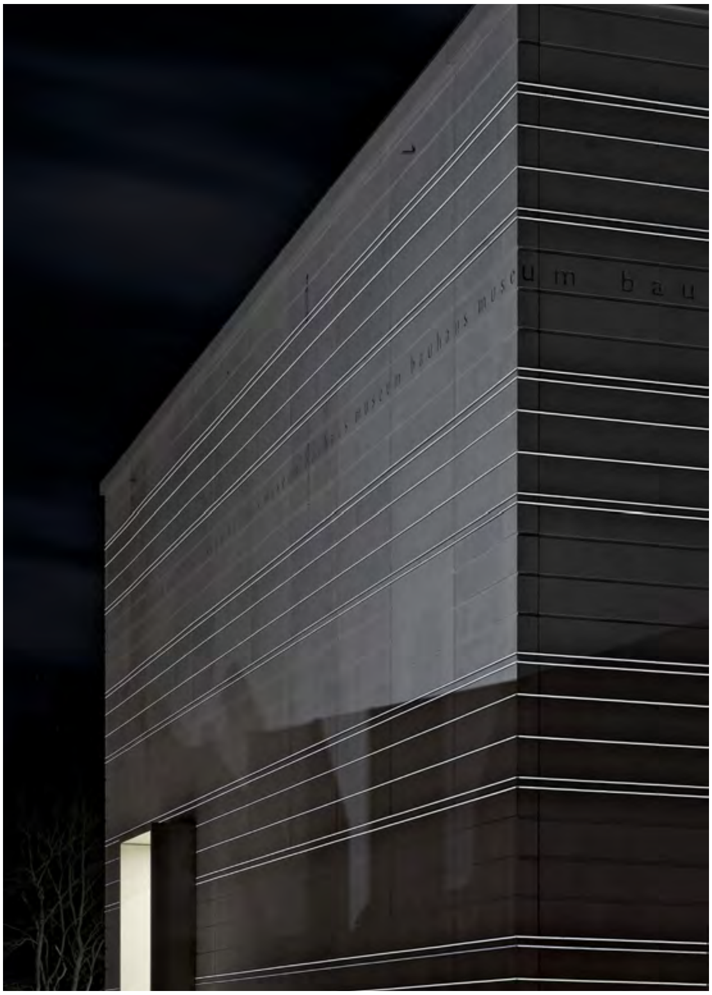
The new Bauhaus Museum Weimar, designed to house 1,000 pieces from the world's largest Bauhaus collection, could easily have comprised a greatest hits of the school's motifs, from Herbert Bayer's sans-serif Universal typeface to the monochrome, glazed facades and projecting balconies of Walter Gropius' Dessau complex. Instead, Hanada has conceived something far more mysterious.

"The museum is reduced to a clearly defined, geometric form," Hanada says of the near-windowless five-storey cube, which stands on the edge of the Weimarhalle Park. The minimalist exterior is framed in precast panels of light-grey concrete. Without the words "bauhaus museum" cast into the concrete in a continuous band at fourth-floor level (at the client's request), you would be hard pushed to guess the building's purpose. "The enclosing shell of light-grey concrete lends the cube stability and dynamic solidity," says Hanada, but it also adds ambiguity, creating an effect that is more sombre than celebratory.

But that's partly the point. Weimar's relationship with the Bauhaus has always been an ambivalent one – Gropius only began what is now the museum's collection when the school was forced to leave the conservative town, moving to more socially enlightened Dessau in 1925. Weimar, former home of Goethe and Schiller, has always preferred to see itself as the cradle of German classicism rather than radicalism.

Hanada alludes to this tension in the museum's design. The cube's rigid modernist geometry is subtly disrupted by classical elements: a pedestal, frames for the windows and entrance, and a plinth highlighted in darker concrete. The building's location is also telling. "The structure serves as a hinge on a fault line in German history," she says, "on one side, the spacious Volkspark created during the 1920s, and on the other, the so-called 'Gauforum' built by the National Socialists." In this way, the Bauhaus is quietly but firmly placed in the context of a messier, more eventful history: the emergence of modernism, its swift expulsion, and the apocalyptic events that followed.

That said, the legacy of the Bauhaus is still etched into the building fabric. The dominant use of concrete is entirely fitting for a museum dedicated to a movement that became a byword for European pre-war modernism: the history of concrete



Photos: Andrew Alberts © heike hanada laboratory of art and architecture

architecture would have looked very different without the works of such Bauhaus alumnae as Gropius, Mies van der Rohe and Marcel Breuer.

The design chimes with Mies' "less is more" philosophy, making resourceful use of space and materials. The precast ribbed slabs are left exposed throughout, their thermal mass helping to reduce the building's energy needs, while the T-beam elements serve a triple role, accommodating the entire ventilation system as well as cabling for the lighting and sound systems. The interiors take their cue from the plethora of museums housed in derelict industrial structures, such as Tate Modern, but given the importance of the Bauhaus to industrial design that seems appropriate. The concrete walls have been coated with limestone slurry rather than painted plaster to create the white backdrops to the exhibits.

The museum also echoes the Bauhaus' concern with the social role of design. The main exhibition is based on Gropius' question, "how do we want to live together?", and uses the history of the Bauhaus to explore issues related to the design of our future living spaces. Hanada argues that the museum's introverted design actually celebrates this public function, both in its use of classical elements commonly associated with civic buildings and in its prominent parkside location. "The connection between the city and the park was very important to me, for the museum is defined by its function in the public sphere," she says.

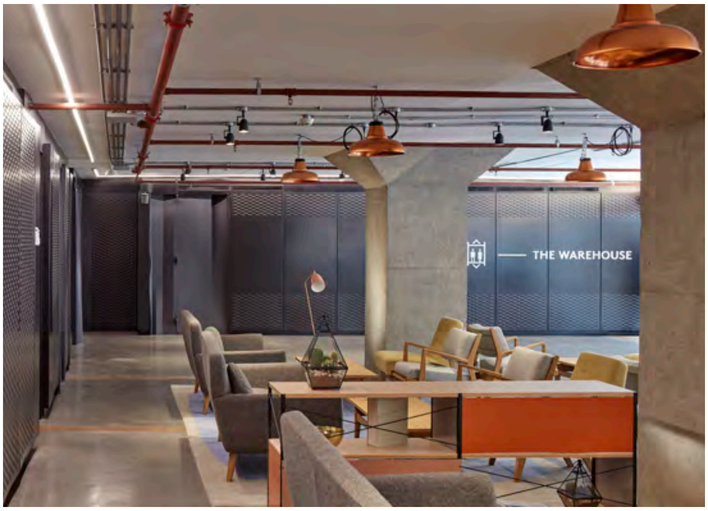
Internally too, she adds, the design "invites one to stroll and linger". A shop and entrance hall is located on the ground floor, with a cafe and toilets below, and three floors comprising 2,000m^2 of exhibition space above. Each of the galleries overlooks double-height spaces, which are arranged diagonally to provide alternative lines of sight and help visitors to orientate themselves. A long ceremonial staircase rises the height of the building, connecting the various spaces together.

The other overtly public gesture is only obvious when darkness descends. Cast into the concrete facade are horizontal grooves embedded with lines of LEDs, which illuminate the building at night, transforming it from geometric precision into something ethereal – perhaps even celebratory.

THE ENCLOSING SHELL OF LIGHT-GREY CONCRETE LENDS THE CUBE STABILITY AND DYNAMIC SOLIDITY

PROJECT TEAM

Architects Heike Hanada, Architekturbüro Manfred Schasler
Structural engineer Ingenieurbüro Trabert
In-situ concrete contractor Hentschke Bau
Precast concrete contractor Hemmerlein Ingenieurbau



Photos: Rob Parrish, Timothy Soar

STAYING BOWER

In Shoreditch, AHMM shows that there's still a place for 1960s offices in the modern world, writes Debika Ray

London's Shoreditch is no longer home only to start-ups and creatives, but to a host of larger and older businesses seeking to attract young talent. The Bower, a 43,445m^2 scheme near Old Street roundabout by Allford Hall Monaghan Morris (AHMM) for developer Helical, is the latest to cater to the growing demand for quality office space.

Originally the site comprised two modernist structures designed in the 1960s by Cecil Elsom for British Telecom – a 14-storey office tower and a lower warehouse, surrounded by parking space. AHMM has converted these into three buildings that contain restaurants, a pub and cafes as well as offices, and frame a new, quiet public street, rather than opening onto the busy main road. "It becomes a piece of city, which is important," says Philip Turner, associate director at AHMM.

Rather than demolish the 1960s buildings – which are often tricky to adapt to modern working practices – the client believed that the existing structures had something special to offer. The warehouse, refurbished first, had an attractive concrete frame with columns that have flared, mushroom-like square heads.

"As the frame goes up from one floor to another, the columns get thinner, but the column heads remain the same, to the point that, at the top, they're quite pronounced in character," Turner says. "It became an active client decision to expose the concrete frame, not just because of its thermal mass and to preserve the full ceiling heights, but because it's a Shoreditch warehouse building, not a West End office, and so that's the look a lot of people want."

Exposing this striking structure involved removing a layer of tiling, a process that was complicated by the discovery of asbestos in the fixing adhesive. Blasting this off using wet abrasive blasting – where high-pressured sand and water is pumped out through a "quilling" gun – yielded an unexpected opportunity. "It has given an amazing pattern to the soffits – a kind of abstract, decorative finish," says Turner.

On the tower, AHMM added three floors and a new facade, and extended the front and back of the building. This enabled the architects to create 5.4m double-height zones, introducing space, light and views where previously floor-to-ceiling heights had been as low as 2.25m. The original glazed cladding was stripped off and replaced with a mirrored wall system, and the concrete frame repaired. Structural engineer Waterman Group had also worked on the original project, so referenced its 1960s drawings when testing the capacity of the existing frame, before adding new substructure.

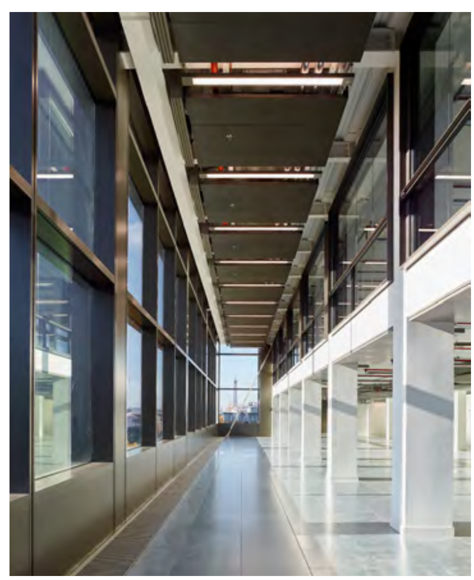
Back in the warehouse, there is a final concrete flourish, where some of the precast panels featured abstract relief patterns. These have been cleaned and exposed in the reception area, ironically adding to the building's contemporary character, says Turner: "It's the sort of thing we actually spend quite a lot of time trying to make now."

PROJECT TEAM

Architect Allford Hall Monaghan Morris
Structural/civil engineer Waterman Group
Facade engineer Arup
Main contractors Sisk, Skanska

CLOCKWISE FROM TOP LEFT

Mushroom-headed columns in the warehouse; original precast-concrete murals grace the reception; the tower has been extended outwards, creating double-height zones at the front and back



Photos: Felix Mooneram

SPECTRAL BEAUTY

BPN's Ghost House brings the spirit of Tadao Ando to a Warwickshire village, reports Pamela Buxton

Birmingham practice BPN Architects had never built an all-concrete building when it embarked on Ghost House, a largely concealed new home in Moreton Paddox, Warwickshire. Created entirely using in-situ concrete, this adventurous design was something of a baptism of fire. The client already had planning permission for a partially submerged limestone and corten-clad house but – as a big fan of Tadao Ando's work – asked BPN to revisit this design in concrete, which is used as both structure and finish inside and out.

"It's very simple in its material palette. All the services were cast in, there were no decorative coverings, just the concrete and the steel-framed windows," says BPN associate Phill Shepherd.

The unusual design makes the most of the sloping site and is bounded on three sides by retaining walls. The entrance is at the upper level via a walkway between reflecting pools of water. Stairs lead down to a lower court and through into the main living space at the rear, which has a 6.3m-high glazed elevation. On this lower level are two bedrooms and a cinema. A symmetrical dual staircase leads back up to the top-lit master bedroom. This 18m-long concrete box spans over the main living area but is set back by 1m at the elevation, creating a double-height space.

BPN worked with structural engineer Design2e on the concrete design and detailing. Huge attention was paid to planning the arrangement of the shuttering. Everything was symmetrical, with the panel widths of wall and ceiling precisely lining up.

The structural slab and retaining side walls are 350mm thick, the latter backed by a 120mm layer of low-absorbency, extruded polystyrene insulation and a tanking membrane. The rear wall is insulated with concrete inner and outer leaves. The 250mm inner layer was cast first, with insulation placed against it, acting as permanent shuttering for the 200mm outer layer. The in-situ pour took 22 months and used phenolic-faced ply formwork.

"At the time we couldn't find an off-the-shelf solution for casting this type of construction which would keep the tie holes consistent with the rest of the setting out," says Shepherd.

CLOCKWISE FROM TOP LEFT
Stairs descend to a lower court, which leads to the main living space; the external walkway slices between two reflecting pools; the interiors are lit by channels of LEDs cast into the soffits

PROJECT TEAM
Architect BPN Architects
Structural engineers Design2e, Webb Yates
Concrete contractor Jon Johnstone Construction
Light channel formers Max Frank

One of the biggest challenges for the team was realising the LED lighting, which is embedded in 65mm x 65mm linear channels that rise up the wall from a height of 0.5m and progress across the ceiling. The architects explored various ways of securing moulds for the channels within the formwork, eventually using extruded polystyrene wrapped in rubber, which was screwed into the shuttering.

As something of a concrete purist, the client wanted no filling or special finish. "He didn't want it too perfect," says Shepherd. "He enjoyed the poured quality and wanted a good finish without it being pristine."

PERFECT TIMING

Remediation works may be finishing operations but they should be carefully planned and phased throughout the build, writes Jonathan Reid

When in-situ concrete is to be left exposed and a high quality of finish is desired, some degree of surface enhancement should be anticipated. If planned from the outset as part of the programme of construction works, the efficiency of the process can be greatly improved, leading to more successful results. The particulars will be project-specific, but establishing a strategy pre-tender will reap rewards in the long run. This article explores the key considerations and the recommended timing of remediation work.

When planning for remediation works, specifiers should initially explore the following aspects.

Quality of finish, potential scope of works and identification of likely issues

The specification should include supplementary information on common issues and best practice to help reduce their occurrence from the outset. Guided by reference projects and subsequently narrowed down to site-specific mock-ups, a framework of quality can be established. Potential project-specific issues will become apparent through mock-up production – this is an extremely useful tool for identifying challenges and adjusting work strategies to reduce the final scope of remedial works. The mock-up will in turn clarify the most appropriate cleaning mechanism, trial proposed sealers and form a benchmark agreement for the quality of any remedial works.

Categorisation of remedial works

Identifying categories of remedial works simplifies identification, and assists in creating a schedule of works when concrete production (or individual phases) have ceased. These can be marked on a plan and cross-referenced to any benchmarks.

Types of access required

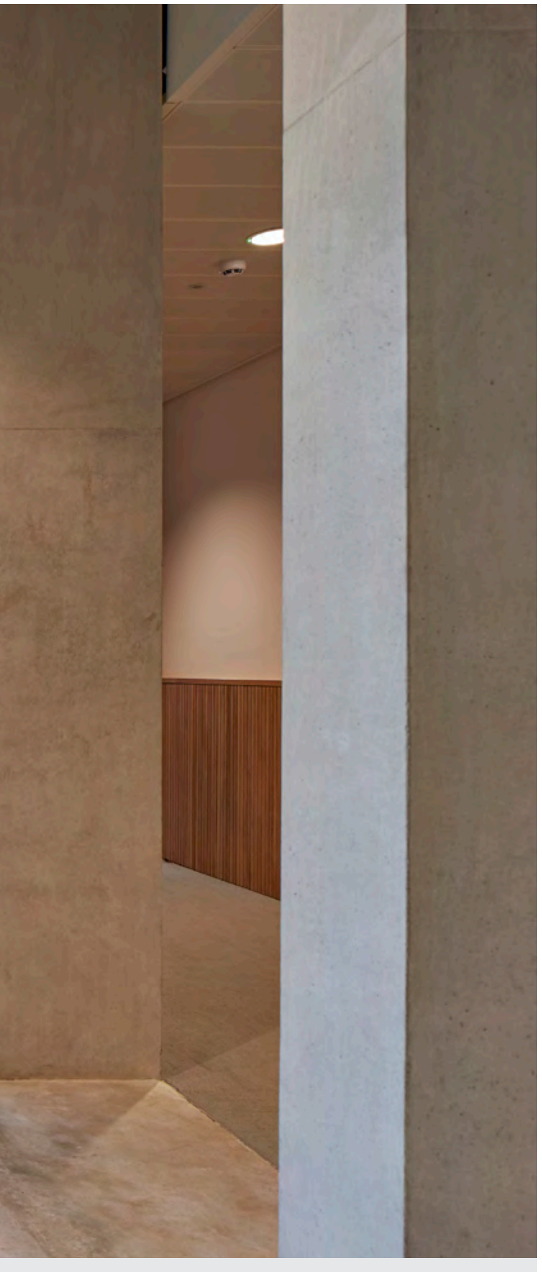
Access considerations are likely to be the main factor determining timings and sequencing of post-finishing work, so an access plan is critical to the efficiency of remediation works. If works rely on a mobile elevated work platform (MEWP), such as a scissor lift or cherry picker, then efficient use of these machines will be a priority. Nearly all soffit work and walls in double or triple-height atriums and columns will benefit from using a MEWP.

▲ St Paul's School, London

A smart new general teaching building designed by Walters & Cohen Architects is being constructed at St Paul's School in Barnes. It is being delivered in two phases to minimise disruption, with phase 1 completed in October 2017.

Exposed concrete is a significant feature of the interiors, with in-situ soffits, frames and stairs all on show. Concrete contractor Toureen Group, well versed in the provision of high-quality concrete surfaces, was proactive in organising the post-striking improvement works. A two-part approach was established soon after the concrete was struck based on a hierarchy of quality and the extent required.

General cleaning and rubbing down was carried out by Toureen, together with isolated patch repairs in less conspicuous areas, made without colour matching. A separate "VIP area" was identified in the stair core, recognising the specialist skill needed to improve the untidy junction and marks created by the grout check. A schedule of remediation works for the stairs was collated in collaboration with GreyMatter Concrete and subsequently subdivided into remedial works categories. A benchmark sample of each category was then carried out for approval. Undertaking this exercise early on proved worthwhile, for setting quality standards, establishing an overall strategy and programming future works.



Photos: Dennis Gilbert / VIEW

LEFT At St Paul's School, Toureen Group and GreyMatter Concrete collaborated closely on remediation works for the stair cores

ABOVE Phase 1 of the new general teaching building was completed in October 2017, with phase 2 due to complete later this year

Through good communication, aligned expectations and early programming, the second stage of remediation works was achieved without disruption to the overall programme, taking place in a cleared area while second fix was taking place. Over a two-week concentrated period, some remediation skills training was also given to the concrete contractor's team.

Phase 2 of the build is due to complete later this year, again with large areas of concrete on show. This time, the team pre-booked GreyMatter, adding the post-finishing improvement works into the programme before the concrete was even placed. However, in this instance the quality of the concrete has turned out so well that its specialist services were not required.

On larger-scale projects, MEWPs are the single most valuable tool for safe, efficient working. If there is to be a raised access floor with services underneath, for example, then finishing soffits above this area becomes a priority before services are installed. Once raised access floors are in place, only lightweight mobile scaffold towers or podiums can be used.

Access to stair cores should be carefully timed so as not to inhibit movement of follow-on trades. If possible, works should be completed early on and subsequently fully protected. An ideal scenario would use temporary scaffolding "Haki" type stair towers which fully restrict general access to the stair cores, but allow free-flow of other trades.

Protection

There are two types of protection to consider: during concreting and after concreting. During the works, the concrete contractor is best placed to arrange protection and this is likely to have a dual purpose, to both prevent damage and aid curing. Reusing ply form-face material can be very useful in this instance. Protection will be removed for any remediation works, so follow-on protection against damage by other trades is highly recommended. This may be best undertaken by the main contractor to mitigate against additional damage.

It is also worth mentioning that damage can be effectively reduced by clearly communicating to follow-on trades that the concrete is a finished item. This is best achieved during initial site inductions.

DAMAGE CAN BE REDUCED BY CLEARLY COMMUNICATING TO FOLLOW-ON TRADES THAT THE CONCRETE IS A FINISHED ITEM

Dust, water and messy operations

There are significant advantages to carrying out dusty, wet and messy work as soon as possible in order to avoid damaging other finished work and to reduce the need, and therefore cost, of protection. This will specifically relate to cleaning, preparation such as chiselling out, and filling operations.

Weather and temperatures

Remediation works are best carried out in warm, dry conditions as this is likely to speed up the process. In warm conditions, proprietary repair mortar can set in 15 minutes whereas it may take up to an hour in cold weather, which can affect its quality. External working in winter months is likely to be impractical and is best left to between spring and autumn in dry weather or under protective cover. Internally it is best to undertake works when the building is weathertight, and preferably glazed to reduce wind chill.

SEQUENCING

Cleaning

Quality judgements cannot be made until the struck concrete has had the opportunity to cure and has been cleaned. Cleaning can greatly elevate the aesthetic quality of the work, and impulsive decision-making should be avoided before it has taken place. Timings for cleaning should allow for a full 28-day curing period undertaken as per the agreed method from mock-up trials. Starting with soffits or areas subject to access restrictions will ease future congestion as the site gets busier.

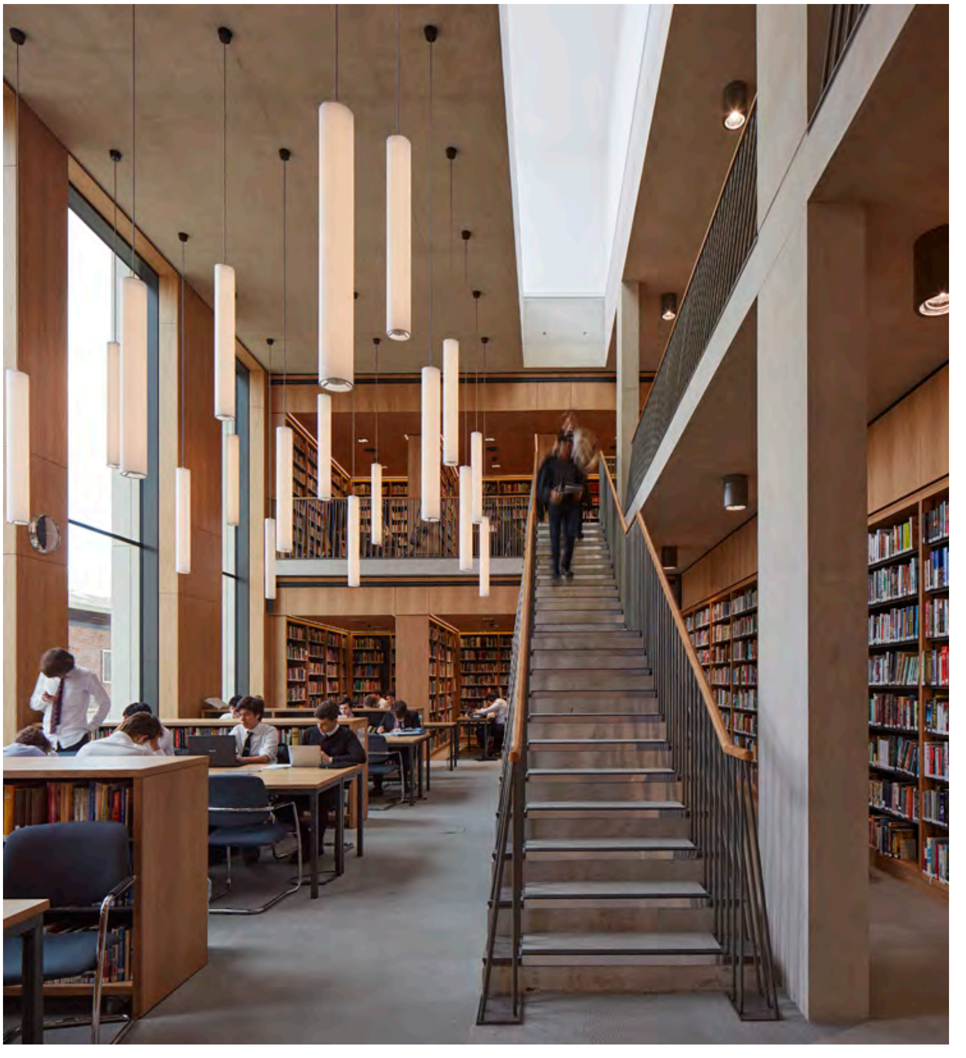
Inspection and schedule of works

Inspection will follow cleaning, with quality assessed in relation to the approved mock-up, reference project and tender document. The schedule of works should be limited to an agreed scope unless additional damage occurs. As the concrete's appearance improves, other nuances tend to become more evident and there is often the temptation to add new items to the scope. This can risk a spiralling of costs and time. Subjective items or those that may improve over time, such as discolouration or tonal variation, should be held in an "abeyance list" for later evaluation. The sequence will be determined by access priorities and the critical path. For efficiency, all works should be grouped and organised by location.

Selecting and sequencing critical and non-critical works

Works might be deemed critical or non-critical where they require differing levels of remediation quality. This is likely to be determined by viewing distances or position – for example, a front-of-house lift lobby versus a fire-escape stair core. Accepting that one size does not fit all will allow for a more flexible and cost-effective strategy. Non-critical repairs, where final colour matching is not essential, may only require generic mortar filling. These can begin as early as possible once the schedule of works is complete.

Critical works are likely to involve specialist input and careful colour matching. Although the first phases of preparation and mortar filling can be carried out early on, as per the non-critical works, a much later phase of colour matching will ideally take place as late as possible in the build. Colour matching is a clean, dust-free process undertaken under the perfect scenario of full access, a weather-tight building with glazing in dust-free dry conditions. Any items previously collated on an abeyance list can now be revisited and treated if they are still thought to be necessary.



ABOVE AND LEFT At St Paul's School, the second stage of remediation works was achieved without disruption to the overall programme

Tie-hole filling

Tie-hole filling can be undertaken before or after sealing but should be one of the latter operations in the concrete contractor's programme. If this is impractical due to access restrictions, it should be remembered that excessive moisture from condensation can darken mortar or tie-hole plugs, especially in stair cores or where large temperature fluctuations might exist. Hence these areas should be left until last if possible.

Sealing

Sealing concrete will again be influenced by access but should be one of the last activities. It is likely to be more efficient if finished work is handed over as part of a decorating or final cleaning package. The surface should be clean and dust-free before application, and those responsible for removing construction dust should also be responsible for the sealant. Walls should always be sealed from bottom to top in a planned sequence with completed areas marked up on a drawing – it is very easy to lose sight of what has and has not been sealed.

Summary

If one considers remediation work to be an essential element of visual concrete production, then developing a straightforward plan will be both simple and highly influential on efficiency and quality. Having a clear understanding of each phase and the best party to undertake it will inevitably lead to a beneficial and integrated strategy.

Jonathan Reid is director of GreyMatter Concrete.
See CQ 259 for his introduction to remediation: concretecentre.com/cqarchive

CONCRETE'S OTHER HALF

With careful planning, timber formwork can offer concrete surfaces of unrivalled tone and beauty, writes Hannah Fothergill

ABOVE It is vital that the joints between the boards are completely watertight

RIGHT The Royal College of Pathologists headquarters by Bennetts Associates, where rough-sawn 75mm-wide pine boards were chosen to align with adjacent hand-set brick courses

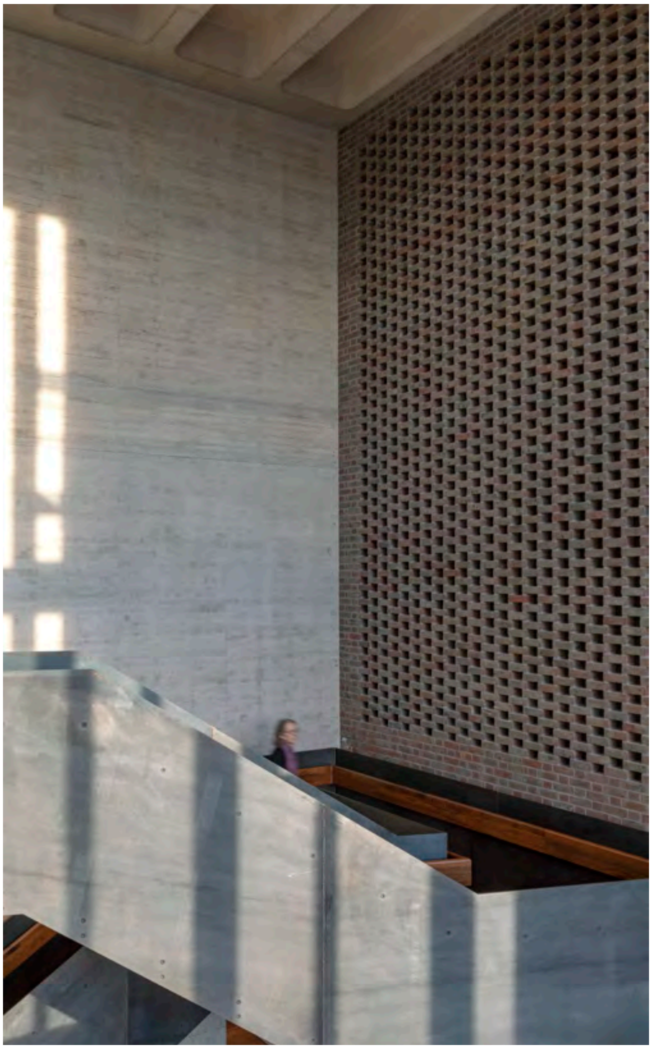


Photo: Peter Cook; construction photos: Grant Smith

Concrete has the glorious ability to pick up every detail of the container it is poured into. In the 1990s and early 2000s, the pervading preference was for smooth-as-silk concrete, but designers are now returning to concrete that has texture, form – and arguably a hell of a lot more character.

Methods of constructing board formwork have evolved considerably over the last 70 years. Nowadays, it is typically a hybrid of steel and timber whereas historically it was only timber – you'll struggle to find a tie-bolt hole anywhere in Denys Lasdun's National Theatre, where the formwork was built piece by piece and propped from the outside. The advent of steel universal formwork systems has vastly improved efficiency, rationalising design and improving safety on site. There are now also huge ranges of form-liner products available, enabling designers to replicate any pattern or texture of their choosing. Rubber liners lend themselves well to large-scale projects where repetition and speed are key factors – AHMM's recently completed White Collar Factory is a good example where this method was used to achieve beautiful textured concrete. As with most things in life, however, nothing quite beats the real thing. Timber has a natural ability to absorb and release moisture, giving the finished concrete a deeper tonal variation and beauty.

When specifying board-marked concrete, it is important to start thinking about site processes and details as early as possible. Supply chain engagement is invaluable for balancing meticulous detailing with an understanding of what can be achieved. Benchmark building visits are key to informing decisions – contemporary examples include the Everyman Theatre in Liverpool by Haworth Tompkins and AHMM's Weston Street apartments in London, both useful references when Bennetts Associates specified the concrete for the Royal College of Pathologists headquarters.

Decisions must also be made about timber species, and board size and texture. On RCPath, we decided to use rough-sawn 75mm-wide pine boards aligning neatly with adjacent hand-set brick courses, whereas Weston Street used 150mm-wide boards with a smoother sawn finish. "Even things like the type of saw used in the mill can make a difference to the finish," says Edward Bourke, contracts manager at Oliver Connell & Son, the subcontractor on both projects. "Generally 75mm-wide planks are cut using either circular saws or band saws, giving the option of different finishes. It can however prove difficult to get hold of 150mm-wide boards that have not been cut with circular saws, and this can lead to problems with semi-circular patterning on the surface of the timber."

However, the most important element is the water content of the timber. This must be uniform: any variation, be it between batches of timber delivered to site or within the planks themselves, will affect the appearance of the finished concrete, in a way that cannot be easily remedied with post-finishing. Humidity-controlled storage of the timber is key. If it is left too long on packers or in straps, localised variation in water content can cause banding to appear in the finished concrete. To reduce this risk, site mock-ups should be done using the intended timber source and, where possible, timber should be stockpiled rather than bought it in at different stages.

Thorough preconstruction review and setting out of formwork also goes a long way to minimise surprises and errors on site. For RCPath, we drew up each board-marked concrete elevation at 1:50 scale to define board heights, lengths and the setting out of tie-bolt holes and construction joints. Skill, time and cleanliness on-site are all crucial. Timber boards need to be accurately cut to size and fixed to a plywood substrate on the formwork. The alignment of nail fixings needs to be thought through as their imprint will appear in the formed face. It is also vital that the joints between the boards are completely watertight to avoid grout loss and aggregate bridging. At RCPath, a very fine bead of silicone was sandwiched between the boards, away from the formwork face, and small enough to avoid any excess being squeezed out and staining the concrete surface. As a second line of defence, 2-3mm of builder's caulk was applied to the form face with a pointing gun and then tooled and trimmed to remove excess.

This is a labour and care-intensive task, but the reward is great. It is no surprise that board-marked concrete is enjoying a revival in these technology-dominated times: we crave materials and spaces that are crafted, unique and thoughtful. The material's memory, the expression of process and embodiment of natural imperfection grounds us in our location and connects us to each other. That's not fashion or fad, that's human instinct.

Hannah Fothergill is founder of Studio Fothergill and a former associate at Bennetts Associates

RETURN OF THE RIB

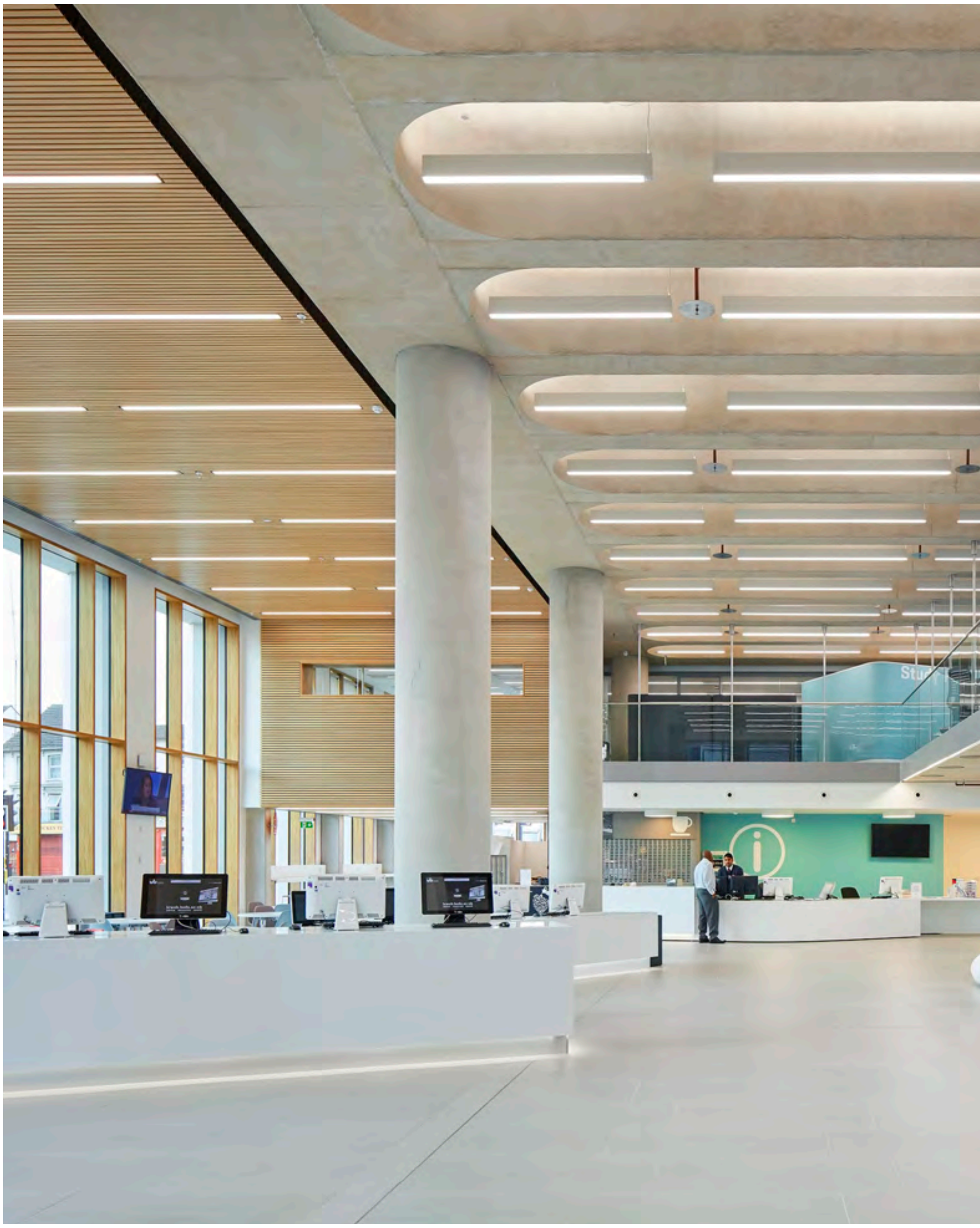


Photo: Hufton + Crow

Ribbed slabs of all varieties offer many benefits for the whole-life performance of a building, write Jenny Burridge and Elaine Toogood

Having been somewhat out of fashion for many years, the ribbed and waffle slabs built 50 years ago are now being refurbished to provide thermal mass and visually interesting soffits. Meanwhile new buildings are being constructed with ribbed slabs to enable longer spans, with less concrete and steel, and therefore lower embodied carbon.

Why specify ribbed slabs?

- **Material efficiency** Although ribbed slabs are deeper than flat slabs, the amount of concrete and reinforcement is considerably less, with a saving of about 20% in the volume of concrete and 10% in the weight of steel. This means smaller loads, resulting in slimmer columns and less extensive foundations. Ribbed slabs can also be post-tensioned, which reduces the concrete volume by a further 10%. They are more suitable for longer spans than flat slabs, and post-tensioned ribbed slabs can be used for much longer spans. It is possible to construct a 15m span with a depth of just 600mm (see figure 2, overleaf).
- **Visual interest** Where the soffit is exposed, a ribbed slab can add architectural interest. The coffers formed by the ribs can be used as the space for lighting and chilled beams.
- **Thermal mass** The potential of concrete to help stabilise internal temperatures is a frequent reason for leaving concrete walls and soffits exposed. Ribbed slabs enhance this by increasing the surface area of the soffit.
- **Vibration control** Ribbed slabs provide a stiffer floor than an equivalent flat slab and therefore reduce vibration from footfall or equipment.

Types of ribbed slab

There are different types of ribbed slab, but the terms "ribbed", "troughed" and "coffered" are used interchangeably by most architects and engineers. In the Concrete Centre book, Economic Concrete Frame Elements to Eurocode 2, we use "ribbed" to denote a one-way slab sitting on beams which are deeper than the ribbed slab. "Troughed" denotes a slab where the beams and the ribbed section are the same depth. "Coffered" tends to be used for a slab where the ribs are not as defined as in a typical ribbed slab, for example at Portcullis House in Westminster. A waffle slab is different to the typical ribbed slab in that the ribs run in both directions producing a soffit that looks like a waffle. These were very popular in the 1960s and 70s, the Barbican Centre in London being a well-known example. In this article, we use "ribbed" as the general term.

Structural design

A ribbed slab can be designed as a slab rather than individual beams provided that the ribs are spaced no more than 1.5m apart, the depth of the rib below the flange is no more than four times its width, and the flange is at least one-tenth of the clear distance between the ribs. The depth of the flange will normally be determined by the requirements of fire and acoustics.

Ribbed, troughed and coffered slabs are all designed as one-way slabs spanning onto primary beams. If troughed slabs are used – ie, the ribs and the beams are the same depth – the most efficient layout is 4:3 with the ribs spanning the longer distance. If the grid is not square, it is usually more efficient to span the longer direction with the ribs and the shorter direction with the primary beams. Shear at the column head is taken by the beam.

Waffle slabs are designed as two-way spanning slabs in a very similar way to flat slabs, splitting the slab into column and middle strips and designed for punching shear at column heads. The coffers for the waffle slabs will normally be left out

Visual ribbed concrete

As with any as-struck concrete, the formwork material used for ribbed soffits will influence the sheen and tone of the concrete surface. Any changes in material will therefore be visible, as will junctions between formwork elements. Addressing both issues in detail is fundamental to a successful outcome.

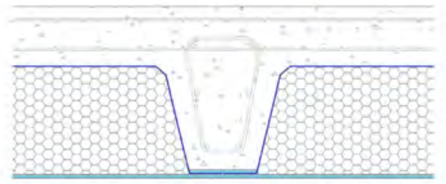
GRP offers the advantage of being moulded as a continuous shape to create the entire trough (including curved ends), reducing the risk of surface variation and the number of junctions required (see details, right). Placing of the folded edge is critical. Details 2 and 3 illustrate good details using MDO-faced ply pushing the junction to the aris where it can be sealed. The GRP gives the concrete a slightly reflective sheen which can be reduced if the mould is rubbed down, but in practice this is not very noticeable if confined to the insides of the troughs.

Correx-coated polystyrene can offer an acceptable surface, and is ideally scored to create a chamfered internal corner, reducing the risk of honeycombing. It comes in 1,200mm lengths, so taped joints will be visible and their workmanship must be controlled on site, as should the vertical termination to the trough. Detail 1 uses a ply insert to cover the ends of the Correx, usefully placing the junction at the arises. A sealed corner is likely to be neater.

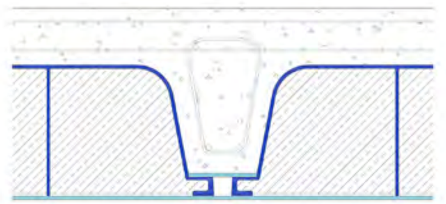
All ply inserts should be cut from the same board to provide a tight abutment between the strips and create the same surface tension, and nail fixings should be set out. Vertical concrete edges are not recommended for these proprietary moulds, with a draft of around 5° required to allow the trough form to be released. Tighter draft angles are possible but typically only for formwork designed to be dismantled on site, for example ply. Designers should consider the practicality of this when designing the section.

Other design tips include avoiding aligning the inside of a trough with a vertical wall. A step forward (as per detail 4) places the cold joint between wall and floor more sensibly in an internal corner. Also, deep troughs are less easily kept clean from debris on site, making it even more critical to tie reinforcement elsewhere.

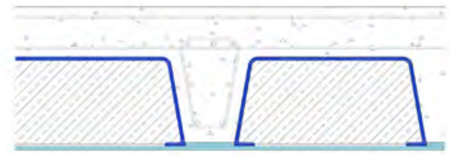
FIGURE 1: FORMWORK DETAILS FOR RIBBED SLABS



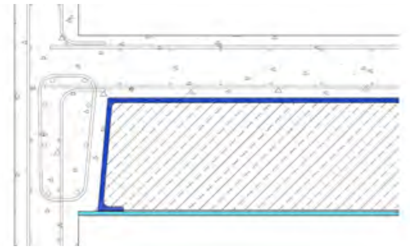
1 Typical cross-section of Correx-faced polystyrene void former. Ply covers joint between troughs. Ideal minimum draft angle 5°



2 Cross-section of detail with GRP void former and ply insert covering joints between trough sections



3 Cross-section of alternative typical detail with GRP void former and ply insert placed between trough sections



4 End section in GRP; profile is set forward of wall

Drawings: Cordek

around the column heads so that punching shear can be resisted.

Figure 2 (overleaf) shows the span-to-depth graphs for different forms of ribbed slabs under an imposed load of 2.5kN/m^2 (residential) and 5kN/m^2 (commercial).

Construction

Ribbed slabs are slower to build than flat slabs because both the formwork and the reinforcement are more complicated. They also tend to have exposed soffits so that the thermal mass benefits can be exploited; therefore more care should be used. Normally the formwork is constructed from a table form with the void formers fixed to the top. The void formers tend to be constructed from polystyrene or GRP. The choice of mould depends on the dimensions, the finish, the installation of the moulds, and intended reuse and repetition. Access and transport to site and positioning of the moulds will all impact budget and programme.

The ribs should always have an angle to the sides, rather than being vertical, to ease the stripping of the formwork. An angle of 4-5° (called the draft) is enough to make the demoulding much easier.

GRP moulds are the most expensive, but because they give the best finish and can be used more times before being replaced, they can also be the most cost-effective. They can give up to about 20 uses, if the contractor is careful. The release agent used on GRP moulds should be oil-based, as solvent-based release agents can damage them.

GRP moulds require a slight radius of 2-3mm on any change of direction so very sharp corners should be avoided. Otherwise the corner becomes a weak point and the mould will not be able to be reused. Joints between the moulds will appear as a line in the finished concrete, so it is worth discussing how best to express them with the formwork supplier.

GRP moulds are all bespoke. Previously there were standard sizes and moulds could be taken from project to project, but that is no longer the case. They can be made on a 13m x 6m pattern machine so 12m-long moulds are probably the largest available. The moulds are stiffened along the length by plywood ribs so that they can be transported and lifted into place. However, though they are moderately robust they do need to be stored carefully while not in use. Storage on site can be an issue with larger moulds.

Photo: Hufton + Crow

LEFT AND PREVIOUS PAGE The University of Bedfordshire library by MCW Architects. The long-span coffered slabs generate large areas of column free space at each floor

BELOW LEFT The bespoke moulds for the coffered slabs were made from GRP

BELOW RIGHT The location of each trough mould is expressed by the rectilinear joint lines and change in surface texture on the soffit at each end

Polystyrene moulds offer a cheaper unit cost, and are available in three different finishes. For ribbed slabs, two are suitable: resin-coated and Correx-coated. The resin-coated moulds are not sufficiently robust to be used more than once; Correx-faced moulds can typically be used three to four times.

Correx cannot be formed around complicated surfaces, but can be curved in one direction, though the curving process results in small ridges on the concrete. Polystyrene moulds are smaller than GRP moulds and several would be needed to form one trough. The joints between the moulds are typically taped and will always be visible, so must be set out and installed carefully.

Trough forms can be created using timber formwork, such as MDO-faced ply. This type of formwork was used on the Judge Business School extension in Cambridge (CQ 264). These can be used for longer troughs or where the shape doesn't lend itself to prefabricated moulds.

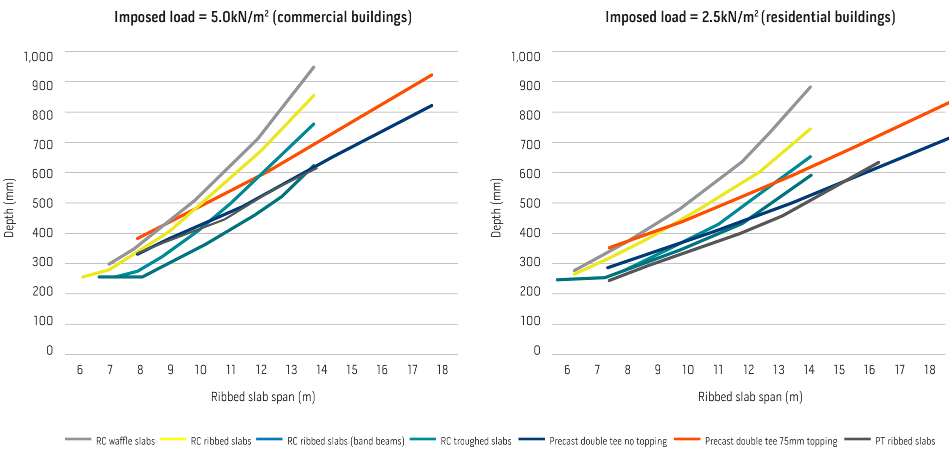
Precast options

Ribbed slabs can also be precast, either as bespoke units or as standard double-T units. The formwork used for bespoke units would be similar in style to that used for in-situ ribbed slabs already described, but with the benefit of factory conditions to maintain and store the units. Transporting the units to site and placing them becomes a more important issue, and the weight of the units can determine the size of crane required.

With thanks to Simon Poole and Dan Ward of Cordek

Photos: Cordek

FIGURE 2: SPAN-TO-DEPTH GRAPHS FOR DIFFERENT FORMS OF RIBBED SLABS UNDER DIFFERENT IMPOSED LOADS



Note: troughed slabs are set at a 4:3 ratio (ribbed slab:band beam) with the span shown being the ribbed slab span. All other span-to-depth ratios are for a square grid.

Source: Economic Concrete Frame Elements to Eurocode 2, published by The Concrete Centre

LASTING IMPRESSION SIMON GOODE

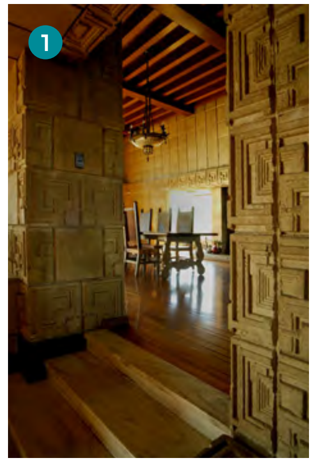
IN PRAISE OF THE SLIGHTLY IMPERFECT

One of our main interests is in sourcing materials that will age gracefully, looking better after a decade or two than they will at completion. As part of a research visit, we went to Ennis House 1 in Los Angeles by Frank Lloyd Wright (1924), which uses handcrafted concrete panels in repetition to create highly tactile external elevations and interiors that are comfortable and warm. Our Lanterna building at Fish Island in Hackney (2018, CQ 266) owes something to this approach: the moulds are handcrafted and the retardant, used to expose the basalt aggregate, was applied by hand, giving the occasional wavy line to the panels' herringbone grooves. It just makes it all a bit less sharp and more human, creating the impression that the building has been there for a long time already.

Another crafted, tactile building is Louis Kahn's monumental Salk Institute 2 (1960), at La Jolla on the Californian coast. While a friend of mine was working there, I had the opportunity to spend long days exploring the faculty buildings. Kahn used a pozzolanic concrete with volcanic aggregate to give the concrete water resistance and a pinkish colouring. Teak panels sit within the structural frame which, in combination with the imperfect in-situ concrete, softens the elevations and provides places of quiet contemplation for Salk's professors.

The Teshima Art Museum 3 by Ryue Nishizawa (2010) on Japan's Seto Inland Sea is a similarly contemplative space, but demonstrates a very different way of using concrete: a pure 60m-wide droplet-shaped structure without any internal columns to support it. The building hosts a single artwork by sculptor Rei Naito, with droplets of water trickling out of the ground, coalescing into shallow streams, and interacting with the concrete surface, rain, snow and insects. The concrete must have a repellent on it, as the water has a mercury-type quality. The result is mesmerising and magical, with no explanation as to how the gradients were formed or the water conduits cast.

Simon Goode is co-founder of Lyndon Goode Architects



Photos: 1.Marmaduke St. John / Alamy Stock Photo; 2.Simon Goode; 3.Iwan Baan

FROM THE ARCHIVE: WINTER 1968

GUARDIANS OF THE ROCKIES

Few architects did more to explore the possibilities of concrete design in the 1960s than IM Pei, who has died aged 102. His confident handling of diverse typologies such as the Luce Memorial Chapel in Taiwan (1963) and the Green Building at MIT (1964) had given him, as CQ put it, "probably more experience of concrete than any other architect in the States".

High up in Colorado's Rocky Mountains, the National Centre for Atmospheric Research represented another "masterly step forward" in the art of concrete expression. Standing like enigmatic sentinels, the buildings were hooded to shade all windows from the strong Colorado light, but also to generate an air of mystery. "You cannot compete with the scale of the Rockies," Pei explained. "So we tried to make a building that was without the conventional scale you get from recognisable floor heights." The finish – "as pink as the rocky landscape which they regally survey" – was the result of extensive bush-hammering, which brought out the colour of the local red limestone aggregate, as if these mysterious, sculpted beings had simply risen from the mountain beds.

Access the full CQ archive at concretecentre.com/cqarchive. A book, *The World Recast: 70 Buildings from 70 Years of Concrete Quarterly*, is available from www.concretecentre.com/publications

FINAL FRAME: TRAM STOP, KEHL

Architect J.Mayer.H has marked the end of the cross-border Kehl-Strasbourg tram line with a stop composed of eight rounded exposed-concrete elements. Two shelters are built from two vertical discs that support the roof; a third vertical disc is formed into a bench. The Berlin-based architect describes the work as an "infrastructural sculpture". The irregular forms were based on precise geometries, he adds. "Basic curvatures got mixed up and recombined to create the organic outlines."

Photo: Frank Dinger