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The Concrete Centre

CONCRETE QUARTERLY

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GLAD TO BE GREY
6a Architects turns down the contrast at photographer Juergen Teller's new studio

FINAL FLOURISH
Post-finishing can bring out the best in concrete – so why is it so often an afterthought?

CRUNCH TIME
Carbonation, and the surprising sustainability benefits of crushing concrete

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AGENDA

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

One certainty in a changing world

It's far from clear what the future holds for the UK as we contemplate an impending Brexit. The implications for materials and labour are potentially wide and very disruptive in many directions: whether there are new opportunities from the government's promised trade agreements, increased demand for innovative off-site solutions as labour shortages bite, or a greater reliance on materials that can be sourced locally, without exposing budgets to volatile currency markets or import taxes.

But looking further ahead, what is certain is our responsibility to continue to cut our energy consumption and carbon dioxide emissions to reduce the global impacts of climate change. There are many innovations within the concrete industry that will play a part, from novel cements and additives that are gradually seeing greater deployment, to the low-carbon cements that are currently under development. Looking much further – several decades – into the future, technologies such as carbon capture and storage will lower the footprint of cement and concrete, as will a carbon-neutral power grid.

Back to the present, there is much work to be done across the construction industry to meet carbon and a range of other sustainability targets. The Concrete Industry Sustainable Construction Strategy was launched in 2008, and the work had begun in 2006 – now more than a decade ago. For 2018, we're reviewing all of our targets, bringing them into alignment with important developments such as the UN's 2030 Agenda for Sustainable Development.

The world has changed since 2006. Since then, we now better understand that collection of data is critical to transparent reporting and that you're never perfect – there is always room for improvement. The social aspects of sustainability have come more to the fore recently – issues such as employment, training and innovation are now entering government procurement considerations. There are much wider issues that we all have to consider now. It's no longer just to do with concrete, but with how concrete's produced, where it comes from, who's working on it, all of its impacts from cradle to grave. We'll be regrouping and refocusing our attention on the areas where concerted action is most required.

Over the coming months, we'll be talking to all of our stakeholders to find out what information specifiers require, the most important considerations for them, and the order of priority. We'd be delighted to hear from readers of Concrete Quarterly.

WE'LL BE REFOCUSING OUR ATTENTION ON THE AREAS WHERE CONCERTED ACTION IS MOST REQUIRED

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CONCRETE QUARTERLY

On the cover:
Juergen Teller Studio in London. Photo by Johan Dehlin
Produced by:
Wordmule
Designed by:
Nick Watts Design

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www.mineralproducts.org

Bartlett reborn

The Bartlett School of Architecture in London has had a makeover. Architect Hawkins Brown stripped the 1970s building back to its concrete structure and remodelled the interior, exposing the frame and complementing it with high-quality joinery.
Lasting Impression P19

BIG bones

Bjarke Ingels Group has revealed plans for 670 Mesquit, a 30-storey building in Los Angeles, with flats and shops all plugged into a gridded concrete superstructure. "The bones of the building are what unite it," says Ingels.

Photos: Jack Hobhouse; BIG; IAAC; incamerastock / Alamy Stock Photo

Printed puente

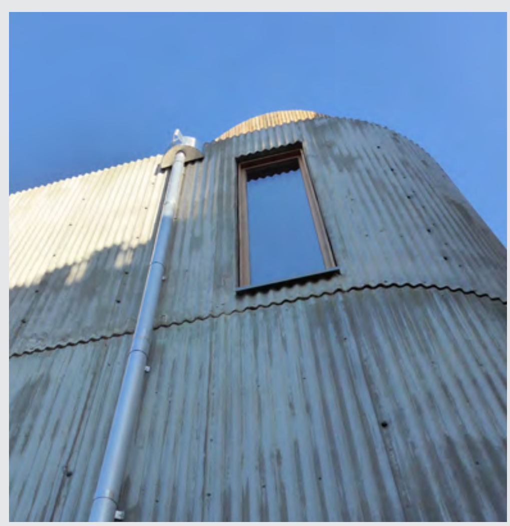
The world's first 3D-printed pedestrian bridge has been unveiled in Castilla-La Mancha park in Madrid. The Gaudìesque 12m bridge was designed by the Institute of Advanced Architecture of Catalonia and printed in micro-reinforced concrete.

In peril on the sea

The Three Ships mural on Hull's BHS store is among a list of the 10 most threatened UK sites complied by the 20th Century Society. The 1963 mural by Alan Boyson, which celebrates the Hull fishing fleet, is composed of nearly 1 million glass cubes embedded in a 66ft x 64ft concrete screen.

PERFECT SKINS

The first Concrete Elegance event of 2017 explored two facades of complexity, rhythm and distinction. The Victoria Gate shopping centre in Leeds (left, page 8) features a dramatic envelope of white concrete panels. Vex house in London (right, page 10), meanwhile, has a fluted in-situ concrete outer wall, which was poured against corrugated steel sheeting to follow the building's complex curves.
For more on future Concrete Elegance lectures, visit www.concretecentre.com



Photos: Jack Hobhouse, Hélène Binet

BACK TO MONO

The London studio that 6a Architects has built for artist and photographer Juergen Teller is almost entirely devoid of colour. But in texture, form and finish, it is as rich as an old master, writes Tony Whitehead

Even by the standards of Concrete Quarterly, the new building on Latimer Road, London W10, is a very concrete building indeed. Admittedly the windows are made from timber and glass, and there are a few brass handrails. But that is about it. The rest: the structure, interior walls, floors, ceilings, soffits, stairs, roof and even gardens are all exposed concrete.

So you might expect the building to lack contrast, feel a bit boring or even oppressive – in fact, the new studio for fashion photographer Juergen Teller is a highly textured, bright, almost playful space, and a superb advertisement for what concrete can do in the hands of imaginative designers.

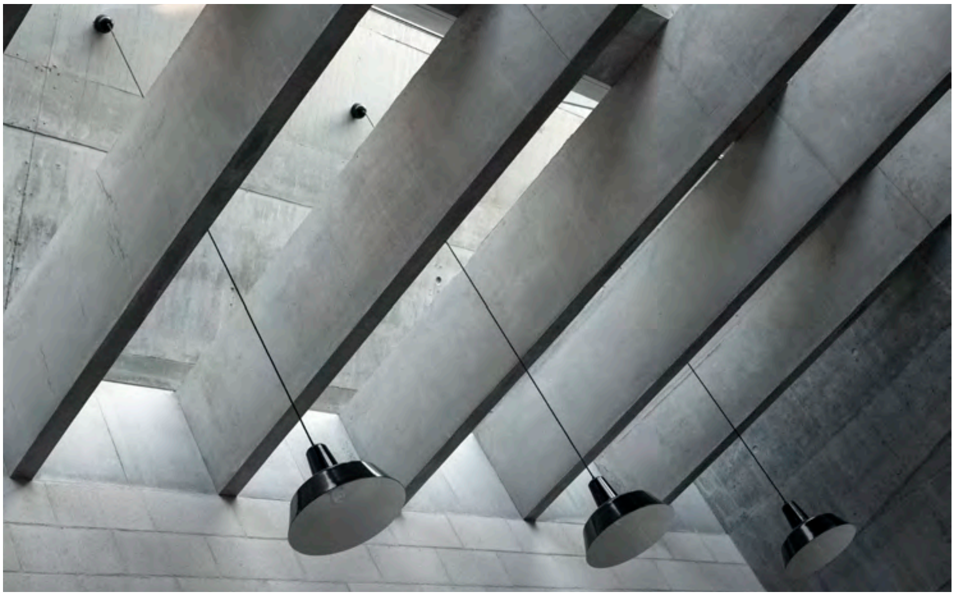
Sandwiched between a brick-built housing terrace and a modern block of flats, the studio fills a 60m-deep site with a frontage just 7.5m wide. It was this very restricted site that first informed the decision to use concrete. "With contrasting architecture either side, the question was how to graft a new building into this site," says Carlos Sanchez of London-based 6a Architects. "Concrete provided the solution because, being a material that flows, it can take whatever form you want."

In practice this meant that the board-marked in-situ concrete that forms the studio's three-storey frontage has been designed from the start to fit with the brickwork to its left. "We had the boards made to size to ensure they were the same dimensions as the bricks and mortar," says Sanchez, adding that, in places, this enabled brick and concrete facades to be physically joined together with a consistent horizontal aesthetic.

Behind the front facade is the first of three

CONCRETE PROVIDED THE SOLUTION BECAUSE, BEING A MATERIAL THAT FLOWS, IT CAN TAKE WHATEVER FORM YOU WANT

Photos: Johan Dehlin



buildings, which contains offices. Moving deeper into the site, this is connected by a garden to the main studio – a largely open space dominated by two slender staircases rising to storage rooms that appear to hang from the ceiling. This in turn leads via another garden to the third building, which houses meeting rooms, offices and a library.

With the exception of the staircases, all the in-situ concrete above ground is self-compacting. While this presented a challenge to the contractor, which had not worked with the material before, it also had a number of benefits, as Sanchez explains. "We chose self-compacting concrete because there was a high level of complexity in some of the pours – especially in the concrete canopies that house the roller shutters to the doors and windows." These contain a lot of congested reinforcement, which would have made it difficult to eliminate air by the normal use of vibrating pokers, he adds, and the formwork also had top shutters under which it would have been easy for air to become trapped. "Self-compacting concrete flows more easily around the reinforcement and so reduces the risk of air bubbles without the need for pokers."

As well as the canopies, other forms presented similar difficulties. These included the sequences of roof beams – spars or ribs just 100mm wide and spaced at 1m intervals below saw-tooth rooflights. Again, reinforcement was too congested to allow the use of pokers, and the sloping saw-tooth forms, like the canopies, also featured top shutters. Self-compacting concrete proved a highly successful solution, flowing into every corner of the forms and producing a finish that exceeded expectations.

Though self-compacting concrete is a more expensive form of concrete, Sanchez says it delivered cost savings in other areas. "Not having to use pokers does save time on site and reduces risk. In the end I'd say it proved a cost-neutral decision."

Inside, it is the walls that catch the eye. These are constructed from white through-coloured fair-faced concrete blocks, 140mm x 225mm x 440mm. "We used lime mortar with these blocks so even in walls up to 12m long there is no need for expansion joints," says Sanchez. "The result is a very beautiful finish, but it took some careful sequencing of work to keep them looking pristine."

The blockwork walls are load-bearing, supporting the in-situ beams and slabs that span the 7.5m width of the site and support the upper floors. "But we needed to keep the blockwork clean and protected from the pours for the slabs. To do this we used the fact that there are actually walls of grey concrete blocks behind the white ones. These were built first and the forms for the slabs were supported off them together with supplementary props."

Once the slabs had dried, the white blockwork was built up to the slab to provide more support, allowing the temporary props to be removed. But would it not have been easier to simply coat the blocks after the pours? "The through-coloured white blocks have an integrity – a special appearance," Sanchez says. "None of the concrete is coloured or painted and it was important to us to preserve that look. In any case, not painting saves time."

Unlike the exterior, the shuttering for the interior in-situ concrete was made from standard-sized, paper-lined MDO boards. "This gives us the matt, non-shiny finish which we wanted as the interior was already quite busy with the blockwork," says Sanchez. The finish is particularly attractive on the vertical faces, such as those on the store rooms'

Making the stairs dance

The central studio building is for the most part double-height, and clear from floor to the saw-tooth roof lights. But at each end it features two straight, slim concrete staircases rising in opposite directions to upper-level store rooms.

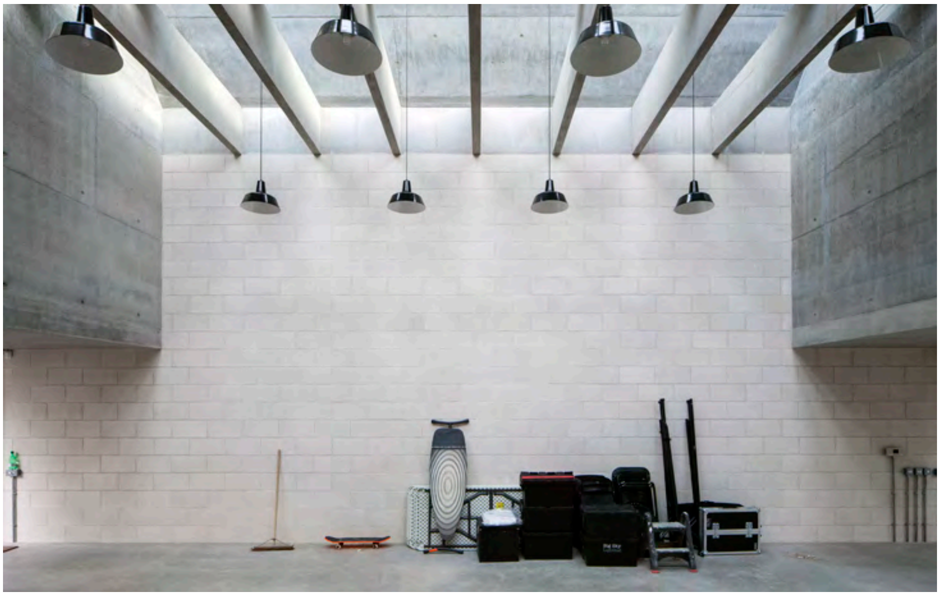
The design and construction of the stairs is key to both the structure and aesthetics of this area – described by Will York, structural engineer with Price & Myers, as the project's "signature space".

"The stairs are the only part of superstructure not done in self-compacting concrete," he says. "In-situ concrete stairs are usually made with the shutter open on each tread, which are trowelled to ensure a flat finish. Self-compacting cannot be trowelled so we used ordinary structural concrete."

Being just 600mm wide, with a 150mm-thick waist, the stairs are very slender – they needed to fit with the architect's vision of a "transparent" centre to the building, allowing occupants to see through from one end to the other. "This made the design of the reinforcement quite tricky," says York, "particularly as the stairs do more than support themselves. They actually play a vital role in supporting the building at this point."

The structural challenge stems from the central building's very open, glazed ends, which do little to stabilise the structure. "At one point, we considered a reinforced portal frame at the ends, but it would have interfered with the desire for transparency in this part of the building. The solution was to use the two stairs as push-pull props."

The stairs, then, are heavily reinforced with careful connection detailing top and bottom. Temporary diagonal props stabilised the supporting walls until the stairs cured and reached sufficient strength to do the job themselves. "I once read that elegance is something that is working much harder than it appears to be – like a swan or a dancer," says York. "I like to think that, with these stairs, we have achieved something elegant."



OPPOSITE Roof beams are spaced at 1m intervals

ABOVE At just 100mm wide, the beams help to draw in natural light

LEFT The structure of a previous building is reused in the garden

PROJECT TEAM
Architect 6a Architects
Structural engineer Price & Myers
Contractor Harris Calnan Construction
Concrete supplier London Concrete
Blockwork supplier Acheson & Glover
Landscape architect Dan Pearson Studio

Treating the timber

The frontage to Juergen Teller's studio features a particularly fine and consistent board-marked finish – the result of a technique that involved pre-treating the timber before the shuttering was built. "It is a method more seen in Europe – particularly Switzerland – than the UK," says 6a's Carlos Sanchez. "The boards are laid out on the ground and painted with a wet cement wash which is then allowed to dry. This semi-fills the pores of the wood. When dry, any excess cement is brushed off, and release agents applied."

The effect is similar, explains Sanchez, to using timber that has already been used for one pour. "Because of this there is much less difference in appearance between new boards and reused boards. It ensures consistency."

It also evens out differences in porosity between individual boards – again helping to deliver all-important uniformity. "We used Douglas fir timber which has a nice raised grain, and this, in conjunction with pre-treating and the use of self-compacting concrete, meant that the grain has been very consistently and effectively transferred to the concrete."

Prior to the construction, sample panels featuring different mixes, formwork and release agents were poured to fine-tune the technique. "This did highlight one important problem," says Sanchez. "We realised that unplaned board edges were not giving us a tight enough fit, and we were suffering grout loss between the boards, which was spoiling the look. The problem was solved quite simply by asking the mill to plane the edges."

lateral walls above the studio, where the more liquid nature of the self-compacting concrete has created faint tide lines. "The layering gives you an idea about how it has been poured, and like the rest of the in-situ concrete we have left it just as it was struck."

The patterns made by the self-compacting concrete and the tile-like white blockwork are illuminated by the windows in the saw-tooth roof, the light filtered through the 100mm concrete ribs of the roof beams. The ribs provide a spatial rhythm running the length of all three buildings, ensuring a both a practical and aesthetically consistent distribution of natural light.

With so much exposed concrete, the building, almost incidentally, benefits from having a large exposed thermal mass, able to keep the building cool in summer, while retaining heat in winter. "We have not gone for an environmental rating, but the windows are triple-glazed, it is very airtight, and with the thermal mass effect you could almost heat it with candles."

The two gardens that separate the buildings also feature concrete. Some of this is the remains of the frame from the building that was demolished to create the site. The effect is of an ancient ruin, only the bones of which are left. On the ground, a thin layer of concrete has been poured and then smashed, allowing plants to seed in the cracks. Maintaining the concrete theme in the gardens helps to unite the interior and exterior spaces, and reinforces the transparent and connected feel that 6a has been at pains to achieve.

Juergen Teller, a photographer who famously prefers to shoot in the real world, as opposed to a studio, is apparently pleased with the results. "For him a studio is more a place to plan – and he never really intended to use this building as a location. But now," adds Sanchez with satisfaction, "now he does."

Photos: Johan Dehlin; David Grandorge

DIAMOND FORMATION

ACME Architects adds lustre to a Leeds department store with a seductive diagrid facade. By Pamela Buxton

Leeds was traditionally known for its textiles. How fitting then that folded fabric was the inspiration for a spectacular concrete diagrid facade that wraps around the city's new John Lewis department store, part of the recently completed Victoria Gate shopping centre.

Designed by architect ACME in collaboration with engineer Waterman Group and concrete contractor Techrete, the acid-etched facade is a tour de force of geometry and texture in keeping with the architect's desire to create a shopping development of rich character. Physical retail experiences "need to be more seductive" in the age of internet shopping, according to ACME associate director Catherine Hennessy. With its enjoyment of pattern and visual delight, Victoria Gate is certainly that.

The £165m project – designed for Hammerson in the Victoria Quarter shopping district – consists of a row of three elements: a shopping arcade, the five-storey department store and a car park. Leeds' architectural heritage was a strong inspiration, and the architects carried out extensive analysis of the many surviving Victorian arcades and the area's grand civic architecture.

The facade concept emerged from a desire to create an articulated frontage with a sense of depth, and with a modularity that could accommodate the store's need for transparent and non-glazed areas. The concrete diagrid did all this through the incorporation of either glazed or solid panels within the composition, as well as nodding to the city's textile heritage in its pleats and folds.

"We felt concrete was an obvious choice for something that repeats and can provide depth," says Stefano Dal Piva, director at ACME, adding that the white concrete gives a quality of permanence while referencing nearby polished-granite buildings and stone civic architecture such as the Corn Exchange and Leeds Town Hall. "Concrete is a fantastic material to get sharpness and to play with weight so that it looks as light as cloth."

CONCRETE IS A FANTASTIC MATERIAL TO GET SHARPNESS AND TO PLAY WITH WEIGHT

The store has in-situ reinforced concrete cores, slabs and columns, while the facade is formed from precast modules fixed to a diagrid steel frame behind the rib lines of the lattice. This accommodates the maximum facade depth of 400mm specified by John Lewis.

The big challenge was to avoid joints that would disrupt the harmony of the pattern. The solution was 326 trapezoidal modules configured so that joints coincided with a fold or crank in the diagrid, which starts from the first-floor level. Module size was governed by the 4.2m maximum height for fitting on a low-loader lorry, with the largest rhombi measuring approximately 7m x 2m. The diagrid cladding panels decreased in size up the building to give the illusion of a curving facade.

A huge amount of work went into rationalising the geometry of the diagrid structure. Extensive structural analysis, including time history and thermal analysis methods, was carried out to establish critical movement for the 500 nodal intersections. Then Waterman Group set out a

Photos: Jack Hobhouse

series of nodes on a 4.2m horizontal grid using six different repeating types with variations at special areas such as the entrance and the stair cores. In total, 50 node variants were used.

There are 16 panel types, cast using four different modules. The formwork for each was adapted to give four thicknesses ranging from 150mm to 400mm in order to create the sense of depth the architects wanted, with the depths becoming smaller towards the centre of each diamond.

ACME worked with Techcrete in Ireland to specify the aggregate for the concrete after testing eight samples of varying stone type, size and cement using sand sourced from Ballylusk, County Wicklow. Rather than a pure white, the practice was looking for a textured appearance akin to Portland stone, in reference to buildings along nearby Eastgate.

In order to emphasise the main diagonals in comparison with the rest of the diagrid, different finishes were specified, with a polished finish used for the main diagonals and acid-etched for the infills. To ensure that the joints were unobtrusive, ACME specified "dusted joints" using crushed concrete bonded onto silicone mastic.

The precast modules, backed with insulation, were installed onto the steel diagrid between September 2015 and January 2016. At upper levels, the panels are propped off the diagrid using corbels at restraint points. While there are other concrete structural gymnastics at play, such as the creation of the store's 21.6m x 19.2m column-free central atrium, the facade is definitely the star attraction.

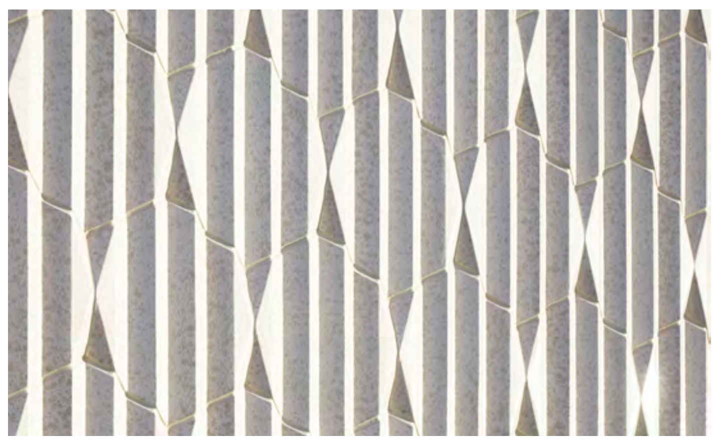
For the adjacent arcade building, ACME also used precast panels, but this time faced with brick. These are combined with a black precast plinth – another reference to the polished granite of nearby buildings.

Realising this development, and in particular the concrete diagrid, has been an undertaking that was only possible with the team's shared use of BIM. The result is a distinctive contemporary addition to Leeds' rich built heritage.

ABOVE LEFT The department store adjoins a brick-clad precast-concrete arcade

ABOVE The concrete diagrid comprises glazed and solid panels

ABOVE RIGHT The store is entered via a column-free central atrium

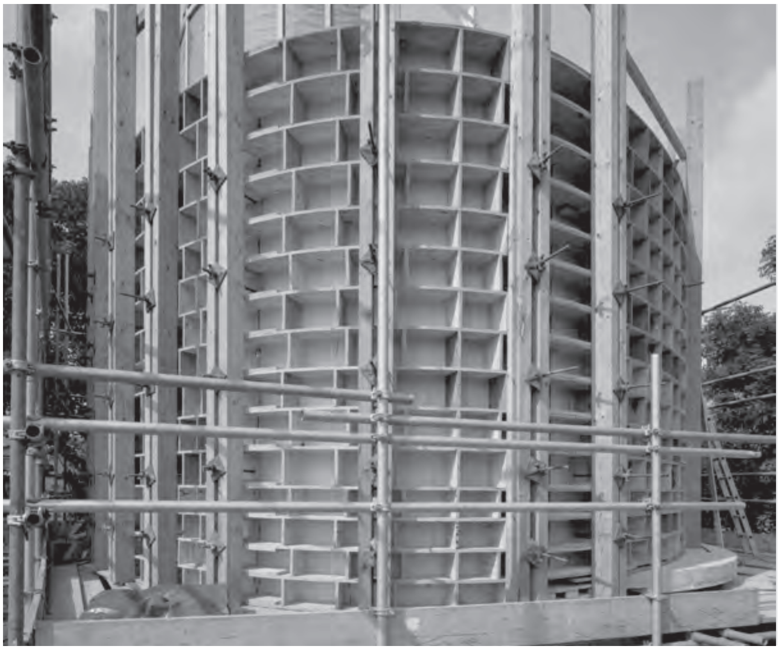


RIGHT The facade's pleats and folds are a reference to the city's textile heritage

PROJECT TEAM

Architect ACME
Structural engineer Waterman Group
Contractor Sir Robert McAlpine
Concrete diagrid panels Techrete
Brick-faced concrete panels Thorp Precast

VEXING LYRICAL



Photos: Hélène Binet; ITAR-TASS Photo Agency / Alamy Stock Photo

Stephen Chance reflects on the exhilarating concrete pour for Vex – part London house, part musical experiment

The great mystery of casting is in what is first hidden and then revealed. In the celebrated bell-making sequence from Andrei Tarkovsky's masterpiece Andrei Rublev, the process of casting is portrayed as a rough, uncertain art. In medieval Russia, a boy makes a leap of faith to lead a group of sceptical workmen constructing the formwork for casting a giant cathedral bell. The process fuses the best technology of the day with brute labour, and portrays tentative leadership and reluctant teamwork, innocent daring and experienced fear.

Meanwhile, in present-day Hackney, site manager Nigel Fanshawe and I are looking up anxiously at the suspended hull of a curving boat-like structure. It contains the mesh armature for the concrete pour of the entire top floor of our project, Vex.

Vex is a new house. It is also a curved, fluted chamber for which the electronic composer Scanner has devised a musical piece, created by manipulating the sound of pouring concrete. We're collaborating to create a building and sound piece based on Erik Satie's Vexations – a short, looping piano work intended to be played 840 times.

The walls' constantly changing curvature has been set out by computer so that the curves meet smoothly, with tangents joining at right angles to shared multi-centre radii of differing lengths. From these, curved walers are CNC-cut. Then comes the heavy work – wrapping the building in bespoke "library shelving" formwork clamped in place by sturdy ranks of twin "soldiers". These restrain the flexi-ply-backed corrugated steel sheets.

In his book Concrete and Culture, Adrian Forty describes the irony of concrete as a modern, indeed modernist, material when its creation can be so stubbornly archaic. This is borne out in Vex's finished concrete surface, its construction manifested in the rhythms of corrugations, in shutter boltholes and the casts of screw heads. There is minimal cosmetic work – just the occasional blowhole infill where the reinforcement cover might be compromised, while accidental variations of surface and tone add a textural layer.

As Nigel and I assist with the concrete pour, checking the formwork below decks for possible weaknesses and supervising from above the vibrating within these thin curving shells, our primary emotions are excitement and fear. Casting the exterior envelope of a whole storey in one go, there is no room for significant failure – no chance to remake and limited possibilities for making good.

Within these walls, Scanner's track Flow tolls, as sonorously, and ambiguously, as Tarkovsky's bell.

Stephen Chance is a partner in Chance de Silva

CLOCKWISE FROM TOP LEFT "Library shelving" formwork was used to clamp the steel sheets in place; an in-situ concrete staircase follows the curve of the shell; the house bears the marks of its corrugated-steel-faced formwork; the bell-making sequence from Andrei Rublev

Photos: Iwan Baan

THE NORTH FACE OF UTEC

Grafton Architects' mountainous Lima engineering school has scooped the RIBA International Prize. Nick Jones reports on a new concrete icon

Grafton Architects' UTEC campus in Lima, Peru, has been described as a man-made cliff, a leader of the new brutalist revival, even a "modern-day Machu Picchu" – and now it has become the inaugural winner of the RIBA International Prize. Not bad for a concrete university engineering faculty built on the edge of a motorway.

So how did this 35,000m^2 concrete giant come to be judged as last year's best new building in the world? The motorway is perhaps a good place to start. Swerving past the UTEC site before snaking down a ravine to the Pacific, the four-lane highway demanded a robust response that could screen the teaching spaces from the roar of traffic. Grafton's approach was to design an imposing concrete edifice that it likened to a "carved mountain", echoing the craggy slopes of the ravine. This north-facing cliff-face shields the rest of the building, which steps down towards the neighbourhood of Barranco in a series of terraces and overhangs (hence the RIBA judges' Machu Picchu comparison).

This may sound like a traditional brutalist strategy – the Smithsons' much-maligned Robin Hood Gardens in east London, for example, faces inwards, presenting a fortress-like posterior to the neighbouring A12. The joy of UTEC, however, is the way that its north elevation acts not only as a screen but as a dynamic public face. The "cliff" is far from monolithic. A series of concrete stanchions rise the full height of the building, leaning slightly outwards towards the sea like the prow of a ship. Between these, a matrix of beams, columns and slabs breaks down the monumental scale, and provides a porous framework into which volumes such as classrooms and laboratories are inserted. Larger spaces including an auditorium, conference rooms and a theatre are housed in the base of the cliff, while a rooftop "loggia" holds the library.

Grafton has described its approach as "structure holding the space", and inside too the exposed concrete frame is to the fore, with different platforms, balconies and stairs suspended between precast beams of varying lengths and thicknesses. The circulation spaces are open to the elements – an advantage of Lima's temperate climate, which rarely strays from the mid-twenties. This allows uninterrupted views out over the ravine to the ocean, and makes the building appear even more permeable. The RIBA judges noted approvingly how "the entire life of this vertical campus is on full display to the people of Lima". Quite masterfully, Grafton has shown how concrete urbanism can enrich and inspire a whole community.

PROJECT TEAM
Architect Grafton Architects
Local architect Shell Arquitectos
Structural engineer GCAQ

CLOCKWISE FROM TOP LEFT Full-height concrete stanchions lean out from the north facade; much of the structure is open to the elements; the building references the nearby cliffs that border the Pacific ocean

END GAME

Jonathan Reid explains how a well-planned post-finishing programme can enhance the look of new concrete once cast on site

We live and work in an ever increasing number and variety of spaces where concrete is used as the finished medium and visual surface; hardly surprising given the material's sculptural versatility and thermal mass qualities. This places an onus on the project team to produce clearly defined specifications, set expectations and present procurement practices that achieve the original aesthetic design intent. Post-finishing programmes can offer valuable support that's missing from specifications with scant "making good" clauses.

What is post-finishing?

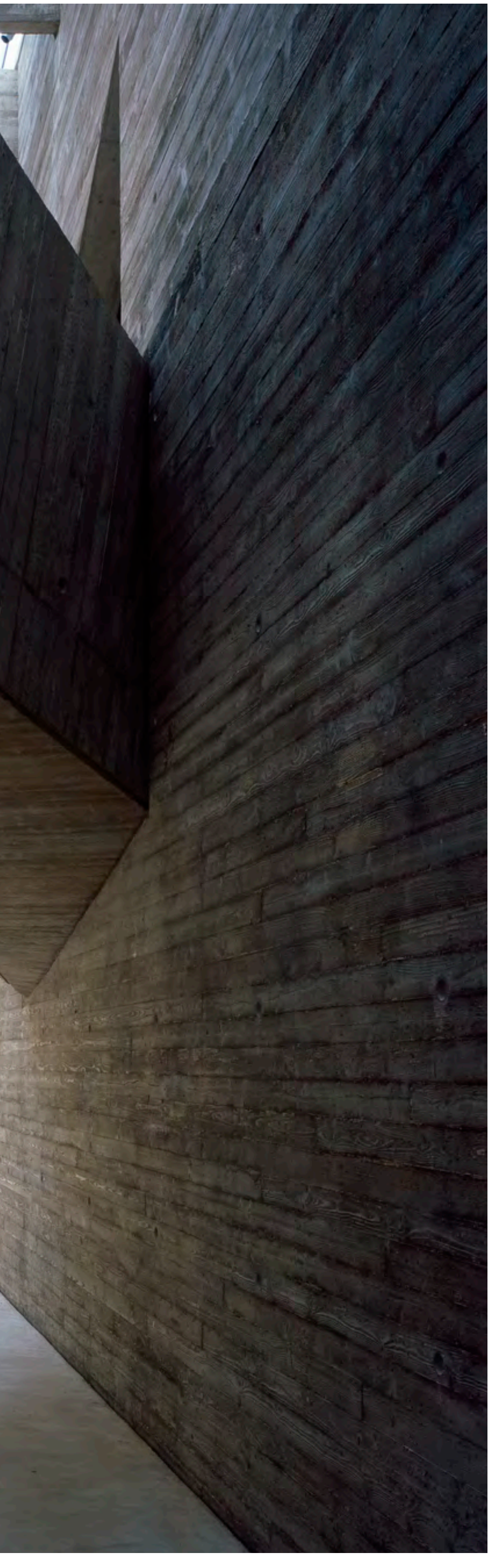
Post-finishing is any controlled intervention or mechanism that improves concrete's aesthetic quality after the concreting process is complete, allowing for future maintenance provision and planning for the end user. Unlike other post-finishing techniques that alter the surface texture of concrete, such as shot blasting, this article will focus on the planning and delivery associated with remediation, or improving the overall appearance of newly formed concrete.

Communication, discussion and planning is key to controlling subjectivity when making aesthetic judgments. Concrete is a natural material, and will always have some tonal and surface variation. Some so-called blemishes are inevitable and often acceptable, depending upon the finish specified.

The objective of integrated post-finishing is to keep the scope of remediation work to a minimum, celebrating concrete itself while improving the aesthetic. Fundamentally, any work undertaken to the as-struck finish must maintain the inherent character and nature of the concrete, unless an applied finish is required.

Planned or integrated post-finishing reduces risk and improves quality under a clear protocol set out at the start of a project. A strategy is established

ANY WORK UNDERTAKEN TO THE AS-STRUCK FINISH MUST MAINTAIN THE INHERENT CHARACTER AND NATURE OF THE CONCRETE



for the following processes:

- Curing and protection
- Cleaning
- Remedial works
- Sealing
- Handover and content for operation and maintenance (O&M) manuals

The flowchart in figure 1 shows the ideal order, process and roles involved in successful post-finishing procurement.

Curing and protection

Curing provides adequate moisture, temperature and time to allow the concrete to achieve the desired properties for its intended use. Maintaining similar levels of moisture in the concrete while keeping an air flow around the surface will prevent permanent discolouration. It is useful to combine protection and curing as one operation by covering or boxing in surfaces with an air gap until the concrete is ready for handover.

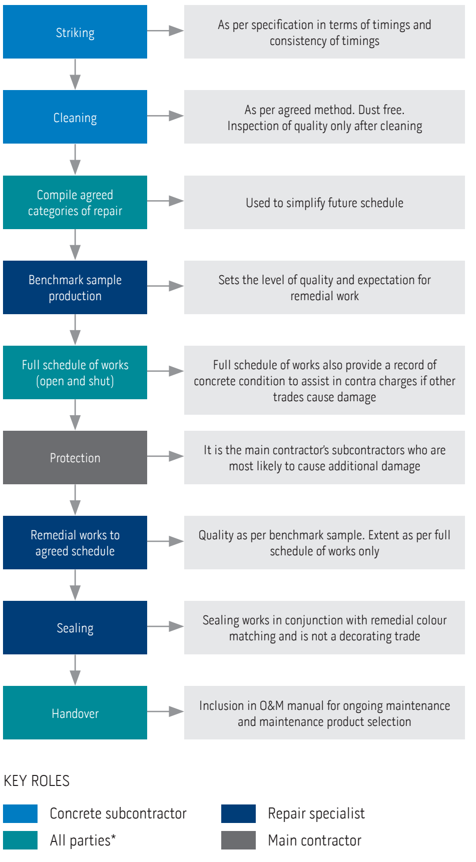
Water ingress, from rain for example, can also create instances of blemishes that cleaning will not resolve. Any protection should be designed to prevent this. Although this is not always practical, it should be noted that such protection can greatly reduce the impact of these blemishes.

Cleaning

The benefits of a consistent cleaning regime cannot be underestimated when it comes to improving aesthetic value. Judging concrete quality is only viable after cleaning, but it can also permanently change the surface quality of concrete.

Methods should be trialled early on depending on the type of surface finish and whether the cleaning is likely to abrade the surface. Soffits often benefit from a different approach to walls on the same project but, whichever method is used, cleaning should start with the least invasive approach. Dry abrasive cleaning will temporarily lighten the tone and wet cleaning will temporarily darken the tone. Only when dust free and dry will the true underlying tone and variation be exposed. Chemical cleaning is

FIGURE 1: ROLES IN SUCCESSFUL POST-FINISHING PROCUREMENT



* All parties being main contractor, subcontractor, post-finishing specialist and architect / client

LEFT Oriel Mostyn Gallery in Llandudno, Wales by Ellis Williams Architects. The high quality of the finished concrete was aided by an integrated post-finishing protocol

BELOW The before and after photographs show what can be done with a clearly defined post-finishing programme. Surface discolouration can be repaired to reveal the true quality of the concrete

Main photo: Hélène Binet; Other images: GreyMatter Concrete

Photos: GreyMatter Concrete

ABOVE The high-quality finish of the self-compacting concrete at London Bridge station's new concourse required some post-finishing

ABOVE An example of construction joint repair

not usually practical for in-situ concrete.

"Active" cleaning regimes should also be maintained during pours. This is key for reducing or removing the risk of grout-loss striations at construction joints on walls and columns. Because grout-tight joints are essential to producing visual concrete finishes, continual inspection during upper pour and compaction is vital. Gentle sponging and buffing of fresh grout loss reduces staining and the need for future cleaning. This is especially true of board-marked concrete where the biggest issue can be unchecked grout stains running from the pour above.

Remedial works

Even with the greatest care and professionalism, some degree of remediation works to visual concrete is inevitable and should be planned for. The biggest potential stumbling block is the failure to to put in place a procedure for how and when to undertake these works and what quality to expect.

Remedial works are intrinsically linked to curing, protection, cleaning and sealing activities, which should be documented and woven into the manual for the O&M programme.

Remedial works should take the following steps, in this order:

- Identifying "categories of repair" as soon as the concrete is clean
- Trialling methods and quality-testing on the mock-up in combination with sealing
- Producing a benchmark sample in situ, treating each category of repair
- Creating a full schedule of works as agreed on site after cleaning is complete
- Undertaking the aforementioned schedule once the protection is removed, the building is weathertight, with glazing, heating and, if possible, lighting installed
- Sealing (if specified) should be implemented as part of the post-finishing package alongside the remedial works programme.

It is very useful to compile a list of repair types early in the contract. This assists in identification and also probable cause, allowing for adjustments in working practices to reduce future issues. Below is a list of common categories of repair:

- Honeycombing
- Blowholes
- Construction joint deflection
- Grout-loss-hydration staining
- Construction damage
- Sand run segregation
- Construction oversights
- Surface discolouration
- Unplanned repairs

Benchmark samples for approval

Producing benchmark samples of remedial processes is key to allowing projects to progress in the knowledge that a full system is in place to deliver the required quality. It is important to produce a full set of samples on the actual concrete for each repair type and for this work to be undertaken as soon as the concrete is clean. Although trials can be undertaken on the mock-up, it is more useful for benchmark samples to be carried out in situ and for these repairs to be inspected from an agreed viewing distance.

It is not particularly useful to present a specific area for approval as natural variations in the material may make this sample non-representative elsewhere. It is more beneficial for each sample to treat each category of repair independently so as to demonstrate that individual repairs will not "interrupt the enjoyment of the design" and will "support the original design intent". Benchmark samples should also be sealed as per the specification so as to make the sample process as comprehensive and informative as possible.

Schedule of works

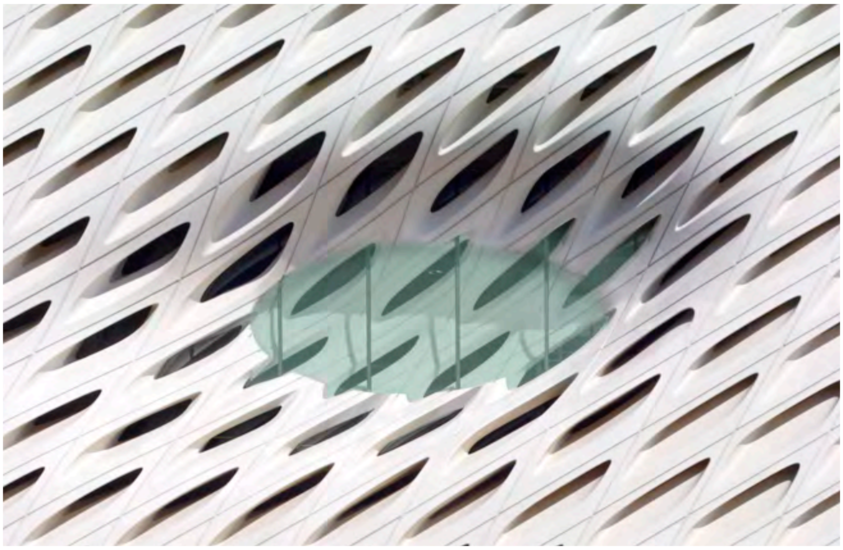
Following the process of approved benchmark remedial works, a full schedule of works should be collated prior to protecting or re-covering surfaces. Projects that commit to a fully agreed schedule of works tend to support the concrete aesthetic more in the long run, limiting "mission creep" that can lead to over-repairing.

Schedules of work detail position, type and location including a "before" image of the concrete. The post-finishing specialist is best placed to collate all before, during and after imagery, compiling reports for handover. This can also be used as a record of concrete condition, limiting liability should further damage be caused by others.

Sealing, handover and O&M manual

Sealers may be used as dust binders, for lessening maintenance regimes or as anti-graffiti protection. Although not essential, sealers provide a degree of protection especially in the public realm. Proposed types should be trialled on the mock-up and tested for suitability, with the following key characteristics noted: maintained or enhanced surface appearance, performance levels in terms of penetration, breathability, dust suppression, hydrophobic nature and light reflectivity.

Jonathan Reid is a remediation consultant and practitioner at GreyMatter Concrete



Photos: Iwan Baan; Milène Servelle; Keith Hunter

DRESSED TO IMPRESS

CLOCKWISE FROM TOP LEFT
GRC is used to sculptural effect on The Broad in Los Angeles; Graphic Concrete at Les Docks Libre apartments in Marseille; Níall Mclaughlin's friezes at East Village Stratford

Elaine Toogood explores the many colours, textures and decorative effects of precast-concrete cladding

Think of a precast concrete facade in the UK and you very likely to conjure up an image of exposed grey walls, with little or no adornment, typical of "brutal" British postwar architecture. Concrete was after all the material of choice during this time of structural expression: inexpensive, quick to build, robust enough to be exposed and without the contemporary insulation requirements to avoid cold bridging.

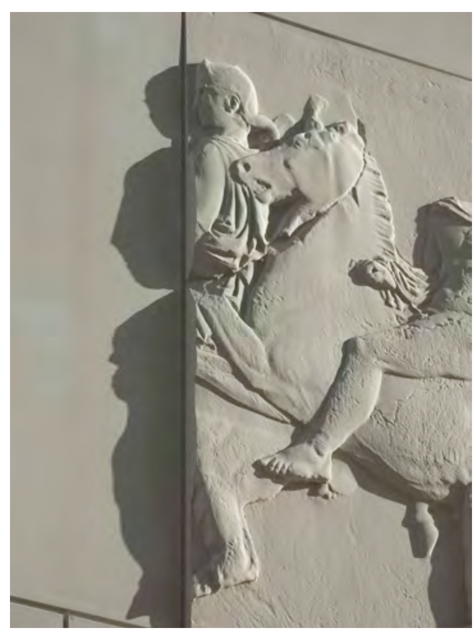
But concrete facades can be, and are, created in many ways, often so different that they may not be perceived as concrete at all. The concrete panel may be hidden behind a thin facing of brick or stone cast into its surface, offering a cost-effective and efficient use of these materials. Or the concrete itself may be designed to resemble the colour and texture of stone, using sands and aggregates for natural colour. Much of the UK's architectural precast concrete is produced in this way and commonly referred to as reconstituted stone, or "recon". The range of colours and textures is further expanded through the use of pigments in the mix, form liners and finishing techniques such as polishing.

In terms of ornamentation too, precast-concrete cladding offers a far wider scope expression than simply the reductive aesthetic of modernism. It is not generally realised that a substantial proportion of the ornate bay columns and other decorative features of late Victorian and Edwardian speculative housing are of precast concrete used as a cost-effective, labour-efficient means of reproducing decorative elements. Towards the end of the 19th century, R. Norman Shaw was designing ornate patterns for precast concrete panels, including the earliest examples of non-structural precast concrete cladding used for William Lascelle's patented domestic housing system. A contemporary incarnation of this might be Aecom's prototype Rational House in Hammersmith, a good illustration of how relief, texture and even different textures can be incorporated into a single precast concrete panel.

Any article about decorative concrete in the UK would not be complete without a mention of Bill Mitchell and his extraordinary body of work, including casting concrete panels from sculpted polystyrene. In the UK, architectural precast cladding is a product that offers bespoke design and great scope for creativity and expression. But this does not preclude the repetition of decorative features, in fact the casting process of concrete facilitates it. East Village Stratford (formerly the Olympic athletes' village) offers many fine examples of sculptural decoration using precast concrete. These include Níall Mclaughlin's dramatic friezes of white concrete, cast in moulds created from a digital scan of the Elgin marbles, and cut using an automatic 5-axis router. Here five different-sized panels were cast from each mould.

Digital technology has also provided a simple means of creating permanent pattern and images through the patented processes of Graphic Concrete and Graphic Relief. While manufacturing processes are evolving, developments in concrete technology also offer opportunities for new forms of expression. Panels using fibres as reinforcement are more slender and lightweight but retain much of the material quality of regular precast concrete. Glass-fibre reinforced concrete (GFRC or GRC) for example, as used on The Broad in Los Angeles by Diller Scofidio + Renfro (see CQ 254), can be just 15-20mm thick, enabling the creation of hollow and therefore lighter 3D forms. Ultra-high performance concrete (UHPC) provides similar slenderness but with loadbearing capacity, dramatically widening the scope of opportunities for design using precast cladding, and potentially incorporating cantilevers and even multiple openings.

So precast concrete manufacturing offers myriad ways to achieve high-quality, expressive and beautiful facades – it's time more of us began to realise its potential.



THE INVISIBLE CARBON SINK

For many materials, demolition and waste processing at the end of a building's life results in the release of CO_2. But with concrete, the opposite is the case. Tom De Saulles considers what carbonation means for designers

The absorption of carbon dioxide (CO_2) by plants and trees is biology 101, but we could be forgiven for not knowing that concrete and other cement-based materials also soak up a significant amount of CO_2 from the air. This naturally occurring chemical process is called carbonation and happens all around us in our buildings and infrastructure.

The carbonation process is the reaction between calcium oxide (CaO), an alkaline product of hardened concrete, and CO_2, which results in the formation of calcium carbonate ($CaCO_3$), or limestone. At a worldwide level, the CO_2 uptake from carbonation is equivalent to roughly 23% of the net CO_2 sink from global forests between 1990 and 2007. This surprising figure comes from a new study led by Chinese Academy of Sciences researcher Fengming Xi, which also estimates that between 1930 and 2013, CO_2 uptake from cement-based materials was in the order of 4.5 billion tonnes.

To those unfamiliar with carbonation, these figures may sound fantastic, as if perhaps the cement and concrete industry has marked its own homework. So it is important to point out that overall emissions from the manufacture of cement continue to be more significant than that from carbonation. More specifically, the study estimates that over the lifecycle of these materials, carbonation accounts for around a 43% takeback in manufacturing emissions, excluding those from the fuel used. If included, you get a more representative figure of around 26%, which broadly aligns with studies from other countries. In mentioning this, it is worth pointing out that regional differences in the use of concrete can affect results. For example, the Chinese study includes cement-based renders, which absorb CO_2

ACCOUNTING FOR CARBONATION

Carbonation has historically been viewed by engineers and designers in the context of concrete durability, and more specifically, the necessity of protecting steel reinforcement from its effects. This is addressed in structural design standards, which set minimum requirements for reinforcing cover and concrete mix design (see box, overleaf). Greater awareness of carbonation does not influence design decisions – all design standards already account for it, and resilience of the structure remains paramount. Moreover, cover is not an issue for mass concrete, nor for concrete block products that contain no reinforcement.

Discussion of carbonation from a sustainability and whole-life CO_2 perspective is a more recent development. This does not necessarily seek to encourage carbonation, but does aim to ensure the implications of this naturally occurring process are acknowledged, and the resulting CO_2 uptake is included in whole-life performance assessments. This is already the case with the BRE Green Guide ratings, which use an environmental profiling methodology that accounts for carbonation. More recently, the development of environmental product declarations (EPDs) allows the process to be fully accounted for in the lifecycle of concrete products, which includes the end-of-life phase.

As a general point, it is worth noting that unlike many of the environmental performance considerations associated with the use of construction materials, the carbonation of concrete is always going to occur, and is not particularly dependent on any specific whole-life scenario. The average reduction in embodied CO_2 for structural concrete is about 7.5% over the lifecycle of a building. Beyond the lifecycle stage, a much greater reduction ultimately occurs that can reduce the initial embodied CO_2 by around a third.

Alternative construction materials rely on unknown assumptions and scenarios for end-of-life impacts and emissions associated with landfill or incineration. In contrast, whatever the whole-life scenario or time period considered for concrete, the fact that the carbonation process will always occur means this end-of-life uncertainty avoided. This provides a useful degree of confidence when undertaking whole-life CO_2 calculations for concrete.

Photo: Queen Elizabeth Olympic Park

ABOVE Some 918 tonnes of crushed concrete were used in the creation of the Olympic Park in London. Researchers at Newcastle University are investigating the absorption benefits of the material in hard landscaping

rapidly due to their high exposed area.

Looking specifically at concrete-frame buildings in the UK, lifecycle carbonation is currently estimated to be closer to 30%, with only a modest amount occurring during their operational life. This type of building doesn't generally feature a render finish, and in any case, the mix design of structural concrete purposefully limits the carbonation process to prevent corrosion of any embedded steel reinforcement, which might otherwise be affected (see box, overleaf). So, uptake during the in-use phase of reinforced-concrete buildings is generally limited.

However, more significant carbonation occurs

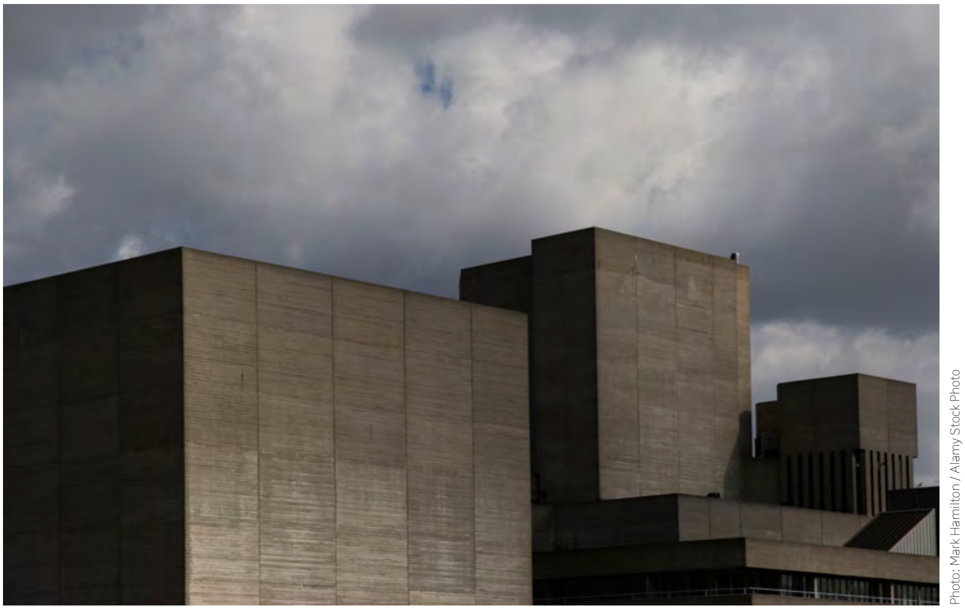


Photo: Mark Hamilton / Alamy Stock Photo

ABOVE The Hayward Gallery under a heavy London sky. BS 8500 states that reinforced concrete exposed to direct rain requires 30mm of cover to resist damage by carbonation over a 100-year lifespan

during the end-of-life phase, when the concrete crushing process greatly increases its surface area and exposure to the air. While deconstruction and demolition may only last a matter of weeks or months, this is long enough for the resulting carbonation to offset around 5% of the material's initial embodied CO_2. Further CO_2 uptake occurs beyond the building's lifecycle, when the crushed concrete goes on to be used in other applications, particularly groundworks. It is during this secondary-life period when most of the carbonation will ultimately occur.

In addition to atmospheric CO_2 uptake, two further absorption mechanisms can come into play, particularly at the end-of-life and secondary-life stages. The first of these involves leaching from exposure to the rain, and the other is a newly discovered process involving microbial soil activity where crushed concrete is present in hard landscaping or brownfield sites. This process is the subject of research at Newcastle University, which is investigating methods of increasing inorganic soil carbon storage through soil engineering. It has estimated that this can result in around 150 tonnes of CO_2 being absorbed per hectare annually.

Finally, returning to the Chinese study, the research paper finishes with an interesting thought: if carbon capture and storage were applied to the cement-manufacturing process, concrete and other cement-based materials might actually represent a source of negative CO_2 emissions when carbonation is factored in. That's something to think about.

FURTHER READING

Whole-Life Carbon and Buildings, The Concrete Centre, available to download from www.concretecentre.com

Fengming Xi et al, Substantial global carbon uptake by cement carbonation, Nature Geoscience, advance online publication, 21 November 2016

TABLE 1: CORROSION INDUCED BY CARBONATION (XC CLASSES)

(Where concrete containing reinforcement or other embedded metal is exposed to air and moisture)

Class	Description	Example
XC1	Dry or permanently wet	Reinforced and prestressed concrete surfaces inside enclosed structures except areas of structures with high humidity. Reinforced and prestressed concrete surfaces permanently submerged in non-aggressive water.
XC2	Wet, rarely dry	Reinforced and prestressed concrete completely buried in soil classed as AC-1 (non-aggressive soil) and with a hydraulic gradient not greater than 5.
XC3 and XC4	Moderate humidity or cyclic wet and dry	External reinforced and prestressed concrete surfaces sheltered from, or exposed to, direct rain. Reinforced and prestressed concrete surfaces inside structures with high humidity (eg. poorly ventilated bathrooms, kitchens). Reinforced and prestressed concrete surfaces exposed to alternate wetting and drying.

THE OTHER SIDE OF CARBONATION ...

While concrete provides a carbon sink by the process of carbonation, talk to any structural engineer and their response to carbonation is that it is bad and to be avoided at all costs, *writes Jenny Burridge*. Stronger, more dense concrete will resist the passage of carbon dioxide into the body of the concrete so, where resisting carbonation is important, the concrete can be specified to do just that.

Carbonation does not weaken the concrete but it does lower the pH, making any steel reinforcement liable to corrosion. When steel reinforcement is placed in concrete a passive protective layer of an alkaline film is formed, but this requires a pH of 10.5 or above. Normal concrete has a pH of around 13, but when carbonated this falls to below 9. If this happens, and there is oxygen and moisture at the surface of the steel, this will lead to rust formation and the resulting expansion can cause concrete to fail.

The normal method of specifying concrete to resist carbonation is by increasing the strength of the mix and increasing the cover to the reinforcement. The cover is the distance from the face of the concrete to the reinforcement. BS 8500-1:2015 contains guidance on the different ways of specifying against damage by carbonation. There are four exposure classes for carbonation: XC1 to XC4 (see table 1). Tables A4 and A5 in BS 8500 give the minimum strengths and covers for the exposure classes for a working life of 50 years and 100 years respectively.

For an XC1 exposure class, the rate of carbonation is relatively slow, and either the oxygen or the moisture required for the steel to rust is not present. So, the concrete that needs to be specified tends to be a lower strength and with a small cover – for example, at least C20/25 strength with a minimum cover of at least 15mm. By contrast, a concrete in an XC4 exposure would need (for a working life of 100 years) to be C40/50 with a minimum cover of 30mm. Lower strength concretes can also be used, but the cover required is increased.

Tests have shown that for concretes with high levels of fly ash (greater than 35%) the resistance to the rate of carbonation is slightly lowered in comparison to other types of cement. So for exposure classes XC3 and XC4, the tables specify that larger covers are needed.

For the structural engineer, carbonation is not all bad, though. At the surface of the concrete, it significantly reduces the possibility of the very rare thaumasite form of sulfate attack for foundations. And once the reinforced-concrete structure has been demolished, the concern about carbonation is no longer relevant. Then, as is explained elsewhere in this article, the carbonation of the crushed concrete, with its larger surface area, can capture some of the CO_2 in the atmosphere.

LASTING IMPRESSION EUAN MACDONALD

LIFE AND DEATH IN A RUGGED WILDERNESS

I grew up in rural Scotland so I didn't have much awareness of concrete, other than as a pretty utilitarian material. I first became aware of it when I was studying at Edinburgh University, through the very controversial work of Basil Spence and RMJM around the central campus at George Square. That gave me mixed feelings, but I also started to appreciate concrete's versatility and its power.

Probably the classic Scottish example is St Peter's Seminary in Cardross (1) by Gillespie, Kidd & Coia (1966). That's a very powerful piece of work, sculptural and playful, but also beautiful and serene. It's brutal in its execution, but delicate and refined as well. I'm always very sorry to see the state it's in now, but it'll be exciting to see its renewal as an arts venue. I think the approach is not to restore the building, but to treat it in its found state – to accept it as a ruin and exploit the strength of what remains, much as some of the buildings I admire riff on a huge landscape and use concrete as a way of making insertions into a natural space. The Temppeliaukio Church (2) – Church of the Rock – in Helsinki by Timo and Tuomo Suomalainen (1969) is excavated out of rock to create a sunken circular space, then above that is a copper dome like a sun, supported by a series of radial concrete columns. It's an amazingly beautiful space. Natural light washes down the smooth concrete columns, which contrast with the rugged quality of the walls, just hewn out of the rock. The Igualada cemetery (3) outside Barcelona by Enric Miralles and Carme Pinós (1994) is a seamless integration of landscape and space, with concrete as a retaining structure. It has such a rich variety of spaces, from very public to very intimate and private, and the geometry is very fluid and plastic.

Zaha Hadid was a master of using the plasticity of concrete, and the work of hers that I like best is the diving boards in the London Aquatics Centre (4) (2012). It's a lovely composition of forms poised at the end of the pool, dynamic and muscular and heroic, but also incredibly delicate and refined. That to me sums up the sport of diving.

Euan Macdonald is a partner at Hawkins Brown

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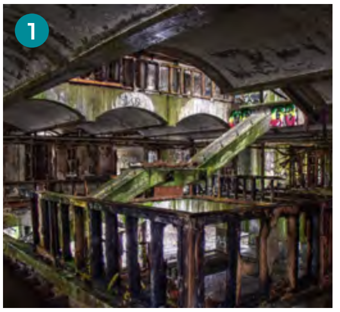

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3


Photos: 1.Mark / Flickr; 2. Jorge Lascar / Flickr; Cecilia / Flickr; Hufton + Crow

FROM THE ARCHIVE: SPRING 1963

THE GREAT JAMBOREE

When John Pawson transformed the Commonwealth Institute into the recently opened Design Museum, it was, to a certain extent, a new building: wrapped in new brick and glass walls, with new timber interiors and a dramatic triple-height atrium. But there was no question that one feature of the existing building had to be preserved: the tent-like concrete roof.

This was certainly what caught CQ's eye when it first visited the RMJM-designed building. The roof captured the "jamboree-like" spirit of the institute, which was designed to celebrate the Commonwealth. But more than this, it was an unprecedented feat of structural engineering by AJ and DJ Harris' James Sutherland. Comprising a central hyperbolic paraboloid surrounded by four separate "warped" surfaces, the roof was resolved as two discrete solutions: while the central section is an in-situ concrete shell, the side panels proved "too steep in places for easy concreting", so were realised as a system of thin prestressed concrete ribs covered with wood wool.

CQ deemed the solution "very satisfactory", adding that "there is a symbolic purpose about it too – the great tent spread over, and unifying, the various exhibits of the Commonwealth" – just as it now envelopes the rich and diverse history of design.

Access the full CQ archive at www.concretecentre.com/cq


– a concrete 'tent' in Holland Park

FINAL FRAME: TAICHUNG METROPOLITAN OPERA HOUSE
Toyo Ito has constructed an opera house in Taiwan from sprayed concrete. The vast complex includes a 2,014-seat grand theatre, an 800-seat theatre and a 200-seat black box theatre, and was erected entirely without beams or columns, relying instead on 58 curved wall units to achieve its cavernous interiors. The formwork required for the curved surfaces would have been so complicated that the contractor decided to apply shotcrete to a steel mesh framework instead.

Photo: Lucas K Doolan