mpa The Concrete Centre

CONCRETE QUARTERLY

SUMMER 2017 | ISSUE NUMBER 260

PIANO'S GRAND ROOF
Expedition Engineering creates the world's largest ferrocement span for Renzo Piano in Athens

MAKING PREHISTORY
Monolithic in-situ concrete helps to bring Lascaux's remarkable cave paintings back to life

OFF SITE AND ON TREND
An essential guide to the increasingly versatile world of precast cladding

CONTENTS

DON'T MISS AN ISSUE

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

AGENDA

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

Take the advice of a 70-year-old …

There was rather a lively debate about which of this issue's featured projects should grace the cover. The two frontrunners were very different: Lascaux IV's simulated caves and concrete geology, versus the delicate, floating-in-the-air ferrocement roof of the Stavros Niarchos Foundation Cultural Centre. The crux of the matter was this: did the image need to look obviously "concretey"? And what exactly does that mean, when concrete can assume such diverse forms?

This is a topic much in our minds at the moment, as we gear up to celebrate CQ's 70th anniversary later this year. Established in 1947, the magazine has documented many trends and breakthroughs over the last seven decades, as even the briefest of trawls through its rich archive demonstrates. It has never retreated from showing concrete in a new light – and so the improbable floating roof won the day.

Another theme that we've been thinking about in our birthday year is longevity. Many of the buildings and works of civil engineering from our previous 259 issues remain standing to this day, and seem set to be with us for decades to come. As we design our current projects, the key question is, over what period should we be looking to "amortise" the environmental costs? The desired lifespan of a building is not a question that many clients – outside of self-build housing and possibly the universities sector – can readily answer.

Yet whole-life assessment is the only meaningful way to determine the true sustainability of anything. This is an increasingly accepted principle, even if understanding of exactly how to do it is some way behind. That's something we at the Concrete Centre have fed back to the Royal Institution of Chartered Surveyors in response to its recent consultation on professional guidance for its members on carbon accounting. The danger in its current approach – well-meaning and methodologically sound though it is – is that building design may become focused on short-term considerations and plump for a more readily applied but much oversimplified metric – that of carbon. Designing for the long term is undeniably much more difficult than just taking a snapshot of a building's carbon impact on completion, but it's vital that we get to grips with it – rather than simply taking the easier route at this crucial stage in our sustainability journey.

Though architects may not thank them often, construction's number-crunchers can play a positive role on projects – but only when they are counting the right costs, allowing the design team to weigh them judiciously.

WHOLE-LIFE ASSESSMENT IS THE ONLY MEANINGFUL WAY TO DETERMINE THE TRUE SUSTAINABILITY OF ANYTHING

HELP US TO CELEBRATE!

This year marks the 70th anniversary of Concrete Quarterly, and to celebrate The Concrete Centre is planning a lively programme of events, looking back at the last seven decades but also forward to the future. We are staging a free exhibition at the Building Centre in London from 1 August until 31 October, and publishing a 240-page book, in partnership with Artifice, entitled "The World Recast: 70 buildings from 70 years of Concrete Quarterly". We are also proud to be making hard copies of CQ available once more, through our brand new subscription service. For more details, go to **www.concretecentre.com/cq**

CONCRETE QUARTERLY

On the cover:
Stavros Niarchos Cultural Centre in Athens by Renzo Piano. Photo: Michel Denancé
Produced by:
Wordmule
Designed by:
Nick Watts Design

mpa The Concrete Centre

The Concrete Centre is part of the Mineral Products Association, the trade association for the aggregates, asphalt, cement, concrete, dimension stone, lime, mortar and silica sand industries.
www.mineralproducts.org

Naked ambition

London mayor Sadiq Khan has backed a new generation of shell houses in Enfield that will sell for up to 40% less than standard new-builds. The flats, by not-for-profit developer Naked Homes, will have an exposed structure and no partitions.

Record pour

Sharjah Municipality has set a new world record for the largest continuous concrete pour. A team of 622 workers poured 20,246m³ over four days while laying the foundation for the Safari Mall in Muweilah.

Deflat refurb reward

The Mies van der Rohe Award 2017 has been won by NL architects and XVW architectur. Their revamp of Deflat Keliburg, one of the biggest modernist apartment blocks in Amsterdam is the first renovation to win the EU prize.

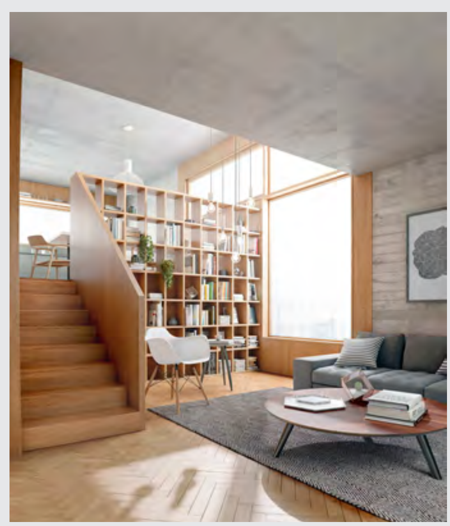
Eco-Gothic

ETH Zurich's arched loadbearing concrete floor slab is just 2cm thick. Inspired by Gothic vaults, it is claimed to be 70% lighter than typical slabs.

Photos: Hugo McCloud; Marcel van der Brug; Khaleej Times (www.khaleejtimes.com); ETH Zurich / Peter Rüegg

CONCRETE AHOY!

In June, Concrete Elegance explores the use of exposed in-situ concrete in two split-level residential projects by developer Roger Zogolovitch. Mole Architects' The Houseboat in Poole (left) and Weston Street in London (right), designed by AHMM use a variety of techniques for creating surface texture, including exposed aggregate and timber boardmarking. **Concrete Elegance takes place on 26 June at the Building Centre in London. To book a place, visit www.concretecentre.com**



Images: Rory Gardiner; Pikcells

In the autumn of 1940, a teenager walking his dog near the village of Montignac in south-west France discovered the Lascaux Caves – the site of some of the world's most extraordinary prehistoric cave art.

Around 2,000 detailed images, some estimated to be 19,000 years old, decorate the limestone walls of the complex. After the war, it became a huge visitor attraction, with more than 1,000 tourists a day flocking to the cave. But by the late 1950s it became apparent there was a problem: opening the cave to visitors had changed the atmosphere inside, and the paintings had begun to deteriorate. The caves were closed in 1963 and, ever since, only rare visits by conservationists and historians have been permitted. A replica, "Lascaux II", opened 200m away in 1983, to become the most-visited prehistoric cave in the world.

Now, however, at the new Lascaux IV visitor centre, tourists will once again be permitted to gaze upon the astonishing art of our distant ancestors – or something very nearly as good. Laser-scanning technology has enabled an extraordinary facsimile of the main cave to be reproduced to within millimetres of the original, while artists and sculptors have toiled to exactly recreate the artwork of our distant ancestors.

But how to frame and present these pictures from the past? Designing a visitor centre which will, in effect, become humanity's only opportunity to experience the caves, perhaps for centuries to come, is clearly quite a challenge. Naturally enough, the first decision facing the design team from Norwegian architect Snøhetta concerned the choice of material.

"We had a big debate about this," says project architect Rune Veslegard. "One option was to use limestone – the stone in the cave and also the local building material. But somehow a steel structure with thin panels of limestone cladding stuck on it would have felt wrong – too lightweight. By choosing concrete instead, we have this feeling of weight, of massiveness, as if it is all carved out of the hillside, like the cave itself."

In fact, the in-situ concrete which forms the facade and most of the centre's structure is of a colour very similar to the local limestone. The pleasing result is that the long lateral lines of the centre seem almost to have been revealed by brushing away topsoil from the hillside into which it is set. Getting the shading right was a priority for Veslegard: "It's not simple. We tried and tested 13 different mixes before we were satisfied that we had got the colour and texture exactly as we wanted.".

USING CAST-ON-SITE CONCRETE GIVES US THESE BEAUTIFUL, CONTINUOUS FORMS – ONE SHAPE FLOWING INTO ANOTHER

Given how strongly he felt about this, the consistency and quality control offered by precast concrete could have been an option. Veslegard, however, was adamant that only in-situ concrete fitted the aesthetic: "Even with precast you would still have had the feeling of something attached to a frame. Using cast-on-site concrete gives us these beautiful, continuous forms – one shape flowing into another. Altogether the project uses 10,000 tonnes of concrete, and it provides this sense of mass and heaviness which is all-important here."

Looking at the long, low and angled facade, it is easy to see what he means. Comprising a series of angled reinforced concrete vertical slabs some 250mm thick, the fact that it appears to float above the glass frontage only serves to emphasise its obvious weight. Movement joints have been kept to a minimum and are all but concealed within the vertical creases formed by the facade's regular change of angle – a trick that helps to maintain the feeling of unbroken solidity.

The facade is supported by a combination of concrete beams and metal trusses which run back into the interior of the centre and which cantilever off internal load-bearing concrete walls. "In addition, there are two large inclined concrete columns near the central entrance which also support these beams," explains Veslegard. "In general, though, we avoided columns as there are no pillars in caves and we wanted to keep the sense that the interior is carved out of the hillside."

Inside the 8,365m^2 centre are the usual facilities: a reception area, shop, exhibition space and also a small theatre. The flooring in these areas is all formed from polished in-situ concrete to which a quartz aggregate has been added to help keep it pale, like the walls. Interior walls are all formed from the same mix of self-compacting concrete used for the facade, and this remains exposed and visible in most areas. The banded pattern visible on the facade continues inside, though some areas, such as the exhibition space, have a simpler finish which reveals the standard plywood boards used for the formwork (see "Get strata", overleaf).

Before entering the replica cave, visitors must pass through a canyon-like circulation area known as the orientation space. This comprises a kind of wide corridor flanked by tall, tilted concrete walls up to 13m high, and lit from above by a glass ceiling.

"The walls are up to 300mm thick and are set at varying angles from vertical," explains Veslegard. "They range from 9° negative to 2° positive. This meant quite a lot of special pieces of formwork to ensure that the angles all met correctly on plan."

Each vertical section was done in one pour, he adds, although each could take up to four loads of concrete to complete. "We decided, even though the concrete is self-compacting, to vibrate it in the break between trucks. This ensured that it did not change appearance between truckloads."

In addition, care had to be taken with curing.

THE WEIGHT OF HISTORY

Massive, monolithic concrete was the only material that could do justice to the remarkable cave paintings at Lascaux, writes Tony Whitehead

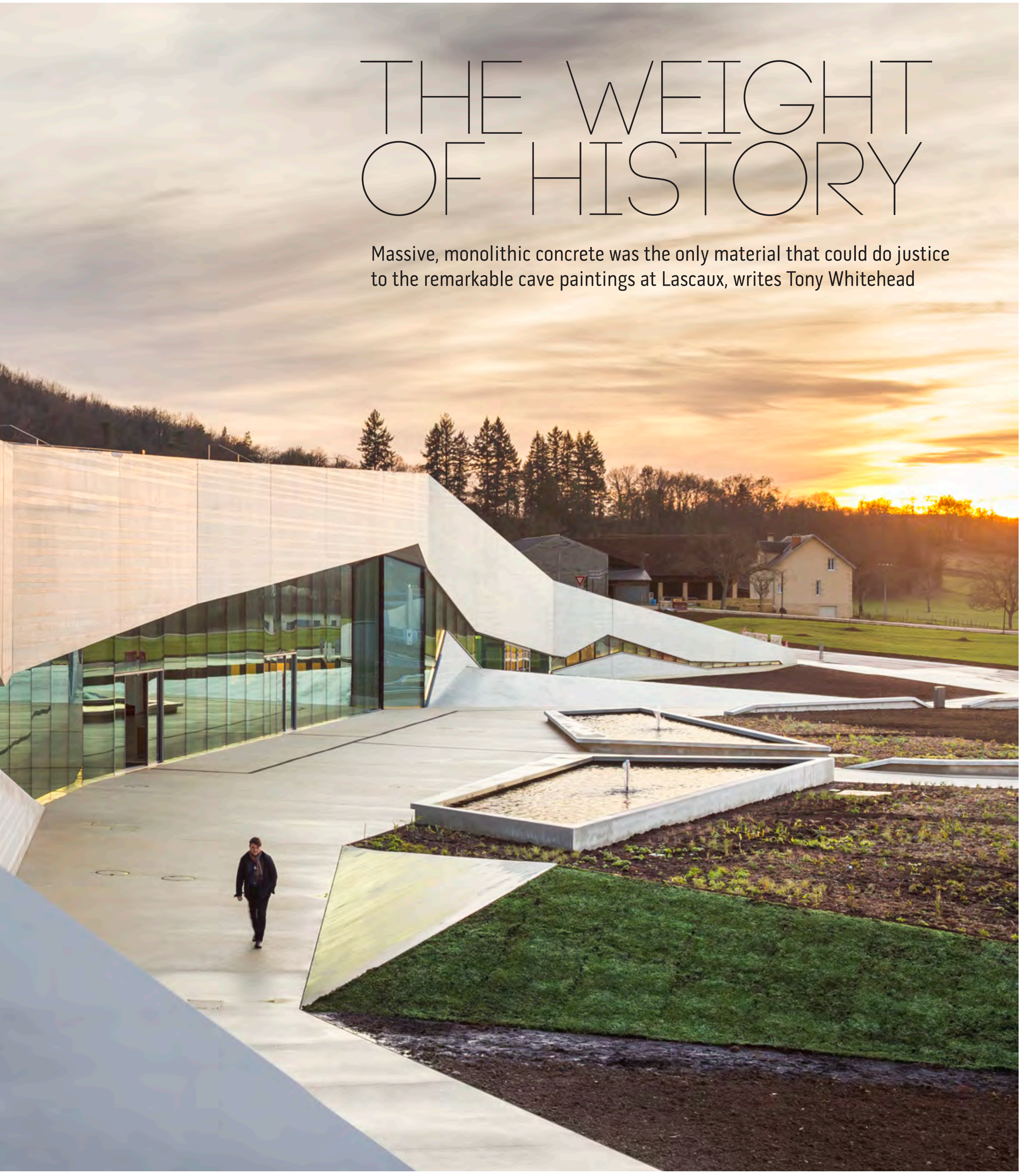
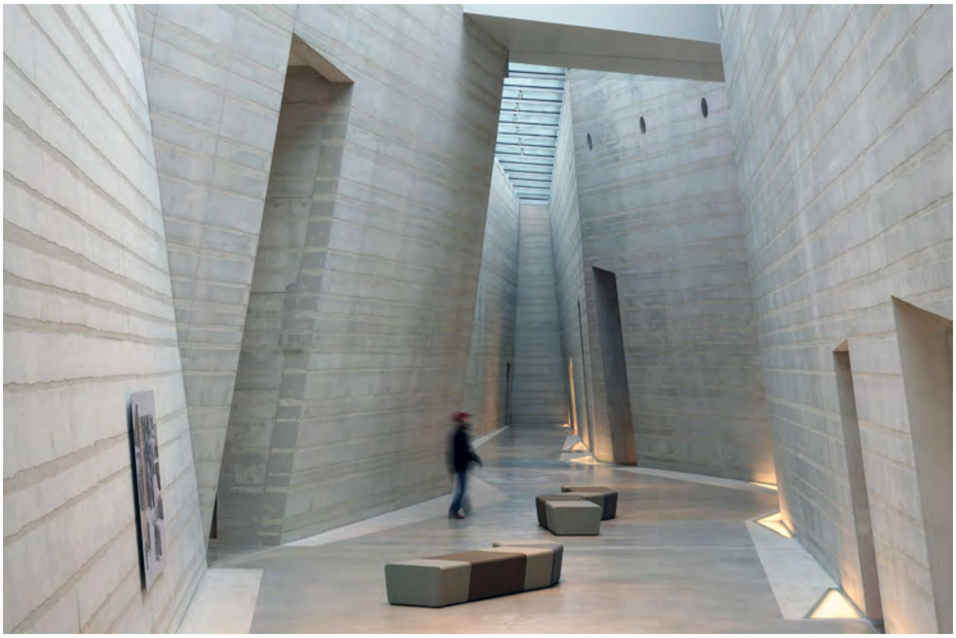
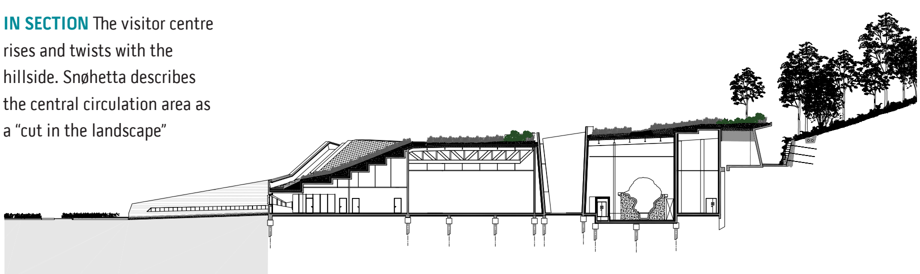


Photo: Boegly + Grazia





IN SECTION The visitor centre rises and twists with the hillside. Snøhetta describes the central circulation area as a "cut in the landscape"

Prehistoric precast

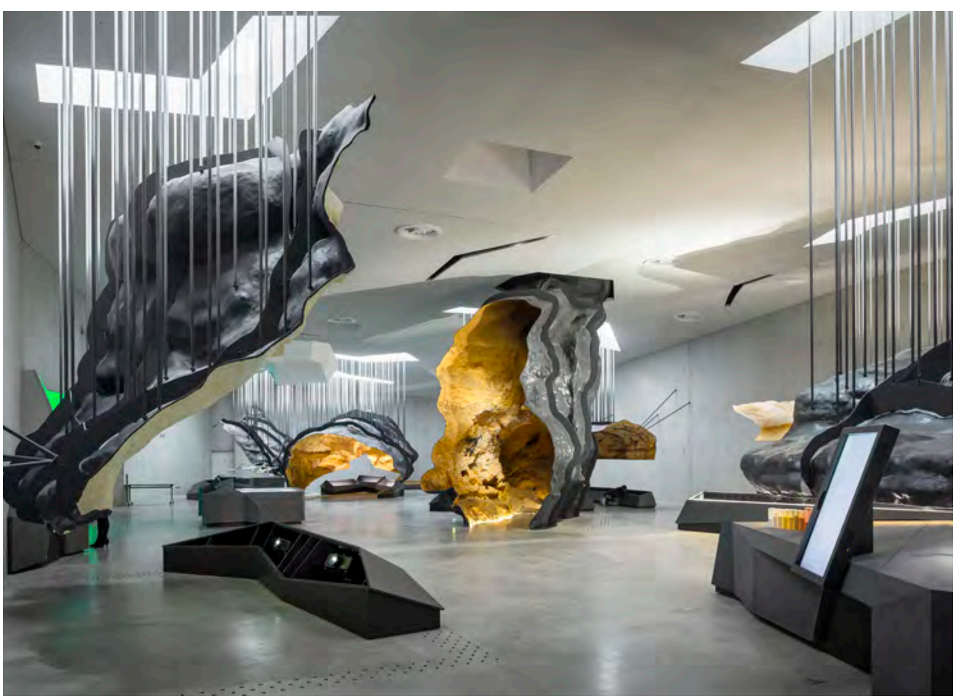
While designer Snøhetta initially strove to create the Lascaux IV visitor centre entirely from in-situ concrete, there are certain areas of the project where precast concrete was a pragmatic and practical alternative.

One such example is the patio garden, a tall-walled but open-air continuation of the orientation space, and here precast concrete has been used as the backing to a water feature.

"Water runs down the wall continuously here, so naturally we had to be concerned about water penetration," says architect Rune Veslegard. "The density and quality control of the precast element gives us more control over that. Behind it is a membrane and then behind that the wall reverts to in-situ concrete."

Externally too, precast slabs have been used. "In France, where you have a membrane, there are rules about access which are difficult to comply with if you are using in-situ concrete," Veslegard explains. "So on the roof of the centre, around the walkway above the glass roof of the orientation space, we have used precast for the low walls and steps."

As Veslegard says, the colour match with the in-situ concrete is so good that the difference does not catch the eye – and the fact that these areas are away from the facade also reduces any visual dissonance.



"It was very important that all the concrete was in the formwork for the same amount of time or it would affect the colour of the finish. For example, we would not cast on a Friday and take it down on Monday."

The finished walls are strong enough to self-support their tilts from the vertical, though they are also tied back to supporting walls. However, because of the weight of the concrete involved, unusual amounts of support were needed to maintain the formwork in position while it was curing.

"The formwork was all steel, from bottom to top on both sides, and each 3m-wide section had around 20 steel rods supporting it," says Veslegard. "It meant that a dense criss-cross of rods made access very difficult in the area which is now the orientation space." With pours of up to 13m, it was essential that the metal formwork was tightly sealed with silicon: "Otherwise, the pressure of the concrete, especially towards the bottom, would have caused leaks."

Entrances to this area have been formed by timber boards, and the technique is evident in the as-struck board-marked finish of the

OPPOSITE TOP The sloping internal walls required high-strength steel formwork

OPPOSITE BOTTOM Eight fragments of the recreated cave are suspended from the visitor centre ceiling

LEFT The reproduced cave paintings have been painted onto a resin/aggregate substrate

PROJECT TEAM
Architect Snøhetta
Main contractor Lagarrigue
Concrete subcontractor Sopreco

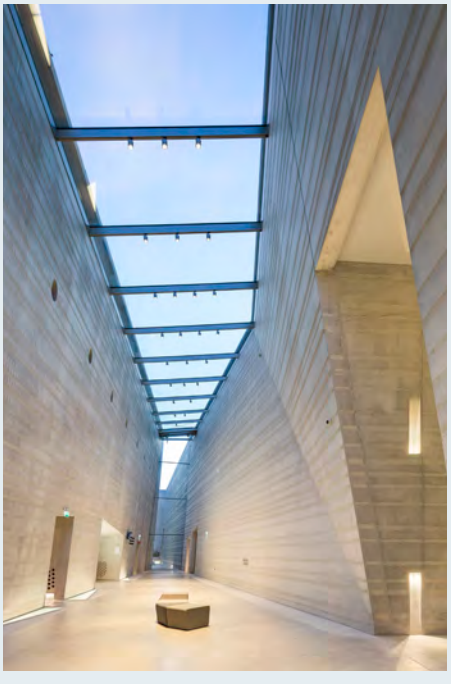
doorways. Air out-take holes near the roof and ducting for lighting were also cast in. "To keep the massive, carved-out feeling, we didn't want things attached or drilled if we could avoid it," says Veslegard. "We cast in everything we reasonably could."

To access the cave itself, visitors must travel by lift to the roof, though because of the way the centre is built into the hill, this is almost level with the ground outside. "We wanted to recreate the feeling of discovering the cave, so entering from inside the centre would not have felt right," he says.

The famous images of hunters and bison have been painted onto a resin/aggregate substrate and, as in the original, these images are above waist height. The lower half of the cave has been created with shotcrete sprayed onto a steel mesh shaped to replicate the rock of the original cave. Sculptors have moulded clay on top of the shotcrete to provide a more natural finish.

Just 200m away from the new centre is the entrance to the original Lascaux cave, though these days of course it is seldom used. So, how to assess the accuracy of the experience provided by a visit to the replica? Not many people are in a position to comment, but Veslegard, as one of the few to have ever visited the original, is pleased with the results. "It is not just the shape of the cave and the detail of paintings which is so accurate," he says. "It is the whole experience: the acoustics, the temperature and the humidity."

The odd thing is that we shall just have to take his word for this. "Yes, it is strange," he admits. "We have effectively made a new reality for the generations to come."



Get strata: Creating the layered concrete walls

The horizontal banding, or striations, which run across the facade, much of the interior walls, and also the canted walls of the orientation space, are the most distinctive visual feature of the concrete at Lascaux. Reminiscent of sedimentary layering, these bands provide a unifying theme and add to the geological references created by Snøhetta's deployment of in-situ concrete.

The banding comprises alternate, slightly wavering lines of rough and smooth concrete and, as project architect Rune Veslegard explains, the effect required considerable attention to detail. "The smooth part is made by the combination of metal forms and self-compacting concrete," he says. "The rough is created, after the formwork has been removed, by applying a metal mask or stencil to the concrete and sandblasting away the outer layer to reveal the aggregate beneath."

Achieving consistent finishes of both rough and smooth meant experimenting with the mix. "First the limestone aggregate was too yellow. Then we found that, even though the concrete was self-compacting, the flow was not good enough."

This, says Veslegard, created unwanted patches of visible aggregate in the finish. "We solved it by increasing the amount of round sand compared with angular sand."

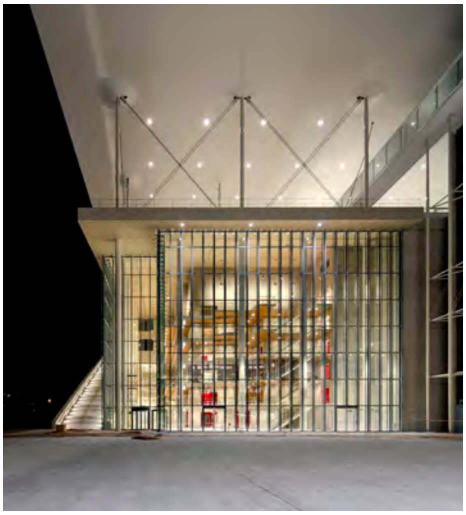
Creating the masks was also a subtle exercise. "Where the walls are vertical, it is quite straightforward to reuse the mask and get the striations to match up in continuous horizontal lines," says Veslegard. "But in the orientation space, because the walls are inclined by different amounts, this was much harder. It meant that for each angle of inclination we needed to make a special mask to ensure everything matched perfectly."

In the orientation space, 30% of the surface has been roughened, but on the external facade the pattern is reversed, with 70% of the surface sandblasted. Veslegard is particularly pleased with the effect of sunlight on the facade. "From one direction the sunlight makes the rough surface light, from the other it appears dark. It means the pattern changes depending on where you view it from, and also the time of day."

Photos: Boegly + Grazia; Eric Solé

PIANO'S LID

The architect's Athens cultural centre incorporates the world's largest-span ferrocement roof. By Pamela Buxton



Canopy seems rather an inadequate word to describe the spectacular structure over the Stavros Niarchos Foundation Cultural Centre (SNFCC), designed by Renzo Piano Building Workshop in Athens.

Believed to be the largest ferrocement span in the world, the solar collector canopy stretches 100m x 100m to cover a vast terrace with views over both city and sea. In doing so, it forms the landmark flourish of the 22,000m² building, which will house the Greek National Opera and Greek National Library within a new public park. The site previously contained a car park left over from the 2004 Olympic Games and is located in Kallithea, once one of Athens' main seaports.

The main building structure has a conventional reinforced concrete frame, incorporating large expanses of fair-faced concrete and a number of long-span transfer structures over atriums and auditoriums. For the canopy, the initial plan was to use a lighter, steel-framed structure but it became clear that this couldn't deliver Piano's desired aesthetic.

"It was very important that it should be visually very light and fine and with a completely un-jointed bottom surface," says Bruce Martin of UK structural engineer Expedition, which worked on the project with local partner OMETE.

After exploring other materials and consulting with experts at Manchester University, Expedition settled on ferrocement, a material familiar to Piano's team, which had previously built a ferrocement boat.

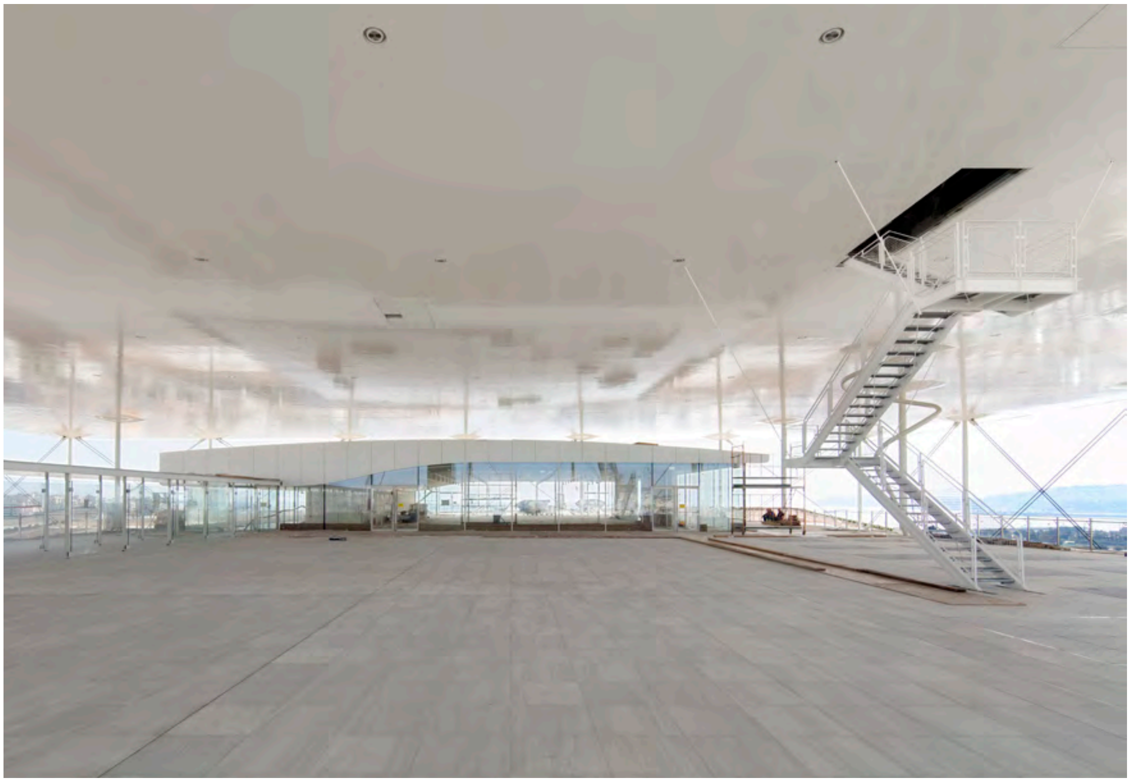
"We saw it had the potential to deliver the finish, and form curved profiles, to a very high quality," says Martin, adding that ferrocement, unlike clad steel, can combine structure, waterproofing and finish in one element.

Given ferrocement's rare mainstream use in construction, Expedition needed to demonstrate that a canopy in this material could not only meet performance standards but could also be tendered, with the monocoque ferrocement produced and installed successfully using local labour with no prior experience of the material. After extensive research and development including the production of more than 100 large ferrocement panels by a local contractor, the team created a 15m x 6m prototype and stacked it with sandbags to test its strength to destruction. It passed with flying colours – despite their best efforts, the team failed to destroy it before the stack became too high to continue with the test.

FERROCEMENT CAN COMBINE STRUCTURE, WATERPROOFING AND FINISH IN ONE ELEMENT

Production was further tested with the construction of two small ferrocement pavilions for the SNFCC park, before manufacture of the canopy itself began.

The canopy tapers in depth from 4.4m to just 23cm at its edge. It is formed from two load-bearing "skins" linked by tubular steel bracing that carries shear forces. Each ferrocement skin was created using up to six layers of fine diameter steel mesh to limit cracking (the outer mesh layers



Photos: Michel Denancé; Yiorgis Yerolymbos

ABOVE LEFT The building comprises many different spaces including two auditoriums, rehearsal spaces and a business incubator

ABOVE The roof shelters a terrace and glass-walled library

FAR LEFT The canopy cantilevers 9.5m from its tapered steel columns

LEFT A prototype of the prefabricated roof panels

are just 0.8mm and 1.6mm in diameter), encased in a cement mortar with a top and bottom outer "cover" layer.

The skins range in depth from 20mm to 55mm, with thicker areas designed where there are connections to the bracing, and in the areas immediately adjacent to the supporting columns. Almost all of the 3m x 7m panels were unique, to take into account variations in curvature. All have bi-directional ribs to prevent buckling.

In total, 717 prefabricated panels were produced using a temporary local factory with three parallel, automated, ferrocement production lines. These were then spliced together to form the final canopy. "Every one that was manufactured was used. I find that amazing," says Martin.

The canopy is supported by 30 tapered cigar steel, braced columns with integral rainwater pipes stretching 9m high on the seaward side and 18m high on the landside. The canopy cantilevers 12.5m and has clear internal spans of up to 75m.

Particular attention was paid to the way the canopy connects with the columns. Column heads are sprung to limit stresses in the (inherently very stiff) canopy caused by wind and seismic loads. They also had to cope with differential settlement of the main building structure and differential thermal expansion of the canopy, whereby higher temperatures on the top of the canopy could lead to a "banana-ing" effect on the structure. The solution was a damper system of fluid-polymer springs adapted from technology used in French rail buffers. This limits stresses in the canopy by creating a soft connection with the columns, thus distributing loads more evenly onto the structure below.

Mindful of the possibility of variations in the colour of the white mortar mix over the expanse of the canopy underside, the design team opted to paint the finished surface, which has the added advantage of helping with durability.

The canopy shelters a vast terrace and also a 30m x 30m, glass-walled library reading room which sits on top of the fly tower of the 1,400-seat auditorium below.

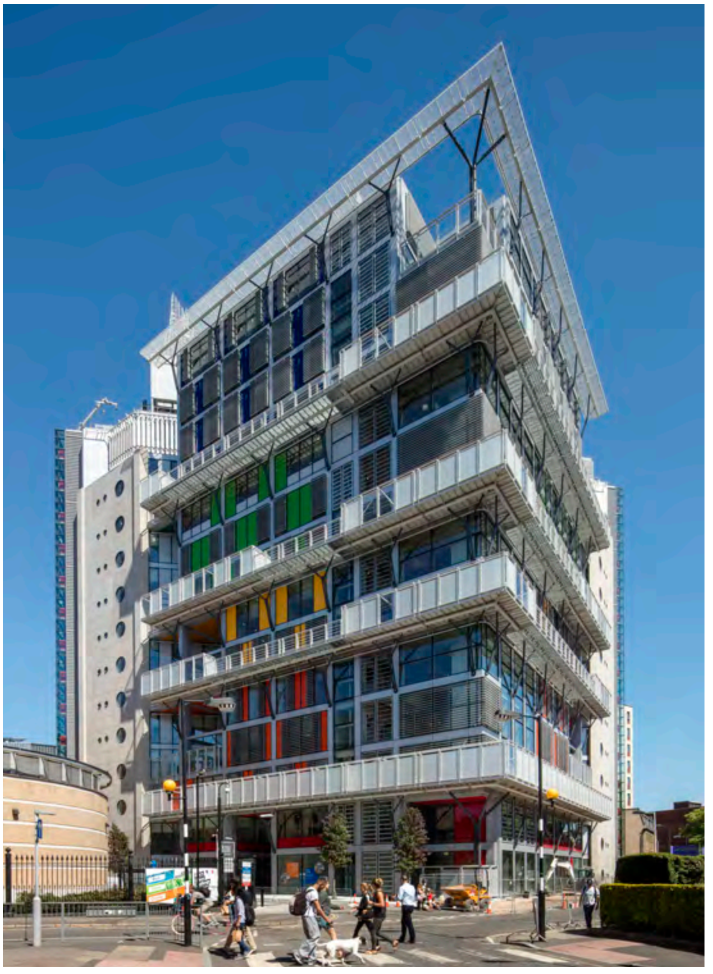
Although the privately-funded SNFCC was launched last year it is yet to open fully. It does however have a LEED Platinum rating – a first for Greece – with the canopy's photovoltaics able to provide the base power supply for the whole cultural centre.

PROJECT TEAM

Architect Renzo Piano Building Workshop
Local architect Betaplan
Structural engineer Expedition Engineering/OMETE
Contractor Salini Impregilo-TERNA

TOUGH GUY'S

Laing O'Rourke's precast solutions helped to create a vibration-free structure for delicate cancer treatments, writes Pamela Buxton



Photos: Morley von Sternberg

A predominantly prefabricated approach to structure and cladding enabled the new Cancer Centre at Guy's Hospital to grow at a rate of a floor every week. But a speedy construction programme, although cost-efficient, wasn't the only factor behind the choice of precast concrete for both frame and cladding at the £160m building, designed by Rogers Stirk Harbour + Partners (RSH+P) and healthcare specialist Stantec on a tight triangular site near London Bridge station.

According to RSH+P project architect Leonardo Pelleriti, the most crucial criterion was stability, since the building accommodates facilities for radiotherapy and chemotherapy. These are housed in a series of two- or three-storey "villages" stacked within the 14-storey tower. "The structure of the building had to be very stable and rigid to limit vibrations," explains Pelleriti, adding that any movement could affect the performance of the treatment equipment within.

A concrete column and slab frame was chosen, supplemented by shear walls and cores, with only the basement and main cores cast in situ. The rest of the structure was made at contractor Laing O'Rourke's Explore factory, with clinical and non-clinical services pre-fitted.

Externally, RSH+P chose unitised concrete cladding in 12m-wide expanses of the facade of both the south-east and south-west walls of the 60m-tall building. "Where there were shear walls, we wanted to express the structural element in the cladding," says Pelleriti.

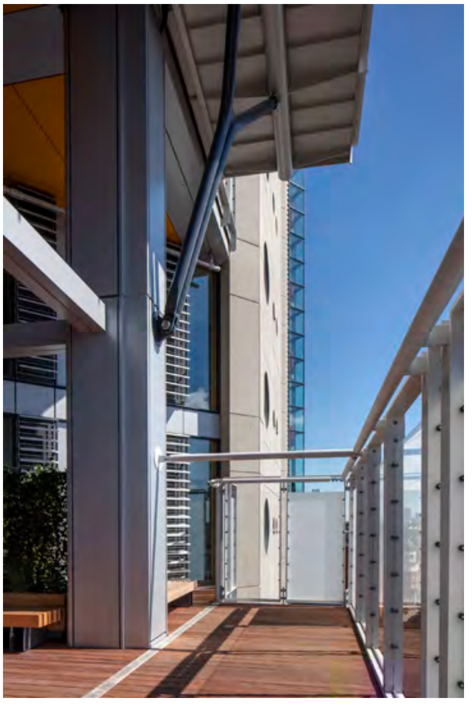
These expanses of cladding are enlivened by three circular porthole windows – one large, two small – per floor, designed to line up with various internal elements, such as the end of a corridor.

The architects worked with structural engineer Arup and Laing O'Rourke to develop the panels, with prototypes and mock-ups built at Explore. Each cladding panel is 80mm thick, with dimensions varying to a maximum of 4,200mm in height and 2,750mm in width. Panels are combined with 120mm of insulation which sits between the panels and the 500mm-thick sheer walls.

Inside, patients and staff are in no doubt that this is a concrete building. In public areas such as the main atrium, the lattice slabs and columns are exposed, with the walls and soffit only clad in clinical areas. This helped the design team achieve its aim of creating a welcoming building that felt non-institutional yet was clinically efficient.

"We didn't want to paint it," says Pelleriti, who has since co-founded the practice Wimshurst Pelleriti. "We wanted to keep the concrete as natural as possible, like stone."

CLOCKWISE FROM RIGHT
The building occupies a tight triangular site near London Bridge; the facades are enlivened by metal balconies and areas of precast cladding; walls are left exposed in public areas such as the stairwells



PROJECT TEAM
Architects Rogers Stirk Harbour + Partners; Stantec
Structural engineer Arup
Contractor Laing O'Rourke

COSMIC LIBESKIND

Durham University's striking new cosmology centre uses a complex and irregular structural concrete frame. Will Mann explains

Arranged in a twisting series of stacked and intersecting blocks, Studio Daniel Libeskind's Ogden Centre for Fundamental Physics is certainly a visually arresting addition to the Durham University campus.

Opened in March 2017, the 2,500m² facility contains 80 offices and research areas for cosmology and particle physics academics. These are set out in a ring over three floors around a central, wedge-shaped atrium. The unusual geometry has been realised using a reinforced concrete slab, and large areas of concrete have been left exposed internally – for both aesthetic and environmental reasons – contrasting with the extensive glazing and timber finishes, including larch cladding.

It may not be rocket science, but the structural design was far from straightforward, according to Arup project director Andrew Wilkinson. "We examined numerous options with the architect," he explains. "The floors spiral up through the building, so finding appropriate column locations was extremely challenging. Eventually we found that by introducing four sloping columns we could reduce both the cantilevers and internal spans, to the point where no downstand beams were required."

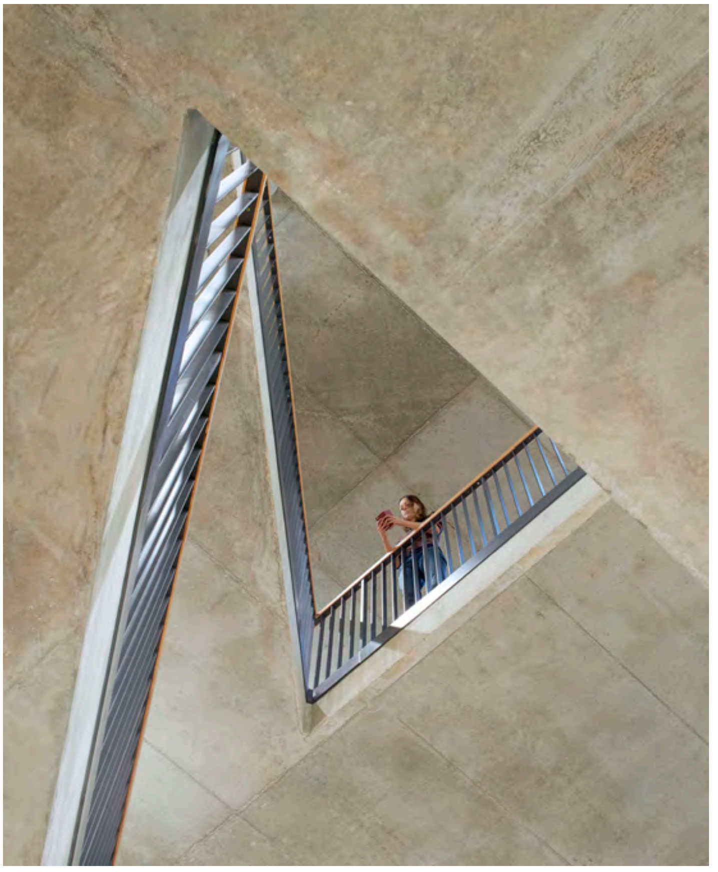
The result is that most edge cantilevers are below 3m, with perimeter column spacing no larger than 9m. There is no structural grid as such, with internal spans varying between 6m and 9m. Most columns are continuous from base slab to roof.

Given Studio Libeskind's interior design concept, the concrete mix was selected specifically with an exposed finish in mind. The client was taken to a project recently completed by frame contractor Cidon at Glasgow School of Art, and the Ogden Centre uses the same Class B and C finishes. Samples of varying mixes were cast to achieve the right consistency of finish and colour.

All concrete in the building was cast in situ, with angled kicker shutters used for the inclined columns, and bespoke angled brackets to create the desired sloping effect on the slab edges.

"The overlapping floor plates meant that some double-height propping was required where there was no immediate floor below to prop off, which necessitated additional temporary works at ground floor level," says Wilkinson.

Apart from its aesthetic qualities, the exposed internal concrete also helped the building to achieve a BREEAM Excellent and EPC A rating. The passive thermal mass attenuates heat gain build-up and assists in moderating internal temperatures. But Wilkinson stresses that this is part of a "whole-environment strategy", incorporating natural ventilation, night purging and solar shading. "These interlinked measures mean the building does not need mechanical cooling or ventilation systems anywhere other than 'landlocked' rooms," he says. "That's a significant capital saving for the client."



CLOCKWISE FROM RIGHT
The building is a spiral in form; angled brackets were used to create the sloping effect on the slab edges; the concrete structure is clad in larch with glazed end facades

Photos: Hufton + Crow

PROJECT TEAM
Design architect Studio Daniel Libeskind
Architect of record Garbers & James
Engineer Arup
Contractor Interserve
Concrete frame contractor Cidon

GOING UNDERGROUND

Basements are an increasingly popular way of adding space – and value – to properties. Elaine Toogood outlines the main considerations

Basements are defined by the Building Regulations of England and Wales as a storey at least 1.2m below its adjoining ground level. The technology and detailing necessary to create a basement also apply to partially submerged properties, for example on a sloping site, or tucked deep into the landscape with a green roof, or spaces below a podium deck. Some waterproofing techniques used for basement design can also be a useful part of a flood-resistance strategy for properties above ground or an appropriate means of managing ground gases and contaminants.

Concrete is the most common material used for basement construction. This is due in part to cost and availability but also to its inherent ability to provide high levels of water resistance, durability underground and a stable structural surface for the support of waterproofing membranes. But the choice of construction is influenced by a range of other factors over and above usual project considerations. This article considers some of the benefits of creating basements in new properties and summarises the key detailed design considerations.

Benefits

Basements are undeniably useful spaces to have, especially where available space above ground is limited. Through good design it is possible to create comfortable, well-lit and ventilated spaces below ground level with potential uses extending beyond storage or garages. In areas with sufficient land value and limited development potential above ground it can be economically viable to excavate basements. A basement can sometimes be the key to unlocking the development potential of a restricted site.

Basements benefit from the thermal properties of their surrounding ground. As a consequence, the amount of insulation needed to reduce heat loss through a basement wall is less than that required on upper floor levels. The thermal mass of the construction and surrounding soil can help to naturally regulate the internal temperature. When coupled with an appropriate ventilation strategy this has the potential to help regulate the temperature of the whole property. The homogenous construction and lack of wall penetrations ensure minimal heat loss through air leakage.

The mass of the earth and concrete also

Photos: Timothy Soar

LEFT 21 Caroline Place in London by Amin Taha Architects. The soffit of this in-situ concrete basement were bush-hammered to create an unusual, rough texture. The mix combined a pale cement with 50% GGBS and a specially sourced pale aggregate. The reinforcement design allowed for an additional 30mm of cover to allow for a similar depth of surface to be removed.

combine to provide excellent acoustic insulation, especially with a concrete ground floor above. Basements can therefore accommodate particularly noisy activities, which might prove difficult elsewhere.

Design principles

BS 8102:2009 is the code of practice for protection of below-ground structures against water from the ground. It defines three main methods or construction systems for providing protection against ground water. These are summarised as:

- **Type A** Barrier protection, or a tanked system with a waterproofing layer located either externally, internally or sandwiched within a structure of reinforced concrete or blockwork
- **Type B** Structural integral protection: reinforced in-situ concrete is designed to be water-resistant by controlling any cracking and using tried-and-trusted details such as water bars
- **Type C** Drained protection: an internal cavity system, which allows any water seeping through external walls and floor to drain to a sump and be pumped away.

It is also common to combine systems. NHBC generally requires a combination of at least two of these systems for any habitable basement.

The choice of construction system is influenced by the grade of basement required (see below), and an assessment of the risk of water ingress for any specific project. The assessment should take account of: proposed and future building uses, their environmental requirements, maintenance, future repairs, and current and future ground and water table levels. An appropriate site investigation and a thorough evaluation of its findings is an essential part of any basement design.

Grade of basement

Basements are divided into three grades of internal environment and associated building uses:

- **Grade 1** is for accommodation where some seepage and damp patches are tolerated, such as car parks (although, NHBC categorises these as Grade 2)
- **Grade 2**, for permanent workshops or garages, allows no water penetration, but some damp is tolerable and some ventilation may be required
- **Grade 3** is where no water penetration is tolerated, and ventilation, dehumidification or air conditioning is required. This grade is appropriate for residential accommodation. The standard PD 5454 provides specific guidance regarding the storage of exhibition or archival documents in basements.

Since building uses change, it is prudent to consider how to upgrade the basement during the design. The client and designer may wish to opt for additional waterproofing or vapour control at the outset to future-proof the property, and in doing so reduce other risks of failure. BS 8102 provides a summary of the appropriate construction system to achieve each grade of basement under different risks of water ingress.

Waterproofing

The correct specification and installation of the waterproofing system is one of the most fundamental decisions in basement design and requires an understanding of all the issues described above. The design of the waterproofing system has traditionally been the responsibility of the architect; however, BS 8102:2009 gives an emphasis on the inclusion of a specialist waterproofing adviser in the design team in order to create an integrated waterproofing system. This can be an architect or another consultant, a manufacturer or supplier, provided they have the relevant expertise.

An exception to this is when the construction method is classified as "structurally integral protection", when it is more likely to form part of the structural engineer's brief – although a specialist waterproofing advisor may still be required.

In any event, a unified approach is required, with defined roles and responsibilities within the design and construction team. Manufacturers offer warranties for the design and workmanship of basements, and some offer supervision, which can reduce the risk for the designer and the client.

Key considerations are the compatibility of waterproofing systems with each other, the

SINCE BUILDING USES CHANGE, IT IS PRUDENT AT DESIGN STAGE TO CONSIDER HOW TO UPGRADE THE BASEMENT IN THE FUTURE


Photos: Nick Rochowski

ABOVE At Perf House, an adapted Georgian townhouse by Andy Martin Architecture in Pimlico, London, pavement lights were used throughout the ground floor to draw light into the basement

structural system, and the sealing around joints and junctions of the waterproof membrane. The membrane should be appropriate to the anticipated movement of the structure it is applied to, in order to ensure that the allowable crack size or movement does not exceed the membrane's strain capacity. This is especially important when refurbishing or extending basements, since movement between existing and new structures must be anticipated. Ideally details and construction profiles will be simple, avoiding nibs and thickening of structure wherever possible to prevent complicated junctions. It is strongly advised that a three-dimensional review of structure and waterproofing is undertaken to identify and avoid complex geometries.

Concrete structure

In-situ reinforced concrete is the most common form of concrete used for basement structures and is appropriate in all types, A, B or C. Precast concrete or hybrid solutions such as twin-wall or smaller units of permanent precast concrete formwork are also possible, as are many insulated concrete formwork (ICF) systems. All require appropriate design of the concrete and a particular focus on junction details.

For ICF, specifiers should ensure that the waterproofing membrane and its fixing methods are appropriate for application to polystyrene. Masonry construction or concrete blockwork can be used with Type A waterproofing protection, but for new-build projects tends to be used for residential, low-risk applications with an externally located barrier, or as the internal wall of a Type C drained cavity basement construction. Secant and contiguous concrete piles are more commonly used for deep basement construction, rather than domestic. They can effectively become the outer wall of a Type C construction, or be faced with concrete and a membrane to provide Type A protection, or lined with a thick reinforced concrete wall to provide Type B protection.

Concrete is itself inherently robust and durable in water, but by itself cannot be regarded as completely waterproof. Its resistance can be enhanced through appropriate mix design and careful specification and execution such as the installation of water bars and stops at all junctions and day-work joints.

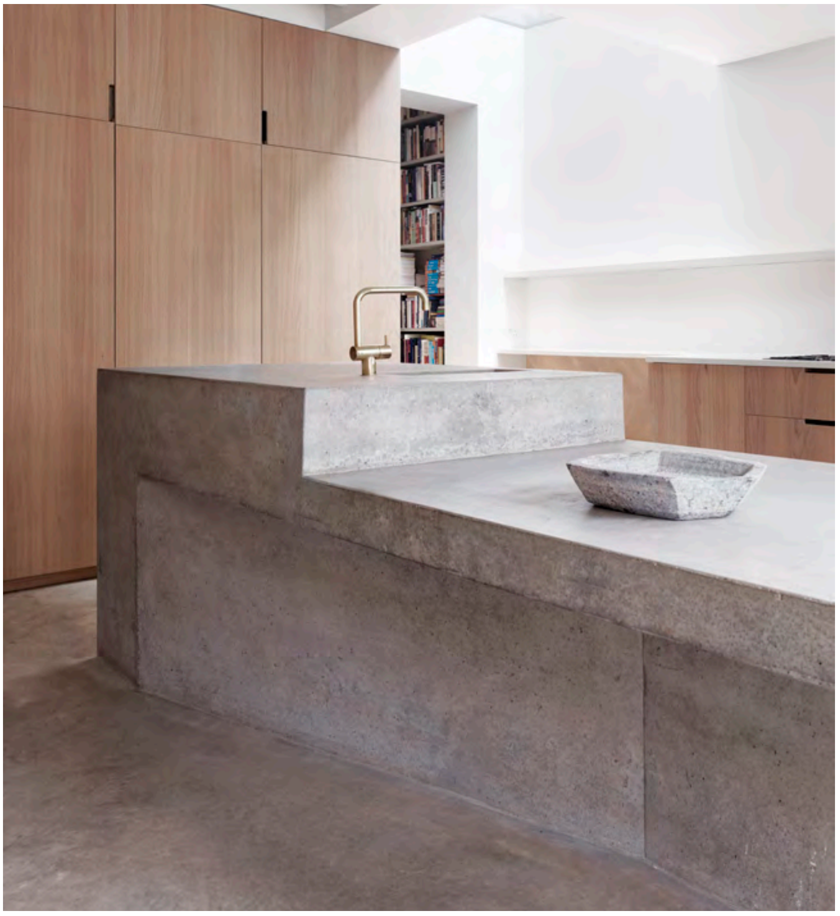
The use of waterproofing admixtures in the concrete can help. The main types are hydrophobic and pore blocking. They act to reverse the capillary or "sucking" action of the tiny capillaries on the concrete surface and effectively block the pores within the concrete when subjected to hydrostatic pressure. The result is dry concrete that protects from water ingress. It is still possible for small levels of water vapour to pass through any concrete. The vapour can be removed by ventilation of the internal spaces or prevented using an additional membrane.

Further information

- Basement Information Centre: www.basements.org.uk

- Basements for Housing and Concrete Basements, published by The Concrete Centre: www.concretecentre.com

- Reducing the Risk of Leaking Substructure, A Client's Guide, Institution of Civil Engineers



Photos: Richard Leeney; GreyMatter Concrete

SEALED AND DELIVERED

CLOCKWISE FROM LEFT
The kitchen island at McLaren Excell's Ingersoll Road project in London was finished with a surface impregnator; Food-safe sealers are available for countertops; A sealed/ unsealed surface

Jonathan Reid explains what to look out for when it comes to choosing sealant types

When it comes to protecting finished visual concrete, choosing the most appropriate type of sealer can be confusing. First, do you need to seal the concrete at all? This depends upon the maintenance demands of the work to be protected and whether sealing the concrete is worth the time and expense. For domestic projects, sealing may be much less of a priority than for a public building where the surface patina may develop more quickly with regular use. In both scenarios, using sealers as dust binders can be useful, as is sealing floors and countertops.

To start with, it is helpful to narrow down the choice by dividing sealers into two broad categories: penetrative sealers and topical sealers.

- **Penetrative sealers** chemically react deep within the concrete pores with minimal change to the appearance. The particle size is small to allow for penetration while maintaining breathability. Types of penetrative sealer include silicate densifiers, silane and siloxane hybrids and siliconates.
- **Topical sealers** are made up of larger particles and they are often described as a coating. While penetrative sealers are designed to reduce common issues such as staining, topical sealers are designed to prevent them in the first place. Topical sealers will alter the natural appearance of the concrete – for example, adding a sheen or intensifying the colour. Some can be hard to apply and can become slippery when wet. Topical sealers include acrylics, epoxies and associated mixtures of epoxies coated with urethanes or polyaspatic coatings.

Silane/siloxane penetrative sealers are often used to protect walls, columns, ceilings and external elements where minimal appearance change is required and the concrete needs hydrophobic protection from weather, water or other liquids, or graffiti. Polished concrete can benefit from the use of a silicate such as lithium silicate to harden and densify the surface, with a penetrative sealer added to boost performance. Food-safe sealers are available for polished concrete countertops.

Topical sealers vary in robustness. Acrylics are often used for less expensive coatings, or to enhance colour or sheen. Their use is associated with stamped concrete and external floors and patios, whereas epoxy systems are more suitable for industrial environments such as warehouses or garage floors.

The guiding principle for sealer selection should be the desired aesthetic performance of the concrete in the immediate and longer term. Either it will be necessary to leave the concrete and its evolving patina in its most natural form, to use a sealer that will cause minimal change to its appearance, or to enhance protection, potentially changing the look and feel of the material. In any event, it is prudent to carry out sample tests to ensure the most appropriate balance is struck between performance, protection and the aesthetic requirements of the project.

Jonathan Reid is a remediation consultant and practitioner at GreyMatter Concrete

PRECAST CONCRETE CLADDING

Concrete panels are an increasingly popular option for architectural and structural cladding, but they require close collaboration from the whole design team, writes Jaylina Rana

With the off-site manufacture of structural components becoming more common, the use of precast concrete cladding panels as the main building envelope has significantly increased over recent years. Precast concrete cladding panels primarily act as weather-proof envelopes, while fulfilling architectural, structural and other requirements in terms of fire resistance, thermal performance and sound insulation. They are used in a variety of structures, including in the residential, commercial, institutional and industrial sectors.

The adoption of the appropriate precast cladding system will be the result of an iterative decision-making process among project stakeholders including architects, designers, planners, contractors and manufacturers, who will have different priorities. For instance, the choice of finish is largely dependent on aesthetic preferences and local planning requirements, which in turn influences the architectural and structural considerations. Therefore, it calls for an integrated

ABOVE Studio Gang's Campus North Residential Commons at the University of Chicago is clad in twisting vertical bands of white precast concrete approach by all key stakeholders early in the design.

The structural design of precast cladding panels is significantly influenced by factors such as panel dimensions, location of the panel joints, number of apertures or openings, the number of storeys and floor-to-floor height of the building or structure.

Common precast cladding arrangements

The arrangement of the precast concrete panels is primarily influenced by the geometry and number of apertures or openings within the facade. The most common arrangements of precast cladding are punched cladding, spandrels and mullions, ribbon cladding and vertical band cladding (figure 1).

- **Punched cladding** Panels are cast with an aperture into which a window or door assembly can be fitted off-site
- **Spandrels and mullions** A series of horizontal (spandrel) and vertical (mullion) panels which span between the openings – for example, windows. The window assemblies are then fitted on site after the cladding has been erected
- **Ribbon cladding** Horizontal panels which are joined at their ends, with windows fitted vertically in between
- **Vertical band cladding** Vertical bands which transfer the cladding loads to the foundations or ground support system.

Types of precast cladding

Precast concrete panels can be designed to be structurally loadbearing or non-loadbearing.

- **Loadbearing cladding systems** typically consist of an inner structural panel, an insulation layer and an outer non-structural panel. This type of cladding is mostly used instead of perimeter beams and columns, to transfer the vertical forces down the structure to the ground.

The most common type of loadbearing cladding system is sandwich panels. The structural concrete inner layer is designed to withstand the applied loadings from the floor and the structure above. The thinner outer layer acts as a weather- and airtight barrier and provides the desired architectural finish for the building envelope. An insulation layer is sandwiched between the inner and outer layers to provide the required U-value. The three layers are linked by connectors to ensure low thermal conductivity (figure 2).

Loadbearing sandwich panels transfer the load from their self-weight (and the panels above) and the dead and imposed loads of the supported floors on to the foundation or supporting structure below. Additionally, these walls have to withstand lateral wind forces on the face of the cladding panels. Vertical continuity such as steel dowel bars or couplers are usually provided between cladding panels to resist the lateral forces applied. The structural layer of loadbearing cladding panels are also tied back to the floor using U-bars and horizontal tie bars.

- **Non-loadbearing cladding systems**, such as solid or single-leaf precast cladding, have no structural function. These precast cladding panels act as weather and air barriers and provide the desired architectural finish to the building envelope. The windows, insulation and internal finishes are most commonly installed after the erection of the panels.

Non-loadbearing panels are either stacked off the foundations or ground beams, or supported by the main frame on or near column positions in order to avoid excessive mid-span deflections in slabs/beams.

- **Stacked system** When stacked, loads are transferred vertically through the panels down to ground through dowelled connections (figure 3).
- **Supported system** When supported, stainless steel brackets mounted on to the base of the panel transfer the vertical and lateral forces to the floor slabs – or secondary structure (figure 4, overleaf).
- **Restraint** Restraint fixings are designed to

FIGURE 1: PRECAST CLADDING ARRANGEMENTS

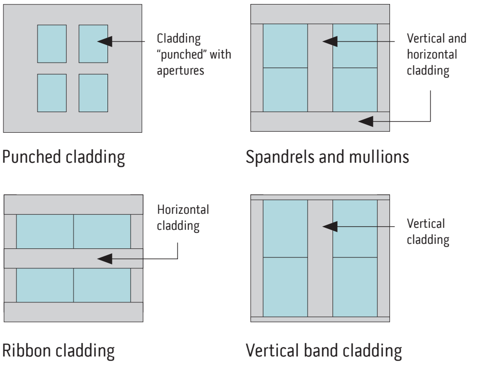


FIGURE 2: TYPICAL CONCRETE SANDWICH PANEL

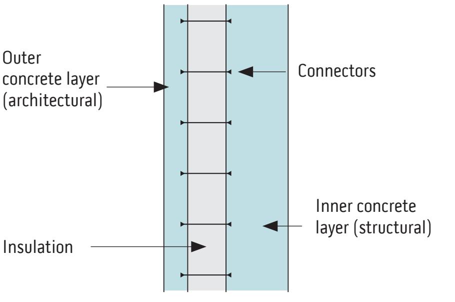
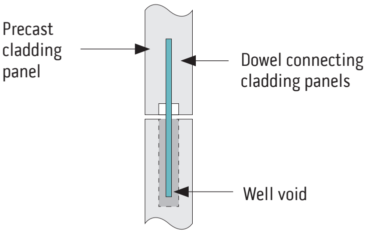


FIGURE 3: DOWELLED CONNECTION IN STACKED CLADDING SYSTEMS



ARCHITECTURAL CONSIDERATIONS

With recent developments in casting and manufacturing techniques, precast concrete facades are now available in an almost unlimited range of colours, textures and finishes.

Colour

Cladding can be manufactured in an extensive pallet of colours, and be designed to match the colours and textures of other materials such as stone, masonry and terracotta.

The colour of the concrete is dictated by the type, consistency, proportion and grading of the cement, fine aggregate, coarse aggregate and pigment. For instance, if the desired colour of the concrete is dark or light grey, then the most commonly available grey cement is used. For lighter shades of concrete such as natural stone, white cement is used. A wide range of naturally occurring aggregates is available in the UK, including limestone, granites and shingles. Fine aggregates, which form about 30-35% of typical concrete mixes, have a significant effect on the colour and can produce a variety of colour palettes from white and buff, to red, green, brown or dark grey. Coarse aggregates also influence colour, particularly when they are exposed in polished or exposed finishes.

Pigments are used in concrete to produce a wider variety of more intense and stronger colours, which cannot be achieved by the use of naturally occurring aggregates. Manufactured inorganic pigments are available in powder, liquid and granular forms. They must complement the type of cement and aggregate in order to achieve the required uniformity and intensity of colour. For example, terracotta-coloured concrete can be achieved by combining red pigment with off-white cements, sands and granite.

Texture and finish

Textures can be formed or cast, post-applied (for example, by etching, blasting or polishing), or cast monolithically with facings such as bricks or stones.

For geometric patterns, false joints, rebates and chamfers, the concrete is cast in special moulds incorporating the desired features. Materials such as stone, brick and terracotta can also be cast in to the concrete panels to replicate the facades of existing buildings. This approach is often used to satisfy planning requirements to ensure the new facade is in keeping with surrounding buildings. Fine textures in recon panels are usually applied to the concrete after curing and demoulding.
For finer textures, the surface of the concrete is etched to remove the top cement and fine aggregate. For coarser finishes, other techniques such as grit blasting can be used.

More information can be found in "Visual Concrete", available to download from www.concretecentre.com

FIGURE 4: TYPICAL CONNECTION IN SUPPORTED CLADDING SYSTEMS

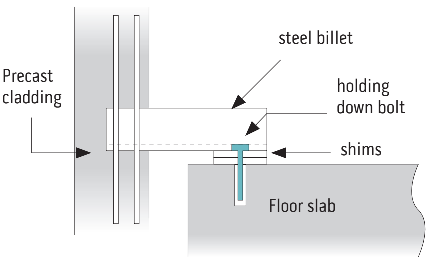
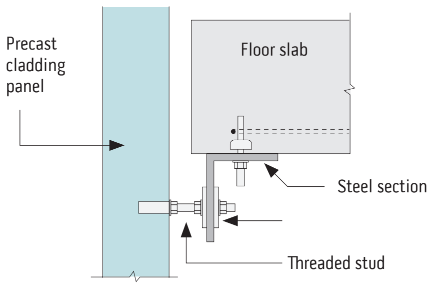


FIGURE 5: TYPICAL RESTRAINT CONNECTION IN CLADDING SYSTEMS



hold panels back to the structure and transfer all horizontal forces (such as wind loading) to the structure. They should be designed to be adjustable to accommodate any differential movement between the structure and the cladding. Particular attention must also be taken of the allowable tolerances in the structure of the building and the manufacture of the precast units. Four restraints are commonly provided in average sized panels, typically at the corners of the panels (figure 5).

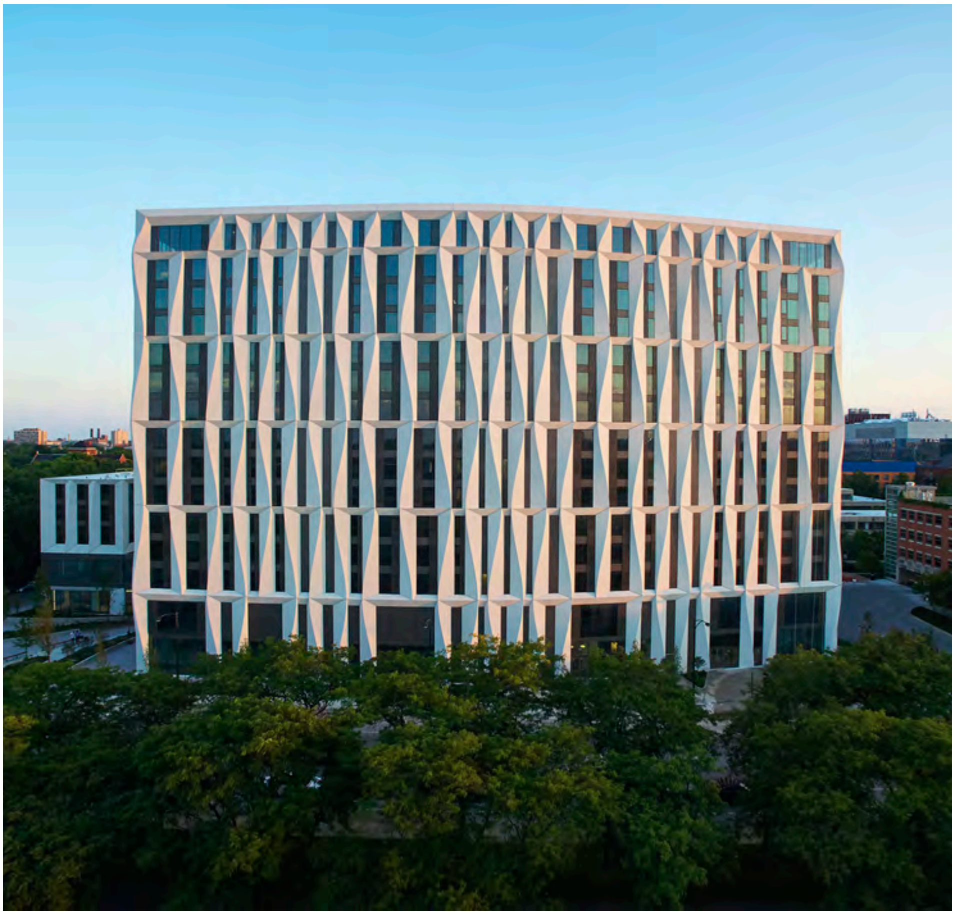
Other considerations

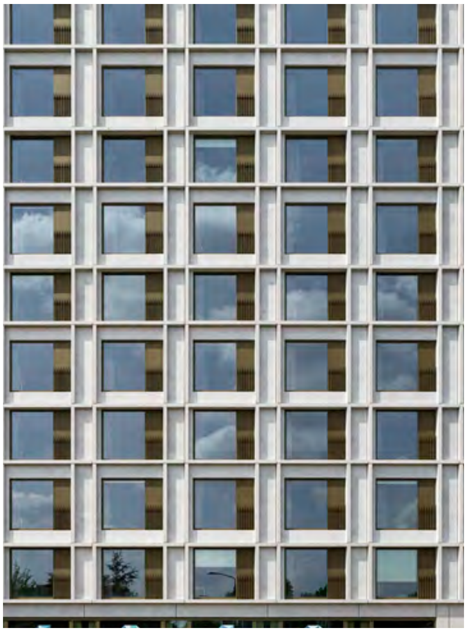
■ **Transportation** Precast concrete products are transported on trailers, which directly influences the size of cladding panels. The recommended maximum vehicle height on UK roads is 4.93m. There are many different trailer configurations that may be used. Typically, panels up to 4m high x 7m long, or 3m high x 13m long, can be readily transported to site. Beyond these parameters, early guidance should be taken from the manufacturer.

■ **Lifting and handling** Consideration must be given to handling and lifting at all stages, including production, transportation and erection, and also to the stresses induced by these operations. Handling must be reduced to a minimum to prevent damage to precast units, whether in the factory, during transport or on site. The strength of the panels at the time of these operations is fundamental in determining additional reinforcement needs. The precast units must also be stored so that delivery in accurate sequence for site fixing is possible.

Lifting methods must be clearly defined through close coordination early in the design process between the cladding manufacturer and site team.

Jaylina Rana is a structural engineer at The Concrete Centre





Photos: Tom Harris Photography; Rasmus Hjortshoj; Stefan Muller

FURTHER INFORMATION

To see case studies of architectural precast, visit www.aspa-uk.org

CLOCKWISE FROM TOP
Studio Gang's ribbon-like Chicago campus facade; Polished precast panels on the loadbearing facade of Office Winhov's Eindhoven University of Technology housing; The double-curved facade of BIG's 1200 Intrepid office in Philadelphia, created by stacking precast panels in a basket-weave pattern

LASTING IMPRESSION MARION BRERETON

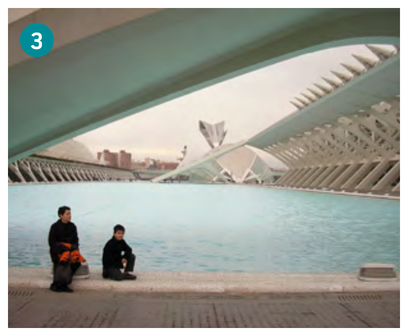
CONTRASTS, CALATRAVA AND CORNISH BLUE

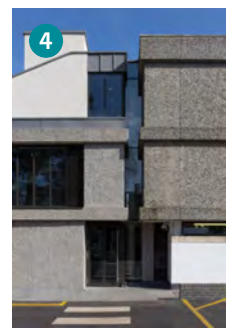
I was born and brought up just by the Thames in SE1, so my introduction to concrete was watching the construction of Denys Lasdun's National Theatre 1 (1976). As a 13-year-old, I hadn't yet thought of becoming an architect but even then I could appreciate that something special was being revealed. I loved the contrast of that Brutalist concrete with the very high-quality materials of the interiors and the colours. There's no airs and graces about Brutalism, but the way the concrete sets off other materials is a wonderful thing. It's like ambergris – it enhances their qualities and allows them to shine.

At architecture school, we went to see Frank Lloyd Wright's Fallingwater 2 and the Johnson Wax Headquarters (both 1939). There you can see the versatility and the beauty up close. In Fallingwater, again it's the concrete in contrast with the other materials, particularly glass, that's wonderful for me. The beautiful ribbed arched structure of Santiago Calatrava's City of Arts and Sciences in Valencia 3 (1998) also stood out for me. It clearly shows what a dream material concrete is for an engineer – the structures it can produce are so impressive, in terms of the elegant shapes and the gymnastics they can perform. It's painted white, which looks absolutely amazing against the Mediterranean sunlight – like something out of this world. You can see why it was chosen as the backdrop for a recent episode of Doctor Who.

More recently, the practice was fortunate enough to extend Powell and Moya's in-situ and precast Wolfson College 4 (1971) in Oxford. I liked the unpreciousness of the in-situ concrete. There's discoloration, and the holes where the panels were removed are not perfectly round, yet they didn't feel the need to touch them up. Sometimes I think concrete is almost artificially touched up today, which seems a shame. In-situ concrete is what it is. But I also appreciate the refinement that's possible with precast. At Wolfson, the panels are perfectly assembled and inset with Cornish blue granite, which gives the building a timeless quality. It looks as good now as it did in the 1970s.

Marion Brereton is a director at Berman Guedes Stretton





Photos: 1. Douglas Miller / Getty Images; 2. Nick Higham / Alamy Stock Photo; 3. Marion Brereton; 4. Quintin Lake Photography

FROM THE ARCHIVE: WINTER 1948

'TOO MIGHTY FOR MEANING'

The early issues of CQ were focused on one thing above all else: power. By the end of 1948, the first four had reported on two modernised collieries, three hydro-electric dams and four power stations. Of these, Ham Halls B station in Birmingham was easily the most imposing. The hyperbolic cooling tower was probably the most iconic concrete form of the 20th century and the four here were at the time the largest in the world: each as tall as Giles Gilbert Scott's mighty Liverpool Cathedral and with the capacity to cool 4 million gallons of water an hour.

The numbers involved in the construction of Hams Hall must have made astonishing reading in austerity-stricken post-war Britain. It was designed to produce 300,000 kilowatts of electrical power, for which it needed up to 8,000 tonnes of coal a day. CQ could not help but compare this with the "meagre allocation" of the rationed British family. It also marvelled at the cost, an estimated £10.5m. "Perhaps you find these figures too mighty for meaning? Then try it this way! A man earning £500 a year would have to have started working nearly 20,000 years before the beginning of the Christian era to earn that amount. Does that make it easier?"

In 2017, CQ is celebrating its 70th anniversary. Find out more, and access the full archive, at www.concretecentre.com

Birmingham gets a new power station — *Nearly a quarter of a million gallons of water and six tons of coal are needed every minute of every day to enable Hams Hall to do its job.*

The cooling towers in course of construction. Each one has a capacity of four million gallons an hour and a range of from 90 to 75° F.

The Hams Hall cooling towers are reputed to be among the biggest erected anywhere in the world.

FINAL FRAME: **RAI AMSTERDAM CAR PARK**

Bethem Crouwel Architects has created a car park in Amsterdam that doubles as a flexible space for conventions and exhibitions. The 30m-high building at the RAI Amsterdam Exhibition and Convention Centre consists of a simple, rectangular building and two helix-shaped ramps that spiral upwards. These towers are built from precast concrete sections cantilevering off a central core. Lit with blue LEDs at night, they have already become a local landmark.

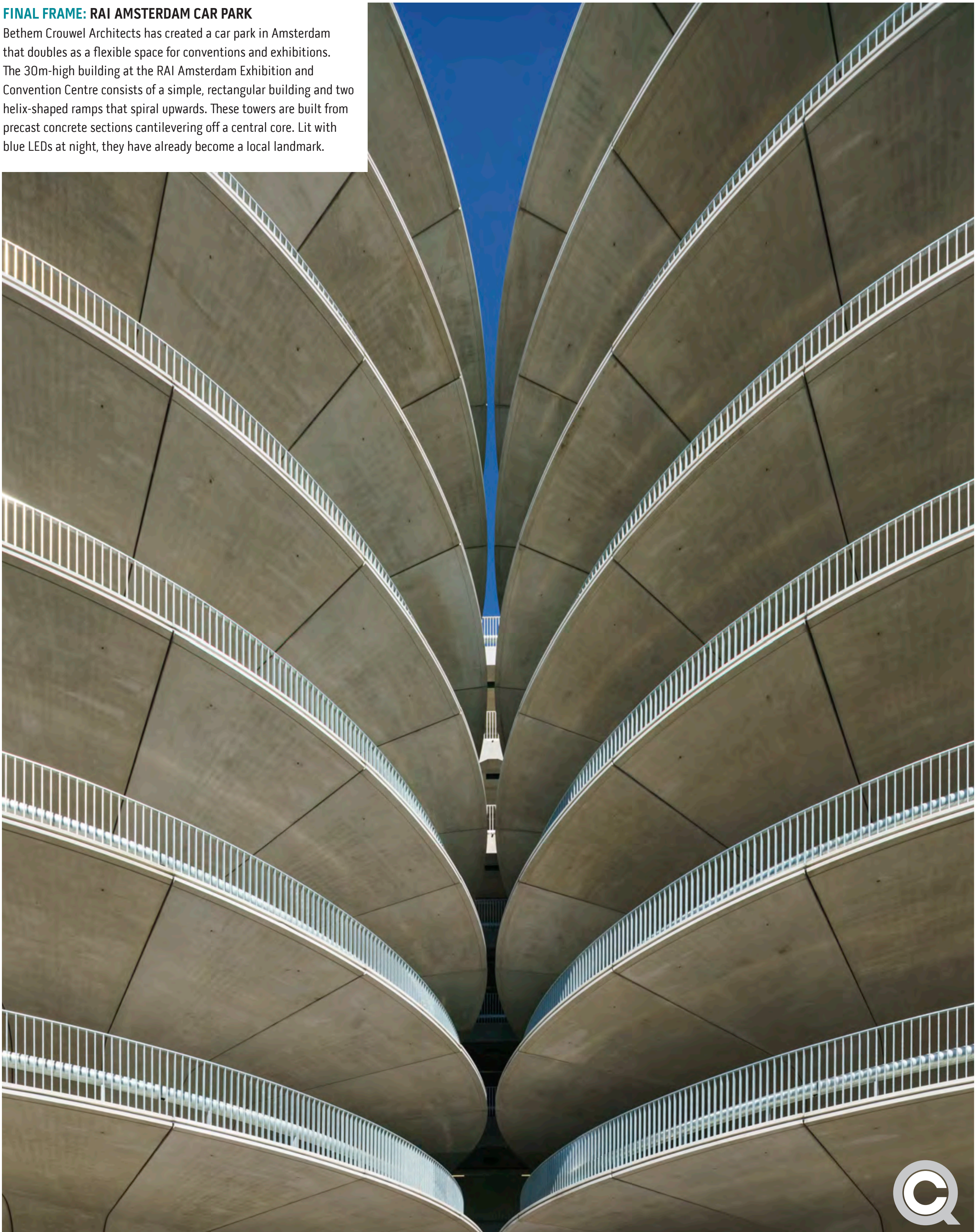


Photo: Jannes Linders