mpa The Concrete Centre

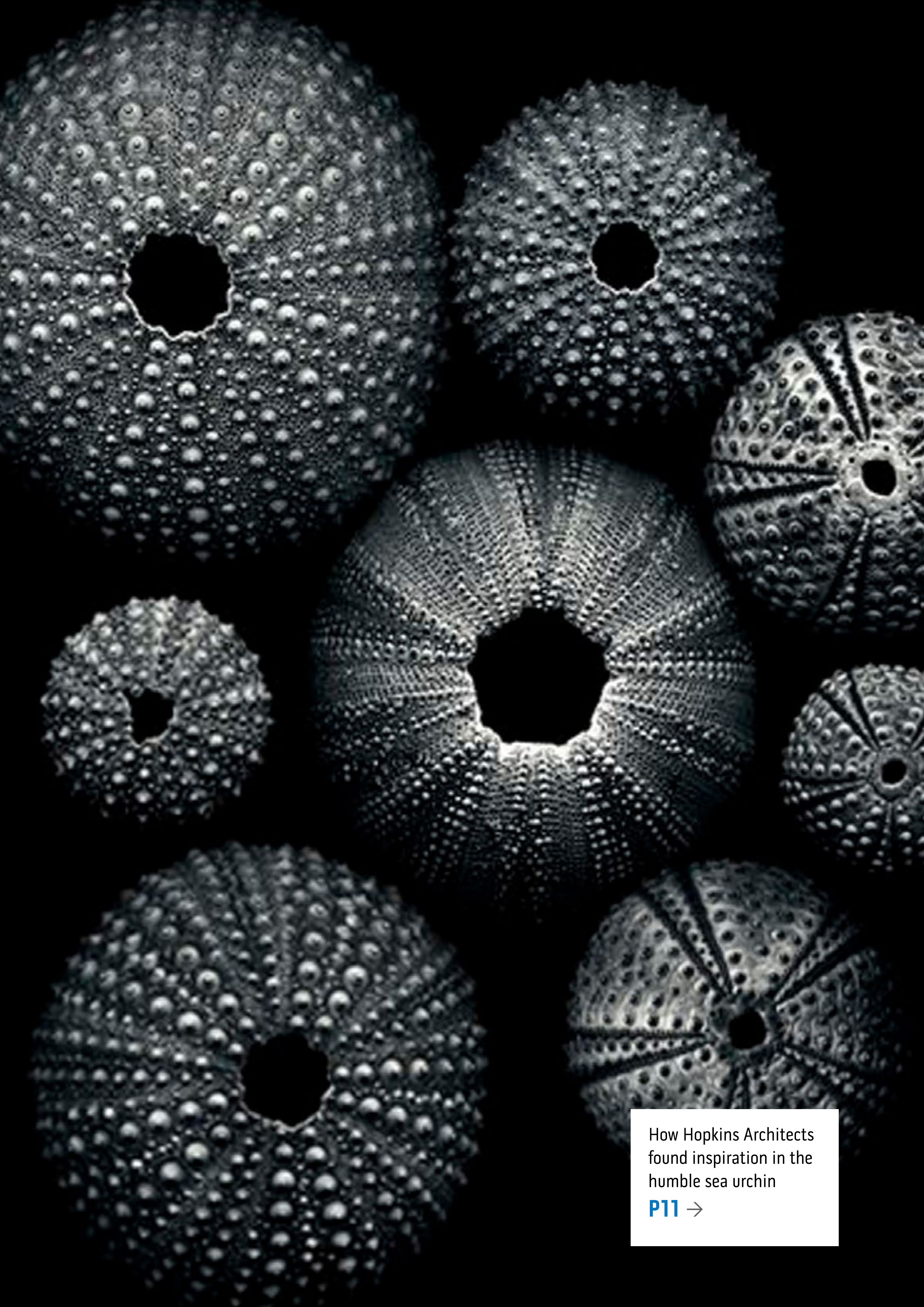
CONCRETE QUARTERLY

SUMMER 2021 | ISSUE NUMBER 275

OVER THE LINE →
A first look at Farringdon Crossrail Station's grand entrances

ETERNAL FRAME →
How to give a concrete structure a second life

POST MODERNISED →
Orms reboots a 1970s Royal Mail office as a global media hub



How Hopkins Architects found inspiration in the humble sea urchin

P11 →

CONTENTS

CASTING OFF

INSPIRATION

APPLICATION

Elaine Toogood
Head of architecture, The Concrete Centre

Life: the bit in-between

The circular economy has been occupying my mind a lot recently – there seems to be a real appetite for more information on exactly how this can be achieved. There's necessarily been a lot of focus on decarbonisation, but that's not the end of the story: we will still need to think about how we can design buildings better to meet the challenges of the future.

A core principle of the circular economy is longevity – keeping materials in use for longer – and this is an area where concrete can make an important contribution. In this issue of CQ, we feature an underground station, a school and a house – none of these are fly-by-night structures, and we want them to be useful for decades, ideally for many generations.

We can reduce the embodied carbon of a concrete frame with material-efficient design and low-carbon mix specification. But once it's built, it becomes a low-carbon resource for the future. Designed well at the start, a concrete frame can be stripped back, retained and reused many times, as the more temporary layers are replaced and upgraded. In fact, from a structural engineering point of view, a new internally located concrete frame that is specified to last for 50 years can last for 100 or more – it's buy-one-get-one-free.

That's not the end of the story. From an architectural point of view, we also need to think about how to make that frame adaptable over time, not to mention beautiful so that people actually want to use them. There can be potential conflicts to resolve – for example, longer 9m spans offer greater flexibility for space planning compared with a more material-efficient 6m span – but, as with everything, it comes down to making reasonable assumptions and working out the optimum balance. We don't need to design a building to become absolutely anything, we just need to think about what the most likely uses are and build in some capacity for those alternative futures. Here, the lessons that project teams are currently learning on reuse projects (such as 160 Old Street, see page 33) will be very valuable.

AN INTERNALLY LOCATED CONCRETE FRAME THAT IS SPECIFIED TO LAST FOR 50 YEARS CAN LAST FOR 100 OR MORE – IT'S BUY-ONE-GET-ONE-FREE

Embodied carbon is often described in language relating to the birth of a building, and the circular economy is often spoken about in terms of designing for end of life. But I think we're missing a vital piece of the story: we need to look at what happens in between, the life and health of a building or structure, so that it can continue to serve us for as long as possible. Concrete requires little maintenance over its lifetime, by comparison with other materials, and where required digital technology and AI is helping with diagnosis.

Keeping the buildings we have as healthy as possible for as long as possible is surely the most sustainable solution for all of us – not just in terms of carbon but for the stability of the cities and societies we're building now. ■

CONCRETE QUARTERLY

Concrete Quarterly is published by The Concrete Centre, part of the Mineral Products Association.

Editing and production: Wordmule
Design: Nick Watts Design

On the cover: Farringdon Crossrail Station. Photo by Morley von Sternberg

INNOVATION

GRAPHENE CONCRETE

MEET THE PIONEERS WHO WANT TO ADD THE SUPER-STRONG MATERIAL TO CONCRETE ON AN INDUSTRIAL SCALE

We have heard a lot about graphene in recent years – the one-atom thick, super-strong version of carbon that will revolutionise material science by making everything stronger, lighter and more efficient in every way. Some 200 times stronger than steel, and 1 million times more conductive than copper, it's truly astonishing stuff.

But applying graphene technology has often proved difficult, and using it to produce a high-performance concrete has been stymied both by cost (until recently up to US$150 per gram), and by the difficulty of distributing graphene evenly through a mix.

This could now be changing as a result of advances made by First Graphene, a firm with its origins in the material's early development by the University of Manchester. "To get the best from graphene, you first need a high-quality, consistent product," says Todd McGurgan, First Graphene's Australia-based commercial manager. "When people have added graphene to concrete before, the results have tended to be disappointing because either the quality wasn't there, or the graphene was not dispersed properly, leaving ineffective agglomerations."

To obtain the desired improvements in performance, atom-sized platelets of a graphene additive are used to enhance the calcium silicate hydrate phase of concrete,

YOU ONLY NEED TINY QUANTITIES – JUST A FEW GRAMS IN A BATCH OF CONCRETE supercharging the strength of the cement as it begins to set. "To properly disperse the platelets so they work as nano-particles, they are pre-dispersed in a liquid formulation, preventing agglomeration and ensuring an even distribution within the cement hydration phases."

First Graphene is working with a number of admixture and concrete producers to test the effects of its product in various types of concrete. "So far we have found significant compressive, flexural and tensile strength gains of around 30%, together with reduced permeability. Further testing shows improvements with sulfate and chloride ingress, drying shrinkage, modulus of elasticity and abrasion resistance."

ABOVE
The graphene platelets are dispersed in a liquid admixture to ensure they are evenly distributed

Of course, existing admixture technology can already achieve many of these desirable effects. But with the addition of graphene as well, a higher performance can be measured: "With the graphene additive, you get the strength with less cement. In addition, it has shown to reduce standard deviation in 'same sample' test specimens, often a problem with very-high-strength concrete mixes."

McGurgan believes it is an exciting time for this technology. "Now we have a reliable product, the plant to produce it at a commercial scale, and costs are significantly down, to below US$350 per kilo. That sounds expensive, but you only need tiny quantities – around 0.05% of the mix, or just a few grams in a batch of concrete."

He stresses that graphene is not a cement substitute, so much as a powerful admixture for high-performance mixes. "You won't need graphene for basic concrete – but for the rest, the potential is massive. The benefits can be applied to many types of concrete, shotcrete, mortars, grouts and concrete repair products."

Graphene is quite definitely a wonder-material. And if First Graphene and McGurgan are calling it right, the long wait to realise its benefits may soon be over. ■

Interview by Tony Whitehead

SHAHED SALEEM

IT UPSET THE MODERNIST CLIQUE, BUT FREDERICK GIBBERD'S LONDON CENTRAL MOSQUE SHOULD BE HAILED AS A CLASSIC

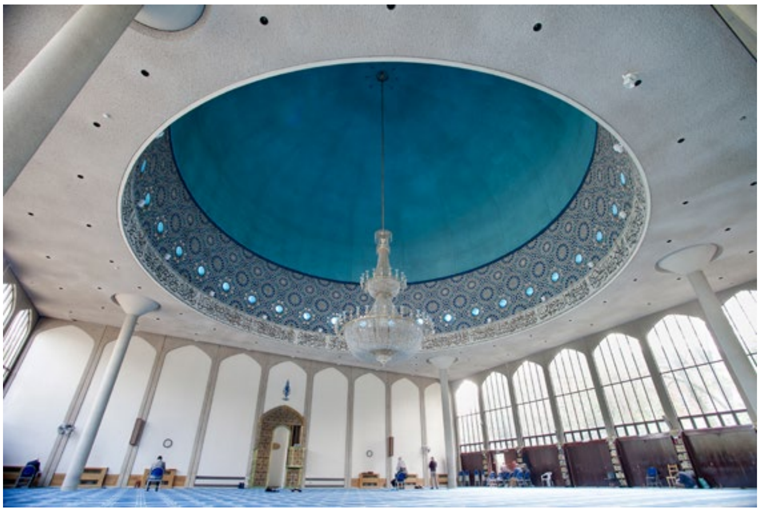
My earliest memories of mosques are of my family's local one in south London, which was above a shop, and then London Central Mosque in Regent's Park (Frederick Gibberd, 1969-77). It was the late 1970s, and I must have been seven or eight. I remember lying under the dome in the prayer hall, looking up, and just experiencing this great blue vastness. It's an enormous space – it was the first time that Muslims in this country had seen Islamic architecture on such a scale.

What is unique about this building is the way that Gibberd plots a course between the historic and the modern. There were three designs shortlisted in the 1969 competition – one was contemporary, one was traditional, but only Gibberd sought to bring these two influences together. It was a time when the British Muslim population was growing rapidly, with migration not only from south Asia but also North Africa and the Middle East. I think Gibberd saw the need for

Photos: Shahed Saleem; Rehan Jamil

TOP
The dome and minaret are less ornate than south Asian mosques

ABOVE
Precast concrete arches frame the curtain wall



ABOVE
Above the prayer hall, the dome sits on a concrete ring-beam

BELOW
The pale concrete was designed specifically for the project

clear Islamic symbols as a common denominator between these different cultures – so there's the dome, the minaret, the pointed arches framing the windows.

But then he places these motifs in a contemporary framework. If you look at the prayer hall, it is a table-top structure held up on four corner columns, with the dome sitting on a concrete ring-beam. This allows the walls to be fully glazed, with the arches holding the curtain wall – it's a very modernist idiom. In the same way, the dome and minaret are Persian in origin, which is less ornate than south Asian architecture. The walls of the dome come down straight onto the ring beam rather than curving like an onion dome, while the minaret is a solid cylinder cast from a bespoke pale-coloured concrete.

Gibberd described the mosque as a "thoroughly modern building", but it has always been misunderstood. The critics gave him a hard time, saying that it was inauthentic and flimsy, and that Gibberd had sold out his modernist credentials by embracing pastiche. They didn't know what to do with it. I think he was simply being far more humane than they realised. They missed the nuance and the significance it had to people of a Muslim background, and didn't understand that it was negotiating a whole series of complex cultural histories.

This is a hugely important religious building, and it has been excluded from British architectural history, so it's time that it was revisited – it could be thought of as the first postmodern building in this country. It doesn't try to be ironic or humorous, but it brings in historical references in a way that hadn't been done for 70 years. ■

Shahed Saleem is director of Makespace Architects and author of *The British Mosque: An Architectural and Social History* (Historic England, 2018). He co-curated the exhibition *Three British Mosques* at the 2021 Venice Architecture Biennale

FROM THE ARCHIVE: WINTER 1977

LONDON GETS BACK INTO SHAPE

While much of the architectural press snorted at Frederick Gibberd for embracing ornamentation at London Central Mosque (see previous article), Concrete Quarterly welcomed this break from modernist norms. "Shape and silhouette are not matters that post-war architecture has thought worthy of much consideration, and surely to its detriment," wrote editor George Perkin. The mosque's "major architectural asset", on the other hand, was its dramatic form, "its gold shimmering dome and slim white minaret rising from a bower of dark summer green".

Perkin liked the fact that Gibberd had embraced both religious tradition and modern construction techniques, particularly when it came to the concrete elements. With engineer Posford Pavry , the architect had developed a new method for building a dome. This involved covering the main hall with a flat reinforced-concrete slab supported by mushroom-headed columns set back from the four corners – "like a table with inset legs". The slab had a large circular hole in the centre with a reinforced-concrete ring beam; this carried the light precast-concrete segments that formed the drum beneath the dome. The dome itself consisted of eight tubular steel lattice frames clad externally with gold alloy sheeting.

Precasting also lent itself well to Islamic design. The facades were composed of repeating precast units, each consisting of two columns joined at the top by a four-centred arch. These were cast with Derbyshire Spar aggregate and white cement, deep-ground for a smooth, pale finish, and infilled with glass or panels of white mosaic. "The repetition of this units," wrote Perkin, "gives an overall unity to the building as well as emphasising its religious purpose." ■

Access the full CQ archive online

The mosque in its park setting (photo: George Perkin).

Islam in Regent's Park

London Central Mosque

Client:	The London Central Mosque Trust Ltd
Architects:	Frederick Gibberd and Partners
Consultant for structural engineering and services:	Posford Pavry and Partners
Quantity surveyor:	John Watson and Carter
Main contractor:	John Laing Construction Ltd
Precast concrete units:	Portcrete Ltd

The London Central Mosque in Regent's park has been widely publicized in the last few months and is therefore no longer architectural news. Still, the fact remains that it has captured the public imagination—perhaps for obvious reasons—in a way that few recent new buildings have managed to do. Clearly its religious purpose and exotic nature set it in a category apart, so that comparisons are not really fair. However, laying that issue aside as much as

The elements of the mosque.

34

View into the main congregation hall from the women's balcony (photo: Trevor Jones).

ISLAM IN REGENT'S PARK *continued*

its religious purpose. Above the wall units is a continuous upstand precast concrete beam, later to be finished in mosaic, which draws a horizontal line around the building in contrast to the verticality of the units below.

A new form of dome construction was developed by the architects for the competition design, subsequently examined by the consulting engineers and found to be valid. The great rectangular hall is covered with a flat reinforced concrete slab supported by mushroom-headed columns set back from the four corners—like a table with inset legs. The slab has a large circular hole in the centre with a reinforced concrete ring beam. This carries the precast lightweight concrete segments forming the drum. On top of the drum is the dome itself and this is a light metal structure of the same four-centred profile as the arched walls. It consists of eight tubular steel lattice frames clad externally with boarding and alloy sheeting of a brilliant gold.

The minaret is placed close to the dome so that their two forms interact as the viewpoint changes. The shaft is an unadorned cylinder consisting of two concentric concrete tubes cast simulataneously with

38

ABOVE
The visitor centre comprises seven interconnected pods with shells of pale precast concrete

ORIGIN STORY

KHOR KALBA

HOPKINS ARCHITECTS' SIMON FRASER ON AN URCHIN-INSPIRED TURTLE SANCTUARY

The Khor Kalba mangrove reserve in Sharjah is a stunning place, facing out over the Gulf of Oman – you go down to the water and you can see turtles and stingrays, flamingos and collared kingfishers. When we first visited the site for the turtle and wildlife sanctuary in 2016, our client [the Environmental Protected Areas Authority] asked, "where do you want to build?" You feel a sense of responsibility when you do a project like this – you're putting something down on land that ideally should not be built on. So we wandered round until we found this old parking lot, strewn with litter and plastic bags, and we thought: we could build on that.

Minimising damage to the wilderness site and touching the terrain as lightly as possible were important themes throughout the project. We started with some basic sketches. The client was still working the programme out as the brief developed, so we needed something we could add to and move around, like drafts on a chequer board. There were piles of broken-up sea urchin exoskeletons all over the place, which have rounded, segmented forms. These gave us the idea for a cluster of seven white concrete pods. They are precast to avoid major building work on site, and sit on simple foundations of in-situ concrete discs, raised above the ground.

At the same time, we were starting work on the Buhais Geology Museum (CQ 273), another environmentally sensitive site 80km away in the Sharjah desert, and we were thinking about designing the projects as a pair. Strangely, we also found fossils of these sea urchins in the middle of the desert, from 65 million years ago, when it was the bottom of seabed. It just reinforced the sense that we should focus on this form.

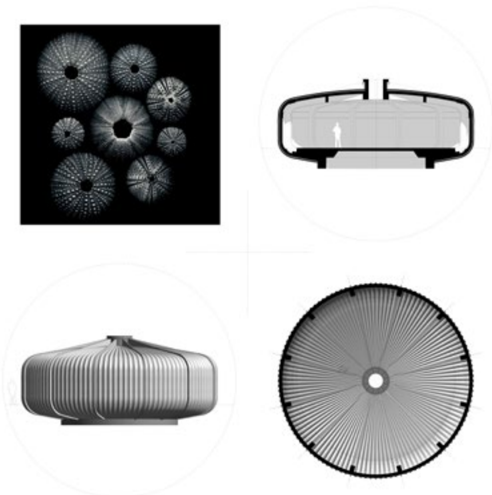
Externally, the projects look quite different. While the geology museum is clad in metal, Khor Kalba's pods have a precast concrete shell to protect them from the corrosive saline environment. The shells were cast in segments, like pieces of a pie, and assembled on site. There are three different sizes of pod – 18m, 22m and 30m in diameter, depending on the use, ranging from a cafe and bookshop to a large aquarium – but they all use the same system. Once we had worked out all the details for one section, it worked like a dream.

We did a lot of studies and samples to get the precast elements right. The concrete has a white aggregate with some shell fragments added, and has been sandblasted to give it a rough texture – we wanted that feeling of shells being crushed into it. It was important that it wasn't too smooth because concrete can appear quite shiny in the strong Arabian light. The precaster did a very good job but, if anything, made it slightly too perfect. I was telling them I wanted more imperfections!

TOP
An oculus in the centre of the dome reflects daylight into the interior

ABOVE
Internally, exposed concrete helps to moderate the fierce

Photos: Marc Goodwin



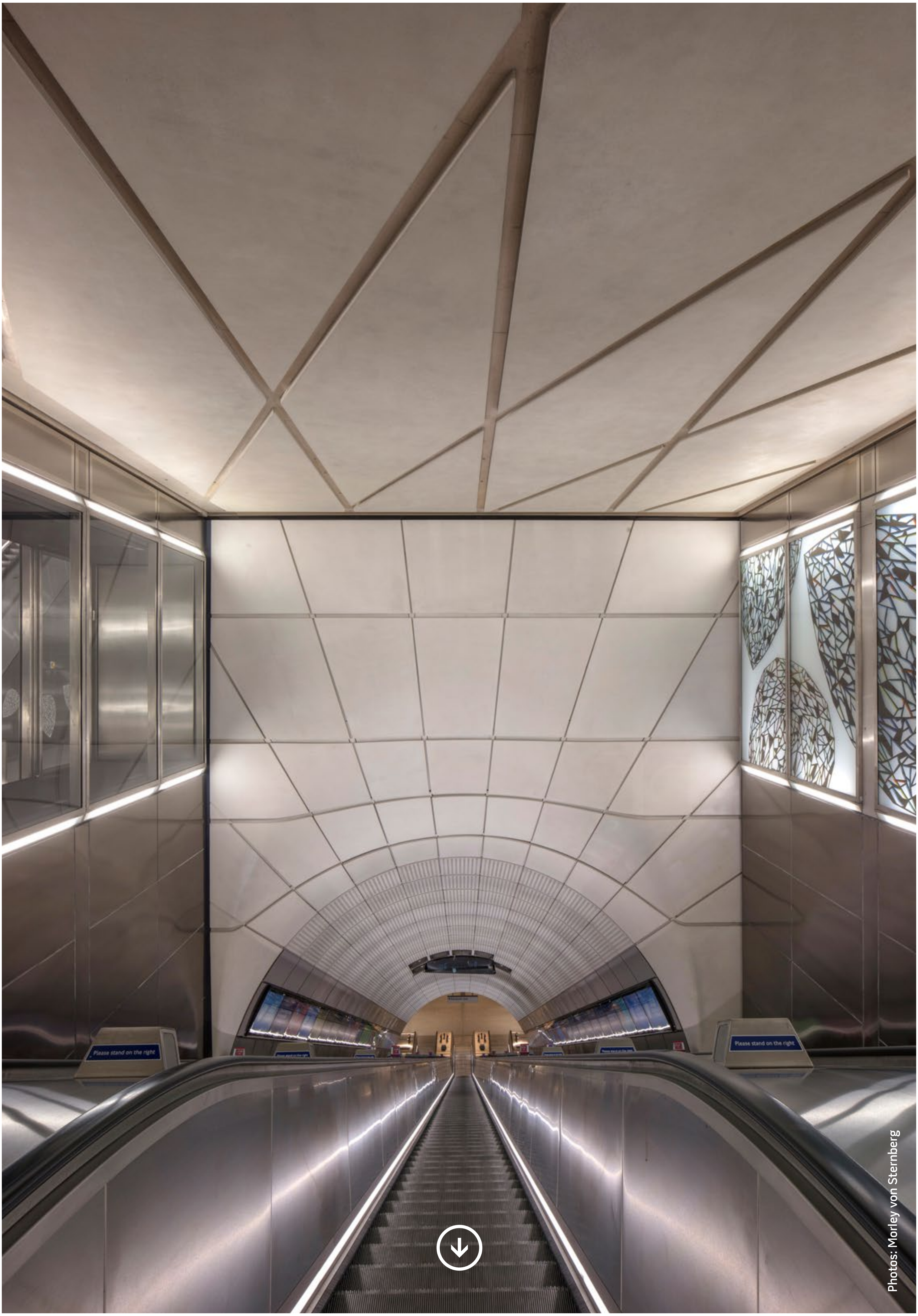
TOP
The concrete has been sandblasted to give it a rough texture

ABOVE
The form of the pods was inspired by sea urchins found on site

The scalloping lends definition to the facade from a distance, which is also important in the strong sun. Again, we did a lot of work exploring how the light hit the surface to ensure that the shape was right. Initially we looked at standard rubber moulds, but then realised we could design our own within the budget. We went through a variety of forms – you don't realise how much work it took to get that fluting. But it looks really sharp. There's a lot of sand and silt in the air, and when the wind rises, you get a light run of sand in the dip of the concrete.

Beneath the precast cladding is a waterproof membrane and a continuous layer of insulation – these are very well insulated buildings. Visitors step out of the heat and into this sheltered space. It's naturally lit, but with reflected daylight from the oculus in the centre of the dome. The precast concrete structure is exposed here too, with a grey tone and a fine sandblasted texture, and this helps to regulate the internal temperature. It's incredibly hot in the summer months, and can get to 52°C, but the thermal mass definitely has an effect, supplementing the mechanical ventilation. In winter, it's a more pleasant climate, so at times you can naturally cool the spaces. It's another aspect of touching the site as lightly as possible. ■

Simon Fraser is a principal at Hopkins Architects



Photos: Morley von Sternberg

MAKING AN ENTRANCE

Passengers at the new Farringdon Crossrail station will be greeted by a sequence of stunning concrete ceilings, writes Tony Whitehead

ABOVE
At the Cowcross Street entrance, 12m-long beams are arranged in a diamond, with downlights cast in at the X-shaped intersection

In March, Farringdon became the first Crossrail station to be handed over to Transport for London. It is notable for a number of reasons, not least its BREEAM Excellent environmental rating. But for passengers departing from this fashionable quarter of the capital, the first thing that will strike them is a stunning cathedral-like concrete ceiling. In fact, this is the first of three such spaces, each a showcase of what different types of concrete construction can achieve.

ABOVE ALL, WE JUST WANTED A DELIGHTFUL WAY FOR PASSENGERS TO GET FROM THE STREET TO THE LOWER LEVEL

The station has two entrances, some 400m apart, and as you enter the westernmost of these, at Cowcross Street, the first of the spectacular ceilings is soon visible. Known as the upper apse, it comprises a lattice of concrete beams arranged in a diamond pattern. These support the sloping concrete panel soffit of a wide stairway with escalators leading down to the station's intermediate level. The beams are massive – up to 12m long. Yet they are also smooth and elegant.

Crossrail says that the diamonds reflect the fact that this entrance is adjacent to the gem-dealing quarter of Hatton Garden – and indeed the X-shaped concrete nodes at the beam intersections even feature cast-in spaces for powerful downlights that shine like enormous solitaires. But the design also has a subtler genesis. "The design evolved under the influence of many factors," says Soji Abass, Crossrail's lead architect for the station. "For example, we wanted to avoid metal ceilings, which require ongoing maintenance. Metal panels get opened and closed to access hidden services and begin to look tired after a while, and there are safety issues with working at height. In contrast, these concrete ceilings are low maintenance."

Hatton Garden certainly influenced the diamond shape, he adds. But the angle at which the beams are set is also taken from the meeting of the two railway lines at this point. "Once we had the angle,

BELOW
On the lower concourse, 225 flat diamond-shaped precast panels sit slightly proud of an in-situ concrete slab

the diamonds naturally followed, and we've then taken advantage of the column-free space to exploit the perspective offered by the sloping soffit. The idea is that the pattern acts as a sign or wayfinder, so people intuitively know where to find the route to the platform. But above all, we just wanted a delightful way for passengers to get from the street to the lower level."

This use of perspective is very effective, though passengers will have little clue how difficult the 25m-wide ceiling was to build. The whole 360-tonne ceiling is suspended from an invisible steel structure above – so the overriding challenge for the contractor was how to safely construct such a ceiling, high above a sloping stair ramp, and beneath the structure that would support it.

ABOVE
The Long Lane entrance hall takes inspiration from its brutalist neighbour, the iconic Barbican estate

A number of potential solutions were examined, as Duarte Seixas, project manager with BFK (the BAM, Ferrovial, Kier joint venture that built the station) explains: "We looked at making this ceiling from in-situ concrete, but it would have been very hard to achieve the finish we wanted on an incline. It would also have been difficult to crane material and reinforcement through a heavy steel structure above. We looked at making just the beams from in-situ and putting precast panels above, but dismissed this for the same reason, so in the end we agreed that the whole ceiling should be precast."

There remained, however, the problem of how to thread 102 large concrete elements through the supporting structure above the ceiling. "It was not doable," says Seixas, "so the solution was to construct a large, inclined, temporary steel structure on which the concrete ceiling could be assembled. The permanent steel structure was built on top, connected to the concrete, and then the temporary steel structure below was removed."

To check that this would work, a large mock-up – with steel supports and an entire diamond's worth of beams and panels – was constructed at the factory of the precast supplier, Evans Concrete Products in Alfreton, Derbyshire (see page 22). "This helped us get a lot of answers," says Seixas. "We tested the finish, the joints, the cast-in recesses for the lights, and even how to lift the sections. Remember, we had to lower these large elements onto an inclined structure, so the lifting eyes had to be oriented to accommodate the angle and positioned to ensure the weight would be balanced."

Once the beams and nodes had been assembled on the temporary structure, the diamonds were then "filled in" with 63 precast slabs placed on ledges running along the sides of the beams. Interestingly, these slabs are not fixed to the beams, but lie loose on the ledges. The reason for this is that, in the event of a bomb blast, the force of the explosion will briefly lift the panels from the beams. This will allow the blast pressure to escape into the voids above, and so prevent the force of any explosion remaining concentrated in the highly populated areas below. "Mitigating the effects of bomb blast is something that affected quite a bit of the design," says Seixas. "To minimise flying debris, for example, cladding panels needed firm fixing to a resilient substrate. Concrete or blockwork walls offered the structural robustness

BELOW
A grid of large square concrete coffers, spanning just over 20m, preside over the eastern ticket hall

LEFT
Forty pile tops were recycled to create the 30° ramp for the Lower Apse escalator

we needed for this."

With the ceiling fully assembled, the permanent steel structure could be constructed above, and fixed to the ceiling via large steel connecting plates cast into the beams. Then came the nerve-racking process of removing the temporary steelwork below. "We checked and triple-checked everything before doing this," says Seixas. "We carried out a finite element analysis to determine how the ceiling was going to behave – how it would deflect – once the supporting structure was removed. If we got it wrong, the ceiling could crack, so we worked out a sequence of releasing the support in phases so that at no stage of its removal would any part become too stressed. After each area of support was removed, the deflection was checked before moving onto the next one."

The result is worth the effort – the intersecting beams creating a bold pattern which, Abass says, changes depending on where you view it from. Ironically, while the concrete appears to express the

Tops secret: How pile waste was repurposed

Once the escalator shaft from the western ticket hall had been excavated, the contractor needed to backfill part of it to create a solid 30° ramp for the escalator to sit on. The default way of doing this would have been simply to fill the void with in-situ concrete, but the construction team came up with a more ingenious plan.

"We realised we already had concrete we could use to fill this space," says Duarte Seixas, project manager with contractor Team BFK. "Another shaft on the site has a secant-piled concrete wall holding back the earth. But as construction progressed, it was always planned that some of these piles would have the tops sliced off to allow for the construction of floor slabs and other features. We looked at using this waste concrete as the backfill, and decided it could work."

The decision involved analysing how strong an assemblage of pile tops would be, and working out how to orient them to fill the void in a way that was both stable and efficient. "In all we had some 40 pile tops, most of them about 2.5m long and weighing around six tonnes each. Some larger 4m sections were cut in half, so we were dealing with more consistent, manageable weights."

As they were removed, these cylinders of reinforced concrete were stacked horizontally, like a pile of logs, to create the backfill. "We would arrange up to three pile sections in a line to fill the space, then another three adjacent to them and so on. Once we had a whole layer, we would stabilise it by filling in the gaps with poured concrete – but considerably less than if we weren't using the pile tops. Once one layer had cured, we could arrange another layer of piles on top, until we had built up the entire incline for the escalator."

As Seixas explains, the technique achieved more than just reducing the need for new concrete: "If we hadn't reused this concrete, we would have had to crush it and remove it from the site. So reusing it reduced noise, dust and site traffic, and helped our programme too."

The contractor calculated that reusing the pile tops saved a total of 16 waste collections, 23 concrete deliveries and 170m^3 of concrete – in all, amounting to 25 tonnes of CO_2. ■

structure, it is not itself structural, being suspended from the now-invisible steelwork above.

By comparison, the ceiling of the area at the bottom of the escalators, known as lower apse, was simpler to make, though still unusual in its construction. This comprises 225 flat diamond-shaped precast panels, each set slightly proud of an in-situ concrete slab. This ceiling supports itself, so there was no issue this time with steelwork above. Nevertheless, various methodologies for its construction were discussed. "Again we considered doing this with in-situ," says Seixas, "but thought we would struggle to match the finish of the precast upper apse ceiling. Having them both precast helps them talk to each other visually."

So after a temporary deck had been put in place, each of the unique, 100mm-thick precast diamond panels was arranged in the desired pattern, and the 100mm gap between each filled by silicon-based formers. These were only 50mm deep, so when the slab was cast on top, 50mm of the gap between each panel was filled with poured concrete. "The silicon is very smooth and comes away from the set concrete easily," says Seixas. "So the small amounts of visible in-situ soffit are also smooth."

Again, the result is stunning, with the pale precast diamonds shown to great effect against the shadowed in-situ spaces between. Above the panels, the substantial 850mm-deep in-situ slab is further reinforced with steel I-beams.

To save concrete and reduce the weight of the ceiling, 550mm-deep polystyrene formers were placed between the steel beams.

Farringdon's third spectacular ceiling – at the eastern ticket hall exit onto Long Lane – is different again, being constructed entirely from in-situ concrete. This time the look is more classically brutalist – a series of large square concrete coffers spanning just over 20m. "This entrance is nearer the Barbican, which was definitely an influence," says Abass. "But also this quarter was less about gems and more about heavier crafts like blacksmiths. So I like the way you can see the natural stratification of the concrete in the coffers – how it too, if you like, has been made by craftsmen."

This ceiling is formed from a 1.4m-deep reinforced in-situ concrete slab, with 1.1m-deep coffers formed by timber void formers, and with the beams in between further strengthened by steel I-beams. Like the other concrete in the station,

ABOVE
A prototype unit erected at Evans' Derbyshire factory

Photo: Evans Concrete

The ceiling now arriving ...

The 102 precast units used to create the upper apse at Farringdon were manufactured by Evans Concrete Products at its factory in Alfreton, Derbyshire. Since the design featured hardly any repeats, all the moulds, for beams, nodes and panels, were bespoke.

"The moulds were timber – essentially ply but with a robust timber casing on the exterior to ensure stiffness," says Stuart Murison, commercial manager with Evans. "Each was also lined with a fibreglass coating to prevent any imperfections from the mould transferring to the finished element. The nodes all featured recesses for lighting and the beam soffits have a longitudinal slot, just to add aesthetic interest, which we made by introducing a thin timber former."

The in-house form design factored in the orientation of each cast to ensure the best finish: "So as you look at the ceiling now, every part that you see would be the soffit of the mould."

The concrete ceiling is non-structural (see page 18) but nonetheless very strong. The 12m-long edge beams, for example, weigh up to 11 tonnes, are heavily reinforced, the coffers are a simple grey: "We thought about adding a sparkly aggregate to lighten the look," says Abass, "but in the end we thought, no, this is London, not Barcelona."

The temporary deck on which the slab was laid was arranged so that the board joints would run along the centre of each beam, he explains. "The joints were primarily introduced to allow each coffer, or waffle, to be independently struck. We carried this joint through into the concrete though, to express the construction."

Designers sometimes flaunt such "marks of making" for their own sake, but here the lines that grace the centres of the 600mm-wide concrete beams tell the story of the ceiling's construction while simultaneously making it better-looking. The coffers are more than just structural and aesthetic features, however: they also house acoustic boards, and downlights that highlight the ceiling's impressive concrete as well as illuminating the ticket hall.

There will be plenty to admire, then, for the 82,000 passengers that are expected to use the station each day. To paraphrase Le Corbusier, light becomes a significant architectural element when it enters into dialogue with the forms it reveals. If you want to see what he meant, just look up when you visit Farringdon station. ■

PROJECT TEAM

Architect Aedas (for Crossrail), Atkins (for BFK)
Civil engineer Scott Wilson (for Crossrail)
Structural engineer Scott Wilson (for Crossrail), Atkins (for BFK)
Precast supplier Evans Concrete

and like the other elements, are made from 50 newton high-strength concrete. "The original design was more slender," says Murison, "but it became heavier, partly to meet the requirements for bomb resistance. The idea is that if there is an explosion, the ceiling stays where it is."

The mix was a CEM III/A, meaning it contained 50% cement substitute, in this case GGBS (ground granulated blast furnace slag). "As well as lowering the embodied carbon footprint of the concrete, this also makes it paler, giving the ceiling a slightly lighter shade."

Evans worked to a tight production schedule, manufacturing all the units within just six weeks. To ensure the concrete reached London clean and undamaged, each unit had its own, specially profiled timber supports to protect it on the road trip down the M1. There was no room at Farringdon to store the units, so delivery was sequenced and the units installed directly from the trailer.

With some of the units, the crane could hook onto the fixings that had been cast into the concrete for connection to the supporting steel structure but, says Murison, they also required dedicated lifting eyes: "As well as a strong connection, we also needed to consider the centre of gravity."

In addition to the elements supplied to form the upper apse, Evans manufactured the 225 flat diamond-shaped precast panels used to construct the ceiling of the lower apse. These were supplied with projecting reinforcement hoops on the upper surfaces to help tie them into the in-situ slab above. ■

CAST THE TOWN RED

Kingsland Road in north London seems an unlikely place for a primary school. A stretch of the A10 that spews traffic to and from the City, land is scarce and prices are high. Yet here is Hackney New Primary School, tucked behind a similarly new colonnaded residential tower.

Photos: Nick Kane; Lorenzo Zandri

Designed by Henley Halebrown, the two buildings could easily be awkward neighbours. The school is a low-lying building that faces in towards its courtyard-playground, while the tower looms over it, 11 storeys high, with loggia-like balconies framing views of the city. What they have in common, however, is a ruddy-faced palette of red brick, red precast concrete and fair-faced in-situ concrete, which stitches the development together into a coherent whole, each part adding something to the other.

READ THE FULL STORY
concretecentre.com/cq

Photos: French + Tye

EXTENDED HORIZONS

Colourful, concrete, a bit gothic … not words you would normally associate with a north London back-of-house extension. After all, these projects tend to be exercises in drawing light into narrow, deep-plan Victorian terraces, and if there is an aesthetic, it is usually a sort of glazed-box minimalism. But when Studio Ben Allen was invited to add a new kitchen and two bathrooms to the back of a house in Hackney, north London, the practice took a more vibrant approach – exploring the possibilities of pigmented precast concrete …

READ THE FULL STORY
concretecentre.com/cq

HEAVY PETAL

In Manhattan, nature has often relied on sleight of hand. In the 19th century, Central Park's hills and meadows were created by a small army of labourers, while more recently the High Line has conjured a green route through the West Side on a disused freight rail line. Now, just off shore on the Hudson River, Heatherwick Studio and Arup have added to this tradition in typically theatrical style. It looks random, a thicket of slender piles supporting a canopy of supersized plant pots. But, of course, that's all part of the trick …

READ THE FULL STORY
concretecentre.com/cq

Photos: Timothy Schenck

Reusing concrete structures: one step closer to a circular economy

An internal concrete frame can remain usable for double the original design life. Jenny Burridge offers some pointers for structural engineers

↓

It's good to see a growing momentum in favour of reusing existing building structures and extending their lives, as the construction industry considers ways to reduce the amount of materials it consumes.

Concrete lends itself well to this approach – as can be seen by the number of buildings that have successfully been given a new lease of life. This year's Pritzker Prize was won by Lacaton & Vassal partly for the transformation of three social housing buildings at Grand Parc in Bordeaux (next page), where the concrete frames were upgraded and generous flexible spaces added to each unit. The case study of 160 Old Street on page 33 also shows how well an older concrete frame can be adapted to form the structure for a new building. In this case, 76% of the original structure was retained, reducing life-cycle emissions by 2,850 tonnes, while increasing the net lettable area of the building by 70%.

Photos: Will Scott

LEFT AND PREVIOUS PAGE
Architecture Initiative's Northampton International Academy – a derelict Royal Mail sorting office reborn as a 2,200-pupil school. Two long voids cut into the floor plates of the two-storey, double-height building wash the deep-plan interiors with daylight

Photos: Philippe Ruault

ABOVE
Lacaton & Vassal won the Mies van der Rohe award for the renovation of three social housing blocks in Bordeaux, which were transformed through the addition of a 3m-deep structural facade

This kind of project is one approach to a circular economy, where the element that is repurposed is not individual beams or columns, but the entire frame. It is possible because concrete is a very durable material – when used internally, designing for 50 years will give at least 100 years of useable life.

Reuse is necessarily always a bespoke solution, and the decision in every case will depend on the unique circumstances of a specific building and the current requirements of the client and the market. But for structural engineers involved in potential reuse projects, there are several steps that will be key to a successful outcome.

Work out what's there

When conducting an initial investigation into the potential for reuse, a first step is to look for record drawings. This will make a huge difference to the design of the modifications – and will act as a useful reminder that the drawings and information we produce for new buildings or extensions today should be kept safe for future engineers. With a copy of the drawings, the checks required to analyse the frame for the new use and loadings becomes much easier.

If the old drawings no longer exist, it will be necessarily to conduct investigations to check what is there. In particular, the following should be analysed:

- Concrete strength, using cores taken from the concrete and analysed using BS EN 13791. Samples should be taken from around the building and include slabs, beams and columns
- Cover to the reinforcement and the distribution of the reinforcement
- Element sizes.

Concrete continues to increase in strength as it ages, so even with the drawings to hand it is worth checking the concrete strengths.

Another resource for checking existing concrete frames might be archive editions of Concrete Quarterly, which go back to 1947 and contain many detailed case studies. The full archive is available in PDF form here.

BELOW
Mæ Architects' refurbishment of an estate of 1960s slab blocks at Hillington Square, King's Lynn, involved demolishing elevated walkways, internal replanning and upgrades to the facades

Assessing capacity

The concrete frame can then be back-analysed to check its capacity and to assess whether this will be sufficient for the new use. The codes of practice that were in use when the frame was built are very helpful in this respect (see table 1, next page), but it is possible to use modern methods of analysis on an old frame. Strut-and-tie modelling is particularly helpful in this regard as it can show many possible load paths within the concrete (for more information, refer to Strut-and-tie Models, The Concrete Centre, 2015).

Broadly speaking, design concrete strengths have increased over the

RECORD DRAWINGS MAKE A HUGE DIFFERENCE TO THE DESIGN OF THE MODIFICATIONS

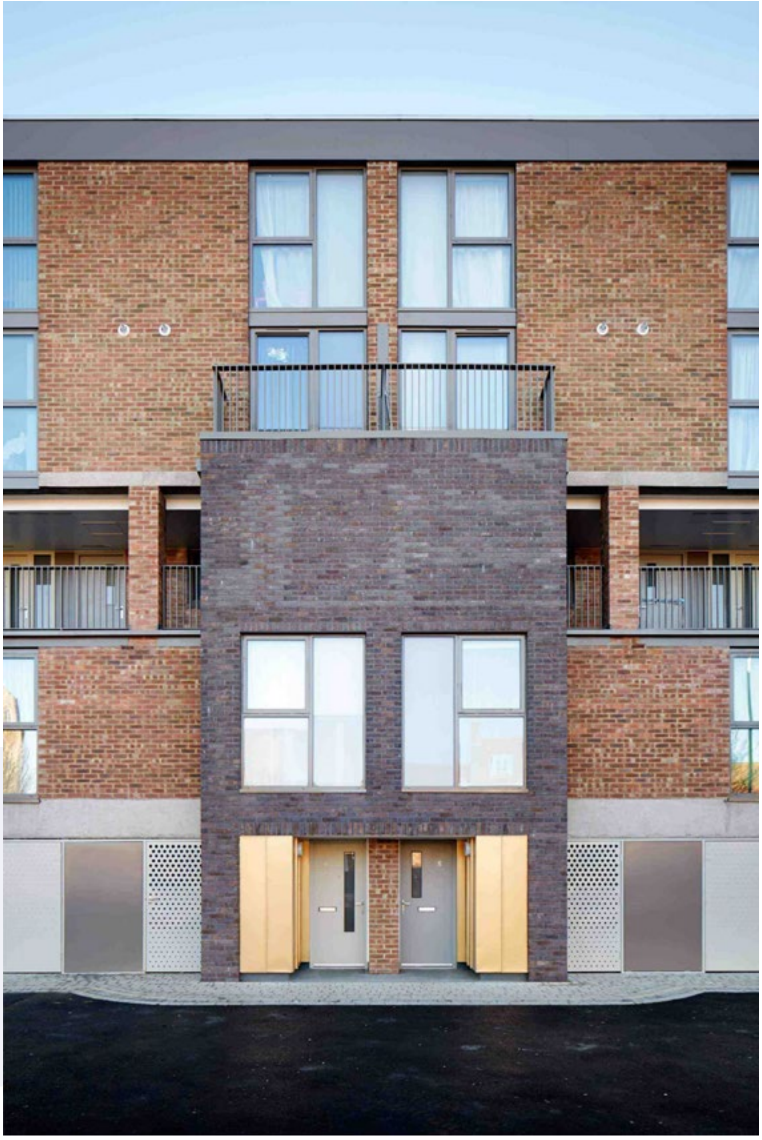


Photo: Mæ Architects

TABLE 1: HISTORIC DESIGN CODES FOR CONCRETE STRUCTURES

Year	Code
1915	Reinforced Concrete Regulations of the London County Council
1934	Code of Practice for the use of reinforced concrete in buildings
1948	CP114, The structural use of normal reinforced concrete in buildings
1957	CP114 revised version
1959	CP115, The structural use of prestressed concrete in buildings
1965	CP116, The structural use of precast concrete
1969	CP114, CP115 and CP116 Part 2 – metric units
1970	Addendum to CP116 to cover large-panel structures
1972	CP110 Code of practice for the structural use of concrete (first design code to include limit states)

years. In 1934, the ordinary grade concretes had strengths of 16–20MPa. By 1985, BS 8110 assumed minimum strengths of 20MPa for reinforced concrete, 25MPa for precast concrete and 30MPa for prestressed concrete. Concretes in the 1980s were typically a cube strength of 30MPa for normal reinforced concrete frames.

Reinforcement grades and types have also changed with time. It is advisable to test reinforcement in buildings dating from before 1960, as it tended to be quite variable. Generally, plain round mild steel bars had a yield strength of 250MPa, with high yield deformed bars 415–485MPa depending on the age and diameter.

The Concrete Society's 2020 publication TR70 Historical approaches to the design of concrete buildings and structures is a very useful guide for the designer.

If a concrete structure does need to be strengthened, various methods can be adopted, from replacement of the over-stressed element to strengthening with additional reinforcement or carbon fibre. The 2012 Concrete Society publication TR55 Design guidance for strengthening concrete structures using fibre composite materials gives guidance on using fibre composites to strengthen both bending elements and columns. The confinement provided by wrapping the column with carbon fibre increases the capacity of the concrete significantly. ■

Jenny Burridge is head of structural engineering at The Concrete Centre

Photo: Marcel van der Burg

ABOVE
The 500-flat Kleiburg in Amsterdam. Its refurbishment by NL Architects focused on renovating the structure, leaving the users to finish the apartments

ABOVE
The entrance has moved to the eastern elevation, away from Old Street, creating a long pavilion-like reception area

▶ Case study: 160 Old Street, London

Orms has reinvented an unloved 1970s office block, expanding the workspace by 70% thanks to spare capacity in the structure

By 2013, 160 Old Street was looking decidedly out of place in London's high-tech quarter. Built in the 1970s as offices for the Royal Mail, it was ripe for demolition, with dated interiors, low ceilings, inflexible layouts and wheezing systems. Fast-forward eight years, however, and it has been granted an unlikely second life, swapping the humble postal service for 21st-century communications as the London base of satellite news giant CNN.

The building may look completely different, but in fact, 76% of the original concrete structure was retained. "Refurbishment is always our first port of call, because of the amount of carbon you can save," says Simon Whittaker, director at project architect Orms. "And this building had good bones to it." According to the Revit plug-in One Click LCA, this reduced life-cycle emissions by 2,850 tonnes.

The other constraints on redeveloping the site from scratch were the existing nine-storey structure's under-reamed piles, which would have been impossible to excavate, and the surrounding buildings' rights to light, which ruled out a new high-rise. Despite this, Orms and structural engineer Heyne Tillet Steel, were still able to increase the net lettable area of the building by 70%, pushing out the perimeter by 500mm, inserting strategic connections between the wings of the E-shaped plan, and adding three lightweight storeys to the top of the structure. "Part of the reason we were able to do that was that the concrete frame had such inherent capacity," says Whittaker. "We added 40% additional load to the frame without having to reinforce it."

The starting point was to understand as much as possible about the original structure. HTS managed to find about 260 of the original structural drawings, from which the team built a Revit model, using the original 1970s concrete codes. "This was one of the first projects that we as an office did in BIM," says Whittaker. "We all collaborated on the model and that gave us a really good understanding of the structure very early on."

As they began to strip the building down to the frame, HTS could then confirm their assumptions by taking core samples. "That verified the strength they were anticipating, but it also verified that the concrete had gained strength since it was poured, which was very useful."

ABOVE
Services are channelled through a metal raft system along the middle of each wing of the building

The structure may have been in good repair, but it was still designed to house a very 1970s idea of what an office should be. Floor-to-floor heights were a slightly claustrophobic 3m and the unusual E-shaped plan meant there were no fewer than five cores, two with lifts and three with stairs. The floor was a clay pot slab, which was in good condition but restricted where ceiling fixtures could go – any damaged pots had to be repaired to maintain fire integrity. All of this presented a challenge, as this was a speculative development and the client, Great Portland Estates, wanted an extremely flexible office space that could suit a variety of tenants.

Orms' guiding philosophy, however, was to work with the fabric of the building. The existing cores were kept, which resulted in the entrance moving onto the eastern elevation, away from Old Street. "Rather than making a new core with all the lifts in one place, we created this long pavilion-like reception area: you deliberately come in right in the middle of the two lift cores and are then directed to one or the other depending on what floor you're going to," says Whittaker. It's an intriguing example of form following a previous, defunct function: "Had it not been for the cores, the reception wouldn't have been quite as generous and open as it is."

Embracing the original structure went as far as leaving a wall in one of the lift lobbies, right in front of a lift entrance. "Originally we said, 'we've got to get rid of it, it's not where you'd want to have this wall', but because it was a shear wall it would have cost about £1m to remove it so we decided to expose it and make a feature of it. We grit-blasted and lit it, and it has become part of the experience of the building."

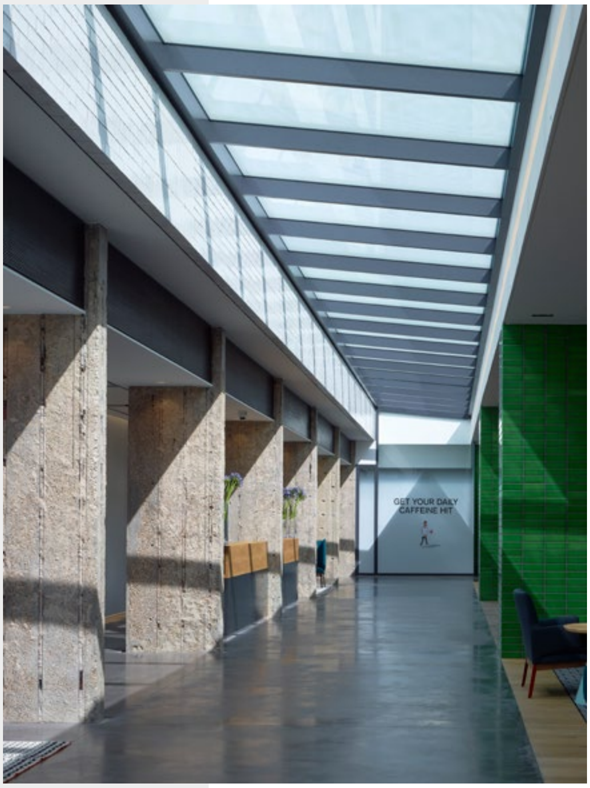
Orms continued to expose the structure wherever possible. "We were quite conscious about how honest we wanted to be with the found elements in the building, and it was just about making the most of all these different things we uncovered." The internal columns on the upper floors have been grit-blasted, while the soffits on the lower floors, once parking and storage areas, have been stripped back to celebrate their deep downstand beams. "It was a very dynamic space to turn into an office, with big structure and big spans," says Whittaker. "They were the spaces that TBS [owner of CNN] took, because of those really interesting volumes."

The columns in the reception area are just as striking. Originally external perimeter columns, these have been grit-blasted to expose the Halfen channels that once anchored the cladding, giving a steel pinstripe to the raw concrete. "We debated whether we should pull them out, but it provided a really good contrast to some of the more clinical finishes in the reception."

The exposed structure also helped to solve the problem of achieving 2.7m-high ceiling heights with so little headroom for manoeuvre. The services are channelled through a metal raft system along the middle of each wing of the building. Beneath this raft zone, the floor-to-ceiling height is 2.4m, but the rest of the soffit is clear up to the structural slab, giving the extra 30cm. "Having multiple cores came to our aid here," adds Whittaker. "We could serve the floor plates from both ends, halving the length of the ductwork, and reducing its depth."

The result – after some suitably media-friendly fitting out – is an office that comfortably holds its own against the district's best white collar factories, with flexible workspaces, new light-filled internal courtyards and external terraces on every floor. Occupants control the lighting and temperature of their desk space using a smartphone app, which is based on a digital twin that records and monitors the building's performance. In time, it will also inform any future adaptations – which should ensure that tomorrow's structural engineers don't have to root around looking for 50-year-old drawings … ■

BELOW
The original external columns, complete with Halfen channels for the cladding, now frame the reception area



Photos: Timothy Soar

FINAL FRAME: WERK 12, MUNICH

This mixed-use building, containing restaurants, offices and a three-storey gym, has been inspired by the reuse of old concrete-framed factories. The in-situ concrete slabs at Werk 12 are 5.5m apart, allowing the addition of mezzanine levels, and all of the circulation is via an external core and 3.25m terraces. The facade incorporates verbal expressions found in German comics, projecting a playful attitude.

Photo: Ossip van Duivenbode