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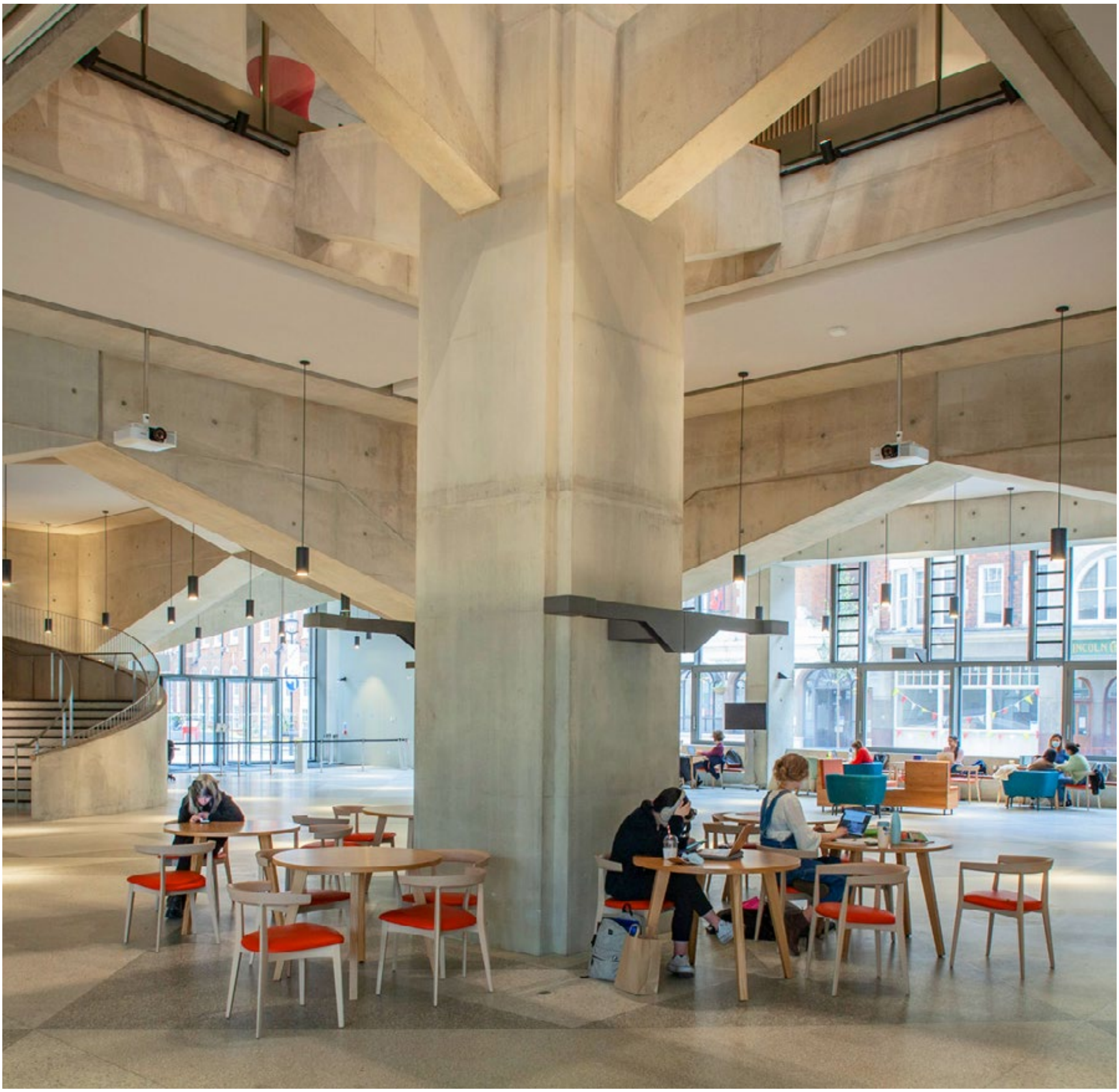

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The only way is up ... inside the world's first multistorey skatepark
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CASTING OFF

INSPIRATION

APPLICATION

Elaine Toogood
Director,
Architecture
and Sustainable
Design

Raising our game

By something of a coincidence, there's a lot of flying concrete in this issue. At LSE's new Marshall Building, at Folkestone's new skatepark, and at the reinvented council building on the north bank of the Seine, each structure has effectively been jacked up to create large, open, multi-use public areas at ground level. Or perhaps it's not a coincidence: offering welcoming, sheltered spaces is a very good way for architects to add to the social value of their projects, especially as cities become more crowded and temperatures rise.

In their own way, each of these buildings adds to the public amenity in their particular location, and each pushes the boundaries of what concrete can do. That's one of the joys of this material: it is endlessly versatile, and it has constantly evolved to meet society's changing needs over its history. The combination of designers' creativity, manufacturers' ingenuity and concrete's inherent performance characteristics mean that it can be almost anything that it is needed to be.

One of society's most pressing needs is for sustainable, low-carbon building materials that can keep people safe and comfortable in a hotter, wetter, stormier climate. This is reflected in two hugely important changes to the Building Regulations: Part L has been tightened up again as part of a drive for a net-zero built environment by 2050; while the new Part O addresses the risks of overheating in highly insulated new homes during warmer summers.

It is increasingly common for designers to request lower carbon concrete in their specification, using GGBS and fly ash as part of the cementitious content, and the next edition of BS 8500 is expected to expand the range of permitted lower-carbon blends significantly, with more use of powdered limestone.

But even before these, and other new lower carbon mixes, become more widely available, there is a lot we can do right now to reduce the carbon of our buildings, without compromising on performance, and while ensuring they deliver the maximum possible value for communities.

ONE OF THE JOYS OF THIS MATERIAL IS ITS ENDLESS VERSATILITY – IT HAS CONSTANTLY EVOLVED TO MEET SOCIETY'S CHANGING NEEDS

We need to keep asking how much better we can do through structural engineering to improve material efficiency – by challenging loading, span and frame selection, for example – to drive down embodied carbon, and take advantage of all the tools that are already at our disposal. Advanced modelling can support this process: Jodrell Bank observatory's new pavilion is the largest reinforced concrete dome in the UK with a diameter of 76m, but a thickness of just 200mm, an incredible feat of structural engineering aided by a complex material behaviour analysis.

We live in challenging times, and the challenge to us all now is to look beyond current expectations and norms and to keep pushing the boundaries. There's always more we can do – and necessity is the mother of invention. ■

CONCRETE QUARTERLY

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On the cover:
The Marshall Building, London School of Economics, by Grafton Architects. Photo by Mark Harrington / AKT II

INNOVATION

KIACRETE

A NEW KIND OF PERMEABLE PAVING EMBEDS RECYCLED PLASTIC TUBES IN A SELF-COMPACTING CEMENTITIOUS MATERIAL

ABOVE
Dr Alalea Kia with the lightweight permanent formwork, which is made from recycled plastic. Once the self-compacting cementitious material has set, the surface is lightly ground to open up the pores

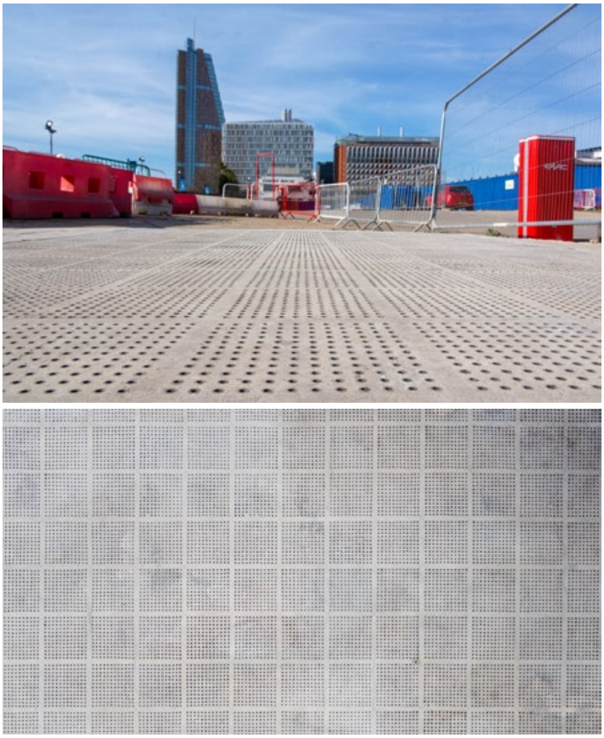
It is well known that both precast and in-situ permeable pavement products can reduce stormwater run-off by allowing rainfall to drain through hard urban surfaces. This makes towns and cities less prone to flooding, helps with groundwater recharge, and can reduce the need for conventional storm drainage.

Unsurprisingly they have become more popular in recent years – but urban floods, driven by expanding cities and climate change, persist. So why are such systems not used even more widely?

Inspired by a desire to help prevent destructive urban flooding, Dr Alalea Kia gained her PhD at Imperial College London, researching permeable concrete pavements. She set out to design a new type of infrastructure that could be used in a wider variety of applications, and require minimal maintenance. Typical permeable concrete uses a no-fines mix to achieve an open structure. Her system, dubbed Kiacrete, comprises a self-compacting cementitious material poured in situ around a permanent formwork of vertical plastic tubes. A trial at Imperial's own White City premises was installed in summer 2020 and, to Kia's delight, is still performing well.

"The lightweight permanent formwork, made from recycled plastic, interlocks like Lego to cover the required area," she says. "We then pour the self-compacting material to the required depth, and once it has set, the surface is lightly ground to open up the pores, creating a direct route for rainwater to flow to the sub-base."

Using a denser concrete with holes gives Kiacrete a higher strength of 50-60MPa, expanding the range of



ABOVE
A trial project was installed at Imperial College's White City premises in summer 2020. It is still performing well, with no maintenance, two years later

locations where permeable paving can be used. The size of the tubes, 6mm in diameter, has also enabled it to perform well in challenging conditions: "Even though the trial is near a dusty building site, the system still works very well after two years in service with no maintenance."

Kia's spin-out company, Permia, is speaking to local government, transport infrastructure operators, engineering consultancies and contractors about installing Kiacrete in different kinds of field site.

"The first trial was relatively light use – pedestrians and occasional site vehicles. But Kiacrete is easily adaptable and we want to test it under more challenging conditions." She is also keen for the technology to be adopted internationally – for example, in monsoon climates.

The diameter and spacing of the tubes, as well as the cementitious material, can be adjusted to suit different applications, she adds, and not only to vary the drainage capacity: "By spacing tubes further apart, for example, we could introduce coarser aggregates into the mix to make it stronger, or add skid-resistance. We can also use rebar between the tubes to make it stronger still – something that cannot be done with open-structure permeable concrete as the water ingress would cause it to corrode."

In 2021, Kia won a Royal Academy of Engineering research fellowship to apply her technology to airports, by engineering a new system capable of keeping them clear of surface water, ice and snow all year round. She has also been awarded a £2m grant by UK Research and Innovation to develop the first permeable pavement with sufficient strength and resilience for infrastructure such as highways and railways. "I want to conduct state-of-the-art research that will benefit the environment and society," she says, "particularly places affected by extreme weather events such as urban flooding and drought." ■

Interview by Tony Whitehead

"THE FIRST TRIAL WAS RELATIVELY LIGHT USE. BUT KIACRETE IS EASILY ADAPTABLE AND WE WANT TO TEST IT UNDER MORE CHALLENGING CONDITIONS"

LASTING IMPRESSION

SASHA BHAVAN

THREE MOUNTAINOUS CONCRETE BUILDINGS IN THREE VERY DIFFERENT LANDSCAPES – A SRI LANKAN JUNGLE, AN ALPINE PEAK AND THE SOUTH SIDE OF WATERLOO BRIDGE ...

When I was applying to architecture school, I had to write an essay about a building I admired. I knew nothing about architecture really, except that I thought I wanted to study it. But I loved the National Theatre (Denys Lasdun 1963-76). So I went to look around it, without any of the baggage of a formal architectural education, just the fresh eyes of a young person. I remember writing about the way the boardmarking followed the form, and how dynamic the space was. Very much later, I went to a lecture at the RIBA by two of the project architects. They described the way in which every board was carefully selected and set out. There were no computers and the drawings were all in imperial, using miniscule fractions of inches. Whenever anyone made the smallest change to the design, all of the boards would have to be set out again, all on tracing paper. It was an absolute labour of love.

I got another chance to see architecture through fresh eyes when I learned to ski. The brutalist Alpine ski station of Flaine (Marcel Breuer, 1969) is a real shot in the arm – the way the clear, sharp shapes and chamfered edges of the precast concrete catch the light on a sunny ski day. It was built from scratch after a group

Photo: UrbanImages / Alamy Stock Photo

ABOVE
The National Theatre, London, by Denys Lasdun, 1963-76

of local skiers set out to find the perfect location for a new resort and discovered this natural bowl high up in the mountains. It was really enlightened of them to recruit Breuer and not go for the classic chalet look. The buildings just seem to rise out of the rock, avoiding the issues of the junction between timber and the ground – it's more like the town has simply grown out of the mountain. The friends I went with thought it was awful though – I had this ongoing programme to try to explain to them why it was so good. They sort of got it once I alluded to Picasso, cubism and abstract art ...

Concrete buildings often evoke a sense of landscape simply by being so solid and permanent – that's maybe why they work in remote places such as mountains. The Kandalama Hotel outside Dambulla, Sri Lanka (Geoffrey Bawa, 1990-93) offers another example, but in a completely different context. Bawa had this idea of creating a building that was part of the jungle. The concrete frame hugs the landscape, snaking along for nearly half a kilometre, and in some places just a few metres deep. I first visited it when it was brand new, a slab-and-column building like a concrete cage. But over the years it has been subsumed by vines and other vegetation. It's an interesting lesson in raising concrete off the ground, enabling the landscape to rise up around it. ■

Sasha Bhavan is a founding partner of Knox Bhavan Architects

BELOW
Hotel le Flaine, Haute-Savoie, by Marcel Breuer, 1964-69

BOTTOM
Kandalama Hotel, near Dambulla, Sri Lanka, by Geoffrey Bawa, 1990-93

Photos: Alastair Philip Wiper / VIEW Pictures; Mark Shenley / Alamy Stock Photo

FROM THE ARCHIVE: WINTER 1968

WEATHERING IN 'A GENTLEMANLY MANNER'

Maxwell Ayrton is best known for designing the original Wembley Stadium and the 1924 British Empire Exhibition. In 1968, however, Concrete Quarterly was more interested in one of his later, more unlikely works. Wappingthorn Farm in Sussex may not seem an obvious landmark in the history of modern architecture, but the dairy, silo and water towers designed by Ayrton in 1929 were pioneering in their use of exposed board-marked concrete. As such, they offered important lessons to the contemporary designers embracing the raw, brutalist aesthetic. How well did this robust, utilitarian material really stand the test of time?

Ayrton was, wrote author J Gilchrist Wilson, "a most sensitive architect with a feeling and understanding for concrete that can be likened to that of a potter for his clay. He was quite definitely a pioneer in the use of concrete and few English architects have used this material with greater understanding, both for its possibilities and its limitations". This adept handling of concrete was in clear evidence on the 40-year-old farm buildings, which had "weathered with distinction". Wilson was particularly impressed with the quality of the bush-hammered finishes, the technique so lightly applied that, in places, the pattern of the vertical formwork laths could still be read. Elsewhere, exposure to the elements had smoothed the surface, revealing close and even aggregate particles.

"Apart from one or two spots of iron pyrites causing rust staining, the concrete has weathered in a most attractive and gentlemanly manner," Wilson concluded. Even the concrete Brosely roof tiles, which had been added in place of the original thatched roof during the Second World War, had taken on an "exquisite" patina of algae and lichen, "helped no doubt, by the cow-dung" – a lesson in concrete finishing that the 1960s modernists chose not to explore. ■

Explore the full CQ archive at concretecentre.com/cqarchive

TOP The bowls rest on perimeter columns, leaving the cafe column-free
ABOVE The building is unheated and simply covered in an aluminium mesh

ORIGIN STORY

F51 SKATEPARK

HOW HOLLAWAY STUDIOS FLIPPED A PLAN FOR A CAR PARK INTO THE WORLD'S FIRST MULTISTOREY SKATE VENUE

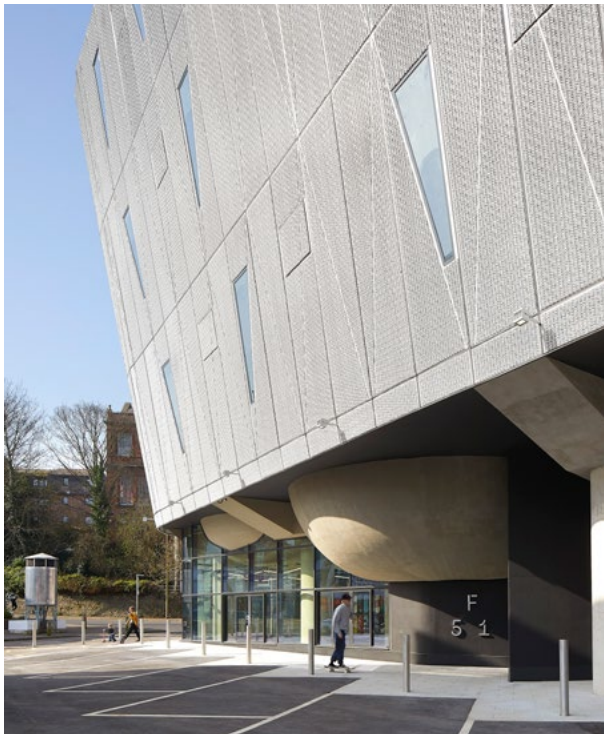
There can't be many buildings in Kent that trace a design lineage back to the Los Angeles drought of 1976. That's when the young skaters of Dogtown first took their boards to the city's dried-up swimming pools, turning these concrete bowls into arenas for their new adrenaline-fuelled sport. The coping stones around the edge of the pools gave the skaters the necessary lift before hitting the downward curve of the bowl, which could be up to 3m deep.

Fast-forward half a century, and the same coping stones can be found framing the two concrete bowls at Folkestone's new F51 skatepark. There is also a colourful mosaic trim, of the type used by 1970s pool designers to cast refracted patterns across the water's edge. But here the bowls have been lifted 4m in the air, above the building's public ground floor and cafe. F51 is billed as the world's first multistorey skatepark, and it's probably also the only place in the world you can have a cup of coffee directly beneath someone crashing headlong into a half-pipe.

Architect Guy Hollaway describes the building as a unique fusion of architecture, engineering and skatepark design, all working in sync. The ground floor is defined by the underside of the bowls, which swell dramatically into the cafe and burst through the entrance facade. On the floors above, the position of the columns defines the bowl design, and some of the columns are even skatable, with surfaces that curve into the floor. "It needs a lot of coordination to get the engineers and skating designers working together to make sure that can happen," says Hollaway.

The scooped-out slabs that form the concrete bowls plunge to a depth of nearly 3m and feature double curvature and irregular contours, with loads that don't necessarily conform to a regular grid. They also act as transfer structures. The building leans outwards like a ship's hull as it rises, partly because its footprint is constrained by a water main, and partly because skaters love nothing more than an angled wall to bounce off ("even the actual form of the outside is defined by skating," points out Hollaway). This has resulted in a series of cantilevers that needed to be drawn back through the structure of the main concrete bowl to the 2.5m-deep piled foundations below.

The 500mm-thick first-floor slab is supported on huge columns of between 900mm and 1,100mm in diameter, with stability provided by an in-situ concrete shear wall and core that rise through the height of the four-storey building. Parametric software was used to work out the most efficient way to deal with the curvature of the reinforcement.



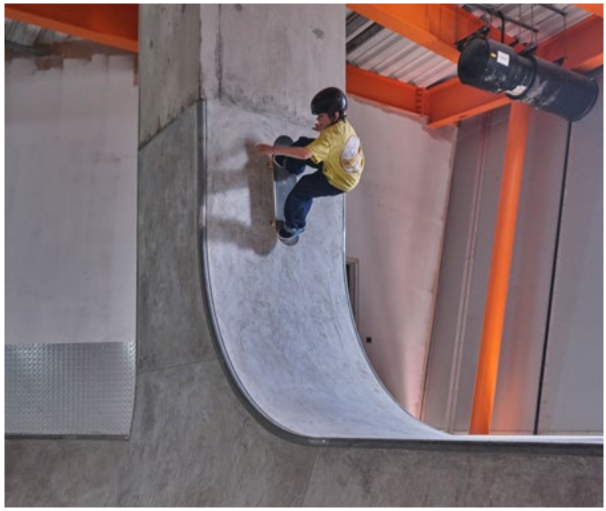
TOP
The underside of the concrete bowls burst through the glazed entrance facade

ABOVE
The 150mm-deep finishing layer was hand-trowelled, then polished

A CNC five-axis machine cut out huge polystyrene moulds of the underside of the skating area, based on the parametric model. These were held in place on site with a temporary scaffold. The reinforcement cage was then laid and concrete sprayed through it to form a 350mm base layer, followed by a further 150mm.

Specialist bowl designer Maverick Skateparks finished the surfaces with a 150mm layer of hand-trowelled concrete, which was then polished. Gediminas Jakutavicius, structural engineer at Ramboll, says the standard of finish required added yet more complications: "What's really, really important for skatepark designers is cracking – they really don't like cracks. And as we had quite a few transfer structures, that was a big, big factor." As with other aspects of the structure, the potential crack widths were modelled extensively in the knowledge that there was no margin for error: any crack in the structure would appear even bigger in the surface finishes.

F51 is also a "cold building", without heating, which meant the concrete had to be of external quality. The outdoors feel is in keeping with a design approach that is deliberately hands-off, leaving its identity to be shaped by the users. Local artists have added their works to the concrete walls – handy visual markers to help skaters judge the height of their jumps. "It's not just about being edgy," says Hollaway, "it's about having something that they want to take ownership of." ■



TOP
Many of the structural elements were designed to be skatable

ABOVE
The contoured slabs were cast using huge polystyrene moulds

MACRO ECONOMICS

From rotated grids to huge trunk-like columns and post-tensioned cantilevers, the structure is the star at the LSE's extraordinary Marshall Building, writes Tony Whitehead

Photos: Mark Harrington / AKT II

The Marshall Building at the London School of Economics is a nine-storey, mixed-use facility designed by Grafton Architects with structural engineer AKT II. Grafton won last year's Stirling Prize for Town House (see CQ 272) – another large multi-use building and "front door" for Kingston University. Like that project, the Marshall Building has been configured to accommodate a wide range of spaces. Both buildings are concrete-framed, broadly brutalist in spirit and with large expanses of exposed concrete inside and out, and each achieves a BREEAM rating of Excellent. There the similarities end, however.

ABOVE
An in-situ helical staircase connects study areas on the first and second floors

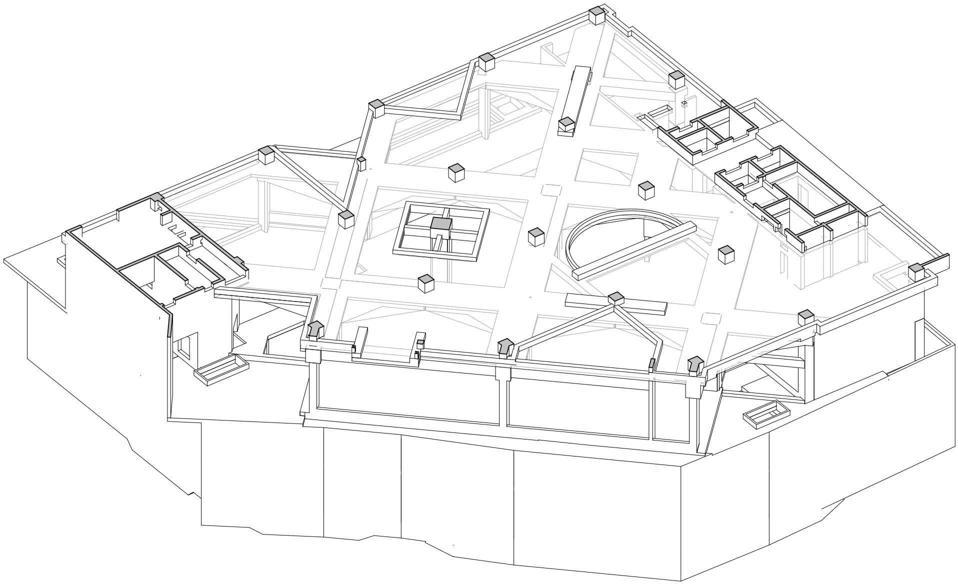
ABOVE
Pigmented precast cladding on the upper floors is toned to match the Portland stone of the lower levels

The concrete cladding of the 18,000m² Marshall Building is smoother, milkier and sits above two lower storeys that are clad, like many of its WC2 neighbours, in genuine Portland stone. In contrast to Town House's stark external framework, the tall rows of vertical concrete fins nod to the classical stone columns of the 19th-century Royal College of Surgeons next door.

But easily the most unusual and fascinating thing about the Marshall Building is its structure. Enter the large, open, ground-floor foyer, and you are at once aware that this building is put together in a less-than-straightforward way. In the centre there is a substantial concrete pillar from which huge beams branch, sloping up through a gap in the ceiling towards the underside of the third floor. Around the perimeter are massive vault-like concrete structures, while a stunning curved, in-situ concrete feature staircase winds up to the first floor. Climb the steps and you discover more sloping beams, more vaults, more concrete. Wherever you are in the lower half of the building, the structure is very evident, all around you, everywhere.

Critics have already acclaimed the sense of wonder this induces. But this perhaps belies the fact that the building's extraordinary structure is designed not just for aesthetic effect but in response to a very demanding brief. There was the very large column-free space required by the professional-sized sports hall, the dimensions of which are effectively set by Sports England. Then slightly smaller, but still large, spaces needed for the lecture

WE SPENT A LOT OF TIME EXPERIMENTING WITH VARIOUS SPANS BEFORE WE GOT EVERYTHING TO FIT PERFECTLY



ABOVE
Structural drawing of the ground floor, which is based on a 15m grid

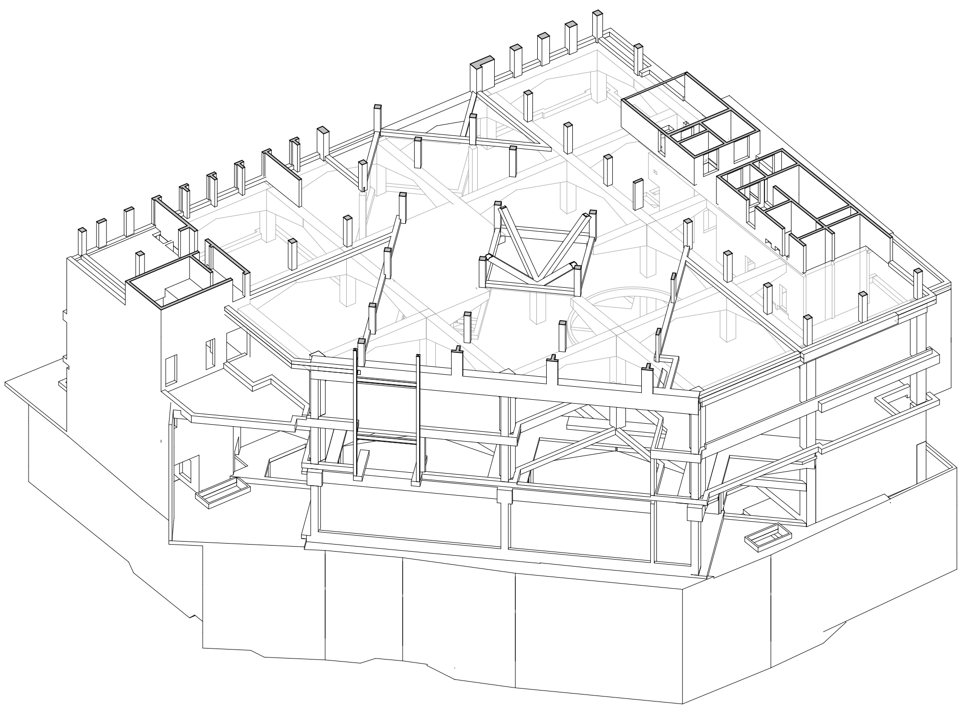
theatres, and finally smaller spaces for offices. From a purely structural point of view, it would have made sense to have the larger spaces higher up, where the longer spans would not have so much weight to support. But this would not have satisfied the client's aspirations, as AKT II design director Marta Galinanes Garcia explains.

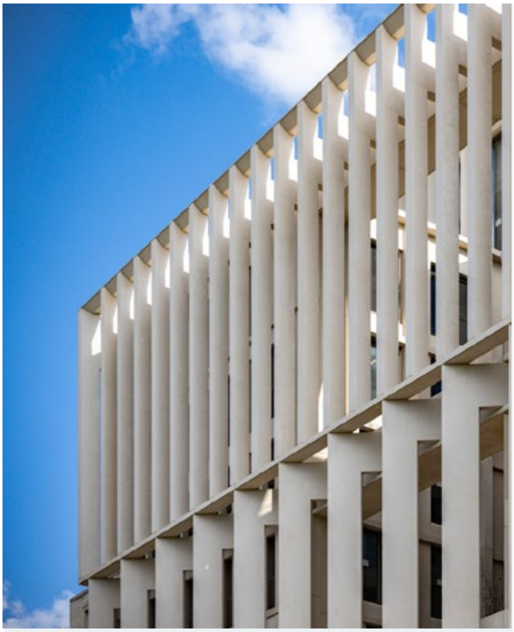
"LSE wanted a welcoming ground-floor reception, open to the public and multi-use – it is also used as a banqueting hall and for other events. That couldn't work if the ground floor had been crowded with columns. And though the sports hall could have been placed high up, that would have brought the offices down into the basement floors with limited views and natural light."

That meant the column-free sports hall was put in the two-storey basement, below a largely column-free area of the ground floor, with lectures theatres above and offices on top – a structural challenge that has informed the shape and character of the entire building.

The basement sports hall is surrounded by chunky 1.5m² reinforced-concrete columns rising from the concrete raft foundation up to the underside of level two. The sports hall ceiling is a column-free, post-tensioned concrete slab. Supporting its perimeter, and spanning just over 15m between the columns, are cantilevering post-tensioned reinforced-concrete beams. These are extraordinary, being 3.75m deep where they meet the columns but tapering to 1.65m deep in the centre. AKT II refers to these beam-column arrangements as transfer "trees". The shallow triangles of space created where the sloping "branch" from one beam meets another give the perimeter structure its vaulted appearance. "Grafton took inspiration from a nearby chapel in Lincoln's Inn," says Galinanes Garcia. "That too is vaulted and we have used this idea of

BELOW
The structure switches to a 10.8m grid for the lecture theatres on the first and second floors





LEFT
The north facade comprises 58 precast fins, echoing the classical frontage of the Royal College of Surgeons next door

Fins at the Inn

The complex facades of the Marshall Building comprise 1,170 precast concrete units covering a total of 12,124m^2. The north face of the building is perhaps the most striking, looking out onto the green of Lincoln's Inn Fields, and featuring two rows of tall concrete fins, one on top of the other. These echo the vertical columns and classical frontage of the neighbouring Royal College of Surgeons, furnish the defining aesthetic of the building, and provide solar shading.

The 38 fins in the upper row are 11.5m high and have a "hammerhead" 2.4m return at the top which links them to the top of the inner facade proper. Cast in one piece, the fins are 500mm deep

achieving a space you can walk into, framed by the structure – even if ours is a little less ornate."

The same structural arrangement applies for the open ground floor, where the vaulted tree beam effect is accentuated by a central concrete "feature tree". This appears to reach upwards to help support the centre of the upper floors – but the look is deceptive. "Below this feature tree is the centre of the sports hall," reveals Galinanes Garcia, "so there can be no supporting column beneath it and it transfers no load down to the basement raft. In fact this tree is constructed from steel beams encased in reinforced concrete and effectively hangs from above with a movement joint separating it from the post-tensioned ground-floor beam."

This tree is structurally activated only when a live load, such as might occur during a heavily populated event on the ground floor, starts to deflect its centre – at which point the movement joint closes and the tree acts like a hook, supporting the ground floor from above. Another feature tree, similarly constructed from steel and concrete, rises from and present a 300mm face to the street. These 5.5-tonne units proved among the most challenging to manufacture, as Techrete project manager Sean Sharkey explains: "The architect, Grafton, wanted a consistent finish front and back – so we had to make these in a mould that was vertically oriented. Though a horizontal mould would have been much easier from a compaction point of view, it would have resulted in one side with a float finish with the other reflecting the lower face of the mould."

Techrete made a prototype vertical mould in timber but found that it began to "belly" at the bottom after about four fins had been made. "This was caused by the pressure of the tall column of concrete and the amount of vibrating that was necessary to ensure even compaction along the height of such a tall element," says Sharkey. "Remaking the timber mould after producing only a few units would have become uneconomic, so we switched to a reusable single steel mould from which we could make three units a week. Being steel, it also helped ensure a smooth, consistent finish."

The 20, slightly shorter 10.6m fins in the lower row are arranged at an angle to the line of the main facade, and have no hammerhead projection. As they were less visible from all sides than the upper row, Techrete was able to cast these horizontally from timber moulds.

The other facades feature a further 19 hammerhead fins, but comprise mainly flat panels, window panels, benches, soffits and copings. Most of these were cast horizontally on table moulds made

the first floor through ceiling gaps to the underside of the fourth floor – the two together producing a "forested" effect.

For its next trick, AKT II has rotated the entire structural grid through 45° to create the lecture theatre spaces. This is achieved by using a slightly slimmer version of the transfer trees, a 10.8m grid, and beams that are 3.5m deep where they join the 900mm^2 columns, tapering to 1.5m at the top of the vaults they create. The more central of these columns land in the centre of the transfer beams below – potentially their weakest point. Although the geometry suggests otherwise, the transfer beams are in fact designed as post-tensioned cantilevers to support the columns above.

ABOVE
The nine-storey building rises above a network of historic streets and alleyways

from steel due to the size of the elements – some of the double-height window panels were 7.5m high and about 7 tonnes.

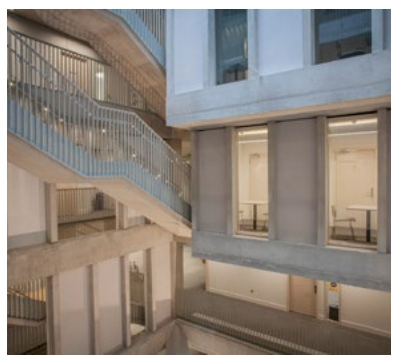
As well as contributing to the uncomplicated look of the fin-free facades, the generous panel dimensions also decreased the number of lifts needed on this constrained central London site. "The installation of all the units was carefully sequenced," says Sharkey. "The larger fins, for example, all interlocked and had to be assembled in order from left to right across the front the of the building."

Unusually, Techrete used two slightly different mixes to create the facades – one with slightly more pigment than the other. "So the main fins are slightly darker than the panels behind them," explains Sharkey. "This was because Grafton wanted the concrete to get a little lighter as you move from the edge in towards the building. We added to this effect by grit blasting the outer fins and the window panels behind them with the same level of pressure, while applying only a light grit blast to the recessed areas within the window panels. The lighter grit leaves the finish less textured and so it appears lighter."

The basic mix for the cladding at the Marshall Building was originally developed for Grafton's 2021 Stirling Prize-winning Town House project, for which Techrete also provided precast. "Apart from the pigmentation we added on this occasion, the main difference is that this concrete was more rigorously vibrated and compacted to further reduce blowholes and provide the smoother, more refined finish."

Not content with doing this once, AKT II has then shrunk the whole grid again, and rotated it a further 45 degrees to configure the office space in the upper storeys. Here the structure adopts a more standard configuration, arranged on a 7.6m grid with standard flat beams and post-tensioned floor slabs. Some of the 500mm^2 columns also land in the centre of vaulted beams below, where they again derive support from the fact that the beams cantilever.

It is undeniably a clever structure, and one that provides aesthetic interest, with the very visible structure inside and angled facades outside. But it is also a logical response to a specific context, says Galinanes Garcia. "We used it to fit very particular internal space



ABOVE
The 18,000m^2 building houses academic offices and classrooms in its upper storeys

requirements into the size and shape of this site. For example, the sports hall could only fit in one place which is quite orthogonal on the page – and rotating the lecture theatre grid allowed us to create some dual aspects. We spent a lot of time experimenting with various spans before we got everything to fit perfectly."

The "transfer on a transfer" structure added further complexity, she adds. "Concrete naturally deflects and creeps, which is normally easy enough to calculate and allow for. Here, though, we were looking at predicting deflection, on deflection, on raft settlement – so even though we love concrete at AKT II, our first instinct was to simplify the calculations by using steel."

This, however, would not have satisfied the architect's intentions. "Grafton wanted an honest concrete aesthetic," says Galinanes Garcia. "It would not have been 'truthful' to have a steel structure clad with concrete as a dead weight. Grafton also wanted to use the thermal mass of the exposed concrete to retain heat and reduce heating costs in the winter, while absorbing heat and reducing the need for cooling in summer." With hindsight, she adds, concrete was definitely the right decision – not least from a carbon point of view. "Although we have used a lot of concrete, a steel structure would have needed to be bespoke and plated, which has a much higher carbon footprint than standard hot-rolled components."

Other measures, designed primarily to speed the project and cut costs, also had the effect of reducing the embodied carbon associated with material use. "We reused the existing basement retaining walls,"

ABOVE
On the first floor, post-tensioned beams taper from 3.5m to 1.5m, forming a vaulted structure

says Galinanes Garcia. "They weren't quite deep enough, so instead of requiring an additional piled wall, we underpinned the existing piles by a couple of metres to give us the depth we needed to get our raft in."

The raft, too, was adapted to save time and material: "We originally envisaged a piled solution, but when we plotted the pile caps they overlapped to such an extent that they resembled a raft anyway. We looked into doing without piles and, after reducing the load of the building by changing the standard floor slabs to post-tensioned slabs, we were able to demonstrate that a raft, 1m thick but 2m thick where the columns landed, would be sufficient to keep settlement to 62mm long-term – within acceptable limits."

ABOVE
Feature "trees" rise up through cut-outs in the slabs of the lower floors

This strategy resulted in saving all the time and material associated with piling, and actually freed up more of the site for use: "We are next door to the Old Curiosity Shop here. It is an old and delicate building, and if we had used a piled solution we would have had to keep our distance from it to avoid it being disturbed by the work."

Further material savings have been made by leaving the interior concrete exposed, and so avoiding the need for plasterboard linings. It meant, however, that attention had to be paid to getting the finish to an acceptable standard. A first mock-up of one of the trees was too rough, with too many blowholes, so concrete contractor Getjar improved the finish by changing the release agent, paying extra

attention to keep the reinforcement free of debris, and ensuring good compaction through careful vibrating.

The concrete mix itself contains 25% or 50% GGBS to further reduce the carbon content, which also gives the finished concrete an attractive pale tone. Galinanes Garcia explains that since GGBS slows the curing process, the proportions of cement replacement were determined by factors such as programme and weather. "But we kept the percentages consistent from floor to floor to ensure there was no noticeable colour difference."

The end result is a fine, light, consistent finish. It is naturally textured, but not so much that it distracts from the real star of the Marshall Building show – that extraordinary structure, and the unique shapes and spaces it has created. ■

ABOVE
The basement sports hall is surrounded by 1.5m² reinforced-concrete columns that rise up to the underside of level two

PROJECT TEAM

Architect Grafton Architects
Structural engineer AKT II
Contractor Mace
Concrete contractor Getjar
Precast concrete Techrete

SATELLITE DISH

Photos: Andrew Brooks, Beccy Lane, Kier Construction

"If you took the dish out of the Lovell Telescope and put it face down on the ground," explains project architect Gary Collins of Hassell Studio, "it would have exactly the same circumference as the dome of the First Light Pavilion."

Built in 1957, the Lovell Telescope at Jodrell Bank in Cheshire was once the largest steerable dish radio telescope in the world. And the First Light Pavilion – the observatory's new visitor centre – is the largest reinforced concrete dome in the UK. The curving slab is 50m in diameter, rising up 8.2m at its apex. With concrete domes such a rare building form in the UK, the structural design was a voyage of discovery. Consultant engineer Atelier One carried out a complex material behaviour analysis, using two

separate 3D modelling programs, to understand the relationship between slab and shell action and how this would be affected by the cracking behaviour and non-linearity of the material. The resulting design comprised a 200mm-thick slab with eight discrete reinforcement zones of radial and circumferential rebar.

As one might expect from a heritage site of international renown, sustainability and environmental impact were key considerations. The concrete was a 40% GGBS specification and has been left exposed on the internal walls to help moderate the temperature.

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BIG NOISE

Manchester Metropolitan University's Grosvenor East provides a new base for the arts and humanities faculty, with TV and radio broadcast studios and rehearsal spaces, as well as offices and classrooms. But it is also a landmark public space, its ground floor housing the Manchester Poetry Library, a 180-seat theatre, cafe and exhibition spaces.

Such diverse uses – with very different acoustic and privacy demands – are not easily housed within one building. "The structural material needed to make those spaces work well, especially being on the busy Oxford Road," says Charlotte Hodges, associate director at Allies and Morrison.

A reinforced-concrete frame with a 5.7m-wide full-height central street formed the basis of the design. A large percentage of the concrete was specified to have an architectural finish, which required rigorous quality control from mix design to formwork detailing. A 40% GGBS mix with a high proportion of fine aggregates was used throughout.

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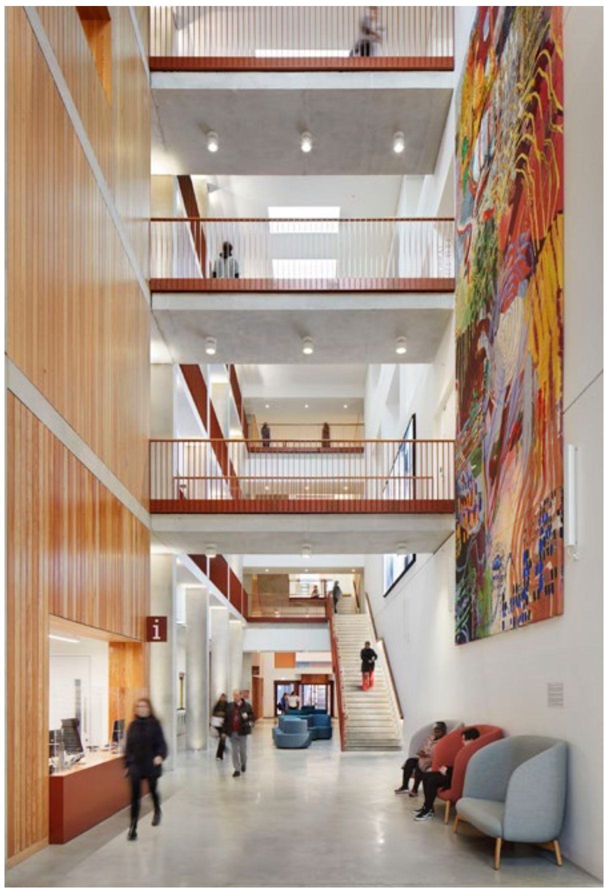

Photos: Jack Hobhouse

Photos: Simon Menges

A graceful concrete arcade has helped David Chipperfield Architects Berlin to reimagine a disused 1960s city administration building on the north bank of the Seine in Paris.

The concrete frame of the 16-storey préfecture de la Seine has been restored and adapted to host a range of new uses, including housing, a hotel and an art gallery. Two new volumes are elevated on a procession of 5m-high structural arches, which invite passers-by to walk beneath them into three courtyards and through to the other side of the block, thereby linking the Seine to the Boulevard Morland behind. The arcade is made from reinforced concrete, cast in situ, with local aggregates and sand added to match the yellowish tone of the Préfecture's Burgundian limestone.

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ABOVE St John's College Library, Oxford, by Wright & Wright and Max Fordham.Heat is supplied to the all-electric concrete-framed building by three ground-source heat pumps, while rooftop PV panels generate a maximum of 42kWp

Ready for zero: Focus on Parts L and O

With tougher targets for both homes and non-domestic buildings, the government is continuing to push construction towards zero-carbon, with further cuts to follow in 2025. Tom De Saulles explains

The introduction of the Future Homes and Future Buildings standards, planned for 2025, is a key element of the government's net zero-carbon agenda. The aim is to deliver new buildings that are zero-carbon ready: in other words, able to become zero-carbon with no future retrofitting required as the electricity grid continues to decarbonise. The first steps have already been taken with recent updates to Part L of the Building Regulations, which came into force in June. The revised Part L includes tougher limits on carbon emissions for new-build, with a 27% cut for non-dwellings and a 31% cut for dwellings, compared to the previous 2013 edition. The intention is for the 2025 Future Homes and Buildings Standards to cut this much further, made possible by even higher levels of energy efficiency and lower-carbon heating. While this is still a few years away, the recent Part L revisions are part of a phased approach to cutting emissions on the road to net zero-carbon.

Part L volume 1: dwellings

For new homes, a key change is that, while gas boilers are still permitted, the use of heat pumps is strongly encouraged and makes it easier to achieve the emissions targets. Even when not used, there is a requirement for dwellings to be heat-pump-ready for future installation. This essentially means central heating systems must, where possible, be capable of operating with a maximum flow temperature of 55°C, which will entail larger radiators, with implications for room layout and aesthetics. This could make underfloor heating a more attractive and practical option, particularly when hot water pipes are embedded in concrete or screed, which transfer the heat relatively freely to the room. This ability to conduct heat, combined with the floor's large surface area, makes even lower flow temperatures possible down to about 35°C, significantly increasing heat pump efficiency. Underfloor systems of this type also open up the potential for smart control with time-of-use tariffs, lowering operating costs and carbon emissions by using the floor as a thermal store to retain and release heat as required.

In contrast to previous Part L changes, the latest cut in emissions has more to do with services, reflecting the progress that has already been made to improve fabric performance. This makes a switch to low or zero-carbon heating systems the next logical step for lowering emissions. Photovoltaics (PV) also play an important role and are likely to be needed to meet Part L requirements, which have been set on the basis that PV is installed.

Photo: Hufton + Crow

ABOVE
The Max Fordham House in north London, which is the first in the UK to be certified as net-zero for both embodied and operational energy. Its total building annual consumption during 2020 was 48kWh/m²/yr. See page 37 for a full case study

There are now four separate Part L targets for new dwellings:

1. Fabric Energy Efficiency Standard (kWh/m²/y), determined by the building fabric
2. Primary energy ($kWh_{PE}/m^2/y$), determined by the building fabric and the fuel used
3. CO_2 emissions ($kgCO_2e/m^2/y$), determined by the building fabric and the fuel used
4. Minimum fabric and building services standard.

The Fabric Energy Efficiency Standard (FEES) continues the government's "fabric first" policy, the rationale being that fabric performance is built-in, maintenance-free and lasts the lifetime of the building, unlike technological solutions. Before the Part L consultation process, the government was minded to drop FEES, but relented when most of the consultees thought otherwise. Another notable change relating to the building fabric is a requirement for detailed design drawings to be submitted for all thermal bridging junctions, together with on-site inspections and photographic evidence. The use of what is now termed "recognised details", from sources such as the Local Authority Building Control, continues to be strongly encouraged. This is a much more efficient and costeffective option than applying the default Y-value for thermal bridging which, although still technically possible, is no longer feasible from a practical perspective.

Primary energy is a new Part L performance metric for dwellings and non-dwellings. It takes account of factors including the energy used to produce/deliver fuel and power to the building, and the efficiency of the heating system. Nearly two-thirds of respondents to the Part L consultation disagreed with using primary energy as a key performance metric and, in response, the government has said this approach will be reviewed prior to the introduction of the Future Homes and Future Buildings Standards.

As before, the Standard Assessment Procedure (SAP) tool for assessing Part L compliance sets a Target Emissions Rate (TER) based on a notional building of the same size and shape. The notional building uses a set of reference values for the fabric and services performance, which includes U-values that remain largely unchanged, with only a small uplift for roofs and windows. While the wholesale adoption of the notional dwelling U-values can be applied to the actual home, some trading between values still gives a degree of design flexibility. However, the tougher Part L targets mean the scope for this is now more limited. For example, this could well result in the notional dwelling U-value of 0.18W/m^{2}K for external walls becoming widely adopted, even though a higher backstop value of 0.26W/m^{2}K is permissible. This is no bad thing, as a value of around 0.18 is more readily achievable these days and should arguably be the baseline for all new-build. It is worth noting that for the 2025 Future Homes Standard, the draft notional dwelling has a wall U-value of 0.15.

BELOW
Howgate Close in Nottinghamshire is a collection of nine low-energy rural homes developed by landowner Dr Chris Parsons. About 50,000kWh of renewable electricity will be generated annually from 138 roof-mounted photovoltaic panels. The concrete structure helps to store heat and regulate the internal temperature, and has achieved exceptionally low air pressure tests of 0.35-0.77m^3/(h.m^2) @ 50Pa

Image: Dr Jerry Harrall

Photo: Willmott Dixon

ABOVE
Willmott Dixon's Aurora office development in Bristol, designed by Bush Consultancy. When completed in 2018, the building achieved a 37% energy saving against Part L targets. The energy strategy involved water-saving technologies, a rooftop PV array and using the thermal mass of the concrete frame to minimise peak loads

Part L volume 2: buildings other than dwellings

The metrics for buildings other than dwellings are the same as for homes, although there is still no Fabric Energy Efficiency Standard. The emissions target (TER) continues to be set using a notional building in the same way as for dwellings (still using the SBEM compliance tool). There is the same new requirement for heating systems to be designed for a maximum flow temperature of 55°C or as close to this as possible, aimed at making heat pumps a more practical option from the outset or at some future point. However, in contrast to new dwellings, heat pumps are not necessarily as well suited to all of the building types that volume 2 covers, particularly those with a significant hot water demand such as hospitals, or those with large open spaces to heat such as distribution warehouses or industrial process buildings. For this reason, the government is mindful that a one-size-fits-all approach to low/zero-carbon heating will not work as well in the Future Buildings Standard, which will need to account for the diversity in non-domestic buildings. This will be one of the areas addressed in a technical consultation planned for 2023, which will be carried out in parallel to a separate consultation for the Future Homes Standard.

Fabric performance has seen more of an uplift for most non-dwellings, with U-values for the notional side-lit building improving from 0.26 to 0.18W/m^{2}K for exposed walls, and from 0.22 to 0.15W/m^{2}K for exposed/ground floors. Roofs and windows have also been given an uplift. The treatment of thermal bridging is similar to dwellings, with a strong push to use suitably calculated construction details, or incur a significant performance penalty, which is likely to result in the need for enhancements to other aspects of the design.

Part O: Overheating mitigation

Part O is a completely new section of the Building Regulations. The combination of warmer summers and the ongoing tightening of U-values has steadily increased the risk of overheating, and Part O addresses this directly, focusing on new residential buildings. The aim is to ensure the application of practical measures to reduce overheating risk and protect the health and welfare of occupants. Part O came into force in June alongside the latest changes to Part L and replaces SAP Appendix P as the means of demonstrating overheating compliance. It provides two main routes:

1. Simplified method

Project risk is considered at the most basic level and is used to set limits for solar control and ventilation. The maximum area of glazing is determined in response to floor area, orientation, location and whether or not cross-ventilation is achievable. To ensure adequate ventilation, the simplified method also uses the basic design parameters to determine the minimum opening (referred to as free area) that must be provided. In high-risk locations, there is a further requirement to provide shading on glazed areas facing north-east to north-west (via south).

2. Dynamic thermal modelling

This provides a site-specific assessment and can be used to demonstrate compliance as long as it is in accordance with CIBSE Technical Memorandum 59 (TM59). This provides a method for assessing overheating in homes using dynamic thermal modelling and includes a compliance criteria. Essentially, it offers a broader range of strategies for limiting solar gain and greater overall design flexibility for reducing

BELOW
South-facing balconies at Hawkins\Brown's Agar Grove building in north London, part of the largest Passivhaus development in the UK. The balconies provide shading in the summer while allowing some benefit from solar gain in the winter

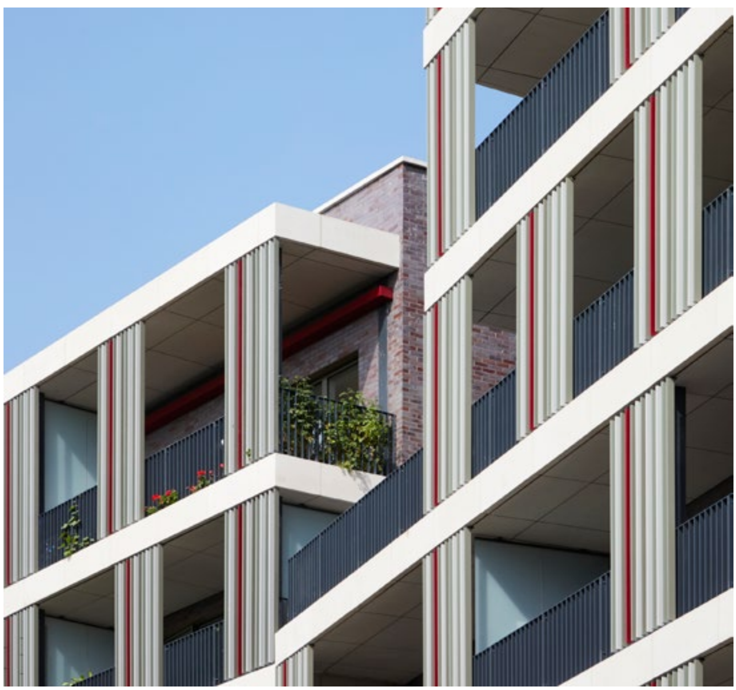

Photo: Hawkins\Brown

Photo: Gusto Homes

overheating. This includes the use of thermal mass. In addition to reducing overheating risk, this may enable greater flexibility with other aspects of the design – for example, by allowing slightly larger windows for improved daylighting and passive solar gain during the heating season. Dynamic thermal modelling also allows the use of mechanical ventilation and, in situations where passive options are insufficient, mechanical cooling is permitted.

Whichever route to compliance is used, Part O includes provisions to ensure the overheating mitigation strategy is usable. These relate to noise, pollution, security and safety issues. Where these performance criteria cannot be met using the simplified method (for example where occupants are unlikely to open windows due to external noise), then dynamic thermal modelling will need to be used and a more tailored design approach taken.

ABOVE
Gusto Homes' Woodlands Edge development near Lincoln, where the glazing strategy minimises heat loss from north-facing elevations (pictured) and maximises winter heating from south-facing windows. Under Part O, dynamic thermal modeling will enable such approaches to balance passive solar gain during the heating season with the overheating requirements set out in CIBSE TM59

The highlighted Part L revisions clearly show the government's direction of travel towards zero carbon and the planned 2025 Future Homes and Future Buildings Standards. The broad objective of these standards has already been established, but many of the details are yet to be developed, awaiting further consultation in 2023. Technical updates to SAP and SBEM are also anticipated in readiness for the new standards.

There is no doubt that technology has an increasingly important role to play, but the fabric-first approach still underpins the zero-carbon strategy. For 2025, there is likely to be more of a focus on the dynamic nature of thermal performance, and less on the traditional steady-state approach. This could provide new opportunities to use concrete to reduce peak heating and cooling loads and shift some of the daily energy demand away from periods of high grid-carbon intensity – something that the next major update to SAP (SAP 11) should help unlock.

For housebuilders, detailed technical guidance and examples can be found in Part L 2021 – Where to Start, published by the Future Homes Hub. ■

Max Fordham House, London

Case study The concrete-framed house that the environmental engineer designed and lived in was the culmination of a career spent finding ways to reduce the energy our buildings consume. His legacy offers a glimpse of a potential zero-carbon future

The Max Fordham House in north London has become the first home to achieve net zero for both embodied and operational energy-related emissions, in line with the UK Green Building Council's Net Zero Carbon Buildings Framework. As measured in 2020, the total building annual consumption was 8.1MWh. This equates to 48kWh/m²/yr, 20% less than the required net zero carbon compatible RIBA 2025 target of 60kWh/m²/yr.

The house, which was designed and lived in by the legendary environmental engineer Max Fordham until his death earlier this year, was designed around a reinforced-concrete frame. For Fordham, this project was the culmination of a life's work on sustainable buildings, and it was important to him that the house was constructed using readily available materials, allowing its lessons to be replicable on more affordable schemes. The simplicity of the house's architecture also reflects Fordham's own engineering philosophy of keeping things practical and unassuming. "Simplicity does go a long way," says Ali Shaw, principal engineer at Max Fordham. "If things are simple, people have the time and attention span to focus on them as much as they need to. When they are complex, people just don't have the time to think through all the possible issues."

The concrete frame comprises a 300mm ground-floor slab, 185mm upper-level slabs, 200 x 200mm columns and 200 x 400mm beams. To reduce embodied carbon, a 50% GGBS mix was specified throughout. The total upfront embodied carbon emissions are

↓

BELOW
Combined with the thermally massive structure, automated, insulated window shutters help to retain heat throughout the night

Photo: Tim Crocker

calculated to be 102 tCO_2e from lifecycle stages A1 to A5, 45% of which relates to the structure. To achieve net-zero carbon for the upfront embodied emissions, verified offsets were purchased for a biodiverse forest planting scheme in Panama and a wind power project in India.

The structure, which is entirely within the highly insulated thermal envelope, plays an important role in the passive heating and ventilation strategy. There is no heating system, and interior temperature varies between 20-21°C all year round. The house is passively solar heated during the day, while the thermally massive structure and automated, insulated window shutters help retain this heat throughout the night. As the house is designed not to need any heating on the coldest day, it needs to be able to dispel heat on every other day. Again, the thermally massive structure and wide-opening windows help with this. Cold fresh air is brought into the building from beneath the car undercroft and supplied silently to inhabited rooms at high speed through 3D-printed jet nozzles. Summer overheating is kept to a minimum, with the internal temperature going above 25°C less than 1% of the time. "If it didn't have a lot of thermal mass in the building, it wouldn't be as comfortable in very hot weather," says Shaw, "but I think it's unlikely it would have had cooling installed. It just would have overheated."

Domestic hot water is supplied by a heat pump and electricity is 100% renewable – a quarter of it being supplied by the house's own 24m² photovoltaic array. ■

BELOW
The late Max Fordham in the home that he and his practice designed with Bere: architects and Price and Myers

Photo: Lydia Goldblatt

FINAL FRAME: HOMERTON COLLEGE, CAMBRIDGE

Feilden Fowles has completed a faience-clad dining hall for Homerton College at the University of Cambridge. The green-tiled building is raised on a pigmented in-situ concrete plinth, using 50% GGBS cement replacement. Columns set out on a 3m x 3m module lend a quiet, rational order to the plan.

Photo: David Grandorge