Changing the DNA: how building using a cement substitute is reducing global carbon emissions

By Thomas Lane - 8 July 2019

Imperial College London's £90m biomedical engineering research centre is built from an unusual material. Thomas Lane reports on how the challenges of working with GGBS have been overcome to imposing effect

When the man who invented a cement substitute that slashes the carbon footprint of concrete donates £40m towards cost of a new research facility, naturally you would expect it to be built out of said material.

Michael Uren discovered that ground granulated blast furnace slag (GGBS), a waste product of steel manufacture, could be used as cement substitute in concrete. Up to 80% of the cement content can be replaced with GGBS, which makes a huge difference to the carbon footprint of the material because cement production is highly energy intensive – cement manufacture contributes about 8% of global CO_2 emissions.

A 1943 graduate of Imperial College London, Uren founded Civil & Marine as a small shipping business in 1955. It grew to become the UK's largest producer of GGBS, with Uren selling it for £245m to building materials giant Hanson in 2006.

He has donated almost half of the £90m cost of Imperial's new biomedical engineering research hub, which is under construction at a new 25-acre White City campus. The 14-storey building will bring together medicine and engineering with the aim of collaborating to advance areas including the treatment of musculoskeletal disorders and hip replacements.

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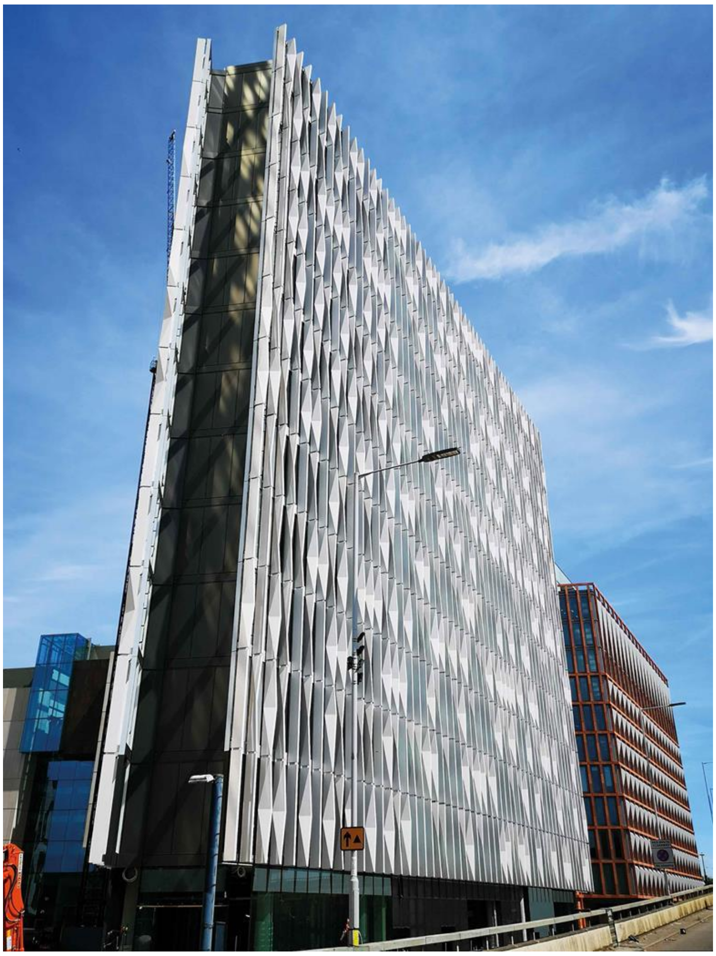
Unsurprisingly, the building features a concrete frame made from GGBS, which is left exposed wherever possible. The architect Allies and Morrison has also taken the opportunity to express the building's function as strands of DNA manifested as vertical fins spanning from the first floor to the top of the south and north sides of the building. These are made from precast concrete and are made from a 50/50 mix of cement and GGBS. Although GGBS is regularly used for substructures and structural frames, its use for decorative applications is highly unusual. For a start, it cures more slowly than cement, which slows down the production process and it has a distinct blue hue, which is not ideal where a pale, concrete-coloured finish is needed. Contractor ISG had the job of working out how to deliver an attractive product that incorporated as much GGBS as possible.



The building features precast concrete fins spanning from the first floor to the top of the building, said to be inspired by DNA strands. These provide solar shading to the south and are purely decorative to the north. The fins are made from a 50/50 mix of white cement and GGBS. The slow curing times of GGBS concrete meant more moulds were needed to keep the job on track. GGBS imparts a blue hue to the finished concrete that disappears with exposure to UV light

Forming the fins

The facade is made from 1,296 4.35m-long fins stacked vertically to create the visual effect of DNA strands, with each one-tonne fin a metre apart. There are seven different fin geometries to ensure the facade does not look repetitive. Precast products are generally turned out of the mould the day after the concrete is poured but the slow curing nature of GGBS means this had to be extended to two days. Despite the extra time, slow curing is an advantage for waterproofing structures as it forms fewer cracks, which means the concrete is more waterproof.

“If you are manufacturing 1,296 fins and you have a set number of moulds, that means your manufacturing period is twice as long,” says Neil O’Riordan, ISG’s project director for the engineering services division, which is delivering this project. ISG solved this challenge by purchasing double the number of moulds. Concrete made with GGBS has a similar strength to 100% cement-based products after 14 days, so the fins could be transported as normal.

O’Riordan explains ISG experimented with the proportion of GBBS to cement by starting off with 100% concrete and gradually increasing the proportion of GGBS. “When we got up to 50% GGBS we saw the initial blue colour had become very prominent,” he explains.

“To deal with this, we sandblasted the fins and acid etched them to bring them back to a paler colour. The blue hue was still visible but fortuitously, given their location on the building, exposure to ultra violet light causes the blue hue to disappear.

The fins have been made by precast specialist Loveld. The concrete for the fins is made with 50% GGBS and 50% white cement. The mix also contains white sand and marble aggregates, which give a very white product. When Building visited, the fins had been in place for several months and there was no trace of a blue tinge. The sandblasting and acid etching process gives the fins an attractive, textured, stone-like quality and demonstrate that architectural concrete can be sustainable and high quality.

The building is adjacent to the Westway. The fins provide protection from headlight glare at night from cars

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Windy city

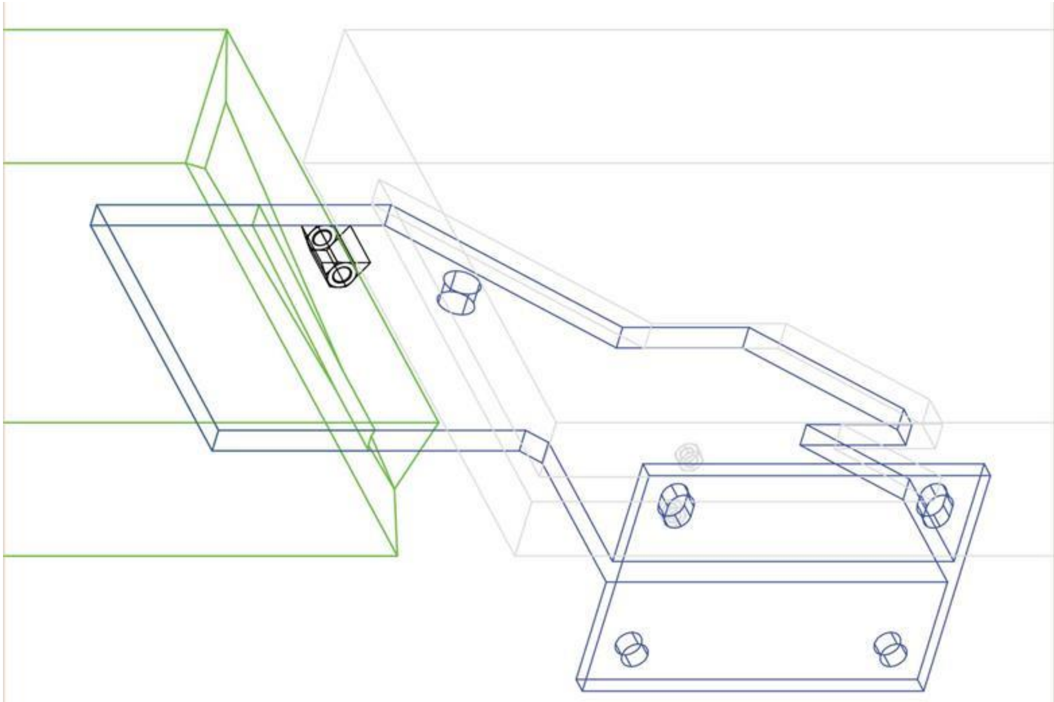
The fins cantilever past the end of the building, so are subjected to additional wind loading. “The loads applied here were up to 10 tonnes on the brackets, which pushed the engineers to the max,” says O’Riordan. Brackets cast into the fins are attached to a horizontal box section fixed back to the frame via more cast-in brackets. These box sections cantilever beyond the building perimeter.

The fins were installed before the cladding as these needed to be guided into position from inside the building. The low level fins were positioned from the ground, with the rest craned into position. Once the fins were completed, the unitised cladding system could be installed from inside the building.

The core is made using 50% GGBS and is constructed to much tighter tolerances than usual because much of the core is exposed. It has been formed to a tolerance of +/-10mm over 14 floors rather than the more usual 25mm, as the lift doors slot straight into the concrete without corner architraves, which are used to help disguise floor-to-floor deviations.

The core was jumpformed, with each floor completed in one 200m^3 pour for a good-quality finish, and was built in all weathers with hot water in the mix and blankets to keep the concrete above 3°C in the winter. The shuttering had to be left on for longer in very cold weather because of the slow curing times of GGBS, adding a week to the core programme.

As for the rest of the building, Allies and Morrison drew up an exacting specification for the concrete frame. Surfaces had to be almost mirror flat, with no deviation over 3mm over 2m. Blow holes had to be less than 5mm in diameter and with a maximum of 10 blowholes 3mm in diameter over an area of $100mm^2$. “This is as difficult as it can get,” says O’Riordan. “What we are trying to achieve is a building with no touching up afterwards.”



Detail of the cast in bracket used to secure the fins to a horizontal box section beam. This is secured in turn to brackets cast into the structural frame

Achieving this specification required meticulous planning with concrete specialist O’Halloran & O’Brien. Two layers of plywood were used for the shuttering to reduce the risk of this bowing under pressure. The sheets were laid out carefully to create a uniform appearance, even the positions of the nails used to fix the ply sheets were carefully planned. O’Riordan said the work was slow to begin with but sped up once the process had been established. The concrete soffits were lightly sanded after the shuttering had been struck to give the finish a visual lift.

The fit out is well under way, with some areas close to completion. Exposed services were planned using BIM to ensure these were neatly laid out with the most efficient use of space. The concrete soffits are proudly displayed, and the lift lobbies and reception feature large areas of exposed concrete. This gives the building a purposeful, no-nonsense quality entirely appropriate for a research laboratory. Externally, the GGBS concrete fins tells a different story, how a prosaic material normally hidden from view can be reinvented for more decorative ends.

Project Team

- Client: Imperial College London
- Architect: Allies and Morrison
- Structural engineer: Curtins
- MEP engineer: Buro Happold
- QS: Faithful+Gould
- Contractor: ISG
- Precast fins: Loveld
- Concrete frame specialist: O’Halloran & O’Brien
- Unitised facade: Félix
- MEP specialist: Michael J Lonsdale