CQFOCUS

LANDMARK CONCRETE BUILDINGS ON THE ROAD TO NET-ZERO | AUTUMN 2022

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CONCRETE QUARTERLY

SEVEN LANDMARKS

In these pages, we have picked seven exemplar projects from the extensive library of case studies on The Concrete Centre website and in Concrete Quarterly magazine. These can be seen as milestones on the road to net-zero, as well as signposts to more detailed information online.

There are many different ways to lower the carbon associated with a building's construction and operation, and to maximise its whole-life contribution to society. The projects here represent a range of sectors, design priorities, construction methods and concrete mixes.

The case studies also span a number of years, and illustrate that carbon reduction and measurement is an ongoing journey, with an inevitable time lag between design and delivery – construction being a multi-stage, multi-year process. These buildings may have been designed to previous targets and standards, using less developed calculation methods.

There is, however, much that we can learn from them as we seek the best strategies to improve and optimise design, and move towards a net-zero built environment.

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CONCRETE QUARTERLY

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Inside cover: White Collar Factory. Photo by Rob Parrish

Photos: Tim Crocker

PRIVATE HOME 2019

MAX FORDHAM HOUSE

Thermal mass is key to the UK's first net-zero house

This three-bedroom Passivhaus in north London is the first home in the UK to achieve net-zero for both embodied and operational energy-related emissions, under the UK Green Building Council's framework. It represents the culmination of a lifetime's work by the legendary environmental engineer Max Fordham, who collaborated on the design and lived there until his death in early 2022.

Fordham wanted the house to be easily replicable, using commonly available materials and construction methods. The structure is therefore largely built from concrete, including a 300mm ground-floor slab, 185mm upper-level slabs and 100mm lightweight blockwork in the external walls.

The concrete frame also plays an important role in the passive heating and ventilation strategy. There is no heating system, and the 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.

As measured in 2020, the all-electric building's annual energy consumption was 48kWh/m²/yr, 20% less than the net-zero-compatible RIBA 2025 target of 60kWh/m²/yr. The total upfront embodied carbon emissions were calculated to be 609kgCO_2e/m² from construction through to practical completion, 45% of which relates to the structure. This sum was offset through a biodiverse forestry project in Panama and a wind power development in India.

50%

GGBS in all sub- and superstructure elements

NO HEATING SYSTEM

Operational energy

20%

below RIBA 2025 target

PROJECT TEAM

Client Max Fordham
Architect bere:architects
Structural engineer Price & Myers
M&E engineer and Passivhaus consultant Max Fordham
Main contractor Bow Tie Construction

50%

GGBS in foundations

THERMALLY ACTIVE SLABS

Designed to reduce energy use by

35%


Photo: Ed Reeve

HIGHER EDUCATION 2020

TOWN HOUSE

Innovative hybrid structure proves a model of material efficiency

Town House is a new "front door" for Kingston University and a landmark public space for the London suburb, from where it draws many of its students. Over six storeys, it contains lecture theatres, study rooms, dance studios, an auditorium, a library and a cafe in a series of generous, flexible spaces, complemented by external terraces and gardens. At ground-level, its boundaries are deliberately open, and a 200m-long colonnade provides shelter to an extended public realm.

The architecture foregrounds the concrete frame, but nothing here is gratuitous. The unique hybrid structure comprises precast concrete columns, double T beams and pre-stressed hollowcore slabs, all stitched together with a reinforced structural screed. This precise, digitally designed assemblage uses material only where it is needed – the downstands of the double T beams, for instance, vary depending on the structural load. Piles were omitted entirely, with the whole building resting on a thickened raft foundation, cast with a 50% GGBS mix.

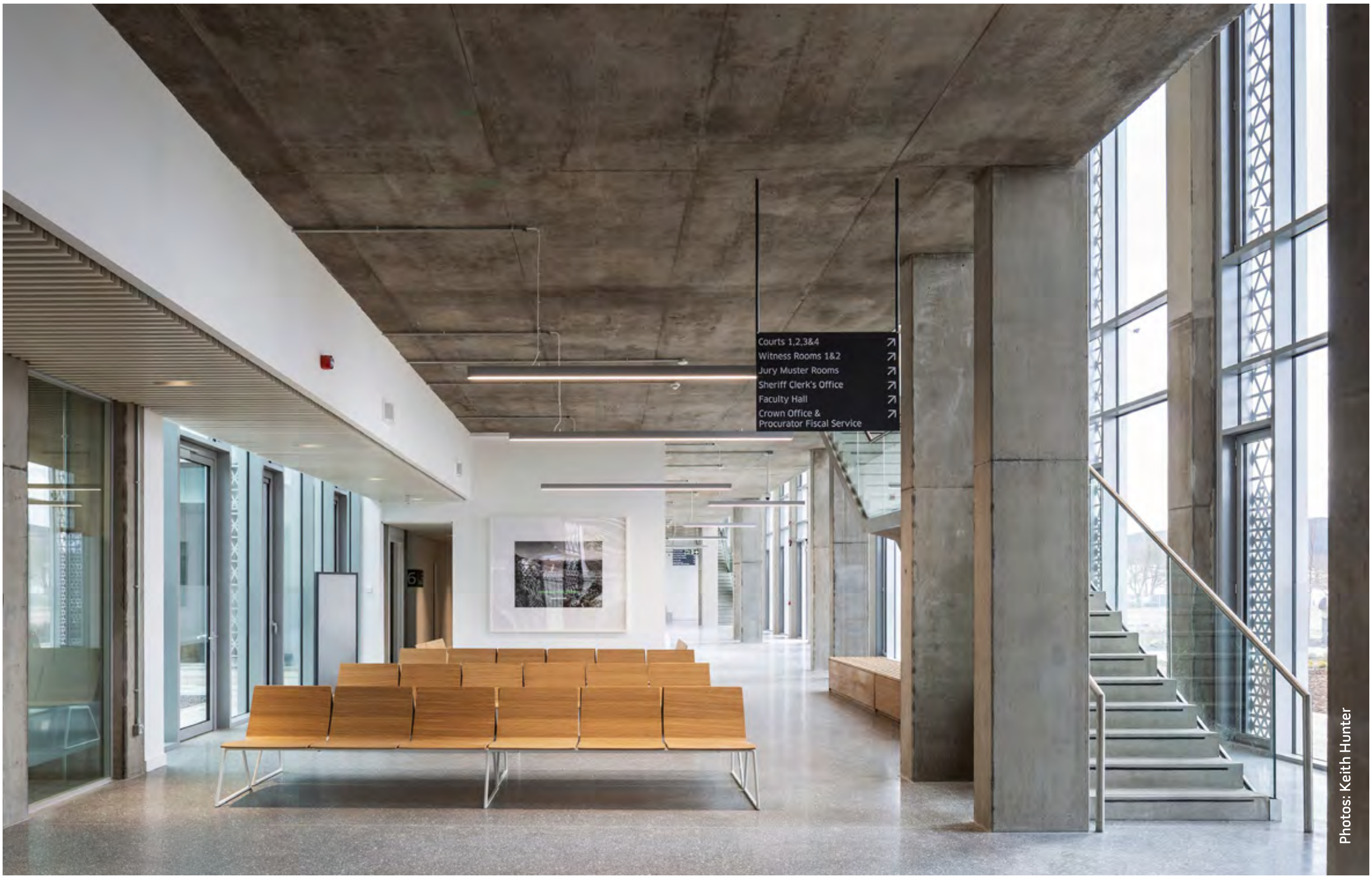
The embodied carbon of the sub and superstructure was calculated at $320kgCO_2e/m^2$. The precast elements, which comprised 85% of the structural frame and contained 36% GGBS, had a carbon footprint of $230kgCO_2e/m^2$.

The design team sought to extract as much benefit from the concrete frame as possible. The thermal mass of the exposed structure – particularly the high surface area of the double T beams – helps to manage the heat generated by large numbers of students and computers. This is supercharged by a low-energy thermally active building system, consisting of pipes embedded in the screed through which cold water can be passed when needed. Meanwhile, the precast-concrete colonnade, with its planted terraces, helps to cool and shade the interior. The building was designed to consume 35% less energy than 2014 Building Regulations. On completion, its total carbon emissions were measured at $12.7kgCO_2e/m^2/yr$.

But perhaps the most sustainable aspect of Town House is reflected in the fact that it won both the 2021 RIBA Stirling and the 2022 Mies van der Rohe prizes – the most prestigious architectural awards in the UK and Europe. The building has a stated design life of 50 years, but celebrated architecture tends to be preserved and in use for far longer.

PROJECT TEAM

Client Kingston University London
Architect Grafton Architects
Structural engineer AKT II
Services engineer ChapmanBDSP
Main contractor Willmott Dixon
Concrete contractor PCE
Precast frame suppliers Banagher, Shay Murtagh, Techrete



Photos: Keith Hunter

PUBLIC BUILDING 2021

INVERNESS JUSTICE CENTRE

70%

GGBS in vertical elements and foundations

Post-tensioning saved

261m³

of concrete

THERMAL MASS KEY TO NATURAL VENTILATION STRATEGY

Highly efficient frame delivers everything from acoustic control to passive energy reduction

Inverness Justice Centre is the first of a new generation of Scottish legal buildings, bringing together sheriff and crown courts, victim support and various public sector and voluntary organisations under one roof. Concrete is integral to the design, which balances a challenging set of requirements for openness and transparency, privacy and security, and – crucially – effective acoustic separation both within the building and against noise from a police station and busy road outside. It is also key to the holistic sustainability strategy, which prioritises low energy use and material-efficient design while creating a durable, permanent, landmark civic building in an under-developed area of the city.

The structural frame is in-situ concrete, its embodied carbon substantially reduced through lean design and the specification of high levels of GGBS throughout much of the structure. The slabs make up 40% of the concrete used, and post-tensioning allowed them to be 50mm thinner – saving 261m^3 of concrete, as well as reducing reinforcement, associated vehicle movements and the overall weight of the structure. In the foundations, columns and supporting shear walls – locations where early age strength is not a major requirement – 70% of the cement was replaced with GGBS, saving 360 tonnes of CO_2 compared with a traditional CEM1 mix.

Large, column-free courtrooms alternate with internal courtyards that allow natural light and ventilation into the waiting and circulation areas. Both the in-situ frame and the precast concrete staircases have been left exposed, further reducing the materials used in the building. This was partly to echo the gravitas and dignity of Scotland's stone architecture within a tight budget – the project was named 2021 Public Building of the Year in the Scottish Design Awards – and partly because the thermal mass of the concrete is used to even out temperature differentials. This provides ideal conditions for a successful natural ventilation strategy throughout most of the building, as well as improving the efficiency of the heating and cooling system in the courtrooms. The annual operational carbon emissions have been measured at 17.4kgCO_2e/m^2/yr.

PROJECT TEAM

Client Scottish Courts and Tribunals Service
Architect Reiach and Hall
Structural engineer Arup
Precast design consultant Etive Consulting
Main contractor Robertson
In-situ concrete contractor Careys
Precast manufacturer Plean Precast

Photo: Jim Stephenson

RESIDENTIAL 2018

AGAR GROVE

95%
reduction in operational carbon

70%
reduction in heating bills

Airtightness of
0.3ACH @ 50Pa
improving on the Passivhaus target by
50%

Estate renewal provides high-quality, low-energy housing for existing and new residents

This multi-phase estate regeneration in north London is a template for large-scale Passivhaus development in the UK – with 379 of its 507 homes being built to the energy-efficiency standard. Phases 1A and B are complete, and include a seven-storey, 38-home block, designed by Hawkins\Brown, and a second development of 57 homes, designed by Mae Architects, both containing a mix of affordable and market-rate apartments. In total, the scheme will provide more than 250 council or affordable rent homes, and will also include the deep retrofit of an 18-storey tower block, saving embodied carbon by reusing the existing concrete structure.

The form and fabric of all the Phase 1 buildings have been designed to maximise airtightness and thermal performance. The in-situ concrete frames are completed with external brick facades in front of an insulated cavity and an inner skin of aerated blockwork. Specially designed cavity ties and structural insulated connectors help to minimise thermal bridging. The airtightness barrier is provided by a 10-15mm parge coat applied to the cavity face of the blockwork, which meant that the airtightness strategy could be kept independent of internal works.

In the Hawkins\Brown building, a communal mechanical ventilation with heat recovery system ensures a continuous supply of fresh filtered air, while renewable energy is provided by a PV array. Dwellings are dual aspect, enabling cross-ventilation, with deep south-facing balconies to block summer solar gains. Monitoring from the first 12 months of occupancy showed an energy use intensity of 62kWh/m^2/yr, meeting the RIBA 2025 target. It also found that internal temperatures rarely dropped below 21°C in winter and only went above 26°C during the peak summer months.

PROJECT TEAM

Client London Borough of Camden
Architects Hawkins\Brown, Mae, Architype
Structural engineer Stantec
M&E engineer and Passivhaus consultant Max Fordham
Main contractor Hill Partnerships


Photo: Rob Parrish

WHITE COLLAR FACTORY

OFFICE 2017

Landmark speculative development is designed for adaptability

White Collar Factory is a mixed-use tower on Old Street's "Silicon Roundabout" at the edge of the City of London. It was the culmination of an eight-year research project to recreate, in a modern, highly sustainable new-build, the features that make refurbished industrial buildings such popular offices. It has 17-storeys – but could have had two more, if the developer had chosen not to provide 4m floor-to-floor heights, maximising natural light and fresh air, as part of a focus on health and wellbeing.

The exposed in-situ concrete frame acts as structure, cooling system and finish. The 350mm-deep flat slabs contain miles of embedded plastic pipes, through which water can be circulated to maximise the passive cooling and heating potential of the thermal mass. This is controlled by an advanced building management system (BMS): five sensors on every floor monitor slab temperature and air humidity to prevent condensation, and the BMS incorporates weather forecasts to allow for the time lag inherent in any thermal mass-based temperature-control system. There are also openable windows behind grills, and the BMS automatically shuts off mechanical air circulation when they are opened.

Although the structure had to fit into an irregularly shaped site on top of four underground railway tunnels, the complex transfer gymnastics are kept to the basement so that the above-ground frame is as standardised and repetitive – and therefore as material efficient – as possible. This is intended to make future retrofits easier, as is the fact that the services are simply attached to the clear, flat concrete soffits. The stand-out timber boardmarking on the exposed concrete surfaces was created not with single-use timber shuttering but bespoke, flexible formliners inside standard plywood formwork, both of which could be reused many times to reduce construction waste.

PROJECT TEAM

Client Derwent London
Architect AHMM
Structural engineer AKT II
Services engineer Arup
Main contractor Multiplex
Concrete contractor Dunne Group

50%

GGBS, plus

200kg/m³

fly ash used as pigment

BREEAM Outstanding

85%

25%

lower operational carbon than Building Regulations

Photos: Jack Hobhouse

RETROFIT 2021

BETON HOUSE

Phase three of Park Hill regeneration offers a masterclass in reusing structures

Over

1 million

tonnes of CO_2e saved

ALL-ELECTRIC BUILDING

Concrete frame preserved for at least another

60 years

Few buildings provide as valuable a template for the retrofit of existing concrete structures as the 1960s Park Hill estate in Sheffield. This is Europe's largest listed building, and is being regenerated in a multi-phase programme by developer Urban Splash. In phase three, local practice Whittam Cox has taken one of the lower blocks of single and double-storey flats and converted it into a terrace of three-storey townhouses for student living. This attempts to address one of the main failings of the estate: single-tenure housing rather than a mix of residents and uses. But the project is also notable for its strict strategy of retaining as many of the physical elements of the once-derelict structure as possible.

This process began with the original drawings, produced by Arup in the 1950s, which were used to develop a 3D BIM model of the existing building. From this, the team could calculate the tonnage of the frame and make a conservative estimate of its embodied carbon. This weighed in at 1,050,480 tonnes CO_2e, which will now continue to be useful for decades to come. In addition, the explicit strategy of retaining non-structural elements, such as floor screeds, concrete balconies, blockwork partitions and stairs, saved a further 577 tonnes CO_2e.

Material efficiency was also improved by the decision to leave much of the internal structure exposed. The original plaster had protected the boardmarked concrete beneath, and could be wet-scraped away and simply finished with an anti-carbonation coat. Elsewhere, more painstaking concrete restoration was needed. Many of the balustrade spindles, for example, showed severe spalling, but rather than removing them, the team managed to save 90% through careful repair work.

Cold bridges have proved a challenge – the estate having been designed before avoidance of thermal bridging was a consideration. Passivhaus modelling was used to work out how thermal improvements could be made. Insulated linings have been used as much as possible to create a break between the external and internal structure, helping to achieve a weighted U-value of 0.22W/m²K. The as-built operational emissions of the townhouses have been measured at $33kgCO_2e/m^2$, but Whittam Cox expects this to improve and is continuing to monitor energy use on a meter-by-meter basis. The building is also all-electric – by replacing gas for heating and hot water, it will rely less and less on fossil fuels as the national grid switches over to renewable sources.

PROJECT TEAM

Client Alumno Group
Architect Whittam Cox
Structural engineer Civic Engineers
Services engineer Cundall
Main contractor Kier Construction

Photo: Tideway

THAMES TIDEWAY TUNNEL

Low-carbon mixes in over

98%

of permanent in-situ structures

Optimising mixes reduced CO_2e by a further

145 tonnes

Reinforcement reduced across all shafts and chambers. At Greenwich, a

40%

saving removed about

100 tonnes

of embodied carbon

London's new super-sewer pushes the boundaries on low-carbon mixes

The mammoth Thames Tideway Tunnel is a 25km, 7.2m-diameter addition to London's Victorian sewage network, to make it fit for the 21st century. Due to complete in 2025, this is an essential upgrade to the capital's infrastructure, which will bring widespread environmental benefits and prevent the release of untreated sewage into the River Thames. But client Tideway also wanted to deliver it with the lowest possible contribution to greenhouse gas emissions. It has challenged the project teams to achieve an 8% reduction in embodied carbon (against a 2016 baseline), and set a stretch target of 10%.

The team on the 10km eastern tunnel sections from Greenwich to Stratford (Tideway East) carried out an exhaustive analysis of the construction process, to identify opportunities to reduce the amount of materials and to substitute lower-carbon alternatives. From the start of the project in 2017 until August 2021, approximately 63% of the concrete poured for the permanent works structures used low-carbon mixes – 87,000m^3 out of a total 137,000m^3. When the precast segments are excluded (which required a very high early strength gain for casting twice a day), low-carbon mixes were used for more than 98% of the permanent structures.

These mixes were specified in the initial action plan but, as the project progressed, the team continued to push the boundaries to further optimise their carbon performance. In the low-heat mix, the proportion of GGBS was increased from 67% to 73%, reducing embodied carbon by 26kgCO_2e/m^3. Overall, 5,000m^3 of this concrete had been poured up to the end of August 2021, saving 125 tonnes CO_2e. In the abrasion-resistant mix, the proportion of GBBS was increased from 40% to 50%, the maximum permitted for this kind of concrete. During the same period, 450m^3 was poured, representing a carbon reduction of 20 tonnes CO_2e.

For the temporary works structures, concrete supplier Hanson designed a range of three mixes that included 80%, 85% and 90% GGBS, to replace C20/25 to C25/30 concrete mixes. These enable a reduction of at least 70kgCO_2e/m^3 and are now approved on all Tideway East sites. The project team also developed an ultra-low carbon mix for higher strength C30/37 to C40/50 mixes. In testing across various sites, it has reached 50MPa at 28 days and more than 57MPa at 56 days, saving at least 100kgCO_2e/m^3 compared to conventional mixes. Pouring 280m^3 for the batching plant foundations saved approximately 20 tonnes CO_2e.

PROJECT TEAM

Client Tideway
Delivery partners Costain, Vinci Construction Grands Projets, Bachy Soletanche (CVB)
Permanent works designer Mott MacDonald
Concrete supplier Hanson

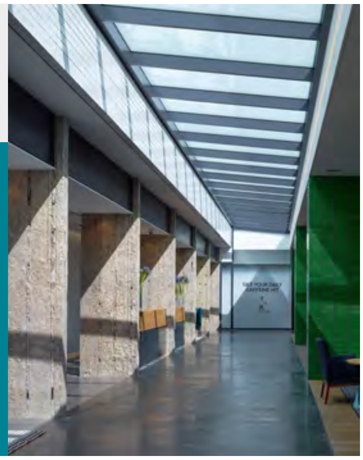
SUSTAINABILITY SNAPSHOTS

160 OLD STREET

70%
of structure retained

EXPOSED STRUCTURE

2,850
tonnes of whole-life carbon emissions saved



ASH COURT, GIRTON COLLEGE

PASSIVHAUS

100 yr
design life

DESIGNED TO BE ADAPTABLE TO CLIMATE CHANGE

BOBBY MOORE ACADEMY

HYBRID NATURAL VENTILATION

HIGH THERMAL MASS

URBAN REGENERATION

CAMDEN COUNCIL HQ

96.7%
BREEAM Outstanding

HIGH THERMAL MASS

ADAPTABLE WORKSPACE

DERWENTHORPE

LOW-ENERGY COMMUNITY

THIN-JOINT MASONRY CONSTRUCTION

SUSTAINABLE URBAN DRAINAGE

THE EDGE

LOW-ENERGY HOMES

HIGH THERMAL MASS

PASSIVE SOLAR GAIN

ENGLISH NATIONAL BALLET

HIGH THERMAL MASS

50%
GGBS

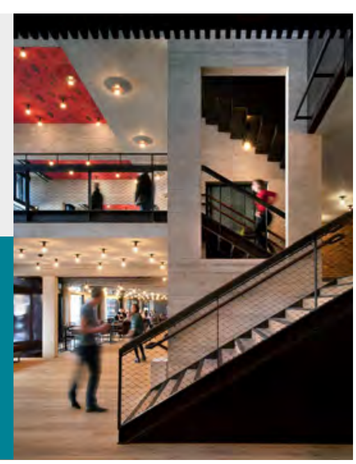
NATURALLY VENTILATED PUBLIC SPACES

EVERYMAN THEATRE

FULLY EXPOSED STRUCTURE

NATURAL VENTILATION

REUSED MATERIALS



Explore many more pioneering concrete projects at concretecentre.com and in the Concrete Quarterly archive

FARRINGDON CROSSRAIL STATION

MATERIAL EFFICIENT

WASTE REUSED

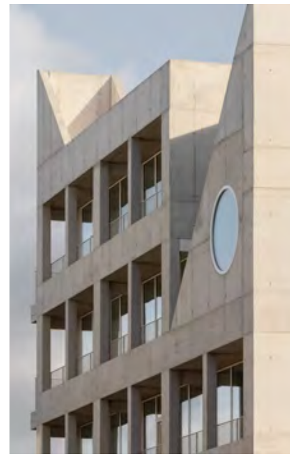
50%
GGBS

HAUS ON THE RIDGE

40%
GGBS

PASSIVHAUS

SOLAR CONTROL



HOUSE FOR ARTISTS

Embodied carbon
20%
below RIBA 2030 target

50-70%
GGBS

FLEXIBLE LAYOUTS

INTERDISCIPLINARY BIOMEDICAL RESEARCH CENTRE

WASTE MINIMISED

50%
GGBS

PRESTRESSED HOLLOWCORE SLABS

OUTHOUSE

STRUCTURE AS FINISH

A+
Energy Performance Certificate

LOCAL MATERIALS

ROYAL COLLEGE OF PATHOLOGISTS

MATERIAL EFFICIENCY

LONG LIFE

HIGH THERMAL MASS

SIMON SAINSBURY CENTRE

HIGH THERMAL MASS

50%
GGBS

DESIGNED FOR LONG LIFE

SEVENOAKS SCHOOL SCIENCE CENTRE

NATURAL VENTILATION

THERMALLY ACTIVE SLAB

50%
GGBS

THE STANDARD HOTEL

LOW EMBODIED CARBON

MATERIAL-EFFICIENT SLABS

URBAN REGENERATION

UCL STUDENT CENTRE

BREEAM OUTSTANDING

50%
GGBS

100%
recycled aggregate in precast elements

Explore more case studies at
concretecentre.com