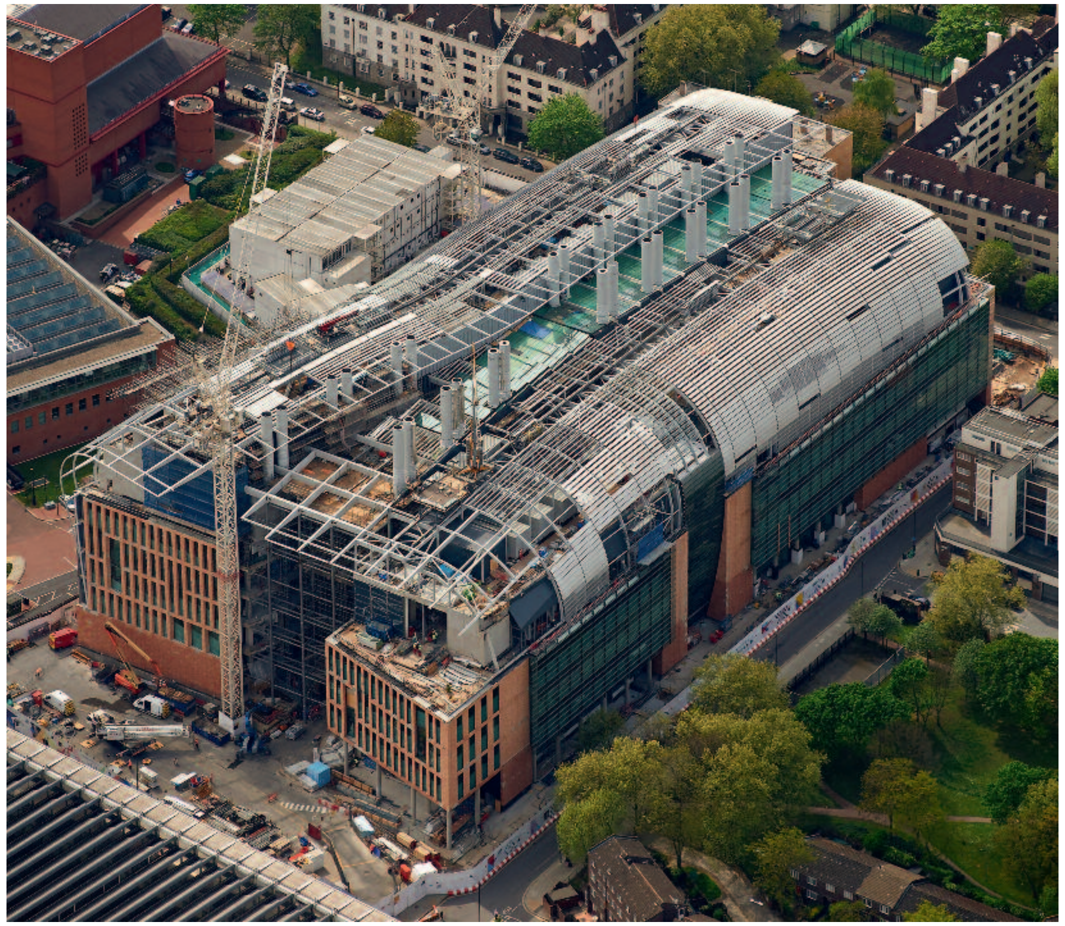
Steel Solutions

Complex curves at the Francis Crick Institute in London, by HOK and PLP Architecture, and Slough Cultural Centre by Bblur, plus new guidance on steel and embodied carbon from Tata Steel and the British Constructional Steelwork Association



HOK and PLP Architecture
The Francis Crick Institute

Accommodating 1500 staff and comprising labs, teaching space, offices and public spaces, The Francis Crick Institute is a major biomedical research facility, due to open later this year in Somerstown, central London. It was designed by HOK, with PLP Architecture invited to collaborate on the development of the external massing and to act as designer for the building envelope.

The body of the building comprises two long laboratory wings that run east to west separated by a glazed-ended atrium that flares out spectacularly to the east. The southern wing consists of ground plus five storeys, the north, ground plus four storeys. The wings are bisected by a north-south atrium dividing the building into four distinct science 'neighbourhoods'. The resulting cruciform atrium introduces daylight deep into the laboratory quadrants through its glass roof and four glazed end walls, offering views into the workings of the building from the external public spaces.

The base of the building, containing public and social spaces, is extensively glazed to link the interior and the exterior. Walkways linking the north and south quadrants animate the east and west walls of the atrium above the two principal entrances at ground level. The laboratory blocks and solid areas of the facade at the lower levels are wrapped in mortared terracotta in reference to neighbouring buildings.

Above the laboratory wings sit the two vast vaulted louvre roofs which echo the roof of St Pancras Station's historic Barlow Shed at the opposite side of Midland Road. These roofs enclose the large plant volumes that are required to service a building of this nature. The southern roof shell incorporates one of the country's largest built-in photovoltaic arrays. On the east and west approaches, the roof shells cantilever beyond the facades below to denote the entrances and to create a strong, welcoming architectural statement.

Top
Construction in progress, May 2014. The 85,935sqm building sits on a 1.5ha site behind the British Library. One third of the building is below grade, in a 16m-deep basement. A double-curved steel-framed roof encloses two plant stacks — one of three storeys, and the other of two. The two halves of the roof overlap above the atrium (phs: Wellcome Images courtesy of Laing O'Rourke).

Above
The louvre-clad roof is open to allow air circulation around the plant stacks.

Left
CGI of the east elevation (ph: Wadsworth 3D).

East entrance wall and canopy

The eight-storey-high east atrium facade has a primary structure of tubular steel sections, with vertical members at six-metre centres, and at each floor level, wind loads are taken back to the cross-atrium bridges which act as a beam in plan. All structural penetrations through the facade are thermally broken using high-load isolator plates. The weather skin is 5.08m-high double-glazing fixed back to vertical glass fins at 0.75m centres spanning floor to floor. The fins are predominately on the outside of the glazed wall, but where the atrium facade abuts the main body of the building, the system reverses with the fins being on the interior. This leads to an unusual detail where the glass fin becomes part of the thermal envelope, which is achieved by adding a further layer of glass to make it a double-glazed unit.

At low level, the facade includes glass revolving door drums, pass doors and glazed make-up air vents. A large laminated glass canopy is supported off the primary structure via plate beams and tubular suspension members through the glazed facade. The canopy is 19m wide and 7m deep, reclining back to a gutter concealed in the offset between the facade glazing at ground and first floor.

Curved roof form

The roof form is derived from a parametric model which allowed many iterations to be tested quickly for form-finding, street view assessment and clash detection. It was constructed using basic mathematical elements such as coordinate systems, planes, points, lines and arcs, arc-composite curves and surfaces.

The generated roof surfaces are flat, single-curved or double-curved. The latter are part of a torus — their curvature in one direction is constant and the key established surface is the exterior face of the steel structure. Everything outside of this is the 'facade' build-up. The model simplified the process of producing elevations and sections necessary to describe the building, and was used by structural engineer AKTII to establish the steelwork set-out.

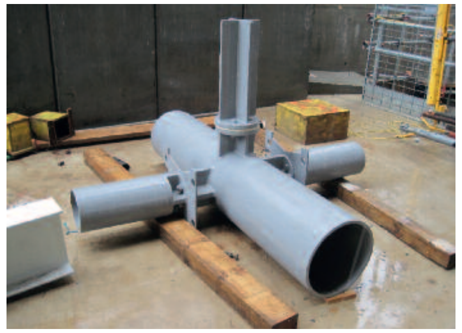
The underlying structure of the roof is painted steel, hooped in the north-south direction and gently curved in the east-west direction. This grid is braced back to the main building frame for stability and is capable of large cantilever overhangs at the east and west ends and on the north side of the higher roof.

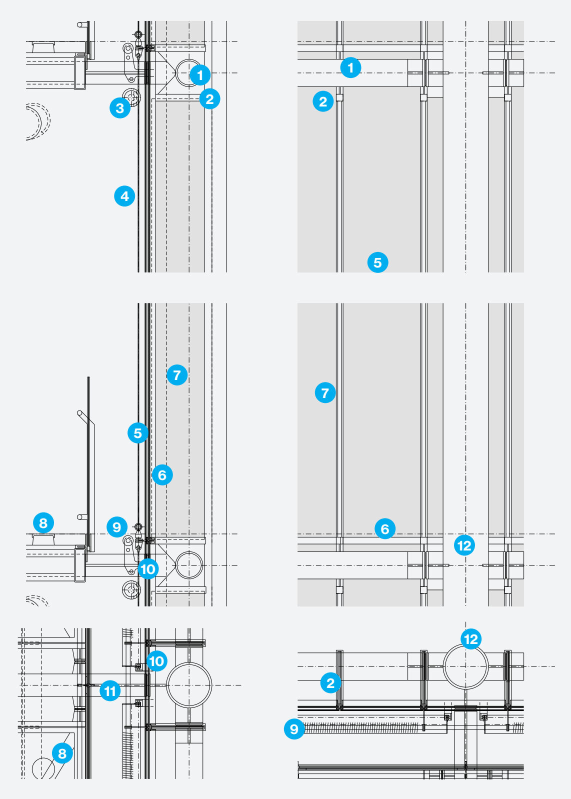
Steelwork contractor Severfield (UK) was responsible for the connection design and fabrication of around 2,300 tonnes of structural steelwork.

Below
East entrance wall and canopy: mock-up of cruciform tubular section of primary steel structure; construction of facade with primary steel structure grid of tubular sections with atrium bridges acting as a structural beam; section, elevation and plans of primary steel structure comprising vertical and horizontal CHS profiles, aluminium carrier frame and double-glazed units; detail axonometric of glass panes and framework of horizontal CHS steel profiles with anodised aluminium carrier frame (phs: PLP Architecture).

Top right
Construction of steel roof hoops in the north-south direction. The visible surface of the roof is a kit of different louvre blades, attached via transverse brackets to an extruded aluminium tubular spine spanning between the main steel hoops. These include solid and perforated aluminium and laminated glass blades, all of different widths, and photovoltaic blades, all angled at 15 degrees to the tangent of the hoop to which they are fixed. The east and west oversailing blades widen and flatten towards their ends to form a continuous curved roof edge. The twist is achieved by simply rotating the blade brackets around the central spine (phs: Wellcome Images courtesy of Laing O'Rourke).

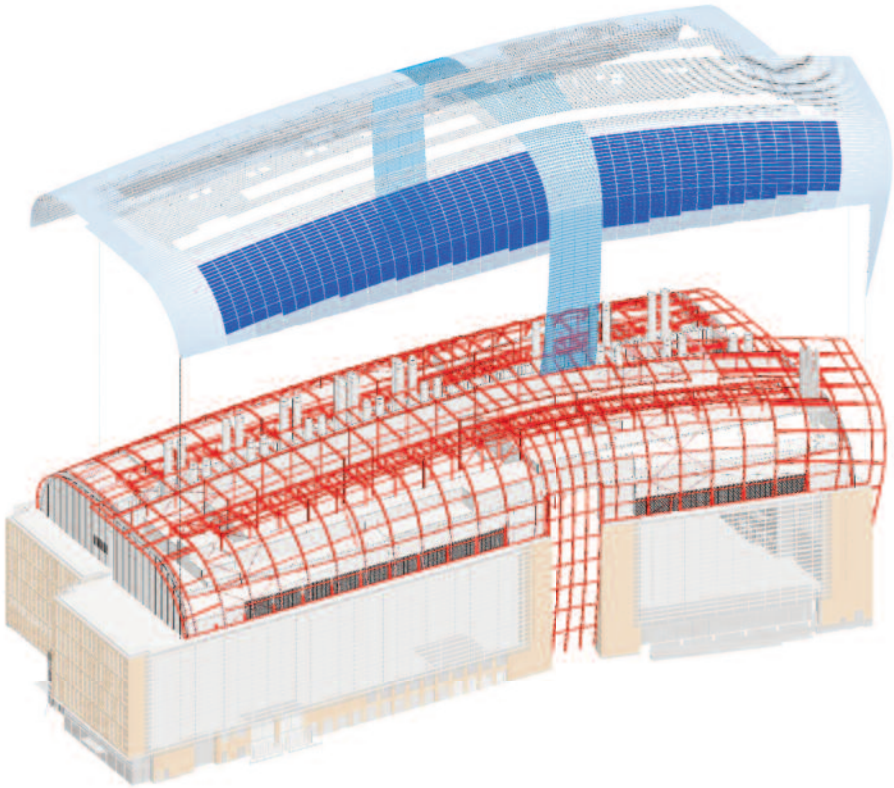
Bottom right
3D composite model of roof louvres, photovoltaic array, steel structure and base of building.

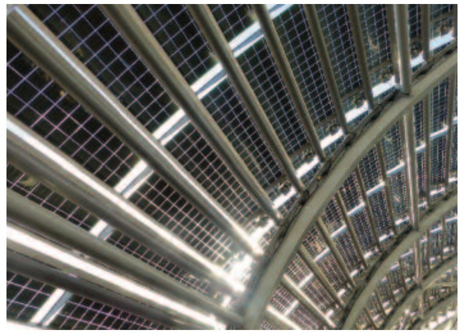




Key

1	Horizontal steel support structure
2	Stainless steel shoe bracket
3	Motorised fabric roller blind
4	Stainless steel blind guide rod
5	Laminated double-glazed unit
6	Anodised aluminium carrier frame
7	Laminated glass fin
8	Internal bridge link
9	Spiral fin radiator
10	Thermally broken structure
11	Steel cruciform beam
12	Vertical steel support structure





Project team

Architect
HOK with PLP Architecture
Structural engineer
AKTII
Services engineer
Arup
Facade engineer
Emmer Pfenninger Partner
Main contractor
Laing O'Rourke
Client
The Francis Crick Institute

Selected suppliers & subcontractors

Curtain wall and envelope contractor
Scheldebouw with Josef Gartner
Steelwork contractor
Severfield (UK)
Louvres
Levolux

Bblur Architecture
Slough Cultural Centre

Due to complete in the spring, Slough Cultural Centre by Bblur Architecture and engineer Peter Brett Associates is a flagship community building forming part of the £450m Heart of Slough regeneration scheme. Conceived as a covered street linking two new public squares, the three-storey structure is fully glazed at either end and features a concave northern elevation that is curved in two directions. The internal accommodation includes a library, gallery, a multi-purpose performance space, classrooms and meeting areas.

Belying its complex fan-like shape, the building employs a regular 7.5 metre structural grid, with only the double-curved north facade constructed 'off-grid'. 'We chose to build in steel primarily for reasons of cost and speed', says Bblur partner Matthew Bedward. 'Steel also allowed us to achieve a sculptural form with relative ease and within a reasonable time scale.'

The primary structural frame comprises 273mm diameter CHS columns supporting 406x178mm universal steel beams, with 350x127mm joists at 2.5 metre centres. The north elevation, which follows the curving perimeter of St Ethelburt's churchyard, adopts a 'long arch' solution to minimise the number of columns that can be seen through the ground floor curtain wall. The aim is to strengthen the visual connection between inside and out, while also giving the structure an elegant lightweight appearance.

Taking the place of the ground floor columns are a series of primary, curved steel I-sections, which are supported by a propped, single radius, 324mm diameter CHS arch that spans almost the entire length of the facade. Closely spaced at alternating vertical centres of 1.1 metres and 2.2 metres, the 152x152mm facade steels form a rigid ladder frame that facilitates fixing of the external metal skin and double-glazed units with the minimum need for secondary steelwork. The 3mm thick polyester powder-coated aluminium cladding panels are curved only in the vertical plane. The horizontal curve will be achieved through faceting, with the shallowness of the radius ensuring a smooth unbroken appearance.

The project was procured using BIM, with Bblur coordinating the master 3D CAD model, and assuming responsibility for all setting out, including the steel structure and services. The model was supplied to specialist steelwork contractor Caunton Engineering relatively early in the detail design process. Liaising with the architect and engineer, the company developed its own fabrication-based model, which was subsequently fed back into the master model and used for clash detection. Bedward describes the process as 'seamless', resulting in a high degree of coordination between the steel structure, services and external skin.

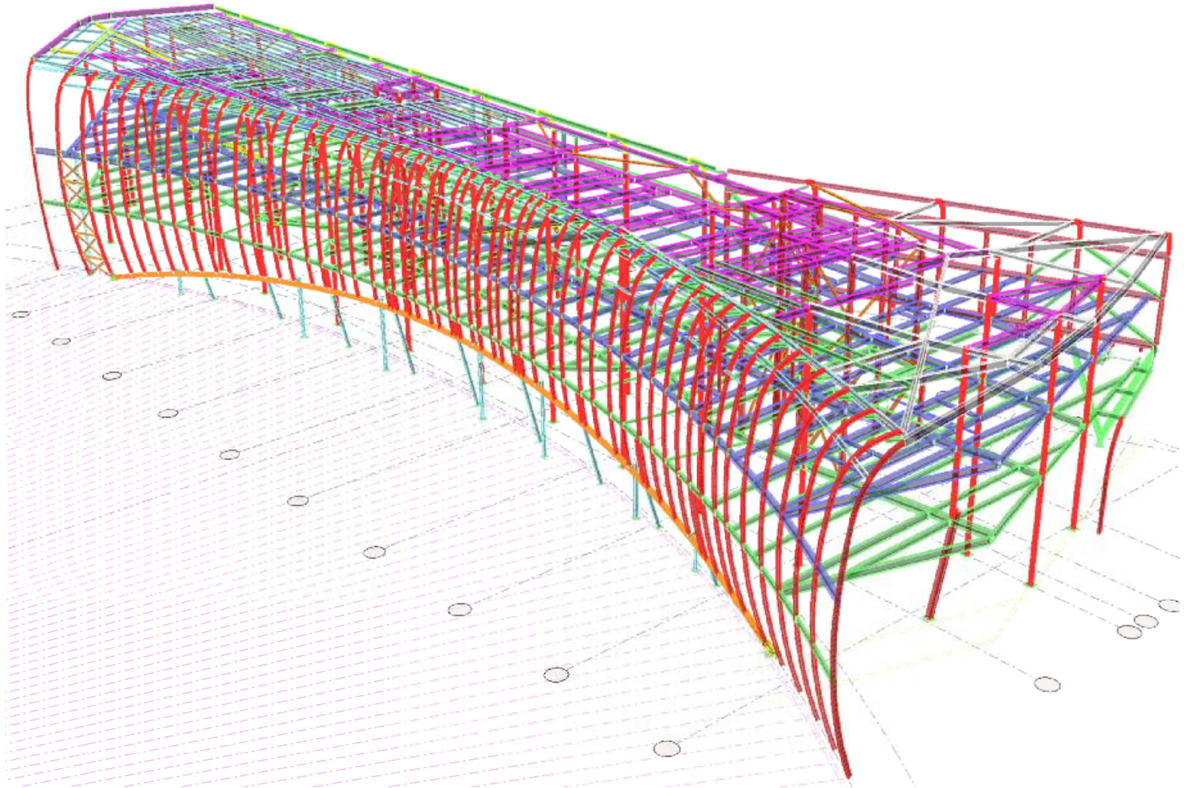
The steel frame was erected in three sections, starting at the east end of the plan and working west. Resembling a 'kit of parts', the frame was bolted together using a crane and cherry picker over a period of four months. The 60 metre long CHS arch comprises three separate sections, which were spliced together on site and temporarily propped while the curving vertical I-sections were bolted to flanges welded to the top face.

Top
Structural BIM model with matching view showing completed steel frame.

Above
The steel structure was erected in three phases — starting from the east end of the plan and working west — over a period of four months.

Project team

Architect
Bblur architecture
Structural engineer
Peter Brett Associates
Landscape
SpaceHub
Broadway Malyan
Interiors
CZWG
Steelwork contractor
Caunton Engineering
Main contractor
Morgan Sindall
Construction
Client
Slough Borough Council
Morgan Sindall
Investments

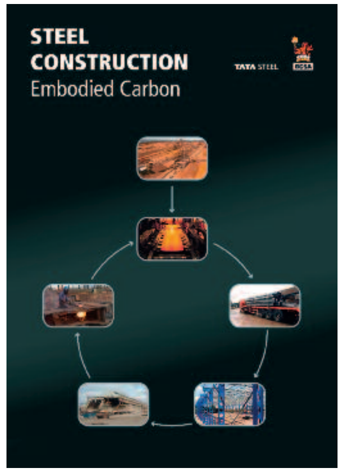


Sustainability with Steel
Calculating Embodied Carbon

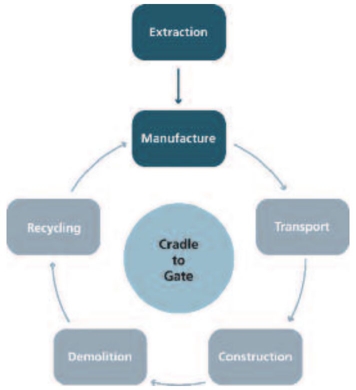
The significant reduction in operational carbon emissions from buildings over the past decade, achieved primarily through better energy efficiency, has led to an increase in the importance of embodied carbon impact. The most straightforward way to measure the embodied carbon impact of construction materials and products is to calculate it using rates of $kgCO_2e/kg$. The key of course is in identifying the correct rates to use.

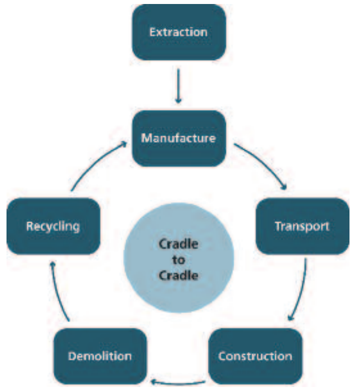
Lifecycle assessment (LCA) is generally used to determine the embodied carbon impacts of construction products, but this must be consistent and rigorous to be useful as a tool for comparison, and should ideally follow the lifecycle stages set out in BS EN 15804. Some manufacturers present data based on 'cradle-to-gate' data that takes into account only impacts from extraction and manufacturing, while others consider all the lifecycle stages of BS EN 15804 — 'cradle-to-cradle' data.

Clearly comparing cradle-to-gate data against cradle-to-cradle data will result in a flawed analysis. Architects should therefore check with the relevant manufacturer how its data has been derived. Comparisons based on $kgCO_2e/kg$ of material should be avoided as different materials are not used in the same quantities within a building to deliver equivalent performance. As a minimum, a $kgCO_2e/m^2$ assessment should be used in considering the effects of material intensity in the 'as built' condition.


STEEL CONSTRUCTION
Embodied Carbon
TATA STEEL

Further details
Steel Construction — Embodied Carbon, a guide published by Tata Steel and the British Constructional Steel Association is available from: www.steelconstruction.info.





Product	BS EN 15804 Modules			Total
	A1-A3 ($kgCO_2e/kg$)	C1-C4 ($kgCO_2e/kg$)	D ($kgCO_2e/kg$)	($kgCO_2e/kg$)
Brickwork	0.16	0.01	-0.0207	0.15
Concrete blockwork	0.09	0.0103	-0.0053	0.10
C40 concrete	0.13	0.0043	-0.0053	0.13
C50 concrete	0.17	0.0037	-0.0053	0.17
Lightweight C40 concrete	0.17	0.0111	-0.0053	0.18
Hollowcore slab	0.2	0.0006	-0.0103	0.19
Hot rolled plate and structural sections [1]	1.735	0.06	-0.959	0.84
Hot formed structural hollow sections [1]	2.49	0.06	-1.38	1.17
Reinforcing steel [1]	1.27	0.061	-0.426	0.91
Steel deck	2.52	0.06	-1.45	1.13

[1] Fabrication (bending, cutting and welding for rebar) impacts have not been included.

End of Life Dataset

Stuttgart-based sustainability consultant PE International has developed an end-of-life dataset that compares embodied carbon data for commonly-used framing materials on a cradle-to-cradle basis. The data covers demolition and recycling impacts (modules C and D to BS EN 15804). Data for all the materials included can be viewed online at www.steelconstruction.info, along with sources for the cradle-to-gate (A1-A3) data. Designers using this dataset can have confidence in its transparency, robustness and consistency, enabling comparison between different frame options to be accurately and effectively carried out on any project.

SCI Carbon Footprint Tool

A carbon-footprint web tool developed by the Steel Construction Institute (SCI) enables designers of multi-storey buildings to estimate the embodied carbon of a building super-structure. The tool, available online at www.steelconstruction.info, can be used in 'auto-generate' mode, whereby the basic geometry, structural grid and floor system are used to estimate material quantities using algorithms developed by the SCI for common structural steel solutions. Alternatively, the 'manual input' mode allows entry of actual material quantities. To compare the impact of a steel-framed building with a concrete-framed building, the web tool should be run separately for each option. Appropriate carbon emission factors are then applied to the material quantities to estimate the overall footprint. Results are presented as a CO_2e figure for the whole building and per square metre of floor area, and a bar chart indicates the contributions of the frame, cores, floors, roof, fire protection and void walls.

Sheppard Robson
One Kingdom Street

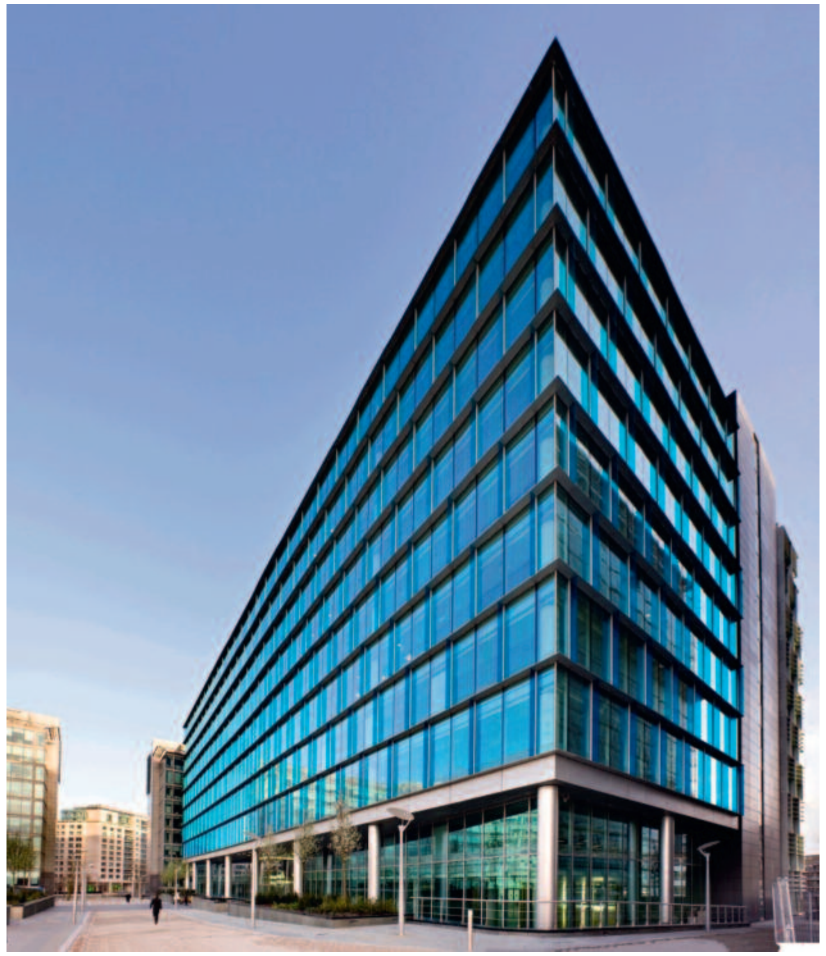
Sheppard Robson's 10-storey office building at Paddington, west London, was completed in 2008 and employed in Target Zero, a research project by AECOM, Sweett Group and the SCI intended to provide guidance on the design of low- and zero-carbon non-domestic buildings.

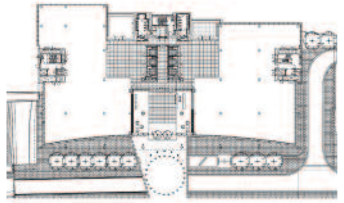
The building has a steel frame on a 12x10.5m grid, with cellular steel beams supporting a lightweight concrete slab on a profiled steel deck. The larger span is dictated by the location of beams within the Crossrail podium deck on which they are supported. The foundations comprise 750mm-diameter bored piled foundations with in-situ concrete pilecaps restrained laterally by the ground beams. The piles are the same size as those used to support the existing Crossrail podium to reduce potential differential settlement arising from the use of different pile diameters.

The embodied carbon impacts for two options were considered on a cradle-to-cradle basis: the as-built steel composite design and a concrete alternative comprising 350mm post-tensioned flat-slab construction. For frame and floors, the steel composite option has an impact of $152kgCO_2e/m^2$ compared to $190kgCO_2e/m^2$ for the post-tensioned concrete option that is 24 per cent greater.

The lighter superstructure for the steel option also results in smaller foundations. Consequently, the impacts from the substructure are different for each option. The foundations for the composite steel option have an embodied carbon impact of $59kgCO_2e/m^2$ compared with $74kgCO_2e/m^2$ for the post-tensioned concrete option, an increase of 26 per cent. When considering the building as a whole, steel composite has an embodied carbon impact of $452kgCO_2e/m^2$, which equates to a total of $14{,}937tCO_2e$. This compares to the post-tensioned concrete's impact of $506kgCO_2e/m^2$, which equates to a total of $16{,}716tCO_2e$, or 12 per cent greater.

Comparative costs were also examined as part of the study. For the frame and floor costs alone, the steel composite option is £316/m² compared to £377/m² for the post-tensioned concrete alternative that is 19 per cent more expensive. When considering the total building costs, the steel composite option is £1869/m² or £61.7m compared to £1941/m² or £64.1m for the post-tensioned concrete option. The concrete alternative is therefore four per cent more expensive than the steel option.





Above, right
One Kingdom Street is 40m high and 81x45m in plan. It accommodates 24,490m² of open-plan, 2.8m floor-to-ceiling office space on 10 floors and, on the eastern half of the building, two basement levels with car parking and storage. The gross internal floor area is 33,018m². The building has three cores and two central atria on its south elevation which house six scenic wall chamber lifts. A typical office floor plate provides approximately 2,500m² of flexible space on a 1.5m planning grid.