Steel Solutions

Complex curves at the Francis Crick Institute in London, by HOK and PLP Architecture, and Slough Cultural Centre by Biblur, 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 £520m 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 (ph: 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).
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 plates. The weather skin is 5.08m-high glass canopy is supported off the primary structural 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 (ph: PLP Architecture).

**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.
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 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 phases, starting from 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.

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**Project team**

**Architecture**
Bblur architecture

**Structural engineer**
Peter Brett Associates

**Landscape**
SpaceHub

**Interiors**
Broadway Malyan

**Steelwork contractor**
Caunton Engineering

**Main contractor**
Morgan Sindall Construction

**Client**
Slough Borough Council

**Investments**
Morgan Sindall Investments

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*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.
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 its using rates of kgCO₂e/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 kgCO₂e/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 kgCO₂e/m² assessment should be used in considering the effects of material intensity in the ‘as built’ condition.

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

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 CO₂ 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.

SCI Carbon Footprint Tool

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, Sweet 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 1520kgCO₂e/m² compared to 1900kgCO₂e/m² 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 590kgCO₂e/m² compared with 740kgCO₂e/m² 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 4520kgCO₂e/m², which equates to a total of 14,937tCO₂e. This compares to the post-tensioned concrete’s impact of 5060kgCO₂e/m², which equates to a total of 16,716tCO₂e, 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 that is 24 per cent greater.

One Kingdom Street is 40m high and 12x10.5m in plan. It accommodates 24,490m² of open-plan, 2.8m floor-to-ceiling office space on 16 floors and, on the eastern half of the building, two basement levels with car parking and storage. The gross internal floor area is 35,018m². The building has three cores and two central atria on its south elevation which house on scene wall chamber kits. A typical office floor plate provides approximately 1,200m² of flexible space on a 1.5m planning grid.