STEEL INSIGHT #16

COST UPDATE AND CASE STUDIES

STEEL INSIGHT

● The latest article in the series provides an update from Gardiner & Theobald on construction costs, while overleaf are two case studies of steel structures used in tight project spaces

COST MODEL UPDATE

Steel Insight 3 "Cost Comparison study" (April 2012) analysed two typical commercial buildings to provide cost and programme guidance when considering available options during the design and selection of a structural frame.

Building 1 is a typical out-of-town speculative three-storey business park office with a gross internal floor area of 3,200m^2 and rectangular open-plan floor space. Cost models were produced for four frame types developed by Peter Brett Associates to reflect the typical available framing options: steel composite, steel and precast concrete slab, reinforced concrete flat slab and post-tensioned concrete flat slab.

Building 2 is an L-shaped eight-storey speculative city centre office building with a gross internal floor area of 16,500m^2 and a 7.5m x 15m grid. Cost models were developed for a steel cellular composite frame and post-tensioned concrete band beam and slab, being two frame and upper floor types that could economically achieve the required span and building form.

The cost models for Building 1 and 2 are regularly updated, and the latest data for Q1 2016 is presented here.

As Figure 1 shows, the steel composite beam and slab option remains the most competitive for Building 1, with comparable frame and upper floors cost and the lowest total building cost.

For Building 2 (Figure 2), the cellular steel composite option has both a lower frame and upper floors cost and a lower total building cost than the post-tensioned concrete band beam option, with lower substructure costs, lower roof costs and a lower floor-to-floor height resulting in lower external envelope costs.

The tender price increases seen Q1 2016 have been modest, so the indicative cost ranges shown in the structural steel frame cost table (Figure 3) remain unchanged since the previous quarter.

However, recently announced increases in steel and rebar prices mean that consideration should be given to the inclusion of inflation allowances for estimates that are expected to be tendered in the remainder of 2016.

To use the table: a) Identify which frame type most closely relates to the proposed project, b) Select and add the preferred floor type, c) Add fire protection if required, d) Adjust the total according to the BCIS location factor (Figure 4).

Before using such standard ranges the anticipated frame weight and variables such as the floor-to-floor heights must be confirmed to determine whether they are above or below the average and to adjust the rate used accordingly.

Similarly, all of the other key cost drivers of complexity, site conditions, location, function, logistics, programme and procurement strategy should be considered in turn.

Figure 1: Building 1 Cost Model (key costs per m^2 Gross Internal Floor Area (GIFA), City of London location)

	Steel composite	Steel and precast concrete slabs	Reinforced concrete flat slab	Post-tensioned concrete flat slab
Substructure	£69	£73	£88	£82
Frame and upper floors	£172	£190	£171	£200
Total building	**£1,914**	**£2,026**	**£2,110**	**£2,094**

Figure 2: Building 2 Cost Model (key costs per m^2 GIFA, City of London location)

	Steel cellular composite	Post-tensioned concrete band beam and slab
Substructure	£78	£84
Frame and upper floors	£238	£274
Total building	**£2,379**	**£2,481**

Figure 3: Indicative cost ranges based on GIFA (Q1 2016)

TYPE	GIFA Rate (£) BCIS Index 100	GIFA Rate (£) City of London
Frame - low rise, short spans, repetitive grid / sections, easy access (Building 1)	110 - 130/m^2	145 - 170/m^2
Frame - high rise, long spans, easy access, repetitive grid (Building 2)	155 - 175/m^2	215 - 230/m^2
Frame - high rise, long spans, complex access, irregular grid, complex elements	190 - 215/m^2	260 - 285/m^2
Floor - metal decking and lightweight concrete topping	55 - 70/m^2	65 - 85/m^2
Floor – precast concrete composite floor and topping	65 - 80/m^2	80 - 100/m^2
Fire protection (60 min resistance)	17 – 26/m^2	20 - 30/m^2
Portal frames – low eaves (6-8m)	60 - 80/m^2	70 - 90/m^2
Portal frames – high eaves (10-13m)	75 - 100/m^2	90 - 120/m^2

Figure 4: BCIS location factors, as 15 April 2016 (UK mean = 100)

Location	BCIS Index	Location	BCIS Index
City of London	127	Leeds	90
Nottingham	97	Newcastle	92
Birmingham	96	Glasgow	95
Manchester	95	Belfast	61
Liverpool	91	Cardiff	96

This and the previous Steel Insight articles produced by Rachel Oldham (Partner) and Alastair Wolstenholme (Partner) of Gardiner & Theobald are available at www.steelconstruction.info

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BIM: EARLY ADOPTERS

Structural steel is one of the few areas in the construction supply chain where BIM is commonplace. BCSA director of engineering David Moore explains why. By Will Mann

The structural steel sector has had a headstart on BIM compared to most of the construction industry.

"We have been using 3D modelling for 20 years – and as that is a key element of BIM it gives us a significant advantage," explains David Moore, director of engineering at the British Constructional Steelwork Association (BCSA). "We are very comfortable working with the software and the BIM protocols. The problems that spring up elsewhere in the supply chain – around file languages, formats, naming systems and so on – have not been an issue for our members because of that 3D modelling experience."

Despite its headstart, steel has not rested on its laurels. In 2013, three years before the government's BIM mandate kicked in, the BCSA set up its own working group to look at the technology, and then rolled out extensive training for members in 2015. This year it has introduced a BIM charter to allow steelwork contractors to demonstrate compliance.

The aim of this, says Moore, is not only to upskill members, but also to push the message up the supply chain about constructional steel's BIM capability.

"The whole BIM process is predicated on having all the supply chain involved from day one of a project," he observes. "But it is more fundamental for the structural frame contractor, as this is the 'coat hanger' on which everything else hangs."

He reels off a whole string of benefits that BIM can offer where the steelwork contractor is involved early [see box].

"It also means benefits for other suppliers," he says. "M&E contractors, for example. Our default position is to provide cellular beams with multiple openings – typically 21 on a 12 m beam – for future flexibility. But if we knew where the service runs were, we would need to create holes at far fewer intervals. This would mean the beam behaves significantly better in fire, and considerably reduces the cost of intumescent paint.

> WE HAVE BEEN USING 3D MODELLING FOR 20 YEARS – AND AS THAT IS A KEY ELEMENT OF BIM IT GIVES US A SIGNIFICANT ADVANTAGE
>
> DAVID MOORE, BCSA

"Having a working model containing all elements of the build allows them to programme the sequence of erection around the staggered installation of the mechanical and process equipment."

BCSA's working group brought together clients, main contractors, consultants, steelwork contractors and software providers, to develop a working definition for Level 2 BIM and identify the software, competence and systems required.

The training has spun out of that working group, and focuses more on processes rather than 3D design, where the expertise already exists. The workshops are aimed at senior managers responsible for BIM implementation, and look at practical and legal considerations, as well as how it fits into working practices

"We have run seven courses so far, training about 65% of BCSA members – though in terms of market tonnage that is a much higher proportion of the market," Moore says.

The charter – which involves a third party audit – obliges members to maximise BIM in design, manufacturing and delivery of constructional steel, and to build on its knowledge of the technology and share it with others.

"We want to tell main contractors we are BIM compliant," says Moore. "It is not just about 3D modelling, it is about showing we have the systems in place, including disaster recovery – main contractors want to feel confident about this."

Crucially, the charter means BCSA members will be certified against the requirements of both PAS 91:2013 and PAS 1192-2:2013 – the latter described by Moore as the "BIM bible".

Next steps in the BCSA BIM training include workshops for programme (4D) and cost (5D).

But while steel is well-prepared for BIM, not all of construction is. Steelwork contractors typically request IFC files or Revit models at tender stage, which they usually import from design software. However, although bigger projects normally provide this information, BCSA members report that overall only 40% of tender packages come with a structural model.

"The front end tendering process is a place where the passing and exchange of information in model format is becoming an accepted activity," says Moore. "But there is considerable variation in the levels of information and model sophistication adopted between different projects.

"Getting accurate and timely information has always been a problem for our members. Hopefully the BIM process will address that."

Key benefits from using a 3D model in the steelwork tender process:

- Material schedule and tonnage can be quickly evaluated and costed
- Numbers of components for estimating purposes can be extracted from the model
- Steelwork surface areas for treatment evaluation and costing can be arrived at quickly
- Models can be broken into phases and construction sequencing quickly generated, including interface with concrete cores and walls
- Temporary bracings can be added to the sequencing to show how stability is maintained throughout construction
- Crane and MEWP positions can be modelled to demonstrate access and capacity requirements
- Safety fans and edge protection can be added to the sequencing model

Potential value engineering benefits

- Fire engineering of beams to reduce cost of intumescent paint
- Re-engineering of multi-storey columns in high-grade steels
- Modularisation of areas of structure to overcome erection difficulties for inaccessible locations
- Reconfiguration of floor grid layouts to reduce beam numbers and speed up overall erection

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8 FINSBURY CIRCUS

● A complex steel frame design was required to fit a new Stanhope office development into a tight site on Finsbury Circus in the City of London. Will Mann explains.

Finsbury Circus has one of the grandest streetscapes in the City of London.

The elliptical-shaped park, half a hectare in area, is the largest public open space within the City's boundaries, and is mostly fronted by neo-classical buildings from the late 19th and early 20th centuries. Being a conservation area, new developments have to respect the scale and the style of the existing buildings.

This is the case with 8 Finsbury Circus, a new, 160,000ft^2, nine-storey development, which has been constructed by Lendlease. The Stanhope scheme is wedged into the crescent of buildings on the north side of the park, and features a mansard roof on the upper floors to fit the street profile and right-to-light planning requirements.

It sits on a pentagon-shaped site previously occupied by River Plate House, which was considered outdated, with inefficient floor plates, and demolished in 2013. Its replacement, 8 Finsbury Circus, will offer far more flexible internal layouts, maximising space on the tight footprint, thanks to the steel-framing solution used for the building. However, the unusual shape of the site has made the structural design challenging.

"The geometry means very little of the steel frame could be set out on a regular grid," explains Waterman project engineer Richard Whitehead. "The central core is only square relative to the north elevation of the building, on South Place Mews. All the other beams that meet the core are irregular lengths because of the pentagonal shape.

"The internal spans range from 8m to 16.8m at the front. Here, because the elevation arcs around Finsbury Circus, the beams fan out, perpendicular to facade."

The steel frame begins in the two-storey basement, which has in-situ concrete floor slabs. "We chose not to re-use the existing foundations, as the location of the core was different and the load distributions wouldn't have worked," explains Whitehead. "So we have installed a concrete raft, although the existing piles have been used for settlement control."

From the ground floor upwards, the structure is composite, with steel beams supporting reinforced concrete floor slabs cast on metal decking.

The South Place elevation to the north features a retained facade which dates from the late 1800s and had to be retained as part of the new development. However, the fenestration didn't match with the design of the new floors, which meant column changes were required for the frame design on this elevation. Rather than risk damaging the facade, contractor Lendlease opted to dismantle it stone by stone, and reassemble it once the steelwork was finished.

"That edge of the steelwork design was tricky," says Whitehead. "Because of the entrance on South Place, we had to create a 750mm-deep cantilever behind the facade. All columns transfer at first-floor level onto the cantilever."

The building's other cantilever, on the north-west corner of the building, was designed to accommodate a service yard and rights of way in South Place Mews. "We couldn't have put a column in that corner of the 'pentagon', so we have designed in a 3m cantilever, from first floor upwards," explains Whitehead.

The mansards also complicated the structural design. "Neither the front – Finsbury Circus – nor the rear – South Place – mansards fitted to the same grid, so we have had to shift the columns to transfer the loads," says Whitehead.

The top two floors have stepped outdoor terraces, the largest 8m deep, so further transfer structures have been incorporated, while the ground floor has yet another transfer structure to accommodate the large entrance foyer. Additional column changes are on the first, fifth and eighth floors.

BIM has helped with the design of this complicated structure, says Whitehead. "We didn't build a federated model, but the steelwork contractor William Hare sat with our Revit technicians for several weeks and used our model to create their own Tekla structures model," he explains. "Additionally, we worked closely with the building services team, tailoring the design of many beams to accommodate the services with maximum openings."

The steel erection has also been driven by the shape of the site.

"The building has an irregular floor plate, but within that there are quite simple geometric zones," explains Lendlease project director John Chesters.


Mansards on the building's upper floors help the structure adhere to right-to-light requirements

WORKSHOPS USING THE STEEL FABRICATORS SOFTWARE MODEL WERE KEY TO INCORPORATING THE REQUIRED DETAILS

JOHN CHESTERS, LENDLEASE

"The floor plates up to level six were the same, and the most difficult section was the curved Finsbury Circus elevation which required beams to be installed to a radial pattern. Above level six there was the complication of the mansard on the south elevation which required some temporary propping."

Two tower cranes were used for the installation. "We split the footprint into four zones, with two zones in progress at any one time," explains Chesters. "The steelwork was installed over three storeys in each visit to each zone.

"The cranes were supported by MEWPs (mobile elevating work platforms) based on the raft foundation, for the first four floors. For the upper floors, static base access platforms, placed on channels spanning between the permanent steel frame members, were used. Smaller MEWPs were used for final checks on the floor plates."

The complexity of the steel frame design meant that more than 2,600 individual crane lifts were required.

An extra logistical complication on the project was Crossrail, which is using the Circus to provide access for the Liverpool Street station works. This meant that most of the steelwork had to be delivered at South Place, the exception being the 16.5m beams, which were unloaded at Finsbury Circus because of their size. "We were able to plan a road closure with Crossrail," says Chesters.

The Finsbury Circus facade will be predominantly Portland stone, to echo neighbouring buildings. However, there are numerous different cladding types across the building. "We're fitting zinc-unitised panels, slate mansard panels, precast backing panels, stone-faced precast panels, not to mention the retained stone facade," says Chesters. "Each of these require different fixing details associated with the steel, and workshops using the steelwork contractor's software model were key to incorporating the required details."

8 Finsbury Circus was completed in the first quarter of 2016.

PROJECT TEAM

CLIENT: Stanhope
ARCHITECT: Wilkinson Eyre
MAIN CONTRACTOR: Lendlease
STRUCTURAL ENGINEER: Waterman Group
STEELWORK CONTRACTOR: William Hare

THE MONUMENT BUILDING

● Structural steel has allowed Skanksa to squeeze a nine-storey office onto a site previously occupied by a seven-storey concrete-framed building, adjacent to the City of London's historic Monument. By Will Mann

It is an understatement to say the Monument Building occupies a tight site. Skanska's new 94,000ft^2 office-led scheme in the City of London is surrounded on all sides by busy roads, tube lines and, most significantly, the historic Monument, which commemorates the Great Fire of London, and gives the building its name.

The site has an irregular, four-sided shape, with Pudding Lane – where the fire started in 1666 – to the east, a London Underground party wall to the north, Fish Street Hill to the west, and the memorial itself to the south.

These constraints have shaped the design and construction methodology for the £35m, nine-storey development, designed by Make Architects and engineered by Arup, including the choice of steel – around a single concrete core – for the the structure.

"Steel was chosen as a framing material primarily for its light weight, plus its speed of construction," explains Michael Heywood, senior structural engineer with Arup.

"Working in an area so closely surrounded by historical and listed structures meant that it was important to minimise the risk of damage through the ground movements associated with demolition and construction activities.

"One way we achieved this through design was to ensure that the maximum loads imposed by the new building were no greater than those imposed by the structures which previously existed on the site."

Three existing properties on the site were demolished before construction got underway in

Cellular beams have been used throughout

December 2013. Although the scheme had originally been designed with piled foundations, the project team wanted to avoid this approach. "It would have meant breaking out an existing foundation slab, and with the Tube, DLR and the Monument itself close by, that would have caused more disruption and added risk," says Brian Nunn, Skanska's construction director.

Instead, an 850mm raft foundation was built on top of the existing slab, although the underlying slab does not contribute any support to the building above. Nine piles were installed on the north elevation nearest to the Tube, 750mm in diameter and 24m deep to stiffen the raft.

"This approach saved us 14 weeks on the programme," says Nunn.

The presence of the 62m-high Monument, and its protected views, has restricted the height of the new development to 55m, within a couple of centimetres of the limit imposed by planners to protect views of the Doric column.

"However, by using steel, we were able to construct a nine-storey building where a seven-storey heavy concrete frame previously stood," explains Heywood.

"We used a composite floor system with cellular steel beams to combine the structural and building services zones. This allowed us to achieve a shallower overall floor zone, maximising the number of possible floors within the planning height restriction, bringing greater value to the project."

> STEEL WAS CHOSEN AS A FRAMING MATERIAL PRIMARILY FOR ITS LIGHT WEIGHT, PLUS ITS SPEED OF CONSTRUCTION
>
> MICHAEL HEYWOOD, ARUP

The steel grid is typically 9m x 10.5m, but varies due to the trapezoidal nature of the site. "We don't have any significantly long spans, but they vary throughout the building, and are up to 14m towards the north-west of the site," says Heywood.

The biggest structural design challenge was in the north-east corner due to the presence of the party wall.

"Here, between levels one and two, we built a pair of storey-deep cantilever trusses to transfer the perimeter building loads away from the London Underground retaining wall," explains Heywood.

The load from the storeys above the cantilever is reduced because of stepped terraces on this corner of the building, at levels four, five, seven and nine.

"Structurally, they allow the building to mimic the loads imposed by the four-storey structure which previously stood here adjacent to the London Underground wall," explains Heywood. "This also helps to control long-term ground movements."

The project has been helped by a highly coordinated design approach in BIM. "This included designing the horizontal service distribution to pass through beam web openings," says Heywood. "This approach required close consultation between structural and services teams early in the design process. It also meant that exercises such as clash detection could be run regularly as the design was developed."

"We set up a two-way link between our modelling and analysis packages, which allowed us to streamline the design process with automated calculations, and meant we could tailor each beam's design to suit the exact load requirements."

BIM also helped with the steel erection process, with a barcode system used for every steel member. "We could check on an iPad the status of any beam – whether it was in the factory, on the way to site, or being installed on the building," explains Daire Hughes, senior project manager with Skanska.

Severfield's 20-week steel erection programme was completed ahead of schedule in July 2015, an impressive feat given the cramped nature of the site, with only one loading bay opposite Monument tube, with room for two articulated lorries, available to the project team.

"Because the steel frame was quick to erect, the overall construction period was reduced, and so disruption to neighbours – and the public – was kept to a minimum," says Nunn.

The Monument Building is scheduled for completion in May 2016. The north, east and west elevations have been clad with alternating glazed and jura limestone panels, while the glazed south side is blanketed with twisting, anodised aluminium fins. These are intended to mimic the fluting on the Monument, and provide solar shading.

It is the first London project for Skanska's development arm which has been built out by its contracting business. Given the deflated state of the London market when it acquired the site in 2012, it should be able to sell the building on for a healthy profit.

PROJECT TEAM

CLIENT: Skanska (development)
ARCHITECT: Make Architects
MAIN CONTRACTOR: Skanska Construction
STRUCTURAL ENGINEER: Arup
STEELWORK CONTRACTOR: Severfield