Building

STEEL INSIGHT #17

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 case studies of steel structures in retail projects

COST MODEL UPDATE

Steel Insight 3 "Cost Comparison study" (April 2012) analysed two commercial buildings to provide cost and programme guidance when considering available options during design and selection of a structural frame. Cost models for Building 1 and Building 2 are regularly updated by Gardiner & Theobald, and the latest data for Q2 2016 is presented here.

Building 1 is a typical out-of-town speculative three-storey business park office with gross internal floor area of 3,200m² and rectangular open plan floor space. Cost models were produced for four frame types developed by Peter Brett Associates to reflect typical 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 with a gross internal floor area of 16,500m² 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 required span and building form.

As Figure 1 shows, the steel composite beam and slab option remains 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 in Q2 2016 are reflected in the updated indicative cost ranges shown in the structural steel frame cost table (Figure 3). All costs in this article are valid as of the end of June 2016 for Q2 2016 and make no allowance for impacts of the EU referendum on price and currency fluctuations. 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 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 it is important to confirm anticipated frame weight and variables such as the floor-to-floor heights to determine whether they are above or below average and to adjust the rate used accordingly.

Figure 1: Building 1 Cost Model (key costs per m² Gross Internal Floor Area (GIFA), Central London location)

	Steel composite	Steel and precast concrete slabs	Reinforced concrete flat slab	Post-tensioned concrete flat slab
Substructure	£70	£74	£90	£84
Frame and upper floors	£174	£193	£172	£202
Total building	**£1,941**	**£2,055**	**£2,138**	**£2,121**

Figure 2: Building 2 Cost Model (key costs per m² GIFA, City of London location)

	Steel cellular composite	Post-tensioned concrete band beam and slab
Substructure	£79	£85
Frame and upper floors	£241	£276
Total building	**£2,411**	**£2,512**

Figure 3: Indicative cost ranges based on GIFA (Q2 2016)

TYPE	GIFA Rate (£) BCIS Index 100	GIFA Rate (£) Central London
Frame 1 – low rise, short spans, repetitive grid / sections, easy access	115 – 135/m²	150 – 175/m²
Frame 2 – high rise, long spans, easy access, repetitive grid	165 – 180/m²	215 – 235/m²
Frame 3 – high rise, long spans, complex access, irregular grid, complex elements	200 – 215/m²	265 – 285/m²
Floor – metal decking and lightweight concrete topping	55 – 70/m²	65 – 85/m²
Floor – precast concrete composite floor and topping	65 – 85/m²	85 – 100/m²
Fire protection (60 min resistance)	17 – 26/m²	20 – 30/m²
Portal frames – low eaves (6-8m)	60 – 80/m²	75 – 90/m²
Portal frames – high eaves (10-13m)	75 – 100/m²	95 - 120/m²

Figure 4: BCIS location factors, as 10 June 2016 (UK mean = 100)

Location	BCIS Index	Location	BCIS Index
Central London	124	Leeds	92
Nottingham	97	Newcastle	94
Birmingham	95	Glasgow	97
Manchester	98	Belfast	62
Liverpool	93	Cardiff	94

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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TAKE A LONG VIEW

Steelwork contractors are reporting a rise in use of long span steel beams across all construction sectors. Will Mann examines why

The long spans possible with constructional steel has always made the material popular among structural engineers in certain sectors. In the industrial market, where uncluttered operational spaces are top of clients' demands, steel has achieved almost complete dominance with a share in excess of 80%, according to the British Constructional Steelwork Association (BCSA).

But now, long span is growing its share in other markets, says Chris Dolling, marketing and technical manager at the BCSA.

"Member feedback indicates more projects using long span structures," he says. "The feedback from engineers and architects is that the more column-free space there is, the more clients like the freedom they have with internal layouts. It is particularly attractive for speculative office development where 12m to 15m grids are becoming more common. When tenants come and go frequently, and the developer has to market the office, if there are internal columns all over the place it is less attractive."

Besides flexibility, there is growing evidence that the open spaces possible with long span structures can improve workplace performance.

Dr Kerstin Sailer is director of research and innovation at architects Spacelab and a lecturer at the Bartlett School of Architecture. "There is strong evidence that longer sightlines – which mean shorter paths through the building – are conducive to more 'generative' working environments," she says. "This means industries which generate new ideas and where information has to travel fast, for example banking. So long span structures that create such spatial layouts will obviously help such knowledge-intensive businesses."

Sailer points to a 2012 study, The Generative Building, which examined the performance of 62 offices with varying levels of internal visibility. It found that the 17 offices where

visibility was higher than average, and sightlines were longer, were more "generative" workplaces. In contrast, 11 offices with below average scores, often with more cellular internal structures, were considered "conservative" in terms of staff developing fresh ideas.

Sailer says that there is no "one best practice ideal", and that different organisations require different spatial layouts. "But generally, the more people you see, the more conversations you have," she observes.

As well as offices, Dolling points to retail as a sector increasingly favouring long spans and open, flexible interiors. "Steel far outperforms concrete in this sector," he says. (See retail case studies, overleaf)

"We are also starting to see the same trend in schools, for the same reasons of flexibility and adaptability," Dolling adds. "St John Bosco Arts College in Liverpool was designed (by BDP) as a steel shed with 55m spans and removable internal configuration to allow for different future uses."

There is, of course, a trade-off with longer spans – bigger, heavier beams mean more steelwork in the building.

Mark Hamer, associate director at structural engineer Sanderson Watts, says: "Clients want the flexibility that long spans offer, but they still have to carry the loads. So longer beams are necessarily heavier and have bigger structural zones, and there is more steel overall in the structural frame.

"We try to keep the structural design as lean and mean as possible, but at some point there has to be a trade off between the increased cost of having more steel in the frame and the flexibility the client requires."

However, Dolling points out there are wider benefits which compensate for any increase in cost of the steelwork.

"Long span beams may be heavier, but the frame will have a lower piece count so steel erection is quicker.

"And with fewer columns, fewer foundations are required, which is a further cost, time and carbon saving. The heavier beams also increase floor mass, which dampens vibrations, so can help meet vibration criteria."

Dolling says a growing trend is the use of cellular long span beams for the integration of building services in deep structural zones. "If this is planned properly, it allows for greater freedom in the services layout," he says, citing the example of Building 101 at the Embankment development in Salford, a 10-storey commercial block with spans of up to 15.3m, where the services were run through 680mm-deep cellular beams in 475mm diameter holes.

"There are many knock-on benefits to this approach," Dolling says. "By running the services through cellular beams, the overall floor height can be reduced, so on a high-rise building the developer can get more floors in."

Ultimately, it is the flexibility long spans offer that appeals most to clients. As Sailer points out: "Long spans give you choice; you can easily segregate more by putting up partitions, if you need intimacy or privacy. But you can't create integration if the building structure is already too cellular. It is a one way street."

"None of us know how we're going to be working in 10 or 20 years time," adds Dolling. "So it makes sense to keep workspaces as flexible as possible."

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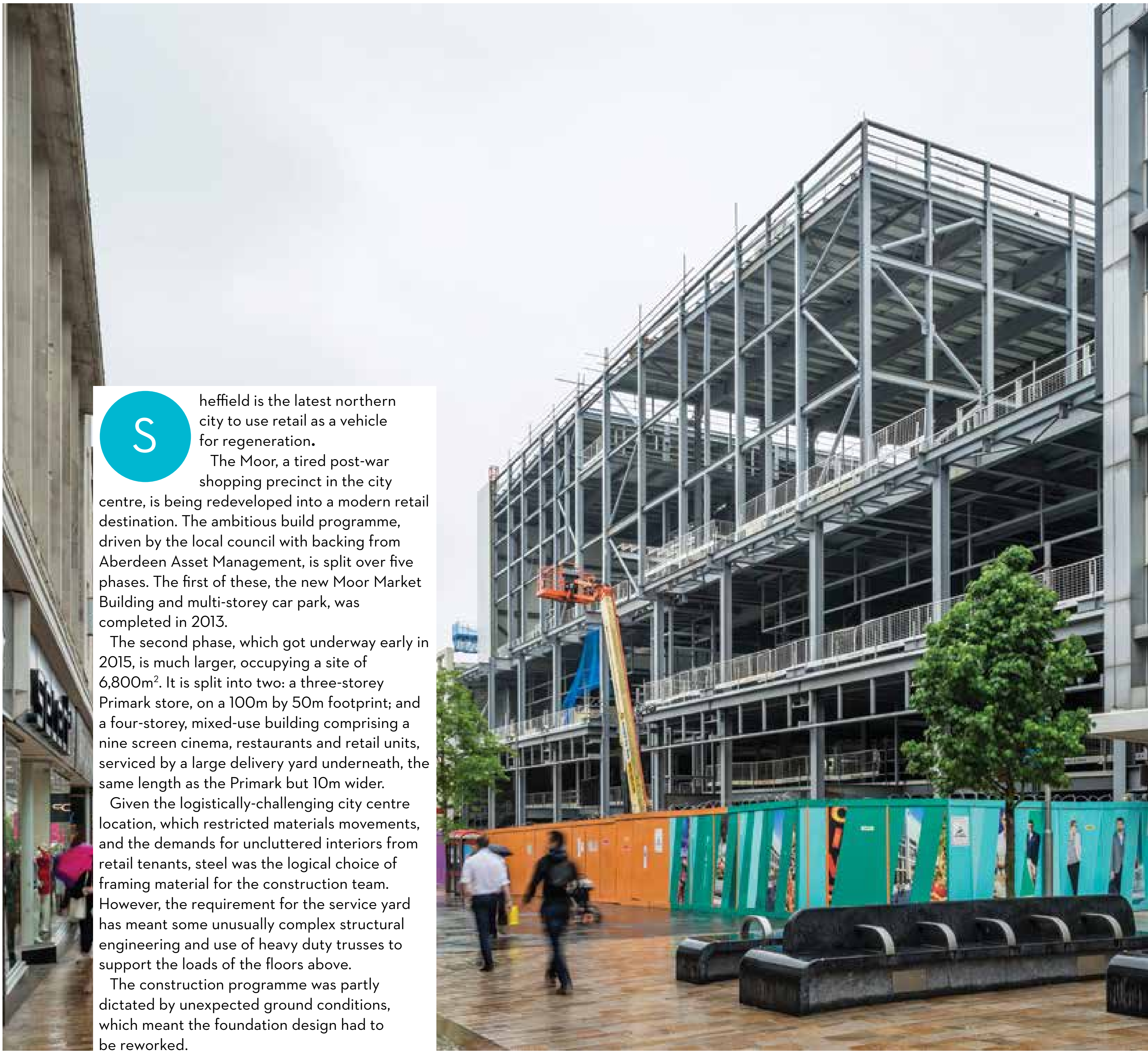
THE MOOR, SHEFFIELD

Heavy duty steel trusses over a service yard have played a key role in phase two of The Moor retail development in Sheffield. Will Mann reports.



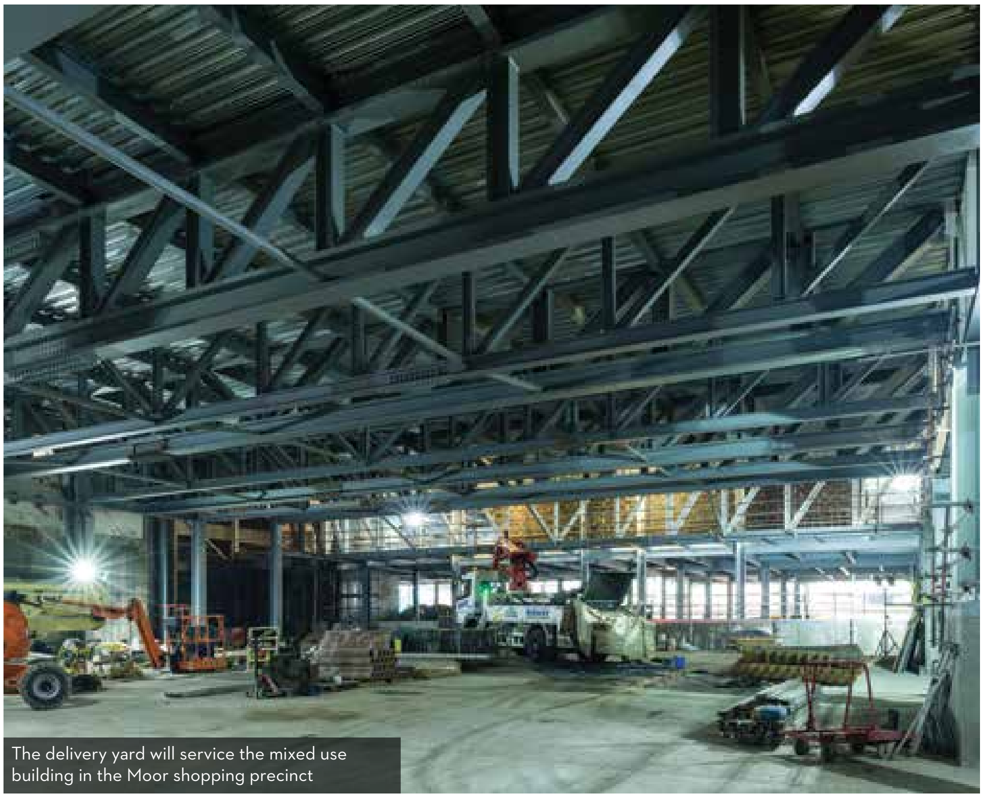
Sheffield is the latest northern city to use retail as a vehicle for regeneration.

The Moor, a tired post-war shopping precinct in the city centre, is being redeveloped into a modern retail destination. The ambitious build programme, driven by the local council with backing from Aberdeen Asset Management, is split over five phases. The first of these, the new Moor Market Building and multi-storey car park, was completed in 2013.

The second phase, which got underway early in 2015, is much larger, occupying a site of 6,800m^2. It is split into two: a three-storey Primark store, on a 100m by 50m footprint; and a four-storey, mixed-use building comprising a nine screen cinema, restaurants and retail units, serviced by a large delivery yard underneath, the same length as the Primark but 10m wider.

Given the logistically-challenging city centre location, which restricted materials movements, and the demands for uncluttered interiors from retail tenants, steel was the logical choice of framing material for the construction team. However, the requirement for the service yard has meant some unusually complex structural engineering and use of heavy duty trusses to support the loads of the floors above.

The construction programme was partly dictated by unexpected ground conditions, which meant the foundation design had to be reworked.


The delivery yard will service the mixed use building in the Moor shopping precinct

Keith Hogger, contracts manager for main contractor Bowmer & Kirkland (B&K), explains: "We had planned to build a reinforced concrete pad foundation, ranging from 600mm to 1,000mm deep, over an existing basement car park, but ground investigations revealed instability under the planned mixed-use building. Here, part of the underlying strata had disappeared, a legacy of the local mining history, and this required PFA cementitious grout injections. Additionally, we changed the foundation design in this area, because of concerns about the strata and also the high loadings from the superstructure, to CFA piling (350mm to 600mm diameter) and groundbeams, with the steelwork structure sitting on pile caps."

However, this unexpected extra work meant that B&K had to change from the original plan and commence with the Primark store first, while the groundworks on the mixed-use building progressed.

"This made the logistics more challenging, as we would have preferred to erect the larger steel frame first, which would have made site access for materials more straightforward," says Hogger.

The two buildings are structurally independent but separated by a 70mm wide movement joint. The Primark store is set out on a 7m x 8m grid, with variations to accommodate the access ramp, lift and cores.

"It is a portalised sway frame to avoid bracing on the glazed elevations at the front, though there is some bracing in the back of house areas," explains Mark Hamer, associate director with structural engineers Sanderson Watts Associates. "The store has suspended floors and a plant roof made from reinforced concrete, designed to act compositely with the supporting steelwork beams."

In a variation during the construction programme, Primark requested that provision was included to allow for installation of an extra escalator at second floor level. "This was after we had erected the steelwork," explains Hogger, "so we created an opening for a temporary infill in the structure, which will allow the tenant to install the escalator during the fit out work. It demonstrates the flexibility of structural steel."

The mixed-use building, which uses almost twice as much steel (700t) as the store, is the more complex of the two, chiefly because of the service area. This column-free space, 10m in height and extending 5m below ground level, has been created with 11 lattice trusses, 28m long and 2.5m deep, and weighing up to 39t.

"These provide support to the columns of the floors above, which follow the same grid as the Primark store apart from on the second floor," says Hamer. "Here, a number of columns are offset to allow for a pedestrianised mall, with transfer beams supporting the cinema. It has been a big challenge chasing all those loads through the transfer structures down into the foundations."

> THE TENANT CAN INSTALL AN ESCALATOR DURING THE FIT OUT. IT DEMONSTRATES THE FLEXIBILITY OF STRUCTURAL STEEL
>
> KEITH HOGGER, BOWMER & KIRKLAND

The third, cinema level of the superstructure comprises two rows of mono-pitched portal frames spanning the screening rooms at 4m centres. "These support composite floors on two levels, including the cinema roof, where the plant is located," explains Hamer. "The cinema also has a floating reinforced concrete floor for acoustic insulation purposes."

Above the auditoriums is a 24m long 17t truss at roof level and a series of 30m long rafters to form the mono pitch roof.

The heavy duty nature of much of the steelwork has added to the logistical challenges for B&K and steel erector Hambleton Steel. "The cinema roof beams had to be brought to site in three pieces for ease of transportation, and the service trusses arrived in two pieces," explains Hogger.

The contractors have used two mobile cranes and one tower crane, supported by MEWPs with reaches up to 25m, to erect the steelwork. Tandem lifts were required for some of the bigger trusses.

"It has been a complicated coordination exercise as we have to bring materials in across a pedestrianised precinct," says Hogger. "There are no storage areas, so we had to manage deliveries on a just-in-time basis. The delivery vehicles had to arrive between 5am and 6am, we would then erect the steel during the course of the day, and the vehicles could only leave site after 6pm."

The build programme is now entering its final stages, and the buildings are being clad with a combination of precast stonework panels – to accelerate construction – curtain wall glazing and traditional metal cladding.

The Moor phase two is due to complete in October 2016.

PROJECT TEAM

CLIENT: Aberdeen Asset Management

MAIN CONTRACTOR: Bowmer & Kirkland

ARCHITECT: Leslie Jones Architecture

STRUCTURAL ENGINEER: Sanderson Watts

STEELWORK CONTRACTOR: Hambleton Steel

BOND STREET, ESSEX

The curvy facades of the Bond Street retail scheme in Essex's county town of Chelmsford have been shaped with a complex steel structure. Will Mann explains.

Bond Street is an eye-catching new retail development in the heart of Chelmsford, county town of Essex.

It's a part of the country known for its fondness for retail therapy, and the striking exterior – clad in over 40 different materials, including glass, masonry and zinc – should help the £50m scheme become a vital destination for local shoppers.

But its central location has made it a logistically difficult project for the construction team. A former car park, the site is bounded on three sides by the pedestrianised city centre, and to the east by the River Chelmer. That partly explains the choice of a structural steel frame. Additionally, steel has helped with the client's flexibility requirements, and made it easier to deliver the scheme inside a tight programme.

Mark Kraut, lead architect with WCEC, explains: "Large, open-plan retail spaces require maximum flexibility in the floor plans, which is obviously easier with steel. When the client doesn't have tenants in all the units, steel offers scope for tweaking the structural design if a prospective tenant has bespoke requirements. Speed was also of prime importance because there was a fixed, end-date agreed with anchor tenant John Lewis; it wouldn't have been possible to construct a concrete frame in the time available."

Before work began, there was a six-month earthworks phase to excavate a 275-space underground car park.

"We had to move 50,000m^3 of material off site," explains Simon Humphrey, project manager with main contractor Bowmer & Kirkland (B&K). "From the outset, this has been a challenging project logistically, with a tight site footprint and limited access, and we have had to organise a just-in-time system for all vehicle movements."

The 300,000ft^2 Bond Street development is split into four separate structures. The biggest of these houses the 120,000ft^2 John Lewis store, and additionally, in the south-west corner, a parade of 10 double-height retail units, confusingly called Block One, even though it is

WCEC

Visualisation of the development's steel framework

structurally attached to the department store to form one large braced frame.

To the south are the L-shaped Block Two, comprising three storeys of retail, then the two-storey Block Three, a standalone braced frame, which abuts a Debenhams store at the southern perimeter of the site. A car park ramp and service yard sits between these blocks.

To the east of the John Lewis store, on the banks of the River Chelmer, is Block Four, which houses restaurants and a five-screen cinema on the upper levels.

The steelwork design has been complicated by the underground car park beneath the department store and Blocks One and Two. "These structures have been largely set out on a 9m x 10.2m framing grid, which extends down into the car park and sits on pile caps and a 450mm foundation slab," explains Kraut.

In the John Lewis store, to create a more open-plan space on the top floor, alternate rows of columns have been omitted. Spans on this floor are up to 24m. The building has a pitched roof supported by two rows of 21m-long x 1.8m-deep trusses.

In Blocks One and Two, again to free up space, transfer beams have been used at ground floor level. These are typically 914UB section sizes of varying weights spanning up to 18m, and supporting two columns up to roof level.

Block Four, housing the cinema, has been the most complex to design and construct.

LARGE, OPEN-PLAN RETAIL SPACES REQUIRE MAXIMUM FLEXIBILITY IN THE FLOOR PLANS, WHICH IS OBVIOUSLY EASIER WITH STEEL

MARK KRAUT, WCEC

"The lower two floors are concrete, while the cinema itself is steel, to achieve the long spans required in the auditoriums," says Kraut.

The cinema steelwork, which has a piece count of over 1,000, has been tied into stair cores rather than using bracing.

The block has an unusual shape, tapering into a "bulls nose" feature at the south-eastern corner while the northern end forms a semi-circle. The structure is based around a 6m perimeter grid, but for the bull's nose, the structural design is cantilevered, sloping outwards from ground floor level and widening up to a maximum depth of 3m. To achieve the bull's nose affect on the facade, extensive secondary steelwork has been required.

"Block Four is curved in plan and section, but we couldn't create that effect in structural steel alone, which is where the use of a lightweight steel framing solution came in," explains Kraut.

Indeed, this approach has been used throughout the project to achieve the complex facade design.

"It is becoming more common for retail projects to keep the main steelwork design fairly straightforward, and pick out the form of the facade using a secondary frame," says Kraut.

"For the pedestrian malls, the facade 'steps in and out', so we created a standard line of columns and beams for the structural steelwork, and then the deviation is achieved with the secondary frame. However, because so many different materials have been used for the facade, the detailing and interfacing has been a big challenge."

Steelwork contractor Caunton Engineering carried out the frame erection using a self-erecting crane and two mobile cranes, the largest with a 100t capacity, supported by mobile elevating work platforms. The John Lewis structure was the first to be erected, following the groundworks phase.

"It was tricky to plan, because the site footprint is tight and we couldn't use tower cranes due to oversailing concerns," explains Humphrey. "Additionally, we had to work out of the basement car park for two of the structures."

The steelwork erection has occupied around half of the 18-month programme, split into two phases. It has accommodated two major design changes.

"Block Four's structure was completely redesigned, down to the foundations, to accommodate a slightly bigger grid," says Humphrey. "It backs on to Debenhams, who wanted the option of extending their store into Block Four at a later date. Additionally, the steel frame was strengthened in the cinema to allow bigger spans – these are up to 16m.

"However, neither of these changes have delayed the project – indeed they show the flexibility of steel frame construction. We could not have hit our programme dates incorporating these changes in a concrete frame."

The Bond Street development is due to open for Christmas 2016.

PROJECT TEAM

CLIENT: Aquila

ARCHITECT: WCEC Architects

MAIN CONTRACTOR: Bowmer & Kirkland

STRUCTURAL ENGINEER: Mott MacDonald

STEELWORK CONTRACTOR: Caunton Engineering