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Edited and written by **Martin Cooper**

Industry Report

STRUCTURAL STEELWORK IN ACTION

> “ To maximise the available space, the frame utilises slim sections

STRUCTURAL STEELWORK IN ACTION

INSIDE STORY

STUDENT ACCOMMODATION REVIVES HISTORIC CHAPEL IN MANCHESTER

A number of structural steelwork's attributes have come to the fore on the restoration and conversion of a Manchester ecclesiastical landmark.

Built in the 1830s by Sir Charles Barry, famous for his rebuilding of the Palace of Westminster, the Welsh Baptist Chapel in central Manchester is being brought back to life with a new steel-framed interior to form student apartments.

The scheme will provide 73 high quality, private residential apartments within the chapel and the adjacent Sunday school building (*see box*). The project also incorporates a contemporary new build element, providing facilities including a fitness room, cinema room and residents' lounge.

The new build will be linked to the restored chapel by an underground passage, excavated through the area that once accommodated a graveyard.

The chapel is situated on Upper Brook Street and the Grade II listed building has been a local landmark for many years, although in recent times it had been derelict and without a roof.

The current work will help remove it from Historic England's At Risk register, while restoration work will repair and revive the existing fabric. This includes retention and repair of the distinctive rose window, corbels and vaulted springers along with the reconstruction of the chapel roof.

A structurally independent steel composite frame has been erected inside the chapel to form a new six-storey apartment block. This new frame supports a new steel and timber roof that that has the same pitch as the original Victorian structure.

PROJECT TEAM

Project:
Welsh Baptist Chapel, Manchester

Main client:
Czero

Architect:
Buttress Architects

Main contractor:
HH Smith & Sons

Structural engineer:
BuroHappold Engineering

Steelwork contractor:
EvadX

SUNDAY SCHOOL WORK

Housing 12 of the project's apartments, the adjacent Sunday school is now linked to the chapel via a glazed passageway.

The building measures approximately 11m by 11m, and to create more floor space, a new first floor has been installed within the load-bearing masonry structure.

Additional headroom was needed and so the building's timber roof trusses have been cut and two steel cranked moment frames installed in their place.

The cut trusses will be retained within the project and act as a key feature within two apartments.

The school building was in a much better state than the chapel and was being used until recently.

Restoration work has included repairing the roof, by replacing missing slate tiles, and renovating the exterior.

"Having an independent frame was important, as we wanted minimal impact on the existing chapel walls," says Buttress Architects' Samantha Gill. "The steelwork sits within and not on the historic building, meaning that there are no additional loads on the stone and brickwork walls. The existing fabric is only tied back to the steel frame by small channels, and so the existing structure acts a cladding around the new structure."

Another reason for choosing steel was that a lightweight solution was needed for the new interior., one that would not require expensive deep foundations. So, like the original chapel walls, the new steel frame is founded on ground bearing foundations.

To maximise the available space, the frame utilises slim sections, typically 152mm by 152mm by 37mm universal columns and 203mm by 133mm by 30mm universal beams, that support metal decking with only a 140mm-thick concrete topping for the floors.

Finding suitable locations for the steelwork's bracing was a challenge for the design team, as BuroHappold engineer Carl Pendlebury explains: "The chapel's existing windows prevented us from using the perimeter steelwork for bracing locations and so we had to put it within a lift and stair core, as well as in the roof."

Steelwork is based around a 4.2m by 4.2m grid pattern for most of the floors, but has been offset across the building and in parts is irregular to avoid putting columns in front of, and obscuring, the chapel's existing windows.

Another design consideration was that the new steel columns could not clash with the vaulted springers that once supported the roof. Spaced along the two main walls at approximately 3.5m intervals, they are now key features of the new scheme and as such they have been incorporated into the third-floor apartments.

Overall the new steel frame incorporates two rows of apartments with a central dividing corridor. This configuration is only interrupted on the uppermost accommodation floor, where some slightly larger rooms are located. To support the column grid change, a series of transfer beams has been installed below this sixth level.

Before the steelwork was erected within the chapel, main contractor HH Smith had already begun its extensive restoration work on the structure, as well as preparing the chapel interior for the installation of the new frame.

Early in the programme, HH Smith installed a tower crane for the site and this was used by steelwork contractor EvadX for lifting steel over the existing walls.

"To make it easier to lift the columns into the chapel we had to splice the members in three," explains EvadX drawing office manager Andrew Roberts.

Space was at a premium and so the steel erection process had to be planned carefully.

"We knew once we had the entire steel frame up we would then have the problem of how to get the mobile elevating work platforms (MEWPs) out of the chapel, as they were hemmed in under the first floor steelwork," adds Roberts. "The narrow entrance we used to get the machines into the structure was now blocked by four new columns."

The solution was to leave the MEWPs where they were until the floors had been cast. At this point the team was able to remove beams under the first floor, which was propped by HH Smith, remove the MEWPs through the entrance, and then reintroduced the four columns using the splice connections. The project is due for completion in July.

Far left: MEWPs work on internal frame
Above left: Cutaway of finished work
Above: Frame sits within existing structure

Key fact

96t
Amount of structural steel used


A steel frame was chosen after comparisons with a concrete design

STRUCTURAL STEELWORK IN ACTION

TIME FRAME

SCOTTISH COMMUNITY CENTRE AND HIGH SCHOOL CHOSE A STEEL FRAME FOR SPEED AND VALUE

Incorporating a number of community facilities as well as a high school, the Newbattle Centre is set to reinvigorate the former Midlothian mining towns of Mayfield, Easthouses, Newtongrange and Gorebridge.

The state-of-the-art community hub and high school is under construction in Easthouses. The centre will replace an existing school and provide a range of facilities for the local catchment area which includes a number of former mining towns.

The steel-framed building is 15,714m2, and it will accommodate a new library, gym, swimming pool, sports facilities (including all weather pitch) as well as a high school containing further community facilities.

The building is being delivered by Midlothian Council's development partner, Hub South East, and its appointed contractor Morrison Construction.

Designed by Cooper Cromar, the £34M project is expected to open in 2018 and will accommodate up to 1,200 pupils.

The Newbattle Centre has three distinct parts, a triple-span structure housing the sports facilities, the teaching block, which is three storeys high and – joining these two parts together – a single storey link structure that accommodates a library, a café and the main entrance/reception.

The sports accommodation was always going to be a steel-framed structure, with its requirement for long clear spans. However, the decision to use a steel framing solution for the teaching block was not so clear cut.

"The client wanted a 3.5m-high floor-to-ceiling height with a clear and exposed soffit, something that had been achieved at one of its previous schools.

"That project had used a concrete frame, but on this project, we suggested a steel solution, which would be more cost-effective and as quick to build," says Morrison construction manager Jeff Thornton.

A frame analysis was conducted, and this showed that the steel option could deliver everything the client wanted. The design incorporates steelwork supporting precast planks from the bottom flange with the aid of welded on plates.

The new building houses community facilities and a high school

"During the fabrication process, all the teaching block's beams had plates welded on to them as landing points for the slabs," explains Hescott Engineering director Alan Scott.

In its finished state, the steelwork has been moved into the depth of the floor, while the underside of the precast slabs and the beams are painted white, all of which creates a seamless clear exposed soffit in the classrooms.

The teaching block has two rows of classrooms, on every floor, positioned along both main elevations. Circulation routes overlook a large open full height atrium located in the middle of the building.

The atrium is topped with roof lights that will allow natural light into the structure's inner areas.

The ground floor of the atrium accommodates the school's dining hall and assembly hall, a facility that can also double-up as a public theatre space.

A wide feature staircase, with terraced seating areasalong one side, leads from this zone up to the building's first floor level.

Structurally, the teaching block is predominantly built around a regular 8m grid. Stability is derived from vertical bracings, which are mostly located in stair cores.

Adjoining one end of the teaching block is the single storey link building. This long-span area houses the main entrance, a library and a café, all of which will be open to the local community.

As the name suggests, the link building offers accessand joins the two parts of the centre. As the entire steel frame of the project is so large – more than 100m long – the link is structurally separated from the sports zone by a movement joint.

The sports zone is divided into three braced long span areas, each topped with a shallow dual-pitched roof. For economy reasons, Westok cellular beams have been used to form each of the three roofs.

Explaining the reason for designing braced frames instead of portal frames for the halls, Arup senior engineer for building structures Gary Stephen says the decision was based on aesthetics.

PROJECT TEAM

Project
Newbattle Centre, Easthouses, Midlothian

Main client
Hub South East Scotland on behalf of Midlothian Council

Architect
Cooper Cromar
Main contractor: Morrison Construction

Structural engineer
Arup

Steelwork contractor
Hescott Engineering

"Portal frames, with their deeper columns, work perfectly well in distribution centres or industrial buildings where it doesn't really matter if columns protrude into the structure.

"But in our sport facilities we wanted the steel columns to be as narrow as possible to give us smooth walls and this meant we had to have braced frames."

> **"In our sport facilities we wanted the steel columns to be as narrow as possible to give us smooth walls and this meant we had to have braced frames**

The bracing is located in the roofs, which are braced in two directions. This then diverts the loads to further vertical bracing positioned in perimeter and division walls.

Of the three sports halls, the middle one housing a fitness suite and changing rooms is the widest with a span of 33m. This hall accommodates a mezzanine level, formed compositely with metal decking.

This extra floor will have a large glazed façade giving people using the facility's exercise machines views over the surrounding countryside.

Either side of this hall are two slightly smaller areas. A multi-sports hall with a 26m-wide span, and an 18m-wide hall housing the centre's 25m-long six lane swimming pool.

Summing up Thornton says: "This is an exciting new development for the communities of Mayfield, Easthouses, Newtongrange and Gorebridge, and Morrison Construction is delighted to be a part of it.

"The Newbattle Centre will provide a fantastic, modern environment for the community to enjoy and a stimulating learning environment for staff and pupils."

COST BENEFITS

Steel construction has many proven benefits over alternative framing materials. Steel is able to demonstrate a uniquely high correlation to circular economy principles thanks to features like its recyclability, versatility, and ability to be designed with future changes of use or material reuse in mind. As a framing material, steel also delivers shorter construction programmes and lower embodied carbon use.

However, cost is always at the forefront in the choice of framing material. The good news is that steel outperforms other materials in this area as well.

The steel sector has a long history of providing design and other guidance that engineers, architects and other construction professionals value in making the design and construction process as straightforward as possible. That service is being extended with a new series of studies called *Costing Steelwork* that will be published quarterly on www.steelconstruction.info

Costing Steelwork is produced by Aecom, the British Construction Steelwork Association and Steel for Life. Each quarter it will examine the key cost drivers for a range of building types, providing a type-specific cost comparison. A cost table will indicate the ranges of costs for the main alternative types of frame.

"The cost ranges will act as a benchmark that can be used at all the stages of the design," explains Steel for Life's Chris Dolling. "We will ensure that the data is always current through regular updates that will be made freely available."

A previous series of *Steel Insight* studies focused on office buildings only, but *Costing Steelwork* will deliver guidance on a wider range of building types. The series starts with a focus on the offices sector, with a detailed cost model based on an office building that has actually been built (*see box*). The study looks at the process of cost planning throughout the design stages, and examines the key steel framing cost drivers for office buildings.

Future updates will provide the same insight for education, mixed-use, retail and industrial buildings, all based on actual projects that have been completed.

ONE KINGDOM STREET

Aecom's cost comparison of an actual building looks at the steel-framed, 10-storey, grade A central London office at One Kingdom Street near Paddington railway station which was completed in 2008.

The building comprises 10 storeys with two basement levels and plant housed at roof level. It incorporates clear spans of 12m by 10.5m and was built with three cores, with an open atrium on the main core.

This cost comparison updates cost models developed in 2010 when the building was part of the Target Zero study to provide guidance on design and construction of sustainable, low and zero carbon buildings. Costs current in the first quarter of 2017 were used for the new Costing Steelwork study.

The 40m high building is rectilinear, with a footprint of 81m by 45m. The western half of the building is partly constructed on a podium transfer structure that encloses works access for the Crossrail project. It is founded on 750mm diameter bored piles with in situ pile caps laterally restrained by ground beams. The piles are the same size as those used to support the Crossrail podium to reduce the potential for differential settlement.

Two structural options were assessed with a concrete-framed post-tensioned concrete flat slab for comparison.

The key costs for both options can be seen above. The analysis shows the steel composite solution as 7% lower than the concrete alternative for the frame and upper floors, and 5% lower for the total building.

Analysis also shows that the steel-framed building has an embodied carbon content 11% lower than the post-tensioned concrete flat slab alternative.

Key costs £/m² (GIFA) for Central London office building

Elements	Steel composite	Post-tensioned flat slab
Substructure	84	89
Frame and upper floors	402	433
Total building	2,485	2,612

COSTS BENCHMARK FRAMED

Aecom has provided costs based on the structural framing of a commercial office development in central London, expressed as a cost/m² on gross internal floor area, to be used as a benchmark. A range of costs is indicated for the key costs drivers as these can vary between projects for a variety of reasons, as detailed in the full report.

To use the table, first identify which frame type most closely relates to the project being costed, select and add the proposed floor type and add fire protection if required.
Any estimate that falls outside these ranges should be taken as a signal that the design should be looked at closely to determine why this might be so.
Location of a project will be a key factor in establishing price and indices are used to allow for adjustment of cost data between regions. The variations in these indices, such as the BCIS location factors as shown right, provide a clear indication that market conditions differ between regions to a significant extent, which is a key consideration for cost analyses to take into account.

Location	BCIS Index
Central London	125
Manchester	99
Birmingham	98
Liverpool	96
Leeds	95
Nottingham	93
Glasgow	93
Newcastle	92
Cardiff	91
Dublin	90*

* Aecom index

Indicative cost ranges based on £/m² (GIFA)

Type	Central London	Notes
Frames		
Steel frame to low-rise office	115-138	Steelwork design based on 55kg/m²
Steel frame to high-rise office	195-220	Steelwork design based on 90kg/m²
Complex steel frame	220-260	Steelwork design based on 110kg/m²
Floors		
Composite floors, metal decking and lightweight concrete topping	75-110	Two-way spanning deck, typical 3m span with concrete topping up to 150mm
Precast concrete composite floor with concrete topping	115-165	Hollowcore precast concrete planks with structural concrete topping, spanning between primary steel beams
Fire protection		
Fire protection to steel columns and beams (60 minutes resistance)	18-25	Factory applied intumescent
Fire protection to steel columns and beams (90 minutes resistance)	20-35	Factory applied intumescent

THE GAP WIDENS

Uncertainty generated by factors like Brexit has increased across the industry, says Aecom in a market update that accompanies its cost analysis, but its impact on market pricing has been muted so far.

The update, based on government figures, shows input costs for all industries rising at their fastest rate since 2008, with further rises to come. Building prices in the first quarter of 2017 rose at a slowing rate, but still one that is higher than the long run averages for tender price inflation. Lower forecast construction output will add some downward pressure to prices over the next two years, although material prices will still rise, albeit at a slower rate.

Aecom expects tender prices to rise 3.2% over the year from the fourth quarter of 2016, and 1.9% in the year from the fourth quarter of 2017.

LIGHT & SPACE

STRUCTURAL STEEL ADDS FLEXIBILITY TO THE BBC'S NEW CARDIFF HEADQUARTERS

Designed by Foster & Partners, the new steel-framed home for BBC Wales is quickly taking shape as part of a large redevelopment of central Cardiff.

The new BBC Cymru Wales Broadcasting House is a 13,900m^2 building set over five floors, including office, studio and production areas, and working space for over 1,200 staff.

The project forms an integral part of the Central Square development, which is radically altering a large swathe of land directly opposite Cardiff Central Railway Station.

On the plot of the city's former bus terminal, the scheme will eventually yield commercial office space, a new frontage to the railway station, and most prominently, a new headquarters building for BBC Wales.

Plot one of the scheme, consisting of an office block, was handed over last year and plots two and three are now under way. For this second part of the development, main contractor ISG will construct the new BBC building and Two Central Square (a 10-storey speculative commercial building) – totalling an £80M package.

Before the steelwork programme could get under way, ISG had to form a 7,000m^2 basement structure by installing secant piles and excavating approximately 50,000m^3 of material, which was removed and re-used offsite.

The BBC building has been designed as a hybrid structure, with a reinforced concrete frame to ground floor level – encompassing two basement levels, three concrete cores and a steel-framed superstructure for the upper floors.

"Steel for the upper levels has been used for a number of reasons, such as speed of construction and the ability to create the 18m-long clear spans in the offices, which provides the BBC with maximum flexibility," says ISG project director Kevin McElroy.

"To help speed up the programme, we also changed the design of one core from reinforced concrete to steel."

The design is also based around creating visibility and connectivity by allowing as much daylight into the inner parts of the headquarters as possible.

To this end, it consists of three main elements: two five-storey office blocks arranged in an L-shape around a centrally positioned media hub structure. Separating the offices from the hub is a large 9m-wide and 30m-high covered atrium.

"All three parts are connected to form one large steel frame, with the cores, which are all positioned in the offices, providing the structural stability," explains Arup director Ben Tricklebank. "The media hub has no cores, but bridges across the atrium connect it to the offices and thereby provide stability."

Steelwork contractor Severfield began its erection sequence with the media hub as this is the most complex part of the headquarters, and the area that will require the longest fit-out.

The majority of the project's steelwork will be left exposed within the completed building, and consequently aesthetically-pleasing CHS columns are predominantly being used.

Visible connection details have been designed to be as aesthetically pleasing as possible too, with many beams tapering to provide the slimmest connection.

Five acoustically isolated television studios are located throughout the five floors of the hub, with the main and largest facility positioned at second floor level. To

KEY FACT

2,100t
Amount of structural steel used

PROJECT TEAM

Project
BBC Wales Broadcasting House, Cardiff

Main client
Rightacres

Architect
Foster & Partners

Main contractor
ISG

Structural engineer
Arup

Steelwork contractor
Severfield

construct the necessary isolated box-in-box configuration, the studio steelwork is supported on acoustic pads set into the concrete slab.

"The studio steelwork had to be erected later than the surrounding main frame as we had to wait until the floors were cast to ensure acoustic separation was achieved," explains Severfield project manager Glen McCleary.

To create the required column-free space for a ground floor studio, two transfer beams have been positioned at first floor level. These plate girder beams measure 20m and 17m-long and weigh 23t and 14t respectively.

Most of the steelwork is being erected with the onsite tower cranes, but for these transfer beams, a 500t-capacity mobile crane was needed.

The hub's uppermost floor steps back to form an outdoor terrace that overlooks the public realm in front of the railway station, while a third of this level is taken up by a roof garden containing a number of planters for shrubs and small trees.

Supporting the roof garden and creating the large column-free space below for the main studio required some bespoke steel design. Four 800mm-deep plate girders, weighing up to 12t and arranged in a diamond formation support the roof garden.

This formation was chosen for its efficiency by lessening the distance the steelwork has to span. The girders are connected to the surrounding steel frame via a series of nodes, all of which cater for multiple beam connections and weight up to 3.5t each.

Topping the hub is a large canopy roof, supported by ten, 28.2m-high CHS columns positioned along two perimeter elevations. Elsewhere the canopy is supported off of the main internal steel frame.

Top left: The steel frame connects the three parts of the building

Top right: Structural steel forms the above ground part of the building

"The canopy supporting columns were brought to site in single pieces as a splice would have ruined their appearance

"The canopy supporting columns were brought to site in single pieces as a splice would have ruined their appearance," says McCleary.

"They are the longest elements to have ever left our Northern Ireland facility, and transporting them to site was very challenging."

Housed within the atrium are three steel feature staircases, providing connectivity between the hub, atrium and the adjacent offices.

The office's design is based on 9m bays with internal spans of 18m. Fabsec cellular beams have been used throughout for service integration and to create the desired clear flexible working spaces.

Summing up, Alan Bainbridge of BBC Property, said: "Getting the BBC project from the design board to site has been a huge team effort and we are delighted that this project is now becoming a reality. Together with Rightacres and ISG and the respective design teams we are developing a facility which delivers real value for money."

The BBC building is scheduled for a Spring 2018 completion, after which a fit-out programme will commence.

STRUCTURAL STEELWORK IN ACTION

CUTTING EDGE

52 LIME STREET IS LONDON'S LATEST STANDOUT COMMERCIAL DEVELOPMENT

> “We've made a considerable weight saving, as all of the beams have varying flanges and webs

PROJECT TEAM

Project name:
52 Lime Street, London
Main client:
WR Berkley Corporation
Architect:
Kohn Pedersen Fox
Main contractor:
Skanska
Structural engineer:
Arup
Steelwork contractor:
William Hare

Featuring a dramatic architectural shape with asymmetric facets and a pointed attic roof structure, 52 Lime Street has from its inception been dubbed the Scalpel, a name that has since been adopted as the official moniker.

Joining a cluster of other prestigious high-rise buildings in the Square Mile, the 190m-high project will offer 36,966m^2 of internal floor area over 35 office floors, retail and restaurant areas.

Designed by architects Kohn Pedersen Fox, the project also includes a public square. The realm may also provide space for public art and tables linked to a specialist ground floor coffee shop, designed as a nod to the 17th century establishments that acted as meeting houses for London's fledgling insurance market.

Setting it apart from its neighbours, the Scalpel features an inclined northern façade, which has a diagonal fold line running from top to bottom giving the building its distinctive look and name.

This façade is formed with a series of cranked plate girder columns, spaced at 6m centres. For the double-height ground floor these columns are vertical, but from first floor they are cranked and slope inwards all way to the building's pointed top.

Elsewhere, the structural frame consists of a composite design with steelwork supporting metal decking and a concrete slab. All of the floor beams are 670mm-deep fabricated plate girders with service holes to allow service integration within the structural void.

Commenting on the decision to use a steel framing solution Skanska project director Ian Perry says: “Using steelwork is an efficient option for this type of construction project, as buildability and speed of construction are vital on a city centre job.”

Key fact

10,500
Tonnes of steel used in the project

Cost also plays an important role in any construction project and the use of building information modelling (BIM) on this scheme has helped the team ensure the steel frame is as efficient as possible.

“We've made a considerable weight saving, as all of the beams have varying flanges and webs depending on the relevant loadings,” explains Arup project engineer Steve McKechnie. “All of this was worked out automatically via the BIM model.”

Having taken possession of the site once the demolition of the previous building to ground floor level had been completed, Skanska's initial task was to complete the basement works before steel erection started.

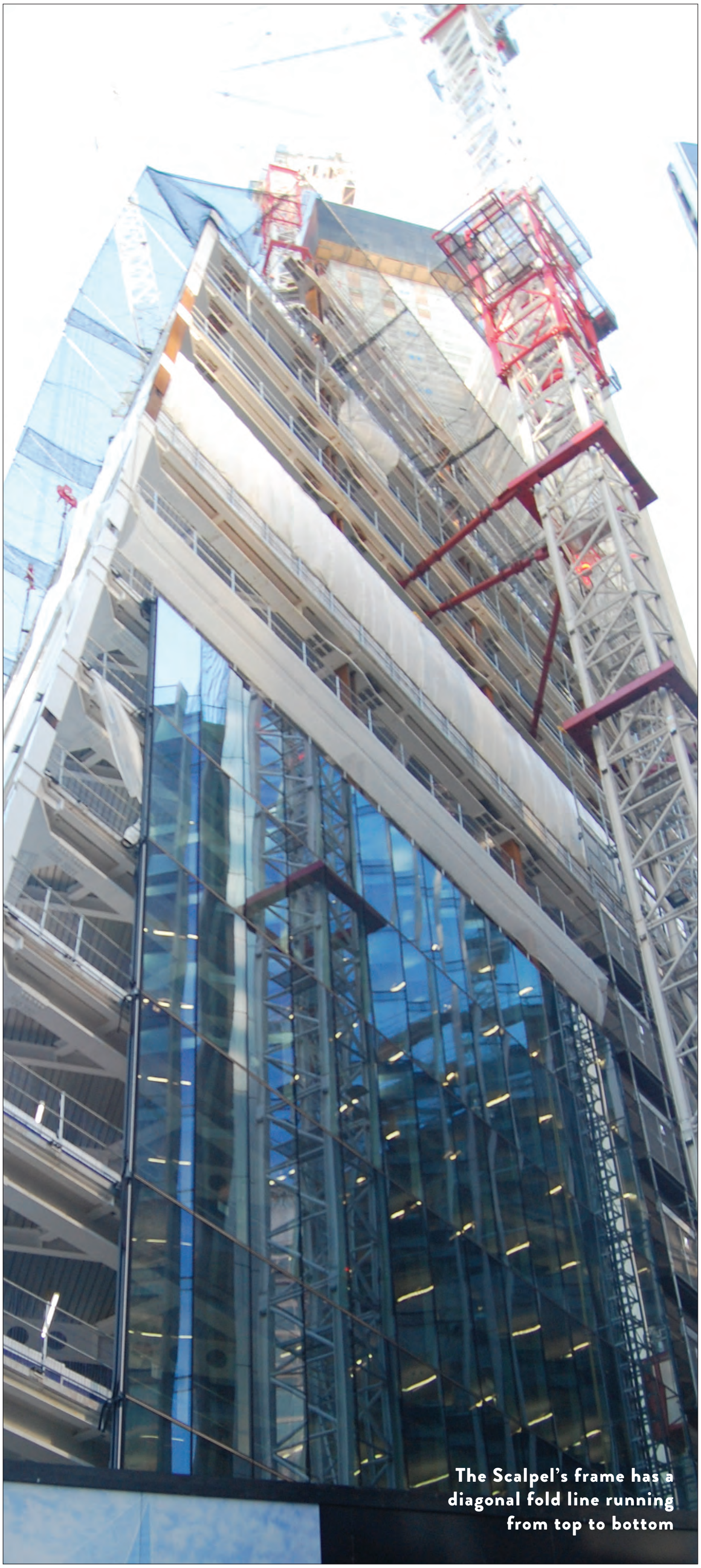
A third of the existing basement was partially deepened, and to keep the construction programme on schedule, the ground floor slab was cast early.

This allowed the basement construction to be done using a top-down method, while the steel erection proceeded above, simultaneously.

Early works also included constructing the building's main concrete core. Once this had reached its halfway point at level 17, the steel erection programme was kicking off at ground floor.

Unlike many commercial buildings, the Scalpel's main core is offset and positioned along the south elevation, which provides shade from solar gain. In this way, the structure's available floor space has been maximised and internal spans of up to 20m have been achieved.

Having an offset core coupled with an inclined north elevation means that the loads on the building are eccentric


The Scalpel's frame has a diagonal fold line running from top to bottom


How the finished building will look

from the main stability-giving core. To counteract this, the north elevation, as well as the east and west facades, have been designed as large perimeter moment frames to add stiffness to the building.

The core houses three banks of lifts, one for the lower levels (1 to 12) one for the mid-levels (13 to 24) and one for the upper floors (25 to 35). This means the core decreases in size towards the top as only one bank of lifts is accommodated at the upper levels. Again, this has helped the project further maximise the available floor space.

Because of the building's inclined northern elevation, floor areas decrease from 1,466m^2 on the second floor to 614m^2 on level 35, the uppermost office floor. Up to level 21, the building has one row of internal columns, but as the floor plates decrease in size, these are no longer needed, and by level 24 there are none.

Topping the building is a 10-storey triangular attic that will house plant and maintenance walkways. A high piece count would have ordinarily been expected for this structure, so in order to make the erection process as easy as possible and iron-out any snags, William Hare will trial erect this portion of the building at its fabrication yard.

"Once it has been trial erected, the attic structure will be dismantled and then brought to site in the largest pieces that can be transported and erected by the on-site tower cranes," explains Perry.

The attic is a complex steel structure designed to be erected floor level by floor level, with each level immediately stable on erection. Designing the attic in this way was vital as there is no core to give stability this high up the building, and no internal floors to provide diaphragm action.

The project is scheduled for completion later this year.