Steel breaks the boundaries

London’s latest skyscraper at 20 Fenchurch Street, known as The Walkie Talkie, is expected to reach its full height this month - and composite steel plays a major role in its challenging construction.

20 Fenchurch Street
RUBY KITCHING

Project
20 Fenchurch Street,
London

Developers
Land Securities, Canary Wharf Group

Architect
Rafael Viñoly Architects

Construction manager
Canary Wharf Contractors (a subsidiary of Canary Wharf Group)

Structural engineer
Halcrow Yolles

Steelwork contractor
William Hare (main structure)

The 38-storey building at 20 Fenchurch Street is the latest architectural icon to appear on London’s skyline. Unlike neighbouring 30 St Mary Axe (the Gherkin) and The London Bridge Tower (The Shard) across the Thames, 20 Fenchurch Street does not taper with height. Instead, the building’s floor plate flares to achieve a 50 per cent area increase at the top, compared with ground level.

The office building has been designed to take advantage of the volume of space bounded by the site and protected historic sightlines across London.

On the ground, this has the effect of creating more public space around it than is usual for most skyscrapers that are built right up to their site boundaries.

The building is expected to reach its full height this month when its uppermost floor, at level 35, is crowned with a portal frame superstructure up to 20 m tall. This 1,200-tonne addition will partially enclose the rooftop Sky Garden, a partially glazed restaurant and bar which offers 360-degree views across London. Open-plan offices will occupy the building up to level 34.

The building’s superstructure is of composite steel and concrete floor construction with steel columns. Around 9,000 tonnes of steel has been used in fabricated box section columns, cellular beams and decking.

Reduced footprint

Double decker lifts reduce the elevator footprint in the building, which means that the services core does not dominate the reduced floor plate at lower levels. Two shuttle lifts serve the Sky Garden.

The north and south elevations of the building have a fully glazed perimeter while the east and west elevations feature vertical aluminium louvres, or fins, for solar shading. The position of these fins line up with the steel members which make up the portal frames over the Sky Garden.

Creating the impression that these lines wrap over the building, the south side of the building, facing the river, is concave and is lower in height than the north elevation, which features a triple-storey space over the Sky Garden. The building’s shape, distinctive fins and glazed elevations have earned it its nickname, The Walkie Talkie.

The core is usually located in the centre of an orthogonal building, which coincides with its centre of mass. At 20 Fenchurch Street, however, the core is located off-centre, creating varying length sightlines across London.

The steelwork contractor William Hare began on site in February 2012. The steel breaks the boundaries of the canary Wharf Estate.

During construction, deliveries had to be carefully managed to reduce disruption to local businesses and traffic. On the west of the site, Philpot Lane had to be closed between 8am and 4pm to allow deliveries to take place. CWC also took responsibility for deliveries to nearby retailers to ensure the highest levels of safety were maintained around the building.

CWC is part of developer Canary Wharf Group, which has transformed the Docklands area of London. The project is one of the first major buildings to be built by CWC outside of the Canary Wharf Estate.

CONSTRUCTION NOTES

The building is made up of two basement levels, offices up to level 35, a Sky Garden at level 35 and roof which takes the building to level 38. Piling on the site commenced in January 2011 at a level 6 m above the existing building’s single basement slab level. This basement area had been infilled to support the existing perimeter cantilevered basement wall. Site workers installed piles and to the underside of the lower basement level and a system of props was introduced to support the upper (existing) basement walls while the fill was excavated and lower basement walls constructed.

To maintain a fast-track programme, Canary Wharf Contractors decided that the core and basement had to be built first to allow tower cranes to be built off the top of the core. These cranes would then be needed to erect the main steelwork.

“this meant the basement propping system had to be designed to allow for the core to slide up through it,” says CWC’s associate director of construction operations Charles Paul.

In August 2011, core construction began and was completed by February 2012 when steelwork contractor William Hare began on site.

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Delivery of some of the longest aluminium members – the fins – on the east and west elevations took place at night during road closures when they could be safely hoisted up by tower crane to level 35 before being erected.

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spans between the core and perimeter columns. To maintain clear spans between core and columns and to limit the depth of beams, prefabricated steel sections of varying thicknesses were specified, installed by steelwork contractor William Hare.

Rational thinking

“We rationalised the shape of the core,” says CWC associate director of construction operations Charlie Paul. “Instead of accommodating services, stairs and lifts, the building’s core only contains stairs and lifts. He adds: “The services risers are located just east and west of the core and are separated by dry-lined partitions. This means that the profile of the core can stay constant throughout the height of the building, as the serving volumes diminish with height, the risers can get smaller, allowing more space to be used as part of the office floor.”

With the height of the building and floor-to-ceiling heights fixed and the core off-centre, the challenge for CWC-William Hare and Halcrow Yolles was to find a structural solution that could accommodate the increasing spans higher up the building. At second floor level, the beams only span about 11 m between core and perimeter column, but as the building flares out, the perimeter of the building is up to 22 m away from the core,” explains Mr Paul.

The solution was to design beams for a maximum 18 m span from core to perimeter column and to make up the remaining distance using a cantilevering beam. Column design had to support this arrangement. For the lower levels, the curved elevation is achieved by positioning straight columns at a constant angle in four-storey units. The curved appearance is achieved by faceting at intervals up the building.

The challenge for successful bonding of these members set the geometry of the facade in addition to transferring the structural forces. Steelwork contractor William Hare developed an endplate with a single fabricated member from the column splices to capture all of the complex four geometry. A welded spigot allowed the upper column section to be lowered onto the spigot, anchoring it in position. Extensive quality control measures were adopted during fabrication to ensure the spigot and box would couple together, leaving minimal gaps. This gave assurance that the correct angle was achieved in the columns, and being a simple and practical connection, meant that splicing these heavy columns at an angle (even at height) was straightforward.

Steelwork contractor William Hare developed the endplate appearance in a curved angle of inclination facing at intervals up the building.

The structural design philosophy required heavily loaded square column sections at the bottom of the building to be fabricated from a single plate up to the core – and a cantilevered section from column to cladding line. CWC could adopt a similar fast-track programme as one of its tall, rectangular buildings at Canary Wharf. The method, as described by Mr Paul, is as follows: “The steel frame structure is built up to level two using MEWPS (mobile elevating work platforms) as a platform. Decking is then lowered onto levels one and two and the MEWPS are lifted to level two, where it commences building levels three and four. We require two floors of overhead protection prior to casting the floor slab, so when we have finished levels three and four, the MEWPS are lifted to level four where erection of steelwork on levels five and six can commence. At this point, levels one and two can be cast and, soon after, fire protection can be applied on level one steelwork. The process means that each trade can complete a floor in a week; one has to wait.”

4D modelling

Four-dimensional modelling was used to demonstrate the anticipated build and programme – that is, how steel building information modelling with time added – as well as the challenge faced by the project to achieve the highest levels of safety and quality (see box, left). “We used information from the 4D model when we were interviewing bid teams. We showed them the challenges and said, ‘go away and find a better solution’, says CWC project planner Darren Rackett.

“The upshot was that tenders were returned with very few caveats, despite the fast-track programme, since the brief and its challenges were made so clear at the programme, since the brief and its challenges were made so clear at the interview stage.” Commercially, there are huge benefits in using 4D BIM because problems are identified and solved before reaching the site. “We’ve managed to find solutions to deal with all the technicalities borne from the complex shape of this building,” says Charlie Paul, CWC.

“The complexity of the building warranted the use of 3D modelling. Using BIM made it much easier for subcontractors to see the challenges we were facing,” says CWC associate director of construction operations Charlie Paul. “Four-dimensional modelling allowed the contractor to track construction issues virtually, so that they did not arise on site. It scrutinised the build programme in real time, giving CWC the opportunity to revise methods and make improvements to schedules, often before appointing subcontractors.

“When we were employing traffic management specialists, we could advise them, not only on the number and location of (dilators) we could shovelling circles and how various scenarios would have an impact on traffic flow. So keen was the contractor to explain participants and the scale of some of the challenges to prospective subcontractors, that during the bid process they presented 4D simulations of each subcontractor package of works to explain to tenderers the scale and complexity of the project. “In terms such as the application of the protection could be scrutinised on the model and then clearly scheduled in for all contractors to see,” says CWC project planner Darren Rackett. Installation and removal of edge protection in the form of story-height netting around the building as a falling debris was also modelled to ensure the activities were progressed to take the safest and most time-efficient way. While edge beams are installed with integral handrails, the netting had to be sequenced to ensure it did not impede connecting and cladding installation. The netting provided additional protection, especially when upper levels of the building stepped down over lower storeys. “4D BIM showed us the windows in time when edge protection could go up and when it could be taken down while allowing work to proceed around it,” says Mr Rackett.

To achieve the highest levels of safety and quality, the 4D BIM models were used to present clients with anticipated build programmes and, as a result, have been able to successfully provide solutions to the challenges encountered during construction, with a particular focus on fire protection. The challenge was to maintain high standards of efficiency as a result of the building being on a fast-track programme. For Mr Paul, it meant mounting the tower cranes on the core for the entire steel frame. Thus put the core on the critical path (see construction notes box). “We didn’t want tower cranes going up through the floors because that would mean you couldn’t finish a floor until they were taken down,” says Mr Paul.

Three tower cranes were built off the core. After the building is complete, the cranes will help dismantle each other until the last crane standing is small enough to be dismantled and transported by piling up to the ground. By rationalising the longer spans and the building into a beam spanning from core – and a cantilevered floor slab, so when we have finished levels three and four, the MEWPS are lifted to level four where erection of steelwork on levels five and six can commence. At this point, levels one and two can be cast and, soon after, fire protection can be applied on level one steelwork. The process means that each trade can complete a floor in a week; one has to wait.”

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A report from AECOM and the Sweett Group offers guidance on cost-effective ways of achieving a target BREEAM rating. It also suggests that higher ratings can be achieved with minimum expenditure.

**Steel Spotlight**

Uplifting buildings

BREEAM RUBY KITCHING

BREEAM assessment involves evaluating a building’s specification, design, construction and use against established benchmarks according to nine categories. Credits are awarded in each category according to the building’s performance, which are then combined to produce a single overall score on a scale of Pass, Good, Very Good, Excellent and Outstanding.

The higher ratings of Very Good, Excellent and Outstanding are increasingly becoming part of conditions set by planning authorities, but can be set by exemplar clients seeking the highest environmental standards.

Research carried out by AECOM and Sweett Group for standard, base-case buildings for five building types - distribution warehouses, supermarket, school, office and mixed-use building - has been consolidated to give a simple summary of the research.

Measures required to improve BREEAM ratings for a typical office building

Project teams a helpful starting point for achieving the desired BREEAM rating in the most cost-effective way. The Target Zero project used real buildings as the basis for each study. As part of the research, the implications of achieving each BREEAM credit were considered and the cost of achieving it determined. Detailed information is contained within the guides published for each building type, but summary statistics have now been produced to give a simple summary of the research.

Comparison of cost uplift for different approaches to design for a typical office building

The research (graph, left) compared the cost uplift for different approaches to design for a typical office building, reflecting the influence of location and other aspects on the achievable BREEAM score and hence cost. AECOM modelled different scenarios, including different locations and site conditions, and different design and contractor assumptions.

Sweet compared cost uplift for different approaches including a typical office building, and found a significant variation in cost depending on whether a ‘poor’ or ‘best’ design and construction approach was adopted.

A ‘poor’ approach is defined as one in which credits are lost when decisions are not taken to pursue them at early stages in the design process. An example of an early design decision is procuring an exemplar contractor that is able to achieve contractor-related credits.

The breakdown of cost by BREEAM category is also shown. For example, the cost from a Very Good rating was only 0.44 per cent (£268,900) when adopting a best approach compared with 2.6 per cent (£1,056,600) for a poor approach. ‘Outstanding’ rating, the cost is dominated by the cost of achieving the mandatory operational carbon reduction targets, i.e. the BREEAM energy credits.

Full details can be found at: www.steelconstruction.info/Target_Zero#BREEAM_results

**Comparative Cost Uplift to Achieve a Higher BREEAM Rating**

<table>
<thead>
<tr>
<th>Building</th>
<th>Capital construction cost (£m)</th>
<th>Capital cost uplift (% of capital cost)</th>
<th>BREEAM Target</th>
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<tr>
<td>Warehouse</td>
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<td>Supermarket</td>
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<td>Office</td>
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<td>1.8</td>
<td>Good</td>
</tr>
<tr>
<td>Mixed-use</td>
<td>32.3</td>
<td>1.6</td>
<td>V. Good</td>
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Cost uplift to achieve a higher BREEAM rating

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<tr>
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<tr>
<td>Office</td>
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</tr>
<tr>
<td>Mixed-use</td>
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<td>Ene 4</td>
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</tbody>
</table>

**Target Zero shows that there are different ways of achieving BREEAM credits and how to do so cost-effectively**

ANT WILSON, TARGET ZERO

It is this credit which is responsible for the leap in cost between an Excellent rating and an Outstanding one, as the table and graph demonstrate.

“To achieve Ene 1, I could require installing a biomass boiler, which could make the energy efficiency of the building worse. But it would lower the building’s carbon content sufficiently to achieve the required BREEAM credits and allow it to achieve an Outstanding rating,” adds Mr Wilson.

He adds that for some buildings, achieving an Outstanding BREEAM rating is very challenging. “For many buildings, the location and site have already been decided, so that can take away scope for achieving the most environmentally efficient shape and aspect,” he says.

City-centre buildings, for example, often score well since they are close to public transport links, but often have a restricted footprint, leading to a less efficient design.

In contrast, out-of-town buildings on larger, more flexible plots of land may score fewer credits for public transport, but can score better for having a more efficient building shape. Mr Wilson’s team concluded that by adopting the best approach to design leads to cost savings and with greater assurance that the highest ratings can be achieved. “Target Zero shows that there are different ways of achieving BREEAM credits and how to do so cost-effectively,” he adds.
Steel choice for college project

In a technical college in south London, a 1950s warehouse is being extensively refurbished – and using the existing steelwork has facilitated a lighter structural frame to deal with poor ground conditions.

**Royal Greenwich UTC**

**Project** Royal Greenwich UTC  
**Developer** Royal Borough of Greenwich  
**Architect** Walters & Cohen  
**Main contractor** BAM Construction  
**Structural engineer** Clarke Nicholls Marcel  
**Steelwork contractor** Bourne Special Projects (part of the Bourne Group)

A £80 million construction and engineering project in Woolwich, south London is being built on the site of a former industrial estate, just a stone’s throw from the Thames Barrier. The project involves refurbishing an existing warehouse to provide workshop facilities and building a new three-storey steel-framed teaching block for 1,000 pupils – all within just 12 months.

The institution will be known as Royal Greenwich University Technical College and it aim will be to offer courses related to construction and engineering. Understandably, the client – the Royal Borough of Greenwich – is keen to see the building become part of the learning experience.

**Steel on show**

“All steel is exposed to show students how the structure was built [so it] relates back to what they are learning in the classroom,” says BAM Construction project manager Kevin Stoney. Part of the project will see a warehouse dating back to the 1950s being extensively refurbished to provide workshops in the academic practical work, including a heavy structures laboratory. Almost all of the retained steel columns, beams and the roof truss, originally fabricated by Dorman Long, will be retained and strengthened to accommodate heavier roof loads (see box opposite page). A new canopy to the north face of the warehouse will create a sheltered practical area.

Structural engineer Clarke Nicholls Marcel produced a 3D model of both buildings and with steelwork contractor Bourne Special Projects, identified solutions which allowed as much of the warehouse structure to be reused as possible.

BAM Construction started on the project in February 2012, working closely with the architect and the client to develop a scheme which allowed the existing building to fit the budget and allow it to be built in a single academic year.

The existing steelwork in the warehouse set a precedent for using the material in the teaching block, but it was also an obvious choice because it facilitated a lighter structural frame, says Clarke Nicholls Marcel associate John Matthews: “The ground conditions were poor, so to limit adding on the foundations, the steel option was retained.”

BAM Construction favoured a steel frame and precast concrete flooring solution as it offered programme advantages due to elements being prefabricated off site.

**Workshop design**

The original warehouse system comprised external and internal masonry shear walls with an absence of horizontal bracing in the roof. For the requirements of the new workshop, internal masonry stability walls and the external north side masonry wall had to be demolished.

To re-establish structural stability, new vertical steel cross bracing replaces these walls. Existing east, west and south side external masonry walls remain. “The original steelwork from 1957 was in good condition, so could be retained, but the removal of masonry stability walls meant that we had to add several tens of tons of cross-bracing,” says Clarke Nicholls Marcel associate John Matthews.

“We were able to keep the roof trusses, but had to add horizontal ties and coping to the external walls,” says Mr Stoney. “We also retained the drainage system and external brick wall on the Woolwich Road and the north side. This meant that we retained this ground floor slab in the warehouse. This retained the original ground floor slab.”

**Contamination risk**

“Since the ground was known to be contaminated due to the area being a former industrial site, we decided to retain the existing ground floor slab in the warehouse. This retained the risk of contaminated ground,” says Mr Stoney. “A new drainage system and external brick wall on the Woolwich Road and the north side of the warehouse was constructed.”

**Building adaptation**

The original steelwork was strengthened to support the heavy roof loads, including a single-storey portal frame building to the west of the warehouse to make room for the teaching block. The remaining site will be converted into two all-weather pitches, a fitness track and delivery area.

The single-storey warehouse measures 66 m x 41 m. Its floor, columns, sawtooth roof and most external walls will be retained.

**Using a reinforced concrete frame would have made the building heavier, requiring bigger pile sizes**

According to Boune’s senior site manager Chip Page. The core is braced and supports floor beams in the final case. Until all the steelwork and precast planks have been installed, temporary steel bracing provides stability.

Entrance to the teaching block will be from the Woolwich Road at first floor level. Clear spans for a ground floor sports studio and assembly area have been achieved by incorporating heavy steelwork in the roof (see box opposite page).

Classrooms and administrative areas occupy the first and second floors of the block. Extensive glazing on the western elevation will allow views across the parkland area adjacent to the site.

Since the teaching block is enclosed by the Woolwich Road to the south, the warehouse on the east and parkland to the west, access to it is limited to just the north side. Despite heavy snowfall halting operations for three and a half days, the block was completed in just six weeks. All the steelwork on the teaching block has now been erected and the strengthening work completed in the warehouse, meaning that in the coming weeks, site workers can install the workshop canopy and fit precast planks in the teaching block.

**The sports studio**

A clear column-free space of 16 m 17 m for the ground floor sports studio in the teaching block has been achieved by hanging the first and second floor slabs from roof columns and transferring the loads to foundations via columns around the studio perimeter. Since the first floor level was fixed by the height of the Woolwich Road and the ground floor slab could not be lowered due to the risk of moving contaminated soil, a deeper beam section at first floor level could not be recommended to span the 16 m distance and keep even the roof flat.

Instead, the studio’s column-free space has been achieved via 254 mm x 254 mm concrete-filled steel hangers, which are suspended from two roof girders running north-south. Vierendeel first and second floor slab over the studio. These girders and 150 mm by 150 mm fabricated sections support the load of these floors. The beams over the kitchen and office area can then remain, the modestly pre-cambered 100 mm x 100 mm sections continue over the roof. This solution has the advantage of locating the large foundations required for the column loads from the transfer system, and away from the existing warehouse foundations where space is limited.

**Management by numbers**

Steel Spotlight

**Architect** Clarke Nicholls Marcel
**Developer** Royal Borough of Greenwich
**Project** Royal Greenwich UTC

**In a technical college in south London, a 1950s warehouse is being extensively refurbished – and using the existing steelwork has facilitated a lighter structural frame to deal with poor ground conditions.**

**In August 2012, five buildings on the 12,000 sq m site were demolished and rebuilding a single-storey portal frame building to the west of the warehouse to make room for the teaching block. The remaining site will be converted into two all-weather pitches, a fitness track and delivery area.**

The single-storey warehouse measures 66 m x 41 m. Its floor, columns, sawtooth roof and most external walls will be retained.

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