

Steel Intelligence



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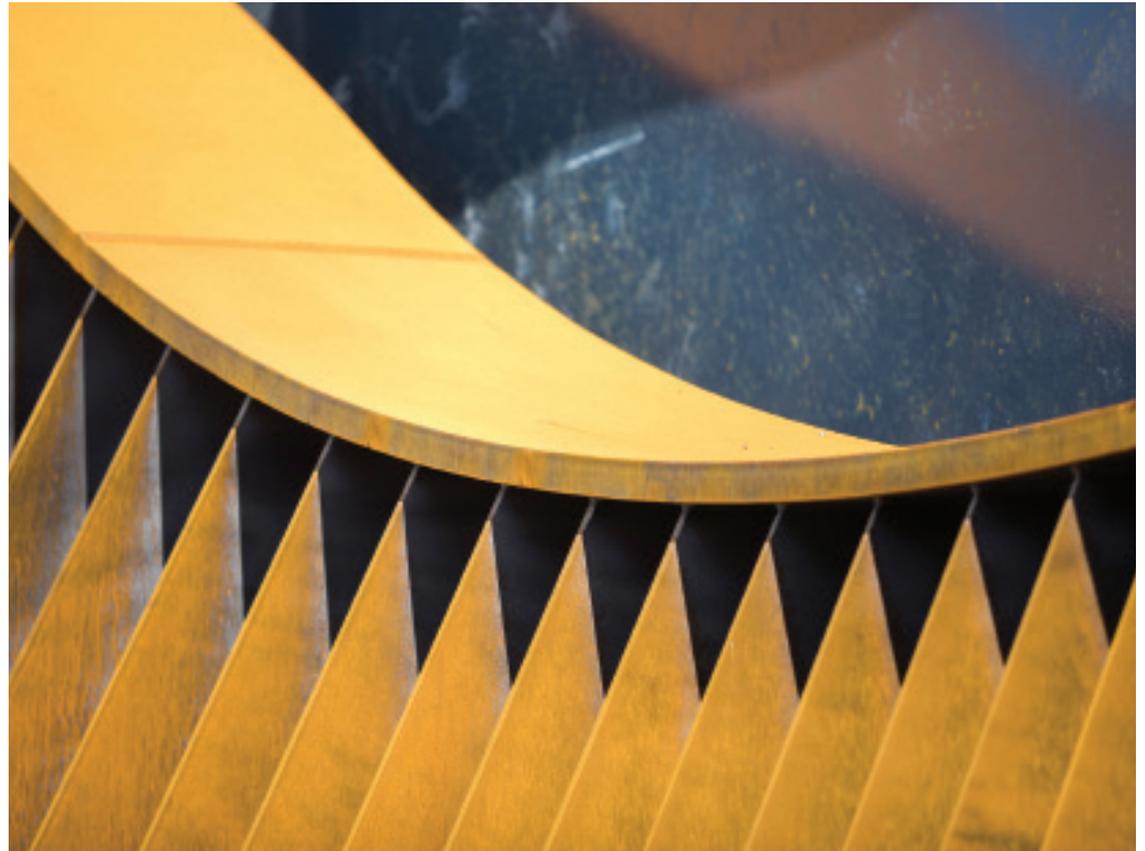


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BDFINICK CAVILLE

In this edition of Steel Intelligence, we look at the often uncelebrated contribution that well-designed infrastructure can make to the quality of the environment. As well as being a vital part of improvements to the rail network around Manchester, the cascading, continuous steel form of the Ordsall Chord (above and p46) has become a local landmark. So too has the flue tower on the Greenwich Peninsula Energy Centre (p51), which has transcended its function to become a distinctive faceted artwork by Conrad Shawcross that brings diversion and delight to motorists inching to and from the Blackwall Tunnel. We also look at the crucially important issue of protecting steel in the case of fire in a Q&A with British Constructional Steelwork Association (BCSA) fire expert David Moore (p49), who answers questions from architects on topics such as intumescent coatings and the behaviour of steel in fire. Finally, BCSA director-general Sarah McCann-Bartlett reassures architects specifying steel that there would be only a low risk to supply in the event of a no-deal Brexit (p54).

Pamela Buxton, supplement editor



Sweet harmony

Two very different rail bridges read as one structure thanks to a huge, concertina-like cascade of steel

Words Pamela Buxton

Close to the first ever passenger railway station at Liverpool Road in Manchester (1830) is another world first, an asymmetric network arch bridge. Spanning 89m and morphing at one end into a dramatic 'cascades' feature, the new bridge over the Irwell is the centrepiece of Ordsall Chord, a hugely complex project to improve rail connectivity in the city by linking its major stations of Piccadilly and Victoria.

This is heavy-duty infrastructure with design ambition in a context steeped in railway heritage. The steel arch and cascade ensemble form a new landmark for a former backland area between Salford and Manchester that is already changing fast – work on OMA's Factory arts centre is under way close by.

BDP has been overseeing the architectural design of Ordsall Chord since 2012, with Knight Architects making 'an outstanding contribution' to developing the detailed design and fabrication coordination of the cascades, according to BDP partner Peter Jenkins. This is the focal point of the 300m stretch of new track needed to bridge both the River Irwell and Trinity Way dual carriageway, passing within a few metres of George Stephenson's 1830 bridge, which was restored as part of the project. The two new bridges link the Chord to the historic Castlefield and Middlewood viaducts, which have both been widened.

The challenges were multiple – the logistics of building over road and river, the proximity to heritage structures, and most important of all, how to create a visually harmonious solution given the very different design structures of the two bridges.

'It needed to be something other than a standard design considering the significance of the heritage structures around it,' says Jenkins.

'Everyone involved in the project recognised that it was vital to produce

something of the highest quality possible,' says Brian Duguid, lead structural engineer at the Aecom-Mott MacDonald joint venture undertaking the project.

He says steel structures were inevitable given the scale of the single span over the River Irwell and the complex site geometries. Various options were considered, with an arch solution most suitable for the stretch over the Irwell and a twin girder bridge supported on four concrete piers the best and most economical solution for the 100m-long Trinity Way bridge. Between the two is the cascades feature (see overleaf), which acts as a unifying device to deliver a clear visual identity. The result is that the two very different bridges appear as one continuous steel form even though they don't completely align, with the closed box form of the arch ribs widening and changing into the open ribbed I-girder form of the Trinity Way bridge seemingly in one fluid form.

'It was quite an achievement to get a big curve to join with the horizontal line,' says Jenkins.

Teamwork paid off

The key to the project's success, according to Duguid, was the early collaborative involvement of steelwork contractor Severfield, whose staff were embedded in the design team for the creation of the BIM Level 2 model. This minimised the need for later reworking ahead of fabrication.

'We recognised that steelwork was a very critical part of the project,' he says. 'We brought Severfield in at the design and modelling stage, with a number of their technicians working in our offices with our engineers to produce a much better design model. This saved time and money and gave the fabricators more trustworthy information, and it's a crying shame we don't do it more often as an industry.'



PAUL KARALIUS

'The architects and engineers all listened to what we were saying and trusted us, and together we came up with a solution that ticked every box,' says Severfield senior project manager Jarrod Hulme.

While a bowstring arch was initially proposed, a more complex network arch construction with a lattice of hangers was chosen as the more robust and efficient structure for supporting railway loads. This structural choice not only enabled the engineers to create a much flatter arch rising to 14.3m to assist with the 'cascade' transition between the two bridges but crucially, it could also deliver asymmetry. This allowed the design team to taper the two ribs of the arch from 2.5m to 0.7m in height so that the structure touches most lightly on the most sensitive part of the site, the riverside closest to the grade I listed Stephenson Bridge. On the other side, however, the bridge was wider to soften the transition to the Trinity Way road bridge. Thirdly, the shallower structure was significantly stiffer, so used far less steel than a conventional arch bridge.

Out of respect for the heritage of the

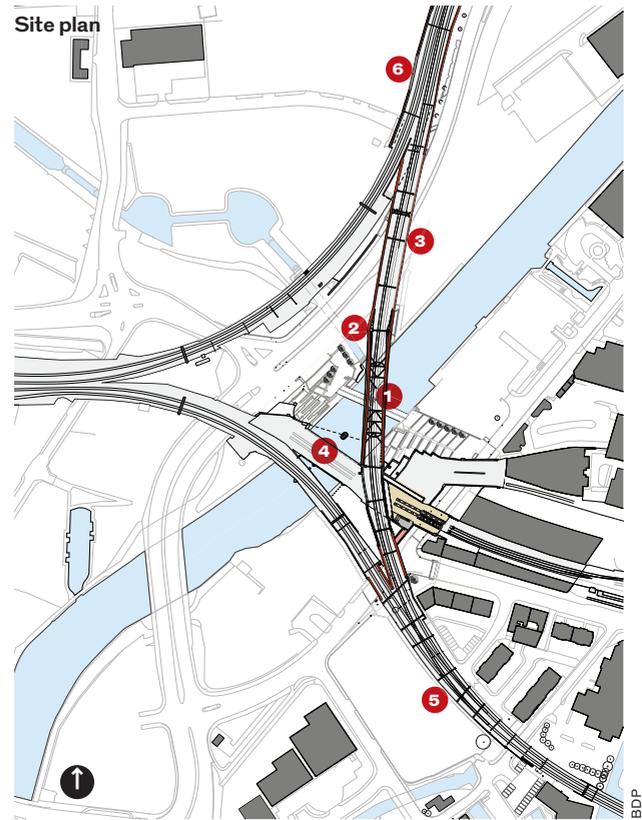


MATTHEWNICHOLPHOTOGRAPHY

Top Ordsall Chord combines an asymmetric arch bridge over the river with an I girder road bridge.

Above The concertina-like cascades create a strong visual identity for the new rail link.

- 1 River Irwell Crossing
- 2 The Cascades
- 3 Trinity Way Bridge
- 4 Stephenson's Bridge
- 5 Castlefield Viaduct
- 6 Middlewood Viaduct



surrounding context, the two ribs of the network arch are inclined inwards by 6° to minimise their visual presence and linked with K bracing. From these ribs, 46 pairs of 85mm diameter steel hangers support a composite, open section steel and concrete deck. An open section was unfeasible for the ribs due to the additional stiffening required. Instead, the ribs are hexagonal in cross section with a 'crease' line formed by welded steel plate positioned at 30% of the overall height of the section to visually divide the surface. This line is carried on through the ribs into the cascades and out onto the profile of the girder stiffeners on the Trinity Way bridge. This fold strengthens the rib sufficiently to avoid the need for welded stiffening, thus simplifying fabrication and reducing costs.

Weathered look

The use of weathering steel was an important part of the design, forming a distinctive visual language, often with concrete, common to other parts of the Ordsall Chord. Its use above live rails and the river on the arch also had maintenance benefits because of the protective patina of rust. On the arch bridge, this contrasts with the painted grey of the deck steelwork.

'It has an amazing colour and texture,' says Jenkins, adding that the rough texture avoids the flat look of a perfect finish and so complements the heritage structures in the area.

'You don't see many weathering steel bridges of this type. There are a lot of big white bridges around but we wanted it to be special to the site.'

The construction sequence was highly complex, involving horizontal assembly of the arch on temporary platforms on the riverbank before it was lifted into place. This enabled prefabricated segments of arch ribs to be welded together on the ground, rather than at height. The network arch structure design added extra complexities, with 136 stressing stages required to 'tune' the hangers.

'The finished structure is very efficient and elegant but the construction stages were highly complex,' says Duguid.

Now operational, Ordsall Chord recently won a Structural Steel Design Award.

'Severfield were absolutely outstanding, and were very engaged with making the architecture vision become reality,' says BDP's Jenkins. ●



Above The cascade form enables a seamless transition between the river and the road bridge.

MATTHEWNICHOLPHOTOGRAPHY

MAKING OF THE CASCADES

This 16m linking device rather steals the show of the new bridges, dipping down from the ribs of the network arch on both sides in a double concertina effect before rising to form the girders of the Trinity Way bridge. In doing so, each gradually increases in height from 2.5m to 2.8m to match the dimensions of the Trinity Way girders. As they dip down to form the concertina, the closed box form of the ribs changes into an open girder with vertical stiffeners that begin densely just 80mm apart and widen through the concertina to 800mm to match those of the Trinity Way Bridge. According to Knight Architects associate Tom Osborne, this dealt with the two bridges being in different planes as well as creating a continuous weathering steel form from the two contrasting structures.

'The job of the cascades is not only to blend the alignments of the two bridges but also the closed structure of the arch with the open structure of the viaduct,' he says. 'The challenge was rationalising something that in a visualisation looks quite simple into the 3D geometries of the fabricated steelwork while retaining the original design intent.'

The original design concept involved a twisted steel web but Severfield used Tekla to achieve the same visual effect with a vertical web through careful positioning of the stiffeners. During the design process, the steelwork contractor was also able to cut the weight of the steel in the cascades by one third, by reducing the thickness of the stiffeners as the spacing decreased.

The two sides of the cascades were manufactured in single pieces by Severfield in its Bolton premises and transported whole to the site, where they were trimmed to fit, installed on bearings and positioned hard up to the bridges on either end.

'The cascades are integral to both the visual continuity of the structures and identity of the scheme,' says Osborne.

Credits

Client Network Rail
Architect BDP
Specialist designer Knight Architects
Structural engineer AECOM Mott MacDonald JV
Concept structural engineer WSP Parsons Brinkerhoff (now WSP)
Main contractor Skanska BAM JV
Steelwork contractor Severfield

Facts and fire

In the wake of the Grenfell tragedy, fire safety is under greater scrutiny than ever before. We invited questions from architects on steel and fire performance and put them to expert David Moore, director of engineering at the British Constructional Steelwork Association

Words Pamela Buxton

Illustration Toby Morison



Q What options are available for protective fire coatings for structural, exposed external steel in relation to appearance and performance?

Tom Osborne, Knight Architects

A Unprotected steel has an inherent fire resistance period of up to 15 minutes according to fire protection calculations, meaning that structural steelwork maintains 60% of its strength at room temperature. Fire protection calculations are based on limiting temperatures of 550°C where steelwork is exposed on all sides and 620°C where it is exposed on three sides.

To increase fire resistance using passive protection the options are reactive (intumescent film coatings) and non-reactive (boards, sprays or flexible blankets).

There are two main types or intumescent protection – acrylic based and

epoxy based. These generally consist of a primer, basecoat and sealer coat and can be applied either on or off-site.

Acrylic based intumescent performs very well in wet (outside) environments while acrylic performs well in dry (internal) environments. Because of the thinness of the coatings, they are particularly suitable for applications on complex shapes.

Intumescent coatings are the most widely used passive protection, accounting for around 70-75% of applications. They typically meet requirements for fire resistance of 30, 60 and 90 minutes, and sometimes as much as 120 minutes.

Encasing structural steelwork with fire protection boards is another option that gives a regular, boxed, appearance. Although mainly used internally, some board products can be used in limited

external conditions. There are two main types – lightweight and heavyweight.

Lightweight boards tend to be cheaper and are more suitable for non-visible applications. Heavyweight boards are more suitable for achieving a good decorative finish since they are better able to accept renders and decorative cladding.

Sprays can be the cheapest approach for large buildings that require high periods of fire resistance. But as the finish can be quite crude, they are unsuitable for aesthetic applications.

Whatever the method of fire protection, a fire safety engineering approach can produce cost savings by enabling a more targeted strategy that puts the fire protection exactly where it is needed. This integrated approach involves the use of codes to design fire protection for individual elements of construction.

Q Is the performance of intumescent coatings on structural steelwork affected when the steelwork is behind additional linings such as walls and ceiling that slow the rate of temperature change?

Brian Heron, Ian Ritchie Architects

A Intumescent coatings intumesce at 200°C, forming a protective char that expands to form a far thicker layer that insulates the steel from the fire. If the steelwork is shielded by other linings, they will still be able to intumesce to give protection but this process will take longer as the steel remains cooler for longer before reaching the point of intumescence.

It is important that a sufficient gap around the structure is left to enable this expansion to take place, depending on the fire resistance period and the type of coating.

Q How predictably do steel structures react in the case of a fire?

Tszwai So, Spheron Architects

A There is this myth that steel is unpredictable in fire – a properly designed and protected steel-framed building will perform extremely well in a fire situation.

A frequent misconception is that steel melts in fire. In fact, it softens and only melts at 1500°C; temperatures rarely get above 1000°C in building fires.

A lot of research has been done in relation to steel and fire so we know a great deal about the performance of steel, which is actually very predictable. I only know of one case where a steel-framed building has entirely collapsed because of fire and that was the World Trade Center Building 7, which was a very unusual situation where there were mitigating circumstances. I was involved in full-scale fire tests at BRE's Cardington site some years ago, where we set fire to an eight-storey steel-framed building and temperatures reached 1000°C. Some of the steel had no fire protection at all and still survived. The building was still standing after the fire.

Fire resistance is another concept that is not well understood. The fire resistance periods required for different building types and heights (see table) is not the length of time that a structure will survive in a real fire. Instead, it refers to how long it would take an element to collapse in a standard fire test within a furnace where the temperature

rises quickly and increases indefinitely. This test is different from a real fire situation, where the fire may decay and/or move once the combustible material has been consumed.

Q Following Grenfell, do you believe that more comprehensive and wide-ranging legislation is necessary to coordinate all elements of a design (integrating cladding and structure) to ensure that buildings are safe?

Peter Jenkins, BDP

A A building should have a reasonable provision of fire-resistance – the issue is not so much how we go about meeting that demand in the design and specification but how to ensure that the right fire protection specification for the building gets through into the construction on site, and that this is supervised and checked. As I understand it, the Hackitt review is proposing an independent authority to approve designs for certain residential buildings, which will have to demonstrate that they can satisfy fire safety requirements before they are built. It will also put some legal responsibility on 'duty-holders' such as the client, principle designer, contractor and some of the subcontractors. I think this would be a good thing.

From the steel perspective, BCSA has the opportunity to promote use of the National Structural Steelwork Specification as best practice for fire protection. We're planning to update clauses regarding the use of intumescent paint to make sure that these are specified correctly and can be competently delivered on site. ●

More information: www.steelconstruction.info/Fire_and_steel_construction

FIRE RESISTANCE LEGISLATION AND STANDARDS

Building Regulations set out the functional requirements for ensuring that buildings are safe and healthy but not, for example, how the need to maintain stability for a 'reasonable' period in the event of a fire can be achieved. As regulations are devolved, these requirements differ between England, Wales, Northern Ireland and Scotland.

Approved Document B is guidance issued by each devolved UK government setting out structural fire resistance requirements to meet designers' obligations on structural stability. Fire protection requirements vary from 30-120 minutes according to building type and height (see table below).

BS 9999 – Fire Safety in the design, management and use of buildings is a code of practice aimed at providing a more flexible approach to fire safety design in order to safeguard the lives of building occupants and firefighters. Unlike the more prescriptive Approved Document B approach, this can be tailored according to an understanding of the causes of risk to life and how these can be mitigated. This can result in reduced fire resistance periods.

FIRE RESISTANCE REQUIREMENTS FOR COMMON BUILDING TYPES, IN APPROVED DOCUMENT B AND BS 9999

Building description	Approved Document B (mins)	BS 9999 without sprinkler system (mins)	BS9999 with sprinkler system (mins)
Open plan office building, two storeys <1000m ² ground floor area	30	15	15
Department store, three storeys	60	45	30
Department store 11-18m in height	60	75	60
Storage building, medium risk, four storeys	90	90	60
Leisure centre, two storeys	60	30	30



Above The flue tower of the Greenwich Peninsula Energy Centre has been utilised for *The Optic Clock*, an artwork by Conrad Shawcross.

Towering achievement

Intense collaboration between architect, artist, engineer and steelwork contractor has given south east London a dramatic new landmark

Words Pamela Buxton **Photographs** Mark Hadden

Why settle for just a chimney when you could turn it into a piece of art? That was the thinking behind the strikingly faceted flue tower of the Greenwich Peninsula Energy Centre, which will be a familiar sight to anyone used to queuing on the adjacent approach road to the Blackwall Tunnel.

Recently awarded a Commendation in the Structural Steel Design Awards, the project began 10 years ago when architect CF Møller won a competition for the design of a 3,000m² low carbon energy centre to serve the planned regeneration of Greenwich Peninsula in south east London. With a mission to demystify the energy generating process, the brief included a visitor centre.

Initially, the concept was for a plinth form to contain the energy centre with a thin blade tower for the flue stack according to architect Brian Cody of CF Møller.

'It was intended to be a striking gateway building as you approach Greenwich Peninsula. Originally the concept was for a much flatter surfaced tower design exploring ideas about translucency and playing with light,' he says.

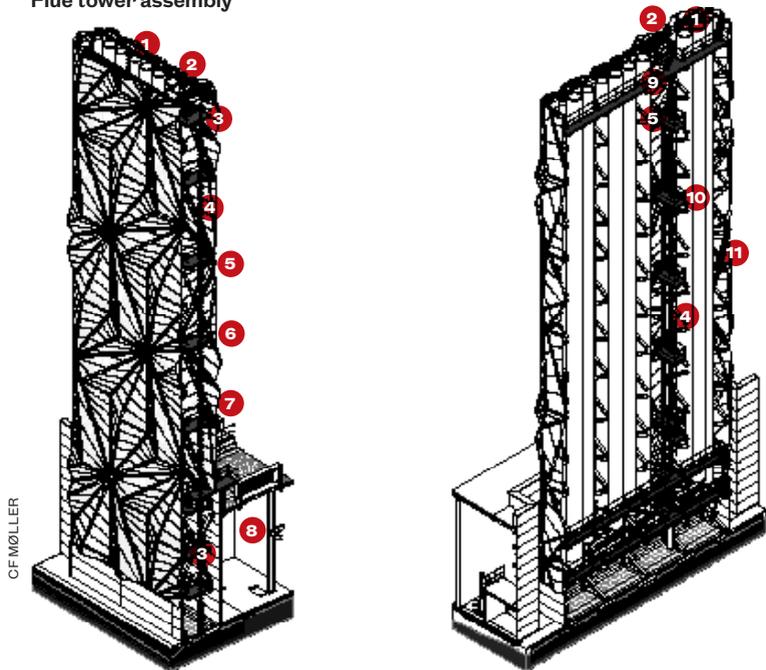
The concept of a podium and blade was kept when the client decided to integrate artwork into the chimney and appointed artist Conrad Shawcross. The piece, entitled *The Optic Clock*, was realised after intense collaboration with CF Møller, engineer Price

& Myers and steelwork contractor Billington Structures, who created the tower from 345 tonnes of galvanized steel and supplied 200 tonnes of steelwork for the structure of the energy centre.

'It could have been quite a standard industrial energy centre but developer Knight Dragon chose to embrace an artistic contribution to the building,' Cody says. 'The idea was to create a very distinctive plinth building in a streamlined, satin-finished black box to contrast with the flue tower, which becomes a 3D sculptural form as it emerges from the plinth, setting up a tension between the two.'

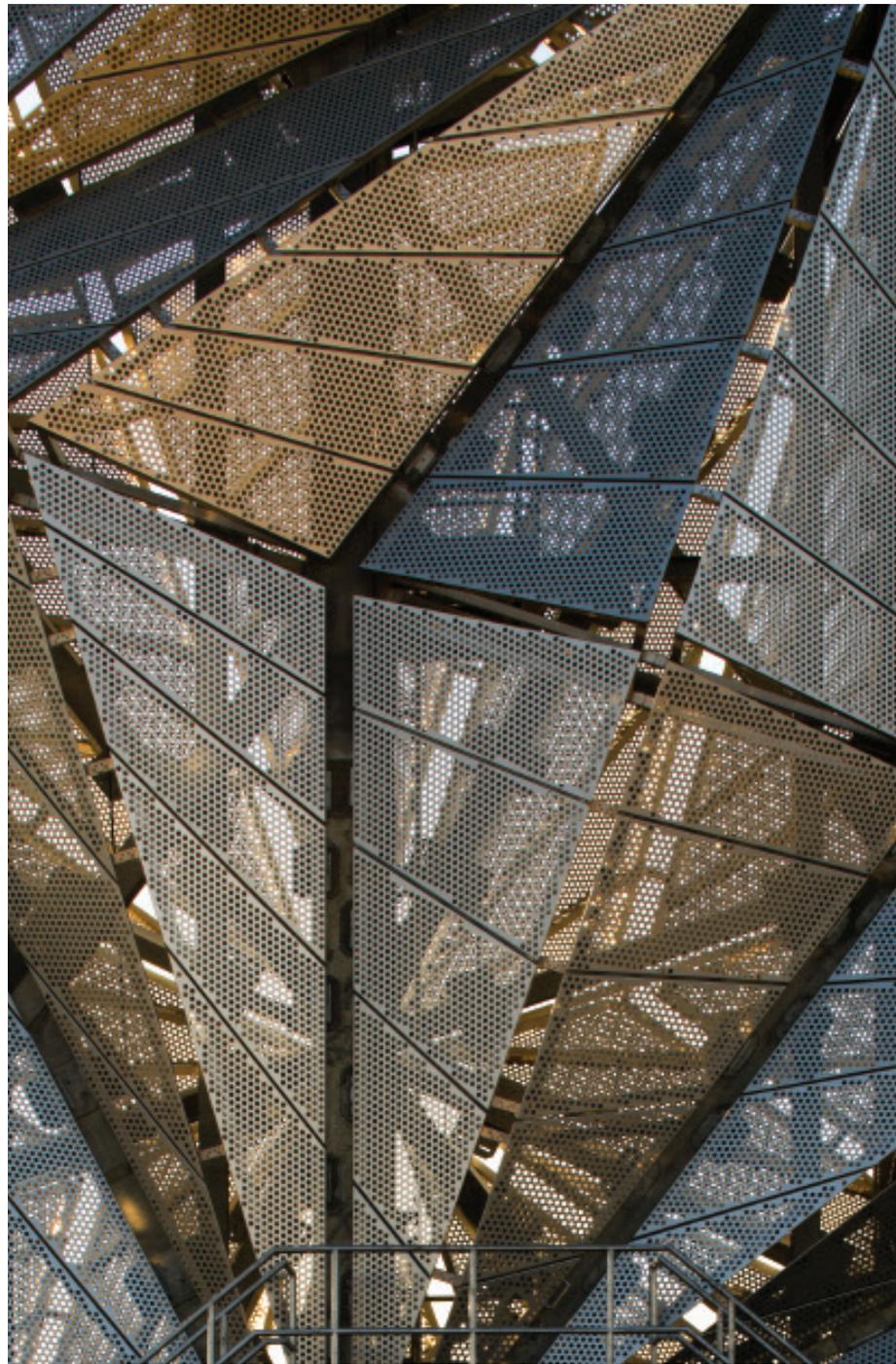
Steel was the natural choice for the

Flue tower assembly



CF MÖLLER

- 1 Boiler & chip flues
- 2 Gantry crane & track
- 3 Full width access platform
- 4 Climbing protection system
- 5 Intermediate landings
- 6 Primary frame
- 7 Cladding
- 8 Plant room
- 9 Access hatch each structural bay
- 10 Access hatch each landing
- 11 Luminaire installed on bracing members



structure of both the 90m long x 25m wide plinth and the 49m high tower of the energy centre, enabling the creation of 20m spans.

'A steel-framed building allows for flexibility. The number of combined heat and power (CHP) and gas boilers will grow over the years as the peninsula is developed. So we needed large column-free spaces in the plinth,' Cody says.

'The tower required a very thin structure so steel was an obvious choice

that enabled us to achieve a thin edge, and allowed for the tower to be perforated to deal with the wind loading.'

On the south side of the building, the architects have included a large expanse of glazing. This not only facilitates views into the energy centre but will maximise natural light in anticipation of future adjacent developments which are planned to rise to the height of the chimney flue.

The tower gives the illusion of

cantilevering out from the plinth at the 3m mark, although the structure actually descends to ground level where it is secured with metre-long bolts. But because its base is encased in the same black cladding as the rest of the centre it disappears into it when viewed from afar.

For the structural design, a BRE wind tunnel study of a 1:200 scale replica was undertaken to measure the effects of a 1 in 50 year storm event, says structural

engineer Amanda Constantinesco of Price & Myers.

'The results of this analysis were used to inform the design, cladding porosity, and form to reduce the effects of vortex shedding and fatigue during its 50-year design life,' she says. 'Acting as a braced cantilever, the tower is formed from five 49m tall latticed girders, connected by a series of raking beams and bracing. The structure of the tower was designed not only to perform the function of a flue tower, but also provide support to the artist-designed cladding system.'

Artist Conrad Shawcross and his team worked with CF Møller's brief for a 3.15m

deep tower capable of accommodating 10 flues in a single row. The resulting artwork creates a distinctive moiré effect of faceted, anodised aluminium cladding panels over the complex structure of the steel tower. The angled facades are designed to catch the light so that the appearance varies in different light conditions. One of the trickiest elements was creating a hidden door within the artwork to provide maintenance access to the tower.

'We relied on the expertise of Price & Myers to develop a solution in terms of sizing of the steel as well as Billington's experience in producing ladder girders,' Cody says.

'We had anticipated the biggest challenge being how we maintained our design concept through to delivery with addition of the artistic intervention. But we found that there was a harmonious common ground between architect, artist, engineer and steelwork contractor towards creating a sustainable and well-crafted building.'

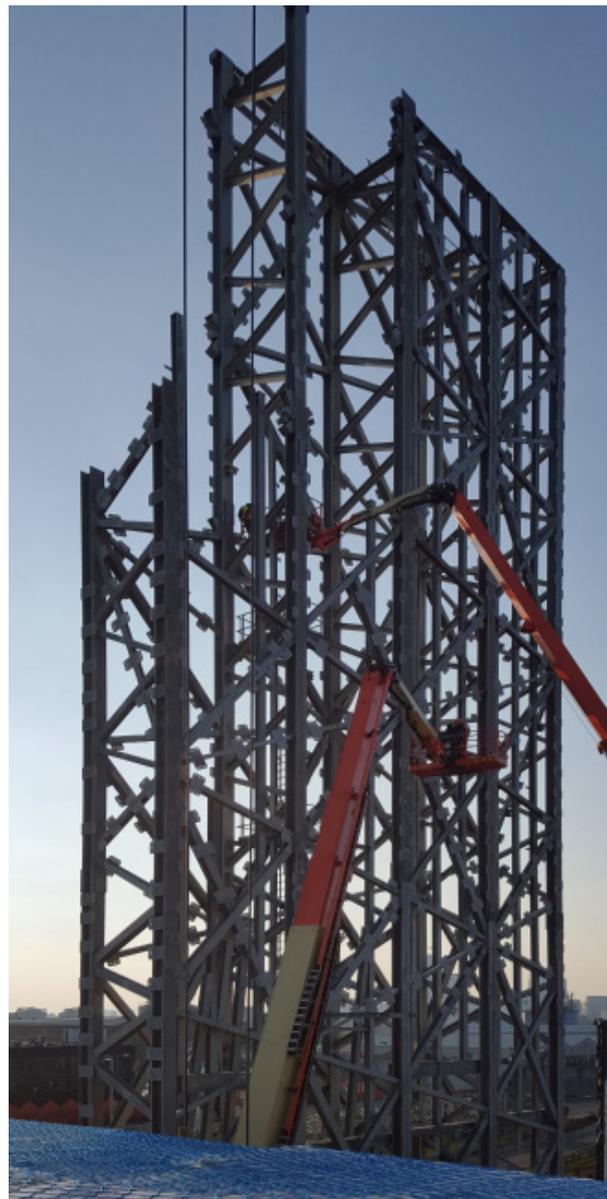
Eventually, some 15,000 homes and workspaces will be powered by the Energy Centre, which is the largest new build residential heat network in Europe.

'Over the next 10-15 years the area immediately around it will develop and it will be interesting to see how it sits within that,' Cody says. ●

Far left View up the flue tower showing the supporting steelwork structure.

Left Detail of faceted cladding, supported on steel bracing, carefully planned to minimise visual intrusion into the artwork.

Right The ladder girders that create the structure for the flue tower during construction.



CF MØLLER

THE FLUE TOWER

The 49m high tower is a self-supporting structure independent of that of the energy centre. This avoids any effects arising from fatigue or cyclic loading transferring to the main building. Containing four flues with capacity for up to 10, it is created from five ladder girders spaced 4.5m apart with diagonal bracing elements clad in aluminium. These were constructed in three sections varying from 13.2m to 20.1m.

'Our intention from the outset was to maximise their size to limit the work on site and more importantly undertake as much of the work as possible within our factory where quality is much easier to control,' says Billington principal engineer (design & build) Craig Clayton. Weighing up to 23 tonnes each, these sections were galvanised at Worksop Galvanizing, and were according to the steelwork contractor the largest frames to be hot-dip galvanised in the country.

One of the major challenges was to retain a sense of lightness by aligning the diagonal bracing with the joint lines in the triangular cladding panels to both support the cladding and minimise the visual impact of the supporting structure. At node positions up to eight diagonal members intersected with the vertical ladder column through connection details developed by Billington.

'This required many different, irregular and multi-member connections, all with unique combinations of connection forces derived from the dynamic structural and fatigue analyses based on wind loading assessed during the wind tunnel testing,' says engineer Amanda Constantinesco of Price & Myers.

'Close coordination with the cladding subcontractor was fundamental to achieving the correct setting out and detail for the hundreds of fixing brackets. Each was fabricated as part of the steel frame with sufficient tolerance to allow connection and adjustment of the cladding panels throughout the build.'

Each ladder girder was brought to site in three pieces and connected on site.

Credits

Client Knight Dragon
Architect CF Møller
Artist Conrad Shawcross RA
Structural engineer Price & Myers
Steelwork contractor Billington Structures Ltd
Main contractor Kier Group

Steel stocks healthy



Sarah McCann-Bartlett, director-general of the British Constructional Steelwork Association, on how a no-deal Brexit poses little risk to the UK's structural steel supply

With the continued lack of clarity to the ongoing Brexit negotiations, the BCSA has carried out its own risk assessment of what a no-deal Brexit could mean for the UK's structural steelwork supply.

The findings, reassuring for all architects and engineers looking to specify structural steel, are that the risk to supply is low. This conclusion has been reached following a risk analysis undertaken by the BCSA and its member companies that looked at the supply of materials and products, the structure of the workforce, stocking trends, and tariffs under World Trade Organization (WTO) rules.

Crucially, 98% of the UK's structural steelwork is fabricated here, which means a no-deal Brexit poses no risk to structural steelwork manufacturing. The key input to this process is of course steel, and the risk to the availability and delivery of hot rolled structural sections is low. This is largely due to a joined-up supply chain that includes a UK producer, European producers, and a

well-established network of distributors and stockholders who keep sufficient levels of stock to support just-in-time deliveries to steelwork contractors.

UK steelmakers currently source their raw materials outside the EU and purchase forward due to long shipping times. A no-deal would have no effect on this trade and any customs delays could be easily absorbed. And if UK-EU trade moved to WTO rules under a no-deal scenario, import duties on raw steel would remain at 0%.

In addition, there is very little risk to labour availability. An average of only 7% of employees working for UK steelwork contractors are from the EU. These form part of a permanent, stable and full-time workforce fabricating structural steelwork offsite in manufacturing facilities and they are employed on the same terms and conditions as UK employees.

Plant and equipment are a high value, long-term purchase with orders for new plant and machinery made many months in

advance. Machinery supplies are expected to be unaffected by a no-deal Brexit. Structural fasteners and bolts used by steelwork contractors in the UK are sourced globally and UK suppliers already have to hold a sufficient stock of product in their UK warehouses. The risk to supply is low.

Currency fluctuations would impact on both input and output pricing since around 55% of raw structural steel is sourced outside the UK, but this is only one of many factors that has an impact on steel pricing models at any one point in time.

A KPMG study shows UK structural steelwork capacity to be between 1.142-1.343 million tonnes in 2019. Since Construction Markets is currently forecasting constructional steelwork demand of 0.93 million tonnes in 2019, there is sufficient latent capacity in the sector to meet projected demand.

In conclusion, Brexit poses no risk to the UK's structural steelwork supply. ●

Full risk analysis: www.steelconstruction.org



Stocks are high: 98% of the UK's structural steelwork is fabricated here.

BARRETT STEEL