Structural Steelwork in Action

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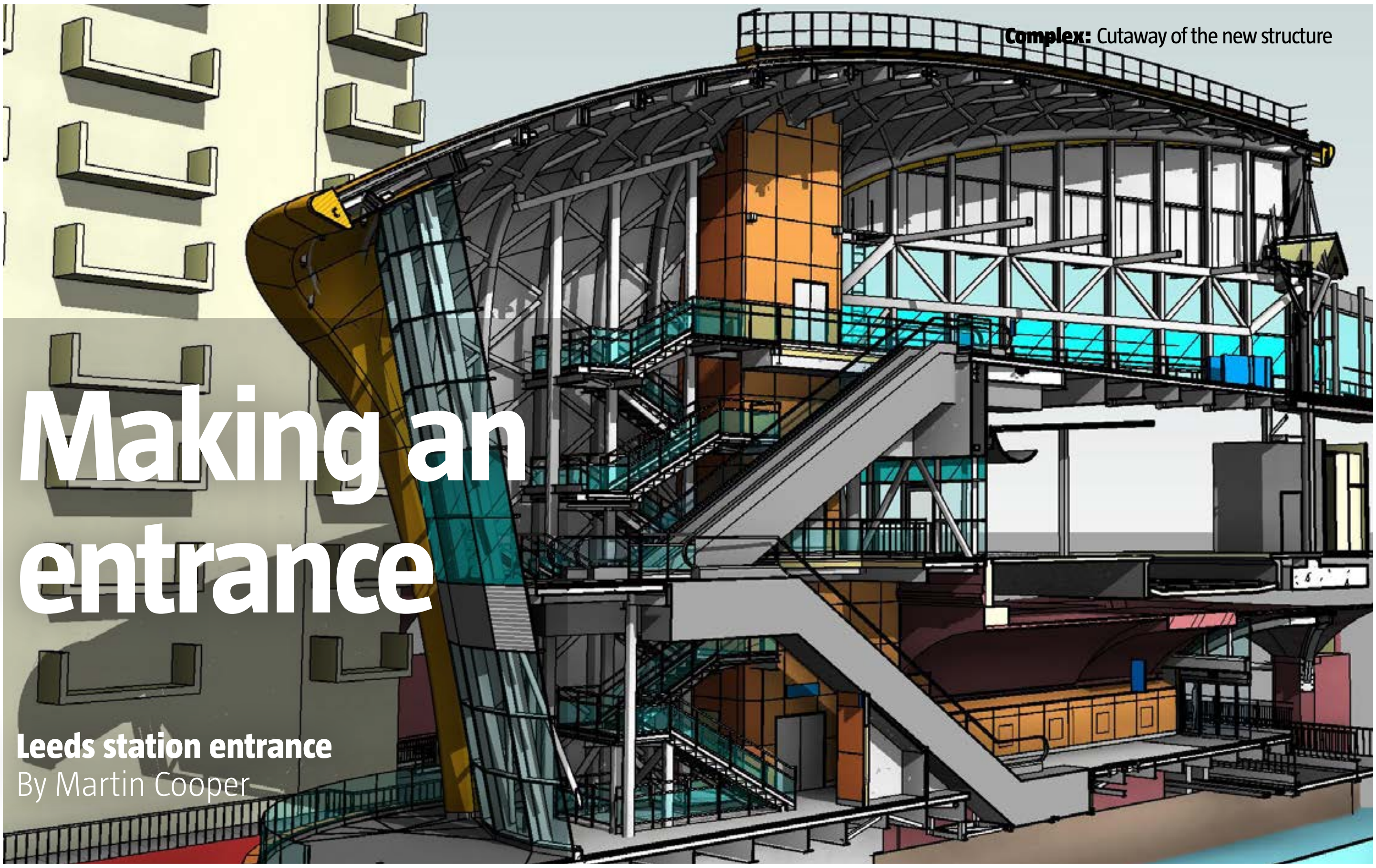
Making an entrance

Leeds station entrance

By Martin Cooper



Complex: Cutaway of the new structure

An eye-catching portal-framed entrance structure, built over the River Aire, will help alleviate passenger congestion at Leeds station.

Big changes are afoot in Leeds as the city takes on a new and dynamic post-industrial look. Although manufacturing is still an important source of employment in the greater Leeds area, it is a different story in the city centre, as banking, finance and media companies dominate the numerous new office developments.

Many of these new office schemes have been built in an area to the south of Leeds station and in turn they have created a demand for the new pedestrian station entrance currently under construction.

The existing main entrance is situated on the north side of the station, and so commuters walking from the south regularly cause pedestrian congestion on the pathways leading around the station. It has been estimated that up to 20% of the city's rail passengers will benefit from and will use the new entrance.

Space for a new entrance south of the station was extremely limited and as the design had to incorporate access to the existing high-level concourse, a location that straddles the River Aire was the only option.

It may be the right choice of location but the new entrance's site has presented the project team with a host of challenges.

"We're building over water and so we have river safety issues, and apartment blocks on two sides mean the site is very constrained.

"The site also requires a large 63m-high tower crane which has been subject to numerous wind stoppages," explains Network Rail Project Manager Luan Anderson.

"We are also working next to and at times over live rail lines, so some of our work can only be done during night-time possessions."

Before erecting the steel-framed entrance superstructure principal contractor Carillion Rail had to install piled foundations and two concrete piers in the river (see box).

The piers are positioned and aligned with the existing rail viaduct arches so as not to impede the flow of the river during heavy rain. This has resulted in the requirement for a steel transfer structure at river deck level to support the primary superstructure columns of the new entrance, as they do not align with the piers.

The transfer deck was the initial phase of William Hare's steel erection programme. The steel was installed via the on-site tower crane, which lifted the members off barges and positioned them between the new piers.

The transfer deck is a series of galvanized beams, positioned at 1.8m centres. The beams span 10.2m between the new concrete piers and cantilever a further 3.5m beyond the centre line of each pier providing support to the columns above as well as support to an access and maintenance deck around the perimeter of the building base.

The beams bear directly onto each pier via a simple baseplate connection. A series of beams cantilever 2.3m beyond the southernmost primary beam to complete the curved plan profile of the deck.

"The main reasons why a steel deck

"The main reasons why a steel deck was specified were the benefits brought by offsite fabrication and speed of erection to reduce the construction time above the river"

John Svikis, Mott MacDonald

PROJECT TEAM

Main clients: Network Rail, West Yorkshire Combined Authority
Architect: AHR
Principal contractor: Carillion Rail
Structural engineer: Mott MacDonald
Steelwork contractor: William Hare
Steel tonnage: 370t

Span: The structure is built above the River Aire. (Inset) The portal frame takes shape

RIVER WORK

The location of the site means much of the work revolves around the River Aire.

Carillion Rail has its main compound and an assembly yard about 1km downstream at Water Lane.

Much of the project's materials arrive at this yard and are then delivered to the project by barge as this is the easiest way to access the site without negotiating the surrounding narrow streets.

"One of our initial tasks was to assemble a jack up barge and float it to the site," explains Carillion project manager David Carlyle.

"At 18m wide the barge provided a working platform for our 26t piling rig and an area from which we constructed the two concrete piers."

Steelwork contractor William Hare is also delivering all of its steel to the site via Water Lane, using a number of pontoons that can be configured to suit the length and weight of the steel members.

was specified were the benefits brought by offsite fabrication and speed of erection to reduce the construction time above the river, which was considered to be a positive health and safety decision," says Mott MacDonald project manager Jon Svikis.

Holorib metal decking, fabricated and cut to size offsite, spans between the beams and provides formwork from which to safely fix reinforcement and pour a 160mm deep concrete floor slab. Pockets were left in the slab ready to receive the superstructure columns and vertical bracing.

Extending from the transfer deck is a new suspended floor and escalator pit that extends through the existing masonry arch. The floor structure comprises two upstand trusses that span 15m and are 2.1m deep.

Sitting on the transfer deck, the entrance superstructure is a series of portalised arches at 1.8m centres.

"The close spacing is to allow the structural zone to be minimised, reduce the load on each transfer beam at river deck level, and to allow the sweeping, curved roof geometry to be achieved without the need for a secondary frame, thereby minimising the overall cladding build-up and maximising the internal space available," says Svikis.

The portals are a maximum of 20m tall, with a horizontal span of approximately 12.5m. Each frame comprises two vertical legs and a curved arch section of varying radii of between 2.8m and 12.3m.

Generally the frames are being erected in four pieces. The frames are braced out of plane via a series of SHS members, forming an inherently stable "diagrid type" structure. In plane stability is provided via moment action of the individual frames, as well as via the 20m-high braced lift shafts that are positioned to the north adjacent to the existing masonry viaduct. There are 11 frames at river deck level; and nine more extending above three existing railway lines to form the connection with the high level concourse.

This involves construction of a new "Ticket Barrier level" above platforms 15,16 and 17, crossing three electrified railway lines. The new ticket barrier level concourse is hung from two primary trusses that span across the lines. These were installed during weekend rail possessions. The eastern truss spans 17.7m and is 1.9m deep, while the western truss spans 19.5m and is 2.3m deep.

To help support the concourse extension, a new column has been introduced on platform 15 on top of the existing Victorian masonry viaduct.

This has meant one of the viaduct's arches had to be strengthened with four plate girder ribs arranged in a cruciform. The steelwork is packed tightly to the existing masonry arch using high strength cementicious grout.

The steel sections are 365mm deep and 325mm wide, fabricated from 45mm plate for the flanges and 25mm plate for the webs. Each of the four ribs is bolted into the existing masonry pier at the springing point, via 1m deep haunches and 40mm thick end plates.

As well as the access points from the high level concourse, low level access to the new entrance will be provided by two footbridges (see box) spanning from both banks of the river and ramps leading into Dark Neville Street within the viaduct arches.

Leeds station southern entrance is due to be completed this autumn.

FOOTBRIDGES

There are two external footbridges that provide access for passengers from the east and west riverbanks into the new entrance as well as two further bridges/ramps leading into the viaduct arches.

The eastern footbridge spans 9.5m, while the western bridge spans 12.8m. Both are welded structures comprising two primary box sections supporting an arrangement of stiffened deck plates and secondary sections.

The eastern bridge will be brought to site as one fully completed element and craned into position, while the western bridge will arrive in two pieces. This is due to the crane lifting capacity restrictions. The shorter section will be temporarily propped, before the larger one is lifted into position. The two will then be spliced together insitu above the river.

Rapid addition

Belfast Waterfront extension

By Martin Cooper

Tight spot: The site is constrained by a neighbouring hotel and the River Lagan

A steel-framed extension to the Belfast Waterfront conference and entertainment venue will not only allow it to host larger events but will boost the wider local economy.

> **"This is a very fast-track programe, mainly due to our funding obligations"**
> Kieran Mooney, Belfast City Council

Work is progressing at pace on the biggest single project in Belfast's £150M investment programme, itself the biggest investment in the city for a generation.

The £29.5M extension to the Belfast Waterfront, Northern Ireland's only purpose-built conference centre, will double its existing conference, exhibition and entertainment space, which in turn will help to attract more international events and act as a catalyst for further economic growth.

The steel-framed extension links into the original concrete framed Waterfront but the new build is a fully independent structure gaining stability from its own braced cores.

The extension is constructed over the existing service yard between the Waterfront Hall and the adjacent Hilton Hotel and also extends outwards along the River Lagan embankment.

Inside the extension there will be 4,000m^2 of conference, exhibition and banqueting space. This will consist of two exhibition and conference spaces. Hall 1 incorporates Halls A, B, C and D, that can be used as one large 1,850m^2 area, or sub-divided via retractable walls into four smaller spaces.

The smaller Hall 2 can also be divided into two separate halls, A and B, or used as one 702m^2 exhibition and conference area.

Elsewhere there are a number of flexible breakout meeting rooms, many of which can also be divided into numerous smaller configurations. The extension also includes a fully fitted-out commercial kitchen to cater for a banquet for up to 750 people, plant and back-of-house zones, circulation routes and a new feature riverside entrance and foyer.

Main contractor McLaughlin & Harvey started work onsite last September and in 68 weeks the project will be complete, with the first events pencilled in for May 2016.

"This is a very fast-track programme, mainly due to our funding obligations," explains Belfast City Council project manager Kieran Mooney.

Finished item: How the extended Waterfront will look

"Nearly half of the project's funding is coming from the European Regional Development Fund (ERDF) and it stipulates that the money must be spent during 2015, so the project will be complete by 31 December."

Despite the time pressure, the scheme is on schedule despite a whole host of challenges that have had to be overcome.

Enabling works and piling were predominantly completed last year, but not without a major service diversion scheme having to be undertaken first (see box).

Walter Watson started its steel erection programme in January and it is scheduled for completion in June.

"The main challenge for us is the coordination of the programme between ourselves and groundwork and envelope works. Due to the

PROJECT TEAM

Main client: Belfast City Council
Architect: Todd Architects
Main contractor: McLaughlin & Harvey
Structural engineer: Doran Consulting
Steelwork contractor: Walter Watson
Steel tonnage: 1,200t

"The long spans required over the service yard and the need to absorb big floor loadings and high frequency vibration from the hall above meant stiff steel plate girders were the only option"
Andrew Gardiner, Doran Consulting

restricted nature of the site the steelwork erection had to commence at one end of the site while ground-works continued on the remainder of the site," says Walter Watson project manager Trevor Irvine.

This requires a high degree of co-ordination between the subcon-tractors to allow passage of plant and materials through the areas where excavations are ongoing and foundations are still under construction.

Further site restrictions arise due to the close proximity of the Waterfront and the Hilton Hotel with noise and vibration being kept to a minimum, and continuously monitored.

The initial steelwork erection was carried out over the existing Waterfront service yard, situated adjacent to the Hilton and which is not being used during the duration of the construction work.

This area has the longest spans of the project, as the grid is 23.5m by 6m in order to accommodate turning trucks once the service yard is back in operation.

Spanning this ground floor area and supporting Halls 1 A and B above, are a series of plate girders varying in depth from 1,500mm up to 1,800mm.

The heaviest girder on the entire scheme is located here and it weighs 21.7t. This 19m-long section has connection plates that have a combined weight of 3t and require 70 bolts.

"The long spans required over the service yard and the need to absorb big floor loadings and high frequency vibration from the hall above meant stiff steel plate girders were the only option," explains Doran Consulting project engineer Andrew Gardiner.

Forming the roof of the expo halls are a series of 23.5m-long tapered Westok rafters and secondary beams erected on a 3m by 3m grid.

The stiffness of the steel frame is very important, not just here but also in the extension's other halls.

The floors have to be able to absorb 10kN/m^2, while the roof steelwork will have to support rigging and exhibits weighing up to 1t apiece.

Due to the project's phased programme Walter Watson has also started erecting the eastern corner of the extension, overlooking the river.

On this part of the steel frame there are a number of large cantilever trusses, 1,250mm deep and cantilevering out to a maximum length of 9m to form a feature element of the structure.

"With steel erection gangs working simultaneously, they will eventually meet up in the middle of the site. In this way we can keep the site accessible for our many other ongoing works," says Donnelly.

ON SITE SERVICES

"The site has every kind of service crossing it," explains McLaughlin & Harvey contracts manager Shaun Donnelly.

"Gas, electricity and a BT fibre-optic cable, feeding a number of high-profile locally-based companies all had to be diverted if possible to the edge of the site."

There is also a main sewer running beneath the site and diverting this would have been time-consuming and expensive. However, actually locating it proved to be very challenging exercise as historical plans of the site proved to be unreliable at best.

"We tried surveying the area but this couldn't accurately pinpoint the sewer, so we had to excavate down 4m to expose the pipe all the way across the site," adds Donnelly.

Plotting the exact course of the sewer was critical for the piling installation, as some of the site's 18m-deep CFA piles have had to be installed within inches of the pipe and hitting it with a pile would have been disastrous.

Steel stays cost competitive

Steel prices

By Nick Barrett

Prices for fabricated structural steelwork fell during 2014 but are now firming again despite falls in crude oil and iron ore prices, warns Gardiner & Theobald (G&T) in its latest structural steel cost analysis.

Although raw steel prices fell due to the influence of world iron ore prices, raw steel constitutes only between 30% and 40% of structural frame costs, and other cost pressures are pushing prices for structural steelwork up from unsustainable levels.

Against a background of rising demand, falling material prices but still depressed margins, steel producers have increased UK sections prices by £20/tonne this year. Independent researchers Construction Markets forecast that UK consumption of structural steelwork will increase by 9% in 2015, after a 6% rise in 2014. G&T says further manufacturer price rises are expected in 2015 as demand continues this forecast improvement.

G&T has incorporated new price information into an updated cost model used in 2012 for a Cost Comparison study that analysed two typical commercial buildings to provide cost and programme guidance to inform the design and selection of a structural frame (see box right).

In updating this cost model, G&T has increased all general cost items by 2.8% to reflect the final quarter of its 2014 forecast of 6% average tender price inflation for London, and the first quarter of a forecast rise for 2015 of 5%.

Increases have also been applied to the frame rates for reinforcing bars, concrete and structural steel to reflect recorded and forecast tender price changes in Q1 2015. Main contractor direct costs have also been reviewed to reflect current tendering conditions, increased demand, more selective contractor tendering and the prevalence of two stage tendering as contractors shy away from single stage tenders amid hardening attitudes to risk transfer.

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

In Figure 2 (Building 2), a cellular steel composite option has a lower frame and floor cost and lower total building cost than the post-tensioned concrete band beam option. Substructure costs are lower as are roof costs. A lower floor to floor height means lower external envelope costs.

Costs shown in the structural steel frame cost table, Figure 3, reflect tender price rises seen in the last quarter of 2014 and those expected in the first quarter of 2015.

G&T says typical costs are based upon the particular project being attractive to the market and the selection of an appropriate procurement route. They warn that, in overheated areas of the market, care needs to be taken with the procurement strategy, as if it is not well thought through and doesn't respond to market conditions, the cost impact on individual tenders could be dramatic.

G&T has observed that the move away from single stage fixed price procurement routes which was seen in London and the South East in mid-2014 is spreading to the regions, partly to overcome a shortage of mid-range contractors.

Contractors' attitudes to risk transfer and complexity have hardened as pressure on estimating resources has grown with the rise in market demand. The numbers of bidders being seen for many projects is below what would

Location	BCIS Index	Location	BCIS Index
City of London	110	**Leeds**	92
Nottingham	96	**Newcastle**	98
Birmingham	91	**Glasgow**	100
Manchester	99	**Belfast**	60
Liverpool	94	**Cardiff**	100

Figure 4: BCIS Location Factors, as 6 February 2015

CASE STUDY: BUILDING 1

Building 1 is a typical out-of-town speculative three-storey business park office with a 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 the typical available framing options; steel composite, steel and precast concrete slab, reinforced concrete flat slab and post-tensioned concrete flat slab.

	Steel Composite
Substructure	£59
Frame and Upper Floors	£153
Total Building	£1,683

Figure 1: Building 1 Cost Model (key costs per m² GIFA, City of London location)

Steel + Precast Concrete Slabs	Reinforced Concrete Flat Slab	Post Tensioned Concrete Flat Slab
£62	£76	£70
£168	£159	£168
£1,713	£1,770	£1,752

CASE STUDY: BUILDING 2

Building 2 is an L-shaped eight-storey speculative city centre office building with a gross internal floor area of 16,500m² and a 7.5m by 15m grid. Cost models were developed for a steel cellular composite frame and post-tensioned concrete band beam and slab, being two frame and upper floor types that could economically achieve the required span and building form.

	Steel Cellular Composite	PT Concrete Band Beam and Slab
Substructure	£62	£66
Frame and Upper Floors	£210	£237
Total Building	£2,095	£2,186

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

have been expected not long ago.

The BCIS location factors (produced by the Building Cost Information Service of the Royal Institution of Chartered Surveyors) which reflect regional differences in construction costs, demonstrate that the gap between City of London, the majority of regional cities and the UK mean of 100 has narrowed as the economic recovery picks up pace across the UK (see Figure 4).

G&T concludes that looking to the rest of this year and beyond, the forecast increase in demand for construction across the UK along with increased wage expectations and rising material prices mean that estimates for projects should include substantial allowances for anticipated inflation.

TYPE	GIFA Rate (£) – BCIS Index 100	GIFA Rate (£) – City of London
Frame 1 - low rise, short spans, repetitive grid / sections, easy access (Building 1)	90-122/m²	100-135m²
Frame 2 - high rise, long spans, easy access, repetitive grid (Building 2)	140-168/m²	155-185/m²
Frame 3 - high rise, long spans, complex access, irregular grid, complex elements	168-190m²	185-210/m²
Floor - metal decking and lightweight concrete topping	50-68/m²	55-75/m²
Floor – precast concrete composite floor and topping	55-73/m²	60-80/m²
Fire protection (60 min resistance)	14-23/m²	15-25/m²
Portal frames – low eaves (6-8m)	55-73/m²	60-80/m²
Portal frames – high eaves (10-13m)	68-90/m²	75-100/m²

Figure 3: Indicative cost ranges based on GIFA (Q1 2015)

Retail therapy

Broadway, Bradford
By Martin Cooper

Fast delivery: Broadway's entire 6,800t steel frame has been erected in just over 25 weeks

The Broadway Westfield shopping centre is set to regenerate a large area of Bradford city centre and make it a major retail destination in Yorkshire.

Back on track having originally stalled in 2008, Westfield's £275M Broadway scheme in Bradford city centre is now under construction and due to open in time for Christmas. The scheme will include two anchor stores (Debenhams, and Marks & Spencer), car parking for 1,300 vehicles and more than 70 other shops, restaurants and cafes.

"Broadway will become a focal point and enhance the city centre," says Westfield head of design and construction Keith Whitmore. "It will also act as a springboard for further regeneration of other parts of Bradford and provide a major stimulus for the regional economy by creating direct and indirect jobs across a range of industries."

Work recommenced on site towards the end of last year and as the 8m-deep basement and the piling had previously been completed in 2008, preparatory works were less extensive then they would otherwise have been.

Above ground, the scheme's design had undergone a value engineering exercise during the intervening years. Structural engineer MPN, who joined the scheme in 2011, and architect Hadfield Cawkwell Davidson, who has been involved since Westfield's original involvement in the scheme in 2006, aided Westfield in this.

Changes to the scheme included reducing the height of the shopping mall from a double level to one level, with single and two-storey shops all accessed from the ground level mall.

> **"Broadway will also act as a springboard for further regeneration of other parts of Bradford and provide a major stimulus for the regional economy"**
> Keith Whitmore, Westfield

PROJECT TEAM

Main client: Westfield Shopping-towns
Architect: Hadfield Cawkwell Davidson
Main contractor: Westfield
Structural engineer: MPN
Steelwork contractor: Severfield
Steel tonnage: 6,800t

Originally a thick post-tensioned insitu transfer slab was designed to span over the turning circle for the service vehicles in the basement and support the multi-storey car park and retail buildings above.

However this was also re-engineered by MPN, on account of the reduced building load of the new scheme, to a conventional steel frame with some large plate girder transfer beams.

In fact, all of the areas of the previous scheme that had originally been designed as a concrete super-structure were converted to steel for the current build, which has contributed to achieving the very tight construction programme on the project. This included many of the projects original slip-formed concrete cores, which where redesigned as steel braced cores.

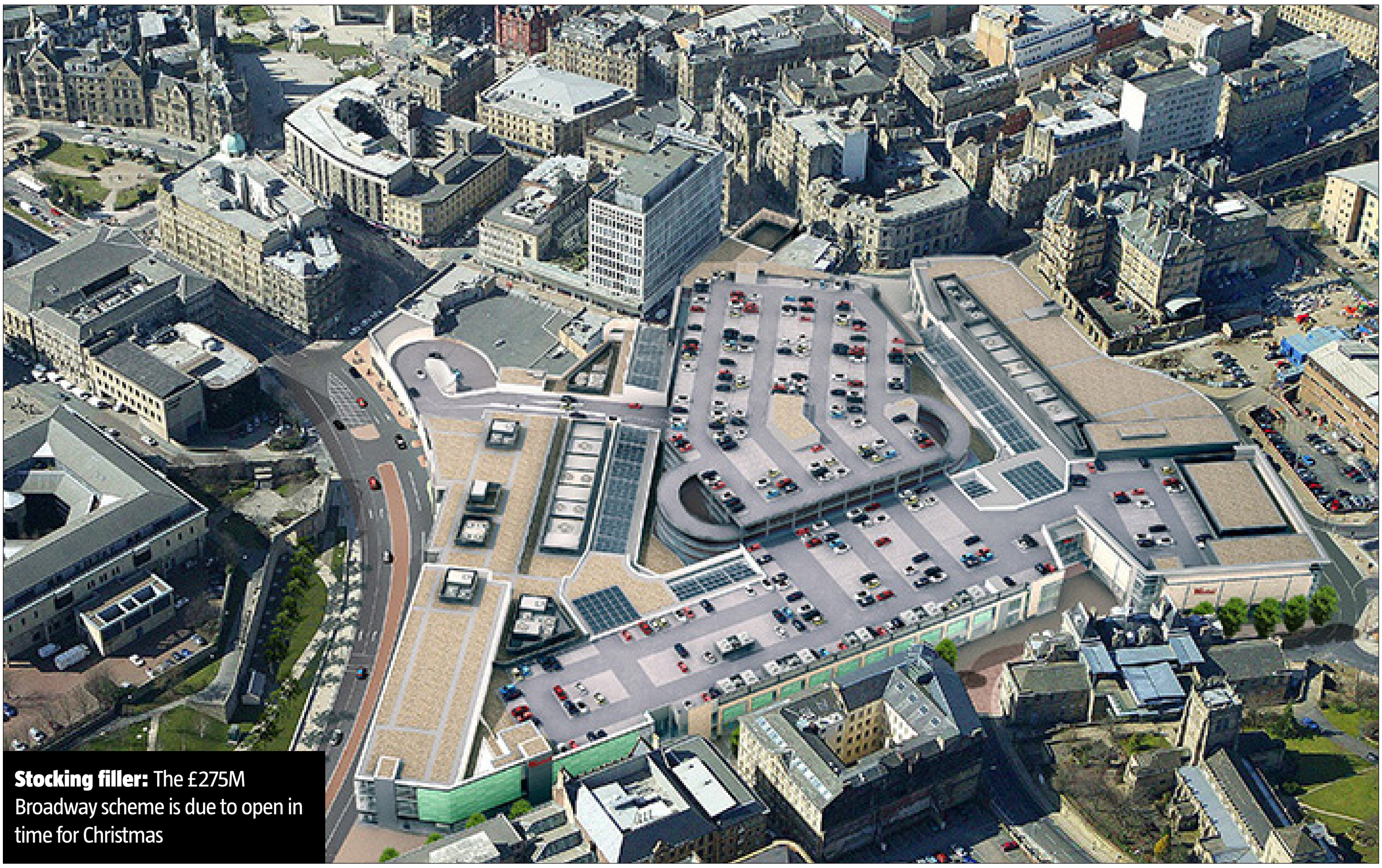
Changing the cores' design meant they could be erected along with the project's steel frame, speeding up the programme so that steelwork contractor Severfield got underway in March and primarily completed the steel erection by early September.

Another reason for the speedy steel construction programme was that the fabrication had begun in 2008.

"We already had more than 2,000t of steel fabricated for the original project and when it stalled we simply stored it away, waiting for the job to resume," says Severfield contract manager Andy Rae.

"Once the project restarted we wanted to use as much of this steel as possible so the majority has been re-engineered into the scheme's new design with very little wastage."

As with many city centre construction projects, the logistics of working in and around a confined site as well as how to make deliveries of steel without causing hindrance to neighbouring



Stocking filler: The £275M Broadway scheme is due to open in time for Christmas

WESTFIELD STATES THE CASE FOR STEEL

"As with many large retail developments, the Broadway scheme has undergone a number of design changes at the request of tenants and some have even taken place during the construction programme," says Keith Whitmore, Westfield head of design and Construction.

"Steel enables alterations to be made easily and this is why it is ideal for retail projects."

"Most of the alterations have been quite small, such as re-positioning lift and escalator penetrations in the frame, but moving a steel column or two is much easier than altering a concrete wall," adds Whitmore.

Steelwork always contributes to a speedy construction programme and Broadway's entire 6,800t steel frame has been erected in just over 25 weeks. This was aided by Westfield's decision to use only mobile cranes and not to install any tower cranes on this project.

Using mobile cranes also means there are no gaps in the frame – where the tower crane would be sat – that need to be in-filled at a later stage, again allowing a faster steel programme.

businesses have been challenging issues for Severfield.

Primarily Severfield erected the steelwork in a sequential manner, from one side of the site to the other. This allowed other trades to follow on behind and left Severfield with sufficient space in which to store some of its delivered steel.

The exceptions to this methodology were the Debenhams and Marks and Spencer (M&S) anchor stores. Positioned at opposite ends of the scheme, the anchor stores had to be erected first as they typically require a longer fit-out programme than the other smaller retail units.

The majority of the retail zone sits above a service basement, and occupies a footprint that is roughly rectangular in shape. Three main covered malls, with exits positioned along all elevations, form a circuit around the development and link the anchor stores.

The M&S anchor store has two main retail levels plus basement service accommodation, roof level customer collection facilities and plant enclosure. Its structural grid is 8.8m x 8.8m, while the grid for the main shopping mall is slightly smaller at 8m x 8m.

The Debenhams store on the other hand has three retail levels (plus basement, roof level collection facilities and plant) and is based around a larger bespoke 10.2m x 12m grid.

"The design of the Debenhams store has gone through a few alterations since the original scheme," explains Rae. "As one of the two anchor stores they decided that they would like an extra floor halfway through the redesign of the project. So all of the steel, which had been pre-made in 2008 for this part of the job, had to be reworked to accommodate this extra level."

Five levels of car parking are located above the central retail zone and this part of the steel frame utilises a 16m x 8m grid to provide column free car parking bays. A couple of steel bridges, formed with 16t beams, link car parking on either side of the pedestrianised mall and these constituted some of the heaviest lifts of the entire steel programme.

The car park also incorporates another important redesign as the main spiral access ramp form was changed from concrete to steel frame.

MPN says it was able to model the complex geometry, which consisted of several curved sections, all of different radii, using 3D Revit modelling software, and then passed this to Severfield as an IFC file for incorporation into their fabrication model. This was intended to allow the ramp to be constructed earlier in the programme to fast track vehicular access to the roof of the scheme for follow on trades.

The final elements of the steel frame erection programme were the installation of a series of portal frames that span the 12m-wide mall and support a glazed roof.

Fine figures: Each of the building's elevations feature either cantilevers or sloping and curving facades

Curving a library

The Curve cultural and learning centre, Slough

By Martin Cooper

A highly architectural and uniquely shaped building is helping to transform Slough town centre.

Part of a multi-million pound regeneration scheme that has already delivered a new bus station, a cultural and learning centre known as The Curve is the latest project to adorn Slough town centre.

As the name suggests the structure is a steel-framed curved rectangle in shape and plan. Each of the building's elevations feature either cantilevers or sloping and curving façades, with the main north side presenting the most striking aspect with a long sweeping, predominantly glazed, elevation looking on to the adjacent listed St Ethelbert's Church.

The three level building is 89.7m long, 15.5m high and has a width, which is 34m at its maximum and 16.5m at its narrowest. With an overall floor space of 4,500m^2, the centre will include a library, café, office space and a 280-seat performance space.

Constructing a building with this kind of complex shape brings with it a whole host of geometry and setting out challenges. The use of a BIM model, shared between the entire project team, made the design process less onerous.

"Our expertise in BIM and 3D modelling using Tekla software has been a great benefit on this project, enabling us to integrate the original architect's model with our own," says Caunton Engineering contracts manager Phil Ratcliffe.

Peter Brett Associates project engineer Mark Way adds: "BIM was the best solution as it allowed everyone to see the same model and this made it possible to detect any possible problems well in advance.

> **"The interface between the roof and the façade steelwork was one of the main design challenges as the roof pitches at three angles,"**
> Mark Way, Peter Brett Associates

PROJECT TEAM

Main client: Slough Borough Council
Architect: Bblur
Main contractor: Morgan Sindall
Structural engineer: Peter Brett Associates
Steelwork contractor: Caunton Engineering
Steel tonnage: 370t

Referring to why structural steelwork was chosen as the project's framing material he adds: "Using steelwork made it much easier to design and form such a challenging shape."

Initially the Curve was to be built with reinforced concrete, but a redesign of the project, instigated by main contractor Morgan Sindall and involving Peter Brett Associates, resulted in the frame changing to structural steelwork.

Not only did this make the project quicker to build it also made the overall frame lighter, saving the client money as shallower piled foundations were needed.

Once foundation installation and groundworks were completed the steelwork programme began in August and was completed in November.

Caunton Engineering erected the structure from east to west, but before the programme reached the final few bays the company realised as the site is quite confined the partially complete frame would begin to obstruct the only access point for steel deliveries.

This could have been a logistical headache if it were not for the fact that there was just enough space for Caunton to stockpile the final 30t or so of steel.

"Once we had the steel stockpiled we also had just enough room to position our 50t capacity mobile crane," says Ratcliffe.

Stability for the frame is derived from bracing, located in stairwells and the lift cores. Early in the erection programme, temporary bracing was also installed to add further stability while the frame was being erected. These temporary props were only removed once the first and second

Literary masterpiece: The Curve is scheduled to open this autumn

ENTRANCE TRUSS

The Curve will have public entrances at both ends with the western end also incorporating a 7m-high void to allow vehicles to access a service yard located at the rear of the building.

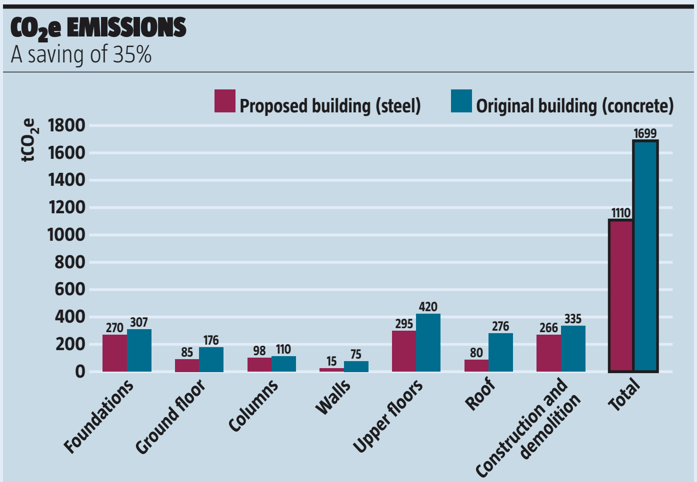
To create this open space a 6m high Vierendeel truss, supported on a V-shaped galvanized oval section column, is positioned along the perimeter of the building.

The truss had to be brought to site piece small, as it would have been too large to transport to site fully assembled. Once at the project the truss was erected piece by piece as there was not enough room on site to assemble it on the ground.

REDESIGN LEADS TO SAVINGS

Peter Brett Associates carried out an embodied carbon calculation to test the assumption that they had improved the amount of embodied energy contained within the structural frame in relation to the original design.

As the graph shows they calculated that a saving of 35% of CO_2e emissions has been made as a result of the building and frame being redesigned in steel instead of reinforced concrete.



floor concrete toppings had been cast as this then provided the necessary composite stability/action.

The structure's perimeter columns are spaced at 7.5m intervals but internally this grid pattern has not been adhered to because of two large atriums that pierce the first and second level floor plates. Most of the internal columns are CHS members, chosen or aesthetic reasons, as they will remain exposed within the completed building.

"The atriums mean we have some beams spanning up to 12m and so we had to limit movement due to wind effects by installing tie beams at first floor level," explains Way.

Creating the feature north façade of the building are a series of curved rib columns supported off of a curving 323mm diameter tubular member.

This main supporting tubular beam curves its way along the entire 89m-long façade, supported on sloping RHS columns. Below the tubular section the façade will be predominantly glazed and consequently tolerances were a challenge on this part of the job.

Specialist bending contractor Barnshaw Section Benders bent all of the ribs and the curved tube. The ribs were delivered to site in complete sections, requiring no splices to form the façade. These ribs vary in height, up to 9m, depending on where they are located along the curving tubular section. As the tubular section's curvature changes radius along its length it was also brought to site in various lengths. To give the tubular section a seamless appearance once the project is complete, the various lengths are connected via internal bolts that are hidden behind plates which were retro welded into place.

The southern façade is less complex and straight in plan, although it does have a bullnose feature where the perimeter columns curve at the top (similar to large hockey sticks) to form the connection with the roof.

"The interface between the roof and the façade steelwork was one of the main design challenges as the roof pitches at three angles," says Way.

Summing up, Morgan Sindall senior project manager Alistair Kendall says: "Morgan Sindall is working within Slough Borough Council's Local Asset Backed Vehicle and a key project within this is The Curve. We are well versed in delivering complex and innovative structures, the latest of which is this new library and community centre for Slough.

"The design of The Curve will make it a local landmark and we're very excited to be leading such an iconic project."

The Curve is scheduled for completion this autumn.