Steel structure raises the roof

The look and functionality of a rail station in Manchester is about to be transformed through clever use of steel and cladding.

Project Manchester Victoria station redevelopment

Client Network Rail

Architect BDP Architects

Structural engineer Holter Consulting

Steelwork contractor Severfield-Watson Structures

ETF2 cladding contractor Vector Foiltec

Steel Spotlight

Victoria railway station in Manchester is undergoing a £44m transformation to bring it into the 21st century. Parts of the station date back to 1844 and were designed by Victorian railway engineer George Stephenson. In more recent years, the station’s train shed has fallen into a state of disrepair with a patch-repaired roof that creates a particularly unwelcoming environment.

Victoria’s redevelopment includes improving the functionality of the station, so that it works more as an interchange for users of Northern Rail trains, Metrolink trams and local buses, as well as the nearby Manchester Arena.

Included in the cost is a £6m curved steel rib and ETFE roof structure, which will allow natural light to flood the station.

Demolition of the old station roof by main contractor Morgan Sindall is now complete and substructure construction has started.

Construction of the new steel roof will begin in early 2014 and continue for 14 weeks. This work will take place while the railway station’s Grade II-listed station offices, Victoria Buildings, are restored. Although the appearance of the structure is that of a canopy extending out from the top of the Arena block and stretching over the train and train lines to the ground, structurally speaking, it works the other way round.

Each rib springs from buttresses at ground level, is then supported by a 20 m-high column and then cantilevers from this point to the existing Victoria Buildings (the Arena). The new roof doesn’t actually touch the old building,” says steelwork contractor Severfield-Watson project manager Gary Dooley. “The aim was to avoid putting extra loads on the existing building. A waterproofing proof ensures that the roof is watertight at this junction and allows the cantilever tip to move up to 150 mm, but does not allow load transfer to the buildings.

Box clever

The ribs are fabricated box-sections: 1.2 m deep and 500 mm wide with 50 mm-thick top and bottom flanges and 20 mm-thick side plates. A single rib is made up of welded sections up to 24 m long.

The sections are being fabricated in Severfield-Watson’s Bolton factory once on site, the 24 m-long sections will be welded together to form single ribs up to 96 m long, before being lifted into position.

Severfield-Watson is also providing the holding-down bolts to connect each rib to its buttress. Some 20, 2 m-long, 40 mm-diameter high tensile Macalloy bars are repaired per buttress. A 90-tonne crawler crane has been identified to lift each rib. One of its main challenges will be to negotiate around the culverted River Irk, which crosses the site. Back in 1844, the single station platform was once accessed via a wooden bridge over this river. It is now surrounded by an 11 m-wide brick-lined tunnel beneath the station. Ensuring that minimal construction loads are exerted over the tunnel has affected the choice of plant and type of structure on the project. The buttresses have been designed to bridge over the river.

Making connections

The rib4s are pre-cambered so that when it deflects under its own self-weight, it pull the member into its final geometry. The columns have been designed to lean towards the buttress in the temporary condition so that as each rib is lowered and adjusted under its self-weight, the column is brought to plumb. Only then can the column base and buttress connections be designed permanently (see diagram right).

The sequence of erection begins at the end of Victoria Buildings. Initially, the first four 660 m-diameter columns will be erected using temporary supports, followed by the first two ribs. At this point there will be extensive temporary steelwork to brace the structure. Permanent bracing will then be installed followed by ribs three and four.

River Irk, which crosses the site. Back in 1844, the single station platform was once accessed via a wooden bridge over this river. It is now surrounded by an 11 m-wide brick-lined tunnel beneath the station. The buttresses have been designed to bridge over the river.

Erection of the 15 steel ribs will take place during night-time railway possessions when rail and tram transport has ceased, avoiding any clashes with Arena users. However, this leaves just a three and a half hour clear window for each lift.

“The wis are able to mobilise and demobilise outside of these hours, so the nearby car park area will be used to assemble, weld and orientate the Rafael (rib) so that they will be ready to lift using bespoke lifting bags when the possession begins,” says Severfield-Watson lead designer Mick Black.

“Working through the logistics of this project is as complicated as a game of chess for us – we’re always thinking about what can go forward, what can be brought in, what needs to be on standby,” says Mr Dooley. He says that some members will be on site for up to three weeks during which time components will be welded, the welds tested and then the steel clad in welded-affected areas before the final paint treatment is reapplied. Each rib is lifted as a single piece and connected at buttresses and columns simultaneously. There is no connection at the building end.

“Working through the logistics of this project is as complicated as a game of chess for us” – GARY DOOLEY, SEVERFIELD-WATSON

Why ETFE cladding was used

Choosing lightweight ETFE cladding (as used at the Eden Project’s biosphere in Cornwall) has allowed the steel ribs span to be further extended. Glazing had been specified. Steel ribs to span further than if biomes in Cornwall) has allowed the

Steel structure raises the roof

The look and functionality of a rail station in Manchester is about to be transformed through clever use of steel and cladding.

The look and functionality of a rail station in Manchester is about to be transformed through clever use of steel and cladding.

The look and functionality of a rail station in Manchester is about to be transformed through clever use of steel and cladding.

The look and functionality of a rail station in Manchester is about to be transformed through clever use of steel and cladding.
Steel has all the angles covered

Steel has helped to deliver the functional requirements of a new cancer research facility, while also realising its bold design.

Project report: RUBY KITCHING

Manchester Cancer Research Centre's new headquarters makes a big statement in the suburban town of Wilmslow. Its crisp lines and bold angles scream out that this is a building making its debut on the world's stage - not just Manchester's. The aim for the facility is for it to be a world-class centre of excellence according to its parent organisation, Cancer Research UK, The Christie NHS Foundation Trust and Manchester University.

Currently under construction on land owned by The Christie's three-storey building is needed to bring researchers and clinicians dotted around Manchester together and to enable their activities to expand. Another aim is to attract world-class scientists to increase the potential for breakthroughs in cancer research.

Its most distinctive features are its dramatic first floor cantilever, sloping façades - flaring out with height – and a central lightwell, sloping façades – flaring out with height – and a central lightwell, sloping columns, which are quite a challenge. That and the steel frame construction followed by clinical trials support staff, who will be based on the same floor.

“Making sure the building is able to fit within the world's stage – not just Manchester's. The construction sequence for the central section of the office block had to be built first to provide sufficient stability to support it. Steel erection commenced with the office block, then the laboratory blocks, followed by the entrance steelwork to connect the two areas.”

The building comprises a central entrance and lightwell flanked by an office block along Wilmslow Road to the west and three blocks of interconnected laboratories to the east. While the entire building is steel framed, floor construction is concrete (steel decking is used in situ concrete) for the office floors and precast planks for the laboratory areas.

The building's most distinctive features are its dramatic first floor cantilever, sloping façades - flaring out with height – and a central lightwell, sloping columns, which are quite a challenge. That and the steel frame construction followed by clinical trials support staff, who will be based on the same floor.

“The building has been designed with the concept of interaction as its main theme, to allow research groups to share knowledge, resources and equipment. “Making sure the building is able to fit within the world's stage – not just Manchester's. The construction sequence for the central section of the office block had to be built first to provide sufficient stability to support it. Steel erection commenced with the office block, then the laboratory blocks, followed by the entrance steelwork to connect the two areas.”

The building comprises a central entrance and lightwell flanked by an office block along Wilmslow Road to the west and three blocks of interconnected laboratories to the east. While the entire building is steel framed, floor construction is concrete (steel decking is used in situ concrete) for the office floors and precast planks for the laboratory areas.

The building has been designed with the concept of interaction as its main theme, to allow research groups to share knowledge, resources and equipment. “Making sure the building is able to fit within the world's stage – not just Manchester's. The construction sequence for the central section of the office block had to be built first to provide sufficient stability to support it. Steel erection commenced with the office block, then the laboratory blocks, followed by the entrance steelwork to connect the two areas.”
Steel Spotlight

Steel speeds laboratory project

A £25m extension to the National Composites Centre in Bristol will help companies to push the boundaries of product design and help the UK lead the world in manufacturing.

**PROJECT REPORT**

**RUBY KITCHING**

Back in 2009, the government decided that one way of supporting the UK’s manufacturing industry was to create technology and innovation facilities where companies could prototype, de-risk and optimise their products. Highlighted in particular was the importance of advanced composites – durable, lightweight and high-performance material used in aircraft, wind turbines and car manufacturing.

A composite material is made from at least two different materials, resulting in a new material with different properties to its constituents. One example of an advanced composite is carbon fibre reinforced plastic.

Support for developing the potential of advanced composites continued through the change in government in 2010 and Phase 1 of the National Composites Centre – owned by the University of Bristol – opened on the northern outskirts of the city in 2011 (see box).

The 6,400 sq m facility attracted some of the biggest names in manufacturing – Bolloré, Airbus and GE Aviation. These companies use the NCC to prototype component parts for cars, entire train carriages and even aeroplane wings made from composite materials.

Soon, the advantage of being able to test products without having the overheads of premises and expensive testing equipment attracted the attention of smaller companies wishing to use the facility on a much smaller scale.

Equally, the larger companies also needed a facility which would suit only single prototype development, but also for developing products for mass production.

One of these talks between industry and NCC is that just two years after Phase 1 opened, work has started on building 9,000 sq m extension next to it. Costing £28 million, Phase 2 is made up of a three-storey Knowledge and Innovation Centre (KIC) and a single-storey ‘high volume manufacturing and large demonstration’ area.

Steel speed

With speed of construction a major factor, a steel-framed structure was chosen for both buildings in Phase 2, similar in form to that used in Phase 1.

Furthermore the University of Bristol engaged in talks with steelwork contractor Billington Structures, ahead of appointing a main contractor, so that steelwork design could get under way immediately. Billington had also worked on Phase 1 of the NCC, so it could carry forward much of the knowledge gained.

Contractor Sir Robert McAlpine started on site in June of this year, when the site was levelled and pad foundations were installed. Billington began erecting steel in August and continued until the end of November.

The construction sequence involved building the KIC first to full height before work started on the demonstration area. The 24 m-wide by 53 m-long KIC block is conventional composite steel beam and column construction with bolted connections and an in situ floor slab cast onto metal decking.

Due to thermal effects it has been built as a structurally separate building to the demonstration area to allow each structure to move independently.

What makes the innovation block more unusual is that for similar spans, there are varying beam sizes. This is because the university specified very different loading criteria for all the different areas. Rooms were designed to accommodate a wide range of activities from investigating the properties of small components to testing part of a plane.

“There are different floor loadings for every area – not just one universal load has been applied,” says Billington Structures project manager to Steve Hayes. “Even where the loads are heaviest, we have had to design beams which fit within the allocated structural zone”.

Beam sizes vary from 186 mm-deep sections to 533 mm, while column sections are 203 mm or 264 mm-deep.

At ground floor, the KIC block contains the main rooms for specialist research including laboratory specification ‘clean’ rooms for testing and freezer stores for temperature-sensitive composite materials.

A lecture theatre occupies the first floor with computer rooms, study areas and informal breakout areas. An open-plan office occupies the second floor and the flat roof will support plant and a roof garden.

Flexible future

Having worked on Phase 1 of the project, Billington understood the need to cater for a range of occupant needs. Some rooms are designed to allow subdivision to gain flexibility for presentations and workshops, but generally the office areas are open plan to allow an open collaborative working environment. Within the build this means that there is a mixture of blockwork partitions, composite clean room walls, and plasterboard or folding walls across the KIC block.

Similarly, services in the building are positioned to allow flexibility for future changes to the demonstration area so that new equipment can be accommodated, where the space is intended for sole use or for sharing.

The 10 m-tall demonstration area occupies approximately 5,000 sq m. Although it is a vast space, it does have three rows of internal columns with roof beams spanning more than 20 m. Northlights in the roof allow natural light to enter the building without allowing direct sunlight to disrupt test conditions. The space is intended for large-scale prototype manufacturing, three gantry cranes supported by double columns to dominate the manufacturing area. Two 10-tonne cranes travel across the main area and a 12-tonne crane services a state-of-the-art hydraulic press. Beam sizes are generally 94 mm deep while column sections are 406 mm or 396 mm-deep.

The hydraulic press, believed to be the only one of its size and specification in Europe, is one of the most important pieces of equipment in the facility and will enable rapid manufacture of large composite components.

The press runs an 11.5 m long by 7 m wide by 4.5 m deep pit, but details of its location and size were finalised after the main steelwork had been designed. When the best location for it turned out to be along a line of internal columns in the demonstration area, two columns had to be removed and replaced by a truss spanning between the two columns.”

“The challenge has been to build a building to accommodate equipment while the exact details of the equipment are still being finalised,” says Sir Robert McAlpine project manager Pete Munn.

Martin Stubbs, Phase 2 National Composites Centre project director, says: “The NCC is an open access facility and so one of the big challenges of the build is balancing the needs of the Department of Trade partners but enabling a wider range of services.”

“The challenge has been to build a building to accommodate equipment while the exact details of the equipment are still being finalised” PETER MUNN, SIR ROBERT McALPINE

This was another reason why a steel framed structure suited the build – any changes could be accommodated easily using additional steelwork or reprogramming the erection sequence.
Steel is the dominant framing material for multi-storey offices. Gardiner & Theobald provide guidance for design teams to ensure that the price is right at early design stages.

**Cost Comparison**

Steel-framed construction has dominated the UK commercial multi-storey building sector for the past 20 years. Reasons include that office buildings often require a quick build programme, need long spans to create open-plan areas and steel provides the ability to integrate services within the structural floor depth – often resulting in extra levels being accommodated within the height of the building.

A steel-framed structure, usually with composite floors or cellular beam openings to accommodate services, often fits the bill perfectly. But every design team has to start from scratch when working on a new building to meet a client’s aspirations and each site’s constraints. Choices are made early in the process on which framing material to use. Making the right choice can lead to more cost-efficient designs, not only on frame but on other elements of the building and changes later in the design process can be costly.

### Benchmark rates

Gardiner & Theobald was commissioned by Tata Steel and the British Constructional Steelwork Association to provide benchmark rates based on real project costs. Table 1 provides current benchmark rates for Q4 2013, which should be adjusted for location using the BCIS index. The rates are updated quarterly and published in the cost section of www.steelconstruction.info along with the BCIS index.

Gardiner & Theobald also provide current comparative cost data for standard construction options for two typical building types: a high-rise city centre building (Building Two) and a low-rise business park building (Building One).

The comparisons were independently developed by Gardiner & Theobald with structural engineer Peter Brett Associates (PBA) and contractor Mace. Peter Brett developed four viable structural solutions for Building One (see box):

- **Steel composite beams and composite slab;**
- **Steel frame and precast concrete slab;**
- **Reinforced concrete flat slab;**
- **In situ concrete frame with post-tensioned slab.**

Two viable structural solutions were developed for Building Two (see box):

- **Cellular composite beams and composite slab;**
- **Post-tensioned beam and slab with in situ columns.**

Typical construction programmes according to current working practices were put forward by Mace, while Gardiner & Theobald assessed cost implications. Results for both buildings demonstrated that it was important to consider whole building costs and not just frame costs because each frame type affected other elements in the project, such as the substructure, roof, services and cladding. Gardiner & Theobald senior associate Rachel Oldham says: “If you just consider the floor and frame, then you will not be including elements which have a significant impact on the cost of the whole building.”

The study compared the cost of different building solutions, taking into account programme, design and whole-building costs. For both buildings the steel-framed options were lighter than reinforced concrete ones and, therefore, required smaller foundations and are quicker to construct. It also points out that there are losses and gains from all structural solutions and that any costing exercise needs to weigh all of these up.

**Cost comparison**

In terms of cost, the steel composite solution for Building One had the lowest with £3,505/m² compared with the highest cost solution, £3,650/m², for the post-tensioned concrete flat slab.

The study says: “The steel composite beam and slab option has both the lowest frame and upper floors cost and lowest total building cost. This option has the lowest substructure costs of all frame options due to the lighter frame weight and the lowest roof cost due to the lightweight steel roof deck.”

The steel cellular composite option for Building Two was £1,681/m² cost less than the post-tensioned concrete band beam and slab, which was £1,822/m².

The cellular steel composite option has both a lower frame and floor cost and lower total building cost than the post-tensioned concrete band beam option. The steel option also benefited from lower substructure costs due to the lighter frame weight and a lower roof weight.

The steel option has a lower floor-to-ceiling height (4.18 m) compared with 4.59 m, which results in a 5 per cent smaller cladding cost and also lower preliminaries costs due to its shorter programme.

The study also investigated the embodied carbon for Building Two’s structural frame options. It found an 18 to 30 per cent lower embodied carbon content for the whole building (excluding operational costs) for the cellular steel option than the post-tensioned beam band option.

### Building 1: Low-Rise Office

This 10 storey three-storey business park office building with a gross internal area of around 3,200 m² has a floor plate width of 18 m, floor-to-ceiling height of 2.8 m, one central core, two lifts and clad in brick. Windows occupy 35 per cent of the facade area.

### Building 2: City-Centre Office

This eight-storey city-centre office building with a gross internal area of around 16,500 m² is L-shaped with a double height reception area, central core and internal secondary escape stair. The floor-to-ceiling height is 3 m, structural grid 7.5 m by 7.5 m and the external envelope is a curtain wall steel structure constructed to storey-height panels 1.5 m wide with feature fins.

**Table 1: Benchmark Rates**

<table>
<thead>
<tr>
<th>Indicator of Cost (as a ratio of the benchmark rate for City of London)</th>
<th>BCS 100</th>
<th>City of London</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frame 1 – low rise, short spans, repetitive grid / access, easy access (building 1)</td>
<td>75-100</td>
<td>90-120</td>
</tr>
<tr>
<td>Frame 2 – high rise, long spans, easy access, repetitive grid (building 2)</td>
<td>125-150</td>
<td>140-170</td>
</tr>
<tr>
<td>Frame 3 – high rise, long spans, complex access, irregular grid, complex elements</td>
<td>140-170</td>
<td>160-190</td>
</tr>
<tr>
<td>Floor – metal decking and lightweight concrete topping</td>
<td>45-60</td>
<td>50-70</td>
</tr>
<tr>
<td>Floor – precast concrete composite floor and topping</td>
<td>45-60</td>
<td>50-70</td>
</tr>
<tr>
<td>Fire protection (60 minute resistance)</td>
<td>7-14</td>
<td>8-16</td>
</tr>
</tbody>
</table>

To determine the cost of a building using the table, add the cost of the frame type, floor type and the protection. The standard ranges should be adjusted to reflect different locations and any variation from the described arrangement.

---

**Additional Information**

- Steel is the dominant framing material for multi-storey offices.
- Gardiner & Theobald provide guidance for design teams to ensure that the price is right at early design stages.

---

**Steel Costs and Comparisons**

Steel is the dominant framing material for multi-storey offices. Gardiner & Theobald provide guidance for design teams to ensure that the price is right at early design stages.
Radical rooftop garden for residents

A mixed-use development in Canning Town will see a supermarket roof play host to a private garden for people living alongside a major road.

**PROJECT REPORT RUBY KITCHING**

Bouygues Development and the London Borough of Newham are delivering one of the most exciting and significant town centre regeneration projects in London. Forming part of the wider £6.5bn Canning Town and Custom House Regeneration Programme, Canning Town in east London is currently undergoing a five-phase, £600m regeneration scheme to create 1,200 new homes and 30,000 sq m of leisure and retail space Hallsville Quarter, as it is now known, is a 6 ha site located at the junction of the A13 flyover and Silvertown Way, both busy dual carriageways in the London Borough of Newham.

The development is ideally located for main roads in and out of London, and is well placed for public transport from Canning Town Tube, bus and Docklands Light Railway station.

To inject some greenery into the urban landscape, Phase 1 of the scheme, which is currently on site, will include a 7,000 sq m private garden including allotments, mature trees and a playground. It will sit on the roof of a steel-framed supermarket 9 m above street level. That might sound unusual, but it makes a lot of sense.

Phase 1 is a mixed-use development with 199 residential units. The 100 sq m site will include three, seven-storey residential blocks and a row of four-storey town houses. These buildings sit in a horseshoe arrangement around the central shared private garden.

The ground and first floors of the entire site are a double-height retail space, which will be dominated by a supermarket. A car park, mainly for its customers, will be located at basement level. The steel-framed structure for the supermarket and roof garden has recently been completed by steelwork contractor Graham Wood Structural. The main contractor is Bouygues UK, led by Bouygues Development.

The primary beam structure comprises I-section plate girders 1.2 m deep and 50 mm thick, weighing around 7-11 tonnes each. Secondary beams are 1.016 mm-deep and 50 mm-thick, also required to create mezzanine retail levels and to support the townhouses and feature screen (see box).

Bouygues UK senior engineer, Rory O’Sullivan says the steelwork has been straightforward. Just 15 plate girders span the supermarket roof and take the heavy garden loads. “The supermarket has spans of 15.5 m and the structure is also required to support about 1 m depth of soil and trees up to 6 m tall. It took just three weeks to erect,” he says.

A steel frame was also the ideal choice for bolt-on mezzanine levels in other retail locations.

**Steel Spotlight**

A PRIVACY SCREEN THAT MAKES A STATEMENT

To screen townhouse residents from the A13 flyover and provide a feature for road users, architect Haworth Tomkins Associates has designed a 100 m long, 8 m tall lattice structure that will support a curtain of vegetation. The steelwork contractor for this structure is S H Structures.

Painted yellow, the screen is made up of 168 mm diameter circular hollow sections arranged in a lattice truss, which cantilevers off the main steel frame at podium (first floor) level. In cross-section, the screen is hockey-stick shaped with the long leg making up the 8 m height and the short leg creating an overhang at the top. A lightweight wire mesh curtain will support climbing plants, such as wisteria. The bottom of the curtain will be fixed to the main steelwork.

The screen will be fabricated and trial-assembled in S H Structures’ factory in Sherburn-in-Elmet, North Yorkshire, and brought to site in sections. “We’ll build it in to the height panels in our factory and then split it horizontally for delivery, because a complete panel will be too wide for road transport,” explains sales and marketing manager Tim Burton.

Locating brackets pre-welded on to the truss will ensure the panel will align exactly on-site before being welded. “The weld will be ground flush and the final topic (of paint) will be applied on-site. The impression will be of a seamless connection,” he adds.

Graham Wood Structural is currently designing the eight-bolt connection between the base of the screen and the main steelwork. The connection has to resist a large overturning force at the base of the screen. The screen top has been designed to deflect up to 185 mm.