Tram plan calls for bridge variety

Nottingham’s tram network is being extended with the aid of five new steel bridges, including one launched across the city’s main railway station.

**Project Report: Ruby Kitching**

A mass transit project is currently under construction to extend Nottingham's tram system, Nottingham Express Transit. Phase one of the route opened in 2004 and currently operates between the city centre and suburbs to the north. Phase two of the network has been on site since 2012 and will connect the city centre to those at its southern end.

The new route is made up of two new lines, both extending from the current tram terminus at the city's main railway station. One line will head south through the town of Clifton and the other south-west through Beeston. Both lines will draw together key conurbations as well as the Nottingham University campus and Queen's Medical Centre. Park and ride facilities at the extremities of the new lines will also encourage the public to leave their cars at free car parks and travel by tram into the city.

More than 17 km of tram line will be built in phase two, and in March 2014 the increase was confirmed by the city's mayor on the large task ahead.

**Bridge Design Looks to Steel for Aesthetics**

“Our main challenge is that we are building in busy urban areas, rather than in a greenfield site,” explains Nottingham City Council project director Chris Deas. “Therefore construction methods have had to take into account much more than just the building process.”

The bridges have been designed, he continues, to enhance their environment. “We considered carefully the look and function of these structures as part of the design process and chose steel because we wanted to achieve something with a contemporary feel,” Mr Deas says. Describing the Karlsruhe and Clifton Boulevard bridges, he says, “These bridges will be the most obvious landmarks of the route – providing interest and excitement to change Nottingham for the better.”

The new tram line will allow the new line to span Nottingham railway station, the A52 dual carriageway, the mainline railway at Lenton south to the River Trent (see box). The steelwork contractor on the scheme is Cleveland Bridge.

**Historic Path**

The bridge that is being built over Nottingham’s main rail station follows the line of a former railway bridge — which was demolished in 1983 — and is able to use some of its foundations. The new 1,100 tonne, 104 m-long, two-span tubular steel Warren truss bridge is similar in style to its predecessor, but with a neat modern twist: jumbo circular hollow sections up to 71 mm in diameter and 40 mm thick have been specified rather than rectangular sections, and the top chords are arched. The truss is deepest at its centre pier.

“Using a truss structure (and circular hollow sections) has meant that it is light enough to be supported by the previous bridge’s substructure, and has made launching a more feasible form of erection,” says Mott MacDonald senior bridge engineer Ray Sexton. The bridge will feature a composite deck and was launched into its final position last month.

Flanking it are two further bridges which will take trams on the Beeston line south across Queen’s Road and down to street level in Station Street to the existing tram line. The Queen’s Road Bridge is a 1,600-tonne, two-span 20 m-long structure comprising twin steel box girders and a reinforced concrete deck, while the Station Street Bridge is a 16 m-long pre-stressed precast beam structure.

In honour of Nottingham’s twin city in Germany, which inspired the council to develop a tram system, the bridge will be known as the Karlsruhe Friendship Bridge.

**Night-time Slide**

Launching involved sliding the structure using a series of hydraulic ram jacks positioned on supporting temporary towers between 8pm and sun up the next day.

“‘We chose steel because we wanted to achieve something with a contemporary feel’”

CHRIS DEAS, NOTTINGHAM CITY COUNCIL

“One of the main construction constraints was that the slender bottom boom sections could not resist high levels of point stress between nodes. In the bridge’s finished state, this would not be a problem. But during launching, there was concern that roller or sliding bearings might overload the section, requiring extra plates to be provided to the section to avoid permanent softness. The length between node points at the bridge length adopted for the launch was designed to be 2.6 m, explains Taylor Woodrow Alstom section manager Paul Channon. “This ensured there would never be a concentrated load halfway between nodes,” he says.

A sliding launch solution was also favoured over rollers for practical reasons: the weight of the structure on the rollers would scrape off the paint during the launch, eventually clogging up the rollers. “If we used rollers, we would not have been able to paint the bottom boom until after the launch,” explains Mr Channon, who adds that this would have affected the programme.

The sliding system, he says, also used hydraulic rams, which were simple to control.

Now the Nottingham station bridge has been launched, Station Street bridge and Queens Road bridge can be built, with the entire line due to open in December 2014.

**“A truss structure means it is light enough to be supported by the previous bridge’s substructure”**

RAY SEXTON, MOTT MACDONALD

**Three More New Bridges on the Tram Network**

**Clifton Boulevard Bridge**

A 61 m-long, single-span bow-string arch structure weighing 920 tonnes is due to be built across the A42 in September 2013 using self-propelled modular transporters during a night-time road closure (see box).

The composite deck bridge has been designed with a steel box section by the architects and an I-section girders along the deck, its ends are currently being constructed and main steelwork is being fabricated off site.

**Lenton South Junction Bridge**

This 380-tonne, 45 m-long single-span steel structure comprises a series of steel crossbeams between two 3 m-deep plate girders (see box). Prior to being installed in February 2013, the plate girders were supported on temporary platforms and bearings while all steel erection and deck concreting took place. Self-propelled mobile transporters lifted the skewed structure perfectly into position on each abutment.

**The Will福德 Toll Bridge**

This three-span structure over the River Trent (see box) has been erected comprising of 91 m-long plate girders. An underbridge unit was used to access the bearings on the upstream plate girder.

Pier strengthening works and steel erection methods had to take into account the river.
Steel Spotlight

Twice as high for office replacement

Building a new office block on existing foundations in a restricted London site around the Olympics challenged conventional construction methods

PROJECT REPORT
RUBY KITCHING

The decision to reuse the foundations of the former eight-storey office block at 6 Bevis Marks in the City of London has had a profound impact on its new, larger replacement. Two lift cores for the new 16-storey building had to go in similar locations as those of the former building and a lightweight frame solution was essential to ensure the existing foundations could be reused. The main steelwork frame, totalling 2,000 tonnes, has just been erected on the project by contractor William Hare. Its client is Bevis Marks Development, a joint venture between AXA and MOPA. The main contractor is Skanska and the structural engineer is Waterman Structures.

Lettable space

“An eight-storey concrete building was demolished and replaced with a 16-storey one using existing foundations,” says Waterman Structures director Julian Traxler. “We couldn’t have achieved that and the net lettable areas required by the client if we hadn’t used a steel frame – it just wouldn’t have been viable.”

Thirty-seven new piles were installed around existing ones to accureate for different loading patterns, but the ethos of the project has been to keep the weight of the structure to a minimum by using elements as light as possible to achieve large useable floor areas.

“Floor beams are made up of fabricated plate girders that have the smallest possible top flanges [to keep the weight low] – just sufficient for the shear stud connection through the metal deck,” adds Mr Traxler.

Beams span up to 13.5 m and are typically 600 mm deep and designed primarily for vibration and response. Openings in the beams for services keep the structure and services zone to a shallow 250 mm. With floor plates up to 85 mm long, the span between columns has been dictated by the position of the two cores and the optimum column arrangement for open plan office spaces.

The L-shaped building sits between the 41-storey Gherkin building at 30 St Mary Axe and more modest seven-storey buildings on Bevis Marks. The new building at 6 Bevis Marks sympathetically steps down from 16 storeys to 12 storeys towards the shorter buildings.

Basement project

The new steel frame and composite floor structure occupy the same area as the former building since the existing single-storey basement could not be retained. The 1 m thick transfer slab forms the new basement and has proceeded up from the basement slab in an anti-clockwise direction from the south east corner of the site.

Columns are typically circular hollow sections in the centre of the building and rectangular hollow sections at the perimeter. To accommodate the perimeter fabricated rectangular sections measure up to 550 mm by 350 mm with plate thickness varying between 12 mm and 19 mm. The columns are bored rather than having intumescent coatings applied because, in the event of a fire, there was not enough room for the coating to expand. To accommodate the largest of these members at ground floor required some clever detailing and design. Bolted splice connections would have taken up too much room, so column had to be welded on site. “To save time and allow construction to proceed, temporary clamps join columns, with welders returning to grind off the clamp and make the permanent connections later,” says Skanska project director Andy Hankin.

William Hare designed a bespoke cantilevered welded frame or “cradle”, which was fixed to the column and floor to allow safe access to the column, that sits on the outside of the slab on three of its sides. The cradle was developed specifically for this building to access all four sides of the column and was modelled into the 3D fabrication computer model to consider splice levels and edge conditions.

Crade saving

Using a cradle meant that much less scaffolding was required on the project, saving time. With the main steelwork now complete, work on site is focused on erecting the roof steelwork to support an ETFE roof. The 690 m² building, which has 22,000 sq m of office space, is due to be completed in November and is aiming for a BREEAM Excellent rating.
CE marking: what you need to know

The legal requirement for CE-marking of construction products comes into force next month with fabricated steelwork to follow a year later. What does it mean for clients, consultants and contractors?

FACT BOX
- CE marking for all construction products will become mandatory in all member states throughout the European Union and the European Economic Area from 1 July 2013, and 12 months later if it has been already CE-marked.
- Part 1 of the CE-marking standard for fabricated structural steelwork, BS EN 1090, describes how components should meet the structural characteristics which make them fit for purpose.
- Natural progression. Accordingly, if a product has already been CE-marked, it will be mandatory after 1 July 2014 as part of their membership audits. Many are compliant already.
- Natural progression. Accordingly, if a product has already been CE-marked, it will be mandatory after 1 July 2014 as part of their membership audits. Many are compliant already.

Natural progression
- The legal requirement for CE-marking of construction products comes into force next month with fabricated steelwork to follow a year later.
- According to BCSC member William Hare, quality assurance manager for steelwork contractor William Hare, explains that the arrival of CE marking in structural steelworks products this July and fabricated structural steelwork products next year is a natural progression for the industry, which has been working hard to have high standards of safety and quality in place.

Ce marking is good for the industry, as we now have a clear, identifiable set of standards for fabrication

Stuart Watt, William Hare

“Ce marking represents a clear set of standards for fabrication that the product’s “declaration of performance means that it is fit for purpose.”

WHAT A CONSULTANT NEEDS TO DO
- Specify all construction products must be CE-marked where appropriate.
- Appoint a steelwork contractor with an “Execution Class” that is equal to that which is required for the project.
- When buying a product, check that the product’s “declaration of performance” means that it is fit for purpose.

WHAT A CLIENT/MAIN CONTRACTOR NEEDS TO DO
-.selecting a BCSC member company will guarantee that the steelwork contractor has the necessary certification to comply with the CPR requirements.
- “Clients and main contractors can, therefore, be confident in the complete supply chain – from manufacture of the steel sections and other products such as structural bolts, welding consumables and proprietary products through distribution to fabrication and erection on site.”
- Compliance requires that a steelwork contractor has been assessed by a notified body such as the SCS and certified that it meets the required standard for factory production and welding.
- Only then can the steelwork contractor CE-mark its products.
- Dr Moore stresses, however, that the CE mark ensures manufacturing quality and fitness for purpose, “you still need to check that the product is fit for your purpose”.

WHAT A MANUFACTURER NEEDS TO DO
- Manufacture are correct for the materials used for its fabrication process.
- He adds that, on the whole, the systems required by the standards were already in place at William Hare, but CE marking has added a further level of assurance, ensuring traceability in all processes.

Steel Spotlight

A CE-marked product means:
- Essential, this creates a common technical standard; a level playing field for safe, comparable and high-quality manufacture for all construction products used in EU countries.
- Essentially, this creates a common technical standard; a level playing field for safe, comparable and high-quality manufacture for all construction products used in EU countries.

Steel Spotlight

WHAT A MANUFACTURER NEEDS TO DO
- Manufacture are correct for the materials used for its fabrication process.
- He adds that, on the whole, the systems required by the standards were already in place at William Hare, but CE marking has added a further level of assurance, ensuring traceability in all processes.

Steel Spotlight

WHAT A MANUFACTURER NEEDS TO DO
- Manufacture are correct for the materials used for its fabrication process.
- He adds that, on the whole, the systems required by the standards were already in place at William Hare, but CE marking has added a further level of assurance, ensuring traceability in all processes.

Steel Spotlight

WHAT A MANUFACTURER NEEDS TO DO
- Manufacture are correct for the materials used for its fabrication process.
- He adds that, on the whole, the systems required by the standards were already in place at William Hare, but CE marking has added a further level of assurance, ensuring traceability in all processes.
Mansfield’s ride to regeneration

Mansfield bus station’s striking design will not only improve public transport links, it will also set the benchmark for high-quality regeneration.

**PROJECT REPORT RUBY KITCHING**

**Project** Mansfield bus station  
**Client** Nottinghamshire County Council  
**Architect** Nottinghamshire County Council  
**Main contractor** Kier Construction  
**Steelwork contractor** William Saunders Partnership

When Nottinghamshire County Council began reviewing its bus stations in 2004, Mansfield bus station was quickly identified as one which needed modernising. The existing station, built in 1977, was looking tired and did not provide the facilities and access requirements that a busy transport interchange should offer in the 21st century.

“It was a product of its age,” says Nottinghamshire County Council lead officer for the scheme Paul Horn. “With numerous steps, insufficient seating and cover, the bus station was fast becoming out of date.”

But the bus station was attached to a car park and was also some distance from the town’s railway station, so it offered very little in the way of integrating public transport in the area. The council decided to step in, offering the bus station’s existing location for retail development and shifting it towards the railway station to create a transport interchange, as well as a much-needed link between the railway station and town.

The new site is a former car park previously owned by Mansfield District Council. Connection to the higher level railway station is via a pedestrian link bridge (see box below).

The bus station scheme began in 2011 by redesigning the road junction to enable buses to turn. This work was designed and constructed by NCC Highways Department. Work on the main structure began in January 2012.

**Quality ambition**

At design stage, the council’s aim was to create a safe, comfortable environment to stimulate more bus travel and create a benchmark for high-quality design in the area.

“We were looking for an airport-styled bus station – something which felt light and airy with clear sight lines to information desks and high-level screens,” says Mr Horn.

With a nod to nearby Sherwood Forest, the structure comprises a system of tree-like steel support structures which at eye level are clad from the Peak District, echoing the material used in an adjacent railway viaduct.

**DELICATE OPERATION**

The 73 m-long footbridge slopes down from a ramp in the train station to the bus station’s second floor level, 3.15 m below. It is 9 m wide by 7 m tall and made up of twin inclined trusses consisting of circular hollow sections, which support the roof above.

Prior to this structure being erected, the bus station structure had to be built as well as two pairs of props support. One pair is located on the embankment of the adjacent railway and another on sloping ground.

To ensure the neighbouring railway embankment wall was not compromised, two pairs of props were used to support the railway embankment and the road structure. These prop pairs were subsequently removed as the station structure was erected.

**SPECIAL BRANCHES**

Each steel perimeter column (‘tree trunk’) of the building is a vertical cantilever with a set of stainless steel pin connections at their tip to receive six ‘branch members’.

These branches spay out from the column head at different angles and are also different lengths.

Pinned connections connect the ends of the branches to rafters in the undulating roof. Column lengths vary (the tallest being 8 m) due to the undulating roof design. In all, no two steel members on the 220-tonne project are identical.

“Modelling the roof was by far the most challenging part of this project,” says NCC structural engineer Mike Wright. “The roof falls in three different directions and getting it to work was what you woke up in the morning worrying about.”

Initially, a faceted perimeter roof beam was designed by Caunton, but this did not give the sweeping curves that the architect envisaged, so curved beams had to be specified.

Erection involved building pairs of columns either side of the bus station first. As the columns are fixed to ground beams, they could not be freestanding, while temporary props were installed from column head to cross beams in the roof.

Three pairs of frames were built at a time to create two bays of the structure, starting from the two-storey end of the building. When all six branches had been connected between column head and rafter on the first frame and steelwork on the second frame had been erected, props in the first bay could be removed and reused further along the length of the building.

Steelwork contractor Caunton Engineering had to design and fabricate bespoke connection details to locate and fix these members. “There are six pin connections to each of the 40 column heads in the structure,” says Caunton contract manager Adrian Dowling.

“Each stainless steel connection is exposed and fits to a cranked cap plate (see each column). Due to the roof geometry, no two supports are the same.”

**“We looked at designing the structure using timber, but the steel option came in slightly cheaper,” recalls Mr Horn.”**

At a public exhibition, the steel design was also slightly more popular, since the railway station is at a level 8.4 m above the ground level of the bus station, the 73 m-long link bridge slopes down and connects to the bus station at second floor level, and at a height that allows buses to pass under it.

**Station shelter**

The bus station roof accommodates the change in height from single-storey shelter to two-storey building (with offices on the upper levels) via an undulating copper coloured, aluminium roof. It has meant that the branches of the tree supports are of varying lengths (see box above).

The bus station has still had to include a few steps and ramps to accommodate the change in ground level on the sloping site. Mansfield bus station is the county’s busiest bus station after Nottingham and sees more than 5 million passenger journeys per year.

The bus station, which opened in March this year, will also house a cafe, toilets and retail units as well as room for 16 bus bays and six bays for parked buses.

“‘We looked at designing the structure using timber, but the steel option came in slightly cheaper,’” recalls Mr Horn.”

“‘We looked at designing the structure using timber, but the steel option came in slightly cheaper,” recalls Mr Horn. “At a public exhibition, the steel design was also slightly more popular, since the railway station is at a level 8.4 m above the ground level of the bus station, the 73 m-long link bridge slopes down and connects to the bus station at second floor level, and at a height that allows buses to pass under it.”
Stonehenge gets more welcoming

The last piece of steelwork has been installed on the roof of Stonehenge’s new visitor centre, and indicates how it sits in the Wiltshire landscape.

INSIDE STONEHENGE

Stonehenge in Wiltshire is one of the most important and popular ancient monuments in the world, attracting more than a million visitors every year. The site is a palace of worship and celebration during the summer months each June.

Stonehenge started life as a simple earthwork enclosure and developed in several stages until the Neolithic period around 2,500 BC. The stone circle, which existing facilities will be dismantled and the landscape restored around the stone circle. The transformation will be complete in summer 2014.

Steel Spotlight

The last piece of steelwork has been installed on the roof of Stonehenge’s new visitor centre, and indicates how it sits in the Wiltshire landscape.

PROJECT REPORT

Dignified, discreet and easily dismantled – these are the main themes of Stonehenge’s new visitor’s centre, located 2.4 km west of the ancient stone circle. The new, more spacious building replaces the current facility, which, English Heritage admits, is a “cluster of old and cramped visitor buildings.”

Construction of the new building is part of a wider £20m scheme to create a more serene atmosphere around the site by relocating the existing visitor centre, parking and roads that sit beneath a gently single-storey steel framed pods.

Corker Marshall, the building is how well it sits in the landscape.”

“Construction of the visitor building is just one aspect in transforming what is widely agreed to be an unsatisfactory tourist and cultural experience,” says Stonehenge director for English Heritage Loraine Knowles. “It is [now] fantastic to see the building taking shape and to see how well it sits in the landscape,” says architect Angela Dapper.

One pod is clad in glass and the other in sweet chestnut timber. The undulating steel and timber roof clad with perforated zinc cladding. A seemingly random arrangement of steel columns span between the ground and pod roof and canopy.

Gentle curves

“The roof gently curves responding to the gentle curves of the Salisbury Plains. Walking through the columns will be like walking through a series of trees, again referencing the surrounding landscape,” says Denton Corker Marshall architect Angela Dapper. One pod is clad in glass and the other in sweet chestnut timber. The glass pod wall house the café, shop and learning zones and the timber clad pod, which also uses structural insulated panels will house a 235m long exhibition space, and toilets.

Steelwork contractor 3H Structures used information provided by structural engineer SKM and Denton Corker Marshall to develop a 3D computer model of the project. The model formed the basis of all subsequent drawing, detailing, material procurement, manufacturing and site installation. Digital information was exchanged between parties as the scheme design developed until the final model was signed off for construction. Main contractor Vinci began work on the site for the visitor centre in July 2012.

Sharp edge

“Steel was the obvious choice to minimise the thin depth of the canopy and achieve a sharp edge,” says SKM project director Matt McNab. “The relative ease of bending steelwork also lent itself to the organic curved shape of the canopy.” He adds that the lightweight steel structure fulfilled the design brief that required that the building be easy to deconstruct as well as construct.

The choice of steel, says Mr McNab, “stemmed not only from a client’s desire for a sustainable building but also for a building that could be removed leaving minimal impact on the landscape.”

Raking canopy

Raking 100 mm wide square hollow section columns provide vertical supports to the canopy. Their slenderness makes them much less visually obtrusive than larger sections, despite there being more than 300 supporting the canopy.

The main challenge for SKM was to solve the problem of lateral thrust in the structure from these raking columns. Stability was achieved using a variety of means without compromising the building’s architecture and included using the moment capacity of fixed columns using a full birdcage scaffold designed with strategically placed screw heads. These were surveyed and set out to achieve the required three-dimensional tolerances.

The roof elevation sequence involved installing one complete griddle of raking columns, followed by propping each one individually and then lifting the roof members into place. Steelwork for the canopy roof arrived on site in 17.5m long truss sections. These curved sections were adjusted to meet the exact requirements of the roof geometry while temporarily supported. Once this shape was achieved, the splices in the ladder trusses were welded together to create the canopy’s undulating form.

In-filling between ladder sections was completed by welding small secondary steel pieces into place.

“There are some 276 site welds within the structure joining the sections of primary truss and the steel grillage system within the roof,” says 3H Structures project manager Dave Poole.

Coordination between architectural and structural details has led to a much simplified set of rules for canopy erection, all the inclined columns have been located and patched to penetrate the canopy soffit at either the corner of the cladding panel or the centre of the edges between panels. With the building now topped out, fitting in has begun in earnest. The new visitor centre is due to open this December, after which existing facilities will be dismantled and the landscape restored around the stone circle. The transformation will be complete in summer 2014.

LOW-IMPACT DESIGN

Currently, the A344 runs incongruously close to the stone circle, so English Heritage’s £27m Stonehenge Environmental Improvement project also includes closing this route to the public from the end of June. Paving areas will also be relocated near the new visitor centre. 2.4 km away from the stones. The stone circle will be accessed via a shuttle service, which follows the existing route of the A344.

The transformation will be complete in summer 2014.

Steel columns support the new visitor centre canopy

300

Slender columns that support the canopy

The new, more spacious building is part of a wider £20m scheme to create a more serene atmosphere around the site by relocating the existing visitor centre, parking and roads that sit beneath a gently single-storey steel framed pods.