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STEEL FOCUS #9

STRUCTURAL STEELWORK

UNITED AT WEMBLEY

A stunning ETFE and exposed-steel atrium links together Brent council's main services, all just a kick away from the national stadium

A DRAWBRIDGE FOR THE 21ST CENTURY

Wilkinson Eyre reinvents the bascule bridge as a pair of majestic sails that soar 40m above Poole harbour

THE MEANING OF WHOLE-LIFE

With building regulations getting tough on embodied carbon, designers need to know how to assess this hidden footprint

They've got it all covered

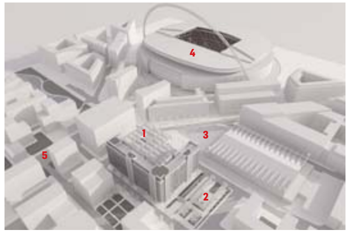
Hopkins Architects' Brent Civic Centre in north London brings together a range of public services in an elegant structure crowned by a stunning ETFE and steel roof

Text by Pamela Buxton

Now football fans flocking to Wembley will have something other than the famous arch to look at as they make their way to the stadium from the underground. Hopkins Architects' Brent Civic Centre, on Engineers Way just off the main pedestrian route to the stadium, opens this summer, dominated by an ETFE-filled roof sailing high over a circular "civic drum" and atrium.

The 40,000sq m building is on course to gain a Breeam "outstanding" rating and combines civic, administrative and community functions. By bringing together different uses within an interactive public space, the architect developed ideas first explored in the Hackney Service Centre, completed by the practice in 2009, according to senior partner David Selby.

The £100 million building brings together 2,000 staff from disparate offices and deliberately seeks to encourage connectivity and openness through its design. This also entailed a rationalisation of office accommodation, with eight seats for every 10 staff to reflect anticipated numbers in the office at any one time.



AERIAL PERSPECTIVE

1 Brent Civic Centre 2 Wedding Garden 3 Arena Square 4 Wembley Stadium 5 Olympic Way

"We wanted to design a building that was both stunning and buildable within the budget," says Selby. "Local authorities want the most sustainable modern building, but not one that is ostentatious. So at Brent Civic Centre, our approach utilised thermal mass, natural ventilation, robust surfaces and suspended services. External features were largely functional, for example the brise-soleil facade. In the case of the atrium, the roof reflected the desire to bring all departments together in one building 'under one roof'. The use of standard steel sections for the roof structure was an economical and elegant solution."

Hopkins opted to orientate the building on Arena Square, with visitors entering the atrium at ground level and proceeding up grand civic steps to the council chamber. Instead of occupying the whole site, the practice left an adjacent space for a wedding garden to support use of the 1,000-capacity community hall as a wedding venue. Administrative accommodation is arranged over nine floors in an L-shaped building wrapping around the rear of the site.

This structure is braced at either end by steel framework - a structural necessity to support the slab where the central columns were removed to facilitate vertical circulation stairs. The cross-braced, glazed elevations reveal staff moving between the floors through perimeter stairs within what Selby describes as "mini-conservatories". The bracing is also symbolic of the connectivity between different floors and departments that the new building aims to embody.

At the front, the civic drum is clad in laminated timber to distinguish it from the rest of the structure, and occupies the south-east of the plan. It includes a ground-floor community hall, and above this, the civic chamber and members' offices. This is reached via the steel-framed, 31m-high atrium that links the drum to the administrative offices and also forms a public space with one-stop shop council facilities at mezzanine level above the ground floor.

The slimline structure of the atrium and roof is set out on a 7.5m grid, and filled with ETFE pillows. "We were pleased it was slender because that was the whole point of using steel - to get a structural efficiency and lightness," says Selby.

"We picked the material that suited the vision," says URS regional director Mike Pauley. "Where we were getting the 15m spans, concrete became too heavy visually to achieve that [vision]."

The exposed nature of the steel created an extra level of difficulty for steelwork contractor Bourne Engineering, which installed 900 tonnes of structural steelwork. "It was a very challenging project," says Bourne design manager James Bichard. "The aesthetics of the structural steelwork detailing was really important because it was all visible."

Brent Civic Centre is at the heart of a rapidly transforming area, with a 160,000sq m mixed-use scheme designed by Make Architects for Quintain planned on an adjacent site. This will provide 1,300 new homes and a large public square.

The civic centre's predicted Breeam score puts it on course to being the greenest public office building in the UK, and the fourth greenest in the world.

The main elevation is dominated by a dramatic steel and ETFE roof canopy soaring over a timber-finned "civic drum".

COMMUNITY HALL

A radial ceiling structure was needed within the 22m-diameter community hall to support the load of the level-three floor slab above. Hopkins designed this as exposed braced steelwork, increasing the challenge for steelwork contractor Bourne.

The structure is formed like a spider web, with 12 cranked sections measuring 5m and radiating out to meet concrete perimeter columns. At the 2.5m crank point, these are linked by steel rods that together form a tension ring. Further connecting wires criss-cross back to the top of the adjacent members to provide cross-bracing. At top and bottom, the members fix into a connecting fin plate that is bolted to a casting plate in the concrete column. The feature fin plate has a slight curve to match the profile of the concrete.

The steelwork has been finished in a micaceous iron oxide top coat and will be exposed as a feature of the hall.

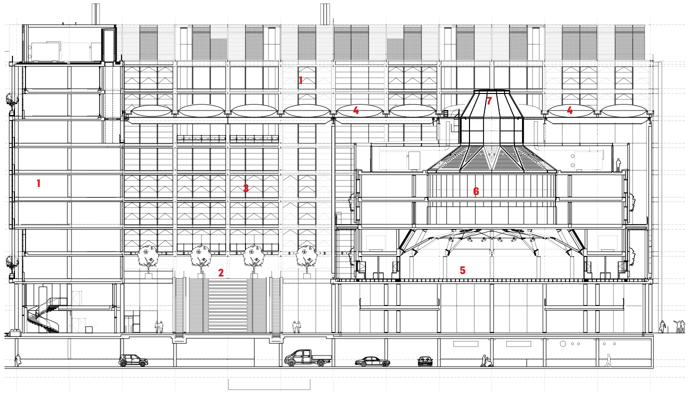
"It took a while to come up with but it's a very simple structural solution of tension and compression," says URS regional director Mike Pauley, adding that the construction method avoided the need for adjustors within the structure.

ATRIUM ROOF

The atrium roof grid is formed by five, 30m-long plate girder I beams, each measuring 950mm x 350mm. These were delivered in sections and welded on site and are linked by beams to form a 7.5m grid pattern.

The beams are supported at their ends by 23m-tall, circular, hollow-section tapering columns, brought to site in two lengths and welded. At the top, the tapered end is pin-fixed to the perimeter roof beams, which are also shaped to accommodate the connection. At the bottom, the columns terminate in a feature pin connection to the end plate of a 7.7m-high concrete column.

The roof beams accommodate integral, 1m-wide, U-shaped, pressed-steel insulated gutters which support the ETFE pillows on all sides as well as dealing with rainwater run-off.



SECTION

1 Office accommodation 2 Civic steps 3 Atrium 4 ETFE roof 5 Community hall 6 Civic chamber 7 Lantern

DRAWING: HOPKINS ARCHITECTS; MAIN PHOTO: JON CARDWELL

The atrium acts as the main visitor entrance for the civic centre. All of the slimline steelwork is visible and is an important aesthetic element of the 31m-high structure.

PROJECT TEAM

Client London Borough of Brent
Architect Hopkins Architects
Engineer URS
Contractor Skanska
Steelwork contractor Bourne Engineering

CIVIC CHAMBER

The double-height council chamber is situated at level three with a central lantern rising from levels five to eight, the latter level visible above the drum roof.

"The steel frame over the council chamber rises from fifth to sixth raking in while also triangulating; a complex geometry to imagine, but one that looks elegantly simple when modelled," says Mike Pauley of URS.

"At the sixth floor, a compression ring holds the ends of the raking members and supports vertical members. These rise up to the seventh floor and support the raking hat that is the glass lantern at the top of the structure."

Unlike the community hall, the bulk of the steelwork is covered by slatted oak veneer panels, with the exception of the central feature lantern.

In association with The British Constructional Steelwork Association and Tata Steel
TATA STEEL BCSA

Raising the main sails

Wilkinson Eyre's Poole harbour crossing is a clever twist on the traditional drawbridge, with diagonal bascules that rise up like the masts of a ship

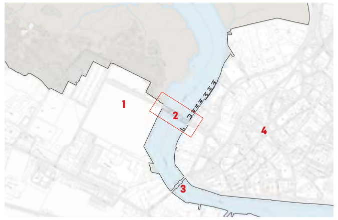
Text by Pamela Buxton

It takes just two minutes to open the latest Poole harbour crossing to allow the busy maritime traffic to pass, and another two minutes to close it back down and allow road and pedestrian use to resume. Since it opened last year, the Twin Sails bridge at the entrance to Holes Bay has greatly reduced the severe road congestion that used to occur every time the existing 1920s bridge rose to allow vessels to pass. As well as these practical benefits, the bridge, designed by Wilkinson Eyre, adds a sail-like flourish when in open mode in reference to its context.

The Twin Sails crossing, which spans a narrow strait linking Poole harbour with the yachting centre of Holes Bay, took 10 years to realise after Wilkinson Eyre and Ramboll won the commission in 2002. Its purpose was not only to ease road congestion but also to encourage regeneration of a brownfield site at Hamworthy on the west side of the bay by linking it to the old town of Poole.

"It had to be robust, open, simple and reliable but [the client] also wanted it to be the catalyst for regeneration and an icon at the same time," says Ramboll associate Steve Thompson, who was design project manager on the Poole bridge.

An above-deck structure couldn't be justified because of the short span. A swing bridge was quickly discounted because of the significant infrastructure needed



SITE PLAN

1 Hamworthy **2** Twin Sails bridge **3** Existing bridge **4** Poole

to construct it in the water. Instead, the designers decided on a twin-leaf, bascule lifting bridge operated using hydraulic technology which meant there were no restrictions on height. Instead of a conventional, straight-edged bascule, the lifting portions are triangulated, creating added drama when raised. In its down position, the aim was for the bridge to be unobtrusive and blend in with the low-lying Poole landscape.

"We're used to seeing bascule bridges with classic 'drawbridge' style leaves, completely squared off at the ends," says Wilkinson Eyre partner Jim Eyre. "The drama of Twin Sails has been created by turning the joining into a diagonal that skews across the decks. As the leaves rise, they separate and reveal their triangular, sail-like forms."

Wilkinson Eyre maximised the height of the bascules to add extra impact to the sail-like forms. "The striking form of the raised bridge celebrates the maritime heritage of Poole, evoking the sails of the racing yachts that pass through the channel in this international yachting centre," says Eyre.

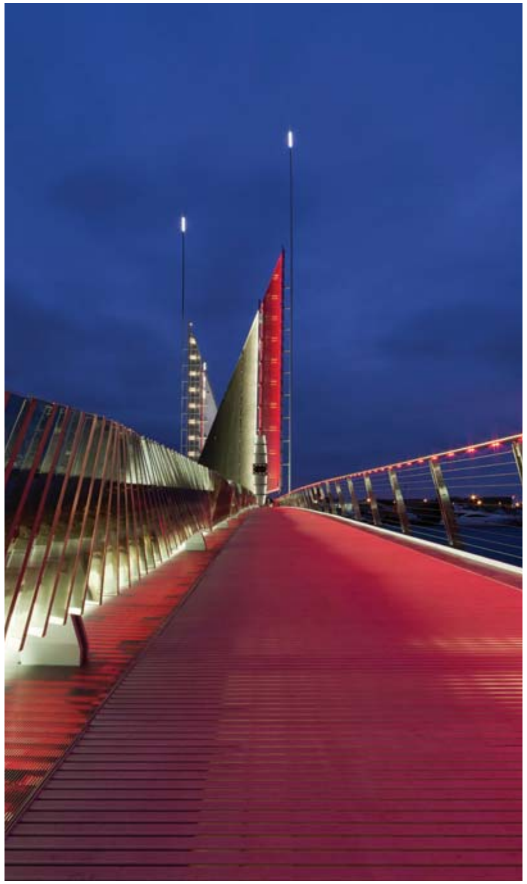
The five-span bridge is 139m long, with a central span of 23.4m to create a 19m clear opening for vessels, matching that of the existing bridge.

Twin Sails opens hourly 15 times a day (5,000 times a year) in a coordinated sequence with the older bridge, positioned just 350m away. Drivers are directed to whichever bridge is open to road traffic by an intelligent traffic management system.

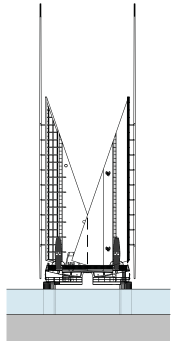
When in the down position, the most noticeable structures on the bridge will be four steel-framed "totems", two at either end of the opening bascules. These house all the paraphernalia associated with an opening bridge such as opening and navigational signals, warning sounds and barrier arms.

Lighting, created with lighting designer Speirs + Major, is used to add to the spectacle of the opening event. In an animated sequence, the white light of the pedestrian walkway begins to turn red, starting from the top of the sail, until the whole bridge glows red.

The triangular sections rise up to twice the height of a conventional bascule bridge. The carbon-fibre masts on either side add a further 20m.



The 2.4m-wide walkways on either side of the bridge are separated from traffic by a stainless-steel screen that is designed in a wave form.



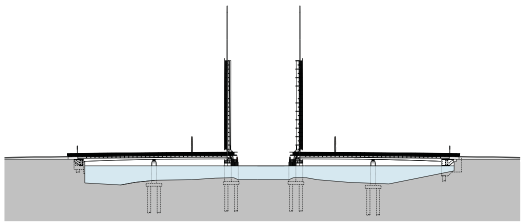
THE 'SAILS'

As the two 35m-long bascules rise through 88 degrees to open the bridge, they appear to cross, in a reference to the shapes of sails of the maritime traffic in the harbour.

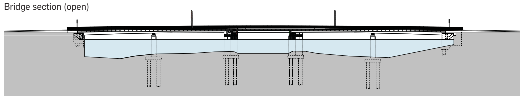
Conventional bascule opening requires an interlocking bolt to contend with the potential rocking movement from one bascule to the other. But a longer, diagonal opening of two triangular leaves enables the bascules to cross 30m onto a pivot bearing on the other side of the span near the apex of each triangle. This gives more support and less differential movement, and avoids the need for a mechanical interlock.

The hydraulic ram opening mechanisms are housed in the main piers, along with other opening equipment and plant rooms.

Carbon-fibre masts with white LEDs at the top are cantilevered off the sides of the bascules to give an extra 20m of height, accentuating the sail-like quality of the bridge when in its raised position.



Bridge section (open)



Bridge section (closed)

The five-span bridge has a central opening of 19m to allow vessels to pass through.

PROJECT TEAM

Client Poole Borough Council
Architect Wilkinson Eyre
Structural engineer Ramboll
Contractor Hochtief
Steelwork contractor Cleveland Bridge

CONSTRUCTION

The bridge was fabricated in large sections by Cleveland Bridge and assembled on trestles on the quayside near the site of the bridge. The team made use of the water as a lifting mechanism by loading the sections on the trestles onto barges at high tide and manoeuvring them into position, where they were fixed by the time the tide fell.

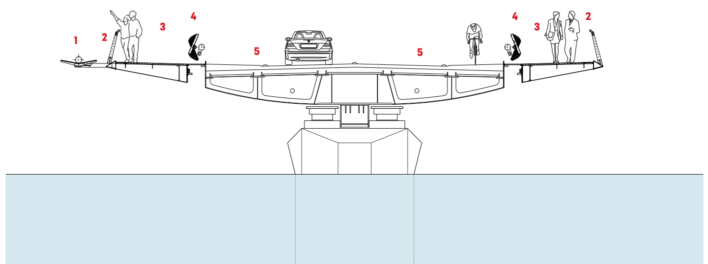
THE DECK STRUCTURE

The road and segregated cycle carriageway structure is a 10.8m-wide steel box with cantilevered steel armatures on both sides supporting the aluminium-decked, 2.4m-wide pedestrian walkways. The deck has a maximum depth of 1.4m, with a triangular nosing on its edge tapering to just 300mm deep to give the illusion of being shallower than it is.

The carriageway has a reinforced concrete deck with the exception of the lifting spans, which are orthotropic steel boxes with steel stiffeners. The deck's hefty transverse steel beams were cast into the heads of the concrete piers.

Steelwork on the bascules is weathering grade, so painting was required only outside the box, and not inside. The paint system used on the bridge's external surface was chosen for its longevity to minimise maintenance. Self-finished materials were used on the bridge where possible.

An undulating, stainless-steel screen separates pedestrians from the cycle path and road, designed to suggest a wave-like form in keeping with the bridge's nautical theme. The hollow, rectangular steel sections are bolted to brackets fitted to the vehicle restraint system. These slats are rotated to create the warping form and are underlit with red LEDs to give a soft glow. On the edge of the pedestrian walkway is a stainless-steel tensioned cable parapet infill system.



SECTION OF THE BRIDGE DECK

1 Mast **2** Handrail **3** Cantilevered pedestrian walkway **4** Stainless-steel screen **5** Roadway

Where the embodied is buried

Upcoming changes to both Breeam and the building regulations are placing the embodied carbon of different structural solutions under the spotlight

Text by Pamela Buxton

As the operational carbon of buildings is reduced following the more stringent requirements of Approved Document L, embodied carbon is moving higher up the agenda when it comes to making decisions about the best way to reduce a building's overall carbon footprint.

Awareness has rapidly increased over the last decade according to Dr Fergal Kelly, director of buildings at development and infrastructure consultant Peter Brett Associates (PBA) and one of the first engineers to calculate the embodied carbon of various structural solutions. PBA's graph (below) shows that embodied rather than operational carbon will soon become the dominant factor in reducing new buildings' carbon footprints, especially with the introduction of the new building regulations in 2016. These have been dubbed "zero carbon" because the regulations will enforce the need for all new homes to be zero carbon from that date – with non-residential to follow by 2019.

"It is likely that embodied carbon reductions will be permitted as an 'allowable solution' in the 'zero carbon' building regulations 2016, and presently these are increasingly being accepted by local authorities as a trade-off against uneconomic renewables targets," says Dr Kelly, adding that embodied carbon is also being given more attention in the current draft of Breeam assessments.

In the National House-Building Council's recent report, Allowable Solutions, Evaluating Opportunities and Priorities, the case is made for investing in embodied carbon initiatives and incentivising it through the allowable solutions agenda for carbon mitigation.

The report said: "It was therefore concluded that embodied carbon is an issue for now. As we make our materials and build our buildings, carbon is emitted which will only contribute to the drastic effects of climate change. Stakeholders agreed that the time was now right to develop regulations and incentives around promoting the measurement of and application of low carbon materials."

'It will become very mainstream. Once people have to do embodied carbon assessments, they will become very interested in them'

Although at the moment it is up to the client to decide whether to commission an embodied carbon assessment of different construction and design options, and how much weight to give the results, Dr Kelly anticipates that this will change in the near future with legislation, which he thinks is inevitable.

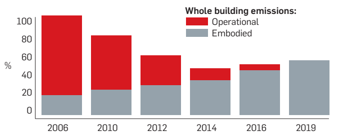
"It will become very mainstream. Once people have to do embodied carbon assessments, they will become very interested in them."

According to a report on cutting embodied carbon in construction by recycling advocates Wrap, the embodied carbon emissions associated with supplying materials can be as much as 50% of total emissions over a building's lifetime.

"If the UK is to achieve its ambitious target of 80% reduction in carbon emissions by 2050, closer attention will need to be paid to embodied carbon in construction – by project teams as well as policy-makers," says Wrap.

Therefore, it is all the more important that the design team understands the impact that its choice of structural systems and materials can have on embodied carbon ratings.

Embodied carbon is often defined as the "cradle to grave" carbon dioxide emissions that occur during the whole life cycle of the building, including gases arising from the processing, manufacture and delivery of materials, products and components required to construct the building, and its end-of-life scenario. However, it excludes the operational carbon occurring during the building use. The following two case studies compare the embodied carbon of concrete and steel structural solutions for both a real and a hypothetical project.



PBA's graph shows the rise in embodied carbon as a proportion of total carbon emissions for a hypothetical building for successive versions of Part L, with 2006 as the base case. As insulation levels increase and M&E kit perhaps becomes more intensive, the embodied energy causes the total carbon to begin to rise again.

For further information on embodied carbon, go to www.steelconstruction.info/Life_cycle_assessment_and_embodied_carbon

ARTISTS' IMPRESSION BY MAKE ARCHITECTS

CASE STUDY 1: TYPICAL CITY-CENTRE OFFICE BUILDING

Peter Brett Associates (PBA) carried out embodied carbon analysis of steel and concrete structural solutions for a hypothetical office building as part of Steel Insight research by Gardiner & Theobald commissioned by the BCSA and Tata Steel. This found that embodied carbon was significantly lower (between 18-30%) for the steel frame than the post-tensioned concrete frame for that particular building scenario.

In the research, the base building is conceived as a typical eight-storey speculative city-centre office building with a gross internal area of about 16,500sq m. The building is L-shaped with a central core and internal secondary escape stair and a double-height reception area. The clear floor-to-ceiling height is set at 3m with a structural grid of 7.5m x 15m.

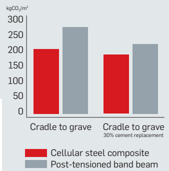
The building envelope is a curtain wall system in 1.5m-wide, storey-height panels, with solar-control fins. Solid areas are lined with cold rolled metal studwork, insulation and plasterboard. The building was assumed to have four-pipe fan-coil air conditioning without natural ventilation.

The steel-framed version uses cellular composite beams and composite slab and has 60 minutes fire resistance. The concrete uses post-tensioned band beams and slab with in-situ columns. The overall floor-to-floor height is 4.18m for the steel option and 4.375m for the concrete option.

PBA's research considers the whole building rather than just the structural frame for each option, but identifies the emissions from the structural elements as these are the main points of difference. Non-structural embodied carbon emissions are consistent across both options and were based on benchmark information. Transport emissions are based on statistics from the Department for Transport on the average length of haul per commodity and on data from the Concrete Centre. Construction and demolition emissions are informed by construction programming information from Mace, UK Environment Agency data and an estimated period for demolition.

To reflect current practice, the assumption was that 99% of the structural steel and 83% of the concrete reinforcement are recycled and 100% of the concrete is down-cycled to provide granular fill material.

Comparison was carried out first using only Portland cement for the concrete mix. Results (below) showed the steel option having over 23% less embodied carbon than the post-tensioned concrete-framed option.



This falls to around 11% less embodied carbon for the steel option if the concrete construction follows the common practice of using 30% cement replacement with fly ash and ground-granulated blast-furnace slag. The figures are $184kgCO_2/m^2$ for steel and $204kgCO_2/m^2$ for concrete.

For further information, go to www.steelconstruction.info/Cost_of_structural_steelwork#Resources

A cutaway of a floor of the base building, which was a typical eight-storey speculative city-centre office development (top).

CASE STUDY 2: OXFORD UNIVERSITY BIOCHEMISTRY BUILDING

PHOTOS: TIM CROCKER

When Hawkins\Brown's Oxford University biochemistry building was in design development, structural and civil engineer Peter Brett Associates carried out carbon dioxide audits of three framing solutions. The results led to the choice of steel for the structural frame.

The proposed departmental building had a footprint of 12,000sq m, with four storeys above ground and two below. The options researched were a 350mm-thick concrete flat slab structure, a conventional steel composite structure and a hybrid of a parallel beam system supporting a composite slab. The latter two gave similar results, with calculations assuming that 85% of the steel would be recycled after demolition.

The research found that a steel composite frame would produce 8% less CO_2 emissions than the concrete option, the equivalent of 456 tonnes of CO_2. When only the structure above ground was considered, the steel option had 22% lower emissions.

The steel composite option produced the lowest haulage emissions, through reduced transport of materials and the potential for out-of-hours delivery for the steel frame, which was an advantage given the congested nature of the site. The construction programme was also faster.

The final solution used top-down construction for the basement and incorporated a hybrid parallel beam configuration to give a shallow and economical floor zone.

The steelwork contractor was William Hare.

Item	Option 1: steel		Option 2: concrete	
	Weight (T)	CO_2 (T)	Weight (T)	CO_2 (T)
STEEL	1,340	1,353	50	50.5
CONCRETE	13,000	1,846	21,760	3,090
DECKING	148	198	-	-
REBAR	630	580	1,220	1,122
EXCAVATION	50,600	-	51,520	-
HAULAGE	3,996 veh	1,270	4,650 veh	1,440
TOTAL		5,247		5,703

NEW LEASES OF LIFE

Steel's ability to be re-used without loss of performance significantly reduces its embodied carbon emissions. Indeed, for steel to achieve its lowest possible embodied carbon rating, it would have to be reclaimed, from a local source, and re-used.

A notable recent example was the London 2012 Olympic stadium, designed by Populous. In this, 2,500 of the 3,850 tonnes of steel tubing used to make the roof trusses was reclaimed from old gas pipes and modified accordingly for the new use. The building had a recycled materials content of 31%.

While reclamation is extremely rare, more buildings are now being designed with reassembly in mind, such as the Prologis warehouse building at Stockley Park near Heathrow airport, which has been specifically designed by architect Michael Sparks Associates so that it can be disassembled and resurrected on another site in the future.

Post-construction steel is also extensively recycled for other types of installation. Each year, an estimated 99% of structural steelwork is recycled, according to Wrap, and 94% of all steel construction products are melted down for re-use in the UK.

Usually, it is impossible to tell where the steel from a particular building ends up, but an exception was Lackenby open hearth steel plant on Teesside. Following the demolition of the plant, 20,000 tonnes of welded and riveted structural steelwork was tracked in its new life by Tata Steel. The steel, as sections, plates and strip, was put to work in uses as diverse as 1p and 2p coins, Ford transit vans, girders for a bridge to the Isle of Sheppey and new buildings at Heathrow Terminal 5, Paddington station and the Oval cricket ground.

Some 2,500 of the 3,850 tonnes of steel tubing in the Olympic stadium's roof trusses was reclaimed from old gas pipes.