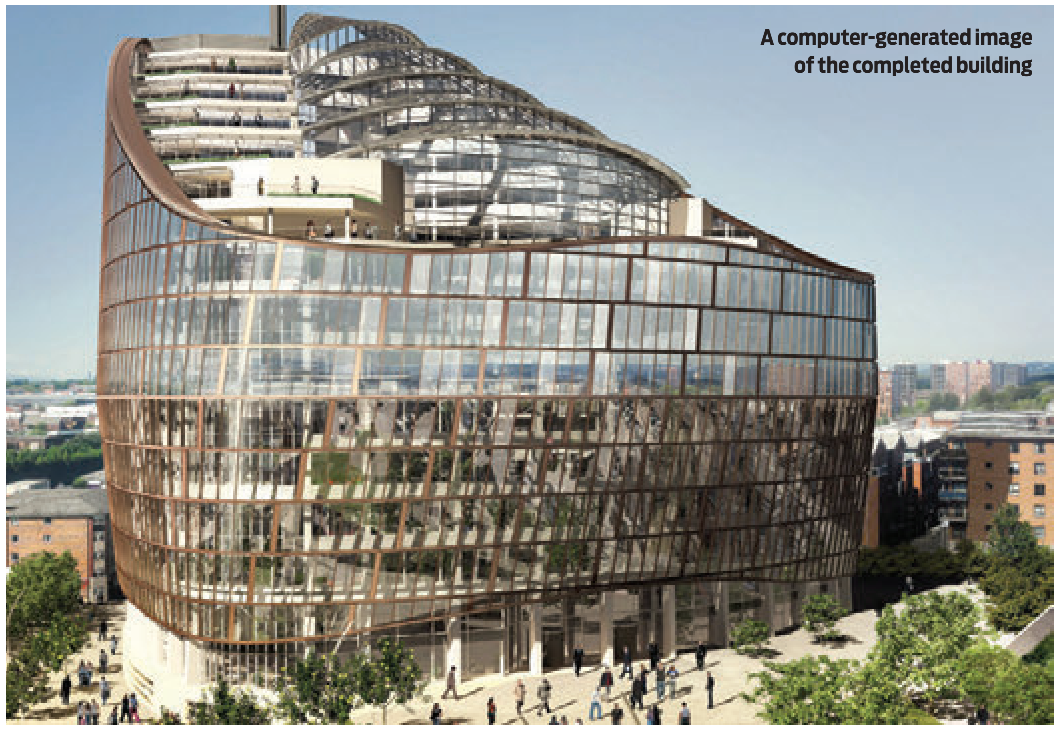
Produced in association with TATA STEEL BCSA

Landmark HQ for Co-op

The Co-operative Group's new steel-framed head office in Manchester will create another architectural landmark for the city and showcase the highest standards in sustainable design and construction

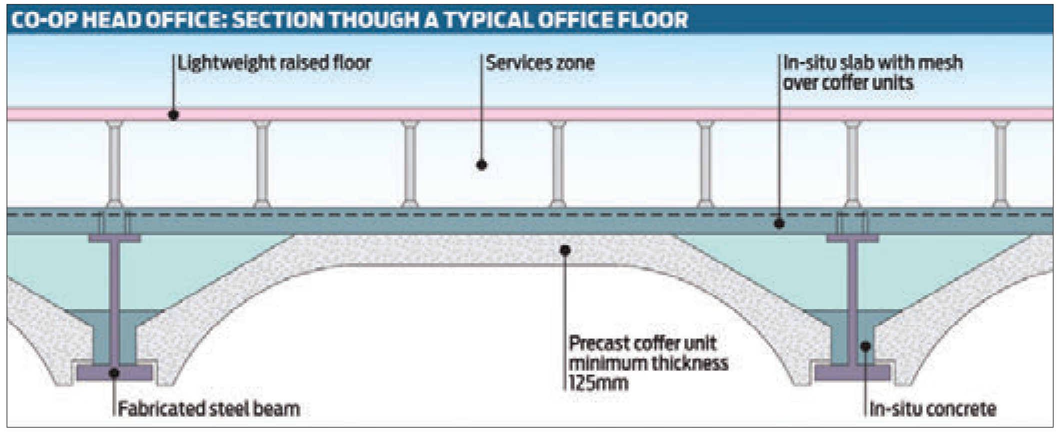
PROJECT REPORT
RUBY KITCHING

Project The Co-operative Group head office, Manchester
Main client Co-operative Group
Architect 3D Reid
Main contractor BAM Construction
Structural engineer Buro Happold
Steelwork contractor Fisher Engineering



A computer-generated image of the completed building

CO-OP HEAD OFFICE: SECTION THOUGH A TYPICAL OFFICE FLOOR



The Co-operative Group, which can trace its roots back to the Rochdale Pioneers of 1844, has made its name as a socially responsible retailer and is the UK's largest mutual business, owned by six million consumers. It claims to be driven by "creating value for customers" rather than "making big profits for shareholders".

The group is investing £100 million in its new head office in Manchester, which has been designed to the highest environmental standards and is set to create a new benchmark in UK sustainable office design. Working with contractor BAM Construction, the project is also being used to help train around 300 apprentices on site.

Staff relocation

The 15-storey steel-framed building will accommodate 3,500 employees who will relocate from eight different less energy-efficient buildings spread around the city. The structure, which has now reached roof level, is the first of many to appear on the group's 8 ha city centre site, which is being marketed for redevelopment.

International engineering consultancy Buro Happold and architect 3D Reid have worked hard to produce a building capable of achieving a BREEAM rating of Outstanding (see box).

The steel frame is supported by cores in each corner and encompasses a triangular glazed central atrium, double skin façade and roof terraces.

A reception area and café occupy the atrium space at ground floor, while meeting rooms are tucked under the surrounding upper levels of offices. Some 30,000 sq m of high-quality office space is provided within the building, with a restaurant at the eighth floor.

Below ground, piled foundations support the building and two levels of basement are made up of between 350 mm and 550 mm-thick flat slab construction. A service yard and 260-person auditorium occupy the upper basement level and a car park takes up the lower basement level.

The main office floor plate is made up of Fabsec cellular beams and precast concrete coffer units with an insitu concrete topping. These fabricated steel I-sections are 590 mm deep and spaced 3 m apart and span a maximum 16.5 m.

Steelwork contractor Fisher Engineering has erected close to 2,000 tonnes of cellular plated beams on this project, used not just for their service holes but also to achieve a shallow floor depth.

Floor solution

Precast concrete coffer units are 615 mm deep overall and a minimum of 125 mm thick. Their edges are notched to sit on the bottom flanges of the beams.

The servicing strategy will be fully integrated into the structure as it is routed across the ceiling, penetrating the steel beam and coffers. A 110 mm-thick topping of reinforced concrete makes up the remainder of the structural floor depth, while a 400 mm-deep lightweight raised floor leaves sufficient room for additional services (see diagram).

"The coffer units span beam to beam and these, along with the bottom flange of the supporting Fabsec members, are exposed in the final state. We therefore had to work to very exacting tolerances," says Fisher Engineering project manager Barry Craig.

The floor build up is unique to this project, since its aim is to achieve the highest BREEAM rating. To contribute to this, steel provides an efficient framing solution and shallowest floor depths, while the precast coffers offer further thermal mass to aid cooling the building.

"Steel was the natural choice for the framing material, as it gives us the required large column-free floors and the option for future flexibility within the building," says Buro Happold associate Paul Richardson.

Corners of the building are bull-nosed and steel beams here were fabricated using plated sections. These beams are deeper at 900 mm for additional torsional stiffness. Generally, the beam depths are constant at 590 mm. While maintaining this constant beam depth, design efficiency is achieved when loads and spans change, as each beam design is optimised through varying flange and web thicknesses.

"We have 18 types of fabricated beams, as well as curved beams," says Mr Richardson. "The building was modelled using Revit to minimise the number of beam sizes, but typically the depth stayed constant while the flange and web thickness varied."

Essentially, the structure of each floor from the second floor up is made up of six identical templates, based on half the area around each of the three cores.

As each of the three cores provide the majority of the structural stability, steel erection begins for each phase with the connections to the concrete cores. The completed cores have cast-in plates in readiness for the steelwork.

Erection sequence of the structure above the second floor took advantage of this repetition. Since the structure was spliced at every third level, the onus was on getting three floors built as quickly and efficiently as possible, so that the next three levels could go up without delay.

Teamwork requirement

The solution required careful coordination between three key trades involved in the floor construction: the steelwork contractor, precast contractor in charge of the coffer units and the concreting contractor responsible for the insitu topping.

Basically, a different trade worked on one third, or phase, of the floorplate at any one time.

This meant that when the first trade, the steelwork contractor, had erected three levels of steelwork in phase 1, the gang could then move on to phase 2 – the next third of the floorplate. This then allowed the precast concrete contractor to begin installing coffer units on the finished steelwork in phase 1.

As the steelwork gang finished another three levels on phase 2, it could move onto the final area of the floorplate – phase 3. This allowed the precast contractor to move onto phase 2 and the insitu concrete contractor to top the floors on phase 1.

With steelwork completed on phase 3, the other two trades could move round while the finished phase 1 floor was ready to receive another three levels of steelwork.

BAM Construction senior site manager Nick Wilde says: "Steelwork leads the way and plays a crucial role on this project, as once it is erected in one phase, the erection gang then moves onto the next phase, leaving behind a frame ready for the precast coffer beams to be installed."

The rotation of trades ensured that a faster programme could be achieved. "It was critical that the concrete slab be completed [in the allocated time] to allow us to move to the splice level as soon as one cycle was completed," says Fisher Engineering project manager Barry Craig.

Atrium roof steelwork is currently being erected. Its glazed roof is made up of a series of five curved virendeel trusses, which are tied together with a steel-framed lattice arrangement forming an armadillo shell-type arrangement. In detail, each lattice is framed by a pair of 300 mm diameter circular hollow sections, which meet at the ends of the lattice. The arrangement maximises the potential for natural ventilation and light.

Lattice steelwork will be welded on site and installed using jigs mounted on the completed terraces or using tower cranes. "A system of temporary props and hangers will support the atrium steelwork until it is all connected up," adds Mr Richardson.

Predominantly glazed, the outer skin is attached to brackets fixed to the main steelwork. These cantilevering arms are of varying lengths and follow the line of the outer skin as it undulates around the perimeter and up all elevations.

The building is scheduled to be completed in August 2012.

SUSTAINABLE CREDENTIALS

The Co-operative Group's new head office is set to be one of the most sustainable commercial buildings in Europe and to be one of the first in the UK to be built to the BREEAM Outstanding designation.

By building to the highest BREEAM standard, the group aims to save 40 to 60 per cent of energy costs compared with the group's existing HQ.

Key features include:

- Central atrium and a double-skinned façade, which is key to creating a more passive approach to heating, cooling and lighting;
- A combined heat and power plant that uses rape seed oil to heat and power the building;
- Heat recovery from the atrium and computer systems to heat the building;
- Low energy computer equipment and systems;
- Combined used water and rain water recycling;
- Low water use appliances;
- High-efficiency lifts;
- Advanced controls and energy monitoring to optimise the building's performance.

The delivery of comfort conditions to the office floors employs a relatively simple philosophy using passive chilled beams with displacement ventilation.

However, enabling this requires a complex array of plant such as combined heat and power and absorption chillers, networked together so that maximum benefit can be gained from energy recovery.

In addition, the building services and structure have been designed together to complement the comfort and energy strategies within the building. Thermal mass within concrete earth tubes and exposed concrete mass throughout the floor plates contributes to a stable, passive and ultimately low-energy environment within the building.

Years of steely determination

Dr Derek Tordoff is retiring after 35 years with the BCSA, of which 27 were spent as director-general. His career has seen some key developments in steel that have shaped the industry. *CN* looks at 10 of the most important

PROFILE
RUBY KITCHING

Derek Tordoff's career in the construction industry began with a degree in civil engineering at the University of Leeds. Upon graduating in 1968, he joined consultant Mott Hay & Anderson in Croydon, Surrey, to design satellite support structures using a relatively new invention called a desktop computer.

The Olivetti P101 was used to carry out repeat calculations to optimise the structures, which would be located in Hong Kong and East Africa and be subject to hurricane force winds. Although he enjoyed the experience of structural design and computer programming, Dr Tordoff was keen to broaden his knowledge and, as part of his professional training, spent the next year of his career building highways and bridges on the new M62 motorway for main contractor Dowsett Engineering.

When the year was up, Dr Tordoff returned to academia to study for a PhD on the optimum design of steel box girder bridges.

Dr Tordoff's computer skills came to the fore as he adapted software produced for NASA's space programme for the construction industry.

NASA's program was designed to determine the best spacecraft design for travelling to the moon. Dr Tordoff had his sights closer to home: developing solutions for steel box girder bridges that satisfied design criteria and were optimised in terms of cost.

He stayed with bridges on his next job at consultant Travers Morgan, where he designed concrete bridges and wrote computer programs to standardise bridge designs for the Department for Transport.

His interest and experience in bridge design optimisation was put to good use in 1976, when he joined the BCSA as chief engineer and assisted in the development of the new bridge design code BS 5400.

Just prior to this, steel bridge design had suffered a dip in popularity following some high-profile box girder bridge collapses. New rules had been published in response that made designing in steel extremely complicated.

The BS 5400 code would take these recommendations into account, but in consultation with BCSA, would be more user-friendly so that consultants wouldn't be put off specifying steel structures.

"At the time, most bridges were made of concrete, so another thing we worked on in conjunction with the DfT was the dual design scheme," recalls Dr Tordoff.

Convincing success

The BCSA convinced the DfT to scheme up a dozen bridge designs in both steel and concrete before putting them out to tender. "Steel bridges came back cheaper in 11 out of 12 of the designs, which was how we came to see steel's rise in popularity."

Moving from bridges to buildings, the new steel design code BS 5950 changed the philosophy of structural design from being based on permissible stresses to limit state, and the BCSA realised again that the complexity of designing in steel was holding back its use.

It commissioned computer programs to be written for single-storey and multi-storey structures to aid designers through this transition. The software is still used today under its commercial name, Fastrak.

In 1984, Dr Tordoff became BCSA director general, where his role involved a more focused approach towards improving steel's share of the construction market. Through design aids, seminars, advice from regional technical managers as well as advertising campaigns, the BCSA and the then British Steel (now Tata Steel) worked together to make sure the advantages of using steel were better understood.

Over the years, he is most proud of the improvements made in health and safety, where accidents and fatalities have fallen by 60 per cent in the last 10 years. But what makes him equally satisfied is the current statistics showing that 70 per cent of all multi-storey buildings are made from steel, compared with 30 per cent when he became director general.

>>> **www.steelconstruction.org/history Read a history of the use of steel in construction**

1 HEALTH AND SAFETY

Construction sites are much safer now than they were 35 years ago, especially for the steel erector who commonly works from height. A combination of compulsory fall arrest systems and elevated platforms to work from, as well as pertinent safety videos, PPE, BCSA health and safety guides, and toolbox talks has helped change the culture of sites and save countless lives.

Ten years ago, the BCSA also introduced the concept that a main contractor needed to check that the site was safe for the steelwork contractor to begin working.

In issuing a Safe Site Handover Certificate, the main contractor would verify that the site was safe by using a checklist specific to steelwork operations.

2 FROM FABRICATORS TO STEELWORK CONTRACTORS

A fabricator used to be a company which built whatever was specified in drawings submitted to it. Nowadays, these specialists give advice on the most economical way to fabricate elements and on the buildability of structures, providing a complete design, fabricate and erect package. These companies are now better defined as 'steelwork contractors'.

3 STANDARD CONNECTIONS

Before standard connections were introduced, each steelwork contractor would have their own way of doing things. Designers also had their own ideas of how they wanted connections to look.

By producing standard arrangements in the form of 'look up tables' and latterly software, a lot of time and money has been saved and scope for error reduced.

4 NATIONAL STRUCTURAL STEELWORK SPECIFICATION

Otherwise known as 'the black book', this document standardised steelwork specifications which previously were bespoke to each consulting engineer. It helped contractors become familiar with what was required and meant that there was less room for error or misunderstanding when standard clauses were used.

Consequently, more effort could be put into understanding where the standard clauses needed to be amended for specific contract requirements.

5 COMPOSITE CONSTRUCTION AND LONG SPANS

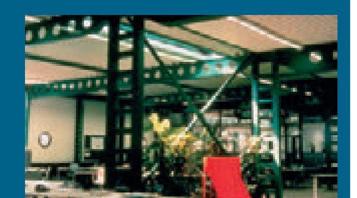
Composite construction allowed slimmer floor depths, which from the 1980s at developments like Broadgate, London, started to offer an extra level of lettable floor space.

The long spans that were also possible became favoured by the rapidly growing City market to create large computer-intensive dealing floors. A column-free environment is now the definition of flexible space, allowing many tenants of a building to fit out floors to their own needs.

6 FIRE ENGINEERING AND LOW-COST FIRE PROTECTION

Fire engineering has been a major advance, made possible by the steel sector's investment into how whole buildings actually behave in fires, as opposed to analysing how a single member fares in a furnace test. Detailed analysis can now determine that fire protection may not be required on some members, but may be critical on others.

Also, as steel's popularity has grown, better and lower cost protective materials have been developed. A fibre-based fire protection coating used to be sprayed onto steel members in a finished building, but now intumescent coatings work more efficiently and are routinely applied offsite to give a cleaner finish.



7 DESIGN/MODELLING SOFTWARE

Computer-aided design and manufacture has enabled more non-standard shaped structures to be built. The steel sector has invested heavily in these types of software from very early on in their development, promoting the use of repetitive elements for economy and non-standard elements for more extravagant buildings.

Steelwork contractors have remained close to the evolution of design and 3D modelling software and most are able to meet ever shorter lead-in times, with the manufacturing data fed directly from the model into the workshop. Steel is the ideal framing material for BIM (building information modelling) with each component being able to be assigned with its discrete properties.

8 STEEL CONFIDENCE

One of the strengths of the steel sector has been the collaboration between Tata Steel, the BCSA and steelwork contractors in funding research, and in providing guidance to designers. Thanks to this support, designers are able to work with steel with confidence.

9 CODES & STANDARDS

The steel sector has invested heavily in guides and software to support BS 5950 for the design of steel structures and to help it become recognised as a worldwide benchmark for efficient design.

It has also helped the UK to become a world leader in steel construction. The sector is currently offering a similar level of support on the introduction of the Eurocodes for structural design through research, training and design guides.

10 SUSTAINABILITY

Steel construction has always had extremely high sustainability credentials, particularly when considering the whole cradle to grave lifecycle of a building.

Steel members can be reused or recycled readily when a building is demolished. The BCSA has invested in Target Zero, a project with Tata Steel, which provides fully costed detailed guidance for designers on how to create highly sustainable, low and zero-carbon developments.

Research says the amount of concrete in a composite floor slab provides sufficient thermal mass to aid cooling a building and that a concrete framed building might need more energy to heat it up.

Produced in association with TATA STEEL BCSA

A strict sequence

A tight schedule and a structure with three distinct framing solutions makes building Big Yellow's storage facility more challenging than it looks

PROJECT REPORT
RUBY KITCHING

Project Big Yellow self-storage unit, Chiswick, London

Client Big Yellow Self Storage Company

Architect Mountford Pigott

Main contractor McLaren Construction

Structural engineer Campbell Reith

Steelwork contractor Caunton Engineering

The finished building will attract the attention of around 80,000 people using the M4 daily

Main contractor McLaren is building storage company Big Yellow's flagship building in London – a gleaming seven-storey steel structure which, to meet the tight 40-week construction programme, has to be built simultaneously on all elevations. As a result, a strict construction sequence is required to complete the project safely and on time.

On top of that, special consideration must be given to all site operations, as the work is taking place next to a busy rail line on one side and adjacent to the M4.

The structure is also quite unusual. The steel-framed building is made up of three sections, each with different structural solutions.

The central section is the most straightforward for steelwork contractor Caunton Engineering, being an eight-storey portal frame structure. Adjoining it is a six-storey section to the west, which is hung from a roof truss and 'sits' over a double-height service yard. A third structural solution involves a two-storey simple framed structure, which fills the remaining east end of the plot.

Its prominent location means around 80,000 people pass the structure daily, so Big Yellow was keen to commission a much more ambitious design than usual in order to catch the eye of all those potential customers.

A Sotherby's auction house warehouse previously occupied the land and was demolished by contractor 777 Demolition prior to McLaren arriving on site in May this year. The new building occupies about half the site, enabling the contractor to have decent-sized storage and loading areas and other site facilities.

The east elevation of the central portal frame section was first to go up, but three full height west elevation columns, which would eventually support the roof trusses, had to be erected almost concurrently. And while the east elevation of the portal frame took shape, the two-storey building to the east also started to gather pace.

> **"A steel frame was ideal for this job because of the convenience of erection"**
> ANDREW FROST, CAMPBELL REITH

However, the west end of this two-storey building would block access to the east elevation, so it could only be completed once the east elevation had been structurally completed and clad.

Once the central portal frame was up to full height, three 26 m-tall 914 x 409 x 343 section west elevation columns could be erected. These were made up of a 16 m lower section supported off a pilecap spliced on site to a 10 m upper section.

The 26 m-tall column would eventually support the 23 m-long steel roof trusses. Tensioned Tirfor wire ropes were used to support the columns during erection while the rest of the structure, including the 23 m vierendeel trusses, were built.

Floors were only constructed on the second and fifth floors, since client Big Yellow would install levels three and four and six and seven using its bespoke mezzanine floor system (see box).

"The final fit-out also includes the installation of staircases and lifts, which has meant we've had to leave openings in the second and fifth floors," explains Caunton project manager Gareth Skelton.

Beams at each level provided permanent bracing to the west elevation columns. Three 23 m-long trusses were then connected to the roof level steelwork of the central portal framed building at one end and to the top of the west elevation columns at the other. Side elevation columns were then erected.

The 12,000 sq m facility is flanked by a busy rail line and the M4 motorway

Swift programme

The erection of the columns took just one week, while the trusses went up in just one day. These 23 m-long trusses travelled in complete lengths from Caunton's Nottingham fabrication yard to reach the site by 7am on the morning of erection.

Forethought had ensured that the site access ramp from the A4 dual carriageway was wide enough to allow these colossal elements to be turned into the site, rather than having to winch them in from the road.

With concurrent critical path operations on three parts of the site and the entire structure comprising steel elements, mobile cranes were favoured over static tower cranes. McLaren project manager Andy Plail says: "With the amount of hook time needed for all the steelwork and cladding within such a tight programme, we've needed up to four 50-tonne cranes at any one time."

Mobile cranes could be deployed as and when required and were ideal for the majority of members, which weighed less than 5 tonnes. When Caunton's 20-tonne truss arrived on site, it was lifted into place using a 200-tonne crawler crane. All elements were bolted together on site, since this would be quicker than site-welding. The floor was in-situ concrete on a composite steel deck with a power floated finish.

Each element will be sprayed with intumescent fire protection once the building is sealed, a task which will take eight weeks. This is to prevent any particles becoming airborne and reaching drivers on the M4. It was deemed easier to apply the coating after erection to avoid damage during handling.

Another quirk of the project was that the west end suspended building with the service yard could not be clad before levels two and five were concreted. "You generally want to get a building watertight first, but here, the building has to be loaded with the concrete first," explains Mr Plail.

Had the cladding been applied before concreting, it would have caused the suspended steelwork to move and the cladding to fail.

Concreting had just been completed when *CN* visited the site in late September and cladding was going up in earnest.

The shell will be handed over to Big Yellow in the new year, with the building opening in May 2012.

MAINTAINING FLEXIBILITY

For structural engineer Campbell Reith, the main constraint was to design a six-storey building from second floor level which also had to span 25 m across a service yard.

"We looked at various options including installing a bridge deck at the second floor, but it would have been too heavy and too deep, and require [more complicated] plated steel girders," recalls Campbell Reith project partner Andrew Frost.

The solution was in the roof where the barrel vault shape offered enough space to accommodate a 4 m-deep truss from which all six storeys could be hung. Vierendeel trusses made up of fully welded beams and columns at each floor level running in the same direction as the roof trusses stiffened up the structure. Since these elements, by definition, lack the diagonal element of a truss, circulation space throughout the building was also maintained.

To maintain future flexibility, client Big Yellow required that some levels should be omitted in the main structures. These would be added during the fit-out stage using bespoke steel and timber mezzanine structures which would sit on the second and fifth floors.

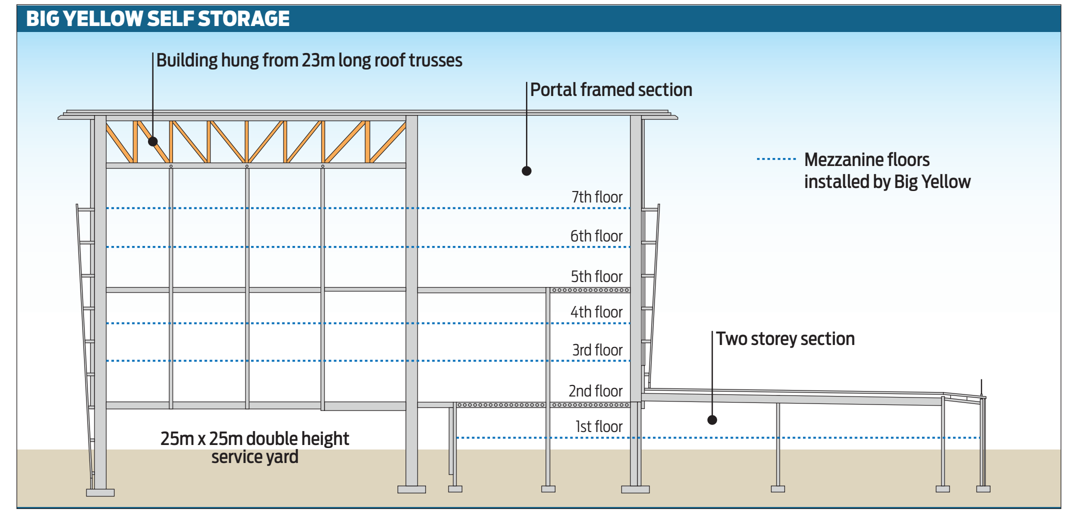
This affected the design in two ways. Firstly, a 6.5 m by 8 m opening had to be left in the steelwork to allow Big Yellow access to install the mezzanine levels. This had to be stiffened with additional steelwork.

Secondly, columns that would eventually support the legs of the mezzanine levels had to be strengthened. Stability of the service yard/six-storey hung structure is achieved via the steel-framed stair and triple lift cores, as well as the vierendeel trusses that also support cantilevered balconies.

"A steel frame was ideal for this job because of the convenience of erection," says Mr Frost. "The main advantage is that you can leave out floor panels, which can be easily filled in later. Steel provides that kind of flexibility which you couldn't really get with concrete."

The two-storey structure will be topped by a green/brown roof to alleviate rainwater run-off. Other sustainable features include rainwater harvesting, storm water attenuation tanks and photovoltaic cells, which will help provide some of the building's energy requirements.

BIG YELLOW SELF STORAGE



Buildings on target

Government policy states that by 2019 all new non-domestic buildings should be built to the highest possible environmental standards and with the ability to generate the little energy they need to function – zero carbon in operation

ZERO CARBON
RUBY KITCHING

TARGET ZERO

The complete results of a £1 million three-year research programme into the measures needed to achieve zero-carbon emissions in five basic building types, that each formed one phase of a five-part study, have just been published.

The Target Zero project was commissioned by the British Constructional Steelwork Association and steel manufacturer Tata Steel to offer some guidance on how to go about designing and building to the highest environmental standards. Crucially, the costs of adopting different low- and zero-carbon technologies are presented within the guidance reports, which are available free of charge at **www.targetzero.info**.

"The government has set up a policy to achieve zero-carbon emissions in new non-domestic buildings by 2019, but there is very little guidance on how to achieve this," says Target Zero project manager David Moore. "What we've developed is holistic guidance, which includes the wider environmental issues, taking it beyond the steel frame."

The original question asked by BCSA and Tata Steel – "how do we design steel-framed buildings that minimise carbon emissions?" – has been comprehensively addressed in the reports.

Independent consultants Aecom and Cyril Sweett carried out the work, which involved taking five building types based on actual buildings and then theoretically stripping them down to meet the minimum requirements for the 2006 Part L of the Building Regulations. These became the base case buildings.

On the case

Each base case building was adapted to make it as energy efficient as possible in terms of improving the building's embodied energy (the energy used to create it), operational energy (the energy used to run it), and BREEAM rating – the industry standard for measuring sustainability of a building. The structure types analysed were schools, warehouses, supermarkets, offices and mixed-use buildings.

One of the resounding findings of the study relates to the fact that the choice of framing material, regardless of building type, makes very little difference to the operational efficiency of a new building. So, despite being funded by the steel industry, the study's findings are as relevant to concrete and timber-framed buildings.

The research reveals that the government's 2013 target to reduce carbon emissions by 44 per cent compared with 2006 levels under Part L of the Building Regulations could be relatively easily achieved in most new buildings using energy-efficiency measures and adoption of low- or zero-carbon technologies, such as photovoltaics. This would be without significant additional cost.

"There are lots of ways to reduce carbon emissions from new buildings, but achieving zero operational emissions is only part of the balanced approach that is required for truly sustainable design. Attention needs to be given to embodied carbon and the measures that achieve the highest BREEAM ratings, as well as operational energy," says Tata Steel general manager and Target Zero project sponsor Alan Todd. "Just focusing on one of these aspects and disregarding the others is unlikely to result in a truly sustainable building," he adds.

The study identifies that one of the toughest scenarios for achieving zero carbon is that of a multi-storey office in a built-up city centre. In these locations, buildings are often surrounded by other high-rise and sit on a tight footprint, so there is little opportunity for significant solar or wind power to play a part in offsetting such a building's heavy reliance on artificial heating, cooling and lighting.

Solar potential

The most favourable scenarios for achieving Target Zero are in single-storey large warehouses that can offer large roof areas for solar energy production, says the study.

Clearly, some factors of building design cannot be determined purely by what produces the most sustainable solution – a building's height and orientation is often fixed by commercial factors or planning regulations, often making it impossible to incorporate a wind turbine or solar power.

However, the reports point to some situations where optimising aspects of design, such as orientation, can have a huge impact on carbon emissions. In the supermarket case study, research found that lighting represented around half of the total operational carbon emissions for the base case building.

So optimum roof light design and orientation would be key to achieving significant reductions in operational energy use.

The study also investigates the current trend for naturally moderating a building's internal temperature by using its thermal mass. The phenomenon allows heat energy to be absorbed by the material, usually concrete, releasing it later.

The Target Zero reports reveal that too much thermal mass in a building can actually be detrimental to efficient heating and cooling. It also explains that while it is generally thought that more concrete in a building equates to more thermal mass, which is good for the environment, there is sufficient thermal mass in the precast concrete or composite floors of steel-framed buildings, and that some concrete buildings could be described as having too much thermal mass.

"If you expose thermal mass, it will save money on cooling a building, but if there is too much of it, you can end up wasting energy just heating the mass rather than the space," explains Aecom head of sustainability Ant Wilson. "Exposing too much thermal mass can actually mean more energy is needed to heat up a building."

Another misnomer which is addressed by the study is the definition of embodied energy. Many analysts consider embodied energy on a cradle-to-gate timescale, which only goes as far as considering the energy used to the factory gate and ignores any later burdens or benefits.

The cradle-to-grave definition of embodied energy considers the full lifecycle and takes into account the energy required to extract the raw material, manufacturing and transporting it as well as what happens after its current use has expired.

End-of-life issues

The report supports the position that for zero-carbon buildings, embodied energy should fundamentally consider the cradle-to-grave definition.

"For me, it's critical that the embodied carbon of a building considers the cradle-to-grave timescale, because the cradle-to-gate concept only covers half the job," says BCSA vice-president and Target Zero project sponsor Richard Barrett. He adds: "Understanding the whole-life cost of a building is essential and to do that you have to look at the end-of-life issues of everything that goes into a building – not just the 30 to 40 years' life of a building itself."

This definition of embodied energy works out favourably from a sustainability point of view for materials such as steel, which are easily reused or recycled when a building is decommissioned. In this respect it compares favourably with materials such as structural timber that are far less likely to be reused or recycled when a building has reached the end of its life.

Lastly, perhaps one of the most thought-provoking outcomes of the study is in analysing the cost of measures which need to be put into place to achieve higher BREEAM ratings. "It is useful for clients to have a clear idea of the cost implications of achieving the higher BREEAM ratings. The Target Zero study shows that across all five building types an Outstanding rating comes at a significant cost uplift, whereas Very Good or Excellent can be achieved at a modest premium," says Mr Todd.

The report states: 'The cost uplift on most buildings to achieve BREEAM Very Good is relatively small. For well-designed buildings, the cost uplift to achieve an Excellent rating is usually below 1 per cent of the capital cost. But to achieve an Outstanding rating, the cost uplift is over 5 per cent in many cases, for even the best-designed buildings.'

The five Target Zero reports are filled with factual data captured during the study, including lots of tips and guidance to help reduce carbon emissions and deliver sustainable modern buildings.

COST UPLIFT TO ACHIEVE HIGHER BREEAM RATINGS

Building	Very good	Excellent	Outstanding
School	0.2%	0.7%	5.8%
Warehouse	0.1%	0.4%	4.8%
Supermarket	0.2%	1.8%	10.1%
Office	0.2%	0.8%	9.8%
Mixed-use	0.1%	1.6%	4.9%

The Target Zero study modelled a number of different routes that designers could take to obtain Very Good, Excellent and Outstanding BREEAM ratings. This table shows the uplift costs calculated to achieve the top three BREEAM ratings for the actual case study building, demonstrating the significant capital cost involved in achieving an Outstanding BREEAM-rated building. Visit
>>>> **www.targetzero.info**

CASE BUILDINGS

Target Zero base case buildings were created from the designs for actual buildings that were generously provided by leading organisations including Balfour Beatty, Prologis, Asda, Development Securities and Peel Leisure. The actual buildings were sustainability exemplars, so it was necessary to re-engineer the designs to just meet the minimum requirements of Part L (2006).

- **Schools** Based on the Christ the King Centre for Learning secondary school in Knowsley, Merseyside. A steel-framed building with a 9,637 sq m gross internal floor area to accommodate 900 pupils and 50 staff.
- **Warehouses** Based on the DC3 distribution warehouse at Prologis Park, Stoke. A 35 m span, steel portal frame structure.
- **Supermarkets** Based on the Asda food store in Stockton-on-Tees. A two-storey steel-framed structure of 9,393 sq m floor area.
- **Offices** Based on One Kingdom Street, London. A 10-storey, double basement steel-frame building with fabricated cellular steel beams supporting a lightweight concrete slab on a profiled steel deck.
- **Mixed-use** Based on the Holiday Inn tower, MediaCityUK, Manchester. A 17-storey steel frame structure with Slimdek floors and two concrete cores.

Produced in association with TATA STEEL BCSA

In the frame

One of the most ambitious heritage projects in recent times is under way at Portsmouth Dockyard with the construction of a finely crafted permanent home for Henry VIII's flagship, the Mary Rose

PROJECT REPORT
MARTIN COOPER

Project Mary Rose Museum, Portsmouth
Main client Mary Rose Trust
Architect Wilkinson Eyre
Interior architect Pringle Brandon
Main contractor Warings
Structural engineer Gifford (part of Ramboll)
Steelwork contractor Rowecord Engineering

Described as one of Britain's most important archaeological finds, King Henry VIII's naval flagship, the Mary Rose, will soon be housed in a new purpose-built museum alongside thousands of objects that were salvaged with the ship's hull in 1982.

Since being raised from the Solent 30 years ago, the remnants of the ship and its artefacts have captured the public's imagination, with thousands visiting the current museum in Portsmouth Dockyard every year.

The preserved objects offer a unique insight into the life and times of a Tudor warship as many of the artefacts have remained unscathed since the fateful day in 1545 when the Mary Rose sank.

About 1,000 of the 1,900 recovered objects are currently on display in the existing museum – the new facility will have more space for exhibits – while the hull itself has been undergoing preservation work, housed in a temporary structure in a nearby dry dock.

The project, largely funded by a grant from the Heritage Lottery Fund, will see the Tudor warship finally ensconced in a permanent building, positioned over this dry dock in which the Mary Rose currently sits.

For the Mary Rose Trust, the project represents a dream come true. "It will combine the two halves for the first time," says the Trust's Chris Dobbs. "Visitors will soon be able to view the preserved hull right alongside many of the ship's objects."

Design concept

Having won a design competition in 2004, Wilkinson Eyre and Pringle Brandon's concept revolves around the preserved starboard portion of the hull sitting in the middle of the new boat-shaped structure. A sort of pearl within its oyster shell, as architect Chris Wilkinson describes it.

Within the museum there will be three visitor galleries, corresponding to the principal deck levels of the ship. These will run the length of the building, imitating the missing port side of the vessel and allowing the original artefacts to be displayed in context.

All through the construction process the hull has remained in the middle of the project, in its 'hot box' – a tent-like structure in which air-drying is proceeding, a conservation process which will not be completed until 2016.

Until then visitors will be able to see this process through viewing ports positioned along each of the gallery levels. On completion of the air-drying phase, the 'hot box' will be removed, allowing visitors new and dramatic views of the ship's original timbers.

The new museum has also been described as a finely crafted, wooden jewellery box, as it will be clad in timber planks both reflecting the structure of the original ship and the nearby HMS Victory. The planks will be painted black and inscribed with carvings used by crew to identify their personal belongings.

Constructing a building which not only encases the ship's hull but also the dry dock in which it nestles has thrown up a number of construction challenges.

The dock itself is a Scheduled Ancient Monument, so there was a requirement for minimal interference to the original stonework. Something lightweight was needed, a structural frame which could also span the dock without interfering with the conservation work going on in the midst of the site.

"The complex shape of the structure and the need for a lightweight solution meant steel was the only real choice," explains Gifford technical director Ben Rowe.

The original design proposed by Gifford was subsequently developed further by Warings subcontractor CSC. The company has played a significant role in ensuring the steel framework and supports were affordable.

The building's main steel columns sit on pads, which are isolated from the dock's stonework by a structural membrane. The pads not only protect the dock but also distribute the structure's loads evenly.

Hull structure

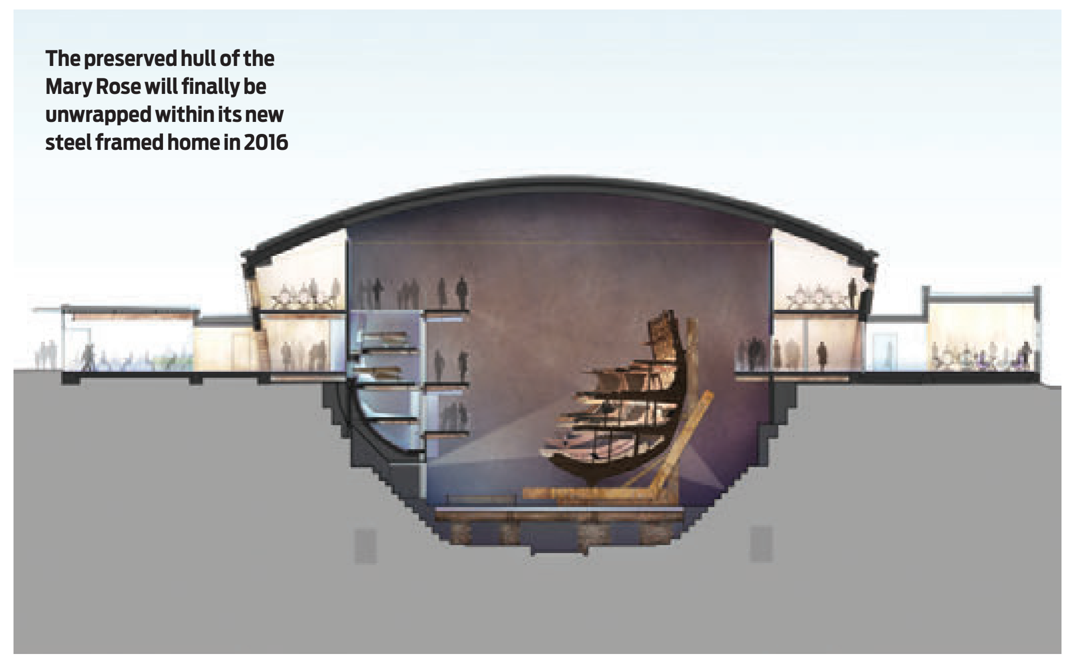
From the dock the steel frame rises up and encloses the hull in an elliptically shaped structure. The frame also includes two pavilions, on the north and south side of the structure – one will house the entrance foyer while the other will accommodate an educational suite.

The museum takes shape adjacent to another historic ship, HMS Victory

> **"The complex shape of the structure and the need for a lightweight solution meant steel was the only real choice"**
> BEN ROWE, GIFFORD

The building's irregular shape has been formed with a number of faceted columns that rise outwards from the pads and then rake inwards to create the appearance of a ship's hull.

The crank or change in direction happens at a number of multi-connections, positioned approximately 3 m from ground level, a point which is nearly a third of the way up the building's side. Each of these hub connections, designed by Rowecord Engineering, not only accepts the two column sections, but also cross beams, floor beams and tubular bracing. All of the connections were prefabricated off site and this ensured these complex pieces of steelwork arrived at the project in the required exact configuration.



The preserved hull of the Mary Rose will finally be unwrapped within its new steel framed home in 2016

The main columns forming the building's rib cage are spaced at 3 m intervals, a width that means the structural bays match the original size of the Mary Rose's gun ports.

"Steelwork was erected one bay at a time, using some temporary propping," explains Warings project manager Nicolas Beausseron. "However, once the bracing – which is curved to match the perimeter shape – was installed, each bay was stabilised, allowing the next bay to be erected."

More steelwork is connected to the perimeter columns, to form the visitor and object galleries that encircle the museum's interior. The visitor galleries curve to mimic a ship's deck and these were formed by staggered beams supporting the flooring.

Truss solution

The lower ground floor of the museum houses not only the hull's 'hot box' but also an array of necessary equipment and plant for ongoing conversation work. So as not to interrupt the important work taking place, two large trusses span this plant area, forming a large column-free zone.

"Prior to installing these trusses a crash deck was installed during the enabling works to protect the equipment," says Mr Beausseron.

When the conservation work is complete in 2016 and all of the equipment is removed, this area will become a new public gallery. Positioned at lower ground floor level, it will offer visitors another view of the unwrapped hull.

Topping the boat-shaped museum is an elliptical roof, which was prefabricated off site and lifted into place over the dock, again minimising disruption to the conservation activities and following a precise methodology to reduce the risk of objects falling on to the hull.

Supporting the roof is a series of 32 m-long curved rafters, installed in three sections, to avoid having to work above the 'hot box'.

Steelwork erection and the installation of the roof was completed during August. Internal fit-out has now started, with the museum scheduled to open at the end of 2012.

Meanwhile, preservation work continues apace on the Mary Rose hull and it will be carefully dried out within the new facility until being finally unveiled in 2016.