JANUARY 2009 VOL 17 NO 1

NSC

NEW STEEL CONSTRUCTION

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Acute hospital for the Midlands
Glasgow gets long spans
Steel bowl for university
College boosts regeneration

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New Birmingham Acute and Adult Psychiatric Hospitals
Client: Consort Healthcare for the University Hospital NHS Foundation Trust and the Birmingham and Solihull Mental Health NHS Trust
Architect: BDP
Steelwork contractor: Severfield-Reeve Structures
Steel tonnage: 12,500t


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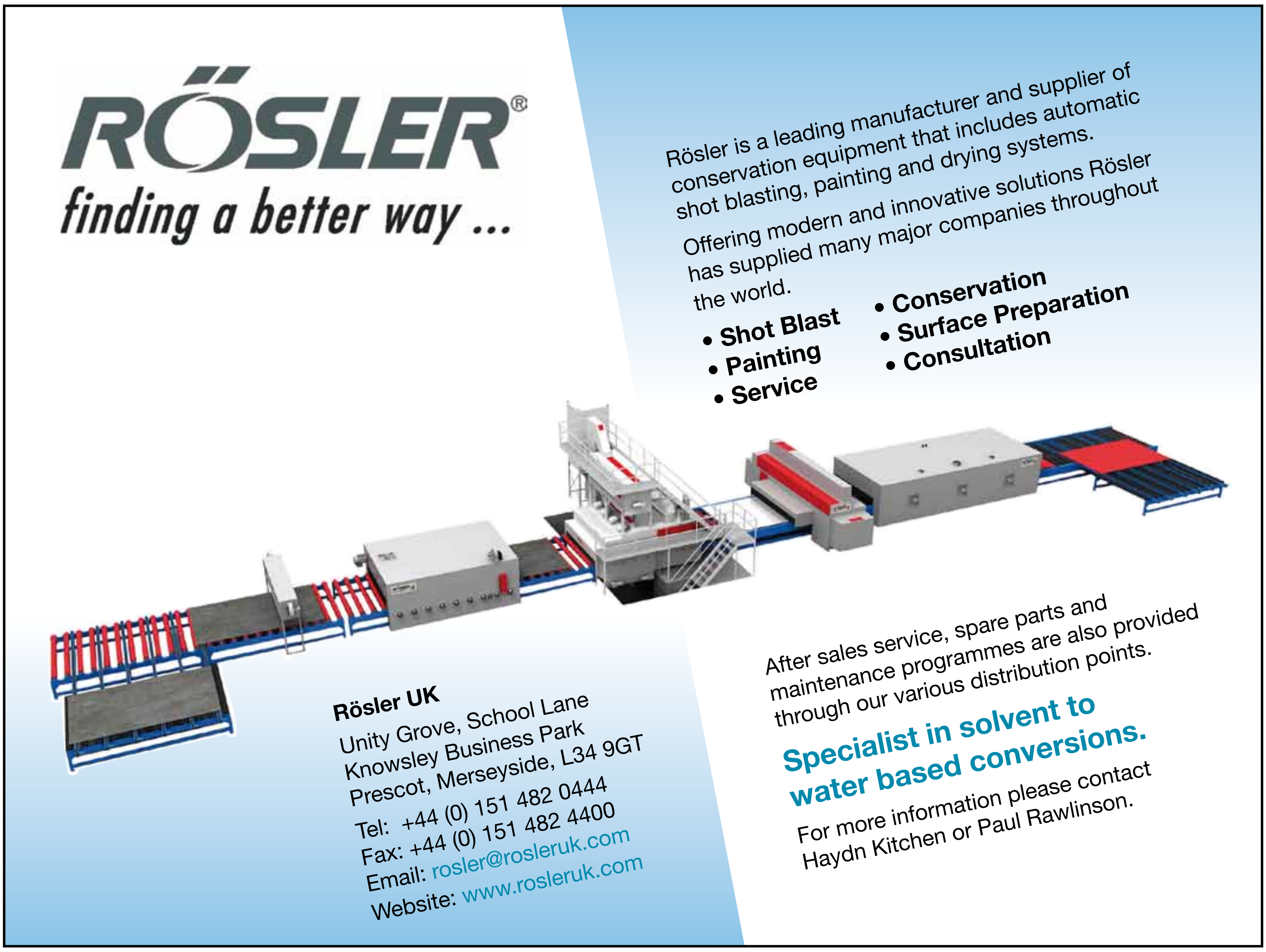
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Recession forges quality solutions

Are the first green shoots of recovery visible in the new construction orders figures released by the government before Christmas? The three month rolling figures to the end of October were certainly a major improvement on the trend revealed previously.

Private commercial orders were substantially down, 17% lower than the previous twelve months, but they were 10% up over three months compared to the previous three month period. Private industrial orders were down 26% in the 12 months to October, but were 44% higher than the previous three months. Encouraging as these trends might be it is of course far too early to say any recovery is in sight, let alone under way. Construction however just might have the bottom of this recession in view.

As we highlighted in our December issue, there is a massive boost coming to government funded construction programmes such as education and transport. The procurement process has been revealed to have serious shortcomings which mean this work is not coming through as quickly as our industry would like, but it is coming. A long term benefit of this might be an overhaul of the way projects are procured, which would benefit construction as well as the people who rely on the facilities like schools, hospitals and roads that the industry builds.

Demand for goods and services is substantially down across UK industry, but a feeling is growing that maybe we have been a bit guilty of 'glass half empty' syndrome. There is still work around and unprecedented steps have been taken to deliver major boosts to world economies. Other major work sources like the London Olympics and Crossrail are gathering pace. The fall in the value of sterling is boosting the competitive situation of the UK's manufacturing exporters. The scale of the government intervention means that there must be a chance that for once construction won't be the last out of a recession.

Since the last significant recession that sent construction reeling in the early 1990's the market and competitive dominance of steel has been on an upward trend. As clients came out of recession they looked with new eyes at what value they were getting for their money, and thanks to the investment in productivity and other improvements by the steel construction sector that had continued through those harsher times, there were better than ever steel solutions available.

Even now we see steelwork contractor members of the BCSA making major investments in new machinery that will deliver productivity and quality advances for years to come. Other research and development programmes by Corus and the Steel Construction Institute and industry partners are continuing.

Difficult times may still lie ahead, but the steel construction sector can be confident that it will be delivering better value and quality than ever when better times return.

Nick Barrett - Editor

Steel frames are the fastest way to build homes

A lightweight steel frame offers the fastest way to build sustainable, affordable and high quality homes. This is according to a BRE study, known as the SmartLife Housing Demonstration Project, conducted to find the best ways to deliver a greater volume of homes in less time.

BRE's Director of Innovation and Housing, Oliver Novakovic, said the organisation had carried out the study because of the lack of data showing how cost effective and quick modern building methods of construction were.

He said the study's findings showed housebuilders had to become more efficient.

"We now have a robust body of knowledge that will inform and enlighten our approach to future house building – once the current credit crisis abates," he said.

Dr Bassam Burgan, Chair of the Steel Homes Group, said: "For a long time we have been saying that light gauge steel offers a quicker, cheaper alternative to other forms of construction, and it is great to see that recognised in a well respected study."

The construction of 106 homes on three Cambridgeshire sites formed the basis for the study. The same house types were built using four methods: brick and block, lightweight steel frame, panelised timber frame and concrete formwork.

The highest achieving system used in terms of speed and cost was light gauge steel frame. On a site with unproblematic access and storage, a steel frame house took an average of 800 man hours per house to build, followed by the next best performer, brick and block.

Steel passes examination for Newcastle school

Covering an area the size of four football pitches (19,000m²), the recently opened steel framed Kenton Secondary School in Newcastle-Upon-Tyne has been described as a blueprint for future educational construction projects due to its innovative design.

The school is made up of five main teaching blocks connected via a curved crescent, or street, which ends at a large sports hall complex.

Mike Goldsmith, Project Engineer for Parsons Brinckerhoff, said the most challenging aspect of the job was the shape, in particular the curved geometry of the street and the sports hall's rear wall.

"The curves of the street aren't uniform, between each teaching block they change," he explains. "Another challenge was where to split the structure for movement joints as generally the whole building doesn't lend itself to this."

Steelwork contractor Hambleton Steel was on site for 21 weeks and erected approximately 1,100t of structural steel for the job.

Michael Dixon, Hambleton's Project Manager, said the job was very complex as there were no square grids. "All steelwork is at a radius, nothing is straight even the teaching block's footprints fan out."

Kenton School, with lottery funded, part public sports facilities, has been handed over to Newcastle City Council's private sector partner Aura.

Aura Chief Executive Kirsty Thirlwell said: "This is the sixth and largest new school we have delivered for Newcastle and it is a great example of the benefit properly directed investment can bring to education."

Partners in Aura are Newcastle City Council, Parsons Brinckerhoff, Sir Robert McAlpine, Robertson Capital Projects and Building Schools for the Future Investments. .

Curving iconic museum docks in Glasgow

An innovative and eye catching landmark structure is taking shape at the confluence of the rivers Clyde and Kelvin in Glasgow.

The £74M Riverside Transport Museum is the vision of Iraqi born architect Zaha Hadid, and is being constructed by main contractor BAM.

When complete, the twisting, curving roof of the 11,200m² building will stream away from huge, glazed gable end elevations to become the city's newest museum.

Watson Steel Structures are currently undertaking the steelwork erection which is expected to be completed later this Spring. The museum will open in 2010.

BCSA provides sourcing option for specifiers

Sustainability requirements are becoming increasingly common in construction specifications, and many companies in the BCSA's membership have signed the Steel Construction Sustainability Charter and been audited to become Sustainability Charter Members. This allows clients with sustainable ambitions to select steelwork companies that share their ideals.

The BCSA scheme is founded on best practice and continuous improvement so that companies can proceed from entry level membership through Silver to Gold status. Recognising that clients are seeking assurance about responsible sourcing, the BCSA has extended the scheme's requirements with respect to supply chain engagement.

It is already a requirement that Gold Members of the scheme must have environmental management systems that are certified in accordance with BS EN ISO 14001. From January 2009 all Gold Members of the scheme must ensure that at least 80% of their supplies of steel are manufactured by companies that also meet the BS EN ISO 14001 certification standard. This requirement is met for all steel products manufactured in the UK by Corus as all its facilities have been certified as meeting the standard.

Specifiers selecting SCM Gold Members will benefit from BCSA's responsible sourcing initiative in the knowledge that these companies are ensuring that their supply chain partners are paying proper management attention to environmental issues.

Stadium work relies on tube expertise

A number of high profile stadium projects are currently under way across the UK and Ireland, with many of them using tubular steel sections for the grandstand roofs.

PP ProTube has recently cut and prepped tubes for two new rugby stadiums, the Leicester Tigers new ground and Munster's Thomond Park Stadium in Cork (pictured).

"Our CNC machines can offer both flame and plasma tube cutting facilities from 48mm up to 1,016mm diameter with a maximum wall thickness of 50mm," said Paul Owen, PP ProTube Account Manager.

From its facility in St Helens, Merseyside, the company can also cut lengths of up to 17m which can be handled with a maximum piece weight of 15t.

PP ProTube has also recently profiled tubes for Watson Steel Structures' prestigious Glasgow Transport Museum project.

Green warehouse lands on blue planet

Atlas Ward Structures has completed erection of nearly 2,000t of structural steelwork for a pioneering warehouse in Newcastle-under-Lyme, Staffordshire for Gazeley, the global provider of sustainable logistic space, and main contractor McLaren Construction.

The project known as G.Park Blue Planet Chatterley Valley is described as a truly 'carbon positive' development and consists of a single 34,000m^2 distribution centre with ancillary office space.

The warehouse forms the initial phase of the wider Chatterley Valley park project which will eventually create thousands of new jobs on the 12.5 hectare former colliery site.

The site's carbon positive credentials will be enhanced by a bio-mass micro power station, which will produce sufficient power and heat for the on site buildings and a surplus that will provide enough energy to power up to 650 local homes.

Other sustainable features of the development will include thermally efficient buildings with air tightness and thermal insulation, systems for energy reduction and the latest solar cell technology which will eliminate night time light pollution.

Tom Haughey, CEO Severfield-Rowen Group, said: "We are pleased to be involved with such a high profile sustainable project as we believe sustainability is key to each of our subsidiaries.

"We have recently achieved Gold standard under the Steel Construction Sustainability Charter."

AROUND THE PRESS

The Structural Engineer
4 November 2008
Value engineering
Part forming the roof over the auditorium is the project's largest single steel element; a 160t 48m long roof truss. With plate girders forming its top and bottom cords, the 6.5m deep truss was lifted into position in 24 individual pieces. It required temporary towers to support it until the entire truss was bolted into position with its connecting steel members and secondary trusses.

Contract Journal
22 October 2008
Speculating with steel
One of the key elements of a speculative build development is a quick construction programme and the entire project has been completed in under two years. Choosing steel instead of other framing materials has helped speed up the programme as all of the 1,800t of structural steelwork was fabricated, supplied and erected in just 26 weeks.

Build It
December 2008
On the crest of a wave
The steel was supplied by fabrication company Evadx in Rhyl after John consulted with experts at Corus. "I phoned Corus to ask their advice on the steel frame and they couldn't have been more helpful. They recommended a mild structural steel that was painted in Bradite epoxy coating for maximum resistance to corrosion and weathering.

New Civil Engineer
27 November 2008
Lights camera action
(Referring to Media City in Salford) "We looked at all framing possibilities for each individual building and steel was the best option for the studio, not just because of the spans, but also acoustically," says Bovis Lend Lease Project Director John Hyne.

Reusing steel is the sustainable choice

The BCSA has recently received a number of enquires regarding the design and construction of projects to be done, in part, with reused steel sections.

"Structural sections can be reused or infinitely multicycled into new steel, unlike other construction materials which usually end up in landfill," said BCSA Director General Derek Tordoff. "When designing with reused steel sections designers need to take into account that the dimensions and mechanical properties vary depending on the date of manufacture."

The BCSA recommends designers refer to the 'Historical Structural Steelwork Handbook' at *www.SteelConstruction.org* for more in depth information on the subject.

An example of reused steel being utilised in a new build project is the BCSA's new Yorkshire office near Garforth. This structure was designed and built using reused sections taken from a nearby demolished warehouse.

Developer John Wilson used 82t of reused steel for the new office building. All the sections were disassembled and then refabricated in to a new frame.

"This is something we do on a regular basis," said Oliver Wilson Corrigan of John Wilson.

Efficiency up at Cleveland Bridge

A new high speed FICEP 1203 CNC DJB Drilling and Bandsaw machine has been installed at Cleveland Bridge's fabrication facility.

Steve Wright, Works Manager for Cleveland Bridge, said: "It is essential during a substantial downturn of the construction industry that we should look to invest in our production capabilities to offer our clients the best possible prices without in any way compromising quality. This FICEP machine provides the efficiencies we required and its unique scribing system offers additional benefits to ourselves and our clients."

This is Cleveland Bridge's first investment in new production machinery for some time and it will operate the 1203 unit alongside another FICEP machine, a TIPO B 25 which was purchased more than seven years ago.

Architectural HQ opts for steel framing

Architect BDP's new Manchester head office has been completed with the aid of Metsec's site fixed framing system (SFS).

The striking six storey building, part of the city's £250M Piccadilly Basin regeneration scheme, is viewed as a flagship HQ and will house 275 BDP staff.

Metsec worked with contractor CPL to design and build an outward leaning external wall, a key feature of the canal side building.

A quantity of 150mm wide studs were supplied by Metsec. These were attached at an angle to the main concrete slab frame with a series of slotted cleats, to form the external sloping facade. To form the inner skin a number of 100mm studs were supplied.

Sustainability was a key requirement for the building, which is the first naturally ventilated office building in Manchester to achieve a BREEAM 'Excellent' rating.

New viaduct for A34 crossing

Steelwork erection for the first section of the new Wolvercote Viaduct on the A34 at Oxford has recently been completed.

The existing concrete viaduct, built in the 1960s has suffered extensive deterioration and is being replaced with a new steel composite structure. The viaduct carries traffic over the A40 Oxford to Cheltenham road, the Oxford to Birmingham railway and the Oxford Canal.

The new viaduct will sit in the same position as the existing structure and causing minimal traffic disruption on the busy A34 means the project team have come up with a novel approach.

A new temporary southbound bridge has now been erected by Costain and steelwork contractor Fairfield Mabey adjacent to the existing bridge. Once this structure is completed, southbound traffic will use it, while northbound traffic is switched to the old southbound bridge. This will allow the northbound bridge to be demolished and completely rebuilt. Once finished northbound traffic will be diverted on to the new structure, allowing the southbound bridge to be demolished.

New concrete piers for the southbound bridge will be constructed and then the entire 250m long temporary bridge deck will be jacked up and slide across on to the new southbound piers. "It's a complex procedure," said Darren Dobson, Costain Project Manager. "But it allows the A34 to have four lanes open during the majority of the works."

The new viaduct is scheduled for completion mid-2010.

Cladding the factory of the future

The Advanced Manufacturing Research Centre (AMRC) dubbed 'the Factory of the Future' has recently been completed by Bowmer & Kirkland for the University of Sheffield.

The facility houses the latest manufacturing equipment and state-of-the-art production capabilities to enable businesses to trial new developments on a full scale commercial production capacity.

The steel framed building, erected by Conder Structures incorporates roofing and cladding products manufactured by Architectural Profiles (APL).

The APL Energi System used on the AMRC is based on a StrongBak structural wall framing system which is said to be one of the fastest methods of total building enclosure and air seal.

The Energi System was able to achieve a 0.2 w/m2/0c insulation performance against a Buildings Regulations requirement of 0.35 and air seal of $2.71m^3/hr/m^2$. Both of these are considered by BREEAM to be in the 'Excellent' rating category.

Witney retail development gets a car park

Conder Structures, working on behalf of Simons Developments, has completed erecting 850t of steelwork for a retail development's car park in Witney, Oxfordshire.

The steel framed car park will provide 650 vehicle spaces for the new £50M, 14 unit Marriotts Close retail and leisure centre (NSC September 2008).

The car park's dimensions of 73.7m x 70.3m were dictated by the need to fit in a required number of spaces into a restricted site.

As part of its extended contract, Conder supplied and installed precast 150mm hollow core concrete units for all eight split levels with a design loading of $2.5kN/m^2$. The design delivers a minimum floor to floor height of 3.075m, with a 2.1m clear height.

In a service yard beneath level three, Conder created a $674m^2$ area clear of internal columns. This was achieved by installing two 21.13m long lattice vierendeel trusses, each weighing 23t.

The ends of the diagonal members were slotted to fit over gusset plates and on the centre line of the booms. The trusses had a critical depth measurement of 3.15m, designed to fit exactly within the storey levels.

NEWS IN BRIEF

Billington Structures has won the prize for business growth at the Barnsley Business Awards 2008. The award, sponsored by the Barnsley Chronicle recognised Billington's achievement of significant and sustained growth over the past three years.

BCSA has formed the **Fabrication and Welding Users group** and its first meeting was held at the BCSA's Yorkshire office on 25 November. The aim of the group is to provide BCSA members with a forum to discuss and address the complete range of practical and technical issues affecting day to day operations. The first meeting discussed the forthcoming introduction of CE Marking and the associated standards BS EN 1090-1 and BS EN 1090-2, the new welding standards and developments in material processing machinery and software.

The new **European Standard for the fabrication and erection of structural steelwork**, BS EN 1090-2, was expected to be published by the BSI as NSC went to press at the end of December. BS EN 1090-2 will eventually replace British Standards such as BS 5950-2, BS 5400-6 and parts of BS 8110.

The doubts associated with application of **BS 6399-2** to large-span single storey buildings together with the recent issues association with the forthcoming wind Eurocode, EC1: Part 1.4 have prompted the BCSA to commission the Building Research Establishment (BRE) to monitor the wind load on a typical hangar. The purpose of the work is to collect data with a view to assessing the validity of the wind load models in BS 6399-2 and EC1: Part 1.4 and whether or not the recommendation 'to ignore local wind pressures in the design of the steel frame' should be reinstated in BS 5950-1. Measurements are to to made during a four month period this winter.

Steel success story at London seat of learning

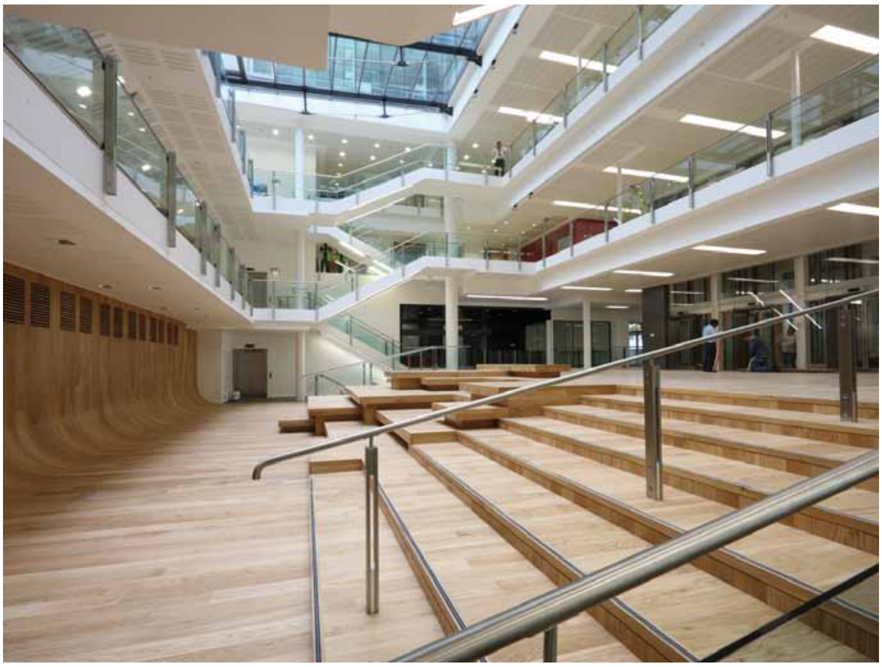
The London School of Economics' (LSE) new £34M Academic Building opened for the Autumn term after an extensive remodelling which required 450t of structural steelwork and the installation of two Corefast modular cores.

The building totals 12,600m² across 11 floors and is arranged in a U-shaped configuration around a glazed atrium.

The building's original facades were retained while the internal structure was demolished and replaced with new floors suspended from a steel transfer truss at roof floor level. This provided an extensive column free 400 seat lecture theatre at basement level.

The 15t steel transfer truss is 17.5m long and is supported on two CHS columns which extend right through the new build section of the building. These columns are 559mm diameter at the lower levels, decreasing to 508mm diameter further up the structure.

The building was designed by Grimshaw Architects and built by Osborne, the engineer was Alan Baxter & Associates and the steelwork contractor was Bourne Steel.



Hospital car park increases capacity and security

A £8.6M steel framed three level car park has been completed for the Basildon & Thurrock University Hospital NHS Foundation Trust, increasing both capacity and visitor security.

Built on the site of the hospital's former 800 space surface car park, the new car park features fluorescent lighting and 50 CCTV cameras to provide security which has been accredited under the Park Mark Safe Parking Scheme.

Tommy Chambers, Divisional Director for main contractor Osborne, said: "Most hospital campuses are fixed and finding more space to expand is difficult. By building a multi storey car park, the Trust has improved parking on site significantly, managed its historical problem of illegal parking and dramatically enhanced safety and security."

The 154m x 64m steel frame was erected by SIAC Tetbury Steel and required 850t of galvanised steelwork. The steel was erected around a 7.2m x 16m grid, which equated to 22 bays long x four bays wide.

Mark Fox, SIAC Tetbury Steel's Associate Construction Director, said: "The project was erected with mobile cranes in nine phases, as this allowed continuity for both steel erection and installation of the precast concrete planks.

"Due to the success of this project we have now been awarded three more car parks with Osborne."

Diary

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Birmingham

4 February 2009
EC3 2 Day course
Dublin

11 February 2009
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New hospitals are super in steel

Speed, efficiency and cost effectiveness are just some of the reasons why a massive Birmingham hospital project is relying entirely on steel as its framing material. Martin Cooper reports from the UK's new super hospital.

The Birmingham New Hospitals (BNH) PFI project is the first new general hospital to be built in the UK's second largest city for more than 70 years and the largest community healthcare development outside of London.

Once complete in 2012, this new 'super hospital' being constructed on a 50 acre site adjacent to the existing Queen Elizabeth Hospital in Edgbaston, will offer 1,213 beds, 30 operating theatres, 15 laboratories, 300 teaching rooms as well as 3,700 car spaces spread over three new multi-storey car parks and a series of other ground level car parks.

Plans for the new hospital and the existing estate also include streamlining local medical services by absorbing all healthcare activities currently being undertaken at Selly Oak Hospital, which will be closed down. Waiting times will also be significantly lowered as the new hospital will be able to treat 21% more patients in its operational area.

The project is undoubtedly big, and the size and complexity of the job has led the project team to use a number of innovative design solutions to provide the most economic and functional structure.

The main structure, known as the Acute Hospital, actually started out as a fully reinforced concrete frame, but as the design developed this changed to a mixture of steel and concrete and then finally a full steel frame.

"Using steel has been a real success on this project," explains BNH Balfour Beatty Project Director Roger Frost. "The speed it can be erected on a project of this size is important and it's efficient and less labour intensive."

This last point is important to BNH, as during 2008 the number of workers on site peaked at around 1,300, a total Mr Frost estimates would have been much higher if prefabricated methods were not used.

"On a project as large as this one, managing the workforce is vital," he adds. "We are extremely safety conscious, but the larger the workforce the greater the possibility of accidents."

Keeping the project moving at a steady pace has also led BNH to use as many off-site prefabricated products as possible, such as fully fitted bathroom pods and fully equipped bed head walls. "Steel comes to site ready to be erected, it's also a pre-fabricated product," adds Mr Frost.

Advance works began on site in late 2004, with the main construction programme kicking off in

Above: The project's main features are the three truncated pods containing the hospital's wards.

FACT FILE
New Birmingham Acute and Adult Psychiatric Hospitals
Client: *Consort Healthcare for the University Hospital Birmingham NHS Foundation Trust and the Birmingham and Solihull Mental Health NHS Trust*
Lead architect: *BDP*
Main contractor: *Balfour Beatty Construction and Haden Young (BNH JV)*
Structural engineer: *WYG Engineering*
Steelwork contractor: *Severfield-Reeve Structures*
Steel tonnage: *12,500t*

Left: BNH estimates that using steel has saved the client time and money while the need for fewer workers has meant a safer site.

Right: Structural steel model of Sector 1 (the first pod to be completed).

Analysis proves vibration performance

Vibration from a number of sources, such as air handling units, was considered in the structural design process. The result of the preliminary design was a robust steel frame utilising a 225mm composite concrete/profiled metal deck floor slab spanning between composite primary and secondary beams. "By using 225mm thick slabs we were able to provide floor beams with a high natural frequency and a slab with inherent mass to damp induced vibration," says Mr Garland.

"It was essential to maintain standard grid arrangements with continuous lines of secondary beams to promote the mobilisation of large areas of floor plate and increase the modal mass for vibration damping."

To validate the preliminary vibration design Severfield-Reeve commissioned SCI to undertake finite element analyses of the floor plates. From these analyses it was found that nine reasonably closely spaced modes of vibration existed which were likely to be the basis for resonant vibration. By adopting accurate loadings and damping factors it was confirmed that the design would meet the vibration requirements of HTM2045 Acoustics Design Considerations 1996.

Following the erection of the steel frame and the installation of the floor slabs, additional elements of sensitive medical equipment were introduced into the building. This equipment comprised MRI and CT scanners and in May 2008 WYG Engineering undertook a review of the now complete Sector 3 structure to assess the feasibility of providing adequately robust spaces to house MRI and CT scanners on areas of existing suspended floor slab. This exercise required an assessment of the structural capacity of the affected areas of the existing building and a vibration analysis, undertaken firstly by hand and then by in-situ testing, to confirm that the structure met with the stringent performance requirements specified by the equipment manufacturers. Vibration measurements were then undertaken on 1 September 2008 to evaluate the response of the floors in accordance with BS6472: 2008 which confirmed that the structure successfully met the vibration acceptance criterion specified for the scanners.

January 2006. The early part of the programme saw the first of three steel framed multi storey car parks built. This freed up space for the rest of the project to get under way, as much of the site was formerly taken up by a ground level hospital car park.

Three new steel framed mental health units were also erected early in the programme. This allowed the existing mental health hospital to decamp into the new facility, which in turn meant the old mental health unit could be demolished to free up even more space for the new Acute hospital building.

BNH used as many off-site prefabricated products as possible, such as fully fitted bathroom pods and fully equipped bed head walls.

The design for the new Acute hospital consists of three truncated pods, connected by walkways and set upon a three storey rectangular podium block. Four reinforced concrete slip form cores, in addition to localised systems of vertical steel bracing, provide each of the pods with their lateral stability.

"The main steel frame was tied into the shear cores using cast in steel embedment plates which were installed during the slip form works," says Andy Garland, Associate at White Young Green (WYG) Engineering. "This ensured that the steel frame would be positively tied to the reinforcement within the core walls and negated the need for drilling of post fixed connections." Fin plates were subsequently welded to the embedment plates ready to receive the floor beams.

The pods are approximately 50m high and contain the hospital's wards on floor levels three to seven, with plant space at level eight. These truncated pod structures have a hollow centre which acts as a large lightwell and allows natural light to penetrate the interior wards. The ward structures also feature sloping roofs which mean they contain six levels on the northern elevation and one less floor on the southern elevation.

On the ground floor of the podiums the accommodation consists of several departments, the major ones being imaging,and outpatients. On the first floor the departments include A&E and education, while the next floor up is the interstitial plant room level known as 2a. The top floor of the poium section, the third floor, contains the main theatre department.

The location of the plant rooms changed during the design process with a view of finding the most functional and cost effective solution. Each change had major ramifications on the civil and structural design, impacting on both the structural grid and the steel frame.

The inclusion of an interstitial plant space was

Above: As steelwork was being completed on the last pod, the cladding process was following close behind.

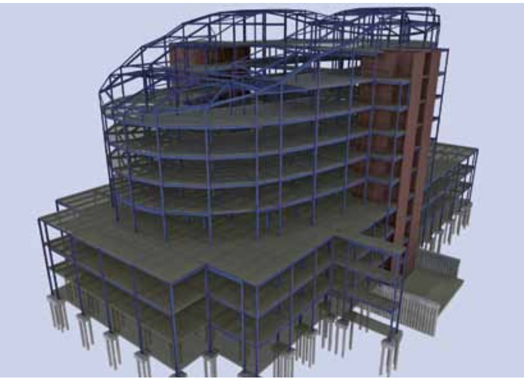
finally adopted at level 2a (third level of podium) which forms the horizontal interface between the podium block and the six storey oval shaped pod above. Transfer structures were installed to transmit the tower column loads into the podium columns beneath, which are subsequently supported directly onto piled foundations.

"The decision to go for an interstitial floor linked in to an overall M+E services strategy connected with theatre locations and riser requirements," explains Mr Garland.

To form this dedicated plant floor Severfield-Reeve Structures designed, fabricated and erected a series of 1,200mm deep plate girder transfer beams which were incorporated into the construction. In this respect, transfer structures occur partly over the upper most rectangular floor plate of the podium, and partly over the lower most radial floor plate of the pods.

Steelwork contractor Severfield-Reeve has also liaised closely with the cladding contractor to ensure the correct connections were supplied and erected. "All cladding is being landed and affixed from inside the building," explains Mr Frost. "This highly efficient method, again because we are using steel, means there is no need for scaffolding."

Efficiency as well as speed of construction have played integral roles so far on this project.



Above: Model of one of the ward pods, its cores and the podium.

Above right: All cladding has been fitted from inside the building, negating the need for any scaffolding.

Right: The three pods are linked by slipformed concrete cores.

As Mr Frost sums up: "By using steel and as much off-site construction as possible we create a more efficient, environmentally friendly and cost effective programme."

Others agree, as the project recently won an award at the Chartered Institution of Wastes Management (CIWM) Awards for Environmental Excellence. The project's award submission outlined the vision to create sustainable, energy efficient, environmentally friendly buildings. The judges were impressed by the clear waste reduction, re-use and recycling measures, with arrangements made with suppliers to ensure products are being delivered without unnecessary waste.

Bowled over by steel

A fully glazed bowl shaped lecture theatre is the centrepiece of a new faculty building for Leeds Metropolitan University. Martin Cooper reports.

Leeds is a city on the move. Like many of the UK's former manufacturing giants, it is reinventing itself with a host of developments, including commercial, residential and hotels, currently under construction.

One of the most striking developments is known as the Rose Bowl, a new home for the Business and Law Faculty of Leeds Metropolitan University.

Situated opposite Leeds Civic Hall, in the heart of the city's Civic Quarter, the main U-shaped building wraps around a distinctive glazed bowl structure which protrudes from the front. Supported on a series of Y-shaped columns, the Rose Bowl will house the faculty's lecture theatres and provides the establishment with a signature frontage.

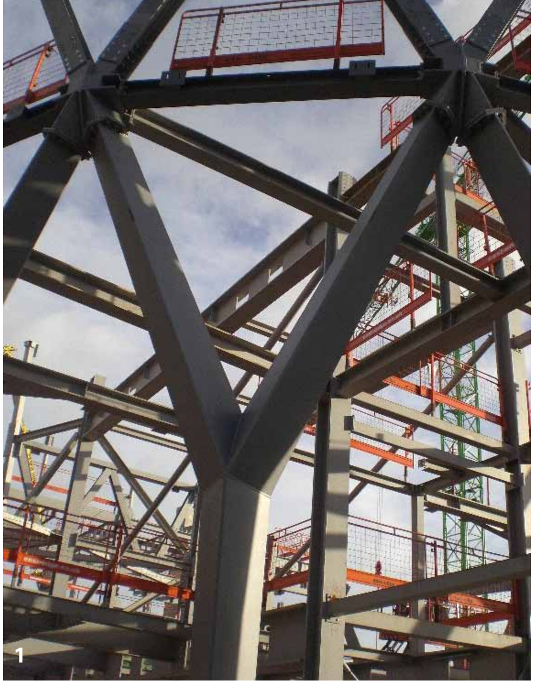
Describing the job, architectural practice Sheppard Robson says its design has responded to the University's aspirations and the development integrates it with a wider context of its location, and orientates the campus towards Leeds city centre, improving the University's status.

Very much at the heart of the project, the Rose Bowl lecture theatre 'pod' will contain one 250-seat theatre, two 140-seat and four 60-seat theatres. As well as having a highly unusual bowl-like shape, which also tapers out as it gets higher, the structure is clad in distinctive triangulated bolt-fixed reflective glass panels.

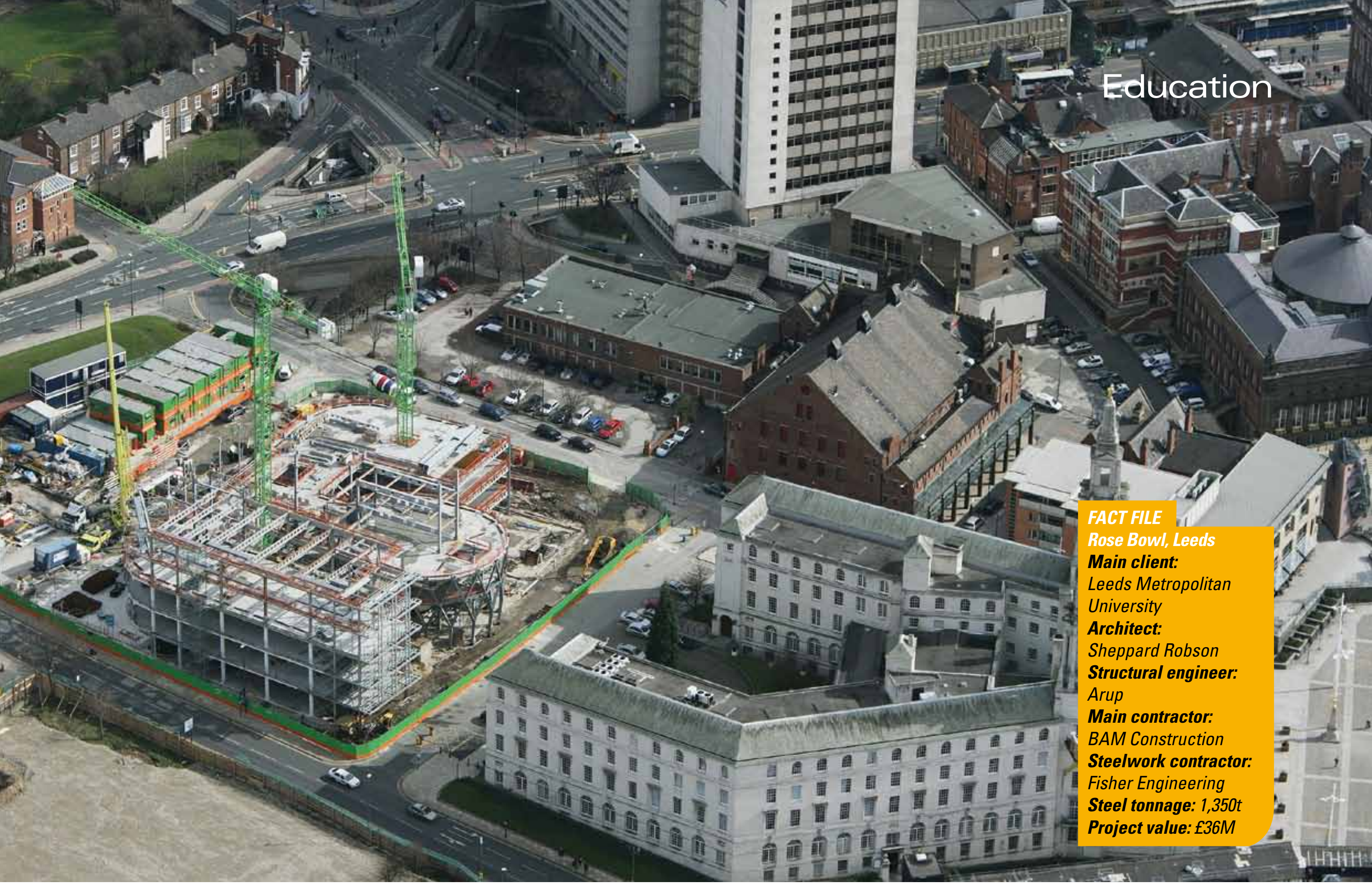
A series of bridges cross a semi public atrium, day lit by a high level structural glazed rooflight, linking the 'pod' to the outer U-shaped four storey main floorplates, which house offices and ancillary teaching spaces.

As well as a complex steel design, the project has also featured a long preparatory programme. The site, formerly occupied by a car park, was sloping, so much so that when the basement was dug out, one end was excavated to a depth of 11m while the other only needed to be dug to a depth of 8m.

This large muckshifting operation, which began in early 2007, resulted in a flat basement slab which eventually took more than 6 months to cast. The cast in-situ concrete basement also includes a piled retaining wall.



1. Feature Y-shaped columns were tied to adjacent members.
2. Columns are connected to a steel diagrid.
3. Scaffolding enabled the pod to be glazed.
4. Fully glazed, the complete Rose Bowl pod.



FACT FILE
Rose Bowl, Leeds
Main client: Leeds Metropolitan University
Architect: Sheppard Robson
Structural engineer: Arup
Main contractor: BAM Construction
Steelwork contractor: Fisher Engineering
Steel tonnage: 1,350t
Project value: £36M

Above: The project's city centre location meant there was little room for steel deliveries.
Left: The front elevation features the distinctive bowl shaped lecture theatre.

Below: Back elevation: The U-shaped office block wraps around the Rose Bowl pod.

From ground level up the structure is steel framed, and steelwork contractor Fisher Engineering initially started by erecting the outer U-shaped faculty. This part of the project primarily contains offices and classrooms, is four stories high with a plant room on the roof.

"We started by erecting the faculty building up to third floor and then the Rose Bowl to the same level," explains Barry Craig, Fisher Engineering Project Manager. "We were then able to use the third floor slab to run our cherrypickers on for the steelwork erection of the upper levels."

The design certainly lent itself to steel, especially the 'pod' theatre structure.

Logistically, the steel erection programme was very challenging as the site is extremely tight, surrounded by busy roads on three sides and the Civic Hall on the eastern elevation.

Consequently, there was little or no room for setting down of steel deliveries. Steel was delivered to site in a 'just in time' sequence.

The above ground superstructure was always going to be steel for its speed of construction," comments Simon Sutcliffe, BAM Construction Project Manager. "The design certainly lent itself to steel, especially the 'pod' theatre structure, as well as the need for long spans in the office block."

Clear spans of 15m are a constant feature of the office block on every floor. "The nature of the occupants means there will be lots of services," comments Mr Sutcliffe. "So cellular beams are used throughout to maximise the 3.9m floor to ceiling heights."

The office block has an approximate length of 60m along its back elevation, and 45m length along the two protruding finger wings. The construction process for this part of the programme was mostly traditional 'stick and beam' using the two on site tower cranes and bringing in a mobile crane when needed.

To begin erecting the Rose Bowl four internal main columns were erected first. "The bowl is essentially an elongated circle in plan, 24m wide x 30m," explains Mr Sutcliffe.

"These four columns were tied in and formed a central braced core, with temporary props in place, the steel was then erected off these large members," adds Mr Craig.

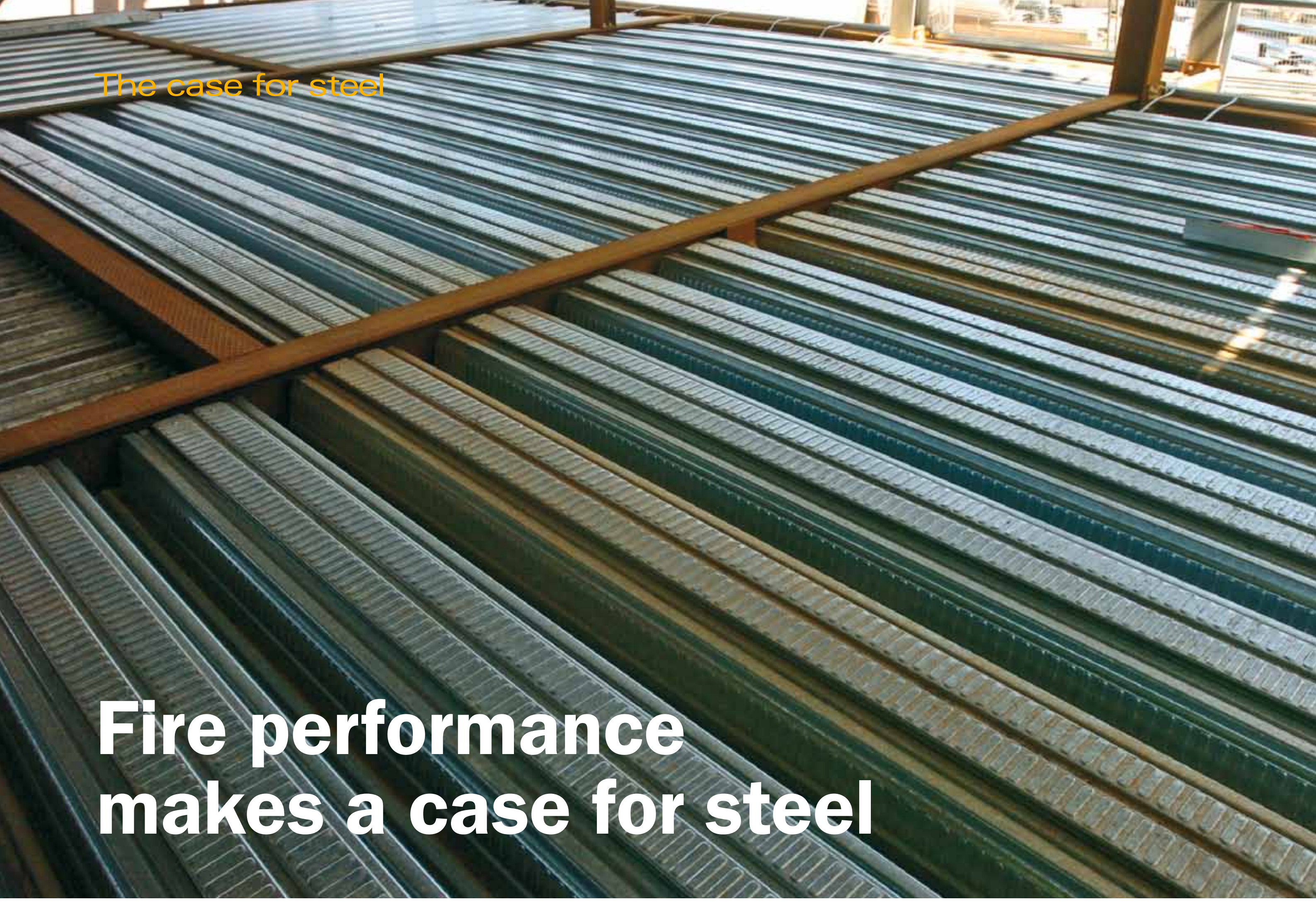
The ring of Y-columns needed a 100t mobile crane, as each of these columns, which were brought to site as complete pieces, weighed around 5.5t.

"We started with the Y-column at the 12 O'Clock position," explains Mr Craig. "Holding this in position with a crane, we then erected an adjacent column with another crane and tied them together with a beam."

Once the first two columns were up Fisher was then able to complete the entire ring of columns, by tying them into adjacent members.

This series of Y-shaped feature columns are connected to a horizontal truss, or steel diagrid, which goes around the circular structure. A series of these diagrids form the bowl shape which is fully glazed.

The node points on each diagrid has a total of six beams connecting to each other. "Accuracy was key for this part of the steel fabrication, because if one node was out the entire 'pod' wouldn't have fitted together," sums up Mr Craig.



Fire performance makes a case for steel

The latest in our Case for Steel series highlights that thanks to a long term, comprehensive research, more is know about how steel performs in fires than any other construction material.

Above: Slimdek flooring can achieve 60 minutes fire resistance without additional applied protection.

Thanks to extensive, long term research more is known about how steel framed buildings will behave in fires than about the fire performance of any other construction material. Structural designers have begun asking questions about the performance of other materials in fire, which are relatively under-researched – for example, concrete has never been large scale fire tested and major doubts have recently been raised about the understanding of the extent and speed of concrete spalling.

The steel sector's commitment to establishing the facts about steel in fires means there are no such worries facing the design community over steel frames. The steel sector has invested considerable resources into understanding how structural steel components respond in fires, so that designers can engineer in the confidence that steel is a safe option.

Steel structures dominate the multi storey buildings market, reflecting the fact that a fire protected steel solution is cheaper than any alternatives, and comes with the confidence of knowing just how a steel structure will stand up to the stresses imposed by fire. Thanks to full scale testing at the BRE's Cardington facility which addressed the behaviour of complete structures in fire, straightforward design approaches have been developed that reduce the extent of fire protection needed. This and much other research, whose results have been freely shared with the design community, provide reassurance that the available steel solutions are technically sound.

The steel sector has invested considerable resources into understanding how structural steel components respond in fires.

Reliable and economic solutions

Steel has been proven to provide a reliable and economic solution, whether protected by any of the wide range of proven protection materials, or left unprotected thanks to advances in structural analysis techniques (see box on structural fire engineering).

The full-scale testing mentioned above has addressed the behaviour of complete structures, and led to advanced design approaches using sophisticated analysis techniques which reduce the extent of fire protection. Simple methods are also available for the analysis of composite metal deck construction which can lead to the elimination of fire protection on mozst secondary beams.

Development of a competitive and efficient structural fire protection industry within the UK has encouraged further commitment to research and development within the steel sector, so specifiers can take advantage of greater choice at lower cost than anywhere else in the world.

Offsite breakthrough

The development of offsite application of

Above: Tests on intumescent coatings have generated product specific performance data, which has been used on projects such as the Royal Shakespeare Company's theatre at Stratford upon Avon.

Below: The Dublin O_2 project extensively used offsite application of intumescent coating.

intumescent coatings has been a breakthrough for the steel construction sector. Offsite application has a number of advantages including reducing construction times; improvements in site safety; speedier access to site for follow-on trades; improved quality control and reduced weather sensitivity. Most long span and cellular construction uses offsite application, as does over half the steel framed commercial construction in the south-east of England.

Not all steel requires fire protection and construction methods have been developed requiring no fire protection. The most successful of these has been Slimdek and Slimflor, pre-engineered shallow construction flooring systems, which can be designed to achieve 60 minutes fire resistance without additional applied protection. If normal downstand composite beams are adopted, simple design guidance is available that can eliminate fire protection from 30% of the secondary beams.

A new British Standard, BS 9999, will be an alternative to the Approved Document B, and will be a source of information and guidance on fire precautions in buildings. Structural fire precautions in this standard will vary from those in the Approved Document, sometimes higher and sometimes lower. However, it will see a significant increase in the number of buildings requiring only 30 minutes fire resistance. In many cases it is possible to design structural steelwork to achieve 30 minutes fire resistance without additional fire protection, by increasing the weight of steel sections or substituting a higher grade of steel.

Protected steel solutions are easily inspected and tested.

A good example of how the steel sector's commitment to research benefits designers and developers is the work carried out on long span beams with openings, which has led to an in depth understanding of behaviour at elevated temperatures. Subsequent developments and thorough testing on a number of intumescent coatings has generated reliable product-specific performance data.

Protected steel solutions are easily inspected and tested, compared to the difficulties associated with inspection and testing of concrete construction on site.

Wealth of test data supports structural analysis

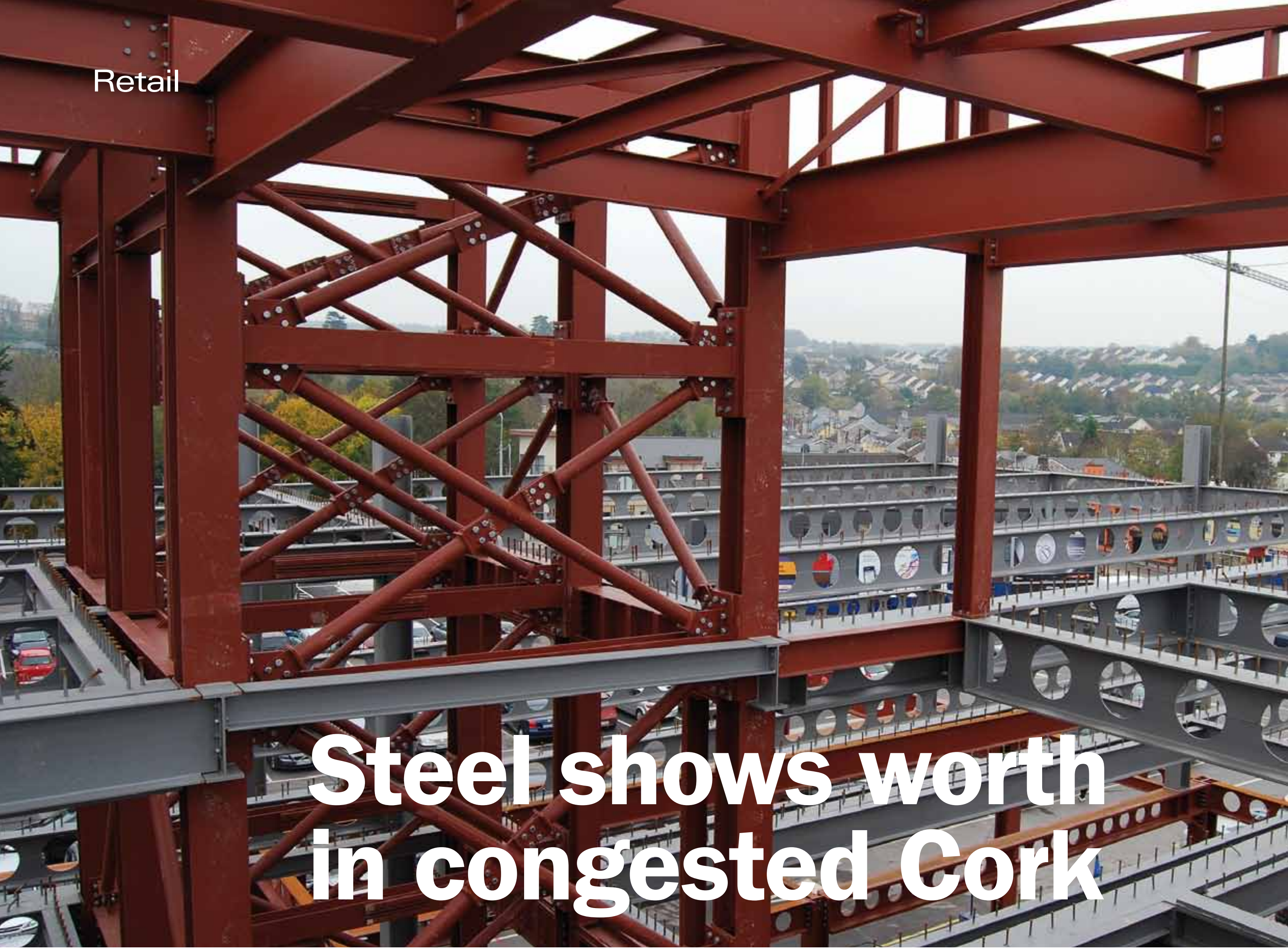
Structural Fire Engineering (SFE) is the name given to a new generation of finite element frame analysis based techniques that allow more efficient fire engineering of structures. SFE has been developed using the results of the extensive testing carried out on how steel behaves in fires over many years.

It means that fire protection to most secondary steelwork can be dispensed with while maintaining a building's ability to perform in line with stringent codes. This analysis can also pinpoint where in a structure additional protection might be added to enhance fire performance.

Architects have seized on the potential of SFE to enhance their freedom to fully express their design ideas, eliminating the need for painted protection for example in areas that they would rather used exposed steelwork for aesthetic reasons. The UK has taken a world lead in development of these techniques and several landmark buildings taking advantage of what SFE has to offer have already been built, saving resources, and time and money for developers.

Designers say SFE is a more rational way of ensuring fire-safe designs than the old prescriptive way of ensuring safety for the time demanded by Building Regulations. It considers the actual loads that fire imposes on structural members, taking account of any shielding applied and considering secondary structural actions.

Alternative load paths are analysed, allowing confident predictions of how the building will behave in a real fire. The traditional approach is based on standard fire tests that do not necessarily reflect accurately what happens in fires; some of the tests relied on for concrete for example are up to 70 years old. Since steel has been extensively and recently tested, there is a wealth of accurate and contemporary data available to inform this sort of structural analysis.



Steel shows worth in congested Cork

FACT FILE
Douglas Village Shopping Centre, Cork
Main client: *Shipton Group*
Architect: *Wilson Architecture*
Main contractor: *Bowen Construction*
Structural engineer: *Arup Consulting Engineers*
Steelwork contractor: *Walter Watson*
Steel tonnage: *5,000t*

A large steel framed shopping centre extension is being constructed on the outskirts of Cork. Martin Cooper reports on how 5,000t of steel has been delivered and erected on a site surrounded by shoppers and their vehicles.

Building a new shopping centre can be a time consuming operation and one which demands a whole host of criteria to be planned well in advance. Constructing a new shopping centre adjacent to an existing mall, one which is surrounded by car parks and busy roads can only exacerbate the workload.

This is precisely the challenge that steelwork contractor Walter Watson has had to overcome while erecting 5,000t of steelwork at the second oldest shopping centre in Ireland, Douglas Village Shopping Centre in Cork.

A new ground level mall, containing a Tesco anchor store with a mezzanine floor, topped with three levels of car parking is being constructed as part of the overall redevelopment of the existing shopping centre, which has remained open throughout the building work.

"We are actually putting the steelwork up on the existing centre's ground level car park," explains Trevor Irvine, General Manager Structural Division of Walter Watson. "The old car park has to remain open throughout, but as our steelwork advances it is getting more confined."

Working around shoppers and their cars is a tricky proposition and steel deliveries have had to be timed so they are delivered and off-loaded outside normal working hours, and then erected that day, as lay down areas are almost non-existent.

The project developer has had to guarantee a minimum number of car parking spaces during the construction work and to facilitate this the new multi-storey car park was partially opened in November, this then allowed steel erection to advance further into the old car park.

Prior to steelwork going up, the old car park was piled with concrete bases and bolts installed for the future steelwork. These foundations were then asphalted over to recreate parking areas.

Above: Cellular beams will allow more light into the large car park, especially at night.

Above: Braced cores provide the stability for the extension.

Unusually, cellular beams were specified for the light and airy atmosphere they will create in the car park.

Left: The project is surrounded by roads and an existing car park.

"The asphalt is dug up to expose the foundations immediately prior to steel erection," explains Mr Irvine.

Working in a live environment and having to keep enough parking spaces available for shoppers are just two of the challenges associated with the job, says James Duggan, Associate Director and Project Manager for Arup. "As well as piling into difficult limestone ground conditions we also had to divert two rivers, with new culverts, which ran right across the site."

The shopping centre's extension is L-shaped and abuts and joins up to the existing mall along two elevations. Steel erection began at the car park entrance - which is half way along the longest elevation - and then advanced in two opposite directions.

This work also included installing the car park ramps from ground floor level to the car park's first floor level. The ramps are steel formed and are a spiral scissor configuration.

They are constructed with box sections which were installed with stubs and crash barriers already attached and once in place they were then infilled with cross member beams.

There are two helical ramps, one for each direction," explains Mr Duggan. "They are a complicated shape and could not have been designed without the aid of a 3D computer design package."

The steelwork for the ground floor level of the extension (retail) is based around a uniform 16m x 7.5m grid pattern, except for the Tesco anchor store which required its own varying grid pattern. The entire floor has a 6m floor to ceiling height and this has allowed Tesco, which takes up approximately half of the ground floor footprint, to have an additional mezzanine level installed. A series of large plate girder transfer structures above the Tesco store and ramp allowed the transition to occur between the varying grids.

Walter Watson began steel erection in August 2008 and completed its work during December. The company had two 50t capacity mobile cranes on site as well six cherrypickers.

"Initially we were erecting 100t of steel a day, which is four truck loads," says Mr Irvine. "However, as the steel frame began to cover large areas of the existing car park our programme slowed down sightly as we could only erect steel at the rate that the old car park was given over to us."

Above the retail level the three floors of car parking are also based around a 16m x 7.5m grid pattern, with a 5.6m cantilever above the existing mall. A central row of columns in the car park, consisting of 356 x 287 members, take the back span loading from the 22m long Westok beams.

"Erecting a cantilever over a functioning shopping centre required careful planning and erection," says Mr Duggan.

Throughout the project more than 2,000t of Westok beams, painted white, have been used for all floors. Unusually, cellular beams were specified for the majority of the project, not for their service holes, but for the light and airy atmosphere they will create in the car park.

The car park has a relatively low head height and the beams will visually open up the space. This was considered very important so that users are not intimidated particularly at night.

"Services will run through the beams at the retail level, but the thinking behind this design for the carpark was that holes in the Westok beams will allow natural light to penetrate through them and they allow for greater dispersion of artificial light at night. Plus, the long spans obviously mean fewer columns casting shadows," explains Mr Irvine.

Stability for the entire extension is derived from six steel braced cores containing lifts and stairs and moment frame connections on the cantilever. Heavy tubular bracing has been used as a feature element along one elevation, while Walter Watson has also erected all secondary steelwork along the two main elevations which will have rainscreen cladding attached to it.

Also included in the project is a new local public library which is attached to the lower end of the L-shape. This is a steel framed two storey structure which shares columns with the rest of the extension.

Keeping the shopping centre's visitors happy with enough parking spaces aside, the construction team are on schedule and the redevelopment is due to open in mid-2009.

Briar Hill Primary School, Northampton
Jessons CofE Primary School, Dudley
Holycross High School, Wishaw
Mossley Primary School, Co Antrim
Queen Margaret University College, Musselbrough
Sacred Heart High School (sports hall)
Bridge Academy, Hackney, London
Cannon Sharpes CofE Primary School, Wigan
Hobmoor School, Birmingham
Newstevenston Primary School, Motherwell
Sundridge Primary School, Kingstanding
Anglia Polytechnic University, Chelmsford
Bulwell Academy, Nottingham
CETL Entrance, Univeristy of Northumbria
Magee College, Derry
Edlington School, Doncaster
Leaney Primary School, Ballymoney
Chapelhall Primary School, Airdrie
Yewlands School, Sheffield
Hinde House, Primary School, Sheffield
Tresham Institute, Kettering
Failsworth School, Manchester

Unity Academy
Open University, Milton Keynes
Whitgift School, Croydon
Clowne Secondary School, Clowne
Greenbank High School, Southport
Project Scan, Manchester University
Shiremoor Middle School
Willesden Leisure Centre, London
Northburn School
Hackney School, London
University of Warwick, Warwick
Camphill Primary School, Ballymena
Thrybergh School, Rotherham
Old Hall Secondary School, Rotherham
Richard Pates School, Cheltenham
Soundwell Technical College, Bristol
Guildford High School for Girls, Guildford
Tong High School, Bradford
Hunsbury Park Primary School Extension, Northampton
Bellinge Primary School, Northampton

Steelwork starts at ground level and is based around a large 9m x 16m grid.

FACT FILE
29 Wellington Street, Glasgow
Main client: BAM Properties
Architect: 3D Reid
Main contractor: BAM Construction
Structural engineer: BAM Design
Steelwork contractor: BHC
Steel tonnage: 1,100t

Cantilevered for success

A new commercial development in Glasgow has been highly engineered to provide both long internal spans and significant elevation cantilevers, reports Martin Cooper.

The credit crunch may be biting hard in some construction sectors - most notably the residential and commercial markets - but in Glasgow there are still a number of high profile jobs on the go, judging by the number of tower cranes visible across the city's skyline.

One of the most visible projects is a new 10-storey office development rising up on the plot of 29 Wellington Street in the city centre. This steel framed building is replacing a concrete framed structure which was built in the late 1960s, although the new build now includes a one level basement car park.

BAM Construction in its role as management contractor has been on site since mid-2007 and began by demolishing the original building. Once this was completed a series of 12m deep cantilevering permanent exposed sheet piles were installed around the site's perimeter, in lieu of contiguous or secant bored piles as suggested by BAM Design.

"This saved weeks of construction time when compared with the alternatives," explains John Keys, BAM Construction's Project Manager. "This greatly facilitated the basement excavation and therefore steelwork erection could commence earlier."

The original architectural concept was based on a standard 9m x 8m central column grid. However, BAM Design suggested losing a line of columns and this resulted in a far more desirable 9m x 16m grid pattern.

This large grid pattern is based around four large 356 x 406 x 634 columns, positioned around 3.5m from one elevation, which also form part of a four-bay full building height moment frame. These columns are 8.9t each and extend from ground floor all the way to roof level. They were installed in three sections: 2 x 13m long columns and then one 7m long member for the eighth floor to tenth floor phase. The column splices were designed by steelwork contractor BHC, based on BAM Design's connection concept featuring countersunk bolt heads, maximising net lettable area.

Structurally one of the main features of the building are its feature cantilevers, one at 3.4m and the other reaching a maximum length of 4.4m. To control the end displacement, the 16m back span beams were designed as continuous non-composite with regards to strength, while deriving benefit from composite action with regards to deflection.

Above: The tight and confined city centre site.
Below: Feature tubular bracing.
Bottom: Impression of the completed building.

"These cantilevers support a unitised glazing system, which stipulates highly onerous deflection criteria of less than 10mm both horizontally and laterally," explains Mohammad Ziauddin, BAM Design Project Engineer. "Furthermore, the building is designed for multiple occupancy, which means that the cantilevers are subject to movement up or down relative to the floor above and below."

Westok beams ranging from 480mm deep to 580mm deep have been used for the long internal spans and cantilevers. This not only provided the benefits of weight efficiency gains and complimentary pre-cambering, but also an integrated distribution of lateral services within the structural zone, giving added flexibility for future multi-tenancy.

"There was no waiting around for the concrete cores to be completed before steelwork erection could begin."

Lateral stability of the steel framed structure is achieved by the use of both steel cross bracing in stair/lift cores as well as moment frames. One elevation has cross bracing comprising 219mm diameter tubular sections in full view as an architectural feature. The lateral forces are transferred to the vertical bracing systems via the concrete floor slabs by a diaphragm action. The horizontal displacement of the building has major significance to the design of the glazing system, due to the potential for racking under wind loading.

"Many projects of this type would have gone with concrete shear walls, but we decided on steel cross braced walls which are easier to erect and much quicker, as they go up with the main steel frame," adds Mr Ziauddin. "There was no waiting around for the concrete cores to be completed before steelwork erection could begin."

The entire superstructure was modelled by BAM Design in CSC's Fastrak Building Designer with lateral loads such as NHF and wind being applied automatically. The Westok beams were also modelled in Fastrak Building Designer but designed using SCI's specialist Cellbeam software. All floor plates are based on the typical second floor level which features the largest floor area. Other floors are simple variations on this level, featuring cut-outs and recesses.

For the steel erection BHC's initial phase was the basement to the second floor. Once this was completed and the floors decked, the second floor slab was cast and this allowed other trades to carry on working below while BHC put its cherrypickers on the slab to erect the floors up to level five.

This methodology was then repeated for another two phases with BHC erecting steelwork from fifth floor to eighth floor, and then finally working off of the eighth floor slab to erect floors nine and ten.

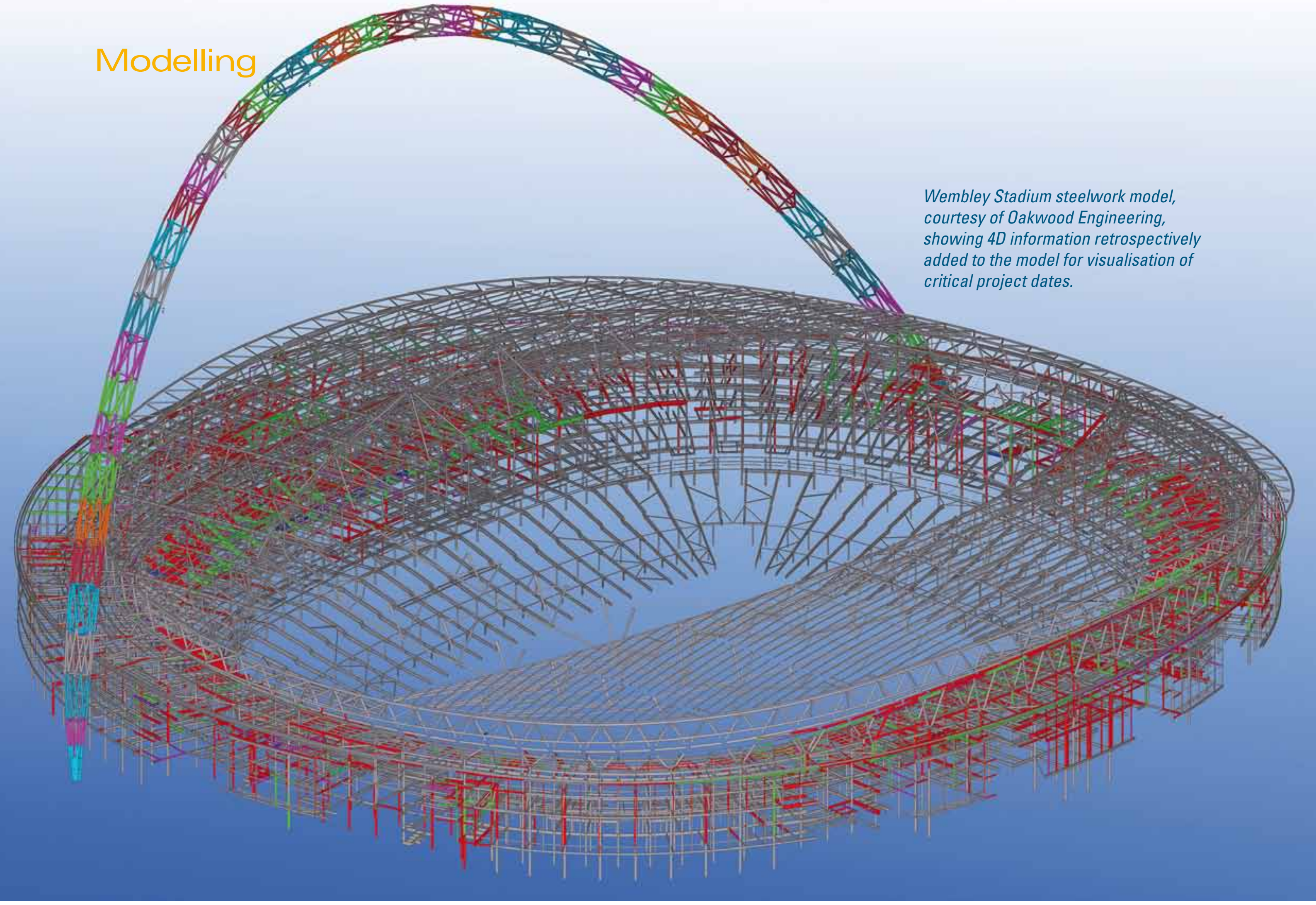
Working in this way the entire construction team was able to erect and fit out the floors in a quick manner. Another consideration, and one which surfaces on many inner projects was the lack of available space for on-site materials storage.

"We had to bring steel to site in 15t loads and lift them immediately to the floor we were erecting off," explains Jim MacDonald, BHC Project Manager. "In this way we didn't overload the on-site tower crane's capacity and we were able to erect each load as it came in."

"It was all down to planning the logistics of the job well ahead as a team," sums up Mr MacDonald.

Keeping ahead of the game and thus completing the project on time are all key reasons why the design team says they chose their methodology.

29 Wellington Street is due for completion by the third quarter of 2009.



Wembley Stadium steelwork model, courtesy of Oakwood Engineering, showing 4D information retrospectively added to the model for visualisation of critical project dates.

Modelling for project success

Developments in Building Information Modelling have moved on in leaps and bounds in recent times. Andrew Bellerby, Managing Director of Tekla (UK), explains how structural models provide added value to construction projects.

The structural steel segment has always been ahead of the main building and construction industry players by adopting 3D modelling technology. Even though we are approaching twenty-years of 3D product modelling, many companies still only use the model data for the production of 2D fabrication drawings; for feeding their MIS systems and for producing NC data. However, many companies are realising that the potential usage of the structural model data is actually far greater.

Companies are now starting to wake-up to the power of the rich data within the structural model and where else it can be used within their internal processes. They also are discovering how structural models allow them to provide additional added value to the projects they are working on. While Building Information Modelling (BIM) as a practise and a process is becoming more commonplace, the structural model, provided by the steelwork contractor, becomes the normal "as-built" project model, as it contains the exact quantities and precise information required for successful completion of the project and so it has become one of the most vital parts on every project.

Who can use the data within the structural model and how?

We have already seen CNC machine manufacturers such as Ficep, with their partner Steel Projects, making use of the Tekla Open API provided with the Tekla Structures software. The application programming interface was utilised to develop a link to extract information from the model to drive their scribing tools and start to move the steelwork industry towards a potentially paper-free workshop.

Another example would be Richard Lees Steel Decking, who have developed a solution for placing the structural decking into the structural model. This allows them to take all the connection materials into account, which they would not previously have easy access to. Other key benefits include being able to "fly" under the deck and identify areas where additional supports are required. The decking sheets can now be downloaded to a laser cutting machine directly from the model, moving the cutting of the deck offsite.

More recently, a bi-directional link between Tekla Structures and Leighs Paints' FIRETEX software has been developed to improve the somewhat time consuming task of fire protection paint calculations. The link will enable information to be passed between the software packages allowing the user to transfer geometry and information regarding the steel structure with speed and accuracy at the click of a button. The FIRETEX software then calculates the required coating thickness based on the information from the model and the required fire ratings, these thicknesses can then be inserted directly back into the model, saving valuable time, providing more accurate paint volumes, and reducing the possibility of errors within the current workflow.

RFID Technology in Construction

The use of bar-coding in manufacturing in the construction industry has never really taken off in a big way, limited often on the shop floor by paint, grime and damage to the bar code stickers themselves. Radio Frequency Identification (RFID) certainly has the potential to take this type of technology to the next level, providing status information of parts, not only in fabrication workshops, but also on the construction site, as well as providing other advantageous information.

RFID technology can give "real time" status information at all stages of the manufacturing and erection processes. Vela Systems (www.velasystems.com) have been working with Tekla to synchronise the status information provided through their RFID software with the Tekla Structures building information model. At each stage of the fabrication, despatch, shipping and erection processes the tags can be read either by scanning manually or by automatic readers positioned at strategic locations.

This information can then be uploaded to a web server at regular intervals. The uploaded data on the web server is synchronised with the Tekla model to provide a visual representation of the 4D (time) project status. This ensures critical aspects of supply chain management and co-ordination becoming centralised in the model. Powerful filtering and visualisation tools in the Tekla software allow the running of simulations and analysing "what if" scenarios to minimise risk and take advantage of the data previously not so readily available. The potential time-savings on projects are huge.

Data Storage by CE Marking

As RFID technology evolves it offers many more options for data storage that could be tagged to the constructed parts for ongoing facilities management. CE marking for the steelwork industry is legislation that we all need to deal with, and the RFID technology certainly opens up new options for storage of associated information.

While many companies will adopt a method of adding the CE marks to drawings and other documents, there is no reason why design or procurement information for example could not reside in the building information model and also on the individual parts by means of an RFID sticker, which of course would still be able to be read even if the stickers are painted over.

Above: Complicated steelwork designs, such as Wembley Stadium, have been made easier thanks to 3D modelling packages.

Tekla with Trimble on Site

Site planning, design co-ordination, and crane positioning are already utilising the 3D interface and the 4D schedule that is associated with the model parts. Development between Tekla and Trimble (www.trimble.com) now takes the Tekla model information into the Trimble Robotic Total Station to simplify the surveying and layout tasks. Tools have been developed so that a survey path and control points are defined in the model. This co-ordination and other information can be exported to the Robotic Total Station, along with a DXF file of the arrangement drawing, visually showing the same information.

The site layout can then be carried out by one person as the information from the Total station is transmitted by radio, the control points are shot, the site features measured, and all project set out points created. This gives an accurate as-built vs. as-designed survey with the information brought back into the model for reporting and tracking. Any re-work is minimised and potential error prone manual calculations are eliminated.

Above: Trimble Total Station displaying the drawing and survey control points.

Conclusions

Any streamlining of existing practises and processes will help minimise costs, which is essential for every company and for every project in the currently economic climate. Making better use of the rich data in the structural model is certainly one way of ensuring that this will happen. The building information model can empower and improve many of the processes currently executed, minimising replication of data input and providing accurate information to help manage projects more effectively and therefore help reduce risk and costs.

Below: The use of 3D models, on projects such as More London plot 7, was critical for the completion of offsite cutting of metal decking.

Flat pack modular construction

An IKEA furniture store and car park in Dublin contains long spans with heavy floor planks requiring the structure to be erected in box-like modules to allow the lifting process to succeed.

Above: Various store functions required two different steel grid patterns.

Swedish furniture giant IKEA is entering the Irish market with the construction of its first store in the Republic at Ballymun, County Dublin.

The steel framed store, which is due to open later this year, will have more than 1,500 car parking spaces and carry almost 10,000 products showcased in over 50 fully furnished room layouts. In house features will also include a number of ancillary facilities such as a 500 seat restaurant, a bistro, a cafe and a Swedish food hall.

Atlas Ward Structures fabricated and erected 2,700t of structural steelwork for the building which has an overall floorspace of more than 53,000m^2. Its scope of works also included the provision and installation of floor planks, staircases, precast walls, floor decking and intumescent fire protection.

Overall, the structure comprises a ground floor undercroft car park with two floors above forming the main store. At ground level (car park) the steelwork is based around a 16m x 8m grid pattern.

At first floor level, the building divides into a warehouse and storage area, which is two levels high and covers approximately 40% of the footprint, while the remainder of the building features a two level retail zone with a market hall on the first floor and a showroom zone on the second floor.

"Because of the different store functions the grid patterns alter at first floor level."

FACT FILE
IKEA Dublin
Main client: IKEA Ireland
Main contractor: RG Group
Architect: OMS (Dublin)
Structural engineer: Blyth & Blyth Consulting Engineers
Steelwork contractor: Atlas Ward Structures
Steel tonnage: 2,700t

Above: A modular construction method was used because of the structure's large footprint.

"Because of the different store functions the grid patterns alter at first floor level," explains David Fiddes, Project Engineer for Blyth & Blyth. "For the warehouse it was important to have a large two-storey high open plan area and so the grid is a larger 16m x 24m pattern."

The adjacent first floor market hall in contrast stays on a 16m x 8m grid. However, on the second floor, this changes, for the showroom area, to the larger 16m x 24m grid.

"So at roof level there are a series of trusses, some spanning 24m and others spanning 16m," adds Mr Fiddes.

Because of the long spans and the high loadings which will be imposed on the frame, especially on the warehouse zone's floor, large 914 x 419 x 388 beam sections were specified. These beams each weighed approximately 6t and carry planks which are 8m long and 400mm deep for the warehouse and 200mm deep elsewhere. In order to achieve an efficient and cost effective design all the beams were designed to act compositely with the precast floor units.

"Because we were responsible for installing the planks along with the steelwork, we had to erect the structure in complete boxes, with each section from floor to roof, including the purlins finished before we moved onto the next zone," explains Bill Armstrong, Atlas Ward's Project Manager. "This was the only way we could have got the heavy planks and beams into place with mobile cranes. The building is just too big to lift sections into place from the perimeter to the middle without using extremely large cranes."

Seaside college connection

Above: Steelwork starts at podium level, above a large underground car park.

Strong coastal winds and an innovative flooring system all contributed to the need for bespoke steelwork connections at a college project in Hastings.

The educational sector has been buoyant of late, with new schools, university buildings and colleges all being built across the UK. One of the largest on-going projects in the south of England is the work being undertaken at Hastings, which will provide two new state-of-the-art college buildings for the Sussex Coast College.

The major part of this project is situated adjacent to the town's railway station and known as Station Plaza. Here main contractor Laing O'Rourke is constructing a six-storey steel framed college building which will provide 20,000m^2 of new learning space.

Overall, the Station Plaza scheme also incorporates four other buildings - three residential blocks containing 103 apartments and a primary care centre - all of which sit on one large concrete podium containing a 324 space underground car park.

Formerly the site was occupied by the railway station's old car park and prior to steelwork erection beginning in March 2008 a large earthmoving operation was required to excavate the underground car park and podium.

The steel framed college building occupies approximately just over half of the podium's footprint and steel is mostly based around a 7m x 8m grid pattern. The structure's entrance area is predominantly a curved facade, constructed with deep curved steel box sections, while the other three elevations are straight. The entire building wraps around an inner atrium which is glazed at roof level.

"We've had to sequence the steelwork with the concrete," explains Paul Westbrook, Erections Manager for steelwork contractor Graham Wood Structural. "We have four elevations and each one was a phase. We erected one phase up to third level and then moved onto the next, while the concreting team worked on the previous phase."

Graham Wood Structural completed four phases and then returned to phase one to erect steelwork from third floor up to roof level. This allowed the sequence to start over again with the concreting team again following on behind.

The reasoning behind this sequencing was the installation of the project's 8m long concrete planks. "They are too long to be lifted through six floors of steelwork," says Mr Westbrook.

The concrete planks in question are Tarmac's TermoDeck and they had an important bearing on the steelwork design. TermoDeck planks are a fan assisted heating, cooling and ventilating system. They use the high thermal mass of structural, hollowcore slabs to warm or cool fresh air before it is distributed into room spaces of the building.

Controlled by the building's management system, a supply of air passes through holes in the slab very slowly, giving plenty of time for passive heat exchange between the air and the slabs. To accommodate these innovative and high efficiency planks, shallow but heavy beams were required.

"We had to keep the floor void slim while the concrete planks sat at the same level as the steel beams, instead of on top of them as would normally be the case," says Steve Forder, Project Engineer for Gifford. "Structurally we had to form a flat soffit so the planks could be dropped into place."

The building's services will actually run along the top of the planks within the structural void. To allow this the design specified shallow, but heavier sections than normal. Gifford provided all the relevant loadings for these beams to Graham Wood and this then allowed them to design bespoke connections.

"As well as the connections we also designed

Below: Bracing is located in steel cores.

the beams to have a plate welded to the bottom flange which the planks then sit on," explains Chris Barnfather, Graham Wood's Chief Engineer. "The majority of floor beams also had pre-drilled holes for the plank's rebars."

Hastings is a coastal town and constructing close to the sea brings with it a whole set of unique challenges, not least the wind. The new college building is not only a stone's throw from the seafront, but also in a valley which exposes the structure to winds from two directions.

"Wind loadings played a critical role in the steel design of the building," says Mr Forder. "Because of the site's exposed location there are potentially some big uplifts on the trusses which span the atrium."

"Wind loadings played a critical role in the steel design of the building"

There are four trusses spanning the structure's central atrium; because the building and atrium are slightly tapered, the longest truss is 21m while the shortest at the opposite end is 16m long.

Each roof truss weighs 2.5t and is 2m deep. "They were all brought to site in one piece and lifted into position by tower crane," explains Mr Westbrook.

To negate any uplift the long span trusses have some deep tie connections. The building was also designed with high torsional loads, particularly around the perimeter, and this also required deep tie connections.

Stability for the structure is provided by braced bays, which are located within stairwell and lift shafts. The design team were faced with the problem of limited locations for putting the bracing, and as the majority of the elevations have windows at regular spacings, the ideal place was within the steel cores.

Summing up the project, Sue Middlehurst, Principal of Hastings College, adds: "With academic and vocational facilities for 2,500 students, our new college buildings will help transform further education in the area. This iconic and inspirational building will also help to mark us out as a leading provider of post-16 education."

The college is expected to open by the end of 2009.

Above: The college will transform the area around Hastings Railway Station.

Below: Shallow heavy beams were required to facilitate the installation of the long TermoDeck planks.

FACT FILE
Sussex Coast College, Hastings
Main client: John Laing
Architect: SMC Charter Architects
Main contractor: Laing O'Rourke
Structural engineer: Gifford
Steelwork contractor: Graham Wood Structural
Steel tonnage: 1,730t
Project value: £75M

Choice of lateral-torsional buckling curves – according to Eurocode 3 and the UK National Annex

Alastair Hughes of the SCI explains some of the subtleties of the interaction between the UK National Annex and the Eurocode itself.

Introduction

Lateral-torsional buckling (LTB) is the instability phenomenon which is liable to limit the bending resistance of a beam whose compression flange is unrestrained, intermittently restrained or flexibly restrained. What distinguishes it from regular strut buckling is that the tension flange, which naturally tends to remain straight, exerts some control over the wayward compression flange to which it is attached. If the compression flange is to buckle laterally, and the tension flange is not, the beam is forced to twist – hence the description 'lateral-torsional'. All conventional sections and even some exceptionally slim and slender RHS are prone to LTB.

Eurocode 3, like BS5950, provides the designer with buckling curves from which a 'buckling resistance moment' can be derived. In Eurocode terms this is $M_{b,Rd}$ – b for buckling, R for resistance, d for design. Needless to say it is a major axis moment M_y. $M_{b,Rd}$ is the product of what the section's bending resistance would otherwise be, eg. $W_{pl} f_y$ for a class 1 or 2 section, and χ_{LT}, a reduction factor for LTB, which is the ordinate of the buckling curve. As with struts, the buckling curves plot (or, in BS 5950, tabulate) strength reduction against slenderness, but an important difference from BS 5950 is that the slenderness in Eurocode buckling curves is 'non-dimensional'. This is tautology, since all slendernesses are non-dimensional, but it is the term that Eurocode 3 has chosen. Eurocode 4 chose 'relative slenderness' and other authors have variously chosen 'reduced' or 'generalized' slenderness. What it actually means, in the LTB context, is given by the expression:

Non-dimensional slenderness (NDS) $\bar{\lambda}_{LT} = \sqrt{\dfrac{W_y f_y}{M_{cr}}}$

where $W_y f_y$ is, again, what the bending resistance would otherwise be, depending on the class of the section, and M_{cr} is what the buckling resistance would theoretically be if strength were limitless (but *E*-value same as steel). The Code itself is silent on the calculation of M_{cr}, regarding it as a matter for textbooks or NCCI (non-conflicting complementary information). Plenty of the latter is available and the subject has been covered in previous issues of NSC.

The advantage of the non-dimensional presentation is that separate curves are not needed for S275 and S355, nor for the stepwise reductions in yield strength at element thicknesses of (in UK) 16 and 40mm.

This article is concerned with the choice of curve for LTB once the NDS has been established.

What buckling curves allow for

Just as with struts, beams failing by LTB deform until the weak-direction moment acting on the flange, magnified by eccentricity, exceeds available resistance. There is interaction between stiffness and strength, because as soon as the extreme fibre yields the bending stiffness of the flange is eroded. This will depend on the residual stresses which result from cooling of the section after rolling or welding. Geometrical imperfections such as initial out-of-straightness also have an effect, and theoreticians have traditionally found it convenient to formulate buckling curves as if nothing else mattered, using a single 'equivalent' geometrical imperfection. Eurocode 3 'imperfection factors' of Table 6.3, each associated with a curve of the set (labelled **a** to **d** in order of severity) represent a continuation of this tradition. For practical purposes, however, the means by which the curves were generated is almost irrelevant; they might as well be regarded as empirical because the assignment of different curves to different sections is made by reference to test results. It is found that deeper-proportioned sections need to be treated more severely than shallow ones and the effects of residual stresses are more severe in welded sections than in rolled ones.

These differences are most pronounced over the middle part of the slenderness spectrum, the one occupied by most practical beams. At very high slenderness, where there is little influence of material strength, the curves tend to converge with each other (and with elastic theory). At very low slenderness, LTB tests indicate that a 'plateau' of $\chi_{LT} = 1$ extends as far as NDS = 0.4 or thereabouts. One of the differences between LTB and regular strut buckling is that for the latter the corresponding plateau only extends half as far.

A choice of two sets of buckling curves for LTB

Eurocode 3 offers the designer a choice, for I-sections at least, between two sets of curves. These are presented in clauses 6.3.2.2 and 6.3.2.3

respectively. Sharp-eyed readers will observe that the 6.3.2.2 set is identical to the strut curves of 6.3.1, save for the plateau extension granted in 6.3.2.2(4) which, incidentally, results in a cliff edge discontinuity at NDS = 0.4.

The alternative, and generally more productive, set of curves is on offer in 6.3.2.3 for rolled I-sections and equivalent welded I-sections. I-sections obviously includes H-sections, and the word 'equivalent' is interpreted to mean 'of similar dimensions', i e up to about 1 metre in height. But that interpretation hardly matters to UK designers, since the UK National Annex takes advantage of an opportunity to exercise national choice. It does so by resetting the parameters in the buckling curve formulation with the effect that for welded sections the curves of 6.3.2.3 now match those of 6.3.2.2 exactly, and they are denied the plateau extension (in either case). For a welded section, the only remaining advantage to 6.3.2.3 is the availability of a favourable modification factor in 6.3.2.3(2), discussed later.

More positively, the UK NA extends the scope of 6.3.2.3 beyond I-sections to include angles (for moments in the 'major principal plane'), all other hot-rolled sections and cold-formed hollow sections. So while choice is (virtually) taken away for welded sections, it is extended to other sections that are rolled.

Figure 1 compares all the buckling curves from clauses 6.3.2.2 and 6.3.2.3. These are the curves available to rolled sections in the UK.

Two traps for the unwary:

- The only thing the two curves named '**c**' have in common is the 'imperfection factor' used to derive them. Curve **c** of 6.3.2.3 lies well above its 6.3.2.2 namesake (and even exceeds curve **a** of 6.3.2.2 over parts of the slenderness range). It is a similar story for curves **b** and **d**. Curve **a** is not used in 6.3.2.3.
- This apparent advantage of choosing 6.3.2.3 is reduced, though mostly not eliminated, by the differences between Tables 6.4 and 6.5 which assign curves to sections. For example, for a UKC section the choice is between curve **a** of 6.3.2.2 and curve **b** of 6.3.2.3, as shown in Figure 2, and it will remain advantageous to opt for the latter. Similarly for most UKB sections curve **c** of 6.3.2.3 will be preferable to curve **b** of 6.3.2.2, as shown in Figure 3, but beware that the UK NA, with its replacement for Table 6.5, has penalized what we might describe as 'slimline' sections with *h/b* >3.1 (which includes several of the recent additions to the UKB range) by assigning them to curve **d** of 6.3.2.3. Depending on slenderness, it may be advantageous to choose curve **b** of 6.3.2.2 for these, as shown in Figure 4 (over page).

Another consequence of the UK NA's intervention to replace Table 6.5 is that distinctions are made between monosymmetric and doubly symmetric sections.

Monosymmetric rolled sections, such as Corus ASB, are allowed to use 6.3.2.3, but they too are relegated to curve **d**. However Table 6.4,

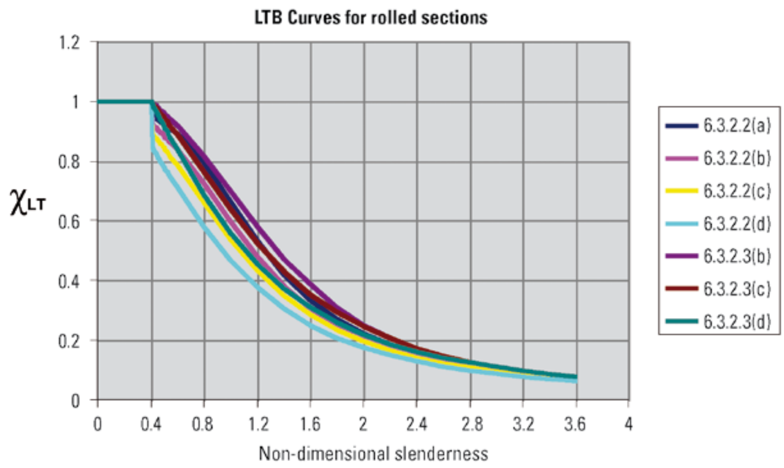


Figure 1. All seven LTB curves from EC3

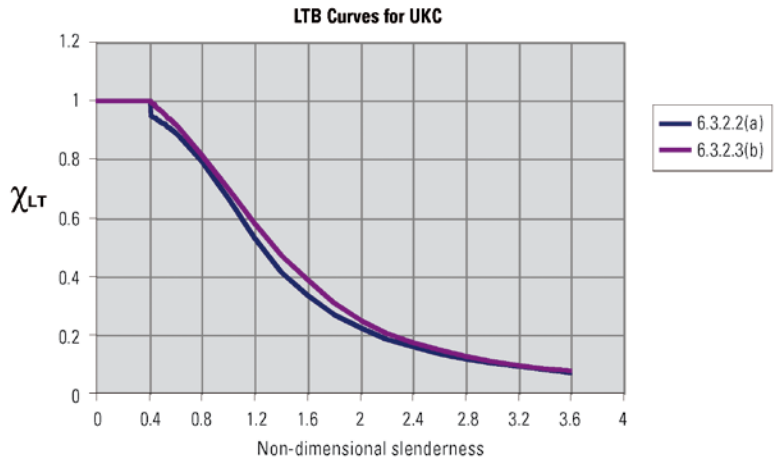


Figure 2 Choice of curve for UKC (h/b ≤ 2)

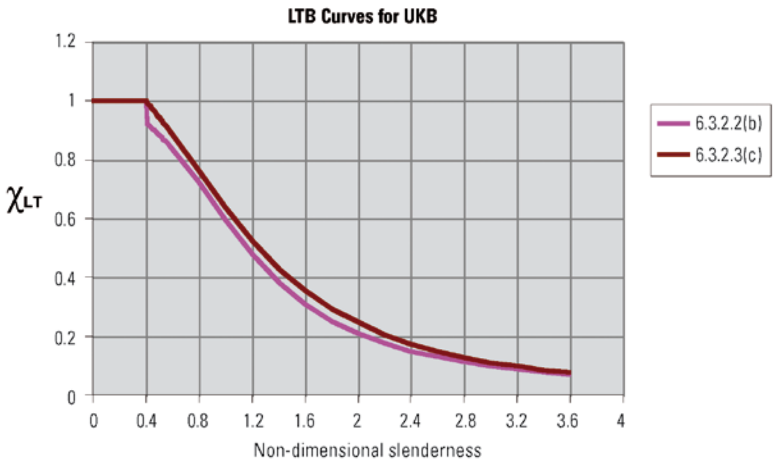


Figure 3 Choice of curve for most (but not all) UKB (2 < h/b ≤ 3.1)

unaltered by the NA, assigns a rolled I-section with *h/b* ≤ 2 to curve **a** of 6.3.2.2 which is likely to be advantageous, as shown in Figure 5 (over page). A welded lookalike, excluded from 6.3.2.3, would be assigned to curve **c** of 6.3.2.2.

Welded sections

As already noted, welded beams are relatively harshly treated by the UK NA, so it may become commercially important to consider whether sections such as SFB and Cellbeams could

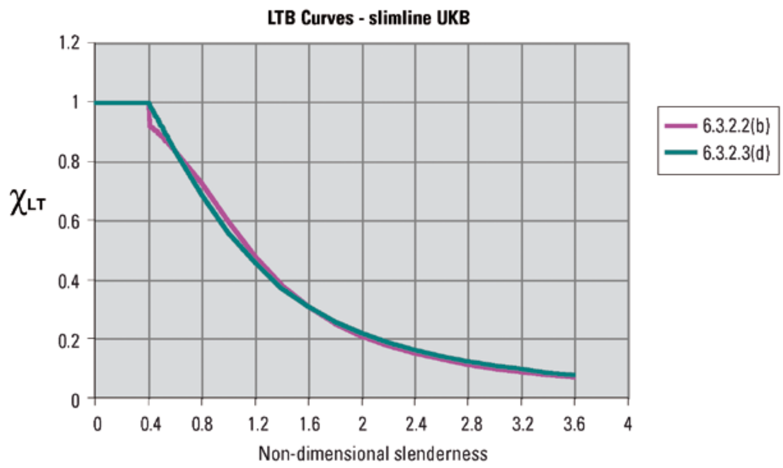


Figure 4 *Choice for 'slimline' (h/b > 3.1) UKB 1016x305, 610x178, 533x165*

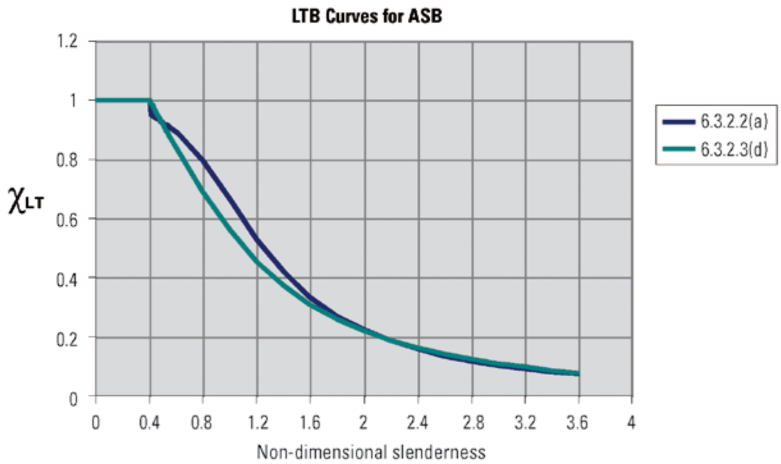


Figure 5 *Choice of curve for ASB*

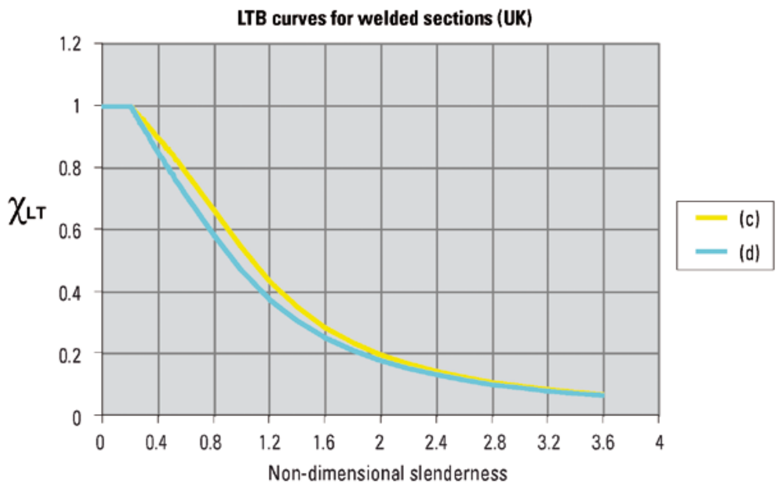


Figure 6 *Curves for welded sections (UK)*

receive honorary 'rolled' status for LTB purposes. Although these are fabricated by welding, it may be argued that the welds are distant enough from the compression flange not to impact the LTB resistance. For these and other out-of-the-ordinary sections, there may be potential for curve assignations to be upgraded if tests are undertaken to overcome the present paucity of data.

The curves for welded sections are shown in Figure 6. There is no choice; the higher curve **c** is for $h/b \leq 2$ and the lower curve d is for typical beam proportions. The UK NA's upper limit (of 3.1) to h/b for the use of curve **d** of 6.3.2.3 does not apply to 6.3.2.2, so its effect is a subtle one: purely to deny a slimline welded beam the use of the modification factor.

A word about the modification factor of 6.3.2.3(2)

This modification factor is to allow for the favourable effect of nonuniform moment, and is influenced by NDS. It can only increase χ_{LT} , so it could safely be ignored. Its favourable effect may not be all that great – a few % at most for a simply supported beam with UDL – but in other situations it can be more significant. Designers should not be perturbed by the fact that nonuniformity of moment may already have been taken into account in the assessment of M_{cr} – this second correction is perfectly in order (as will be a third, if an evaluation of the *k*-factors of expressions 6.61/62 is to follow). It may also be helpful to be reassured that what the UK NA has to say about the modification factor (in NA 2.18) is not in any way conflicting with what is in the Code, merely offering a more general formulation.

The effect of this modification factor could tip the balance in favour of 6.3.2.3 over 6.3.2.2 in a marginal case, because (whether by accident or design) it is not available to the latter.

Conclusion

While 6.3.2.3's buckling curves (which are specifically for LTB) will normally be more productive than those of 6.3.2.2 (which are, essentially, the strut curves and regarded as a safe lower bound) there are circumstances in which either the Code or the UK NA rules them out. There are also sections whose curve assignations by the Code and/or the NA have the effect that the reverse will, or (depending on slenderness) may, be true. If comparison is necessary to decide which is advantageous, it is not enough simply to look at the buckling curves, because of 6.3.2.3's χ_{LT} -enhancing modification factor.

Footnote

The Code's formulae for the lateral buckling curves are to be found in expressions 6.56 (for 6.3.2.2) and 6.57 (for 6.3.2.3), using imperfection factors from Table 6.3 in both cases. The UK NA endorses these recommended values, and the curve assignations of Table 6.4 for use with 6.3.2.2. However it exercises national choice in two ways where 6.3.2.3 is concerned. For welded sections only, it resets the parameters of expression 6.57 so as to make the curves identical to those of 6.3.2.2 (and the strut curves). One of these parameters is the plateau length. Because 6.3.2.2(4) obtains this from 6.3.2.3, the effect is to deny welded beams the plateau extension irrespective of clause allegiance. The second major intervention of the UK NA is its Table 6.5 substitute whose effects, on both rolled and welded sections, are described above.

40 Years Ago in

BUILDING WITH STEEL

Unusual television studio

The building illustrated is clad with 85 tons of sheet lead – chosen for its sound insulating qualities – colour a soft grey. The cantilever doubly curved roof is a steel space truss: three arches in high tensile steel span the building between two concrete piers. The arches have tapered wide flange cross sections which have a maximum depth of 27 in. at the apexes.

The steel space truss resists the roof deadload of a 4 in. thick lightweight concrete slab: this is cast on steel mesh and finishes flush with the top surface. Under live load the concrete roof and supporting space trusses act compositely.

Steel tubes – maximum diameter 8 in. – for extra heavy cross sections form the longitudinal, diagonal and edge members of the cantilever spans. Gusset plates at the connections of the tube resist shear stresses between truss and concrete deck, so ensuring composite action.

The building is in Marina City, Chicago, and was designed by Bernard Goldberg Associates, architect-engineers of that city. The unusual roof was designed by Hannskari Bandel, Severud Associates, New York.

New and Revised Codes & Standards

(from BSI Updates October and November 2008)

BRITISH STANDARDS

NA to BS EN 1994:-
UK National Annex to Eurocode 4. Design of composite steel and concrete structures

NA to BS EN 1994-1-1:2004
General rules and rules for buildings
No current standard is superseded

NA to BS EN 1994-1-2:2005
General rules. Structural fire design
No current standard is superseded

NA to BS EN 1998:-
UK National Annex to Eurocode 8. Design of structures for earthquake resistance

NA to BS EN 1998-1:2004
General rules, seismic actions and rules for buildings
No current standard is superseded

NA to BS EN 1998-4:2006
Silos, tanks and pipelines
No current standard is superseded

NA to BS EN 1998-5:2004
Foundations, retaining structures and geotechnical aspects
No current standard is superseded

NA to BS EN 1998-6:2005
Towers, masts and chimneys
No current standard is superseded

BRITISH STANDARDS REVIEWED AND CONFIRMED

BS 5080:-
Structural fixings in concrete and masonry

BS 5080-1:1993
Method of test for tensile loading

BS 5080-2:1986
Method for determination of resistance to loading in shear

BS 5950:-
Structural use of steelwork in building

BS 5950-8:2003
Code of practice for fire resistant design

BS 8100:-
Lattice towers and masts

BS 8100-2:1986
Guide to the background and use of Part 1 'Code of practice for loading'

BS 8100-3:1999
Code of practice for strength assessment of members of lattice towers and masts

BS 8100-4:1995
Code of practice for loading of guyed masts

DRAFT BRITISH STANDARDS FOR PUBLIC COMMENT

08/30167121 DC
BS EN ISO 14174 Welding consumables. Fluxes for submerged arc welding and electroslag welding. Classification

08/30167126 DC
BS EN ISO 14171 Welding consumables. Solid wire electrodes, tubular cored electrodes and electrode/flux combinations for submerged arc welding of non alloy and fine grain steels. Classification

08/30177295 DC
BS ISO 14341 Welding consumables. Wire electrodes and deposits for gas shielded metal arc welding of non alloy and fine grain steels. Classification

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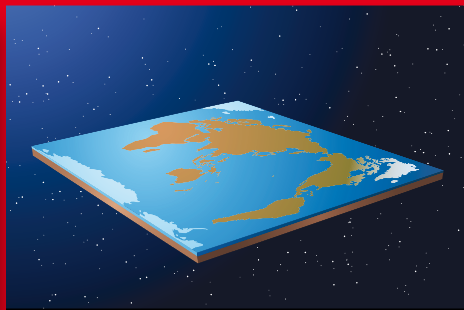

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AD 329
Dealing with connection design in a 3D frame analysis

For a structure modelled in a 3D frame analysis, the ends of every beam element have six degrees of freedom and hence there are six possible forces or moments that can be transferred through each connection. The default assumption of a normal 3D general frame analysis package (as opposed to a design model package used for whole building design) is that all degrees of freedom are constrained; then each connection transfers two shear forces (forces orthogonal to the member axis), two bending moments, a torsional moment (about the member axis), and an axial force. However, in many practical cases of building frames, the magnitudes of some of these forces and moments are very modest and can be neglected. Where this is the case, some of the constraints can be omitted and the following offers advice on modelling the connections in a 3D general frame analysis.

i) Ensure that the end restraints to beam elements reflect the behaviour of the connections. For example, a normal moment connection between a beam and a column flange has significant moment capacity and stiffness for bending in the plane of the beam and column but is weak out of plane. The model should reflect that behaviour and hence the ends of the beam element should be restrained about its major axis direction and pinned about its minor axis direction.

ii) If the presence of ‘pinned connections’ about the beam minor axis at the ends of beam elements causes instabilities in the global analysis model, provide end restraints and then consider whether the out of plane moments are small enough to be ignored. ‘Small’ is a question of judgment, based on the magnitude of the forces and the scale of the connection.

iii) Provide torsional restraints at both ends of a beam member, to avoid instability in the analysis model. Unless there are torsional loads on a beam, the resulting torsional moments will normally be sufficiently small that they can be ignored.

iv) In all cases, the design assumptions must be compatible with the physical details – and the practical connection details should be carefully considered before making assumptions in the design model.

If the frame analysis gives significant out of plane bending and torsional moments in a 3D analysis model the reasons should be carefully examined – it may be that an unstable part of the structure is being supported by twisting of a member and torsion on a connection, when the more appropriate approach would be to re-configure the structure.

Note that published connection design models only deal with major axis bending, shear and axial force. Configurations that give rise to significant minor axis effects or torsional effects will require more detailed design of the connections.

Further guidance is given in SCI publication P148 (*Modelling of steel structures for computer analysis*, 1995) and chapter 3 (Connection design programmes) of BCSA publication No 41/05 (*Steel details*).

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AD 330
Vibration of steel staircases

The Advisory Desk has received a number of queries asking for guidance on vibration of steel staircases. In fact, guidance is already given in several parts of SCI publication *Design of floors for vibration: A new approach (P354).* This AD collects that guidance and adds references to other sources of information that may be relevant when analysing the vibration behaviour of steel staircases. This AD also identifies some other design considerations that may be relevant.

General approach

Steel staircases are, by their nature, highly susceptible to vibration as they combine low levels of damping (typically $\zeta \approx 0.5\%$), low mass and high levels of human-induced excitation. The general approach outlined in Chapter 6 of SCI P354 can be used to determine the dynamic behaviour of the staircase, but clearly the applied forces will be different for people travelling up and down staircases than for walking across floors, and acceptable levels of vibration also differ.

Applied Loads

In P354, the response is determined from the modal properties of the staircase (frequencies, modal masses and mode shapes) and the frequency and amplitude of the applied vertical load. The peak amplitude of the load in each mode is generally given in terms of Fourier coefficients, α_n, which represent the proportion of a person's weight that is acting at each harmonic of the activity frequency. These Fourier coefficients are given in *Human induced loading of flexible staircases* (Bishop, Willford & Pumphrey, 1995 and Kerr & Bishop, 2001), and depend on the speed of ascent or descent. ISO 10137: 2007 (*Bases for design of structures – Serviceability of buildings and walkways against vibrations*) reproduces the worst case of these in Table A.4, and these are also given in Table 3.2 of P354 :

Activity	Harmonic number, n	Common range of forcing frequency, nf_1 (Hz)	Fourier coefficient for vertical direction, $\alpha_{n,v}$
Ascending or descending stairs	1	1.2 to 4.5	1.1
	2	2.4 to 9.0	0.22

In P354 floors are categorised as either low-frequency or high-frequency, the latter case responding to impulsive excitations rather than responding resonantly. No specific analysis is given by Bishop et al for the impulsive loads that will be experienced by staircases with natural frequencies that exceed the upper limits of the Fourier terms given in ISO 10137. Further Fourier coefficients (up to the 6th harmonic) are presented in the paper; these could be used to determine a more comprehensive response.

Acceptability criteria

Bishop et al. also give guidance on the acceptability criteria for staircases, and their research indicates that for multi-person excitation, a maximum multiplying factor of 64 applies. Typically this is achieved by designing staircases for a limiting multiplying factor of 32 for light use (such as offices) or 24 for heavy use (such as public buildings and stadia) under single person excitation using the Fourier terms given above. The limits for staircases are higher than for floors because the frequency of exposure to staircase vibration is generally significantly lower than for a floor, and the audio and visual stimuli that accompany the movement reduce the associated level of annoyance. For narrow staircases with no landings, it is unlikely that there will be stationary people on the stairs to receive the vibration, and as vibration is, in the main, a serviceability issue, in these cases the level or response is less critical.

Other design considerations

An additional design consideration for staircases is to ensure that the interaction between a staircase and the floors it links is such that excessive vibration does not carry onto the floor plate and therefore affect nearby rooms. This can generally be achieved by attaching the staircase in the vicinity of columns, and by avoiding features such as cantilever beams which are highly susceptible to vibration issues.

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The British Constructional Steelwork Association Ltd

You can find email and website addresses for all these companies at www.steelconstruction.org

BCSA is the national organisation for the steel construction industry. Details of BCSA membership and services can be obtained from Gillian Mitchell MBE, Deputy Directory General, BCSA, 4 Whitehall Court, London SW1A 2ES Tel: 020 7839 8566 Email: gillian.mitchell@steelconstruction.org

KEY

Categories
- **A** All forms of building steelwork
- **B*** Bridgework
- **C** Heavy industrial plant structures
- **D** High rise buildings
- **E** Large span portals
- **F** Medium/small span portals and medium rise buildings
- **H** Large span trusswork
- **J** Major tubular steelwork
- **K** Towers
- **L** Architectural metalwork
- **M** Frames for machinery, supports for conveyors, ladders and catwalks
- **N** Grandstands and stadia
- **S** Small fabrications

Quality Assurance Certification
- **Q1** Steel Construction Certification Scheme Ltd
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- **Q3** Lloyd's
- **Q4** Other

Classification Contract Value
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Notes
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* For details of bridgework subcategories contact Gillian Mitchell at the BCSA.

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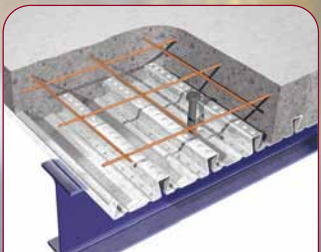

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