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Industry CPD

Steel and off-site construction

This CPD module, sponsored by Steel for Life, will look at the structural steelwork construction process with a focus on established off-site processes and practices and the benefits provided.

Continuing professional development (CPD) ensures you remain competent in your profession. Chartered, Associate and Technician members of the Institution must complete a specified amount each year. All CPD undertaken must be reported to the Institution annually. Reading and reflecting on this article by correctly answering the questions at the end is advocated to be:

1 hour of verifiable CPD

It is known that the UK government wants construction and infrastructure projects to incorporate greater levels of off-site manufacturing. More recently, government has said that it also wants to take a more standardised approach to design, including componentisation. They refer to this as a platforms approach.

With the majority of the value add for structural steel already occurring off-site – in some cases up to 90% – the structural steelwork sector is well placed to be an early adopter of these new approaches.

An erected steel frame on site

About steel and off-site construction

Designers and specifiers have long recognised the benefits that steel offers the construction sector noting steel framing as the original off-site framing material.

Fabrication of individual steel pieces takes place off-site under controlled, highly regulated and safe factory conditions where the use of digital design and leading-edge fabrication systems delivers precision-engineered components with minimum waste. Steel components are further pre-assembled or fabricated into modules either off-site or at the site at a low level.

Steel structures are often prototyped or trial built off-site to ensure a perfect fit when the fabricated steel modules undergo final assembly on site. This means that the majority of the value add for structural steel occurs off-site.

Structural steel procurement

In responding to the tender request, the steelwork contractor will get a price for the rolled steel they will need to buy, either directly from the UK mill or from one of the UK's many steel stockholders or distributors. Once the job is secured by the UK steelwork contractor, the steel will be ordered. When the steelwork contractor wins a contract, this is based on a set of 'estimate drawings'.

On an average contract, the lead time (time before the steel is required on site) may be 10 working weeks. These 10 working weeks are for the steelwork contractor to design the connections, detail the steelwork (drafting the components, working out how the smaller lots go together, etc.), issue the drawings/model to the works, order and receive the steel, fabricate the steel and deliver the steel to the construction site.

The client's consulting engineer will normally take the architect's '3D model' of the building and provide the structural layout and member sizes. Additional information such as the design

forces in the connections may be added for later use by the steelwork contractor. This 'model' is then transposed into structural and detailing information by the steelwork contractor using well-known software packages. In many building projects, the main contractor will manage a Building Information Management (BIM) system into which all the key parties (and especially the steelwork contractor and other specialist subcontractors) will provide their detailing information to enable the BIM model to be updated and act as a comprehensive source of geometric building data for all of the construction 'team'.

The steelwork contractor will create details of all the connections based on the forces specified by the consulting engineer, and may employ their own consulting engineer for specialist design and temporary works tasks.

Once the job has been confirmed the steel will typically be procured through the stockholder or distributor route. Orders have to be placed earlier for steel to be bought directly from the mill. If the steel is an unusual grade it might need to be rolled specially or ordered through one of the established routes.

Some products might also need to be purchased through, or fabricated by, specialist suppliers, e.g. cellular beams (beams with large holes in them to accommodate services), asymmetric beams or plate girders.

Steelwork contractors receive changes to the drawings routinely from the consulting engineer and the main contractor and they have to deal with them as efficiently and as safely as possible. The best way to deal with the changes is by addressing them off-site in the factory before the steel goes to the construction site.

Design

The steel construction sector has been utilising 3D design software for more than a quarter of a century and is well versed in the benefits and efficiencies it provides to manufacturing and construction programmes. Today's computer software is integral to the design, fabrication, erection and everyday operational processes at most steelwork contractors' facilities.

Software is interwoven into each stage of the steel fabrication process, supporting activities such as knowledge and bid management, project planning, frame analysis, connection design, 3D modelling, BIM coordination and the fabrication process itself.

During the design phase, the structural steel will be modelled to facilitate fabrication. Materials Resource Planning (MRP) software then processes the bill of materials data from the model which is used for procurement of materials, manages data to drive automated cutting and fabrication machinery, plans logistics, as well as piece weights for crane planning. MRP software can also be used to monitor progress of fabrication by capturing data about each part as it passes through the different fabrication processes.

The structural steelwork sector is also seeing the adoption of modern scribe marking technologies. Software can allow for full or partial contours to be scribed directly onto the steel to indicate the position of the parts that need to be welded, saving valuable time and minimising errors. In addition, information can be marked on the steel indicating quality, traceability, welding information and assembly details.

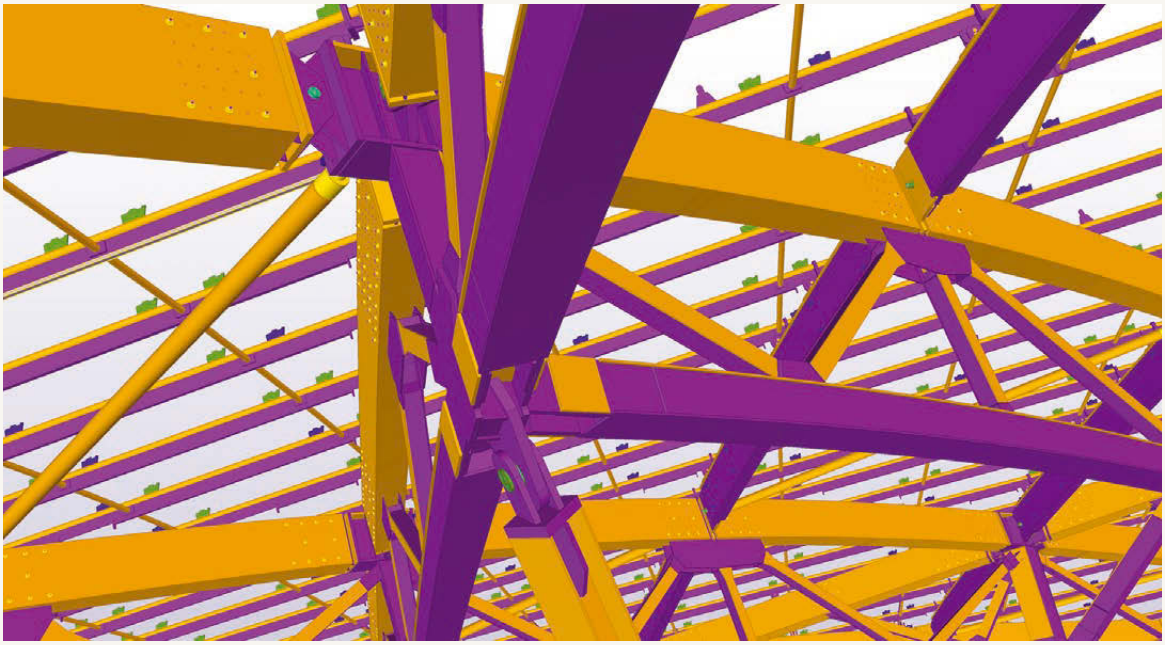
Fabrication

Once the 3D model and the steel are received in the factory, fabrication will commence. Steelwork fabrication processes include:

- →| design and detailing of connections and attachments
- →| cutting to length and chamfering of beams, columns and bracing
- →| drilling of holes for bolts
- →| welding, which is a core activity in the fabrication factory; it is used to prepare joints for connection on site and for the attachment of other fixtures and fittings
- →| blast cleaning and painting steelwork
- →| attachment of fitments for installation and protection, e.g. edge protection
- →| manufacture and attachment of secondary components, such as cleats, shims and bolts and lifting lugs
- →| curving of members, forming of openings, which is often carried out by specialist companies
- →| in some cases, partial concrete encasement and shear connector welding in the factory
- →| scheduling for delivery on a 'just in time' basis and transport from the fabrication workshop to the construction site
- →| design of temporary works.

Advances in quality and productivity in the steel construction sector are largely due to developments in fabrication machinery. The manufacturers of steelwork fabrication equipment have invested heavily in research and development to produce the technological advances required by today's steel construction sector.

Manufacturers of steel fabrication equipment work closely with steelwork contractors planning



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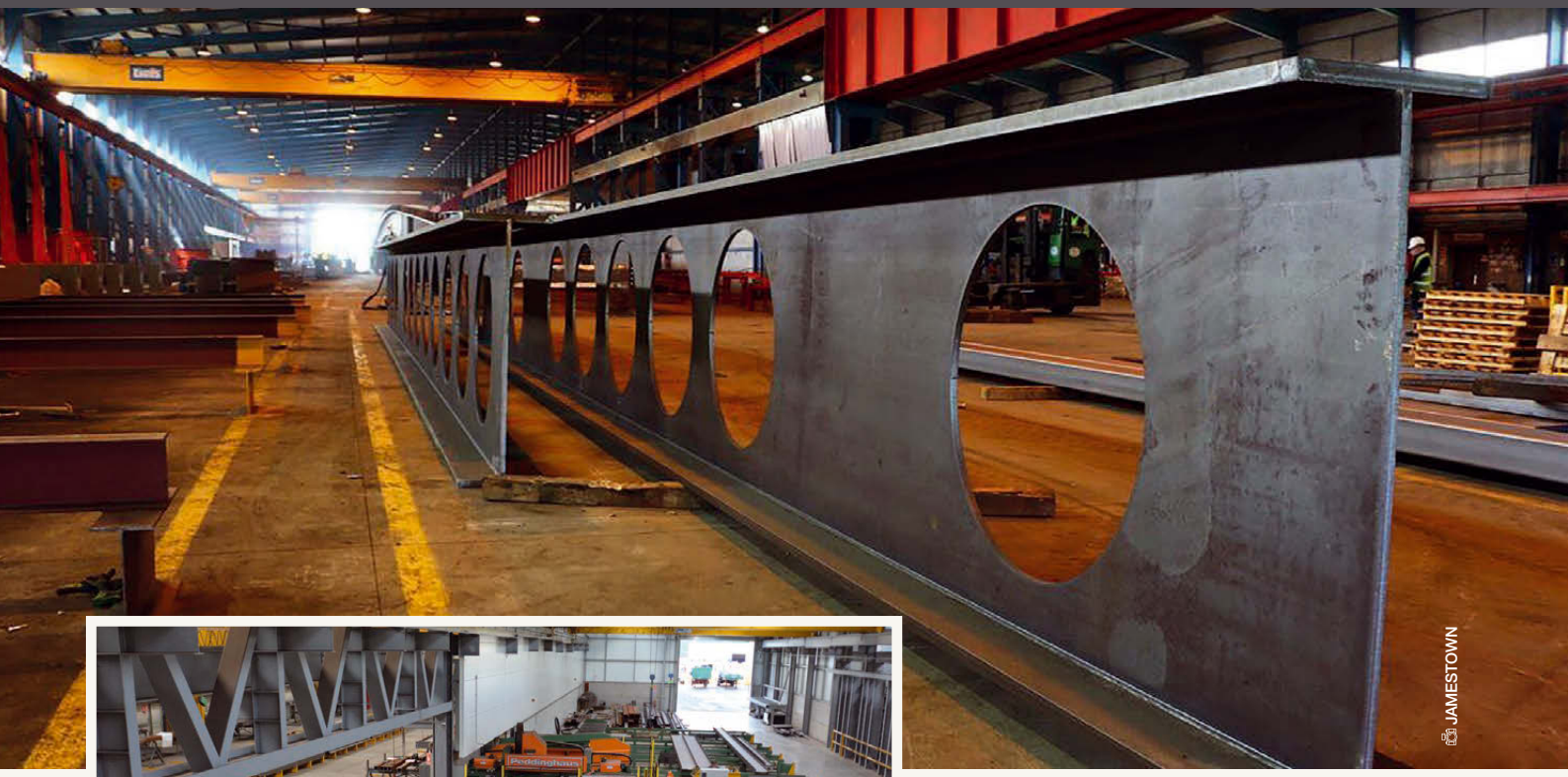
↖An example of a 3D frame model



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↑ Prefabricated structural steel in a factory ready for transportation

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↖ A structural steelwork fabrication factory

the factory design and layout with real-time simulation to find the best flow of material and maximise production based on required output through the use of advanced simulation software.

Computer Numerically Controlled – or CNC – machinery is the standard today and is integrated into each stage of the steel fabrication process. The process may vary between each steelwork contractor but will generally commence with the efficient and seamless transfer of 3D model information from the design office to the equipment in the factory.

> **“MANY PROCESSES ARE FULLY OR AT LEAST SEMI-AUTOMATED**

Health & safety

Safety is promoted by off-site production, as manufacture under factory-controlled conditions is inherently safer than is possible under typical construction site conditions. On-site operations are in the hands of highly qualified site erection teams who are specialists and are obliged to hold recognised qualifications.

With so much work carried out off-site, the on-site construction programme is reduced and the build programme is relatively unaffected by adverse weather conditions. Furthermore, steel components can be pre-assembled or fabricated into modules either off-site or at low level, which reduces the need for working at height. Steel can be delivered to site as and when it is required, reducing the need for potentially hazardous on-site storage.

Benefits of off-site construction

The benefits of off-site construction have long been appreciated by designers, contractors and owners of buildings.

Being fabricated off-site in closely controlled factory conditions means everything is produced to high standards of accuracy and defect free – effectively ‘right first time’. Factory-based manufacture allows full integration with the latest computer-aided design and computer-controlled production developments. Digital design for manufacture and assembly, including full Level 2 BIM, has additionally created new skills in the sector. Many processes are fully or at least semi-automated, with industrial robots routinely being used in fabrication factories for operations such as welding. Coatings including intumescent paints can also be applied off-site, indeed the factory application of this type of coating reduces the risk of delay to following trades. It also helps minimise the on-site construction programme.

Off-site manufacture of constructional steelwork results in waste being minimised beyond what can be achieved with alternative materials.

There are other advantages. With on-site work reduced largely to speedy assembly, using structural steelwork means local communities are spared much of the noise and dust inevitably generated by other construction works. Logistical benefits are also derived from steelwork’s ability for timed or just-in-time delivery as dictated by site requirements. The erection of steelwork direct from the just-in-time delivery lorry minimises the requirement for set-down and storage areas, which can be important where space is at a premium.

Additionally, fewer people are required on site, which helps to mitigate issues around skills shortages, and improves on-site safety. The

need to work at height is reduced due to the majority of the work taking place off-site, also providing a skills and safety benefit.

The stable long-term nature of jobs in a steel fabrication factory assists in the training of a specialist workforce. Such skills development both motivates the workforce and increases the efficiency of off-site steel construction. Off-site steel construction also benefits communities that might not benefit directly from investment in construction or infrastructure such as those outside London and the south, but ongoing manufacturing employment brings stability and growth to such areas.

Standardised steel modules

A new study from the British Constructional Steelwork Association and the Steel Construction Institute supported by Innovate UK investigating the opportunities to increase construction sector productivity using off-site steel modules was released in 2020. The project highlights some progressive, modular opportunities and focuses on steel composite cores, standardised steel columns, dry floor plates and facade and roof panels.

The study noted that steel composite cores could shorten a construction programme from 18 months anticipated with a traditional core to 10 months and at a reduced overall cost. Additionally, they can provide a precision-engineered solution and support the government drive for a Platform Design for Manufacture and Assembly (P-DfMA)-based approached. A platform approach to DfMA is the use of a set of digitally designed components across multiple types of built asset that are then used wherever possible, minimising the need to design bespoke components for different types of asset.

It also looked in more detail at standardised steel columns and dry floor plates. The study noted that single-storey columns are easier to handle than longer elements and more suited to robotic welding where material handling of long members is difficult. It was suggested the same performance as the traditional option can be achieved with less material by producing composite column sections, manufactured off-site. Other benefits include being smaller, lighter and easier to transport.

The off-site, factory production of the floor plate panels means that the panels are precise components, fabricated faster and provide a dry solution. Panels are shallow, typically less than 20% of the storey height, meaning that multiple floor panels may be transported to site in one load.

Questions

To claim your CPD certificate, complete the module online by 31 July at: www.istructe.org/industry-cpd

1. Up to what percentage of the value-add for structural steel occurs off-site?
- ☐ 40%.
- ☐ 50%.
- ☐ 60%.
- ☐ 90%.

2. When a steelwork contractor wins a contract it will be won based on what?
- ☐ Price.
- ☐ Estimate drawings.
- ☐ Relationship between client and contractor.
- ☐ Feasibility study of project.
- ☐ Location of contractor.

3. On an average contract the lead time is how many weeks?
- ☐ 5.
- ☐ 8.
- ☐ 10.
- ☐ 12.
- ☐ 15.

4. What is the best way for a steelwork contractor to deal with changes to drawings?
- ☐ Address them in the factory before steel is delivered to site.
- ☐ Assess changes on site.
- ☐ Work with the consulting engineer and main contractor via email.
- ☐ Liaise with the client to see if changes are absolutely necessary.
- ☐ Outline new plans and submit to the main contractor.

5. Who specifies the forces the steelwork connections need to be able to handle?
- ☐ The consulting engineer and/or the steelwork contractor's own consulting engineer.
- ☐ The main contractor.
- ☐ The architect.
- ☐ The client.

6. Which of the following are benefits associated with off-site construction?
- ☐ Higher standards of accuracy.
- ☐ Reduced on-site waste.
- ☐ Fewer people working on site.
- ☐ Reduced working at height.
- ☐ All the above.

7. How could the use of a steel composite core affect a construction programme?
- ☐ It would lengthen the programme.
- ☐ There would be little to no change to the programme.
- ☐ It would reduce the construction programme.

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