CO_2 2.Low carbon

Developing a low-carbon, circular economy for steel

Walter Swann explains how structural engineers can support a transition to a low-carbon steel industry through their design and specifying decisions.

Introduction

Steel has a significant role to play in the circular economy, but one key component is missing – the balance of supply with demand[1]. Even though most scrap steel arisings are captured and recycled or reused, the global demand for steel is such that it exceeds the availability of scrap by a factor of 3. Furthermore, global steel demand is not predicted to peak until mid-century, with scrap volumes not matching demand until even later. Therefore, without a dramatic decrease in material usage, there will continue to be a need for primary steelmaking to meet the demands of society well into the second half of the century.

The challenge, therefore, is to transition to carbon-neutral primary steelmaking as a matter of urgency, while manufacturing products that support lean design. This article outlines ways in which the structural engineer can engage with and support the steel industry in that transition.

Production

Steel products can be manufactured entirely from recycled scrap ('secondary steel'), or from a mix of recycled scrap and new steel created from iron ('primary steel'). Let's start by recapping the ways in which these processes can vary.

Ironmaking is part of the primary steelmaking process **(Figure 1)**. Globally, around 1200M tonnes[2] of iron is produced annually in the blast furnace (BF) process using coke to reduce iron ore. Another 100M tonnes[2] is made by reducing iron ore, often with natural gas (CH_4), in the direct reduced iron (DRI) process to produce solid 'sponge' iron.

Once you have iron, you can create primary steel in either a **basic oxygen furnace** (BOF), or an **electric arc furnace** (EAF). In a BOF, steel is made by injecting oxygen into the liquid BF iron to remove excess carbon. Scrap steel is used as a coolant, the percentage varying from plant to plant, but typically 10–15%, with a technical maximum of around 30%. The A1–A3 embodied carbon factor (ECF)[3] for steel from the BF-BOF route is ~2500kgCO_2e/t.

An EAF can be used to produce steel from DRI iron (DRI-EAF), 100% scrap steel (scrap-EAF), or a mixture of both. Steel produced though the scrap-EAF process has an A1–A3 ECF of ~500kgCO_2e/t and that from DRI-EAF ~1000kgCO_2e/t.

Scrap, steelmaking and module D

Scrap is an integral and important part of the steelmaking process. Consequently, the steel industry itself drives demand for scrap. A 2012 UK survey revealed that 93% of structural sections were recycled and 7% were reused[4], so specifying recycled content has little impact on overall recycling rates, as they are already close to the practical maximum.

The end-of-life value of BF-BOF steel is not realised until it enters the recycling loop for the first time. Here, it often becomes the scrap charge for the EAF, and in doing so displaces the need for steel made from primary resource. This results in an environmental benefit that can be thought of as the A1–A3 ECF for BF-BOF minus that for EAF. Typical module D benefits of BF-BOF steel are in the range of 1600–1800kgCO_2e/t, and, of course, once in the loop steel can be recycled many times over.

Mapping products to processes

Globally, 1800M tonnes of crude steel is produced each year, with a 70:30 split between BOF and EAF. For the EU28, this figure is 160M tonnes per year, with a 60:40 BOF:EAF split (from 60 blast furnaces and 150 electric arc furnaces). The UK produces 7M tonnes per year of crude steel, with an 80:20 BOF:EAF split. According to World Steel data, buildings and infrastructure account for approx. 50% of global steel consumption.

This split between BOF and EAF manufacture is not reflected equally across all products. Cladding, decking, hollow sections and plate are manufactured almost entirely using BF-BOF, whereas reinforcement, open sections and sheet piling are manufactured using either BF-BOF or scrap-EAF.

In developed economies with mature, well-established scrap flows, there is a natural transition toward scrap-EAF production of engineering steels, reinforcement and sections. This is evidenced in Europe and the USA in

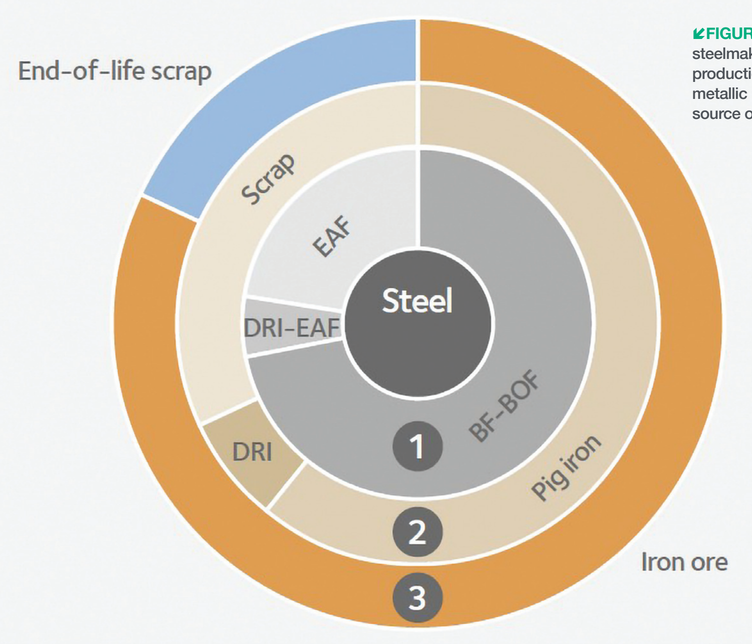

FIGURE 1: Global steelmaking by (1) production route, (2) metallic input, (3) source of iron[1]

higher percentages of EAF manufacture relative to the global average, which will, of course, increase over time.

Journey to carbon-neutral steelmaking

As part of ArcelorMittal's commitment to the Paris Agreement, the firm is developing two routes to carbon-neutral primary steelmaking. The first involves displacing fossil carbon in the blast furnace with circular carbon (biowaste materials from forestry and agriculture)[5] and coupling this with carbon capture and use (CCU) to produce bioethanol, and carbon capture and storage (CCS). The first industrial-scale pilot plant in Europe to do this will go live in 2022.

The second method involves a transition to 100% hydrogen DRI, initially with fossil-based hydrogen, and ultimately transitioning to green hydrogen from the electrolysis of water using clean electricity[5]. The first industrial-scale DRI plant to run entirely on hydrogen is anticipated to come on stream in 2025.

So, what should a structural engineer do?

Step 1: Follow the **refurbish** – **reuse** – **reduce** – **recycle** hierarchy.
Step 2: Design like a steel fabricator – skin down the loads, design for least weight, design to a unity factor of 1.00, manage deflection, then review through the lenses of cost, carbon and pragmatism.
Step 3: Support steelmakers that support the Paris Agreement.

Refurbishment is a very effective means of reducing demand for construction materials; many of the barriers to **reusing** existing steel elements are perceived rather than real, and can be overcome if approached early enough in the design process[6,7].

Reduce starts with grid selection. The grid should play to the strengths of the material being used. Think holistically: what offers better carbon value – a short span sitting on a transfer or a clear span throughout?

Reduce challenges inappropriate structural zones, yet understands that structure, facade and servicing all have to interface with one another. If an option leading to suboptimal structural design offers greater carbon reductions overall, through operational carbon associated with space heating/cooling and material savings in facade, then it might be a better overall choice[8].

Reduce favours high-strength steel where it delivers carbon value. Any S355 column in multistorey construction that is a 305 UC 137 or greater will deliver an approx. 30% reduction in weight and a minimum reduction of 30% in CO_2e when redesigned in S460.

Reduce favours trapezoidal decking, which uses less steel and less concrete to do a similar job to a re-entrant profile (although this may need to be balanced with fire and acoustic considerations).

> **"RESEARCH AND WORK WITH YOUR SUPPLY CHAIN TO DETERMINE WHICH PRODUCT GROUPS ARE AVAILABLE BY WHICH PROCESSES**

Reduce manages deflection. Computers are binary and can't make engineering judgements on deflection criteria. Engineers can. Does 1mm over the code limit warrant a 10% increase in weight/carbon? Pre-sets and pre-cambers for permanent load can be used, especially where there's repetition – use the two-thirds rule[9].

Support the commitment to decarbonise

In the UK and Europe, steelmakers work to the same environmental standards and legislation in terms of emissions, ensuring a level playing field and preventing carbon leakage. Agree with your clients and design team to support those steelmakers that are certified to ResponsibleSteel[10] – a broad environmental, social and governance standard where alignment with the Paris Agreement is mandatory.

Understand the complexities of the supply chain. Specifying that all steel should be from an EAF source, or specifying a minimum recycled content percentage, is understandable but does not address the need to decarbonise primary steelmaking. Nor does it address the fact that, while technically possible, not all construction products are currently made solely by the scrap-EAF process. Researching and working with your supply chain to determine which product groups are available by which processes can help to establish an honest ECF.

Conclusion

To help create a low-carbon and circular world, support those companies that are investing in creating sufficient supplies of future scrap, and that are making primary steel with low-carbon technologies. Design steel frames as efficiently as possible, taking advantage of high-strength steels where it makes sense to do so, and build on and improve the inherent demountable nature of steel-framed construction to promote increased steel reuse. Where that's not possible, rest assured that the steel will be captured, recycled and made into new steel products.

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