Circular Steel in the Built environment

Summary of the event

Introduction

Steel is one of the most widely used and most polluting construction materials with each tonne of steel produced creating an average of 1.85tCO2[1], resulting in the steel industry being responsible for 7% of all manmade carbon emissions[2]. UK steel production results in around 11.6 million tCO2 a year with most steel being produced by Blast Furnace[3]. However, 18milliotn tCO2 a year[4] also occur from importing steel to be used in the UK within manufacturing and construction.

Currently, 99% of all UK structural steel sections are recovered, with 86% sent for recycling and 13% for reuse.[5] As steel is a particularly durable material it can often last well beyond the 60-year design life and it can be reused at a similar structural capacity as their previous lifetimes.[6] Encouraging the reuse of steel over recycling can lead to carbon reductions for the user's Whole Life Carbon Assessment compared to buying recycled and new steel.

Why steel?

Steel has been uniquely placed as a high-carbon material which is experiencing supply issues, price fluctuations, and is relatively easy to reuse and recycle. The UKGBC Circular Economy Forum has focused on steel reuse in one of the working groups where members have been able to explore the barriers, enablers, and lessons from live projects with steel reuse, recycling, and net zero steel. Off the back of the work of The Forum, it was decided that a whole-day event to bring together the steel supply chain would help enable discussion between different stakeholders and help create consensus regarding steel reuse and Net-Zero steel within the construction industry. The topics below were selected to provide an overview of a project lifecycle and to explore how steel can be reused at every stage of a project. Net-Zero steel was also discussed to help those present understand the challenges of reaching net zero steel production and the options available to them if they need to specify new on projects.

Why was the event needed?

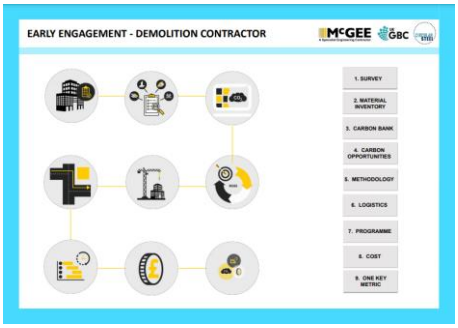
Circularity is becoming increasingly important as it reduces resource use and can enabler carbon reductions, increasingly important for Net Zero targets and ambition. The Net Zero Whole Life Carbon Roadmap for the Built Environment calls for a focus on a circular economy with second-hand material markets and reuse helping to lower the embodied carbon of buildings[7]. Equally, the report How Circular Economy Principles can impact Carbon and Value provide examples of the carbon reductions possible through reuse materials, including steel[8].

The British Construction Steelwork Association (BCSA) have produced a decarbonisation roadmap for 2050. Within this, the circular economy for steel is said to be "proven" with the circular economy helping to reduce the carbon impact of structural steel production by 15%.[9] The BCSA decarbonisation roadmap does recognise that there are logistical and supply chain barriers to adopting a more widespread reuse of structural steel[10]. The event was designed to tackle some of these barriers by bringing industry stakeholders together to discuss where those remaining barriers are and how they can be overcome.

Deconstruction, testing and re-work, and reuse

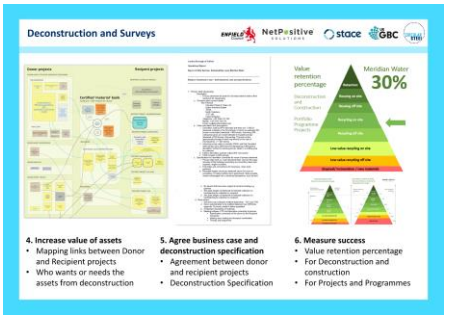
The first section explores how to deconstruction of existing structures on a site can be done to enable reuse of the materials already there. As well as the testing and re-work needed so they can be used on another site, as well as some examples where steel has been successfully reused on another project. To access the boards in full see the link here.

Deconstruction and Surveys



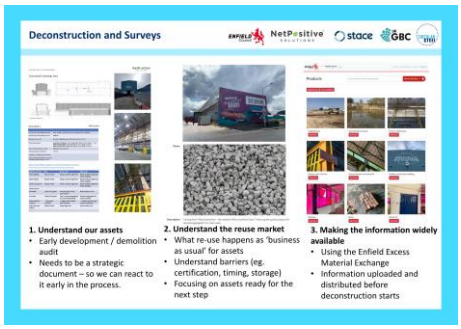
Charlie Wedgewood (McGee)

"Buildings are full of embodied carbon. Materials are valuable, so why waste them. This McGee workflow assesses and calculates how much carbon is stored in your existing building. We will then develop a strategy to realise the potential of your "carbon bank". This maximises the use of zero carbon materials, reduces residual carbon and eliminates waste. We can demonstrate the impact of Circular Economy principles early in the design process that enables mature discussions and balanced outcomes."

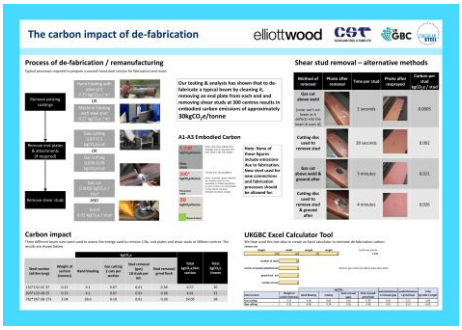


Rafe Bertram (Meridian Water)

" The Meridian Water story is about creating value for the building and building materials assets we own. By first understanding the assets we have, and the existing or emerging reuse market they can contribute to. We then have a way to let the market know about our assets (https://enfield.excessmaterialsexchange.com/). We then match donor materials to recipient projects, set up the business case and specification for the transfer and measure the success of it with the Value Retention Metric."



Testing and Rework

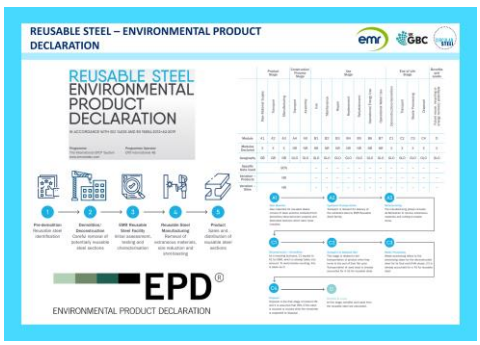


Penny Gowler (Elliot Wood) and Roy Fishwick (Cleveland Steel and Tubes)

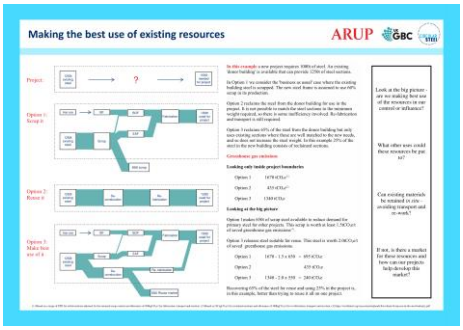
"Defabrication: With the recent trend for specifying reused steel for UK construction, Elliott Wood and Cleveland Steel & Tubes joined forces to measure how much energy is used when cleaning and de-fabricating steelwork so it's ready for fabrication. We then calculated the associated carbon with each process and established a figure of approximately 30kgCO2e/t, significantly less than the greenest prime steel.

Acceptance: When salvaging steelwork from existing buildings, it's important for the structural engineer and demolition contractor to agree acceptance criteria for the steelwork. For example, what level of corrosion is acceptable, how many 'dings' are allowed on the flanges. The board shows the acceptance criteria agreed for a current project where the demolition contractor is on site, deconstructing 2,000 tonnes of steel for reuse."

Guy Mercer (EMR)



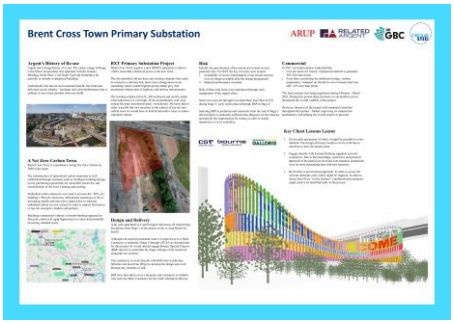
"Capturing the lifecycle impacts of reusable steel is vital for confidence in design. EMR's first Environmental Product Declaration (EPD) does precisely that, enabling low carbon design options to be tabled with confidence"



Dominic Munro (ARUP)

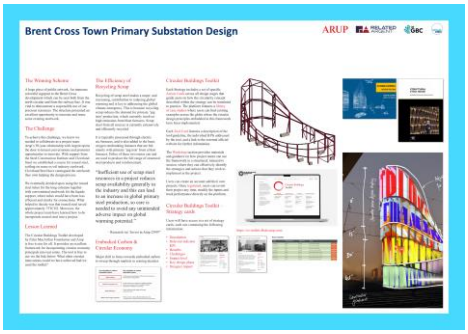
"A look at the true value of reclaimed steel as a resource for reducing greenhouse gas emissions. It shows how our use of reclaimed steel needs to first recognise the finite nature of this resource, and then to make the most efficient use of it."

Reuse examples



Rick Totten (Related Argent) and Ben Glover (ARUP)

"Related Argent are delivering a 21m tall, 55m long piece of public artwork wrapped around their new substation at Brent Cross Town, which is pledged to be net zero carbon by 2030. Working with Arup, Bourne Special Projects, and Galldris almost 50% of the structure was substituted with reused steel sourced from Cleveland Steel."



Paul Cluskey (Cantillion)

"Cantillon led the 'urban mining' of reusable structural steel on One Broadgate in conjunction with developers Fabrix and British Land. Working with structural engineer AKTII, the team were able to simplify the process and apply practical thinking to the opportunities that Steel reuse presents."

The Steel from One Broadgate has been used in the 55 Great Suffolk Street and Roots in the Sky Projects (Case studies are linked).

Procurement and Risk:

This panel discussion set out to discuss the key issues and barriers which can prevent the reuse of steel within a project. The main result from the discussion was that there needs to be better communication to insurers and underwriters to explain the due diligence of the process to re-test, re-fabricate, and re-warranty steel as this will help reduce risk perception around reused steel. As reused steel is subject to the same manufacturing standards as new steel theoretically there is no more risk with reused than new. Although the risk perception is currently a barrier the over-scrutiny of the reuse processes should mean that they will become accepted, and we are heading towards a market norm. There will still be instances where it could be seen as riskier due to the size and scale of the project. In the room there were representatives from the majority of the supply chain from demolition, design, procurement, clients, manufacturers and stockist who would be willing to make this work, thus reusing steel should be achievable as the stakeholders needed to make it work are in agreement that it ***can*** work.

There were still some barriers identified which will still be a problem until steel reuse becomes more widespread. Specifying reused steel can cause problems due to the volatility of the market, there potentially needs to be targets or a hierarchy of preferences for steel reuse. Until there are storage sites able to hold steel and a better flow of reused products to match supply and demand flows it is going to be harder to procure reused steel in the normal way. Equally, it is important to ensure that the contractor is engaged early if you want to have reused steel to ensure it can be achieved in procurement. This is because it can be harder for the contractor to find reused steel as there is

not a set supply or price for reused currently. Early engagement and 'wiggle room' in the contract will help to overcome this.

There are still a few barriers remaining with risk. Until the due diligence is done on the process as outlined above, reused steel may be perceived as riskier. The payment for the steel may also take place early in the process and to the donor building rather than the manufacturer. This could also be seen as risky with concerns over where the deposit is held and how it is protected. Until the market becomes more evolved there is likely to be a period of over-scrutiny before procuring reused becomes a market norm.

We have seen how the market has changed this year with more pressure around carbon on projects. This has led to examples where steel has been reused between buildings within the same portfolio as well as reused steel being procured from reuse specialists or directly from other developers. However, many of these examples are focused in London so it's important that the supply chain across the UK is engaged in these discussions to develop the reused supply chain.

The discussion also identified that there is a role for Steel stockholders. They could be a crucial role in the reuse of steel as they could act as a material bank due to them already having the storage space for steel. There needs to be more reused steel stored to start up the second-hand market and their involvement could help overcome some of the current barriers to widespread steel reuse.

Reuse steel has to be lower than new to have a business case however the price of new structural steel has faced rising costs recently[11]. This has helped to make reused steel a more attractive option with cheaper costs to procure and if procured in the UK, a more stable supply. Clients do want to tell the story but not pay more, whilst contractors can find what the client wants but could risk losing the contract if more expensive due to the nature of the supply chain. If carbon pricing is considered in the project or became mandatory this may swing the balance towards reuse. However, currently, clients are more willing to offset post-construction.

Net Zero Steel:

This discussion highlighted the ways to decarbonise steel production and explained the challenges in doing so. The situations where it may be appropriate to have new steel, over reused depending on the design and life plan of the building where also explored.

There are two main ways in which steel is made. This is either through Blast Furnace Basic Oxygen Steelmaking or the use of an Electric Arc Furnace. The method of producing steel from each furnace type is explained below. It is important to understand how steel is currently made as the method of production currently used affects the options for decarbonisation of steelmaking. On average one metric ton of steel results in 1.8mt of CO2e however this varies for each method of steelmaking.[12]

- **Iron production**:
  Blast Oxygen Furnace uses coking coal being burned as a reducing agent to produce iron from iron ore[13]. Iron ore, coke, sinter, and limestone are fed into the top of the blast furnace. Hot air is fed into the furnaces and temperatures higher than 2000oC are reached to reduce the iron ore to create iron which collects at the bottom of the furnace. the impurities combine with limestone to form slag, which is less dense and can be removed from the iron[14]. The liquid iron has unwanted elements removed, like sulphur and phosphorous[15].
- **Blast Furnace - Basic Oxygen Steelmaking (BF-BOS):**
  Scrap metal, liquid iron (hot metal), or a mixture of both, are added to one of the BOS vessels and high purity oxygen is blown through a lance, at twice the speed of sound on onto the surface of the liquid iron[16]. The quantities of scrap, hot metal ore, and other fluxes are monitored to ensure the correct temperature and composition of the steel[17]. Lime is added to remove the unwanted elements which form slag and oxidisation occurs to form carbon monoxide which can be captured, cleaned, and used as a fuel[18]. When the oxygen blowing is complete the steel is poured into ladles where the desired steel chemistry is achieved by adding alloying elements.[19]
- **Electric Arc Furnace (EAF):**
  An EAF can use 100% scrap to produce steel[20]. Cold scrap metal is charged into the furnace and electrodes are lowered into the furnace with an electric current passed through the charge to create a high-current electric arc[21]. This melts the scrap, and lime, fluorspar and oxygen are blown in, and combine with the

impurities in the liquid metal to form slag[22]. Once the correct composition has been achieved the steel is tapped into a ladle where alloys can be added to make the specific grade of steel required.[23]

- Secondary steelmaking can occur depending on the grade of steel required.

There are a number of routes available to decarbonise steel depending on the region the steel is made in and the technology used there to the current make steel. To reach net zero in steel we will need to look at grid decarbonisation for EAF and a move to hydrogen, or investment in Carbon Capture and Storage (CCS) at existing plants. CCS may require more investment to make it viable on a large scale.

Options for decarbonisation of steel:

- Natural gas-powered and use energy efficient direct reduced iron or hot briquetted iron Electric Arc Furnace
- Retrofit BF BOFs with Carbon Capture and Storage (CCS) or Carbon Capture and Utilisation (CCU) technology
- Or hydrogen-reduced Electric Arc Furnace powered by renewables, this makes steel with a carbon intensity of 0.2tco2 per metric ton of steel[24]. This also depends on the availability of hydrogen and the type of hydrogen used[25].

McKinsey and Company expect hydrogen to be as cost-effective as carbon capture and storage technologies by 2050[26]

Figure 1: Structural steelwork: 2050 decarbonisation roadmap[27]

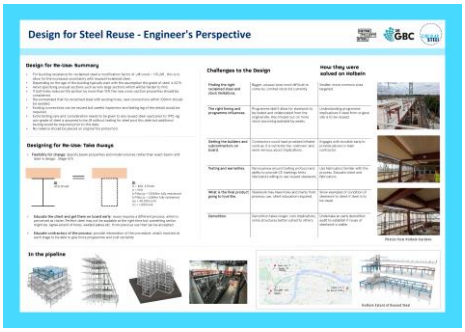
One challenge is there are still issues is with which steel to specify to ensure a low carbon design. Design teams cannot specify the amount of recycled content in steel as there cannot be high recycled content steel and there is likely to be a global demand for new steel as the need for its use in buildings expands. One way could be to look at the carbon intensity per ($kgCO_2/m^2$), meaning there could be a mix of reused and new steel within the building. The best option may be to have a hierarchy for specifications from reuse, to recycled content, to new. Carbon calculation tools do not give an accurate estimation of the embodied carbon in steel which can further complicate things.

There is an argument to support those who are trying to decarbonise their steel production and invest in the tools and processes to do that. Hydrogen could be crucial to net-zero steel in the UK but will involve large investment into the infrastructure. Whether you decide to buy new may also depend on other factors as buying new UK steel will bring a social value element by supporting jobs and local communities within the UK.

It is important to remember that reusing steel will not destroy the steel industry as there is a growing demand globally and recycled steel is less commonly made from structural steel and other steel products have a higher turnover. Equally, looking at designs and a leaner use of steel will also be important for making resources go further. The BCSA decarbonisation roadmap shows this can create a 17.5% CO2 reduction for steel in the UK[28].

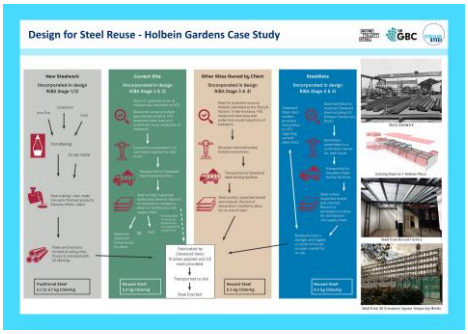
Design

Rob Mills and Laura Batty (Heyne Tillet Steel)

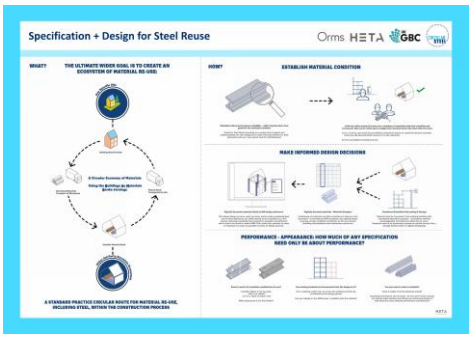


"With Holbein Gardens topping out on site recently, delivering over a third of the new steel from reused sources, HTS present the challenges and lessons learnt from going through the steel reuse journey and describe how the design was approached from an engineering perspective"

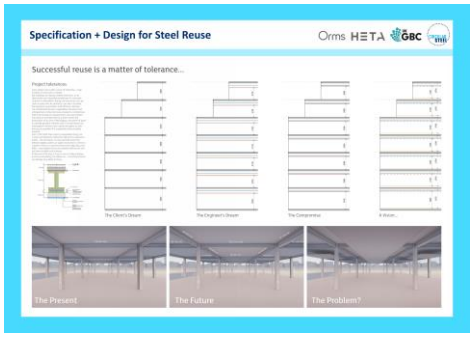
More detail on the Holbein Gardens project can be found in the case study HERE.



Rachel Hoolahan (Orms Architects) and Nicholas Arthurell (HETA)

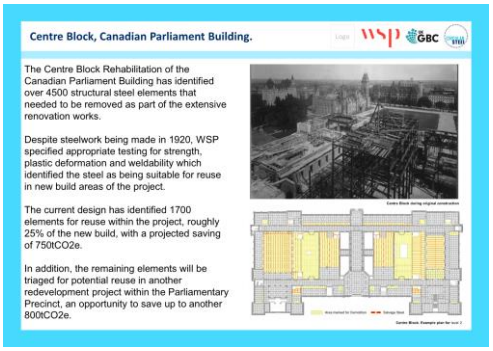


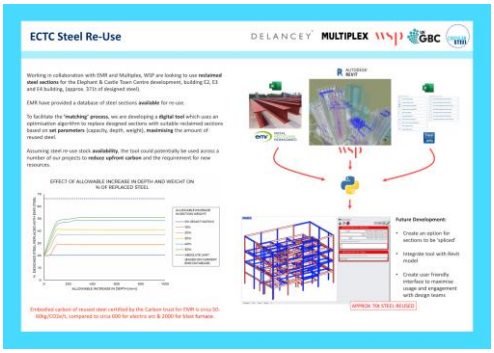
"Successful reuse requires flexibility in the specification, and therefore a flexibility in design. In reality, this simply requires an additional tolerance to be understood and factored in. Tolerance is also required from an aesthetic perspective, as it will be near impossible to get everything identical. But is this really a problem? Can we not just celebrate the differences instead?"



David Leversha (WSP)

Centre Block, Canadian Parliament refurbishment:
“In delivering the net zero transformation of the 1920’s historic Parliament, WSP has identified over 4500 structural steel elements that need to be removed and overseen a comprehensive testing programme. To date WSP have identified where 1700 structural elements can be reused, with a projected saving of 750tCO2e. Additional digital mapping of structural steel requirements and supply is ongoing to reuse more elements within the project with corresponding carbon savings.





Elephant & Castle Town Centre:
To maximise the reuse of structural steel elements within the design and fabrication process, WSP have developed an optimisation algorithm to automatically match available stock from EMR (and other sources) to the design requirements. Mapping criteria can be amended to minimise wastage with future development work on going to automatically amend the design to suit available stock."

Reusable steel markets

One barrier to reused steel in general, and a reused steel market, is the availability of storage sites. There are a few (CST and EMR) businesses currently focused on or trialling steel reuse however this is not yet at a scale to cover the UK. Steel stockists holding reused steel could be one way to tackle this and expand the quantity of reused steel which can be stored for reuse in the UK. Equally, there could be a role for digital platforms or local authorities to support the reuse markets. However, they may be better suited for faster-moving materials, rather than steel.

Another barrier is the space needed to store steel. There could be a collection of hubs around the UK, also whilst it's a developing market the steel may take longer to be required on projects compared to a more developed market where there may be a better flow between materials coming out of projects and being used in the next one. Currently, if you ask a reused steel stockist to procure two years ahead they should be able to do so. Equally, a contractor will need a longer timeframe to procure reused steel, meaning early engagement is important for this to develop.

An inventory of reused steel could be a useful way to develop the knowledge of what reused steel is available and the quantities. This would need to be regulated to a degree to ensure quality but also prevent greenwashing between the different steels available on the market (reclaimed, reused, excess stock).

Steel needs to come out in the longest lengths possible when a building is deconstructed to enable it to be reused. For recycling steel, lengths normally need to be less than 2m but to reuse in a building this would be too short. When taking a structural steel beam out of a building you may lose 0.5m of each end as a result of the cutting. This means that designers need to be prepared to adapt designs to use shorter lengths of steel and designs which are column free may not be possible whilst shorter beam lengths are being used. Early engagement will also be helpful here to provide the designer with the lengths of steel available for them to be included in the design. It is also important to design the steel into a building in a way which means it can easily be recovered with as much length maintained as possible.

Concluding remarks: Will Arnold

Early engagement is key for procuring reused steel and ensuring it can be embedded in the design. Collaboration and working with designers to explore options is important to guarantee that reused steel will work in the design and can be procured. Equally more sharing is needed, sharing of what you are doing, sharing of case studies, and knowledge sharing to get new norms. This will help reach a tipping point in the mainstream alongside supporting large stocks of reused steel to be collected for use on projects, further helping it self-propel and become market-led.

There are currently limited options to decarbonise new steel and limited volumes of scrap steel to make enough recycled steel to meet demand. We can't make new steel from thin air so some new will have to be used. Primary steel production needs to be decarbonised, but it is energy intensive and expensive to do so. If new steel is needed, try to use less with shorter loads paths to ground and designs being strength-led. Design efficiency in this manner can create a 17.5% CO2 emissions reduction[29].

Reused steel is 50kgCO2/tonne so use reused steel, if possible, then look at a hierarchy in terms of procurement looking at recycled steel. When specifying steel, ensure that reused steel is only used if the correct grade is available, if not it may be better to use new. Currently, 86% of steel is recycled and 13% is reused[30]. There needs to be an increase in the amount reused compared to recycled and shift the technical barriers to enable that. As an industry we need to get to a point where specifying reused steel is as easy as new, and "Make it seem normal". The reality is there are people within the industry willing to make this work which reduces many of the barriers.

There does still need to be the client's willpower to do this. Political willpower will also help with suggested legislation such as Part Z. And 2050 is NOT the goal, 2030 is, in 7 years. the Climate Change Committee are on the right track but it is not enough. So we can't wait.

Actions to take forward:

- The tools are there so look for personal opportunities to reuse steel.
- Unlock abundance. Share knowledge and experience. Look beyond steel and at other materials and wider than London.

- Be positive. Action is needed in 2 years, but we mustn't wait. 2030 is the goal. Use your position and shout about this to others.
- Involve the steel stockers as they may be able to store and supply reused steel
- Work with educating the insurers on how de-fabrication, testing and rework, re-fabricating, and certification of reused steel to help reduce risk perception
- Understand how steel is made and how much structural steel can be low carbon

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