TOWARDS DIGITAL SHARING OF VERIFIED GLOBAL WARMING POTENTIAL DATA IN CONCRETE REINFORCING BAR

Lee Brankley, Ayhan Tugrul, Ladin Camci, Dave Knight, Chin Seng Yap

Synopsis:

Construction industry professionals' expectations of the quality and accessibility of Carbon Dioxide equivalent (CO2e) emissions data with concrete structures have increased considerably because of Net-Zero declarations, the widespread adoption of reduction targets and transition pathways towards these goals.

This paper outlines how Life-Cycle emissions data is accurately calculated for specific steel producers, reinforcing products and fabrication, how 3rd party verification provides confidence in it and how an innovative collaboration is developing a solution that aims to digitise the steel reinforcing steel supply chain so this information can be used by design engineers and other construction stakeholders to help drive down emissions.

The paper explains describes digitally connection of numerous discrete construction project IT systems to systems used in the material supply chain, enabling the assurance and compliance evidence for a safety critical product such as reinforcing steel to be utilised throughout the process.

This is laying the foundation to create a digital twin of the built assets with accurate reinforcing steel information being traced from as-designed 3D Building Information Management models (BIM) through manufacturing, robotic-driven fabrication and installation, to as-built BIM models for handover.

Upfront 'embodied' carbon emissions – measured as its Global Warming Potential (in CO2e per tonne of reinforcing product) - and other environmental data, held within a fully verified Environmental Product Declaration (EPD) will flow through this system enabling the easier identification and selection of lower emission concrete reinforcement and the accurate calculation of asset level embodied emissions. This in turn can improve the scores available within 'Green' building and infrastructure rating systems and can support sound decision making in the race to Net-Zero.

Keywords:
Reinforcing Steel; Net-Zero; Environmental Product Declaration; Certification; Embodied Carbon, Digitisation, Building Information Management Models (BIM)

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DRIVERS AND CONTEXT

At the time of writing in February 2022, 193 parties had ratified, accepted, approved or are in the process of accession to the 2015 Paris Agreement. The agreement seeks to mitigate the worst risks of global heating, by securing Nationally Determined Contributions (NDC's) from each party, which together seek to limit Greenhouse Gas (GHG) emissions such that global temperature rise this century will be kept to well below 2 degrees Celsius above pre-industrial levels and to pursue efforts to limit the temperature increase even further to 1.5 degrees Celsius.

This has been followed by numerous 'Net-Zero' declarations. Figure 1 below is an extract from netzerotracker.net which tracks net-zero declarations across all countries, territories, every region in the largest 25 emitting countries, and all cities with over 500,000 population. It also tracks the top 2000 publicly listed companies. The data clearly shows that most emissions and a growing proportion of sources are now covered by commitments to decarbonise.

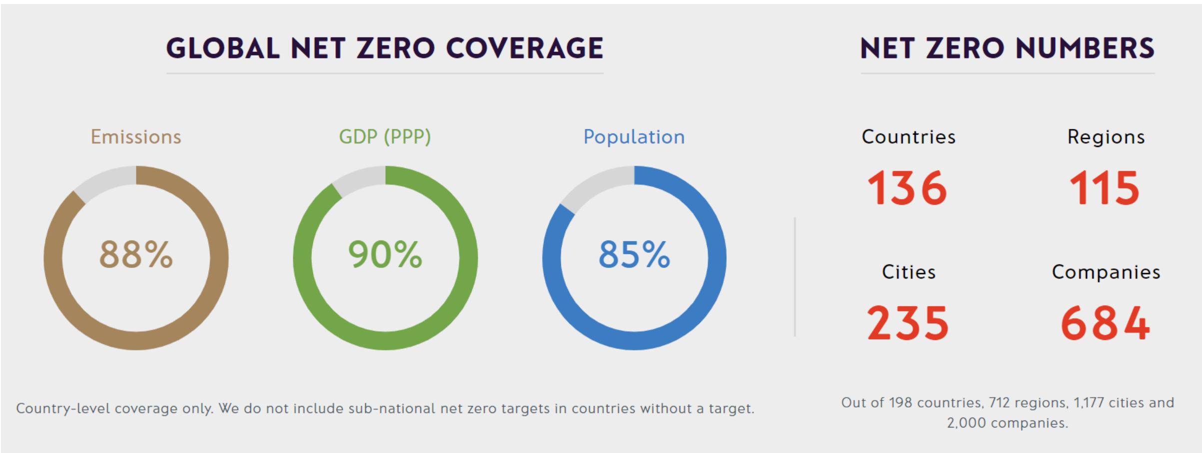

Figure 1: Extract from netzerotracker.net showing Net-Zero commitments

The construction industry is no exception, with many construction clients and building developers adopting Net-Zero targets. This is unsurprising considering that according to the United Nations Environment Programme and the Global Alliance of Buildings and Construction [1] overall, buildings and construction accounted for 36 per cent of global energy demand and 37 per cent of energy related CO_2e emissions in 2020. 10% of which resulted from manufacturing building materials and products such as steel, cement and glass. This includes the fall in emissions related to the Covid-19 pandemic. Emissions are rising once again as Covid-19 lockdowns are relaxed as economies and industrial activities, scale back up, mainly in developed nations [2].

Importantly, if net-zero ambitions are to be achieved, and costs are to be minimised, early actions are needed. As the International Energy Agency puts it 'Staying on [the roadmap] requires the massive deployment of all available clean energy technologies – such as renewables and energy efficient building retrofits – between now and 2030' [3]. This is recognised by the construction industry and has led to a period of intense activity in declarations, target setting, transition pathways and standards development.

Major infrastructure agencies and projects have set CO_2e emission short, medium and long-term reduction targets out to 2050. For example, HS2 – a new £100 billion high speed electric rail route in the UK [4] has set targets to decarbonise its corporate activities by 2025, deliver a 50% reduction in emissions by 2030 and net-zero construction and operations by 2035. The UK National Highways [5] has defined a trajectory of 0-10% reduction by 2025, 40-50% by 2030, 70-80% by 2035 and net zero by 2040 against a 2020 baseline for maintenance and construction.

This is mirrored in many geographies globally, for example, the Australian headquartered, globally integrated real estate and investment group Lendlease has adopted a net zero carbon emissions target by 2025 and an absolute zero target by 2040. Daito Trust Construction Co., Ltd. headquartered in Japan commits to reduce absolute scope 1 and 2 GHG emissions 55% by 2030 from a 2017 base year and Multiplex Constructions Middle East to reduce absolute scope 1 and 2 GHG emissions 63% by 2033 from a 2018 base year. All firms have additional scope 3 reduction targets and the targets have been approved by the Science Based Targets Initiative (SBTI) [6].

Demand led initiatives such as SteelZero, convened by The Climate Group [7], brings together construction and property members who commit to reducing carbon emissions from their procurement, specification or stocking of steel by 50% by 2030 and 100% by 2050. A similar initiative, ConcreteZero, has been formed for Concrete. Architects Declare, Engineers Declare and other similar movements from all construction disciplines have now come together under the BuiltEnvironment Declares movement, through which commitments to take positive action, cooperate internationally and share open-source knowledge, have been made by over 7000 members globally [8]. Standards and specifications like PAS 2080: Carbon Management in Infrastructure, are being revised and refocused on accelerating emissions reductions in line with the science and transition pathways [9].

DATA CHALLENGES AND OPPORTUNITIES

This rising demand serves to highlight significant challenges in data provision and how the digital exchange of Global Warming Potential (GWP) data from construction materials suppliers with design engineers, fabricators, contractors and clients can be part of the solution.

Concrete reinforcement is ubiquitous, as it constitutes a part of many building and infrastructure projects. Being made from materials produced by the two highest emitting industries, steel and cement, it offers an obvious target for decarbonisation. Steel production is estimated to be responsible for 7- 9% of global warming emissions, according to the World Steel Association (worldsteel) [10] and cement 8% according to research by Chatham House [10]. worldsteel also estimates that out of a global steel production of 1,768 Mt in 2019, 52% was used in buildings and infrastructure [12]. Data for reinforcing steel production is harder to come by, with estimates of approximately half of this being used for concrete reinforcement.

The carbon emissions associated with the production of reinforcing steels are critical to the steel industry and will be part of any modern steel producer's performance monitoring. However, providing a full life cycle picture of emissions including transport from steel producer to fabricator and from fabrication, installation and end of life management, may not be available to engineers, designers and specifiers. When data is available it may not be comparable unless based on Life-cycle analysis (LCA) to defined international standards, notably ISO 14040:2020 ISO 14044:2006 and reported within Environmental Product Declarations (EPD) in accordance with EN 15084: 2019 (Sustainability of construction works).

Often generic data based on averages of the GWP of this steel is used to calculate the embodied emissions. The actual emissions of reinforcing steels used in projects can vary considerably, dependent of project location, the steel production route used to produce the steel, the amount of renewable generation in the national grid, energy inputs used at the production site and other factors. For example, the worldsteel average GWP (expressed as tonnes CO_2e per tonne of steel product) in 2020 is 1.85 [12]. The range of GWP from EPD from steel producers approved to the CARES Sustainable Constructional Steels (SCS) certification scheme is from approximately 0.39 to 2.58 [14]. Approximately 80% of the approved steel producers are Scrap based Electric Arc Furnace steel producers, of which the CARES sector average of these is 0.76 [15].

While most carbon emissions are from steel production, transport between steel producers and the carbon emissions from steel fabricators should be included to improve accuracy. CARES has calculated transport GWP data for any given project based on the suppliers and tonnage suppliers. CARES also provides a carbon footprint to EN 15804 for approved steel fabricators. As EPD's and Carbon Footprints are mandatory requirements of the 3rd party verified SCS certification scheme and the EPD's are subject to an additional 3rd party verification by BRE, a high degree of confidence in the data can be provided.

Getting accurate data for a project is clearly important. At concept and design stage, generic averages may offer suitable estimates. When reinforcing steel is being procured and delivered for the project, more accurate data representing Life cycle GWP based on the specific steel producers of the reinforcing steel as per the EPD, transport emission data between steel producer and fabricator and carbon footprint data from fabricators should be applied. When brought into contractor and client systems and combined with data from other products, this enables a better picture of the actual 'as built' upfront, embodied emissions to be gained. If they cannot easily get this data nor bring it easily into their systems, then challenges remain.

DIGITAL CONSTRUCTIONAL STEELS SUPPLY CHAIN

To help address these challenges CARES, as an independent not for profit company, has developed its Cloud and digital ecosystem to securely hold, consistent digital reinforcing product data, which remains associated with the product as it passes through the supply chain. It builds on CARES chain of custody model which provides 100% physical traceability of the product, from the steel producer, transportation to the fabricator, to the construction site and use in reinforced concrete. It provides the foundations for the development of a digital shadow or twin of the product as it passes through stages of production, supply and use. Currently, product conformity data and GWP data is incorporated into the CARES Cloud and this is now being used to drive performance improvements.

Digitisation across the supply chain is accelerating. For the power of this data to drive safety and sustainability objectives, stakeholders must be able to share and access data relevant to their roles. Each stage of the supply chain typically operates numerous discrete IT systems. The CARES Cloud provides secure digital storage of CARES approved reinforcing product data, where the data owners maintain ownership of their own data and its uses. The use and benefits of this nascent ‘digital twin’ flow right through the construction materials supply chain.

Steel Producers

Steel compliance data has been provided in many reporting styles and formats, including paper copies. To support steel producer’s digitisation strategies, and to provide improved data consistency, quality and timeliness, the CARES Cloud enables the automated upload of quality performance test results and certifications at approved production sites. Application Programming Interfaces (API’s) enable automatic uploads from steel producer databases. A dashboard enables steel producers to view their long-term quality levels and EPD data, including the GWP, which is associated with each batch.

Architects and Design Engineers

When construction design engineers are confident in the reinforcing steel yield strength and the other reinforcing steel attributes, they can use less material for any given application. It increases modelling accuracy when developing reinforcement design specifications and supports the use of 3D design applications. Design options can be modelled to understand the structural impact of design changes and can be used to optimise the design, for example, on the mass of materials used, for example, for floors and associated emissions reductions by applying the GWP to the mass of steel used.

Fabricators

Fabrication detailing is similarly enhanced. Applying high quality data to the steel fabrication process helps to improve accuracy, reduce waste, and deliver quicker implementation. The Rebar 4.0: supply chain made smarter study, partly funded by UK Research and Innovation, assessed the feasibility of using digital reinforcement data to drive robotic fabrication, efficiencies and resulting emissions and cost savings [16]. This is especially beneficial when high volumes of standard reinforced concrete sections are needed, such as tunnel segments or precast panels. The study (unpublished) identified additional benefits including reducing fabrication and installation health and safety risks from greater offsite construction and reducing potential exposure to welding fumes.

Contractors

The ability to delivery client carbon emission reduction often rests with its contractors. As cited earlier in this article, they often have their own ambitious emission reduction targets. With steel producer agreement. CARES can provide access digital reinforcement information and data through the CARES App. Scanning of QR codes on bundle labels, supports the tracking of incoming materials, down to a few metres. This helps efficiencies, reduces losses and wastage, with associated emission reductions. Contractors can then bring this into a Building Information Management System, providing information at a structural element level. This approach termed the ‘golden thread’ by Dame Judith Hackett in the ‘Building a Safer’ Future Report, commissioned as part of the enquiry into the Grenfell Tower fire disaster by the UK government, supports building safety [17] as well as carbon emissions reductions.

Asset owners and developers

From the client and contractor perspective, they need confidence that their procured materials will meet their requirements and specifications. Detailed, design relevant, commercial confidential, product quality characteristics can be shared by contractual agreement, between relevant stakeholders. When incorporated into a Building Information Management System, it can become digitally associated with the asset and provides an ongoing record of the materials and their specifications and certifications.

Demonstrating carbon emissions data and effective management of emissions supports higher scoring within building and infrastructure rating systems. For example, the BREEAM New Construction 2018 rating system [18], Mat 02 criteria provides credits for having an EPD available, Mat 03 for the responsible sourcing of construction materials and Mat 06 credits evidence showing how efficiencies have been gained. Similar criteria are contained within many other building and rating systems globally and a number of these are being enhanced with greater focus on carbon emissions and measuring how the built environment can contribute to reductions.

The power of collaboration

Innovation pilot projects have brought together construction clients, design engineers, fabricators and contractors which have demonstrated the potential to connect data held on different Clouds and enhance access opportunities. For any given delivery contractors can be sure it meets the requirements of the defined product conformity standard, this presents an opportunity to reduce overspecification. This can produce considerable material savings, reducing mass, carbon emissions and cost.

The most commonly specified characteristic yield strength of reinforcing steel is 500MPa. However,
publicly available research suggests that the characteristic yield strength of much of the reinforcement in the UK exceeds 500Mpa [19]. Use of higher yield strength reinforcing steel means less reinforcing steel needs to be used. Assuming 520Mpa is specified, the construction project can save up to 4% of the reinforcing steel by mass and carbon emissions in the strength-governed elements. Assuming a market price of £550 per tonne, this equates to a saving of £22,000 for an order of 1000 tonnes. Using the CARES sector average GWP data, this equates to an emissions reduction of 30.4 tonnes of CO_2e.

Industry level uses

This constructional steel data supports the development of industry wide approaches to enable the connection of these discrete data sets within defined conditions to help optimise the supply chain. Certification evidence for a safety critical product, the GWP and other environmental attributes held on EPD for reinforcing steel are all held digitally and are publicly available at both a specific steel producer level and at an industry average level.

Increasingly the costs of carbon are being accounted for in decision making. With the price of carbon within emissions trading schemes having risen consistently, optimising reinforcing steel use, could also represent a further saving. For example, each tonne of carbon emissions, in February 2022, was approximately £87 in the UK Emissions Trading Scheme [20]. If this were to be incorporated into product costs, then the additional cost of these embodied emissions, for a project using 1,000 tonnes of reinforcement would be £87,400. As carbon taxation and the use of these prices to understand potential costs and risk exposure becomes more common, having accurate GWP data becomes more critical.

A further advantage of digital exchange of data and having a digital record in a BIM, is that it better enables modular design and the potential for reuse. Knowing the structural characteristics of a particular concrete slab or modular panel, means it has the potential for reuse in a different application when the current use finishes. Where these options are designed in, whole concrete panels and slabs can be repositioned and repurposed, reducing the need for fabricating new and avoiding the materials and carbon emissions associated with the initial production and even from the demolition and recycling processes.

CONCLUSIONS

Upfront 'embodied' carbon emissions (Global Warming Potential in CO_2e per tonne of reinforcement product) and other environmental data, held within a fully verified Environmental Product Declaration (EPD) can flow through construction supply chains using digital data exchanges. When the data is effectively shared with relevant stakeholders, it enables the easier identification and selection of lower emission concrete reinforcement and the accurate calculation of asset level embodied emissions. This in turn can improve the scores available within 'Green' building and infrastructure rating systems and can support sound decision making in the race to Net-Zero.

This digital exchange of verified GWP data is laying the foundation to create a digital twin of the built assets with accurate reinforcing steel information being traced from as-designed 3D BIM models through manufacturing, robotic-driven fabrication and installation, to as-built asset BIM models for handover to clients.

As efforts to accelerate decarbonising the construction sector grow apace, having accurate digital GWP data is quickly becoming a prerequisite for concrete reinforcement. This data is now available through the CARES Cloud for many geographies and its use can support construction and infrastructure clients commitments to reduce their asset level CO_2e emissions and their wider decarbonisation strategies.

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