CO_2 2.Low carbon

Carbon targets for bridges: a proposed SCORS-style rating scheme

Cameron Archer-Jones and Daniel Green propose a version of the IStructE's 'SCORS' rating scheme for bridges and encourage engineers to adopt carbon targets for their projects.

Introduction

In October 2020, the Institution of Structural Engineers Climate Emergency Task Group published a detailed proposal for a Structural Carbon Rating Scheme (SCORS) for buildings[1].

In this article, the authors adapt the same methodology for application to bridge projects – a Structural Carbon Rating Scheme for Bridges (or SCORBS). The rating scheme has been informed by analysis of COWI project carbon data and can be used to communicate the carbon performance of a bridge project or a set of design options.

As per the original SCORS proposal, the authors also reinforce 'the need to adopt (and hold ourselves to) low targets that are periodically updated and that tend towards zero, starting immediately'.

SCORS for bridges

Using SCORBS

Figure 1 shows the SCORBS rating 'sticker' suggested for use by bridge engineers in communicating the carbon performance of the designs we produce to those we work with and for.

The SCORBS rating of a design, an asset, or a company's portfolio of work is based on the estimated A1–A5 emissions of the primary structure (superstructure plus substructure, including foundations) and the superimposed dead load, calculated in accordance with *How to calculate embodied carbon*[2] (HCEC). The carbon footprint is normalised in line with PAS 2080[3] cl. 7.1.2 using the functional area (FA) of the bridge deck **(Figure 2)**.

Bridge assets are assigned a letter and a colour between A++ and G depending on the normalised carbon footprint. This rating can be conducted at any stage in design or construction, with the underlying calculation updated to an appropriate level of detail at each stage, as described by Arnold *et al.*1

GLOSSARY

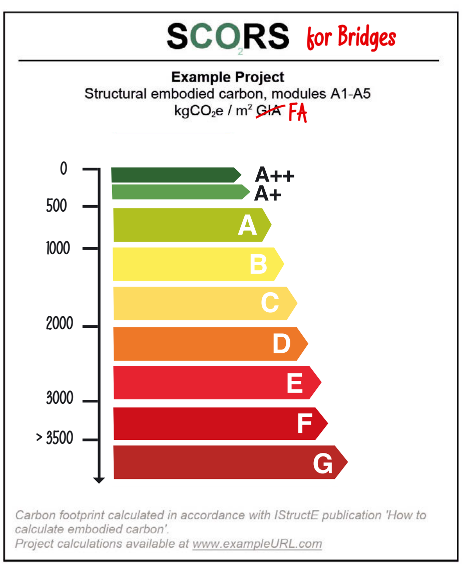
Carbon = Carbon dioxide equivalent emissions – a unit of global warming potential corresponding to 1kg of carbon dioxide ($kgCO_2e$).

CapCarb = Capital carbon associated with construction of the asset, the equivalent to upfront carbon for buildings (corresponding to lifecycle modules A1–A5)

UseCarb = In-use carbon associated with use of the asset by the public (corresponding to lifecycle module B9)

OpCarb = Operational carbon associated with ongoing energy use, maintenance, refurbishment or replacement works (corresponding to lifecycle modules B1–B7)

FIGURE 1: Proposed Structural Carbon Rating Scheme for Bridges (SCORBS)



A final carbon count should be uploaded to a shared database, such as the Built Environment Carbon Database (www.becd.co.uk – in development), to drive progress around industry understanding of carbon.

Infrastructure vs buildings

HCEC outlines extensive guidance for this calculation which is not repeated here. However, it is primarily buildings orientated and some aspects of the guidance should be adapted for application to transport infrastructure projects. For example, superimposed loads, such as surfacing and parapets, should be included for a bridge.

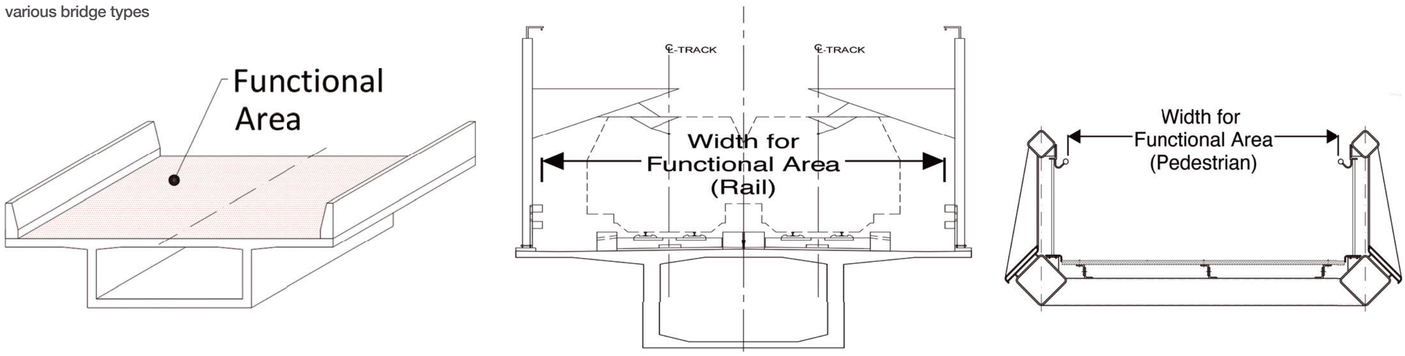
In addition, for A5a emissions, i.e. those due to site activities, explicit calculations should be made rather than relying on a capital cost multiplier. For instance, activities that require significant temporary works or consume large quantities of sacrificial material should receive close attention, as should double-handling of bulk materials over a large site.

It can be difficult to obtain emissions data related to construction site activities, even at a late stage in the project. In the absence of primary data from an active site, a first-principles approach should be adopted, focusing on the most energy-intensive processes.

Communicating with SCORBS

The SCORBS sticker is presented as a communication tool around which stakeholders in a project can have a conversation, regardless of their level of carbon literacy. An A rating in green or an F rating in red gives context through instantly understandable cues. The normalisation of the results and transparency of the rating

FIGURE 2: Functional area depicted for various bridge types



will give users confidence that the assessment in front of them is meaningful and free of greenwash.

Structural engineers might use the rating to communicate the implications of design decisions to clients. Clients might use it to incentivise emissions reductions and publicise their sustainability credentials. Businesses might use it to track the performance of their portfolio over time and set internal targets.

For simplicity, no differentiation is made between the use-case for different bridge structures. An A rating corresponds to a score between 500 and 1000$kgCO_2e/m^2$ regardless of whether the bridge carries highway, pedestrian or rail loading.

It is important that the SCORBS rating is presented clearly, as a measure of the performance of the bridge design in delivering a perceived benefit. It does not represent a holistic appraisal of the overall carbon impact of the project, but it does meaningfully reflect the performance of the structural design in isolation.

What does 'good' look like for a bridge?

The intention of the SCORBS rating is to clearly communicate to all stakeholders in a project how 'good' the project's carbon performance is. To appropriately incentivise users, it is important that 'good' is related to the net-zero objective, even if this might reflect negatively on typical practice in 2021.

Current UK industry targets

Unlike in the building sector (RIBA, LETI), no industry-level guidance currently exists for appropriate carbon targets on individual transport infrastructure projects.

An Infrastructure Task Group is currently developing a Whole Life Carbon (WLC) Roadmap for the UK Green Building Council (UKGBC), with the intention to report in time for COP26[4]. This will provide a science-based trajectory for reducing infrastructure emissions in line with a 1.5°C target, against which major projects may be assessed and prioritised. One must presume that the inevitable conclusion of this process will be the allocation of WLC budgets for all major projects in the near future.

However, assessments of WLC in transport infrastructure are typically dominated by UseCarb and modelling of speculative traffic flows far into the future[5]. This is unhelpful in some respects for the practising bridge engineer, as the UseCarb is not a measure they can easily influence, but it obscures the certain impact of CapCarb emissions, which they can. Approx. 1% of total UK emissions are attributable to CapCarb emissions specifically on infrastructure projects[6].

Consequently, we follow Arnold *et al*. and choose instead to define a 'structural carbon' target, excluding UseCarb and OpCarb since a design team can only be incentivised to optimise a parameter that is under its control.

Drilling down further into CapCarb emissions specifically, the recent UKGBC public consultation document implies loosely that its roadmap will be calibrated based on assumed reductions in CapCarb intensity ($kgCO_2e$/£ spent) of approx. 30% on 2018 levels by 2030. Incorporated in this figure are allowances for increased material efficiencies, decarbonisation of site activities and transport, and reductions in the carbon intensity of steel and concrete production through use of carbon-capture technologies. Furthermore, there is an implicit subsidy assumed from a nominal allocation of carbon offsets which are attributed to the built environment in order to meet the final net-zero target.

Meanwhile, the Highways England 'Net Zero Highways' plan published earlier this year targets an overall 40–50% reduction in CapCarb emissions by 2030, reaching net zero (with only 5% residual offsetting) by 2040[7].

First-principles approach

In the absence of a definitive roadmap for CapCarb in transport infrastructure, a first-principles approach is proposed.

- We know that adherence to a 1.5°C compatible pathway requires a far greater rate of change in the period from now until 2030, with perhaps 50% of emissions reductions required in the next eight years, and the remaining, incremental savings eked out over the following two decades.
- We cannot be certain what allowance, if any, will be available for continued CapCarb emissions through unproven carbon offsets in 2050. In this respect, we believe it is prudent to adopt the 'Absolute Zero' philosophy espoused by UK FIRES (AZERO)[8]. This report is particularly dismissive of the prospect that technological solutions will provide answers to the construction industry's challenges in the short term.

We believe this is a reasonable characterisation of the challenge for the UK infrastructure industry, including the bridge community.

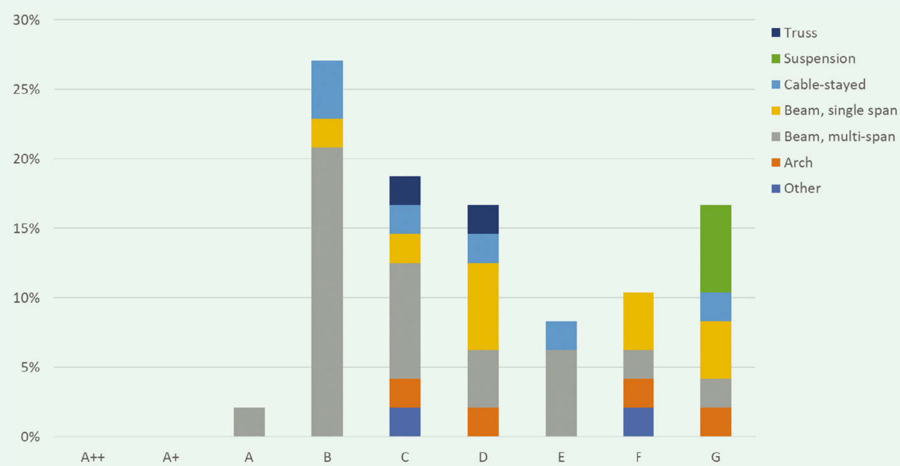
The implication is that change must occur immediately in the way we use the tools we already have. Continued emissions at current levels will exhaust the remaining carbon budget within approx. 10 years. (In the UK, CapCarb expenditure on infrastructure remained consistent from 1995–2018[9]). Post-2030, technological development in material production will be crucial to reduce emissions; however, over the next decade at least, a large proportion of existing CapCarb emissions must be eliminated through immediate changes in day-to-day practice, or a reduction in construction activity.

This sentiment is reflected in AZERO, which identifies a 2050 pathway for construction where savings are driven through material efficiency prior to 2030 and the phasing out of conventional materials from then on.

We want SCORBS to communicate this trajectory in a meaningful way. SCORBS therefore broadly follows SCORS and is calibrated such that:

- average current practice delivers a high D/ low E rating, leaving some room for negative differentiation down to a G rating
- by 2030 the average rating must reach a minimum of a B, with individual projects routinely aiming for better. This is an ambitious but plausible aim using current materials and

↘**FIGURE 3:** Histogram of SCORBS ratings for bridge structures in COWI's dataset



careful planning
- by 2050 the average rating must reach A++, corresponding to near-zero carbon emissions that might feasibly be offset.

Benchmarking SCORBS

The calibration of the of the SCORBS rating scheme is based on recent carbon footprint studies carried out on both historical and current COWI projects **(Figure 3)**. For an example of the embodied carbon calculation and output, see 'Design and construction of Hams Way Footbridge, Worcester'[10].

The COWI project carbon database is expanding rapidly, and currently includes a large number of completed bridge designs, encompassing a span range from 10m to >2000m, plus varying structural systems, design loads/standards and locations.

To date, we have focused on new bridges, but have also started deriving CapCarb associated with strengthening schemes, although these have not yet been included in the database due to limitations in defining the functional benefit to normalise CapCarb.

To derive construction emissions, this study adopts a first-principles approach based on various sources. For example, the fuel use and plant gangs characterised in SPONS[11] were used to quantify emission factors per unit of material processed on site.

The average carbon intensity for a bridge in the dataset is 2300kgCO_2e/m^2 with some clear dependencies including:

- **span length:** found to be strongly proportional to carbon intensity, except for very short spans. This dependency makes separating the influence of the structural system (e.g. girder vs cable-stayed) on the carbon intensity difficult, since the structural system is also proportional to the required span length.
- **principal superstructure material:** steel and composite steel-concrete bridges (2570kg/m^2) typically have a greater carbon intensity than concrete bridges (1590kg/m^2).
- **loading type (road, rail, pedestrian, etc.):** no clear proportionality is observed within the current dataset; however, it is acknowledged that more data is required to isolate the influence of the loading type with consistent span lengths.

These key statistics and trends generally match similar results documented in a recent study titled 'The Carbon Footprint of Bridges'[12]. This study also focuses on A1–A5 modules, drawing upon carbon data from 200 different bridge structures, and documents an average carbon intensity of 2420kgCO_2e/m^2.

To date no attempt has been made to quantify the uncertainty in the carbon calculations themselves. These generally rely on published industry-average carbon factors for material manufacture (modules A1–A3), fuel consumption and typical construction activities (modules A4 and A5).

This weakness when compared with a detailed lifecycle assessment is acknowledged; however, the approach used in this study is still strongly advocated due to its relative simplicity. This approach allows the engineer to complete carbon calculations very early in a project lifecycle, while also helping to establish 'rules of thumb' for reasonable levels of carbon intensity, much like steel tonnages for bridge decks.

Setting targets

The end game isn't to compile the largest database, but to use the data to help develop bridge designs with the lowest possible embodied carbon. To improve quickly, this requires ambitious targets to be established within design offices and project teams. SCORBS provides a framework for setting these targets, but it must be used in the context of carbon management processes similar to that defined in PAS 2080[3].

Target 2030

To meet the 2030 target, all structural/civil engineers need to start quantifying the embodied carbon in their schemes now, and this calculation needs to be integrated within the engineering design, not tacked on at the end. The practical steps required can be broken down as follows.

Understand your references

There are a growing number of very useful reference documents to help an engineer understand, quantify and manage carbon within their portfolio. For anyone venturing into this space, the IStructE's 'Climate emergency' material is an excellent starting point **(www.istructe.org/climate-emergency/)**.

For the bridge engineer, the HCEC guide is currently being revised to include additional bridge-specific guidance. It is particularly important to remain aware of limitations with any of the guidance material in relation to key carbon data (e.g. assumed recycling rates, sustainability of cement replacements).

Prioritise areas to focus on

Once there is an initial embodied carbon estimate for a project, this needs to be broken down into useful components to focus optimisation effort. The authors recommend segregating the calculation such that the contributions from different materials, components or sub-systems can be compared.

For example, it would not be unrealistic to find that a significant portion of the CapCarb of a bridge that crosses navigable water is locked up in substructure elements governed by ship impact loading. This may provide a strong driver to revisit the concept, or carry out a probabilistic assessment using recorded shipping data with a view to reducing the overall carbon.

Set targets

With the capability to perform calculations in place, it is then important to set incremental and progressive targets for project carbon performance using SCORBS. To reach the 2030 target, a 10% saving in a typical project year on year, every year, is required.

This is only part of the solution though. To successfully implement these changes, your organisation must treat the process as a critical business function. You might consider driving behaviour through internal targets for the uptake of carbon calculations, targets for communication with clients, and targets for the sharing of data both internally and externally.

Low-carbon design philosophy

Achieving consistent incremental carbon performance targets will be hard. The IStructE's low-carbon design philosophy can help as it

➘ **FIGURE 4:** Repeated 70m post-tensioned concrete approach viaduct with optimised cross-section achieved mid-B rating with SCORBS

sets out a practical approach to reducing carbon in designs with a hierarchy of: i) minimising material use; ii) specifiying low-carbon materials; iii) and, lastly, considering offsetting. The typical road bridge depicted in **Figure 4** is an example of an efficient span length being adopted with an optimised cross-section to achieve a low normalised CapCarb.

Beyond 2030

The steps set out above will only get us so far. To go beyond the 2030 target of 50% carbon savings compared with 2020, we need to lay the groundwork for future carbon savings. Key actions required include:

- upskilling/re-skilling to focus on refurbishment. e.g. the strengthening of Melbourne's West Gate Bridge **(Figure 5)** increased the trafficable width along the bridge by 5m, and would be rated A in SCORBS
- investigating novel materials or novel approaches to established materials, focusing on pragmatic solutions with timescales that are compatible with the 2050 net-zero timeframe
- taking every opportunity to provide test cases for innovative new materials, e.g. fibre-reinforced polymer footbridge prototype shown in **Figure 6**, and share the learning and results with others
- working with the whole supply chain to embed circular economy principles into projects.

Conclusions

This article demonstrates the urgency of the need for bridge engineers to consider CapCarb and proposes a rating scheme to measure the performance of the designs they produce. The scheme intentionally follows the rating system proposed by Arnold *et al.*[1] and, in a similar vein, we are calling on our colleagues and industry bodies to adopt this.

We recognise the variability of project constraints, e.g. site geometry, intended use, design standards, etc., but using a rating system like SCORBS provides the framework to challenge the brief, champion rehabilitation, carry out further design refinements, and/or propose alterations to the preferred construction sequence in order to save carbon.

The targets outlined above are daunting as they represent a major challenge to the status quo. However, we should be cognisant of the

➘ **FIGURE 5:** West Gate Bridge refurbishment (Melbourne) including widening, strengthening, Bridge Specific Assessment Live Loading (BSALL) to increase trafficable deck area and performance of existing asset

FIGURE 6: Fibre-reinforced polymer footbridge prototype (FUTURA) included in COWI database

fact that we are starting from a low bar. The construction industry is known to be wasteful, and the authors' experience suggests that, with concerted effort, 30–40% carbon reductions are plausible on many projects today when compared with typical reference designs.

With collective action we can also look ahead beyond 2030 to achieve greater carbon savings and support the movement to control global warming. Any readers seeking to collaborate with a bridge-specific focus within the IStructE's Climate Emergency Task Group are asked to get in touch at **climateemergency@istructe.org**

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Acknowledgements
The authors would like to thank our colleagues at COWI for their support, in particular Olivia, Floss, Marcus, Maya, Freya, Yash, Hannah and Katy for their help compiling the COWI project carbon database.

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