Technical Position Paper

Structural concrete and global greenhouse gas emissions

The Institution of StructuralEngineers

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This paper outlines the Institution's recommended approach to minimising greenhouse gas emissions when designing and specifying concrete.

It sets out the routes by which concrete production is responsible for carbon emissions, the three main ways in which such emissions can be reduced (by reducing concrete volumes, cement quantities, and changing to lower-carbon cements), and proposes a series of recommendations for structural designers and policymakers.

The paper's scope includes use of concrete for all structural applications globally, but it is recognised that the authors' most direct experience is based in the UK.

The paper does not consider other aspects of sustainability such as human rights or biodiversity loss, nor does it tackle the question of whether concrete is the right material for a particular design.

Recommendations

The Institution recommends that structural designers should:

1. **Support and inform clients in setting appropriate carbon targets** for their project, explaining the concepts in this paper to avoid overambitious and unachievable targets being agreed – and acknowledging the need to reduce carbon at both a project scale and the global scale.
2. **Where concrete is to be used, do so as efficiently as possible** to balance concrete strengths and volumes to minimise overall emissions. Work collaboratively with the wider design team, from the start of the project, to identify key design decisions that **follow the Institution's Hierarchy of Net Zero Design**[1], enabling inherent efficiencies from aspects such as closer column spacing, straightforward load-paths to ground, more efficient floor systems (e.g. waffle slabs, post-tensioning, vaults), and reduced use of basements – all in conjunction with considering strengths and cement contents.
3. Specify concrete to **minimise the amount of Portland cement used**. Consider the use of performance specifications, developed in collaboration with the supply chain, to encourage the full use of locally available methods of reducing emissions – including reduced reliance on early strength gain or workability.

continued overleaf...

[1] https://www.istructe.org/resources/blog/the-hierarchy-of-net-zero-design/

4. **Avoid reliance on constrained and highly-utilised secondary cementitious materials (SCMs)** such as ground granulated blast furnace slag (GGBS), referring to the cross-industry paper on the use of GGBS in reducing global emissions[2]. Work with clients to set out other options to constrained SCMs (such as in points 1-3) from the outset of the project.
5. **Work with the supply chain to source the lowest-carbon Portland cement (PC) possible**[3] based on recognised rating schemes where possible[4]. Encourage the use of innovative technologies to accelerate upscaling where appropriate, noting that these may not yet be covered by codes of practice.

The Institution recommends that policymakers should:

1. **Understand how concrete emissions relate to your country's net zero pathways (and consumption-based footprint)**, forecasting future concrete use and emissions, and thus concrete's emissions relative to your net zero trajectory.
2. **Set policies that require the construction industry to seek the lowest carbon concrete** feasible on projects[5], but **without over-using SCMs** that are already constrained and highly utilised, such as GGBS[1].
3. **Create market conditions to incentivise investment** in novel technologies, such as those outlined in the Institution's concrete technology tracker[6].
4. **Incentivise the creation of industry guidance and upskilling** relating to the reduction of concrete volumes, reduction of PC use in concrete, and use of lower-carbon PC.
5. Use **publicly funded projects to accelerate the adoption** of the policies contained within this paper, where appropriate to do so.

Context

Concrete production is responsible for 7% of global carbon emissions[7], and so minimising concrete-related emissions is key if the world is to decarbonise on a 1.5° trajectory and reach net zero by 2050.
Concrete is typically made locally to the place where it is used, and so issues and solutions can vary by location, however this paper discusses themes that are shared globally. More information as to the origin of carbon emissions for concrete can be viewed at the Institution's website[8].

Most of the emissions related to concrete come from the production of Portland cement ('PC'), often referred to as CEM I by the concrete sector. Figure 1 shows typical emissions related to a single block of concrete.

From the emissions related to PC production around the world, approximately:

- 10% are linked to the use of electricity (so relatively easy to decarbonise)
- 30-40% are linked to the burning of fuels to create heat (harder to decarbonise)
- 50-60% are from the chemical reactions during the process (which cannot be avoided)

[2] GGBS is a constrained and highly utilised global resource. Specifying more than a 'fair share' on one project will result in someone else using less, meaning that whilst global supplies must continue to be fully utilised, any local increase in the amount of clinker substituted with GGBS is unlikely to decrease global emissions. Refer: www.istructe.org/resources/guidance/efficient-use-of-ggbs-in-reducing-global-emissions/

[3] For example, through the use of the ConcreteZero specification guidance: www.theclimategroup.org/concretezero-publications

[4] This article from The Structural Engineer provides an overview of three such schemes: www.istructe.org/journal/volumes/volume-103-(2025)/issue-3/classifying-the-embodied-carbon-of-concrete/

[5] For example, the Industrial Deep Decarbonisation Initiative seeks to accelerate the use of low-carbon concretes on government projects, though we note that it does so in conflict with the GGBS footnote below. decarbonization.unido.org/projects/iddi/

[6] www.istructe.org/resources/guidance/concrete-technology-tracker

[7] gccassociation.org/cement-industry-net-zero-progress-report-2024-25/

[8] https://www.istructe.org/resources/guidance/arup-material-guides/

The use of steel reinforcement to create reinforced concrete typically adds a further 20% to the total emissions, compared with unreinforced concrete. Steel is not covered in depth in this paper, refer to the institution's paper on steel[9]. Emissions related to the use of formwork should also be considered – *How to calculate embodied carbon* gives more information on this[10].

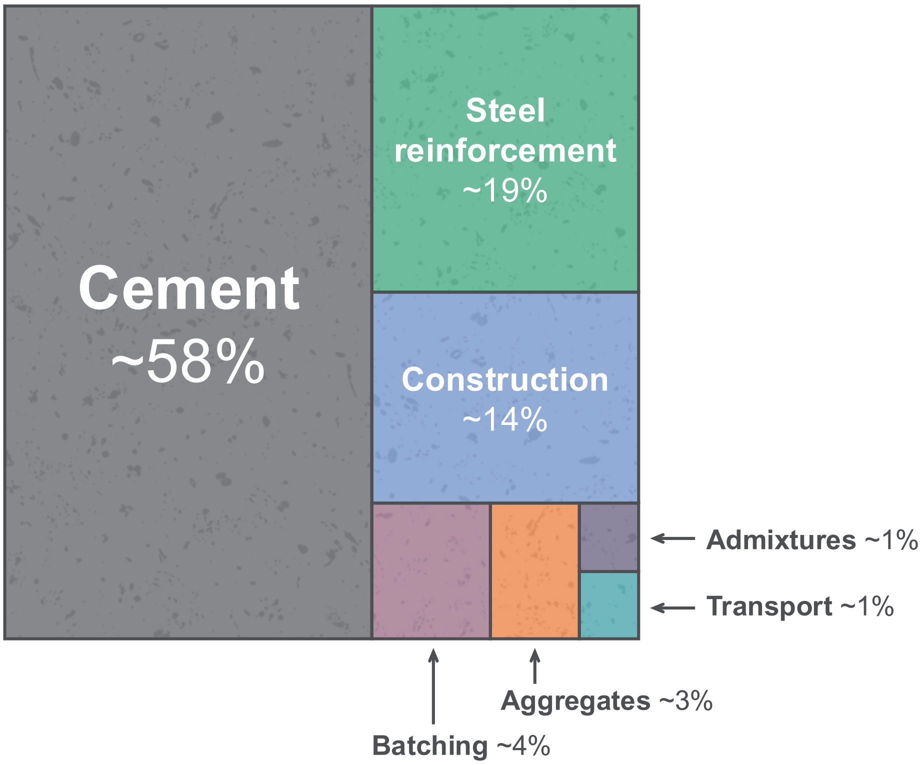

Figure 1: Greenhouse gas emissions for a typical block of concrete

Reducing greenhouse gas emissions related to structural concrete at a global scale

There are three main routes to reducing concrete-related emissions.

1. Reduce the volume of concrete

Existing technologies and construction methods can be used to reduce concrete volumes. This includes reuse of existing structures, reduced span lengths, simple structural configurations, and avoiding the use of basements in most circumstances[11]. It also includes using the most efficient floor system possible in each situation – a waffle slab uses around half the amount of concrete that a flat slab does; similarly, post-tensioning can be an effective way to reduce thicknesses.

Note that in some instances, reducing volumes may not reduce emissions, if this results in an increase in use of cement (e.g., due to increased need for early age strength or workability) that outweighs the saving in concreate volume. Embodied carbon calculations should be used to identify the lowest-carbon balance.

For more information on the efficient use of concrete, refer information on the Institution's website[12], and the Mineral Products Association[13].

[9] https://www.istructe.org/resources/guidance/technical-position-papers-materials-and-emissions/

[10] www.istructe.org/resources/guidance/how-to-calculate-embodied-carbon/

[11] Note that there are sometimes situations where the addition of a basement can bring overall material efficiencies (e.g. where excavation is needed anyway, or buoyancy created by a basement reduces foundation forces).

[12] For example, refer www.istructe.org/journal/volumes/volume-99-(2021)/issue-10/marginal-gains-carbon-in-concrete-buildings/

[13] www.concretecentre.com/Resources/Publications/Specifying-Sustainable-Concrete.aspx

2. Reduce the amount of Portland cement in the concrete.

Minimum cement contents are determined by requirements such as strength, durability, workability, visual finish – review these to check that the strength class and minimum cement content specified is not too onerous. Contractors will often need to add cement beyond the minimum to increase early strength gain or workability[14] – designers and contractors should collaborate to determine the optimum mix for each project[15].

PC can often be replaced with other secondary cementitious materials (SCMs). The most common are ground granulated blast furnace slag (GGBS) and pulverised fly ash (FA). However, GGBS is a globally constrained material that is already near-fully utilised, and so increasing its use in one location will not reduce global emissions. For more information on this, refer to the cross-industry paper on the use of GGBS in reducing global emissions[1]. FA is likely to be constrained in the future, if it is not already; certainly in the UK it is already very limited. As of yet, no-one has been able to yet prove the viability of use of stockpiled FA. Both GGBS and FA are also co-products of polluting industries that will be phased out.

Alternative SCMs such as pozzolanas, limestone fines, and calcined clays, exist around the world and are abundantly available. Many such SCMs are not yet commercially available, but will scale if investment and interest is accelerated. As such, they should be used to replace PC where appropriate to do so, in a way that the wider industry can learn from. Updates to various codes of practice allows the codified use of many SCMs (e.g. in the UK, BS 8500 now allows ternary blends including limestone fines[16], and Flex 350 sets out testing regimes for non-standard mixes[17]) and some multi-component mixes such as "LC3" have been shown to increase mix efficiencies[18]. Novel SCMs are also being developed, for more information on these, refer to the Institution's concrete technology tracker[19].

It is possible to replace PC entirely, such as by using alkaline activated cementitious materials (AACMs). These technologies only exist at small scale at the moment, and current commercially available AACM technology relies on GGBS which isn't scalable, due to its global constraints. It is possible that in the near-future, AACMs using other materials (e.g. calcined clays) could be scaled to reduce reliance on GGBS for these technologies.

3. Use lower-carbon Portland cement

Existing technologies can reduce the emissions related to producing PC, such as more efficient kilns, or the use of lower-carbon fuels.

Carbon capture, utilisation and/or storage (CCUS) is also recognised as likely to play a role in enabling existing methods of cement production to continue without releasing current levels of carbon emissions into the atmosphere. However, there is currently no indication that CCUS will scale up as fast as is needed in the next decade, and it is noted that current methods of carbon capture are highly energy intensive. Separately, we note that some "Novel SCMs" discussed in the previous section are created by utilising or storing carbon dioxide that has been captured. This carbon mineralisation offers good future potential for CCUS, overcoming the need to transport and store carbon dioxide in liquid or gas form.

At a global level, the largest overall emissions reductions will occur when zero-carbon PC and/or PC-free concretes become commercially available. However, no such material is yet available at scale today, and so at a project scale, the order of interventions shown above reflects the level of opportunity for reducing emissions – with reducing the volume of concrete providing the biggest short-term opportunity.

[14] Water is added to improve workability – which then requires further cement to be added to maintain the water:cement ratio.

[15] Refer BS 8500 guidance also: www.concretecentre.com/Resources/Publications/How-to-design-concrete-structures-using-Euroco-(3).aspx

[16] www.concretecentre.com/Structural-design/Standards/Standards-for-concrete.aspx

[17] www.concretecentre.com/Structural-design/Standards/BSI-Flex-350.aspx

[18] www.LC3.ch

[19] www.istructe.org/resources/guidance/concrete-technology-tracker

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