2.Low carbon

How can we reduce the embodied carbon of structural concrete?

Paul Astle explores potential ways in which engineers can seek reductions in the embodied carbon of structural concrete.

Structural concrete underpins our society and, arguably, our profession. However, we must make changes in how we specify, design and use this material if we are to meet the increasingly urgent carbon reduction targets that are required. This article focuses on the embodied carbon in structural concrete once its use has been optimised, considering key questions that engineers may ask.

Figure 1 sets out the breakdown of embodied carbon (modules A1–A5) associated with 1m^3 of a typical structural concrete (RC 25/30)*.

Most of the embodied carbon is associated with the cement, followed by the steel reinforcement. The aggregates, while accounting for approx. 80% of the mass, account for less than 5% of the carbon. As such, when it comes to carbon reduction, it is the cement and steel that we, as engineers, should focus our attention on – although we aren't the only ones that have an influence.

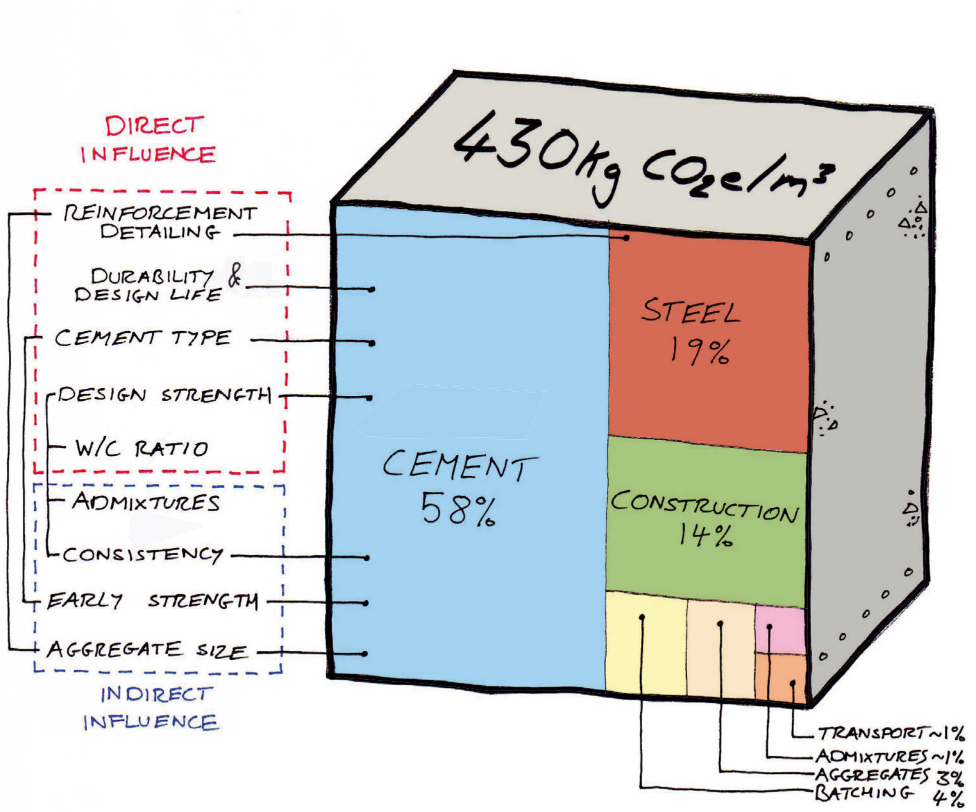

FIGURE 1: Breakdown of carbon in 1m^3 of structural concrete and influences that affect it

Can we just reduce the carbon intensity of Portland cement?

The carbon emissions in Portland cement (PC) comprise, approximately, 10% kiln operations, 40% thermal energy, and 50% associated with the chemical decomposition of limestone ($CaCO_3$) into lime (CaO). It is possible to reduce the carbon associated with kiln operations, and substitute fuel in the thermal energy; however, the release of process CO_2 cannot be avoided in the production of PC. As such, the cement industry is relying heavily on carbon capture and storage to reduce emissions in the future[1], although this is not yet commercially viable.

Can we just replace the PC?

Many readers will be familiar with the use of supplementary cementitious materials (SCMs) to bring down the carbon intensity of cement. The two most common SCMs, ground granulated blast slag and fly ash, are by-products of steel blast furnaces and coal-fired powered stations, respectively. There is a dwindling supply of these SCMs, which may also become more expensive, but until alternatives are readily available, we should maximise their use.

Many engineers may have also experienced resistance to the use of SCMs when discussing the need for early strength gain and strike time with contractors. Guidance is available which assesses the impact of SCM use on strike time[2]. However, it is always best to discuss this with contractors. It should be noted that excessive rigidity in the use of SCMs can lead to unintended consequences, such as an increase in cement content to compensate for the use of SCMs.

Can we specify maximum cement content?

Suppliers often provide concrete with cement content greater than is needed for the specification, in response

* This is based on the following assumptions: 300kg/m^3 cement with average additions (0.83kgCO_2e/kg); 100kg/m^3 steel (0.84kgCO_2e/kg); water–cement ratio = 0.5; 20mm aggregate; placed *in situ*; 11km transport distance; construction value based on a total construction rate of 30kg/m^2 (250mm concrete/m^2 and 50% emissions allocated to structure).

to contractors asking for a greater consistency than will be achieved with the minimum amount of cement while meeting the water–cement ratio. Increasing cementitious content allows more water and fines, improving consistency and flow.

Furthermore, when we design concrete elements with heavily congested rebar, or a high-quality finish, it is common for contractors to use a smaller aggregate to facilitate placement. Smaller aggregates require a greater cementitious content. Perhaps we need to agree a cement content limit on the project before we start such discussions?

Can we consider actual strength?

Finally, with other drivers such as consistency and congestion influencing cement content, we are often given far more strength in our concrete structures than we assume in our designs. Could we engage with the contractor to agree concrete strengths aligned with the construction needs – leading to less reinforcement or smaller elements?

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The engineer’s role

As engineers, we have huge influence on the amount of embodied carbon in concrete, but our specifications must not be written in isolation. We must engage with contractors, subcontractors, suppliers and clients to make sure that, collectively, we realise the carbon reductions we all need to make. This may require us to change how we design and build, but will ultimately leave us with lower-carbon solutions.

HAVE YOUR SAY

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REFERENCES

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2) Concrete Society (2011) *TR 74: Cementitious materials: The effect of GGBS, fly ash, silica fume and limestone fines on the properties of concrete*, Camberley: Concrete Society