ice

Knowledge

The Green Construction Board

Low Carbon Concrete Routemap

Setting the agenda for a path to net zero

Low Carbon Concrete Group
The Green Construction Board

ice.org.uk

The concrete challenge

Concrete is the most used material on the planet. It is strong, durable and the constituents are abundant almost everywhere. We rely on many forms of concrete each day, from pavers that we walk on to high-performance structural concrete used in our tall buildings and infrastructure. It is an incredible material that has supported the development of our societies and improved the quality of life for billions of people.

Concrete is made up of three main constituents:

- Aggregates (gravels and sands) 70%-80%
- Cement (the active ingredient) 10%-20%
- Water (which reacts with the cement) 5%-10%

Up to 90% of the greenhouse gas (GHG) emissions associated with concrete are in the cement

Conventional Portland cement is made by heating limestone and clay and grinding it into a fine powder. The process of heating and decomposing the limestone releases about 0.86kg CO_2e1 for every 1kg of cement produced. This is partly down to the chemical process as well as the energy involved in heating the limestone.

UK CEMENT CONSUMPTION

11.7Mt
UK cement consumption per year[1]

9Mt
CO_2e per year[2]
Equivalent to emissions from **7.2 million** cars (assumes 125kg CO_2e/km and 10,000km/year)

1.5%
UK GHG emissions (2018)[3]
8% global GHG emissions (2018)

22,500,000m³
Ready-mixed concrete[2]

\+

Other cement-based products
Precast concrete, mortar, architectural items, ground improvement techniques, furniture, etc

The challenge we face is how to continue to use concrete when the active ingredient in it is such a potent source of greenhouse gas emissions

1. European Ready Mixed Concrete Organization – ready-mixed concrete industry statistics 2018. Table 2a.
2. Based on final UK greenhouse gas emissions national statistics. UK Government document, BEIS, 2021 and industry statistics.
3. Based on UK's carbon footprint 1997-2018. UK Government, DEFRA, 2021 and consumption emissions using refs 1 and 2.

A zero carbon future

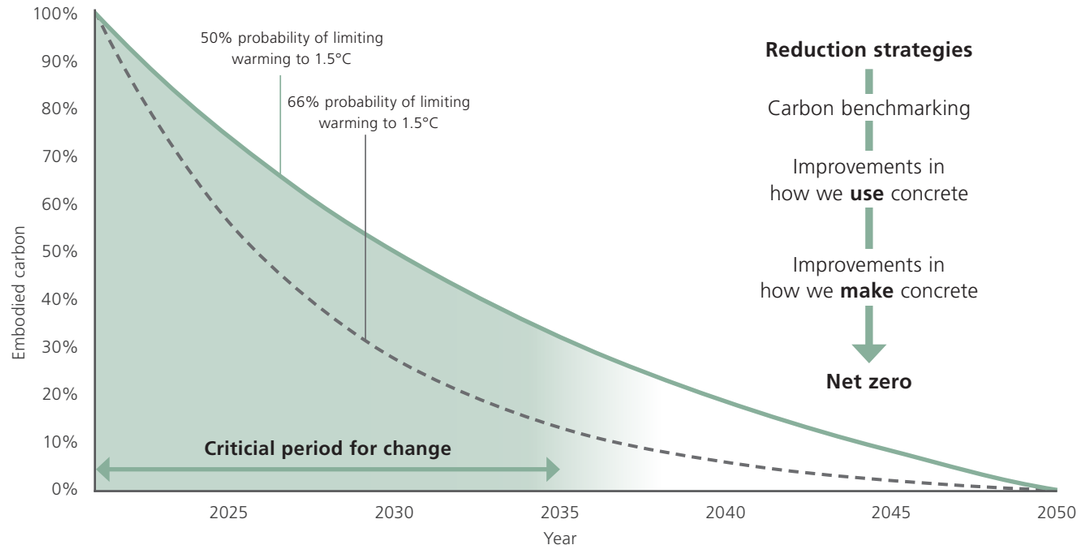

Fig 1: Idealised reduction rate for embodied carbon in concrete

The Low Carbon Concrete Routemap focuses on seven strands of knowledge that must be developed concurrently to reduce the embodied carbon of concrete. An eighth strand provides a framework of opportunities for further engagement. The ability of each strand to contribute will require continued research and development to meet the target of net zero by 2050, with the next 10-15 years being critical. The first strand covers the continuous process of accurately benchmarking concrete. Strands 2, 3 and 4 are related to the use of concrete by designers and contractors. Strands 5, 6 and 7 are related to the production of concrete. Here is an introduction to each strand and the Low Carbon Concrete Group (LCCG) routemap:

1 DEFINING AND BENCHMARKING THE CARBON IN CONCRETE

A zero carbon future for concrete can only be mapped out from an accurate starting position. The LCCG has been working with industry to establish appropriate boundaries to classify concrete by carbon. Further work is required to build on this data and establish a simple rating system for carbon in concrete.

ACTION:
Cross-industry efforts to standardise measuring, reporting and benchmarking of the greenhouse gases associated with different types of concrete.

CONCRETE MIX – EMBODIED CARBON RATING CERTIFICATE

A++	<75
A+	75-125
A	125-160
B	160-190
C	190-225
D	225-275
Special	>275

B 164kg CO_2e/m^3

All figures kg CO_2e/m^3
Bounding figures are only applicable to specified strength class

Data:

Concrete mix	Option A
Cube strength, f_{cu}	30 MPa
Cement type	IIIA
SCM	GGBS
Cement content	260kg/m³
w/c ratio	0.65
SCM content	40%
Aggregate size	20mm
Admixtures	Superplasticiser

STRENGTH CLASS *C25/30*

Fig 2: Example of a possible approach to carbon rating for a given concrete

Using concrete

Strands 2, 3 and 4: Best practice in using concrete

There is huge variation in how concrete is used and specified. It is possible to reduce significantly the carbon intensity of concrete through better design, specification and construction practices – this requires a focus on carbon and the necessary guidance and support.

ACTION:

A coordinated approach between industry and government to optimise the use of concrete for carbon.

2 KNOWLEDGE TRANSFER

Knowledge transfer is crucial to addressing barriers and accelerating the use of lower-carbon concrete. There needs to be clear guidance on how to specify, design and use lower-carbon concretes within the existing standards, as well as a better understanding of performance and how and when to engage with stakeholders. Coordination between institutions and trade bodies is important to ensure guidance is effective.

3 DESIGN AND SPECIFICATION

The use of concrete must be optimised within the design process regardless of its carbon intensity. Guidance that demonstrates how material savings can be made through efficient design is required. The specification of concrete and concrete products must include carbon intensity, and specifiers need to understand how they can work to reduce it while meeting other performance requirements.

4 CONSTRUCTION AND OPERATION

Consideration must be given to how a concrete will be produced and whether in-situ or precast concrete offers greater potential carbon savings. The performance requirements, installation method and project-specific logistical constraints should all be considered during early collaboration between the concrete producer and the project team. There must also be a clear plan for verification of the material to avoid waste or an excessive testing regime.

Left: Hollowcore precast panel EPD

Above: Concrete placement using a concrete pump

Making concrete

Strands 5, 6 and 7: Best practice in making concrete

There is also huge variation in how concrete is produced and the constituents used. While the engineering performance of concrete is standardised, its carbon intensity is not and there are many opportunities using existing technologies as well as new approaches.

ACTION:

Concrete industry to coordinate modernisation to allow the standardisation of the carbon intensity of concrete production with support for new technologies. Government support will accelerate this process.

5 OPTIMISE EXISTING TECHNOLOGY

Within current standards and practice, it is possible to produce concretes that have lower embodied carbon. To achieve this, stakeholders need to work together to ensure that all options for cement types are considered. In addition, the project team must work to ensure that the cement content is optimised for a given cement type. Collectively this optimised approach will realise significant carbon savings over typical practice.

6 ADOPTING NEW TECHNOLOGY

Concretes that use cement blends or contents outside of current standards will be part of the overall solution to reducing the carbon intensity of the industry. Some of these concretes are an extension of existing technology, while others adopt wholly different chemistry. Wherever possible and appropriate, these new technologies should be supported by the industry to allow the development of standards and an increase in commercial readiness and application.

7 CARBON SEQUESTRATION

Carbon sequestration within concrete can offer some benefit in performance and the potential reduction of atmospheric CO_2. Guidance on how to use novel carbon curing technology and a better understanding of how to maximise long-term carbonation is required. Carbon sequestration technology to reduce the intensity of cement production requires large-scale industry and government support and should be recognised as an end-of-pipe solution that should be considered only once other carbon-saving opportunities are maximised.

Above: Precast panels at the Global Change Institute made using Wagners EFC

Right: Waste clay at a quarry with potential for use as calcined clay

Low Carbon Concrete Routemap

Low Carbon Concrete Routemap

8 A FRAMEWORK OF OPPORTUNITIES FOR FUTURE ENGAGEMENT

Strands 1-7 set out decarbonisation knowledge and where further development is required to realise carbon savings. Strand 8 sets out how this knowledge will contribute to a net zero future for concrete and is an invitation for collaboration from all stakeholders. The opportunities and ideas seek to address the climate and biodiversity emergency and focus on the next 10 years. There is no one technology, idea or opportunity that can address the concrete challenge and the LCCG proposes multiple areas for development, all of which can in principle be delivered at scale in the UK.

	2022		2024	2030
1 CONTINUOUS BENCHMARKING	Public reporting of CO_2e for all concrete works against the LCCG benchmarking as standard practice	Clients define product requirements using the LCCG benchmark rating criteria and commit to buying concretes that meet that criteria	Periodic updating of LCCG benchmark and guidance	CO_2e calculations based on kg CO_2e/kg of materials as used, not general database values
2 KNOWLEDGE TRANSFER	Formation of Concrete Decarbonisation Task Force and repository to showcase low-carbon technologies and initiatives	Working group to assess risk and consequence levels and where the use of different concretes should be accepted or expected	Develop performance-related standards	Greater understanding of cement options embedded into engineering training
3 DESIGN AND SPECIFICATION	Increase utilisation factors and optimise elements through geometry, including forming voids and profiled sections	Include requirement for embodied carbon measurement within specification and set a target if possible, using the LCCG benchmark	Reduce minimum cement content in BS 8500-2	Continuous improvements in efficiency, designing with re-used elements and for re-use
4 CONSTRUCTION AND OPERATION	Allow the concrete supplier the maximum possible flexibility to meet or beat the specified upper bound kg CO_2e/m^3	Continue to decarbonise the production of Portland cement (CEM I)	Modify batching plants to enable production of lower-carbon concretes	Reclaim cementitious material and aggregates from demolition arisings
5 OPTIMISING EXISTING TECHNOLOGY	Increase and optimise use of GGBS and PFA as an SCM	Use of current-generation AACMs and geopolymers that make use of GGBS and PFA if they can be shown to meet necessary requirements	Fly ash reclaimed from stockpiles as an SCM	AI/sensing enabled real-time adjustment to optimise mix design
6 ADOPTING NEW TECHNOLOGY	Identify clays in the UK with mineralogy suitable for calcining to use as cementitious materials (SCM or AACM)	Convert PAS 8820:2016 to a British standard	Research and trial clay as an SCM at higher % replacement than currently permitted by BS EN 197	AACMs based on calcined clay (including metakaolin)
7 CARBON SEQUESTRATION	Identify optimal locations for factories that will make use of captured CO_2	Increase in projects using concretes that incorporate CO_2 and also cure using it	Establish pilots of CO_2 capture at cement works	Synthetic SCMs/AACMs that sequester CO_2 during manufacture

USING CONCRETE

MAKING CONCRETE

2050
Mass roll-out and transition to
NET ZERO

Established in 1818 and with more than 95,000 members worldwide, the Institution of Civil Engineers exists to deliver insights on infrastructure for societal benefit, using the professional engineering knowledge of our global membership.

The Low Carbon Concrete Group (LCCG), formed of professionals from the concrete and cement industry, academia, engineers and clients, has been brought together by the Green Construction Board in its role as the sustainability workstream of the Construction Leadership Council. The group has been working together since January 2020 with a bias towards action and is now preparing the Routemap for publication in early 2022.

For further information contact:
Andrew Mullholland
Amcrete UK Ltd
andy@amcrete.co.uk

Follow us on Twitter
@ICE_engineers

Low Carbon Concrete Group

Institution of Civil Engineers is a Registered Charity in England and Wales (no 210252) and Scotland (SC038629).

ICE
One Great George Street
Westminster
London SW1P 3AA
UK

Get in touch
For more information, please contact:
ICE Knowledge
E: **knowledge@ice.org.uk**
W: **ice.org.uk**