# Carbonation of Concrete

## Key facts

1 **Concrete naturally absorbs $CO_2$ from the atmosphere throughout its lifetime.**

2 **Products, such as mortar and concrete blocks, carbonate rapidly. Reinforced concrete carbonates slowly - by design - to protect steel reinforcement from corrosion.**

3 **Improved demolition practices and innovative industrial carbonation techniques can enhance and accelerate carbonation $CO_2$ capture.**

Carbonation is the naturally occurring process in which concrete absorbs $CO_2$, permanently removing carbon from the atmosphere.

**Carbonation of concrete is a well-established science and recognised by the IPCC (Intergovernmental Panel on Climate Change) as an important carbon emissions sink.**

**MPA is developing a government funded scientific model to calculate $CO_2$ removals from the atmosphere due to concrete carbonation.**

## Carbonation

- The science of carbonation, the natural reversal of the calcination reaction in the cement production process, is well-established.
- Concrete and other cement-containing products, such as mortar, absorb $CO_2$, removing it permanently from the atmosphere.
- The rate of carbonation depends on the specification of the concrete and the conditions to which it is exposed.
- Carbonation increases when concrete is crushed at the end of its life.
- Industrial Greenhouse Gas Removal (GGR) technologies, e.g. $CO_2$-curing of concrete, accelerate and enhance carbonation.

## Reversing calcination

Cement is made by heating limestone (calcium carbonate) to around 1450°C to break it down into calcium oxide and carbon dioxide.

Approximately two-thirds of the $CO_2$ emissions from cement manufacture, and just over half of the $CO_2$ emissions from concrete, come from this 'calcination' reaction.

Cement is mixed with water, aggregates (crushed rock and sand) to make concrete and other products, such as mortar.

The cement 'binds' the concrete and $CO_2$ immediately begins to be removed from the atmosphere. This 'carbonation' process mineralizes concrete, enhancing its stone-like properties.

The speed of carbonation depends on multiple factors, such as the concrete strength, porosity, and exposure. Mortar and precast concrete blocks carbonate rapidly. Reinforced concrete structures are designed to carbonate very slowly, to protect the steel reinforcing bar. At the end of life, crushing will increase the exposed surface area of the concrete, so carbonation can be accelerated and maximised.

**Carbonation occurs naturally throughout the concrete lifecycle, accelerating when concrete is demolished, crushed, and recycled.**

## Carbonation in the Lab

Carbonation starts from the concrete surface. Laboratory testing can show how carbonation progresses over time.

A pink dye is applied to a freshly cut surface of the concrete sample. The dye will become colourless if the concrete has already carbonated. Concrete that has not yet carbonated will remain pink.

Using concrete samples of different ages shows how carbonation increases over time as $CO_2$ is absorbed from the atmosphere.

# Calculating the carbon absorbed by carbonation

**Carbonation reverses the cement 'calcination' reaction.** Calcination is key to cement production. Theoretically, all this $CO_2$ could be reabsorbed by carbonation.

**Construction standards such as BS EN 16757 give a methodology for calculating the $CO_2$ removed by carbonation over the lifecycle of a single building product.** Mortar and concrete blocks carbonate fully in a few months or years, whereas for reinforced concrete very little carbonation occurs during the primary service life of the building or structure - most of the carbonation will occur when the concrete structure is eventually demolished, crushed, and recycled.

**For National Greenhouse Gas Inventories,** the carbonation process is the same but the reference frame for the calculation is different: the $CO_2$ removed by carbonation in a single year by all the concrete and cement-containing products in the country. Methodologies have been proposed by IVL Swedish Environmental Institute.

A simplified calculation, based on an international literature review, is that, on average, 23% of the raw material calcination $CO_2$ emitted during production of the cement consumed each year is reabsorbed.

The UK concrete and cement Industry roadmap also uses this methodology as an estimate of current carbonation. **In the UK, 23% of the calcination $CO_2$ emissions is equal to 12% of concrete's total $CO_2$ emissions.**

IVL recommend that more robust calculation methodologies require country-specific market data on typical applications of concrete and cement containing products, and software models for computation.

**MPA is leading a consortium funded by the UK government to develop a robust scientific model to calculate the UK carbon emissions sink due to carbonation based on national concrete usage.**

## Enhancing carbonation

**Improved demolition practices and enhanced carbonation techniques could maximise the amount of $CO_2$ absorbed and permanently removed from the atmosphere.**

Optimising demolition practices, e.g. storing crushed concrete to allow better air circulation, and facilitate rapid and complete carbonation, before the crushed concrete is reused or recycled.

Industrial technologies which enhance and accelerate carbonation are in development including winners of the Carbon XPrize[1]:

- **CarbonBuilt[2]** uses $CO_2$-rich industrial flue gases directly to cure precast products.
- **CarbonCure[3]** injects $CO_2$ into concrete during mixing, where it mineralizes.

Other industrial carbonation technologies in development include:

- **Carbon8 Systems[4]** Accelerated Carbonation Technology (ACT) processes industrial waste products into construction aggregates.
- **O.C.O. Technology[5]** uses ACT to turn industrial waste products into Manufactured LimeStone (M-LS), a carbon negative aggregate.
- **FastCarb[6]** Accelerated carbonation of recycled concrete aggregate.
- **Solidia[7]** cement is made in a conventional kiln but uses less energy. Solidia cement is the binder in Solidia concrete, which is factory-cured with $CO_2$ to make precast concrete products.

1. hiips://www.xprize.org/prizes/carbon/articles/xprize-announces-the-two-winners-of-20m-nrg-cosia-carbon-xprize-with-each-team-creating-valuable-products-out-of-co2-emissions
2. hiips://www.carbonbuilt.com/
3. hiips://www.carboncure.com/
4. hiips://c8s.co.uk/
5. hiips://oco.co.uk/
6. hiips://fastcarb.fr/en/home/
7. hiips://www.solidiatech.com/

## Key policy enablers:

1 **MPA is working with government to improve the accuracy of UK emissions reporting to the United Nations Framework Convention on Climate Change by ensuring national accounting includes the $CO_2$ permanently captured and stored by the natural carbonation of concrete minerals.**

2 **Scale up enhanced carbonation technologies, that use, store and permanently remove $CO_2$ from the atmosphere.**

3 **Encourage and incentivise demolition practices to maximise carbonation of end-of-life and recycled concrete.**

4 **Ensure that carbonation is fully accounted for in construction product and building lifecycle assessment (LCA) methodologies over the whole lifecycle, including demolition at the end-of-life and secondary life reuse and recycling.**

UK Concrete is part of the Mineral Products Association, the trade association for the aggregates, asphalt, cement, concrete, dimension stone, lime, mortar and silica sand industries.

www.mineralproducts.org

Follow us:

@thisisconcrete

this-is-uk-concrete

www.ThisisUKConcrete.co.uk

MPA UK Concrete
Gillingham House
38-44 Gillingham Street
London SW1V 1HU

Tel 020 7963 8000

mpa UK Concrete