Research Challenge Brief

Calling all Innovators!

Searching for research solutions to model Recarbonation of Cement emissions in Australia

Smart Crete CRC

CEMENT CONCRETE & AGGREGATES AUSTRALIA

CEMENT INDUSTRY FEDERATION

Background

Concrete is the world's most used building material and cement is an indispensable material required to produce concrete. The key constituent of cement is clinker which is produced under **high temperatures** in rotary kilns from locally sourced raw materials such as limestone and clay.

The emissions from cement manufacturing related to the calcination of limestone, fuel use and electrical energy usage currently account for **6-7 per cent of global CO_2emissions** and about 90% of the CO_2emissions for concrete manufacture. . In Australia, cement manufacturing emissions represent approximately 1 per cent of domestic emissions.

SmartCrete, Cement and Concrete Aggregates Australia, Cement Industry Federation and the RACE for 2030 CRC partnered to establish a **decarbonisation pathways** report for the Australian concrete sector. View the full report here.

Approximately 55 percent of the CO_2emissions from cement production originate from the calcination of limestone ($CaCO_3$) during clinker manufacture to form CaO. These are commonly referred to as "process emissions" (VDZ, 2021).

When exposed to CO_2concrete, which contains cement, will bind CO_2through a **Recarbonation process**. The Recarbonation process is a chemical reaction by which CO_2reacts with hydration products in concrete, such as $Ca(OH)_2$, to form calcium carbonate ($CaCO_3$) as follows:

$$Ca(OH)_2 + CO_2 \rightarrow CaCO_3 + H_2O$$

CO_2uptake can occur during infrastructure **use**, **end of life** and **secondary use** stages.

Recarbonation of Concrete

In the International Panel for Climate Change (IPCC) Sixth Assessment Report (2021) the United Nations (UN) acknowledged that recarbonation of concrete absorbs a significant proportion of the CO_2 emissions over the lifecycle of concrete elements and estimates that approximately 200 million tonnes of carbon are absorbed worldwide by this "cement carbonation sink" (Friedlingstein et al, 2020).

As such, recarbonation of cement in concrete is critically important in terms of the actual net lifecycle CO_2 emissions from cement and concrete.

The rate and amount of CO_2 that is bound by the concrete depends upon the concrete quality, exposed surface area and environmental variables. It is estimated that on average 75 percent of the CaO in the concrete can recarbonate over time (degree of carbonation).

Models for calculating the rate of carbonation exist relating a carbonation depth, d, to the square root of the carbonation time, t, and an apparent diffusion coefficient, k or d = k $\sqrt{t}$.

The carbonation rate depends upon several factors including the mass transport of CO_2 in the concrete, humidity, temperature and ambient CO_2 concentration. The carbonation rate is often determined by measuring the depth of carbonation (mm) as a function of time (years) and determining the apparent diffusion coefficient, k, with units of mm per year$^{0.5}$.

Recarbonation of Concrete

Carbonation also reduces the pH of the concrete and the depth of carbonation is typically measured by using a pH indicator (phenolphthalein) which changes colour below pH of 9.4 (typically sprayed on the surface of an extracted concrete sample).

The values of k for concrete typically varies between 2 and 15 mm/yr$^{0.5}$ providing a depth of carbonation between 14 and 106 mm for 50 years exposure.

The degree of carbonation that occurs in the carbonated layer can also vary in terms of the amount of available CaO that is converted to $CaCO_3$ from anywhere between 30 to 100 percent.

The carbonation depth, calculated or measured, can be converted to a carbon uptake for a given concrete volume considering:

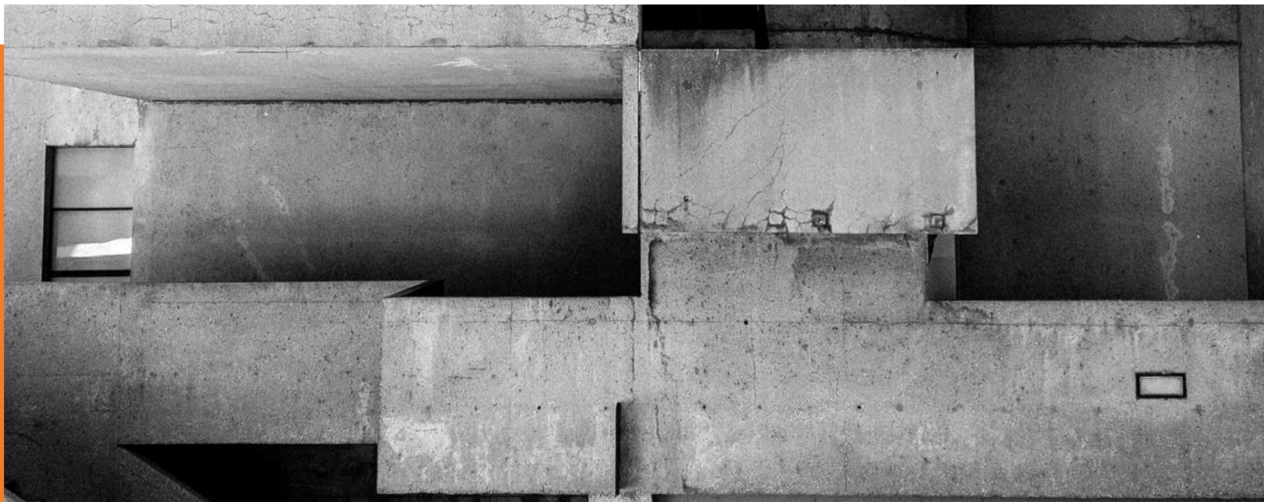
- the exposed concrete area;
- the cement content of the concrete;
- the clinker to cement ratio;
- the CaO content of the clinker;
- the fraction of CaO that is converted to $CaCO_3$ and;
- the molar ratio of CO_2 to CaO

The carbon uptake for a given concrete volume can also be determined by measuring the CO_2 content in the carbonated and uncarbonated concrete, determining the difference and multiplying by the exposed concrete area.

The total amount of CO_2 uptake occurring in a country depends upon:

- the inventory of concrete structures (buildings and infrastructure),
- the amount of new concrete products each year;
- the amount of concrete that is demolished every year and;
- considering the variables in the carbon uptake calculation.

CO_2 emission calculations for cement are developed by the IPCC, reported nationally, and include emissions from calcination and fossil fuel combustion. Currently no consideration is given to the recarbonation of cement in concrete and a detailed investigation needs to be undertaken in Australia.



Recarbonation of Concrete

The IPCC provides guidelines on calculation methods with different complexity and accuracy.

A Tier 1 model, which is the simplest, is already accepted based on previous studies around the world and provides an estimation of 20 percent of the process emissions for CO_2 uptake during the use stage.

A Tier 2 model is a more detailed calculation model and following methods that have already been developed and provided in publications such as Andersson et al (2013), Fitzpatrick et al (2015), Annex BB of BS EN 16757 (2017), Stripple et al (2018), Andersson et al (2019) and PD CEN/TR 17310 (2019).

This project's objective is to undertake a Tier 2 calculation for estimating the annual uptake of CO_2 in existing concrete structures in Australia.

Calling for Research Submissions

Scope of work required

- Literature review
- Classify concrete structures in Australia in different applications based on market segment.
- Determine historical and forecast cement and concrete use in each of the applications.
- Estimation of concrete types (grade, cementitious contents) and relative volumes being used in each application.
- Estimation of concrete surface areas for each concrete type in each application.
- Estimation of exposure environments for each exposed surface for each concrete type in each application.
- Estimation and measurement (for verification) of carbonation diffusion coefficient, k, for each concrete type and considering exposure environments.
- Estimation and measurement (for verification) of degree of carbonation , for each concrete type.
- Develop model for CO_2 uptake for concrete applications.
- Calculate the CO_2 uptake during use in each application.
- Calculate the CO_2 uptake during the end of life and secondary use for each application.
- Calculate the annual CO_2 uptake from the inventory of concrete structures in Australia.

The work will include using reliable sources of construction data, such as Macromonitor reports (to be supplied to Research Partner), and design information to determine the concrete volumes, concrete types, expected surface areas and exposure environments.

The carbonation diffusion coefficient and degree of carbonation can be estimated from the concrete type and exposure environments considering the available literature and investigations but will also be required to be measured (field and lab testing) to verify the assumptions used in the modelling.

Calling for Research Submissions

Project Timeframes

The project is to be completed within six months of commencement.

Project Deliverable

The Project will have a comprehensive work plan that will be agreed with the Project Partners within one month after commencement.

The Project will have an interim report submitted within three months and a final report and model submitted within six months of commencement.

Project Information

Market information of cement and concrete use in Australia will be provided by the Project Partners (e.g. Australian Construction Materials Forecasts by Macromonitor).

The information provided and generated by the project will remain commercial-in-confidence to the Project Partners.

Submission of Proposals

Response to RFP in the form of a Proposal shall include information on the following:

Understanding of the Project

- Provide a narrative that describes the research partners knowledge and understanding of this Project.

Project Team

- Describe proposed staff for the project team and allocated percentage to the Project.

Relevant Experience and Capabilities

- Provide summary of proposed staff relevant experience and capabilities.

Resources

- Describe resources you have in place to deliver Project objectives.

Project Methodology

- Describe how the Project will be managed from start to finish including methodology, project management tools, communications with project partners and verification of work.

Project Schedule

- Provide proposed timeline for key tasks and reports related to each stage of Project

Project Budget

- Provide proposed budget based on expected costs (labour and expenses) for each stage of Project.

Project Risks and Mitigation

- Based on information provide and scope of works list expected risks and mitigations to deliver the Project report to the quality, timeframe, and budget.

Proposal Submission

Submissions close on Friday 16th of December

Submit your research proposal to info@smartcretecrc.com.au

Calling for Research Submissions

Evaluation and Assessment

The evaluation of Proposals will be based on the information provided by Respondents in their Proposals completed in accordance with this RFP. This information may be supplemented by additional material submitted with Proposals.

A preliminary evaluation of the Proposals will be undertaken, and short-listed Respondents invited to meet to discuss the Proposal with the Project Partners.

Selection of preferred Research Partner will be notified upon final evaluation.

Submit your Research Proposal to info@smartcretecrc/com.au

References

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