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Nordic Innovation Centre

January 2006

CO₂ uptake during the concrete life cycle

Executive Summary

- Contribution of cement products to climate change significantly over-estimated
- 20-35 % of total CO₂ emissions may be reabsorbed with good recycling practices
- 86 % of the concrete is carbonated after 100 years



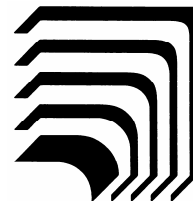
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Title: CO ₂ uptake during the concrete lifecycle		
Nordic Innovation Centre project number: 030185		
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Abstract: The objective of this project is to provide documentation of concrete carbonation during service life and secondary use. It is to be used for life cycle assessments of specific concrete buildings and structures and for evaluating the effect of concrete carbonation on the overall CO₂ emissions from cement and concrete production in the Nordic countries. The project results show that the net CO₂ uptake during a realistic lifetime is dependent on the type of the concrete, its application and the percentage of concrete rubble generated and the recycling rate and use of the concrete rubble. In countries with the most favourable recycling practice it is realistic to assume that 86 % of the concrete is carbonated after 100 years, taking up approximately 57 % of the CO₂ emitted during the calcining process. Examples of impact of CO₂ uptake in life cycle screenings show that 70-80 % of the potential CO₂ uptake has been absorbed within 100 years lifetime after demolition and crushing. This corresponds to 20-35 % of the total CO₂ emissions in the life cycle of the analysed concrete products. Thus, the CO₂ uptake in cement based materials has a significant impact on the society's total CO₂ emissions and on environmental screening of these materials. The project results are of benefit both for the cement and concrete industry as well as society. The response to the preliminary results has so far been varied, but overall characterized with a great interest. The project has been carried out with a limited budget and the analysis is based on a number of assumptions and uncertainties. There is a need for further work in the field which should be aimed at validating the results, removing assumptions, expanding the analysis to Europe, including new member states, developing methods to optimise/accelerate CO₂ uptake by crushing and storing demolished concrete and disseminating results to the cement and concrete industry and to national and European politicians.		
Topic/NiCe Focus Area: Environment, Materials & Production		
ISSN:	Language: English	Pages: 8
Key words: CO ₂ uptake, cement, concrete, environmental screening, CO ₂ policy, recycled aggregates, carbonation, carbon dioxide, life cycle.		
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Project No: 03018

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Executive summary

Objective

The objective of this project is to provide documentation of concrete carbonation during service life and secondary use. The purpose of the documentation is twofold. Firstly, it is to be used for life cycle assessments of specific concrete buildings and structures. Secondly, it is to be used for evaluating the effect of concrete carbonation on the overall CO₂ emissions from cement and concrete production in the Nordic countries.

Cement production accounts for 3-5 % of the total man-made CO₂ emission in Europe. Approximately half of that stems from the calcinations of limestone, i.e. a process where limestone is decomposed and CO₂ gas is released to the atmosphere. Theoretically, hardened concrete binds approximately the same amount of CO₂ in a process called carbonation. Due to a lack of knowledge and documentation this effect is not presently taken into account in environmental assessments.

The objectives have been met, though the results are based on a number of assumptions and uncertainties which show a clear need for further work in the field.

Method/implementation

The project has been carried out in 4 phases.

Phase 1: CO₂ binding capacity

The first part of this phase has been a literature study to lay down a suitable conceptual model for concrete carbonation that is suitable for the present project. The model as well as the mechanisms of carbonation is valid for pure Portland cement as well as combinations of Portland cement and fine powders, e.g. fly ash, silica fume, limestone and blast furnace slag. The data used for validation has been data from the literature, from condition surveys and damage analysis of existing concrete structures and from other R&D projects. Focus has been on concrete produced for passive environmental class because this class covers approximately 70 % of all concrete and because very little is known about the carbonation in this environment. The important parameter for CO₂ uptake is concrete quality correlated with water/binder ration and porosity, the cement/binder types, the microclimate (wet, dry, sheltered etc.) and the surface (paint, wallboard etc.).

Phase 2: Mapping the present and future concrete production

When the CO₂ binding capacity is known from phase 1 for different types of concrete, it is necessary to know the amount produced of each type of concrete to calculate the total CO₂ absorption, i.e. to map the typical distribution of concrete qualities. The study covers today's distribution as well as the distribution 50 years back and scenarios for the future distribution. The quality of the data varies substantially. It has been necessary to supply the data with qualified estimates in order to make the required reliable estimate for the CO₂ uptake from concrete. The data quality is varying and a number of assumptions have been made.

Phase 3: CO₂ uptake in demolished and crushed concrete

An essential part of the CO₂ binding will take place after demolition of the structure. Knowledge about this is very limited. In this phase testing of CO₂ uptake in crushed concrete has been carried out for different concrete types and compared with the model from phase 1. This included the set up of a relevant test method. In addition realistic scenarios for what happens to the concrete after demolition are formulated. The results indicate that most of the carbonation can be obtained within 3-6 weeks of accelerated testing depending on the concrete type. Also the results indicate that an amount of CO₂ will be taken up within a fairly short period of time after crushing. This uptake corresponds to more than 50 % of the CO₂ released by calcination during Portland cement clinker production. The project has not included validation of the laboratory tests with real life CO₂ uptake of demolished concrete.

Phase 4: Preparing the documentation

All previous phases include different aspects of life cycle assessment, but this phase ties the phases together. The goal of the project, the documentation of CO₂ uptake due to concrete carbonation, is synthesised in the shape of two independent reports. This includes a guideline on how to take CO₂ uptake into account in life cycle screenings and in a report evaluating the effect of concrete carbonation on the overall CO₂ emissions from cement and concrete production in the Nordic countries.

Concrete results and conclusions

The project results show that the net CO₂ uptake during a realistic lifetime is dependent on the type of the concrete, its application and the percentage of concrete rubble generated and the recycling rate and use of the concrete rubble. In countries with the most favourable recycling practice it is realistic to assume that 86 % of the concrete is carbonated after 100 years taking up approximately 57 % of the CO₂ emitted during the calcining.

Over 100 years, one year of Nordic concrete construction is calculated to absorb 0.34, 0.22, 0.24 and 0.021 million metric CO₂ in Denmark, Norway, Sweden and Iceland, respectively. This implies that about 0.5 % of the total national CO₂ emissions will be reabsorbed in concrete in Denmark, Sweden and Norway. The corresponding number for Iceland is about 1 %. The calculated CO₂ uptake implies that about 20 % of the total amount of CO₂ emitted in the production of the Portland cement utilized in Nordic concrete construction will be re-absorbed in 100 years.

The guidelines have been prepared according to the ISO-standards, 14040-43. The guideline describes all significant contributions to a CO₂ balance and how to implement this in practice. The principle is illustrated with two examples, i.e. an edge beam as a part of a highway bridge construction and a typical roof tile. 81 % of the potential amount of CO₂ uptake has been absorbed within 100 years of the construction has been demolished and crushed. This corresponds to a reduction of almost 20 % of the total CO₂ emissions during the life cycle. The total CO₂ emission includes e.g. other raw materials, concrete production, transport, construction. For the roof tile the corresponding numbers are 72 % of the potential CO₂ uptake has been absorbed within 100 years which corresponds to a reduction of more than 35 % of the total CO₂ emissions during the life cycle.

Thus, the CO₂ uptake in cement based materials has a significant impact on the society's total CO₂ emissions and on environmental screening of these materials. The existing models for calculating carbonation do not take into account that the concrete is crushed and recycled after use. Consequently, the contribution of the cement and concrete industry to net CO₂ emissions is strongly overestimated. With the new results from the project it will be possible in the

future to make more correct life cycle screenings and CO₂ calculations. This can have a significant influence on CO₂ policy; on the criteria for environmental labelling; and on the selection of materials based on principles of environmentally correct design. Furthermore, the results of the project are a valuable input for national and Nordic work with product information for concrete products, environmental labelling, etc. as well as for the environmental policy.

The project results are of benefit both for the cement and concrete industry as well as society. The response to the preliminary results has so far been varied, but overall characterized with a great interest. The Danish authorities (Danish Energy Agency) are positive and have required a minor report based on the preliminary results of the Nordic project. They are requesting International back-up in order to obtain acceptance in the European Commission of CO₂ uptake.

Recommendations

The project has been carried out with a limited budget and the analysis is based on a number of assumptions and uncertainties. One of the most important is that the statistical mapping of concrete production divided into quality, construction type and environmental exposure class is not carried out in much detail. Another important uncertainty is that calibration of laboratory test of accelerated CO₂ uptake with field measurements has not been carried out.

There is a need for further work in the field which should be aimed at:

- validating the results of the study
- removing assumptions of the study
- expanding the analysis to Europe, including new member states
- developing methods to optimise/accelerate CO₂ uptake by crushing and storing demolished concrete
- disseminating results to the cement and concrete industry and to national and European politicians

Project reports

The project has been documented in five reports. Three reports cover the background data and the last two reports include the results of the project.

The background reports are:

- Carbon dioxide uptake during concrete life cycle, state of the art, published by Swedish Cement and Concrete Research Institute - CBI, www.cbi.se, ISBN 91-976070-0-2
- Information on the use of concrete in Denmark, Sweden, Norway and Iceland, published by Icelandic Building Research Institute, www.ibri.is, ISBN 9979-9174-7-4
- Carbon dioxide uptake in demolished and crushed concrete published by Norwegian Building Research Institute, www.byggforsk.no, ISBN 82-536-0900-0.

The reports with results are:

- Guidelines – Uptake of carbon dioxide in the life cycle inventory of concrete, published by Danish Technological Institute, www.teknologisk.dk, ISBN 87-7756-757-9
- The CO₂ balance of concrete in a life cycle perspective, published by Danish Technological Institute, www.teknologisk.dk, ISBN 87-7756-758-7

Nordic Innovation Centre

The Nordic Innovation Centre initiates and finances activities that enhance innovation collaboration and develop and maintain a smoothly functioning market in the Nordic region.

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