Proposed topic for Master's thesis

Sustainable building with concrete
Strategies and design recommendations for CO_2-reduced (high-strength) concretes

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Start: from now on

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Background

The entire construction industry is currently undergoing a transformation towards more climate-friendly construction with new materials and innovative, automated manufacturing processes. In addition to sophisticated, human-centred architecture, the sustainable use of resources and materials and the reduction of CO_2 emissions will be essential in the future. Concrete, the most frequently used building material in the world, plays a major role here.

Concrete contains cement as a binding agent. The production of this component alone causes around 6-7% of the world's CO_2 emissions, around four times as much as all global air traffic [1]. The reason: Cement clinker is required for the production of cement, which is burnt from limestone, sand and clay at high temperatures using a large amount of energy. Furthermore, the chemical reactions which takes place during this process cause the majority of CO_2 emissions. During the deacidification of the limestone, unavoidable, raw material-related CO_2 emissions are produced. The reduction of this chemically bound CO_2 is an essential key to the sustainable use of concrete.

What is CO_2-reduced concrete?

CO_2-reduced concretes or RCC concretes (Reduced Carbon Concrete) are concretes that have a lower global warming potential (GWP) compared to standard concretes. In conventional concretes, around 80 % of CO_2 emissions come from the Portland cement clinker content used [2,3]. With high-strength concretes (HPC), the proportion of clinker and thus the CO_2 emissions increase further. The greatest lever for reducing the GWP is the reduction or substitution of the cement clinker content. There is promising potential in processes for

- Reduction of the cement content in concrete
- Use of clinker-reduced cements
- Use of alternative binding agents with low global warming potential

In recent years, promising concepts such as calcined clays, BCSA cements, CSH binders, flour-grain admixtures and tensile fibres have been researched. These approaches can significantly reduce CO_2 emissions and at the same time dispense with the limited availability of by-products from energy-intensive industries such as fly ash, granulated blast furnace slag or silica fume. Furthermore, various methods are currently being investigated to capture the CO_2 produced during the clinker burning process and either use it further or store it safely ("Carbon Capture and Utilisation", CCU for short, and "Carbon Capture and Storage", CCS for short) [4].

High-strength concretes are also characterised by their high density, which gives them excellent strength and durability properties. They enable a reduction in the amount of material used and thus an additional improvement in the CO_2 balance. In combination with a reduced cement content, a lower proportion of clinker and the use of alternative binding agents with a low global warming potential, high-strength concrete is an important building block for sustainable construction in the future.

Goals and procedure:

The main aim of this work is to develop strategies and design recommendations for the use of CO_2-reduced concretes, focussing on high-strength concretes. To this end, initial investigations have already been carried out at TUM, which will be built upon. First of all, the current developments in the field of CO_2-reduced concretes and the investigations carried out at TUM will be summarised in a comprehensive literature review and suitable formulations will be recorded or developed. The Global Warming Potential (GWP) of these formulations will be evaluated and classified using suitable methods, whereby the formulations will be analysed on the basis of their components. In addition, suitable mixtures will be realised, as well as the quantification of the essential fresh and hardened concrete properties. On the basis of mix variations and optimisations, design recommendations will be developed that enable a targeted improvement in concrete quality and sustainability. These recommendations take into account both the technical requirements and the ecological aspects in order to maximise the efficiency and performance of the CO_2-reduced concretes.

The work offers profound insights into experimental research in the field of sustainable solid construction and enables independent scientific work, but always in close professional coordination and supervision. On completion of the work, the aim is to publish the results jointly.

The procedure can be organised as follows:

- Literature study on CO2-reduced concretes, GWP, etc.
- Evaluation and classification based on GWP
- Preparation and concreting of selected formulations in the laboratory
- Quantification of key fresh and hardened concrete properties
- Mix variation and mix optimisation
- Development of design recommendations
- Preparation of the written version

Previous knowledge:

- Motivation and interest in the topic and in practical laboratory work
- In-depth knowledge of solid construction
- Independent way of working

Sources

[1] VDZ, Hrsg. Dekarbonisierung von Zement und Beton – Minderungspfade und Handlungsstrategien: Eine CO_2-Roadmap für die deutsche Zementindustrie. Düsseldorf, 2021. Verfügbar unter: https://vdz.info/dekarbonisierung

[2] InformationsZentrum Beton GmbH: Umwelt Produktdeklaration InformationsZentrum Beton GmbH – Beton der Druckfestigkeitsklasse C 25/30. Erkrath, 2023., Verfügbar unter: https://www.beton.org/betonbau/planungshilfen/umweltproduktdeklarationen/

[3] InformationsZentrum Beton GmbH:Umwelt Produktdeklaration InformationsZentrum Beton GmbH – Beton der Druckfestigkeitsklasse C 50/60 . Erkrath, 2023, Verfügbar unter: https://www.beton.org/betonbau/planungshilfen/umweltproduktdeklarationen/

[4] Pressemitteilung Heidelberger Materials: https://www.heidelbergmaterials.de/de/media/baufachpresse/baufortschritt-catch4climate