Karlsruhe Institute of Technology

Division I – Biology, Chemistry, and Process Engineering

Institute for Technical Chemistry (ITC)

Division II – Informatics, Economics, and Society

Institute for Industrial Production (IIP)

Net-Zero Circular Concrete

New Concrete from Demolition Waste – Without Emissions Affecting the Climate

The Net-zero Circular Concrete project develops process chains for zero-emission recycling of concrete waste arising when demolishing buildings. Old concrete is crushed and sorted into coarse and fine fractions. Limestone is added to the fine fraction to produce a binder at moderate process temperatures. The coarse fraction absorbs the carbon dioxide (CO_2) produced in the course of the process. Together with the binder, it is used for the production of new concrete. This circular approach reduces the consumption of resources as well as the production of waste and greenhouse gas emissions.

Building Is Associated with a High Consumption of Materials and Energy

When constructing buildings and infrastructures, huge amounts of materials, in particular concrete and cement, are consumed, because they are inexpensive and have a long durability. Construction of a new single-family house alone requires about 100 cubic meters of concrete, corresponding to 230 tons of concrete and 35 tons of cement.

To produce cement, limestone is needed. It is mostly extracted in the vicinity of the cement plant. Then, fine sand, coarse gravel, and water are added to produce concrete at a concrete factory. To reach the high process temperatures needed, energy from the combustion of fossil fuels or waste materials is applied.

In Germany, about 30 million tons of cement are produced every year. This is associated with a high consumption of materials and energy and with the emission of more than 20 million tons of CO_2.

New Concrete Cycle

For recycling, old concrete is crushed mechanically in a first step. The fragments are sorted into fine and coarse fractions. The fine concrete fraction is mixed with limestone and processed to a new type of cement clinker, so-called belite cement clinker, in a rotary kiln.

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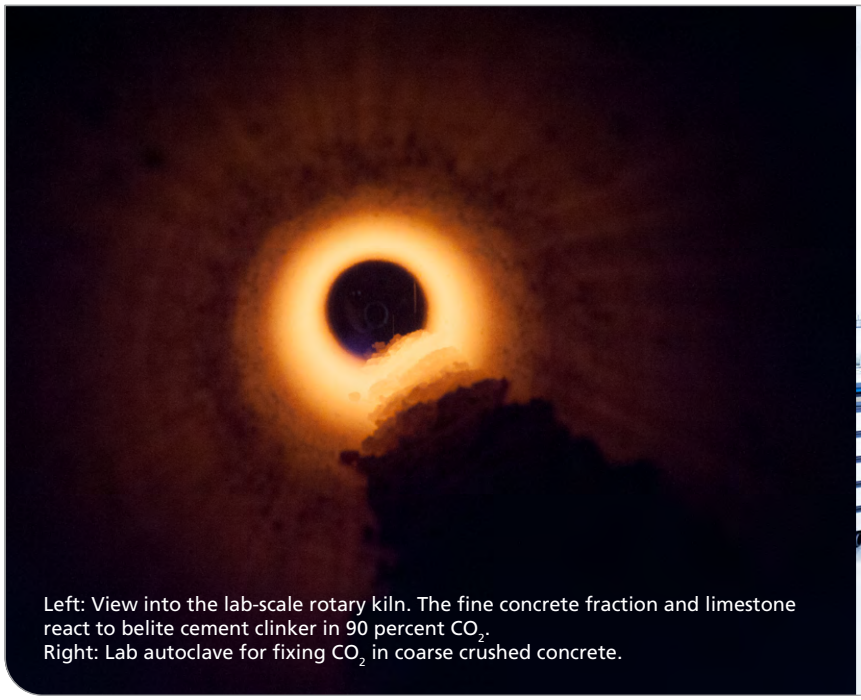
The necessary process temperature amounts to 1000 °C which is comparatively low. This temperature can also be reached by electric heating, ideally with renewable energy. As in case of conventional cement production, CO_2 is released. The CO_2 atmosphere even is favorable for the reaction. Instead of emitting CO_2, it is bound by a chemical reaction with the coarse concrete fraction, resulting in carbonation by mineralization. To accelerate this process that is slow by nature, an autoclave is used.



Left: View into the lab-scale rotary kiln. The fine concrete fraction and limestone react to belite cement clinker in 90 percent CO_2.
Right: Lab autoclave for fixing CO_2 in coarse crushed concrete.

Concrete Based on Recycled Cement and Recycled Additives

The new binder and the carbonated sands and gravels are used for the production of new concrete. If only a part of the cement required comes from the Net-zero Circular Concrete process, no major modifications are required.

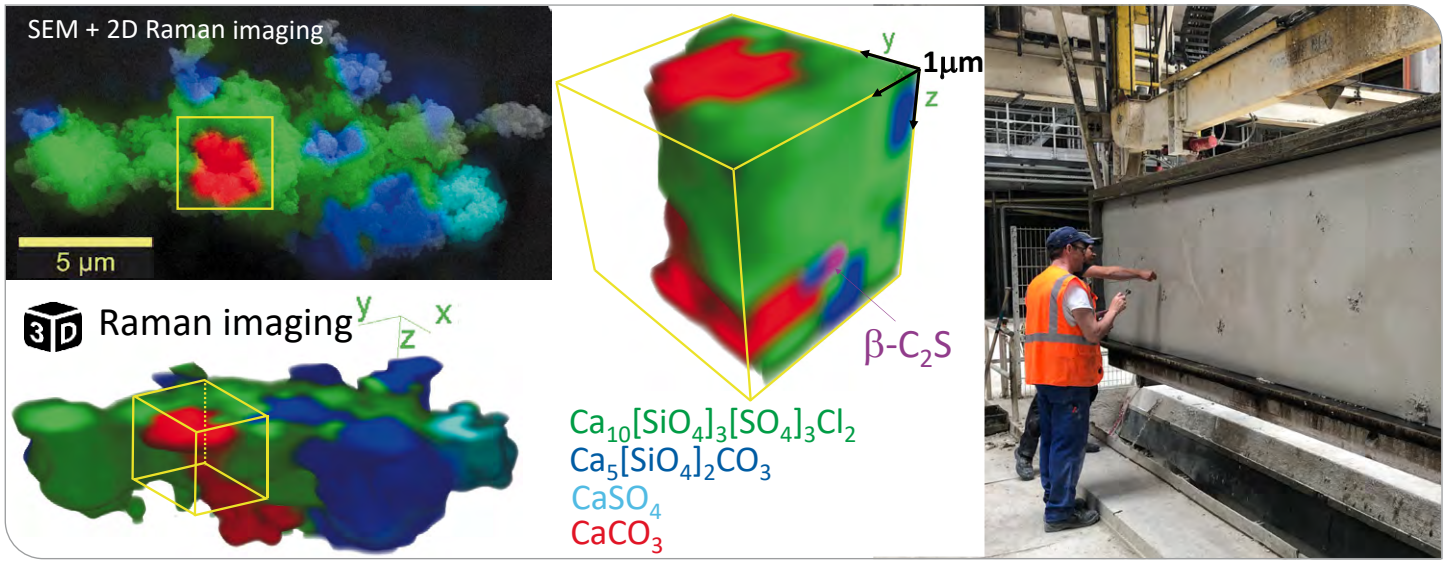
Economic and Climate-relevant Aspects

The process costs mainly result from the fact that energy is consumed to reach the process temperature. In case of larger plants, costs will be lower due to scaling effects. However, this will not be sufficient to reach the cost level of primary production. Moreover, the availability of old concrete is limited. According to statistics, every German citizen consumes 2 to 3 tons of fresh concrete every year, while the amount of concrete waste from the demolition of buildings is about 1 ton only. Hence, the new process will reduce part of the annual CO_2 emissions of more than 20 million tons of conventional cement production only. Still, this would be a major contribution to climate protection.

Upscaling at a Pilot Plant

The large amounts of cement required can only be produced at accordingly large and/or many new plants. To date, several tons of belite cement clinker have been produced at non-optimized plants of our partners. Industrial use was tested for selected applications.

To gain know-how for efficient upscaling, a pilot plant is being set up at KIT. There, cement clinker production will be studied and optimized. Use of recycled cement in new products is tested in a number of projects with industry partners. In parallel, the underlying chemical reactions are studied.



Left: Formation of belite (β-C_2S) in belite cement clinker from finest aerated concrete sands (flux agent $CaCl_2$) at 800 °C. Right: 25 percent of conventional cement is substituted by belite cement clinker for aerated concrete production (test at XELLA Technologie und Forschungsgesellschaft mbH).

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MARIE CURIE ACTIONS

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