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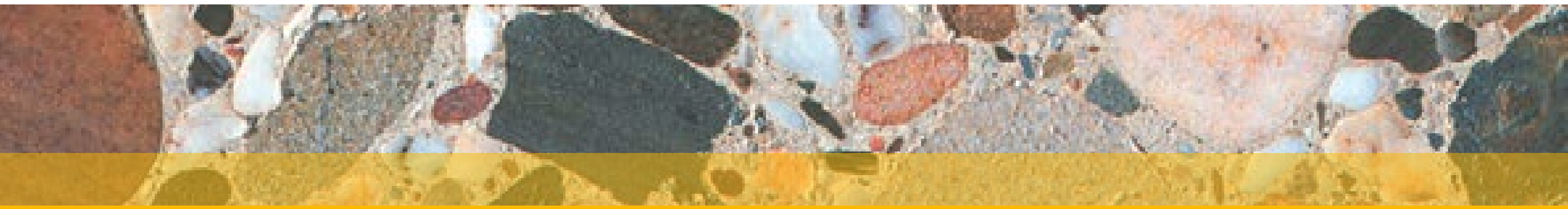

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NEWSLETTER

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Upcoming ECRA seminars:

- Energy Efficiency and Waste Heat Recovery
  4–5 September 2018

- Cement and Admixtures
  23–24 October 2018

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The evaluation of energy utilisation and WHR in a circular economy

Efficiency of clinker production in the context of alternative fuel co-processing

The clinker production process in modern cement plants is one of the most efficient industrial processes there is. In addition, all fuel ashes occurring in the burning process are fully recycled. This unique combination of co-incineration and material recycling ("co-processing") therefore makes a significant contribution to resource efficiency and the circular economy. In the assessment of the energy efficiency of a process, not only the energy demand of the process itself is an important factor. Other aspects such as waste heat utilisation, possible impacts of material recycling and/or fuel properties also have to be taken into consideration.

Technical audits at cement plants usually focus on the thermal and electrical energy efficiency of the plants. An extended evaluation matrix on the basis of earlier model calculations focuses on the fuel energy demand of the clinker burning process and the energy efficiency of cement production. The BAT range stated in the European BAT reference document (BREF) for the energy demand of the clinker burning process is also addressed, namely 2,900 to 3,300 kJ/kg of clinker (**Fig. 1**). The energy demand given in the BREF is to be viewed as an optimum value which can be attained in a performance test. According to the BREF, the annual energy demand may be 160-320 kJ/kg of clinker higher on account of start-up and shutdown operations or kiln stoppages, for example. Assuming a BAT value of 3,000 kJ/kg of clinker, this results in an annual BAT level of 3,160-3,320 kJ/kg of clinker for the precalcining plant taken as a basis in the BREF with a kiln capacity of 3,000 tonnes per day. With the inclusion of the publicly available data of the Cement Sustainability Initiative (CSI), the influences of kiln capacity and the use of alternative fuels were integrated into the evaluation matrix – on the basis of a complex fuel mix. As shown by Fig. 1, data determined in audits fits into this matrix very well.

Energy demand and utilisation

The energy demand for the clinker production process depends on a variety of parameters, including above all the plant design and the moisture of the raw materials to be dried. It does not however provide any indication of the energy efficiency of a plant. Cement plants are usually designed for the drying of locally available raw materials by utilising the heat of the rotary kiln exhaust gases. Plants working with relatively moist raw materials thus have a higher clinker-specific energy demand than those using less moist raw materials. This does not however have any negative effect on energy utilisation and thus on the energy efficiency of the process. In addition, the calorific content of the rotary kiln exhaust gases and the cooler exhaust air is often used for drying other main cement constituents (primarily blast furnace slag), as is that of coal, petroleum coke and increasingly also alternative fuels. So far, waste heat-derived power generation is only employed in a few plants in Europe. Such measures have no influence on the fuel energy demand of the plant, but they do increase their efficiency.

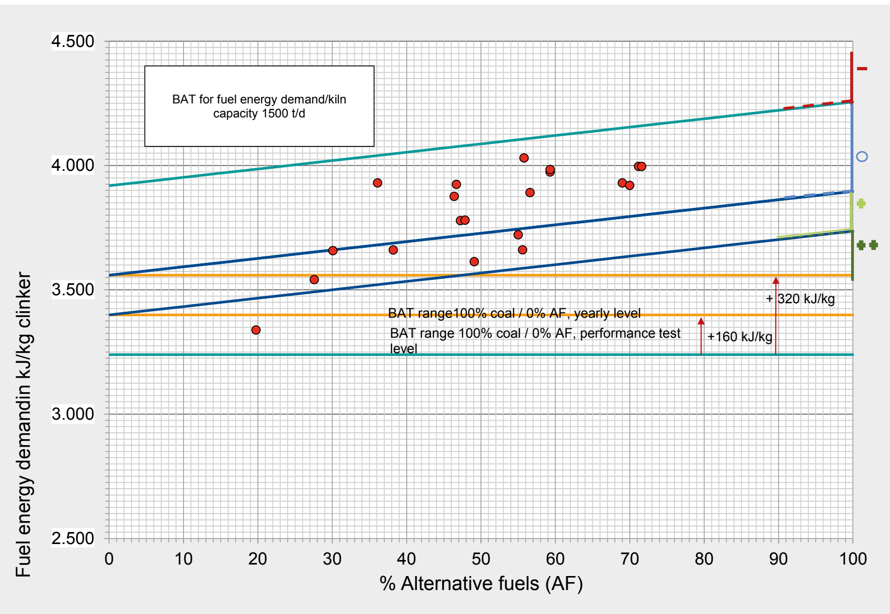

Figure 1: Evaluation matrix for fuel energy demand (kiln capacity 1,500 t/d)

Requirements for alternative fuels

Depending on their physical and chemical properties, an increase in the use of fuels with lower calorific value may increase the fuel energy demand, but in most cases it also provides greater potential for additional thermal efficiency.

The fuel ash occurring is fully incorporated into the clinker and so ultimately becomes part of the cement. This combination of co-incineration and material recycling is a unique feature of the clinker production process. It must however be ensured that the fuel ash is of additional benefit to the production process. Furthermore, the fuel mix must satisfy the basic requirements for the burning process. Qualitatively high-grade, pre-treated alternative fuels are a prerequisite for very high substitution rates in relation to fossil primary fuels.

Assessment of energy utilisation

To fully elaborate the benefits of co-processing, ECRA developed guidelines for the assessment of the energy utilisation of cement plants and worked out an energy performance index as a measure of energy utilisation, taking into account the specific requirements of the production process. According to this, the energy performance index is between 70 % and 80 % depending on the framework conditions applied. The European data of the CSI-GNR database for 2014 served as a basis. For more extensive assessment, various scenarios were studied for optimised BAT model plants from the abovementioned model calculations on the influence of the fuel quality employed and the raw materials to be dried (**Fig. 2**). Standard alternative fuels were also characterised on the basis of their properties and classified in terms of their energy utilisation, taking into account possible pretreatment measures.

Alternative fuel usage in a circular economy

In 2016, around 24 % of municipal waste in the EU was landfilled. This figure varies greatly between the member states. The conclusion drawn from this by the EU Commission is that no overcapacities currently exist in the area of waste incinerators and co-incineration plants. There should accordingly be sufficient suitable materials available for co-incineration in the EU. An increase in the proportion of material co-incinerated at cement plants would make a major contribution towards avoiding CO_2 emissions, reducing the volume of waste landfilled and at the same time preserving natural resources by incorporating the fuel ash into the product. Cement plants satisfy the process demand. The selection of the waste and its appropriate treatment for use as alternative fuels allow for co-processing, making an appreciable contribution towards a sustainable and progressive circular economy in Europe in the future.

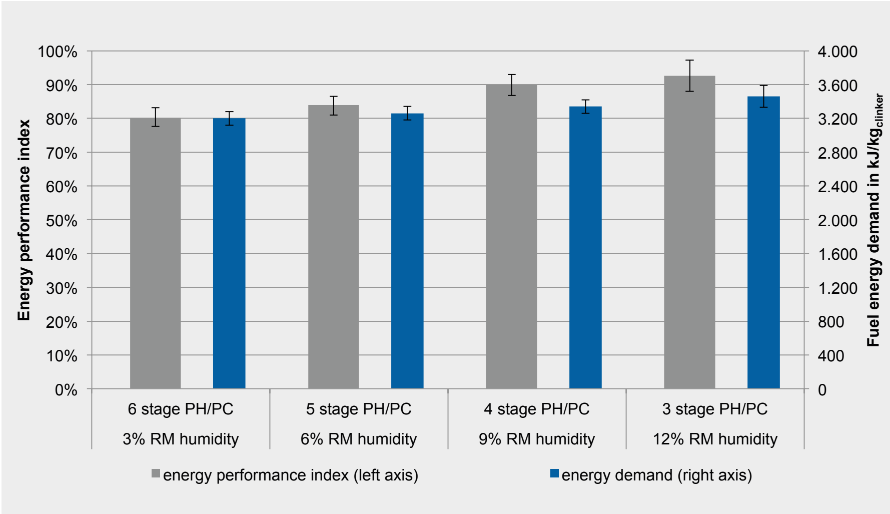

Figure 2: Energy performance index and clinker specific energy demand for optimised BAT model plants (3,000 t/d, 100 % coal) with different raw material moisture contents

The effects of temperature on cement-superplasticizer interactions

Blended cements facilitate a more uniform concrete performance in hot and cold weather

The use of clinker-efficient cements with higher proportions of further main constituents enhances the robustness of the interactions between superplasticizers and cement against temperature fluctuations. Cements with several main constituents compensate the temperature-dependent action modes of superplasticizers more effectively and clearly balance out the consistency of fresh cement paste and concrete.

Superplasticizers are essential components of modern concrete. They improve the workability of concrete and have positive impacts on its compressive strength and durability. Knowledge about their modes of action and their interactions with cements is based on results mostly obtained in the laboratory at standard temperature of around 20 °C. In construction practice, the temperature can strongly deviate and then the same type and dosage of superplasticizer can cause incompatibility reactions in concrete such as a too fast consistency loss or delayed plasticisation. In light of the broad range of climatic conditions world-wide, knowledge about the interactions between cements and superplasticizers in dependence of common low and high temperatures therefore became necessary.

Research programme

The influences of temperatures ranging from 5 °C (cold weather concreting) to 30 °C (hot weather concreting) on the interactions between three superplasticizers and ten cements were determined. The superplasticizers were commercially available. They were based on naphthalene sulfonate or polycarboxylate ether (PCE). The cements had the same clinker and a systematic variation of the type and proportion of limestone, calcined clay, fly ash or blastfurnace slag as a further main constituent. Depending on the temperature, the ionic composition of the pore solution, the zeta potential and rheometric properties of fresh cement paste were determined. Also, the sorption of the superplasticizers, their plasticizing effect, the saturation dosage and the duration of plasticisation were examined by way of chemical analyses, rheometry and consistency tests. The quantity of superplasticizer added was based on its dry material mass content (active agent) and was related to the mass of the cement. The findings were validated in concrete trials.

Saturation dosage

The dosage of superplasticizer for the maximum flowability (saturation dosage) of the reference samples with Portland cement decreased considerably on reducing the temperature from 30 °C to 5 °C. This can be attributed to the reduced reactivity of cement at lower temperature. A larger proportion of the mixing water remains for liquefaction, and furthermore a lower specific surface area exists due to the retarding of hydration. Consequently, the use of the same superplasticizer dosage at both temperatures without any adjustment to the concrete composition can result in an insufficient or excessive addition of the superplasticizer.

Benefits of blended cements

The influence of the temperature on the saturation dosage decreased no-

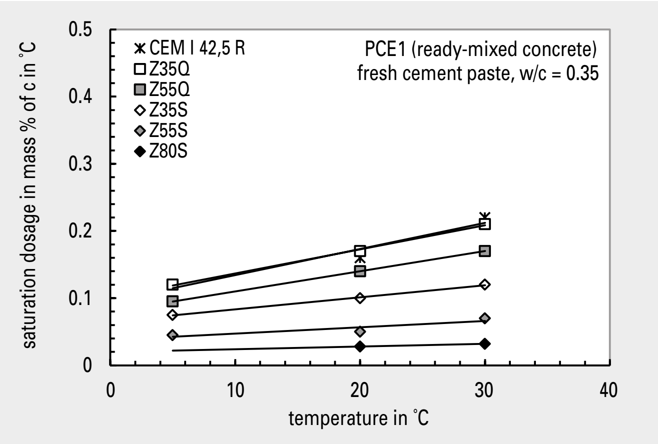

Figure 1: Saturation dosage (active substance) of fresh cement paste with a polycarboxylate ether (PCE)- based superplastizier as a function of the temperature and the proportion of calcined clay (Q) or blastfurnace slag (S) of 35, 55 or 80 mass % in the cement

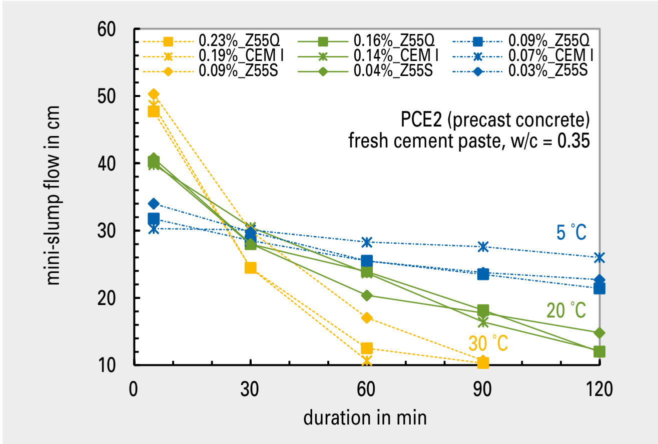

Figure 2: Dispersing effect of a polycarboxylate ether (PCE)-based superplasticizer (see key for the dosage of active substance) and plasticisation time as a function of the proportion of calcined clay (Q) or blastfurnace slag (S) in the cement and the temperature

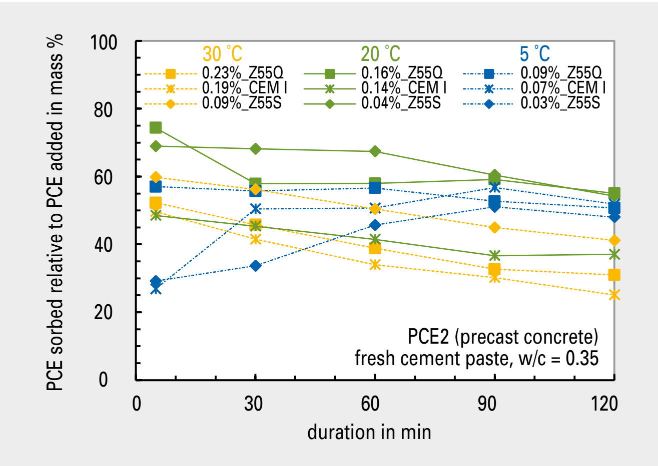

Figure 3: Sorption of PCE (cf. Fig. 2) as a function of the proportion of calcined clay (Q) or blastfurnace slag (S) in the cement and the temperature

tably with an increasing proportion of the further main constituent in the cements (**Fig. 1**). This was because of the lower clinker content (reactive, temperature-dependent component) in the cements with several main constituents resulting in an enhancement of the robustness of the respective cement-superplasticizer-interactions against temperature fluctuations. Fig. 1 also shows that in addition to the enhanced temperature robustness, an increasing proportion of blastfurnace slag in the cement decreased the saturation dosage, especially at high temperature. The samples with cements with 55 or 80 mass % blastfurnace slag S (Z55S, Z80S) thus exhibited low saturation dosages nearly unaffected by the temperature. This applied also to the other superplasticizers as well as to the cements with limestone or fly ash. It mainly occurred on their smaller specific surface area acc. BET to be covered with superplasticizer molecules. Constituents with a far larger specific surface area (e.g. limestone with higher clay content or pozzolanic materials, cf. calcined clay Q in Fig. 1) increased the saturation dosage compared to the cements with an equal proportion of limestone, fly ash or blastfurnace slag.

Action mode of superplasticizers

The PCE-based superplasticizer recommended by the manufacturer for use in ready-mixed concrete (PCE1) achieved the desired moderate increase in the consistency of the cement paste and concrete regardless of the cement and with comparatively low temperature dependence. In the course of investigation of 120 min, the sorbed quantity of PCE1 increased moderately ensuring the distinct retention of the consistency. The consistency retention was slightly more pronounced at 5 °C, but unwanted delayed plasticisation did not occur. Depending on the nature and molecular structure of the PCE the action mode changed significantly with the temperature. **Fig. 2** shows that the strong and short time plasticizing effect of the PCE for precast products (PCE2) determined with Portland cement at 20 °C intensified at 30 °C and vastly lessened at 5 °C. The plasticizing effect of PCE2 at low temperature was more like a PCE for ready-mixed concrete. It was moderately and hardly diminished within the test duration. These changes in the action mode of this PCE can be attributed to variations in its temperature-dependent sorption behaviour (**Fig. 3**). At 30 °C PCE2 desorbed during the experiment resulting in the marked consistency loss of fresh cement paste and concrete, whereas at 5 °C the sorbed quantity mostly increased over time leading to the distinct consistency retention. As also shown in Fig. 2, an increasing proportion of the further main constituent in the cement reduced the influence of the temperature on the mode of action of PCE2. The cements with several main constituents also reduced the temperature influence on the effect of the superplasticizer based on naphthalene sulfonate contributing equally to a more uniform consistency of fresh cement paste and concrete.

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