european cement research academy

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NEWSLETTER

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EN 206: Resistance classes for durability properties of concrete?

Further development of the European Concrete Standard: Pros and cons need to be evaluated

Requirements on the durability of concrete in the European Concrete Standard EN 206 are defined through exposure classes ("standardised ambient conditions") that are implemented through national requirements. A CEN working group has started to define resistance classes for concrete to reach a Europe-wide comparable definition of the performance of concrete regarding its durability.

Within the concept of resistance classes, which is currently designed for the exposure classes XC, XS, and XD, and which has been derived from the design working life acc. ISO 16024, the penetration velocity of the carbonation or chloride front into the concrete is taken as a basis. Assuming a service life of 50 years, a resistance class R20 with carbonation means for example that after 50 years the carbonation front will not exceed a depth of 20 mm under certain storage conditions with an acceptance probability of 90 %. A resistance class R60 with chloride exposure ensures that under defined test conditions after a time span of 50 years the critical corrosion-inducing chloride content of 0.5 % (based on the cement mass) will not exceed a depth of 60 mm with an acceptance probability of 90 %. The compliance with the criteria of the respective resistance classes can then be verified through descriptive specification of requirements for the concrete compositions (cement type, addition of additives, water/cement ratio) or through a performance test of the concrete or its raw material respectively. The designer can vary the minimum concrete cover through the equivalent choice of a resistance class.

Possible Implementation

So far, the essential basis for the establishment of classes results from service life calculations. Applicable forecast models for the carbonation- and chloride-induced depassivation of the reinforcement (exposure classes XC, XD, XS) are available. The risks for the exceedance of the limit state "depassivation of the reinforcement" that are associated with the damage mechanisms mentioned can be evaluated through reliability analyses. The reliability is described through the so-called reliability index β, which is connected with certain probabilities of occurrence (e.g. the probability of occurrence of around 7 % = reliability index beta = 1.5).

The concept of resistance classes as it is currently being discussed assumes that for concrete in the exposure classes XC2 to XC4 the reliability index will uniformly lie between 0.5 and 1.5 in the future. Through the coupling of the exposure class descriptions with the input parameters that go into the model, the minimum concrete cover can be defined as a nationally defined parameter. The link from the input parameter "resistance class" via the curing duration, the relative humidity, the aspired working life and the number of rain occurrences leads to the concrete cover (**Fig. 1**).

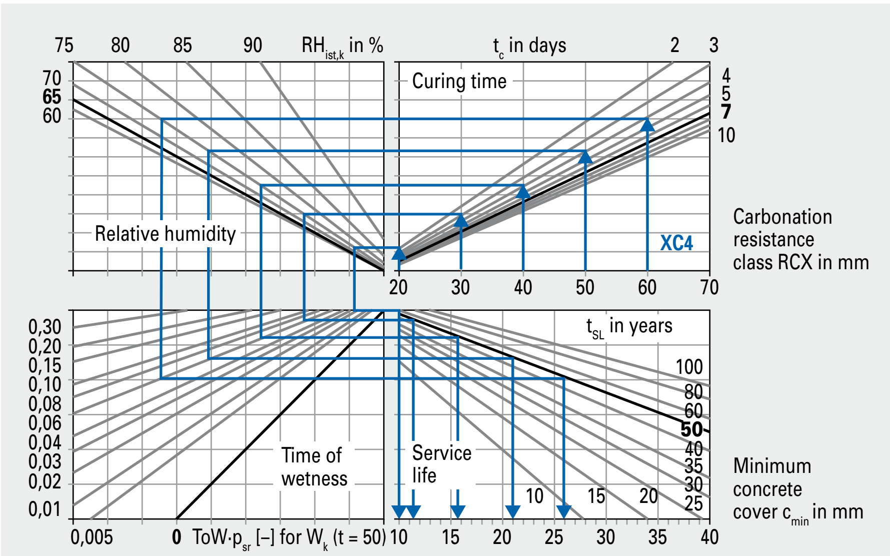
Today, many countries allow the application of different cements (CEM I to CEM III) in one exposure class (e.g. external components) with the same water/cement ratio, and in many cases also a constant concrete over-coverage.

Chances and risks

Comparing the classes defined in this way (here: carbonation) and their application possibilities with the deemed-to-satisfy-rules currently valid in Europe, the following becomes clear: the classification would in some countries lead to a differentiation of the application of cements within the same exposition class which is non-existent today. Some – today common – cement types would presumably only gain access into a class with high carbonation resistance through an adjustment of the concrete technological boundary conditions (e.g. lowering the w/c ratio or increasing the cement cover).

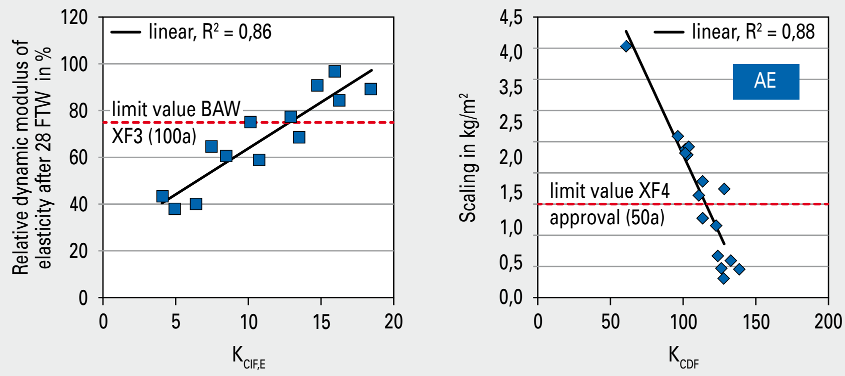
An important question is how the designer would deal with having the option of a "compensation possibility" between concrete quality and concrete cover, and how it could later be ensured that the concrete quality and the concrete cover in the building would match. The designer would, through the choice of a certain class, make a sort of „pre-selection" of the concrete constituents. At best, he would do it consciously, taking into consideration the region affected and the projection of reasonable transport distances. In the worst case scenario, he will not take this into account or would be oblivious to the consequences of his decision.

On the other hand, when defining durability classes in the future, a



*) Graphic: Stefanie von Greve-Dierfeld – Dissertation TU Munich

Figure 1: Relation between carbonation-resistance class, curing duration, ambient humidity, frequency of water moistening and minimum concrete cover acc. Gehlen and Greve-Dierfeld 2014



c	w/c
320 kg/m³	0.50

$$K_{CIF,E} = \frac{HG_{28d}}{P_{57\mu m} - 0,02\,\mu m}$$

$$K_{CDF} = HG_{2d} \times L \times \frac{P_{57\mu m} - 0,01\,\mu m}{P_{ges}}$$

Figure 2: Relation between durability characteristics of hardened cement paste or standard mortar and the relative dynamic modulus of elasticity (freeze-thaw test) and the scaling (freeze-thaw test with de-icer)

connection to a durability potential of cements in the cement standard could perhaps be achieved if a correlation between durability characteristics on hardened cement paste or mortar respectively and durability parameters on concrete is generated. **Fig. 2** shows this through the example of a relative dynamic modulus of elasticity (freeze-thaw test) and the scaling (freeze-thaw test with de-icer). Symbols used are:

- HG_{2d}/HG_{28d}: Degree of hydration after 2 and 28 days respectively on the hardened cement paste, calculated from measurements with simultaneous-thermo-analysis
- L = Air content in fresh mortar (can be estimated)
- P = Pore share of the mercury intrusion porosimetry on standard mortar at the age of 28 days

Recent developments in emissions abatement for NO_x, TOC and mercury

Two new approaches: A combination of RTO and SCR, and a split pre-heater system

Emission Limit Values (ELVs) laid down in the EU's Industrial Emissions Directive (IED) have been challenging and will continue to be so in the years ahead. Emission abatement techniques new to the cement industry have been introduced in the past years and are being tested with regard to their technical and economic feasibility for the clinker burning process. Such new concepts are for example a combination of RTO technology (Regenerative Thermal Oxidisers) and SCR (Selective Catalytic Reduction), and a separate treatment of filter dust in a split pre-heater system for quenching mercury cycles in the kiln. Both techniques still need to be proven with respect to their long-term reliability.

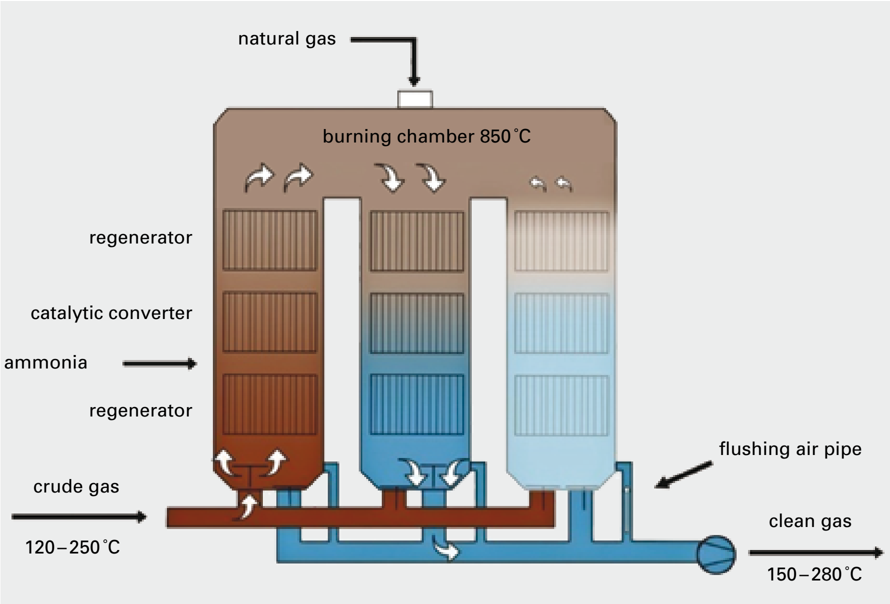
In the EU, the environmental regulations for industrial production facilities were set out in the IED to be transposed to Member States' legislations by the beginning of 2013. While no limits have been fixed for plants using regular fuels only, plants using alternative fuels have to meet the stipulated emission limits. In any case, under the directive, ELVs have to be based on Best Available Techniques (BATs), and their associated ELVs (BAT-AELs) contained in the BAT conclusions. They are to be updated regularly to reflect the development and introduction of new technologies and techniques.

NO_x reduction

Since the 1990s, NO_x has been one focus of emissions abatement in the cement industry. The selective non catalytic reduction process (SNCR) has been proven as a technically and economically appropriate measure. However, in some regions NO_x limits are even stricter than those of the IED, and their combination with limits in the NH_3 slip pose a challenge for the respective cement producers. While the SNCR process can be optimised to a large extent, it may in individual cases reach its limits. In this case the selective catalytic reduction process (SCR) is a possible solution. This technology, which is fairly new to the cement industry, has been proven to work under industrial conditions, as was shown in demonstration plants in Austria, Germany and Italy in the past years. It should be noted that SCR technology is cost-intensive, and electrical energy consumption increases by about 5 kWh/t of clinker, mainly due to the associated pressure drop.

Organic emissions

Organic emissions originate from fuels and raw materials used in the clinker burning process. The excellent burning conditions are sufficient to destroy these compounds fed to the hot area of the process. However, due to the counter flow of gases and materials, organic constituents may evaporate from the raw materials and leave the pre-heating process before being destroyed in the hot area. Therefore, feeding alternative raw materials in particular with organic contents in the right location is of high importance. In cases where raw materials with high organic content are used, a possible abatement solution is one which is implemented at a cement plant in Austria, where a Regenerative Thermal Oxidiser (RTO) was installed downstream from the dust filter to ensure a complete combustion of these components. However, an additional firing using natural gas as a fuel is



Source: Scheuch GmbH

Figure 1: Combination of RTO and SCR for the abatement of organic compounds and NO_x

required as the gases have to be heated up again to a temperature above 850 °C.

Combining RTO and SCR

SCR in its tail-end configuration requires an operating temperature of more than 250 °C and therefore a re-heating of the exhaust gas. A new concept, now in the early stages of demonstration in a cement plant in Austria, combines the advantages of both technologies into a single installation by including catalytic components in a part of the regenerative ceramic elements for the heat recovery process (**Fig. 1**). As in common SCR installations, ammonia solution is injected in the appropriate temperature window for NO_x reduction. Since the installation and commissioning took place only recently, it remains to be seen if the technology proves to be a feasible abatement strategy for the cement industry.

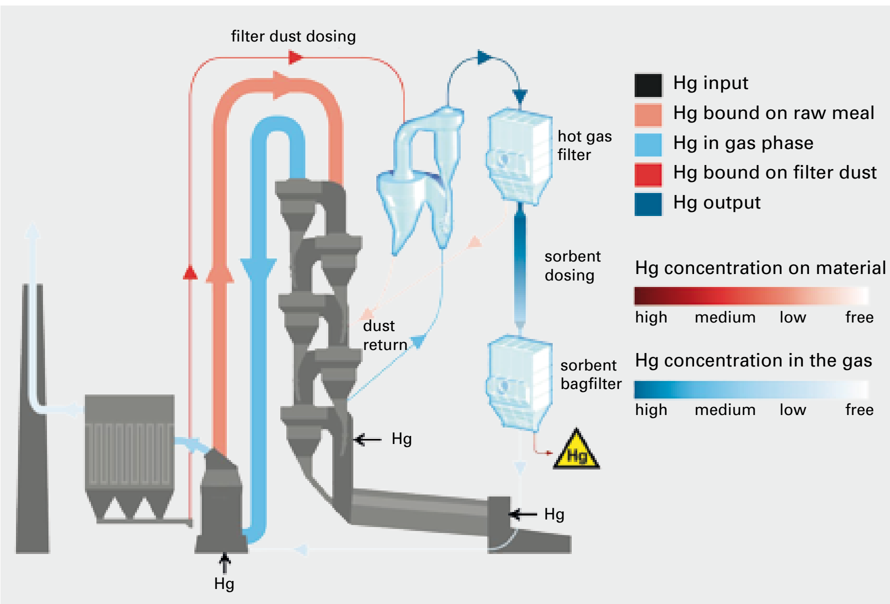
Mercury reduction

Due to its toxicity for human health and the environment, mercury emissions have been addressed at a global level by the Minamata Convention on Mercury, a global and legally binding treaty targeting at the reduction of mercury emissions. The import, export and production of most mercury-containing products will be banned by 2020. Plans to minimise mercury emissions from existing small-scale and industrial mercury emitters are to be drawn up and new facilities are to install BATs.

Traces of mercury are introduced to the cement production process naturally, occurring in both raw materials and fuels in varying concentrations. For the reduction of mercury emissions, the BAT is to control the amount of mercury fed to the system by a careful selection of input materials. While the mercury content in natural raw materials cannot be influenced, it is recommended to control its content in alternative fuels and raw materials whenever needed.

If mercury emissions need to be reduced, shuttling precipitated dust during raw mill off operation is a proven method applied in many cement plants and the first choice to limit the build-up of a mercury cycle within the system by taking out mercury from the process. In cases where high mercury cycles or inputs reach the limit of dust shuttling, it may be supported by the injection of sorbents with a high specific surface upstream from the dust filter during raw mill off operation.

A new concept aims to prevent the build-up of mercury cycles. At another cement plant, all precipitated dust is being constantly treated in a split pre-heater system with hot exhaust gas from the lower pre-heater stages in a slipstream to evaporate the mercury. The dust is precipitated in a hot gas filter while mercury in the gas phase is separated from the gas stream by means of activated carbon with a separate fabric filter (**Fig. 2**). Having been commissioned in spring 2015, the installation is showing promising results but still needs long-term experience to prove its reliability.



Source: Scheuch GmbH

Figure 2: Thermal treatment of filter dust for mercury separation

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