



**ecra**

european cement research academy



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# NEWSLETTER

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## Upcoming ECRA seminars/workshops:

- Performance-based Specifications for Cement and Concrete  
21–22 June 2017
- Kiln Examinations: Energy/Material Balances and Efficiency  
5–6 October 2017

# Performance-based durability specifications for cement and concrete?

European assessment document (EAD) with verification methods for durability properties

**The durability of concrete structures is ensured mostly by “deemed to satisfy” rules, for example for the concrete composition, based on long-term experience. This principle has proved successful in wide areas of building with concrete. In some cases however this system reaches its limits, for example when new building materials of which there is no long-term experience are to be used. The introduction of performance concepts requires clear conditions with respect to test methods and the assessment of results. Durability tests for new cements and performance testing on alkali-silica reaction can be seen as examples.**

The framework for the equivalent durability procedure on a European standardisation level has been published as Technical Report CEN/TR 16563. To date, the European standards do not include a closed concept to assess the durability of concrete by performance testing. The European Technical Evaluation (ETA) is available as an instrument besides the standardised route. If a performance feature is not included in a European (harmonised) standard, the

preparation of a European assessment document (EAD) can be requested by the producer of a building product. On the basis of the EAD and with appropriate results from the investigations the building products can be given the CE mark.

## Testing new cements

The EAD 15001-00-0301 for Calcium Sulphoaluminate based cements has recently been published on the EOTA website. It contains verification methods for numerous durability properties. These methods have been developed or used in the past for cements on the basis of Portland cement clinker. An overview of the essential characteristics related to durability is given in **Table 1**. For every essential characteristic there are at least two assessment methods available. The results of the tests are given in the ETA as levels.

## Assessment background

Once the cement or concrete has been tested under defined conditions, the result has to be assessed with regard to a certain application. The assessment criteria should take into consideration the transferability

to practical conditions. The assessment background should exclude unsuitable variants which have caused damage. Solutions which are well-trying and proven in practical experience should pass the test. For carbonation testing it is possible to make use, e.g. of the evaluation background shown in CEN/TR 16563, Appendix B and EAD 15001-00-0301, Annex D.

Another example is ASR performance testing with the 60 °C concrete test with external supply of alkalis for concrete roads. Drill cores from damaged and undamaged concrete carriageways have been used to make a “calibration” to practical conditions. The cores (15 cm diameter x approx. 30 cm) were taken from the road pavements of several concrete motorways. The pavements were assessed visually and allocated to a damage category during visits to the sections. The drill cores were mainly taken from the first traffic lane, which is the lane most heavily stressed by lorry traffic. The trials were carried out with a 3 % NaCl solution and were intended to indicate the relationship between the damage category of a road pavement observed in practice and the residual expansion potential of the concrete in the “60 °C concrete test with external supply of alkalis”.

The expansions of the half drill cores in the 60 °C concrete test with external supply of alkalis in a 3 % NaCl solution are shown in **Fig. 1**. The markers have been coloured to correspond to the damage categories of the road pavements.

While using an expansion of 0.3 mm/m after ten cycles (140 days) as assessment criterion it was possible to differentiate between the concretes as follows:

- Concretes from road pavements in the first traffic lanes of federal motorways that after 10 to 18 years of intensive use exhibited no signs of a harmful ASR or slight cracking that was not attributable to an ASR or discolouration (no damage due to ASR),
- Concretes from road pavements in the first traffic lanes of federal motorways that after 9 to 15 years exhibited longitudinal and transverse cracks and in which loss of substance had occurred in some cases due to ASR (damage categories II and III).

**Table 1: Essential characteristics, assessment methods and criteria**

No	Essential characteristic	Assessment method	Type of expression of product performance (level)
...	...	...	...
14	Sulfate Resistance	<b>Method 1:</b> Flat prism method <sup>1)</sup> <b>Method 2:</b> Square prism method <sup>2)</sup>	<b>M1</b> $S_{FPM}$ ; $E_{dyn}$ , expansion <b>M2</b> SSPM:
15	Carbonation of concrete	<b>Method 1:</b> RILEM CPC 18 <b>Method 2:</b> CEN/TS 12390-10, Annex A	<b>M1</b> $C_{dcr}$ : mm, mm/d <sup>0.5</sup> <b>M2</b> $C_{trc}$ : rel. carbonation depth
16	Resistance to chloride penetration	<b>Method 1:</b> EAD 15001-00-0301, Annex E <b>Method 2:</b> EN 12390-11:2015	<b>M1</b> $D_{mig}$ : mm <sup>2</sup> /s <b>M2</b> $D_{diff}$ : mm <sup>2</sup> /s
17	Freeze-thaw resistance (without de-icing agent)	<b>Method 1:</b> Cube test CEN/TS 12390-9 <b>Method 2:</b> CF test CEN/TS 12390-9 <b>Method 3:</b> Beam test CEN/TR 15177	<b>M1</b> $FT_{cube}$ : Scaling in mass % (100 FTC) <b>M2</b> $FT_{CF}$ : Scaling in kg/m <sup>2</sup> and RDM (28 FTC) <b>M3</b> $FT_{beam}$ : Scaling and RDM (56 FTC)
18	Freeze-thaw and de-icing salt resistance	<b>Method 1:</b> CDF test CEN/TS 12390-9 <b>Method 2:</b> Slab test CEN/TS 12390-9	<b>M1</b> $FTS_{CDF}$ : Scaling in kg/m <sup>2</sup> and RDM (28 FTC) <b>M2</b> $FTS_{slab}$ : Scaling in kg/m <sup>2</sup> and RDM (100 FTC)

<sup>1)</sup> acc. to EAD 15001-00-0301, Annex B  
FTC: Freeze-thaw-cycles

<sup>2)</sup> acc. to EAD 15001-00-0301, Annex C  
RDM: Relative dynamic modulus of elasticity in % acc. to CEN/TR 15177

### Durability indicators for cement

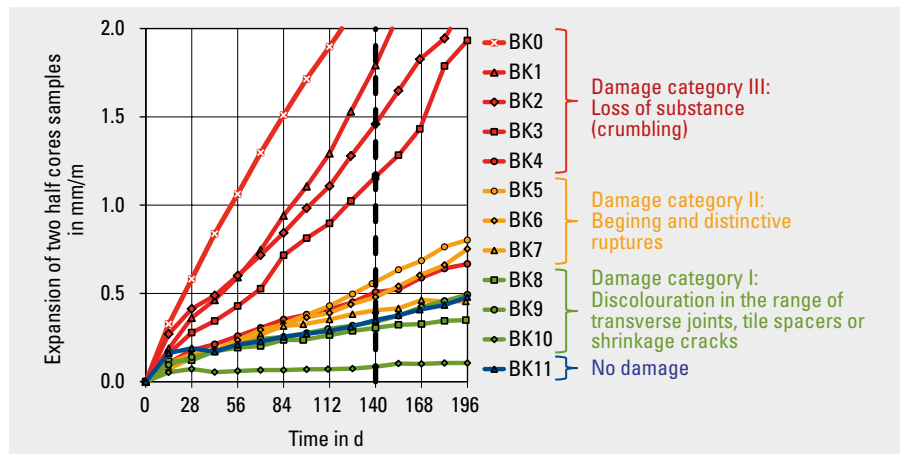
An interesting question with regard to the development of the cement standard in the future is whether it is possible to establish correlations between parameters tested on hardened cement paste or standard mortar and the results of durability tests on concrete. In the case of durability parameters such as chloride migration or freeze-thaw testing acc. EAD 15001-00-0301, any parameters seem to be suitable that can provide information about the degree of hydration and formation of the microstructure.

Examples are given in **Fig. 2** for chloride migration (left) and freeze-thaw-resistance (right). HD is the degree of hydration determined by simultaneous thermal analysis with mass spectrometry on hardened cement paste at different ages (e.g. 7 d, 28 d). Porosity  $p$  at defined pore sizes (e.g.  $p_{57\ \mu\text{m} - 0,02\ \mu\text{m}}$ ) was determined by Hg-Penetration on mortars. In **Fig. 2**, left, the relationship between the characteristic value

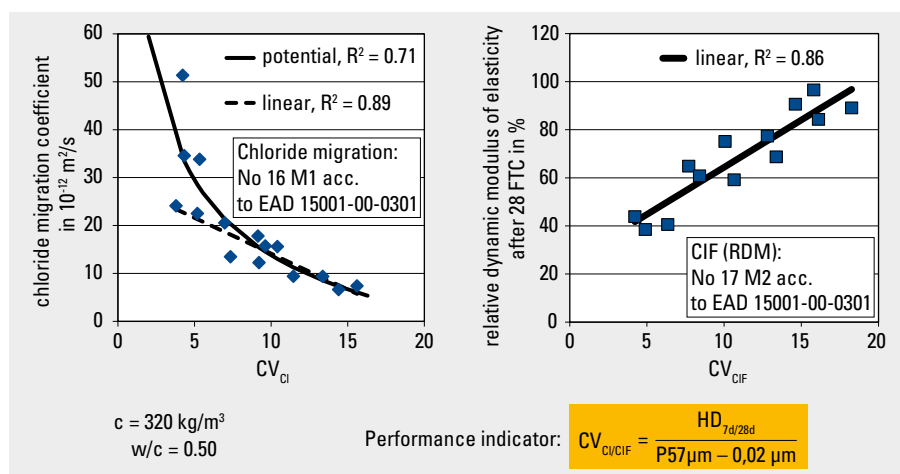
$$CV_{Cl} = \frac{HD_{7d}}{p_{57\ \mu\text{m} - 0,02\ \mu\text{m}}}$$

and the chloride migration is shown. The correlation coefficient  $R^2$  is 0.71. At least a characteristic value of  $K_{Cl} > 7$  is required within an approval procedure. In the field of hydraulic engineering, the characteristic value  $K_{Cl}$  should be  $> 12$ .

For the CF/CIF-test according to CEN/TS 12390-9 / CEN/TR 15177 the relative dynamic modulus of elasticity has to be greater than 0.75 (75 %) after 28 freeze-thaw cycles (and scaling has to be less than 1,000 g/m<sup>2</sup> after 28 freeze-thaw



**Figure 1: 60°C concrete test with external alkali supply 3 % NaCl-solution: Drill core halves of pavements**



**Figure 2: Durability indicators for chloride migration and CIF test**

cycles). In **Fig. 2**, right, the relationship between the characteristic value

$$CV_{CIF} = \frac{HD_{28d}}{p_{57\ \mu\text{m} - 0,02\ \mu\text{m}}}$$

and the relative dynamic modulus of elasticity is presented. This relation-

ship is linear. As a characteristic value of approx. 14 the investigated cements and concretes meet the acceptance criterion securely. In both cases – chloride migration and CIF-test, no reliable correlation to strength was given.

## A systematic approach to optimisation: Energy and material balances

Kiln examinations and measurement techniques are standardised methods for kiln evaluation

**Energy and material balances can help to optimise cement kiln operation with respect to economic aspects, efficiency and environmental impacts. To obtain useful and comparable results, standardised methods have to be used, such as kiln examination tests. Energy and material balances can provide**

**current data about for instance fuel energy consumption of the kiln system, chlorine cycles, clinker output and cooler efficiency. These data can be useful for checking warranty performance of the system. On the basis of the results, measures for the individual optimisation of the kiln system can be identified.**

Kiln trials create a reliable basis for the optimisation of individual system components, operation and cement quality, and also for the reduction of emission levels. The objective of balances of volatile, e. g. alkali, chlorine and sulphur, and non-volatile compounds is the assessment of material cycles and coating formation. For instance, the utilisation of alternative fuels usually entails higher chlorine input into the kiln system, which in some cases results in malfunctions due to increased coating formation in the kiln inlet section and in the lower cyclone stages.

### Objectives of performance tests

A kiln trial, aiming at the investigation of material cycles, provides

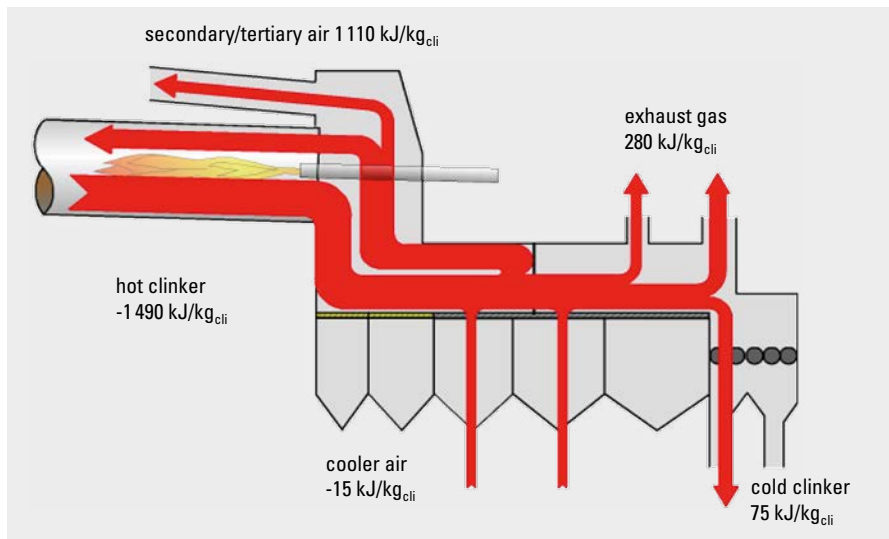


Figure 1: Energy flows at the clinker cooler as determined by an energy balance (example)

reliable data for the design or up-grading of a bypass system. Balance investigations for trace elements can be carried out in order to obtain more knowledge about the behaviour of heavy metals in the kiln plant. The heat recuperation of clinker coolers is influenced by the cooler operation, cooler exit air and secondary air, and at precalciner kilns by tertiary air. The degree of heat recuperation affects the fuel energy consumption and energy balance of the complete kiln line. Therefore, the determination of cooler efficiency may result in optimising the operational mode or in modifying the cooler technology (Fig. 1).

#### Planning plant trials

The reliability of the values measured depends on the successful realisation of the performance test. In the planning phase of a kiln trial, many details have to be considered. Balance boundaries have to be defined and suitable measurement techniques have to be chosen. Besides taking the necessary measurements for the energy and mass balances, it is highly recommendable to carry out additional measurements and samplings in order to evaluate the kiln operation and the level of material cycles. The essential operational mode should already be determined during the planning phase. All circumstances of the performance test and all samplings and measurements which have to be carried out should be outlined in a measuring plan.

Ideally, the measuring plan should include detailed working plans for all participating persons as well as an analysis plan for all samples. The inspection of the measuring sites

prior to a kiln trial is also necessary to ensure the success of the examination. Generally, measuring and sampling points have to be prepared for the examination beforehand. Often, measuring sockets and openings have to be cleared, crusts removed and threads taped. If necessary, a platform has to be erected in order to reach the measuring points. Some measurement devices need operating resources, so electric power, compressed air or water have to be provided close to the measuring points.

#### Sampling and measurements

Representative sampling and sample preparation are of decisive importance for the chemical analyses. Besides samples of solids, taken from belts or at the discharge end of conveyers, dust samples from gas streams also often have to be taken. Volume flow measurements including gas concentration and humidity analyses are integral parts of kiln trials. If energy balances are carried out, the measuring of wall heat losses also has to be part of the kiln trials. At all measuring points the requirements of health and safety at work must be fulfilled.

#### Evaluation of energy balances

The individual system configuration has to be taken into account regarding energy balances. Trials for energy balances can be executed for both grate and preheater cyclone plants without or with precalciner technology including tertiary air ducts. Examinations of sub-systems such as cyclone stages, the precalciner stage, the cooling area and the clinker cooler are also possible. There are no constraints with regard to grate,

planetary or rotary coolers. Energy balances are carried out in order to gather data on the kiln performance and to provide warranty performance data such as fuel energy consumption, process efficiency and cooler efficiency. Gas and material streams carry thermal and chemical energy across the balance boundaries. Methods and techniques are standardised in the VDZ code of practice "VT 10: Executing and Evaluation of Kiln Performance Tests", which is used by cement producers worldwide. It includes the calculation of the main parts of energy streams, taking into account sensible and latent energy, humidity, clinker reactions and fuel energy. The description of heat losses by radiation and convection beyond the kiln walls, and the electric power consumption complete the list. All energy streams are summed up in an energy balance.

#### Evaluation of material balances

Balances of non-volatile compounds are necessary either to determine the kiln feed/clinker ratio or to finalise the balance. Non-volatile compound balances help to adjust the kiln feed composition with regard to the input of fuel ashes or the discharge of dust in preheater exit and bypass gas. Trace elements build up inner cycles between the preheater and the rotary kiln or outer cycles between mill systems and the kiln line. Balance investigations indicate the most effective way of discharging trace elements and diminishing cycles.

In order to assess alkali, chlorine and sulphur cycles, the measurements have to be supplemented with samplings of hot meal in the preheater. The evaluation of volatile compounds identifies spots of coating formation. Based on volatile compound balances and estimates of the cycles, the risk of cyclone blockings can be assessed.



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