

## European Product Standards - update on status and changes with relevance to CCPs -

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### Abstract

The utilisation of Coal Combustion Products (CCPs) in Europe is based on requirements in standards and national legislation which are subject to regular revision by CEN or national authorities. The European standard EN 450-1 has recently been revised and will be published soon. The revision result particularly in the increase of the maximum amount of co-combustion materials, the deletion of the lower limit value of the categories for LOI classes B and C as well as modifications for requirements of parameters and for test procedures, especially regarding wet and dry sieving. Also the standards for hydraulic road binders (EN 13282) and hydraulically bound mixtures (EN 14227) are under revision.

With the revision of the aggregate standards also the essential requirement No 3 (ER3) on Hygiene, Health and the Environment will be implemented in product standards. An overview of the work on harmonised test procedures for the emission of regulated dangerous substances (RDS) will be given. The aggregates standards will be the first to implement respective parameters for RDS. The industry is requested to prepare data bases to allow proper evaluation of construction products, i.e. also CCPs used as e.g. aggregates.

The Construction Products Regulation (CPR) is partly in force by April 24, 2011 and will be fully implemented by 1 July 2013. With this final implementation the essential requirement ER 3 and ER 10 have to be considered in the next revision of product standards. Furthermore, the producers have to declare the performance of their products.

**Keywords:** coal combustion products, fly ash, FGD gypsum, standardization, EN 450, EN 13282, EN 14227, CPR

### 1 Introduction

Coal Combustion Products (CCPs) are produced with the production of electricity in coal-fired power plants. CCPs is a synonym for the combustion residues boiler slag, bottom ash and especially fly ash from different types of boilers and of desulphurisation products like spray dry absorption product and FGD gypsum. The use of CCPs has several environmental and technical benefits. It has developed by the years and is based on requirements of standards or other specifications which are subject to regular revision by CEN or national authorities.

Recently, the European standard EN 450-1 fly ash for concrete has been revised. Within the revision of EN 450-1 the definition of fly ash, the amount of co-combustion materials and the requirements for chemical parameters (LOI, free lime, reactive SiO<sub>2</sub>, and phosphate) have been modified. In the definition of fly ash the criterion for reactive silicon dioxide was deleted. The maximum amount of co-combustion materials will be increased from 20 to 40 % and the proportion of ash derived from

co-combustion material from 10 to 30 % to include the experiences gathered with European Technical Approvals over the last years. For green wood, e.g. not recycled wood, the maximum percentage of co-combustion material can be increased to 50 % by mass. For the LOI classes B and C the lower limit values have been deleted. Furthermore, the test procedures for phosphate and especially regarding wet and dry sieving have been modified and the limit value for free lime was increased to 1.5 % by mass with soundness testing in case of higher free lime content. The revised standard EN 450-1 will soon be published, part 2 regarding conformity evaluation remains unchanged.

Also under revision are the standards for hydraulic road binders prEN 13282 which will result in three parts. Part 1 will define the requirements for rapid hardening binder, part those for normal hardening binders and part 3 will deal with the conformity evaluation. With the revision of the EN 14227-series for hydraulically bound mixtures part 3 for fly ash bound mixtures and part with the requirements for fly ash for bound mixtures are of importance. The European Standards EN 13055- Part 1: "Lightweight aggregates for concrete, mortar and grout" and EN 13055-2 Lightweight aggregates - Part 2: "Lightweight aggregates for bituminous mixtures and surface treatments and for unbound and bound applications" were merged to one standard according the decision of TC 154. The new standard EN 13055 will be entitled "Lightweight aggregates for building, civil engineering and other applications".

On March 9, 2011, the Construction Products Regulations entered partly force and on 1<sup>st</sup> July 2013 will fully replace the Construction Products Directive (CPD). The Regulation shall ensure reliable information on construction products in relation to their performances. It requires changes for producers regarding the preparation of declarations of performance replacing declaration of conformities and third parties have to be accredited and notified by 1<sup>st</sup> of July 2013. With the CPR also a new Annex ZA as well as the requirements for essential requirement (ER) 3 "Hygiene, Health and Environment" and ER7 "Sustainability" have to be considered in product standards. Aggregate standards are the first for implementation ER3 in the revised standards.

## **2 EN 450-1 Fly Ash for Concrete**

The European Standard for "Fly Ash for Concrete" EN 450 was first published in 1994 [1] and the revised standards EN 450-1 und EN 450-2 entered force on January 1, 2007 [2, 3]. EN 450-1 deals with definitions, specifications and conformity criteria for siliceous fly ash, which is produced by burning of pulverized coal, with or without co-combustion materials, and collected in a dry state, or which is processed by e.g. classification, selection, sieving, drying, blending, grinding or carbon reduction or by a combination of these processes. This is because in some countries fly ash has been processed according to national regulations for years or, in some cases, decades. EN 450-2 deals with the conformity evaluation of fly ash for concrete produced in power plants and in processing plants. Most important is the documentation of procedures for the production control in a works quality manual. However, the revision of EN 450-2 was stopped after the enquiry due to formal reasons. The revision will be completed together with other standard for system 1+ evaluation.

In CEN/TC104/WG4 all proposals for modifications of the standards have intensively been discussed. All changes in EN 450-1:2012 [4] have been documented in a respective background report which will be published as CEN report after final review [5]. In relation to the previous standard, the following changes have been adapted:

- The definition of fly ash has been modified – the requirement for reactive silicon dioxide has been deleted

- The permitted amount and type of co-combustion materials have been increased
- The requirement for the lower limit of LOI for category B and C fly ash has been deleted
- The requirement for free lime (CaO) has been changed – the upper limit value was deleted and the limit value for consequent testing of soundness has been increased
- The testing of magnesium oxide has been restricted to the initial type testing
- The amount of total phosphate has been limited by a new requirement, soluble phosphate has to be tested in initial type testing for fly ash from co-combustion

Furthermore, the test procedures for chemical analysis and especially for fineness regarding wet and dry sieving were modified. An overview of the physical and chemical requirements in the revised EN 450-1:2012 [4] compared to the existing EN 450-1:2005/ A1:2007 [2] is presented in table 1. The background for the changes is given in the following clauses.

## 2.1 Definition of fly ash

In the definition of fly ash according EN 450-1 (clause 3.2) [4] the part “...., the content of reactive SiO<sub>2</sub> as defined and described in EN 197-1 being at least 25 % by mass” was deleted as definitions shall not contain requirements. The requirement however still exists as requirement for initial type testing. The definition was further reformatted for formal reasons.

By definition fly ash has to be derived from the burning of pulverised coal with or without co-combustion materials. This is only possible in dedicated boilers where combustion of finely ground fuel takes place in a cloud, with combustion temperatures of 1300 – 1500 °C. This means that ashes from other boilers like grate-fired and fluidised bed combustion boilers do not meet this definition. In other words, the definition guarantees that combustion takes place at high temperature, which is high enough to facilitate glass formation in the fly ash.

## 2.2 Type and amount of co-combustion materials

With the revision of EN 450-1 in 2005 [2] the Commission and the Dutch representatives in WG4 agreed to limit the maximum amount of co-combustion to 20 % and to collect the experience with higher shares of co-combustion with European Technical Approvals by the next revision of the standard. Due to this, the experience with the higher shares of co-combustion was presented to WG4 and all reports showing that the properties of fly ash do not change with the higher shares of co-combustion were provided. Therefore, the amount of co-combustion materials in EN 450-1:2012 [4] was increased from 20 to 40 % and the proportion of ash derived from co-combustion material from 10 to 30 %. For green wood, e.g. not recycled wood, the maximum percentage of co-combustion material was increased to 50 % by mass. The proportion of ash derived from co-combustion shall be calculated with:

$$M = 100 \cdot \frac{K_1 \cdot A_1 + K_2 \cdot A_2 + \dots + K_n \cdot A_n}{K_c \cdot A_c + (K_1 \cdot A_1 + K_2 \cdot A_2 + \dots + K_n \cdot A_n)}$$

where:

M is the proportion of co-combustion ash in total fly ash, in % by mass

A<sub>i</sub> is the ash content of co-combustion material no. i, in % by mass

n is the number of co-combustion materials being used

A<sub>c</sub> is the ash content of coal, in % by mass

K<sub>i</sub> und K<sub>c</sub> are respectively the proportions of co-combustion material(s) and coal being fired

and where:

$(K_c + K_1 + K_2 + \dots + K_n) = 1$  and  $K_c \geq 0,60$ , or  $0,50$  if the co-combustion material is green wood only

Although the increased shares seem to be high it has to be noted that the high rates cannot be reached for all co-combustion materials. Table 2 shows the revised table of co-combustion materials. Line 1 and 2 of the table in the EN 450-1:2005 were merged as all descriptions of biofuel materials are now compiled in EN 14588 [6]. As a definition for green wood is missing in that report a definition was included in EN 450-1:2012. Green wood is defined as

*wood originating from trees, bushes and shrubs that is created when processing wood as cross-cut ends, planings, saw dust and shavings used in the form of dust, chips and pellets*

The combustion of waste wood is excluded. The higher share of co-combustion cannot be fully used for all materials in table 2 as they lead to e.g. increased contents of lime, alkalis or phosphate. Table 3 shows which parameter will restrict the amount of co-combustion material. It has to be noted that the fuel based limits ( $K_i$ ) or the upper limits of single parameters are based on average calculation for the ash content of coal and has to be evaluated for the specific situations.

## 2.3 Modification for chemical parameters

### 2.3.1 Loss on ignition

The lower limit of LOI for category B and C fly ash has been deleted due to two reasons:

- a) With the introduction of the revised EN 450-1:2005 three categories of LOI were introduced, each covering a range of 5 % by mass but only category A with a lower limit of zero. The statistical assessment has to be evaluated by variables. The system used is designed for normally distributed data sets and acceptability constant together with producer and consumers risk. The system was established by D.B. Owen in 1962, but for one sided evaluations only! Whenever the data sets for LOI fulfill the requirement of normal distribution the lower limit values in categories B and C require a revision of the statistical evaluation procedure as a double sided distribution has to be considered. This aspect was not considered in the last revision and is corrected in the revised version. In countries where class A fly ash can be used no changes will appear.
- b) The production of fly ash of LOI category B and C with given requirements for statistical evaluation of lower limits, consumer and producer risk etc is only possible in a very small and non-practical production window. It leads i.a. to the situation that a fly ash with lower LOI cannot be used in concrete as it is below the lower limit.

As a result of these changes - in practical terms - the quality of the fly ash regarding LOI complying to category A, B or C will not change. This is demonstrated with the following examples using a typical SD of 1.3 and a typical  $k_A$  of 1.61 (for 60 – 69 results):

*Cat A: Limit 5 %; mean value 2.2 %, follows: range is limited to 0 and 4.3 % by mass*

*Cat B: Limit 7 %; mean value 4.0 %, follows: range is limited to 1.9 and 6.1 % by mass*

*Cat C: Limit 9 %; mean value 6.0 %, follows: range is limited to 3.9 and 8.1% by mass*

With the existing lower limit the fly ash according LOI category B and C would not meet the requirement in EN 450-1 and could therefore not be used in concrete. Also a “better” quality would not conform to the standard. However, with the deletion of the lower limits the quality of fly ash in respect

of consistency of LOI will not be negatively influenced as the inherent statistical evaluation procedures required will still ensure a low standard deviation for LOI will be achieved.

### **2.3.2 Free lime content**

The minimum free lime content above which soundness has to be tested has been increased from 1 % by mass to 1.5 % by mass while the maximum amount of free lime of 2.5 % by mass has been deleted. The modifications are based on statistical analysis of data compiled by ECOBA (see figure 1). In the compilation also data not conforming to EN 450-1 are included for demonstration purposes. The results show that for up to 1.5 % by mass of free lime, soundness expansion is minimal. Above this content the soundness values may increase, but still no fly ash exceeds the limit of 10 mm. Based on these data it is concluded that for only above 1.5 % by mass of free lime, soundness has to be proven.

### **2.3.3 Magnesium oxide**

The risk of unsoundness by periclas reaction appeared to be extremely small. Therefore, the analysis of magnesium oxide is restricted to fly ash from co-combustion in the initial type testing.

### **2.3.4 Phosphate**

The requirement for phosphate ( $P_2O_5$ ) has been modified. For the continuous proof the content of total phosphate will be determined in accordance with ISO 29581-2 [7] and shall not be greater than 5.0 % by mass. The modification is based on a data compilation of ECOBA in European countries (see figure 2) and the acceptance of the XRF test procedure in quality control. The determination of the content of soluble phosphate will only be determined in initial type testing for fly ash from co-combustion. For the continuous proof the content of total phosphate ( $P_2O_5$ ) will be determined in accordance with ISO 29581-2 and shall not be greater than 5.0 % by mass. The modification is based on a data compilation in European countries (see figure 2).

## **2.4 Modifications for test procedures**

With the revision of the standard also the use of tests methods are modified as follows:

- For the analysis of the chemical main constituents the new standard allows to use other methods than the classical wet chemical methods, namely X-ray fluorescence analysis (ISO 29581-2 [7]). By this, the use of the XRF-analysis need no longer to be classified as alternative method with the proof of equivalent results but will be used directly as reference method.
- the fineness of fly ash is a steering parameter in power plant operation and has to be tested at least once per day. As the wet sieving process according EN 451-2 [8] is time consuming and as the airjet sieving is established in more than 90 % of all European power plants the airjet sieving according EN 933-10 [9] was accepted as alternative test procedure in the revised standard. The acceptance is based on former round robin tests showing a good correlation (figure 3).

## **3 EN 206 Concrete**

In September 2010, the revision of the European standard EN 206 was officially started. The necessary modifications and proposals for further changes have been discussed before in the respective working groups. In spring 2012, the first draft of the revised standard EN 206 [10] was send

to enquiry in the CEN member states. In November, CEN TC 104/SC 1 will finally deal with the comments and the final decision about the revised standard will be taken in 2013.

In 2007, CEN TC 104/TG 5 „Use of additions“ was reactivated to deal with the rules of application for additions in the European member states and to make proposals for the revision of the existing rules and the integration of performance concepts used in the member states. The following changes to clause 5.2.5 of EN 206-1 have been proposed:

1. Extension of the k-value concept also to CEM II/A cements and to GGBS (see table 3). The k-value for GGBS has to be defined on national level.
2. Integration of the principle of the equivalent concrete performance concept (ECPC) as practised in the Netherlands under BRL 1802 [10] for fly ash and BRL 9340 [11] for ground granulated blast furnace slag. The ECPC permits amendments to the requirements for minimum cement content and maximum water/cement ratio when a combination of one or more specific additions and one or more specific cements are used, for which the manufacturing source and characteristics of each are clearly defined and documented. The equivalent performance of the concrete is evaluated by comparison with a reference concrete in conformity with the requirements for the relevant exposure class. The detailed description will be published in a CEN technical report.
3. Integration of the principle of the equivalent performance of combinations concept (EPCC), i.e. combinations of a cement (mostly CEM I) and additions (fly ash, ground granulated blast furnaces slag and powdered lime stone). The 'equivalent performance of combinations' concept treats a combination of a cement and an addition (or additions) as being technically equivalent to a standardised cement of the same nominal composition. This concept may permit a defined range of combinations to count fully towards the requirements for maximum water/cement ratio and minimum cement content, which are specified for the standardised cement. The EPCC is mostly used in the United Kingdom where the mortar compressive strength of a combination of a specific cement and a specific addition is tested in different cement/addition ratios. If the required minimum strength is achieved the combination according BS 8500-2 [12] can be used as an alternative to a cement. The detailed description will be published in a CEN technical report.

#### **4 Revision of EN 13282 Hydraulic Road Binders**

The revision of the European standard for hydraulic road binders ENV 13282 [13] resulted in the preparation of three parts. prEN 13282-Part 1 is dealing with rapid hardening hydraulic road binders [14]. These are cement based binders which follow the requirements as already known from ENV 13282. prEN 13282-Part 2 is dealing with normal hardening hydraulic road binders [15]. These binders have lower cement contents, the compressive strength has to be tested after 56 days (part 1 at 28 days). In addition to the main constituents acc. EN 197-1 also specific FBC-ash, specific Basic Oxygen Furnace (BOF)-slag and paper sludge ash with defined chemical and physical parameters can be used. Furthermore, a slaking procedure was implemented to guarantee that also lime rich mixtures can be evaluated in the laboratory. This is a major change as these binders have not been subject to extensive laboratory testing before but on field test only. The laboratory test is the consequence of the production in a plant and of the harmonized product standard. Part 3 of the standard series will deal with the conformity evaluation.

## 5 Revision of EN14227 Hydraulically Bound Mixtures

In June 2009, the revision of the EN 14227-series for hydraulically bound mixtures was decided. The standards under revision cover cement bound (part 1), slag bound (part 2), fly ash bound (part 3) and hydraulic road binder bound (part 5) mixtures. The revision of these standards focus the structure and the gradings of the mixtures. Part 4 deals with fly ash for fly ash bound mixtures and gives the definition and requirements for siliceous and calcareous fly ash [16]. In May 2011 the standards were sent to the so called “enquiry” to CEN member states. The comments have been dealt with in the responsible working group and in May 2012 they were sent for formal vote.

Also in May 2012, the working group started the revision of the standards for soil treatment (part 10 – by cement; part 11 – by lime; part 12 - by slag; part 13 – by hydraulic road binders; part 14 - by fly ash).

## 6 Revision of Aggregate Standards

The European standards for aggregates (EN 12620 aggregates for concrete; EN 13043 aggregates or bituminous mixtures and surface treatments...; EN 13139 aggregates for mortars; EN 13242 aggregates for unbound and hydraulically bound materials ...and EN 13055 for lightweight aggregates) are under revision. The discussion focused the scope of the standards, the definitions considering also other aggregate standards (i.e. EN 12620, EN 13242), the test methods described in the annexes and the annex of factory production control and minimum test frequencies. The requirements for conformity evaluation have been extracted into a separate standard [17] which is referred to in all the aggregate standards. As this standard was rejected by the members states in the unified acceptance procedure (UAP) the other aggregate standards have not been implemented yet. A new UAP procedure for prEN 16236 is under preparation.

The European Standards for lightweight aggregates EN 13055- Part 1: “Lightweight aggregates for concrete, mortar and grout” and EN 13055-2 Lightweight aggregates - Part 2: “Lightweight aggregates for bituminous mixtures and surface treatments and for unbound and bound applications” were merged into one standard according a decision of TC 154. The new standard EN 13055 will be entitled “Lightweight aggregates for concrete, mortar, grout, bituminous mixtures, surface treatments and for unbound and bound applications [18]. The standard is in the so called enquiry stage, i.e. it will be commented by the CEN member states.

Regarding ashes used as aggregates two main issues have to be considered:

- 1 The materials allowed to be used according to the respective standards are listed in an Annex A. In addition to the source also the history of use is evaluated. The list is based on a compilation of all information of the materials used as aggregates in working group 12 of TC 154. The definitions of such materials were compiled in an additional report which will be finalized by end of 2012. Ashes from coal-fired power plants are listed in the Annex A. Materials not listed in Annex A have to follow a specific procedure to get the materials accepted as aggregate.
- 2 The aggregate standards will serve as a first example for the implementation of the essential requirement (ER) 3 “Hygiene, Health and Environment” in the CE marking of products. This reflects the already existing requirements for leaching into soil and ground in some member states and is now addressed as testing of regulated dangerous substances (RDS). As a precondition two

working groups of TC 351 “Horizontal testing” have developed three test procedures. Two of these standards deal with the release into soil and ground, one for bound and one for unbound materials. The standard for bound materials “Generic horizontal dynamic surface leaching test (DSLTL) for determination of surface dependent release of substances from monolithic or plate-like or sheet-like construction products” is well known as tank leaching test, the test procedure for unbound materials is the so called upflow-column percolation test. The third test procedure is for determination of the emission into indoor air. The test procedures are at present under consideration regarding their robustness. First results showed that they are robust [19].

The results of such tests will help producers to decide whether their products can be evaluated as “Without Testing” (WT), “Without Further Testing” (WFT) or Further testing (FT). FT would require testing of specific parameters on a regular term. Today, the industry is preparing for dossier preparation to allow the CEN technical committees to evaluate the parameters and schemes to be considered in the CE marking of the specific products.

## **7 Construction Products Directive**

On March 9, 2011, the European Parliament and the Council of the European Union have adopted a new Regulation laying down harmonised conditions for the marketing of construction products to ensure reliable information on construction products in relation to their performances. This is achieved by providing a “common technical language”, offering uniform assessment methods of the performance of construction products. The goals of the Regulation are the same as those of the Construction Products Directive (CPD): to foster the free movement and use of construction products in the internal market. The aim of the revision is to attain these goals more easily, more transparently, more efficiently and at lower costs. The regulation retains many of the core elements of the CPD. New emphases are a common technical language to support the definition of harmonised conditions for the marketing of construction products and clear terms for access to CE marking. The Regulation (EU) 305/2011 is partly in force since April 24, 2011. From July 2013, the Regulation will fully replace the current Construction Products Directive (89/106/EEC) [20]. By 1<sup>st</sup> July 2013, producers of construction products and third parties should consider as follows:

- Third parties have to be accredited and notified (activity has to start directly as by 1<sup>st</sup> July 2013 all third parties can only work when being accredited and notified).
- Producers have to prepare a declaration of performance (replacing declaration of conformity – by 1<sup>st</sup> July 2013). The declaration should be based on the parameters given in the product standard and have to be based on the data of the single producer.

Note: A working group group is ordered to prepare master DoPs by spring 2013

- A new annex ZA was provided in March 2012 and will replace the existing one in product standards. Standards under revision will have to include the new annex. The procedure to update all existing standards is not known yet.
- The requirements for ER3 “Hygiene, Health and Environment” and ER7 “Sustainability” can only be described in the declaration of performance when the TCs have agreed on parameters. By this, the Declaration of Performance has to be updated when these parameters are available.



## 8 Conclusions

Coal Combustion Products are used as construction materials according European and national standards and regulations which are subject of regular revision. The standard for fly ash for concrete has been revised and will be published soon. Compared to the existing standard the share of co-combustion materials was increased and requirements for parameters and test procedures have been revised. At present, also the standard for concrete EN 206 is under revision. For CCPs the clause 5.2.5 with the application rules is of importance. Beside the k-value concept also the principals of performance concepts will be described. The standards for hydraulic road binders as well as for hydraulically bound mixtures have been revised and are waiting for final acceptance by the CEN member states. The aggregate standards are partly already revised and are on hold as long as the specific standard for conformity evaluation has been finally accepted.

In April 2011, the new Construction Products Directive entered partly into force which will fully replace the Construction Products Directive by 1st July 2013 aiming at uniform assessment methods of the performance of construction products. By that date producers have to prepare a declaration of performance replacing the declaration of conformity for their products. The CPR will also address the essential requirements (ER) 3 for "Hygiene, Health and Environment" and for ER7 "Sustainability" in the CE marking of construction products. The aggregate standards will serve as a first example for the implementation of ER 3. The industry is preparing for dossier preparation to allow the CEN technical committees to evaluate the parameters and schemes to be considered in the CE marking of the specific products.

## References

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Table 1 Requirements for fly ash according EN 450-1:2005/A1:2007 compared to EN 450-1:2012

property	unit	requirement according EN 450-1:2005/ A1:2007	requirement according EN 450-1:2012
loss on ignition category A	% by mass	≤ 5,0	≤ 5,0
category B		2,0 – 7,0	≤ 7,0
category C		4,0 – 9,0	≤ 9,0
water requirement <sup>1)</sup>	%	≤ 95	not modified
fineness fraction > 45 μm	% by mass	≤ 40 (category N) <sup>4)</sup> ≤ 12 (category S)	not modified
soluble phosphate (P <sub>2</sub> O <sub>5</sub> )	% by mass	≤ 100	not modified <sup>6)</sup>
total phosphate (P <sub>2</sub> O <sub>5</sub> )	mg/kg	-	≤ 5
Initial setting	min.	2C <sup>2)</sup>	not modified
sum SiO <sub>2</sub> + Al <sub>2</sub> O <sub>3</sub> + Fe <sub>2</sub> O <sub>3</sub>	% by mass	≥ 70	not modified
reactive SiO <sub>2</sub>	% by mass	≥ 25	- <sup>6)</sup>
activity index 28 days	%	≥ 75	not modified
91 days		≥ 85	
total content of alkalis	% by mass	≤ 5	not modified
reactive CaO	% by mass	≤ 10	not modified
sulphate (SO <sub>3</sub> )	% by mass	≤ 3	not modified
free calcium oxide	% by mass	2,5 <sup>3)</sup>	<sup>5)</sup>
soundness	mm	≤ 10	not modified
magnesium oxide (MgO)	% by mass	≤ 4,0	not modified <sup>6)</sup>
chloride (Cl <sup>-</sup> )	% by mass	≤ 0,10	not modified

<sup>1)</sup> only applicable for category “S” fly ash

<sup>2)</sup> initial setting of fly ash cement paste shall not be more than twice as long as the initial setting time of the test cement alone.

<sup>3)</sup> if the content of free lime is greater than 1,0 % by mass, the fly ash must be tested for conformity to the requirement for soundness

<sup>4)</sup> the fineness shall not vary by more than ±10 % from the declared value.

<sup>5)</sup> if the content of free lime is greater than 1,5 % by mass, the fly ash must be tested for conformity to the requirement for soundness

<sup>6)</sup> only in initial type testing of fly ash from co-combustion

Table 2 Types of co-combustion materials in EN 450-1:2005 compared to EN 450-1:2012  
(Table 1 of the EN 450-1)

	EN 450-1:2005/ A1:2007	EN 450-1:2012
1	Vegetable material like wood chips, straw, olive shells and other vegetable fibres	Solid Bio Fuels conforming to EN 14588:2010 including animal husbandry residues as defined in 4.5 and excluding waste wood as defined in 4.52, 4.132 and 4.174
2	Green wood and cultivated biomass	(deleted, as meanwhile part of EN 14588 [6] <sup>1)</sup> )
3	Animal meal	Animal meal (meat and bone meal)
4	Municipal sewage sludge	Municipal sewage sludge
5	Paper sludge	Paper sludge
6	Petroleum coke	Petroleum coke
7	Virtually ash free liquid and gaseous fuels	Virtually ash free liquid and gaseous fuels

<sup>1)</sup> Definition for „green wood“ given in EN 450-1 as not given in EN 14588:2010

NOTE Other types of co-combustion materials not included in Table 3 (Table 1 of revised EN 450-1) may be subject to an ETA.

Table 3 Limiting parameters for co-combustion materials according table 1 of EN 450-1:2012 [4, 5]

	Type	Limited by
<b>1</b>	<b>Solid Bio Fuels conforming to EN 14588:2010 including animal husbandry residues as defined in 4.5 and excluding waste wood as defined in 4.52, 4.132 and 4.174.</b>	
	green wood 1	Co-combustion fuel based
	green wood 2	Co-combustion fuel based
	green wood 3	Co-combustion fuel based
	bark wood	reactive CaO
	Cacao shells	Na <sub>2</sub> O equivalent (K)
	palm kernels	total P <sub>2</sub> O <sub>5</sub>
	poultry dung	reactive CaO
<b>2</b>	<b>Animal meal (meat and bone meal)</b>	
	meat & bone meal	total P <sub>2</sub> O <sub>5</sub>
<b>3</b>	<b>Municipal sewage sludge</b>	
	municipal sewage sludge	total P <sub>2</sub> O <sub>5</sub>
<b>4</b>	<b>Paper sludge</b>	
	Paper sludge	CaO
<b>5</b>	<b>Petroleum coke</b>	
	Petroleum Cokes	-*
<b>6</b>	<b>Virtually ash free liquid and gaseous fuels</b>	
	Industrial HC liquid	Co-combustion fuel based

\* prevented by national environmental regulations

Table 4 Rules of application for the k-value concept for use of additions (proposal in revised EN 206) [4, 5]

addition	cement acc. EN 197-1	k-value	Max amount of addition, to be accounted to the (w/c)eq ratio
fly ash	CEM I	0,4 <sup>1)</sup>	f/c ≤ 0,33
	CEM II/A		f/c ≤ 0,25
silica fume <sup>1)</sup>	CEM I und CEM II/A (ohne CEM II/A-D)	2,01) für (w/c)äqui ≤ 0,45 2,01) für (w/c)äqui > 0,45, except for XC and XF, where ks = 1,0	s/c ≤ 0,11
ground granulated blastfurnace slag	CEM I und CEM II/A	0,6 <sup>2)</sup>	g/c ≤ 1,0
<sup>1)</sup> maximum k-value			
<sup>2)</sup> recommended value (to be defined on national level)			

Fig. 1 Relation between free lime and soundness (LeChatelier test)

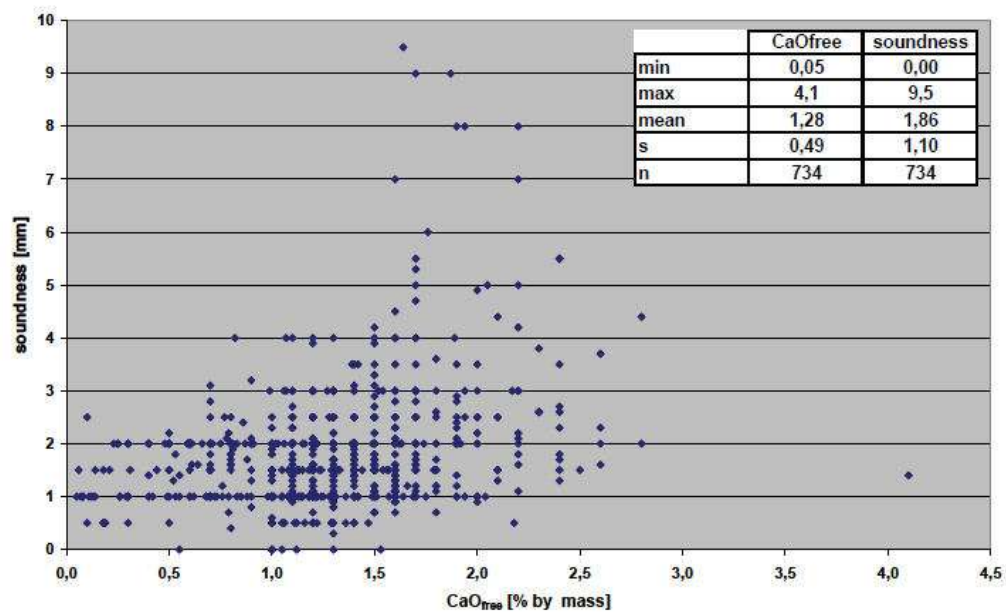


Fig. 2 Relation between the content of total phosphate and soluble phosphate

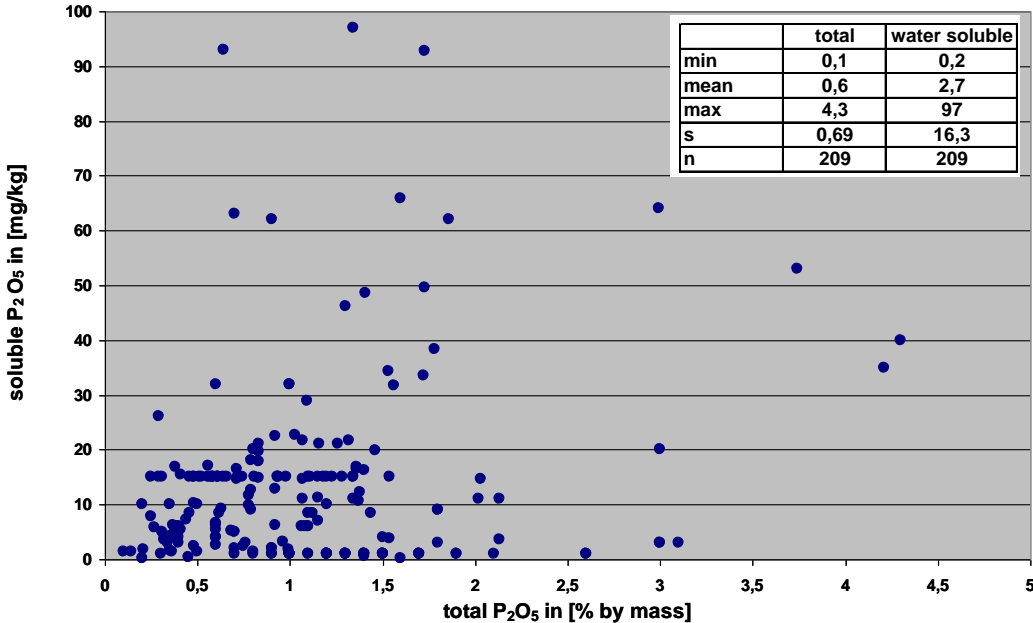


Fig. 3 Comparison of wet and dry sieving on a 45 µm sieve

