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Limitation of sulphur- and chloride-cycles by means of bypass systems

A high removal efficiency requires careful adaptation to individual kiln situation

In recent years the increased use of secondary fuels and raw materials has led at many clinker kilns to higher inputs of chloride-, sulphur- and alkali- compounds. Consequently, the so-called inner recirculation systems of these materials augmented between the sinter zone of the kiln and the hot part of the preheater. Without additional technical measures this can cause operational troubles, resulting in kiln stagnancies and thus losses of production. The new situation caused many kiln operators to install bypass systems.

Modern plants for burning cement clinker operate according to the counter-current principle. This means that the prepared raw meal is preheated by the hot kiln exhaust gas. At the same time hot clinker from the kiln is used to preheat the combustion air. Under these conditions chloride-, sulphur-, and alkali-compounds evaporate in the sintering zone and recondensate in the lower part of the preheater. Depending on the specific situation these compounds can build up cycles which can affect the kiln operation.

Options to limit cycles

To ensure a trouble-free kiln operation, sulphur- and chloride cycles can be limited in two ways, either by reducing the input of these compounds or by removing a part of the recirculating materials from the kiln-preheater system. Such a removal is most efficient at the point of the highest concentration when the loss of material, gas and thermal energy is at its lowest. However, for that purpose the recirculation profile of the whole kiln system must be known and has to be determined by measurements.

In kilns with cyclone preheater three options have proved to reliably limit the inner cycles. Which one of these options is preferable for which specific kiln depends on the level of the recirculation system and the volatility of the compounds to be discharged. At lower recirculation levels dust can be removed from the exhaust gas dust filter, preferably at times when the raw mill is not operated. The installation of a meal bypass system can also be used for the purpose of the removal of less volatile materials. In this case hot meal can be removed from a lower cyclone stage. Finally the installation of a gas bypass has particularly proved to be effective for the limitation of the chloride cycles.

Dimensioning of gas bypasses

Gas bypass systems shall effectively remove the largely evaporated alkali chlorides at the prevailing temperatures in the kiln inlet and riser duct with low thermal losses. Therefore, the alkali chloride removal is most efficient in those parts of the riser duct where dust concentrations are low and gas temperatures are high. However, because alkali sulphates are already combined with particles to a large extent in this part of the kiln, they tend to remain in the kiln system because of the low-dust take-out. As a consequence, gas bypass systems have to be dimensioned according to the input of alkalies, sulphates and chlorides, their molar ratio as well as the lime saturation factor of the raw material and the temperature profile in the kiln plant. **Fig. 1** schematically shows the kiln inlet area of a two-string cyclone preheater with a modern gas bypass system.

Efficiency of bypass systems

Fig. 2 and **3** show the effectiveness of bypass systems at various kilns

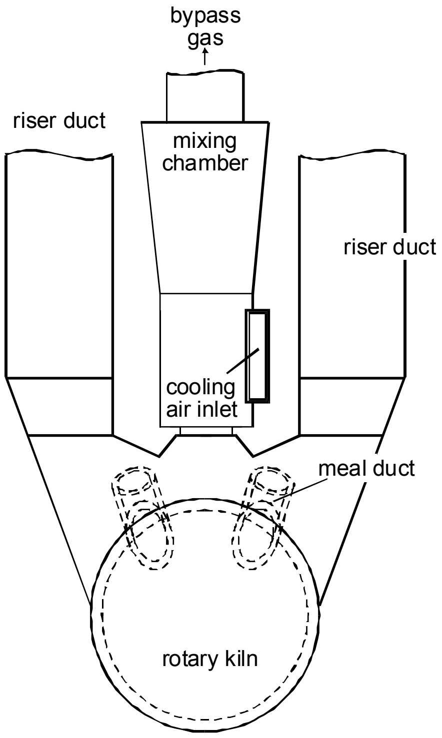


Fig. 1: Two-string cyclone preheater with a gas bypass system

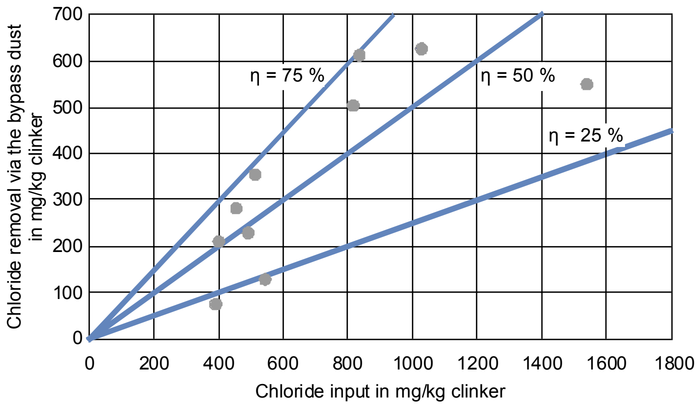


Fig. 2: Chloride-removing efficiency of bypass systems in various works

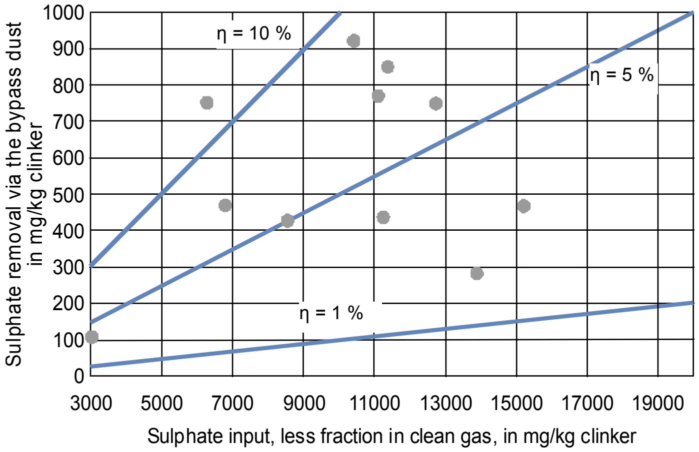


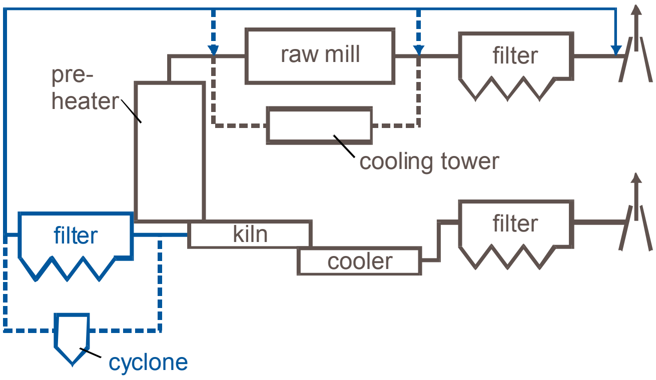
Fig. 3: Sulphate-removing efficiency of bypass systems in various works

for the removal of chloride and sulphate, respectively. The investigations have shown that the efficiencies of bypasses are between 20 and 75 % for chlorides with reference to the total input of chlorides into the kiln system. The removal rates for sulphur can be adjusted to be between 2 and 12 % with reference to the input of sulphur.

Gas flow designs of gas bypass

The design of the exhaust gas flow control of the gas bypass and the exhaust gas recovery must be adapted to the individual kiln system in order to allow optimum utilisation of the energy and material content of the bypass flow. This applies in particular to bypasses retrofitted to existing kilns. In this case, the bypass system cannot be seen separately from the existing kiln. Apart from the material composition of the bypass dust and its use, the thermal potential of the bypass gas with regard to the overall production process and the emission situation must be taken into account as well. **Fig. 4** shows an example for the utilisation of the bypass gas in the raw mill and a bypass dust collection in an electrostatic precipitator or cyclone. In such a case of bypass gas utilisation the SO_2, which is often present in high concentrations in the kiln inlet, is largely bound to the raw material in the raw mill.

Fig. 4: Utilisation of the bypass gas in the raw mill and bypass dust collection in an electrostatic precipitator or cyclone



Utilisation of bypass dust

The removal of bypass gas is linked with the precipitation of considerable masses of bypass dust. Besides partly decarbonated hot meal the dust contains alkali-chlorides and sulphur-compounds. The utilisation of bypass dust depends on the composition of the dust. The biggest portion of the bypass dust is used as a minor additional constituent in cement, according to the European cement standard EN 197-1. Other possibilities of utilisation are usage in agriculture, in roadwork or conditioning of sewage sludge. Moreover, bypass dust can be used as a raw material component for glass production.

Traffic route engineering

Concrete for durable and environmentally compatible carriageways

The passenger and goods traffic in Europe is growing steadily. In spite of the support for local public transport and the extension of the rail network, an increasing proportion of the transport service continues to fall to the road. In particular, the increase in heavy traffic combined with an increase in axle loads is leading to increased stressing of the road system. Concrete construction offers competitive solutions, which can cope with the loads, especially for motorways and ballastless rail tracks. Concrete roads and concrete slabs for railways are dimensionally stable, have a high load-bearing capacity, a long service life and require little maintenance.

The Research Institute has carried out numerous investigations on the development of cement based materials for road construction, especially noise-reducing pavements and the re-use of recycled building materials, to improve the performance of cement based road construction. A further program has dealt with air-entrained concrete.

Noise reducing road pavement

There is a potential for noise reduction both in the optimization of conventional methods of construction with dense concrete and also in the development of new open-pore concrete. The options for improvement in dense concrete pavement tend to lie in improved evenness and more effective surface texturing.

Much more difficult is the development of open-pore concrete. This concrete is generally produced with a gap-graded aggregate. It contains 5/8 mm chippings and in some cases, a very small proportion of fine sand. The cement content lies between 280 and 350 kg/m^3 and the w/c ratio is about 0.25 to 0.30. Porous concrete has a void content of about 25 % and is applied in a layer thickness of 4 to 8 cm on subconcrete which has already hardened, or on fresh concrete which has not yet set.

Many investigations were carried out to improve the durability of this porous concrete. Several additions (superplasticizer, micro-silica, polymer suspension) were added to different mixtures. In September 2002 a test stretch was build on a road in Germany. A porous concrete top layer (thickness 8 cm, voids content 25 %) was spread with a paver onto a bottom layer concrete (**Fig. 1**). First noise measurements showed that the noise emission of porous concrete is comparable to roads with porous asphalt layers. The test stretch is under traffic load since November 2002. Now the long-term behaviour must be proved.

Recycling in road construction

Road paving concrete from motorways is a high-grade and consistent building material. After 30 years, this concrete may reach a compressive strength of up to 100 N/mm^2. The old concrete slabs are crushed, lifted and broken. The aggregates are subdivided into the fractions of 0/2 or 0/4, 4/8, 8/16 and 16/32 mm. In general, the recycled aggregate with a grain size of > 2 mm is used for the bottom layer concrete. The concrete crushed sand is used predominantly in frost protection layers and in hydraulically bound subbases. Investigations in the Institute on the re-use of crushed sand in new paving concrete demonstrated that with an increasing content of crushed sand, the amount of superplasticizer and air-entraining agent added must also be increased, to ensure sufficient workability and a sufficient air content. The strength properties and the resistance to freeze-thaw attack with de-icing salt, are only very slightly influenced by an increase in the crushed sand content, which is insignificant. However, the shrinkage and swelling is considerably increased, and the wear resistance is decreased. The problems associated with the use of crushed sand lead to the exclusion of this sand from the manufacture of concrete for roads.

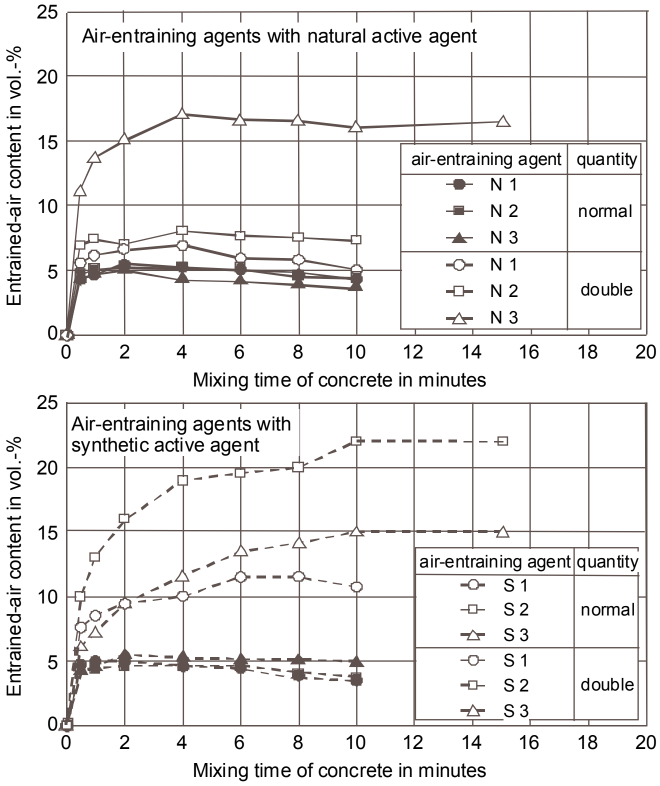


Fig. 2: Air void formation relative to the mixing time, active agent and quantity of air-entraining agent

Air-entrained concrete

Damage as a result of freeze-thaw-attack with de-icing salt has practically ceased since concrete for motorway pavements now contain artificially introduced air voids. However, unusual air void formation had been observed at some individual road construction sites in recent years. It was found, that the hardened concrete had a much higher air content than the fresh concrete.

First investigations with road concrete were performed with 6 different air-entraining agents – 3 with natural and 3 with synthetic active agent. The amount (normal quantity) of air-entraining agent was chosen in such a way, that the air content of the fresh concrete was about 5 vol.-% after a mixing time of 2 minutes. Then the air void formation was determined as a function of the mixing time, with normal quantity of air-entraining agent (AEA) and with twice the normal quantity (**Fig. 2**). With the normal quantity, the concretes with the 6 different air-entraining agents showed identical behaviour. The required air content of 5 vol.-% was achieved after a mixing time of about 1 minute.

A different behaviour pattern was apparent when twice the normal quantity of AEA was applied. In the concretes with air-entraining agents N1 and N2, the air contents increased by only about 2 %, to about 7 %. After a mixing time of about 1 minute there was no further change in air content. With the concretes with air-entraining agents N1, S1 and S3 there was a two- to three-fold increase in the air content. The concrete with air-entraining agent S2 showed a four-fold increase compared to when the normal quantity of AEA was added. Significantly longer mixing times were also necessary before the air-entraining agents were fully activated and a constant air content was obtained. However, it was not possible to assign the behaviour of the air-entraining agents systematically to a particular type of active agent – synthetic or natural.

The research about the basis of air-entraining agents is continuing on to find out the influence of different ingredients of active agents on the air void formation. This will lead to the development of an optimised, robust AEA.

To avoid excessive air content in future, the following recommendations are given:

Air-entrained concrete should be mixed for at least 45 seconds. In additional performance tests the behaviour of the selected AEA should be tested. The air content should be determined with normal (45 sec.) and extended mixing time (5 min.) and even with higher quantities of air-entraining agents.

Fig. 1: Spreading of porous concrete with a paver

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