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Cement Lime Gypsum
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ISSUE
2017

SPECIAL 2017
Drymix Mortar
Construction Chemistry

ZKG INTERNATIONAL

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CONSTRUCTION CHEMISTRY


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Anke Bracht
Editor ZKG INTERNATIONAL

For five years now …

… in the ZKG special edition Drymix Mortar | Construction Chemistry we have been informing you about the latest news and trends in the drymix mortar industry. Once again, the 2017 edition is dedicated to product innovations and recent developments from this special area of the construction materials sector.

As usual the technical papers start with contributions from the materials science field. The topics vary for example from the resistance of mortars to frost and salt frost attack (p. 20) to the use of recycled autoclaved aerated concrete (AAC) from processed construction and demolition waste for producing dry premixed mortars (p. 36).

Following the theoretical part, the application sector starts under the heading "Process" with a contribution on the optimization of crushed sand production for the drymix mortar industry. Under the "Engineering" label the latest plant concepts and technology for drymix mortar plants will be described (from p. 52).

All this is rounded off by product and company news as well as our service categories such as selected patents and events.

We are looking forward to seeing you at the idmmc 6 and/or the European Coatings Show in Nuremberg/Germany at the beginning of April!

Yours most sincerely

Anke Bracht
Editor ZKG International

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ZKG INTERNATIONAL

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Turnkey processing solutions for dry mortar mix plants

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Federal German Association of the Lime Industry
Bundesverband der Deutschen Kalkindustrie e.V.
Federal German Association of the Gypsum Industry
Bundesverband der Gipsindustrie e.V.

04.05.–10.05.2017, DÜSSELDORF/GERMANY

Enormous interest in interpack 2017

Photo: Messe Düsseldorf/ctillmann

interpack 2014

interpack 2017 is recording the highest demand among exhibitors in its history of over 55 years. By the official closing date of this outstanding international event for the packaging industry and related processing industries, exhibitors had booked about 20 % more space than was available at the exhibition centre with its 262400 m² in 19 halls. Around 2700 exhibitors can therefore be expected again from 04.05.–10.05.2017, coming from about 60 different countries. As before, another trade fair will be running in parallel, entitled components, special trade fair by interpack. It will feature products from supplier industries of the packaging sector. This event, too, is now fully booked, yet it will occupy more than twice as much space as in 2014, at its première.

Special topic: Industry 4.0 – in partnership with VDMA

Where size and internationalism are concerned, interpack is a unique platform for businesses offering products and solutions in packaging technology and related processes as well as packaging media and materials for the various segments of this industry: food, beverages, confectionery and pastries, pharmaceuticals, cosmetics, non-food consumer goods and industrial goods. The products and services presented here will be supplemented by several innovative specialist areas. Working together with the German Engineering Federation (VDMA), interpack 2017 will put the focus on Industry 4.0, in particular. The special show will take the form of a Technology Lounge at the VDMA stand, featuring examples of solutions in packaging machinery and process engineering and opening up new opportunities for applications in security, traceability, copying and counterfeit protection as well as in customised packaging.

components trade fair now entirely in tandem with interpack

Following the première of components, special trade fair by interpack, in 2014, the general idea of this trade fair has been substantially revised for 2017. Visitors will now find it at a central location within the exhibition centre, in Hall 18, a temporary lightweight hall, approximately 5000 m² in size. It is situated between Halls 10 and 16, complementing interpack for its entire duration.

Hundreds of companies from the supplier industries will each have their own stands, offering products in drive, control and sensor technology, industrial image processing, material handling technology and other (machine) components. components will be freely accessible to all interpack visitors and exhibitors.

www.interpack.com

27.09.–28.09.2017, MUNICH/GERMANY

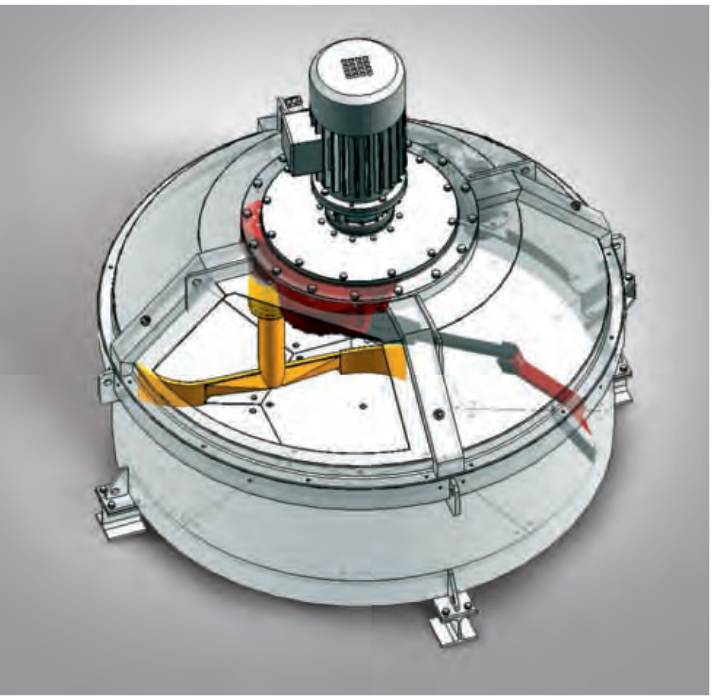
International PCE Conference at TU München

On 28.09.2017, Technische Universität München (TUM), the Chair for Construction Chemistry of Prof. Plank will host the "2nd International Conference on Polycarboxylate Superplasticizers (PCE 2017)". This full-day conference will offer insights into the latest developments of PCEs presented by speakers from key players in this field. Topics covered include cement compatibility, clay tolerance, synthetic aspects, interaction with novel binders and a global market analysis for PCEs. The conference will be preceded on 27.09.2017 by a full-day workshop on PCE superplasticizers where chemistry, preparation, analysis and application of PCEs will be presented. Both events will take place at the Garching campus. Abstract submission for the conference is now open and will close on 15.04.2017, the deadline for full paper submission is 30.06.2017; registration will open on 20.04.2017.

www.pce-conference.org

TUM

High-Performance Turbine-Mixers THT



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DEUTSCHE BAUCHEMIE E.V.

Deutsche Bauchemie launches competition for the 2017 "Science Medal" and "Promotion Award"

In 2017, the German building chemicals industry association Deutsche Bauchemie e.V. will again be conferring awards for innovative and practice-oriented dissertations and diploma theses written by qualified young talents. The submission deadline for the current competition is 21.04.2017.

Conducted biennially by this Frankfurt-based industrial association, the competition aims to foster budding scientists from diverse German universities, colleges and polytechnic institutes. Another of its purposes is to help the building chemicals industry secure more public awareness with regard to things like raw material research and development, the formulation of performant, sustainable building products, and their application in the construction sector. With a remuneration of € 4000, the "Science Medal" is intended for young graduate students who have finished their dissertations within the last three years. Graduates of diploma and master's studies are invited to enter their theses on building-chemical topics in the "Promotion Award" competition worth € 2000.

All entries will be examined for significance and topicality by a committee of appraisal composed of distinguished professors of building chemistry, all handpicked by the executive board of Deutsche Bauchemie. Their decisions will be based on the papers' scientific quality, presentation of contents and practicability. Both awards will be presented to the laureates at Deutsche Bauchemie's next annual meeting in Lüneburg on 23.06.2017.

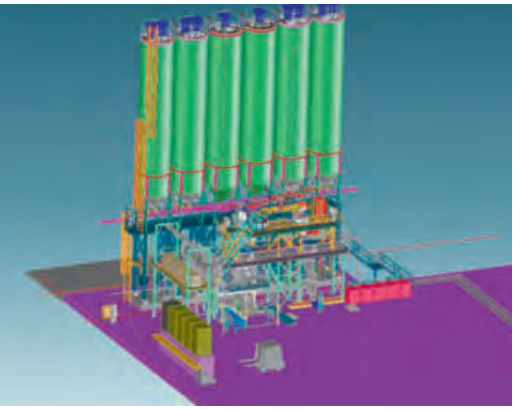
Additional information and the formalities are available for downloading from the association's homepage:
www.deutsche-bauchemie.de/wissenschaftsmedaille
www.deutsche-bauchemie.de/foerderpreis

Deutsche Bauchemie e.V.

Deutsche Bauchemie Promotion Award

KNIELE BAUMASCHINEN GMBH

New mixing plant in Saudi Arabia



Kniele

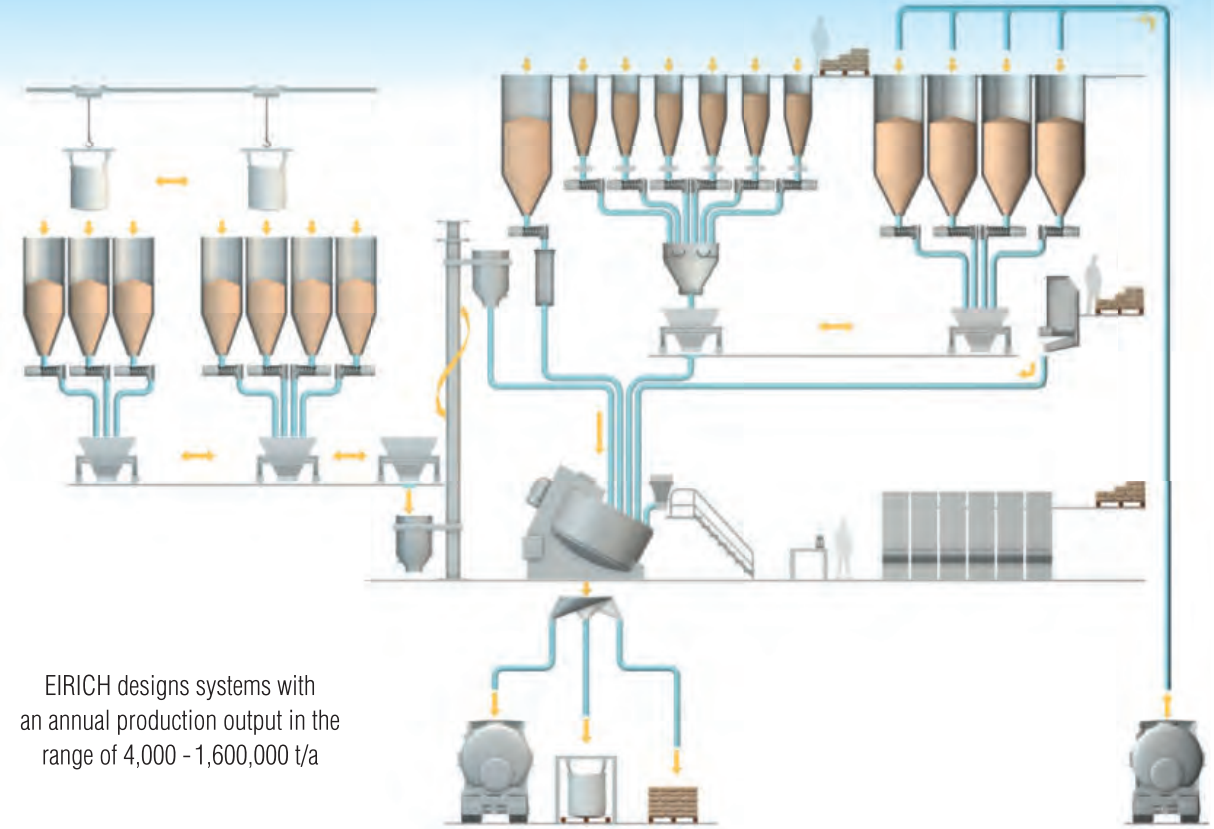
3-D drawing of the new mixing plant

For the production of plasters on the dry side and an adhesive on the wet side, a special mixer has been designed and engineered, which is currently being installed at the Nova al Taknia plant in Saudi Arabia. Ten silos for sands and binders have been installed, as well as five sack feed hoppers for special components, an automatic Flex 70 colour metering system from Würschum as well as an additive weigher for liquid components on the wet side.

For production of the drymix mortar, a KKM 1125 cone mixer supplied by Kniele has been selected while for the production of the adhesive, a KKM 375/550 cone mixer will be used. Metering and weighing of all components is controlled with a Bikotronic control system, which is used to control the entire process up to metering into buckets on the wet side.

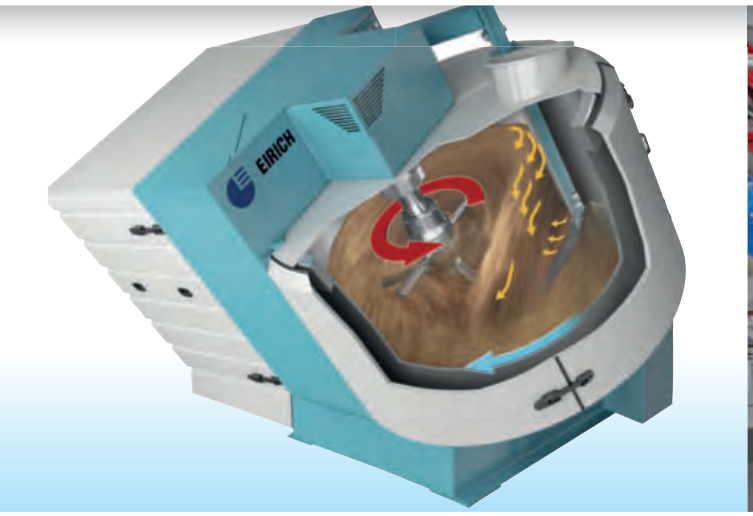
For filling into sacks, two pneumatic packers supplied by Bates in the Netherlands have been chosen and on the wet side a very special screw feeder system with weigher supplied by WMW has been installed. In the final development phase, an integrated sand processing plant with screening into different sizes will also be installed.
www.kniele.de

EIRICH



EIRICH designs systems with an annual production output in the range of 4,000 - 1,600,000 t/a

Plaster and Mortar Manufacturing



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LAHTI PRECISION OY

Customized and versatile drymix plant – FlexiBatch concept from Lahti Precision Oy

All Lahti Precision Oy

1 System side view

Some ten years ago various leading drymix producers started to look for flexible and somehow "portable" drymix plant concepts for their market analyzing purposes and also for a plant concept that could be installed in difficult infrastructure locations in emerging countries. The main drivers were quick set-up of the plant, low height requirement in order to use an existing building or warehouse, easy to relocate the plant to another location and relative low investment cost as well as easy operation and maintenance, quick change from one product to another without any risks of contaminations between various products and raw-materials. The previously mentioned targets coupled with the ability to produce drymix products from simple mortars up to the most complex products, proved to be an impossible task for that time's technology and plant concepts, i.e. an all-in-one package solution could not be reached without compromising the product portfolio, jeopardizing product quality or the investment budget.

FlexiBatch – Drymix plant

Lahti started to develop various concepts keeping in mind the above-mentioned targets and can today proudly present the FlexiBatch concept which ultimately reflects all competitive aspects mentioned in the abstract. In the beginning it started as a "mini-plant concept" having a mixing capacity of approximately 5 t/h, but finally proved to deliver a mixing capacity range from 5 t/h up to 20 t/h, covering annual production ranges from 25 000 t to 100 000 t. Three standard plant sizes were established, introducing mixer net volumes of 500, 1000 and 2000 l. Each one of the three FlexiBatch plant models can be widely extended and converted to fulfill the customer's needs by installing a large number of options related to raw materials handling and logistics, matching the plant with local job site requirements, local market requirements, raw materials and end products logistic challenges and last but not least investment budget. Keeping this in mind the plant owner benefits from the resulting low costs for local steel structures, foundation and other civil works as the plant can be erected on top of existing warehouse floors without any building facilities.

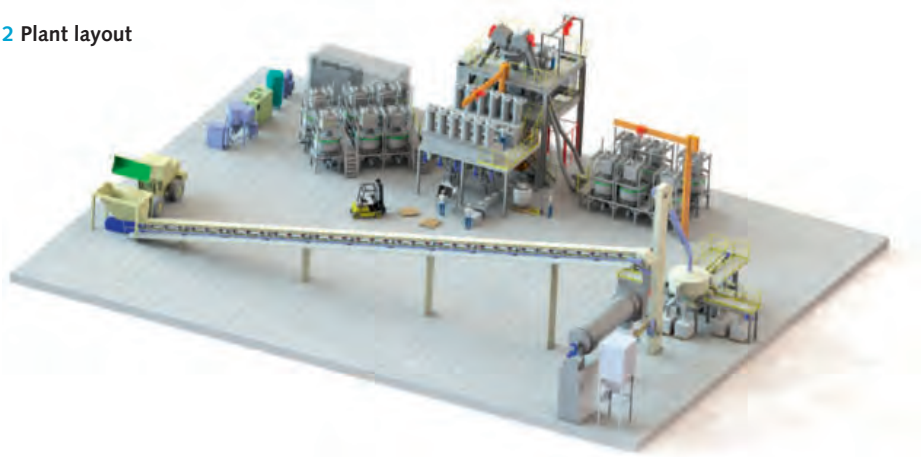
Aggregates and binding materials handling

FlexiBatch is truly flexible in aggregates and binding materials handling and logistics. All possibilities are available from small/big-bags serving as material storage up to more complex automatic aggregates preparation plants incorporating crushing, drying, grinding and screening and/or large silo storage with direct dosing into the process etc. This part of the plant is always selected and designed in close co-operation with the customer in order to tailor it to fully match with the local raw materials logistics and availability. As such this part may constitute the major part of the investment, unless original FlexiBatch "all raw materials delivered in bags" logistics system is feasible. Therefore this plant section should always be designed with great care. Naturally Lahti utilizes fluidization, special material conveyors, and best design practices in this section as well as in other plant sections.

Conveying

There are three critical conveying points in the plant. a) collecting the materials horizontally after the big-bag dosing units; b) lifting the dosed materials after the collecting conveyor up to the checking hopper scale on the top of the batch mixer; and c) conveying the dosed additive batches into the mixer. In the Flexi-

2 Plant layout



3 Mixing station

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We know how

Special products combined with technical support for construction, coatings, specialties

Accelerators
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Anti-Shrinkage Agents
Defoaming Agents
Special Cements Additives
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Rheology Modifiers
Hydrophobic Agents
Set Retarders
Super Plasticizer
Polymer Dispersions
(Acrylic & Polyurethane)
Polymer Powders
Pigments
(Organic & Inorganic)
Dyes
Cellulose Fibers
Acrylic and Propylene Fibers
Lightweight Aggregate

Epoxy Resins
Ketone Resins
Hydrocarbon Resins
(Liquid & Solid)
Additives for Masterbatches
and Compounds
Multicolor Aggregates
Extenders and Fillers
Wetting Agents
Dispersants
Polyols
Oils
Primers
Metallic Fibers
Epoxy Curing Agents
UV Resins
Chromo Reducers
Fluorescent & Phosphorescent
Pigments

4 Weighing electronics

Batch concept these three tasks are handled in an optimum way by utilizing best available technical practices incorporating the ability to maintain high purity while changing the recipe, low wear and tear of the process equipment, and the lowest possible segregation.

Weighing

FlexiBatch incorporates the best of the best weighing equipment, with weighing performance being in line with commercial weighing. This performance can be verified against OIML III regulations as the weighing components are selected from the certified line of equipment (instrument, load cells and load cell installation kits).

Dosing

FlexiBatch incorporates numerous alternative dosing principles (cumulative or loss-off-weighing) and equipment which will be always selected based on material properties and accuracy demand dictated by the recipe or better stated, by the range of recipes. Mostly these consist of dosing equipment based on Lahti's fluidized dosing and conveying systems as well as Lahti's specially designed and well-proven screw feeders equipped with motorized agitators. For low & middle budget applications additives can be dosed manually but even in these cases the dosed amounts and materials are registered by the control system in order to keep the accurate batch log and minimize human error. Manually dosed additives are an extremely feasible & economic choice for plants having 5 to 10 t/h mixing capacity or applications that require frequent recipe changes, i.e. production of state-of-the-art technical mortars.

Mixing

The FlexiBatch plant incorporates high-quality twin-shaft mixers equipped with four high speed choppers for the 10 t/h and 20 t/h versions. The 5 t/h version has a single shaft mixer with one chopper. All these mixers provide excellent mixing results, and are the same mixers that are used at Lahti's large traditional tower plants. Optionally all these mixers can be equipped with liquid spraying systems and/or semi- automatic (easy) cleaning systems.

Packing

The two basic FlexiBatch concepts offer one or two spout packing machines depending on the mixer size selected (500 or 1000 l). In the case of 2000 l mixers, even three or four spouts are possible on special request, however this slightly increases the plant's height. These bagging machines are either the fluidized or impeller type depending on the product granulometry and other bagged product properties. In all cases the packing machines can be optionally equipped with fully automatic empty bag placers, ultrasonic sealing, check weighing, automatic saddle height adjustment, and other options. Automatic empty bag manipulation incorporated with possibility to operate the machine manually in emergency or special situations is possible (this is achieved by installing the bag feeder(-s) on a "wagon" that can be easily pulled backwards for the operator to have space to handle the empty bags in front of the spouts safely).

Palletizing and pallet wrapping/hooding

All FlexiBatch versions can be optionally fitted with automatic palletizing systems (robot type or conventional high speed palletizer) but in the basic versions palletizing is done manually to reduce the budget and specifically when capacity is 5-10 t/h.

FlexiBatch plant control system

The core of the control system is based on a Windows 7 platform running a Siemens WinCC user interface application engineered by Lahti, logic operations are carried out with a Siemens S7 series PLC, 1500 CPU series with distributed I/O modules. On top of everything there is high speed internet communication for remote maintenance and remote program changes as well as an incorporated comprehensive batch reporting database module. This package of top class engineering is well proven in practice and therefore together with the FlexiBatch modular and "ready-engineered" plant mechanics it offers a superior speed for putting the plant into operation compared with any other drymix concept in the market.
http://lahtiprecision.com

5 Robot packing and palletizing line

LAHTI PRECISION OY

Lahti Precision has supplied worldwide hundreds of demanding industrial bulk materials handling plants, since the foundation of the company in 1914. The over one hundred years of success proves the sustainability and strength of the company both technically and economically. Lahti has been able to renew the company, develop it with the times as the requirements of the markets and the customers have evolved. The company has delivered plaster and mortar (drymix) plants since the 1980's especially in Asia, the Middle East and CIS countries achieving a vast experience in operating in different countries and cultures. The company is well known for its commitment to deliver its promises which is part of our Finnish heritage.

KNIELE BAUMASCHINEN GMBH

Special mortar mixing machine

Bridevaux stone supplement mortar is a mineral-based mortar for soft sandstone, hard sandstone and limestone. It is easy to model, so it is well suited for edge and sculptural forms. For efficient production of the stone supplement mortar, Bridevaux invested in a special mixer supplied by Kniele Mischtechnik. This is an automatic dry mortar mixer for special mortar.

Working closely with Urs and Philipp Bridevaux, Kniele Mischtechnik, an engineering company based in Bad Buchau, developed this mixer as a prototype specifically to meet Bridevaux's exacting requirements.

The outstanding feature of the machine is the incorporation of a patented KKM cone mixer. With this mixer, the quality of the mortar can be improved as the mixture and composition of the mortar can be better controlled. The standards to be met by the mixing performance were very high and for this purpose, the following components for metering with precision accuracy were installed:

Four manual sack chutes with integrated sieve for all binders and fillers so that even the smallest lumps are removed before reaching the mixer. Six day silos with metering screws and a specialist colour metering system for six highly concentrated colour stains that can be metered accurately almost to the last gram. Furthermore, pre-metered aggregates can be added manually as the range of different aggregates used is very wide. The mixed mortar is filled into 30-litre buckets directly from the mixer via a weighing balance. The automated production of the Bridevaux stone supplement mortar has enabled the company to increase its capacity.

www.kniele.de

Kniele

Mortar mixing machine

MASCHINENFABRIK GUSTAV EIRICH GMBH & CO KG

Scale-up for mixing of solids

Maschinenfabrik Gustav Eirich GmbH & Co KG

Eirich mixer Type RV19 in a dry mortar plant in France

Scaling-up of mixers is a regular requirement when mixes which are developed and tested in the laboratory are needed in larger quantities or when production is to be started after completion of the development phase. A large range of criteria need to be taken into account. Here once again a customer has confirmed that he can transfer formulas developed in a 1-liter mixer to larger Eirich mixers without any change in quality.

The need to transfer values from a laboratory system to a production system is a regular requirement in every industry (Figure). Often it is not very easy. When it comes to scaling-up, the volume of the process material increases to the third power but the wall surfaces of the unit only to the second power. In pushing mixers (e.g. ring-trough and planetary mixers) and mechanical mixers (e.g. plowshare mixers), therefore, additional tool sets are required; the power density in the process material changes. In the case of plow-share mixers there is the additional requirement for highspeed choppers to assist with the mixing process and disagglomerate very fine materials, the effect of which, according to the literature, is not scale-up-compatible.

For developers in particular it is desirable for the process to be capable of being transferred to larger units straightforwardly as from a certain (laboratory) mixer size. In such a case it is an advantage if the laboratory mixer is a mixer with a mixing principle which permits upscaling. At first glance it seems surprising that Eirich customers report that they are able to achieve the same mixing quality in both small and large mixers without any change in the mixing parameters. By way of example, there are manufacturers of dry mortar which prepare small volumes (such as samples of new formulas or subsequent deliveries, including colored plaster) in a 150-liter mixer, and large volumes in a 3000-liter mixer. How is this possible?

The reasons are simple. Due to the design of Eirich mixers, only a single mixing tool is required for any mixer between 1 l and 3000 l, namely the rotor. The rotating container transports the mix, while all the tool has to do is mix. It requires virtually no contact with the bottom; friction and wear are minimized. The tools can therefore run faster as well if required. In addition: The energy input into the process material can be very precisely defined by means of the type of mixing tool, the tool speeds and the direction of rotation. The parameters vary according to the specific application but, once defined, generally remain unchanged when it comes to upscaling. Within a single revolution of the container, 100 % of the mix is moved by the tool; the mixer therefore mixes without demixing.

The system-immanent characteristics of Eirich mixing technology therefore enable the process parameters to be easily transferred to production machines; production can usually be started without any further extensive adjustment work. The test centers at all Eirich sites around the world have mixers available for trials starting in sizes of just 1 l. This enables the diverse possibilities available for mixing, granulating, coating, kneading, and dispersing to be demonstrated to prospective customers.

www.eirich.de

BASF SE

Excellent rheology and stabilization of flowable mortars

BASF

Self-leveling underlayment stabilized with Starvis 3070 F

Self-flowing mortars help to save time and money at building sites. The powdery Melflux superplasticizers and stabilizers from the Starvis range of BASF that are used for floor screeds and self-leveling underlayments exhibit very good flow behavior and perfectly stabilize mineral particles. Starvis prevents unwanted effects such as sedimentation or bleeding. Starvis-based mortar products are particularly robust when it comes to water and raw material fluctuations: They greatly improve the quality of floor constructions and help to avoid complaints at construction sites. Since Starvis products can be combined with Melflux superplasticizers, they enable a rheology profile that is individually geared towards customer requirements.

www.basf.com

WACKER CHEMIE AG

Novel dispersion for hydrophobic construction solutions

Wacker, the Munich-based chemical group, presents a new polymeric binder for formulating two-component water-repellent construction applications. In flexible sealing slurries, the hydrophobic Vinnapas 760 ED dispersion not only ensures excellent tensile adhesion strength after prolonged exposure to water and outstanding crack bridging, even at low temperatures. It also displays superb processing properties. The dispersion is thus ideal for use in waterproofing systems for indoor pools, basements and bathrooms.

Vinnapas 760 ED is a terpolymer based on vinyl acetate, ethylene and vinyl ester that finds use as a hydrophobic binder in two-component cementitious sealing slurries. A special feature of the dispersion is its vinyl neodecanoate component, which Wacker markets under the Versa brand. Together with ethylene, this considerably increases the elasticity of the end product. As a result, the coating is more extensible and very flexible even at low temperatures. Additionally, it is highly resistant to hydrostatic pressure.

As a mortar additive, Vinnapas 760 ED ensures outstanding crack bridging, both for static and dynamic cracks – even at exceptionally low temperatures down to -20 °C. Sealing systems based on Vinnapas 760 ED thus achieve crack-bridging class O2 as per EN 14891.

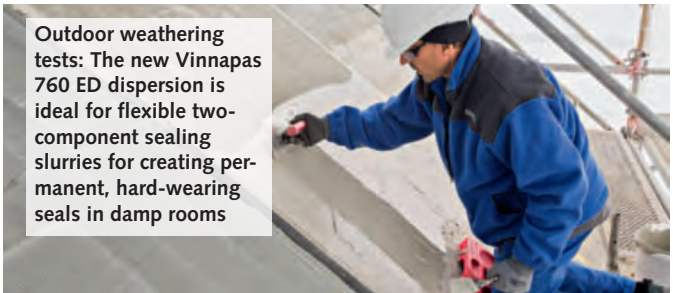
Thanks to the new dispersion, the end product bonds reliably and permanently to difficult substrates. Vinnapas 760 ED is readily compatible with different types of commercially available cement. The high solids content of almost 60 percent moreover makes it possible to tailor the polymer/cement ratio to individual requirements without increasing the viscosity.

According to assessment by the German Federal Institute for Risk Assessment (BfR), the material is suitable for contact with drinking water, because it does not require any additional solvents, plasticizers or film-forming aids. Furthermore, the dispersion is manufactured without the use of alkylphenol ethoxylates (APEOs). Vinnapas 760 ED has very little influence on cement setting behavior.

The new Vinnapas 760 ED dispersion is thus ideal for the formulation of two-component sealing slurries used, for example, to waterproof indoor pools, basements and bathrooms, as well as water pipes and sewers.

www.wacker.com

Wacker Chemie AG



Outdoor weathering tests: The new Vinnapas 760 ED dispersion is ideal for flexible two-component sealing slurries for creating permanent, hard-wearing seals in damp rooms

SIKA DEUTSCHLAND GMBH

Quickly functional, high-strength, horizontal leveling mortar SikaScreed HardTop-60/-70/-80

1-3: Sika Deutschland GmbH; 4-5: Sika Schweiz AG

1 and 2 SikaScreed HardTop-70 excels with very low shrinkage and can accept a Sika synthetic-resin covering 2 hours after placement

SikaScreed HardTop-60 is a quickly functional, high-strength, polymer-modified, industrial-grade leveling screed mortar for interior application in storehouses, production bays, etc. This cementitious product can be applied in layer thicknesses of 8 to 80 mm in a single operation. Thanks to its rapid drying, low shrinkage and high abrasive and compressive strength, it is well suited for major and minor repairs – and reaches full-load functionality within 24 hours. SikaScreed HardTop-60 also serves well as leveling mortar for Sika synthetic resin flooring.

For optimal adhesion to the substrate, these products require the use of a bonding agent. The resin-bonded 2-K product SikaScreed -20 EBB is intended for use as a bonding bridge for SikaScreed HardTop-60. Applied to the dry or, at most, slightly moist surface, it ensures adhesion for SikaScreed HardTop-60 spread "wet on wet". A mere three hours after final troweling, the mortar is ready for coating over.

The product variant SikaScreed HardTop-70 is intended especially for outdoor architectural elements like terraces, arcades or concrete slabs exposed to light mechanical loads and the effects of weather. Applied to a small-area surface in a layer thickness of 10 mm, this cementitious, polymer-modified leveling mortar cures quickly and is rapidly able to bear loads thanks to the SikaScreed Blitz Formula. This soft-plastic premix mortar can be poured on in thicknesses up to 200 mm, all in one operation. Two hours later, SikaScreed HardTop-70 can be coated over and, after another 18 hours, unhesitatingly put to use as a substitute floating screed and covered with any arbitrary finishing material. The clou: for layers thick or thin, curing involves almost no shrinkage, and complete internal drying is assured. In addition, thanks to its crystal-quartz aggregate content, SikaScreed mortar meets the highest of standards for the flexural strength, compressive strength and abrasion resistance of horizontal surfaces. Indoors and outdoors alike, this minimizes time lost due to interruptions of use.

This SikaScreed variant also requires the use of a bonding bridge to optimize the material's adherence to the substrate. The polymer-modified cementitious bonding bridge SikaScreed-10BB is the primer of choice for surfaces subject to normal wear and tear. Surfaces intended for more demanding use require an epoxy resin-based bonding bridge, i.e., SikaScreed-20 EBB.

SikaScreed HardTop-80 rounds out the SikaScreed product family. This variant was developed for major and minor repairs on industrial flooring subject to heavy loads. It displays the same characteristics as SikaScreed HardTop-70, but can be applied in layer thicknesses ranging from 8 to 80 mm. Full functionality for heavy traffic is achieved within 24 hours. Indeed, the leveling mortar can be coated with a Sika synthetic-resin covering no more than 5 hours after its application. In this case, SikaScreed-10 BB is the exclusively prescribed bonding agent.

3 This leveling mortar was developed especially for outdoor architectural elements like terraces, arcades or concrete slabs exposed to light mechanical loads and the effects of weather

www.sika.de

4 and 5 Thanks to Sika's Blitz Formula, SikaScreed HardTop-80 renders heavy-duty industrial flooring fully functional within 24 hours. It can be used both for large and small surfaces

ARDEX GMBH

Flexible adhesive from Ardex offers reliability for applicators even in difficult weather conditions

Ardex GmbH

The new Ardex X 90 Outdoor flexible adhesive

Ardex has developed a new cement-based flexible adhesive that offers users reliability outdoors in both normal and challenging weather conditions. The Ardex X 90 Outdoor MicroteC3 flexible adhesive features weatherproof technology. As a result, it provides a high initial bond – and is consequently just as suitable for low temperatures from +5 °C as for high temperatures. In addition, the adhesive is resistant to driving rain after just two hours.

The new Ardex X 90 Outdoor is the ideal flexible adhesive for balconies and patios. The product is designed to work in all temperatures and weather conditions. But the most important advantage for users is that they can lay tiles outdoors even at low temperatures. Up to now, they have had to wait until the weather was warm enough. But especially in spring and autumn – when most patios and balconies are built – the low temperatures overnight play a crucial role.

Ardex X 90 Outdoor maintains all the properties of a fast-acting flexible adhesive. The new weatherproof technology ensures a short setting phase even at low temperatures, a fast bond reliability and a particularly high freeze-thaw resistance. This is enabled by the new Microtec3 technology. The C2 freeze-thaw cycling requirements specified in EN 12004 are surpassed by far.

In addition, high temperatures and rain cannot harm the new flexible adhesive. When it is very warm, most fast-acting adhesives work even faster, the working time is shortened drastically and the danger of damage increases. Ardex X 90 Outdoor allows a long working time even in very hot weather. On top of this, after just two hours, driving rain can no longer harm the flexible adhesive; a sudden rain shower will not wash out the components so that the adhesive bond is not weakened.

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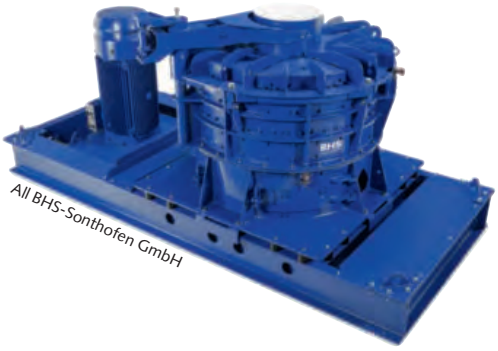
BHS-SONTHOFEN GMBH

More efficient crushed sand production



1 The new rotor impact mill of type RPMF

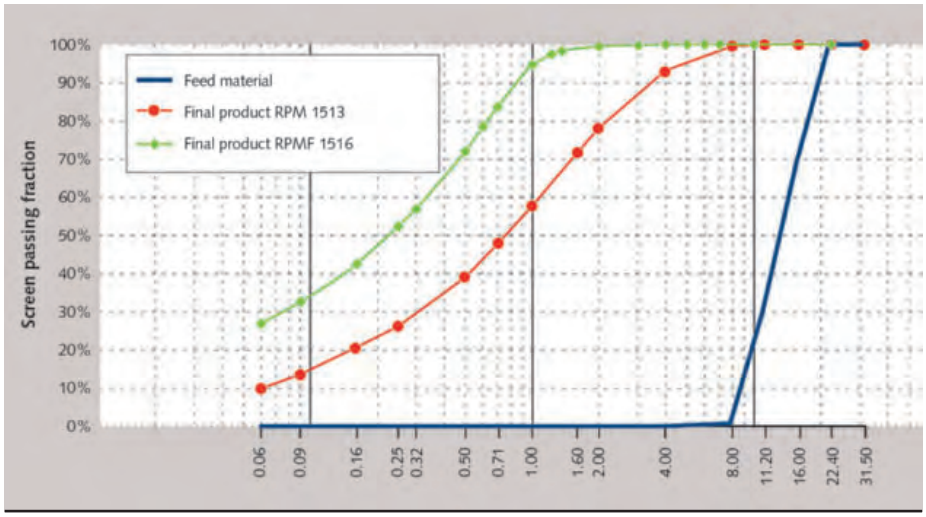
BHS-Sonthofen introduced their new rotor impact mill of type RPMF (Figure 1). The new RPMF machines produce even finer fractions as well as output material with a significantly higher proportion of fine sand (Figure 2). As such, machines of this type are more efficient in producing crushed sand.

The RPMF design is a variant of the rotor impact mills of type RPM, which are known in the industry as "sand makers." BHS designed both types of machines to be used primarily with pre-crushed, brittle and mildly abrasive materials such as limestone. Impact crushing has proven to be the best method for crushing these kinds of materials. BHS-Sonthofen developed the new machine type specifically for finer output sizes. Thanks to a longer, narrower milling gap and increased circumferential speed (of up to 90 m/s) in the rotor, machines of type RPMF archive higher reduction ration than other machines do. As a result, they provide users with output material that contains a higher proportion of fine-sand.

Ludwig Bechteler, Sales Director of Mixing Technology at BHS, oversaw testing for the new machines: "The tests conducted in our technology center demonstrated that RPMF machines produce a significantly higher proportion of usable fine sand in the grain-size range of 0-1 mm than rotor impact mills of type RPM do. For example, RPMFs produce over 50 % more usable dry mortar sand." The new machines of type RPMF also feature a significantly narrower gap between the grinding tools and the anvil ring. The gap width can be set to a minimum of 5 mm (Figure 3).

The new machines yield significantly more fine sand and make plants more efficient in producing sand by reducing the return flow of coarse material, which in turn reduces the number of times that material needs to pass through the mills.

3 The gap between the impact hammers and the anvil ring can be reduced down to 5 mm



2 The RPMF1516, which boasts a circumferential speed of 90 m/s, produces a higher proportion of usable fine sand grain than the RPM1513, which has a circumferential speed of 62 m/s, as demonstrated by this graph depicting sample dry mortar sand production

This also means that these machines require less screening and conveyor technology. Moreover, since they produce finer feed material, these machines reduce workloads for ball mills, which can crush material to a particle size of under 40 µm. The feed material can have a particle size of up to 32 mm. A BHS rotor impact mill of type RPM can be used to pre-crush feed fractions up to 56 mm.

BHS-Sonthofen produces the new rotor impact mills of type RPMF in two different designs:

- RPMF1116, which has a circumferential speed of up to 90 m/s and a throughput of up to 25 t/h
- RPMF1516, which has a circumferential speed of up to 90 m/s and a throughput of up to 55 t/h

The technology in detail

The RPMF machines combine high rotation speeds and a narrower milling gap, so the engineers who designed them needed to control significantly greater centrifugal forces while maintaining a tighter production tolerance.

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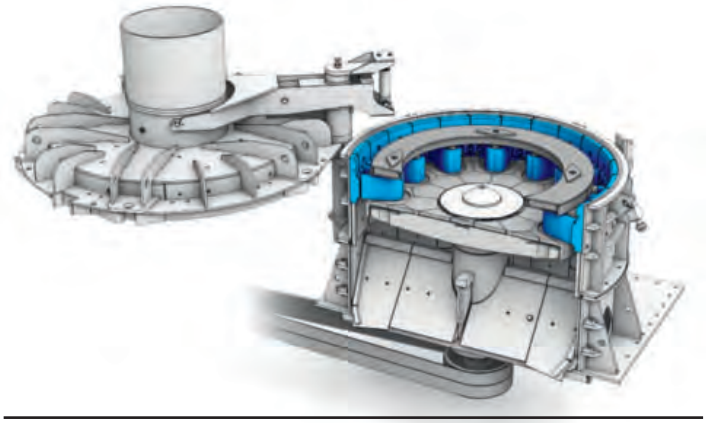
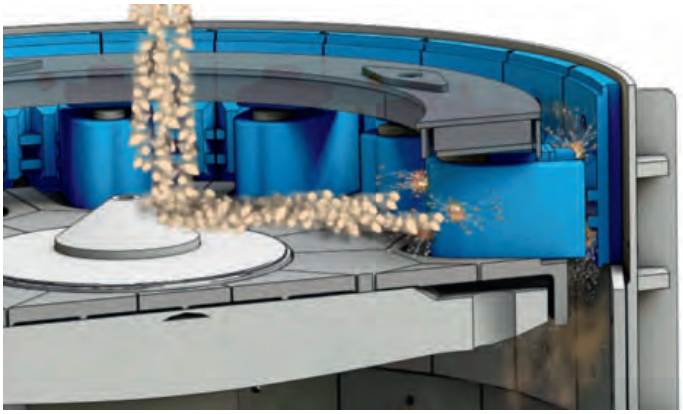
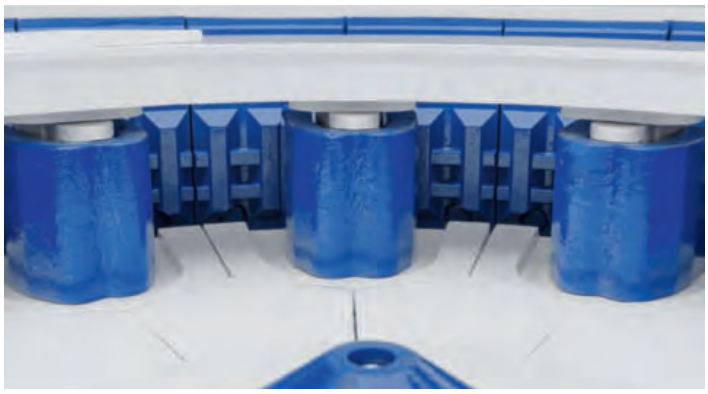
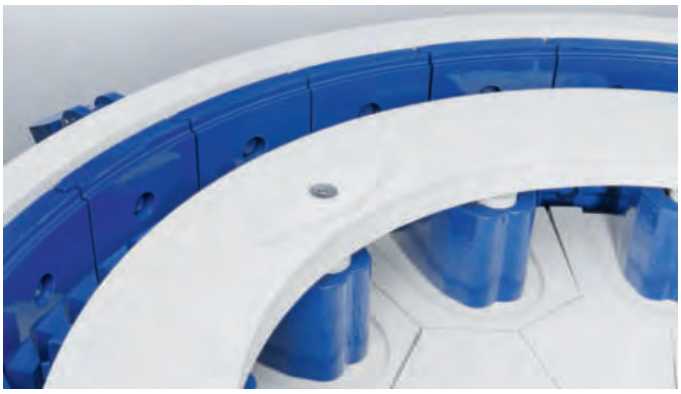


4 The cover of the new rotor impact mill of type RPMF can be rotated electrohydraulically, which makes it very easy to access the inside of the machine



5 The feed material is hit by the horseshoe-shaped hammers, which throw it against the anvil ring



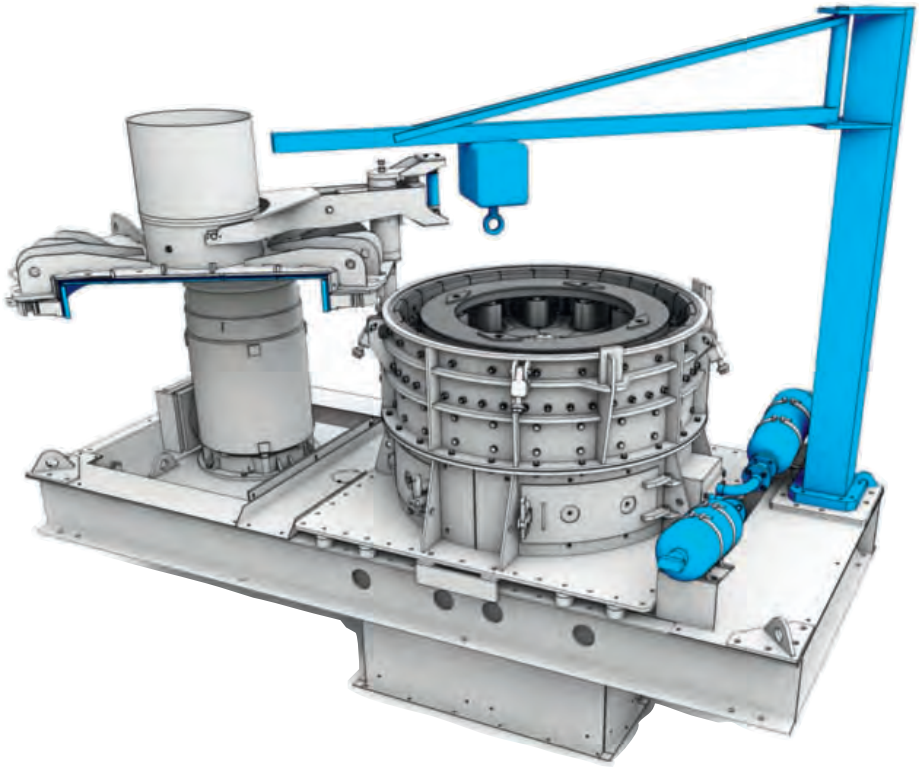


6 The rotor ring (white) holds the hammers securely in place

The feed material is inserted into the machine from above via the central feed-in pipe (Figure 4). When it impacts with the rotor, the material is accelerated towards the outside through centrifugal forces; there, the horseshoe-shaped hammers hit it and throw it against the anvil ring (Figure 5). As the material impacts with the ring, it is subjected to impact and shear forces that crush it (Figure 6). After the material rebounds from the anvil ring, it comes into contact with the hammers once again, which further crush it and throw it back against the anvil ring. The process is repeated multiple times, subjecting the feed material to intense stress. The material leaves the rotor through the gap between the rotor and the anvil ring, falling down through the two outlet chutes.

The mill can be operated alternately clockwise and counterclockwise, which reduces wear on the hammers. Easy-to-replace spacers allow the operator to modify the milling gap in accordance with the wear on the impact hammers.

www.bhs-sonthofen.de



7 An optionally available crane greatly facilitates component replacement

FRANKEN MAXIT GMBH

Maxit's mineral repair mortar for masonry precision blocks unites thermal insulation with structural stability

Franken Maxit, Azendorf

"maxit therm 825" unites high compressive strength with excellent thermal insulation

At the Bau 2017 in Munich, Franken Maxit introduced a lightweight mineral repair mortar called "maxit therm 825". Offering both high strength and thermal insulation, this mineral repair mortar is an on-site all-rounder: for setting up the calibrating layer, for grouting vertical joints, lintels and roller blind housing, and much more.

"maxit therm 825" provides an assured minimum compressive strength of 10 N/mm^2 (mortar class M10), and its thermal insulation properties correspond to those of lightweight masonry mortar class LM21. This insulating performance is achieved by adding mineral rock material like expanded clay or perlite to keep the dry apparent density at 1.3 kg/dm^3 or lower. This mortar therefore satisfies the strict requirements both of Eurocode 6 and of the applicable thermal insulation directives. This not only makes it an outstanding material for the calibrating layer, but also a very versatile problem solver for sundry building site tasks: filling holes in walls, grouting vertical joints, closing up slots and chases, placing lintels and other built-in fitments, installing rolling blind enclosures, setting U-blocks, you name it. Until now, all these jobs called for numerous different mortar products.

The way this mineral repair mortar behaves in case of fire is also a major safety factor: "maxit therm 825" belongs to flame class A1 and is therefore noncombustible. Also, masons are interested not only in the quality of the finished wall, but in the working properties of the product. One ton of dry material delivers approx. 1600 l of green mortar.

Used together with Maxit's "mortar pads", "maxit therm 825" yields an optimal combination. While the dry mortar pads ensure an excellent masonry bond, the masonry precision block mineral repair mortar covers all other potential application requirements.

www.franken-maxit.de

In certain applications mortars can be exposed to frost or salt frost attack during the cold period of the year. There is no established test method for mortars with such exposure. Various methods were therefore assessed and their suitability was evaluated in student theses.

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INGENIEURGRUPPE GEOTECHNIK | BAUHAUS-UNIVERSITÄT WEIMAR

Investigation of test methods for determining the resistance of mortars to frost and salt frost attack

1 Introduction

Testing the resistance of concrete to frost and salt frost attack is a high-profile research subject [1] because of the mass usage of this construction material. The corresponding test methods are regulated in relevant standards. Mortars are used in significantly smaller quantities and also only a certain proportion of these material mixes requires a high frost or salt frost resistance. No direct method for testing these requirements has been standardized in Germany. For plastering mortar as per DIN EN 998-1 [2] the freeze-thaw resistance of single-coat plastering mortar only has to be assessed indirectly by testing the adhesive tensile strength and water impermeability. For all other plastering mortars it holds true that "... the freeze-thaw resistance has to be assessed and stated in accordance with the regulations that apply at the intended

place of application of the mortar". Nor does DIN EN 998-2 [3] for masonry mortar form a normative basis for a direct test method. Instructions for the avoidance of frost damage to mortar are given in Appendix B, in which it states that "The ambient conditions to which the mortar is exposed should be borne in mind before selection of the mortar. This includes protection against water saturation. ... The influence of a possible surface coating (e.g. paint) should be checked." Examples are also given of buildings at risk, but no specific instructions are given for carrying out a test. However, a comparative method is desirable for special applications, such as external renderings in splash water zones and external joints. At present the products from various dry premix mortar producers are stated to be "frost resistant" without any information about the test method.

Different methods were applied and compared in two student theses [4, 5] at Bauhaus Universität Weimar to identify suitable and practical test methods with reproducible results. Initial conclusions about the basic viability of existing methods can be drawn from the results of the investigations. However, further research is needed to adapt them to the different types of stresses to which mortars are exposed.

2 Test methods

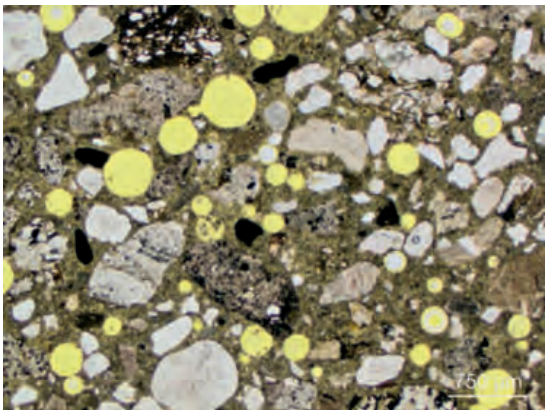
In Central Europe there are several relevant test methods for determining resistance to frost and salt frost attack. For concrete the main ones are the CIF and CDF tests, the slab test and the cube method. These are standardized in DIN CEN/TS 12390-9 [6]. The evaluation criteria for the CIF and CDF methods are contained in an instruction sheet issued by the BAW (Federal Waterways Engineering and Research Institute) [7]. The Knöfel/Schubert freeze-thaw test [8] or the test method for the freeze-thaw resistance of agglomerated stone as specified in DIN EN 14617-5 [9], among others, are used for mortars. A characteristic of these last-named test methods is that they have a great deal of freedom regarding preparation and implementation, which is inevitably at the expense of precision and reproducibility. For example, the requirements for the test specimens, their preparation and for the pre-storage are non-existent or inadequate. The temperature regime should also be regarded as critical. The test methods that have been mentioned for concrete are more precise in this respect and define the essential test parameters more accurately. The important parameters of the methods used are listed in Table 1 for comparison.

An initial thesis [4] just compared the plain frost test methods. The CIF test [6], the Knöfel/Schubert freeze-thaw test [8] and the test method specified in DIN EN 14617-5 [9] were applied to various mortars and evaluated. Exposure to de-icing salt was then also taken into account in a subsequent thesis [5]. The CDF method [6] was used for this purpose as well as three variations of the Frohburg/Stark modified CDF method [10] for noise protection walls, with particular consideration of vertical placement conditions. The CIF test was also used as a reference.

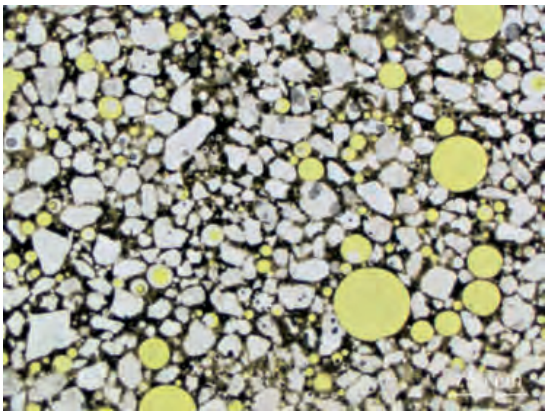
Mortar prisms (40 x 40 x 160 mm³) were used in all cases as the test specimens. Nine prisms were produced for each test method and stored for at least 28 days (in accordance with [11]). The lateral

Table 1 **Parameters of the test methods**

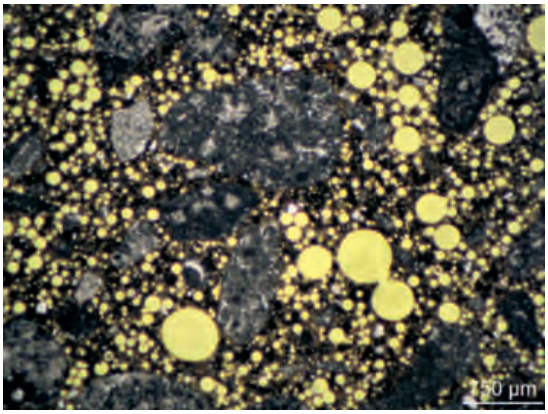
	CIF method CDF method	"Knöfel/Schubert method"	DIN EN 14617-5	Frohburg/Stark-method
Preliminary treatment	7 days capillary suction	constant weight	constant weight	1 d capillary suction in 1.5 % NaCl solution 1 h draining before freeze-thaw
Temperature test points specified	yes	no	no	yes
Test liquid	demineralized water/ 3 % NaCl solution	tap water	tap water	1.5 % NaCl solution during suction, freeze-thaw in air
Cooling rate	10 K/h relatively slow (4h)	13.33 K/h relatively fast (3h)	not specified, test pieces are placed in test chest at -20 °C	10 K/h relatively slow (4h)
Min. temperature	minus 20 °C	minus 20 °C	minus 20 °C	minus 20 °C
Holding time at min. temperature	3 h	2 h	4 h	3 h
Heating rate	10 K/h relatively slow (4 h)	13.33 K/h relatively fast (3 h)	very fast, samples are placed in warm water at 20°C (for 2 h)	10 K/h relatively slow (4 h)
Liquid take-up during freeze-thaw	yes	no	only during thawing	no
Max. temperature	20 °C	20 °C	20 °C	20 °C



1 Photomicrograph of thin section of M 10, relatively dense microstructure with large air voids



2 Photomicrograph of thin section of FM 10, microstructure with small and large air voids



3 Photomicrograph of thin section of TM 20, microstructure with many well distributed small air voids and a few large air voids

surfaces were then sealed with epoxy resin as the freeze-thaw attack was to take place exclusively uniaxially through the test surface. In the other points (e.g. preliminary saturation) the tests corresponded predominantly to the standard guidelines of the methods. In each case three prisms were tested together in one container.

The Frohburg/Stark method developed originally for porous adsorption concrete (noise protection walls) appeared to be suitable for testing the mortars as the test specimens have the opportunity to drain before the freeze-thaw treatment and the actual freeze-thaw cycles take place without any in-situ test liquid. This resembles the real conditions to which mortars are exposed in wall base courses. The preliminary saturation was carried out for 1 day (F/S 1), 3 days (F/S 3) or 5 days (F/S 5) in 1.5 % NaCl solution. The samples were placed on a grid to drain one hour before the start of the freeze-thaw treatment. The freeze-thaw cycles were carried out in the same way as the CIF/CDF cycles, but without test solution and without spacers (test surface lying directly on the bottom of the container). After every two freeze-thaw cycles capillary suction of test solution was carried out for 30 minutes, followed by cleaning in the ultrasonic bath and determination of the amount of scaling (test criterion).

3 Test mortars

Three ordinary commercial mortars were used for the tests – an M 10 masonry mortar, an FM 10 joint mortar and a TM 20 trass cement mortar. The characteristic values of the mortars can be found in Table 2. The precise compositions were not known. Figures 1 to 3 show the very different microstructures of the hardened test mortars in thin sections.

The samples made with the TM 20 and FM 10 mortars were principally characterized by large numbers of air voids in the favourable range (≤ 300 µm). On the basis of the characteristic values of the hardened mortars and microstructural characteristics it was possible to estimate the expected resistance to frost and salt frost attack. The prediction, which also takes account of practical experience with the mortars used, assumes the following sequence: TM 20 (many micro air voids, high strength) > FM 10 (significantly lower micro air void content, lower strength) > M 10.

4 Results

During the course of the first student thesis it was established that the existing methods for testing the freeze-thaw resistance of mortars (DIN EN 14617-5; Knöfel/Schubert) not only permit too much latitude in the test conditions but also are unable to differentiate between the different mortars. In contrast, the CIF method gives the first usable results for differentiating between the different types of mortar, but only on the basis of the amount of scaling. None of the methods gave an indication of internal damage of the samples (drop in dynamic elastic modulus). As no adequate differentiation between the different mortars was obtained in the first thesis, test methods for salt frost scaling were used in the second thesis as these are known to intensify the exposure. The CIF test was carried out again as a reference. The results of the CIF test (Figure 4) confirmed the assessment by the first thesis and indicated clear differentiation

between the different mortars. The results corresponded to the expected sequence of the freeze-thaw resistance of the individual mortars. However, with a scaling of less than 300 g/m² after 28 freeze-thaw cycles (FTC) even the weakest mortar (M 10) still showed a good frost resistance, at least according to the existing concrete tests. The scaling criterion for concrete (exposure class XF 4) in the CIF test is 1000 g/m² after 28 FTC [7].

None of the three variants of the modified Frohburg/Stark CDF method permitted any differentiation between the mortars. The duration of the capillary suction had no significant influence on the external damage. Similar results were obtained for all variants. Application of this method for mortars with a dense microstructure (when compared with porous adsorption concrete) is not practical.

As expected, the CDF method (cf. Figure 5, note the scale) caused the greatest damage to the specimens when compared with the other methods. The results also confirm the preliminary assessment of the mortars. A scaling of 13632 g/m² after 28 FTC was measured for M10 (cf. Figure 6), 1431 g/m² for FM 10 and 303 g/m² for TM 20. The generally recognized test criterion for scaling for concrete in exposure class XF4 [14, 15] is 1500 g/m² after 28 freeze-thaw cycles [7]. This means that the FM 10 and TM 20 mortars would have good to very good resistance to salt frost attack but the M 10 mortar would be unsuitable for the corresponding exposure. The internal damage was also determined in the CIF and CDF tests. The measured changes in relative dynamic elastic modulus showed no damage to the internal microstructure. The only exception was the M 10 mortar in the CDF test in which the extremely high scaling also led to internal damage.

5 Discussion

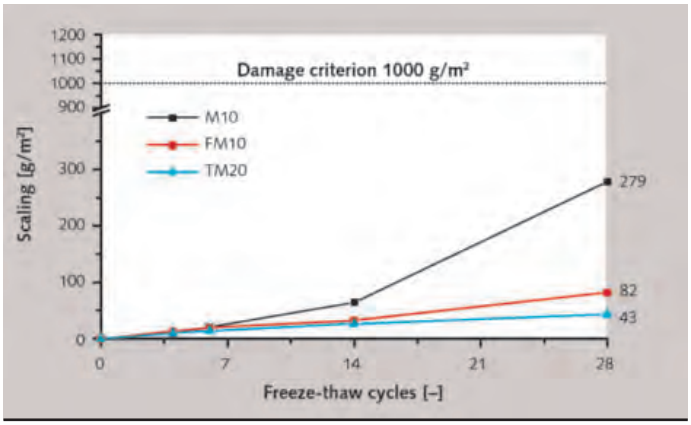
Before testing a mortar regarding its frost or salt frost resistance it is recommendable to evaluate, which exposure the mortar will face in practice, just as DIN EN 998 Part 1 [2] and 2 [3] suggest. A test method with the appropriate criteria would then be allocated. According to current understanding the tests are only able to differentiate pure frost attack or salt frost attack. It is not yet possible to set different degrees of saturation (horizontal or vertical components). It is true that the existing freeze-thaw tests for mortars specified in DIN EN 14617-5 [9] and by Knöfel/Schubert [8] require little in the way of equipment but they exhibit weaknesses with respect to their implementation as the description of the test algorithms permits a great deal of latitude. These methods were not able to differentiate between the different mortars.

The CIF method proved to be the most suitable for determining the plain freeze-thaw resistance. It allowed the various mortars to be differentiated on the basis of the scaling although the results from all the mortars still lay in the favourable region.

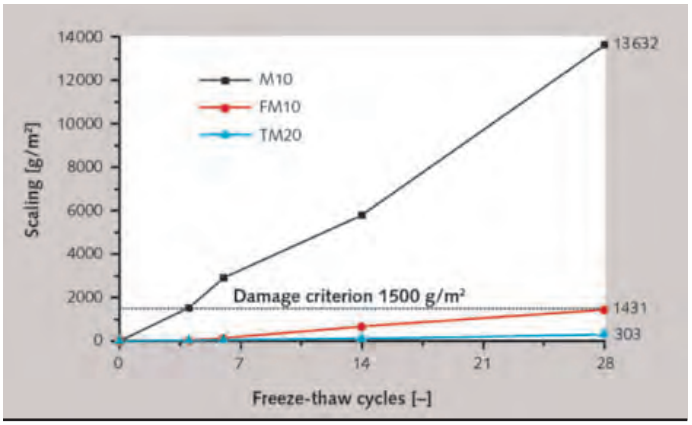
Table 2 Characteristic mortar values

		M 10	FM 10	TM 20
Dry mortar	Maximum particle size [mm]	4	1	4
	Particles <90 µm [mass %]	19.1	18.5	35.6
	Proportion of clinker in particle size <90 µm [mass %]*	67.5	78.4	42.5
	Proportion of X-ray amorphous material in particle size <90 µm [mass %]	0	0	17.3
Fresh mortar	Water/binder ratio	1.1	1.0	0.8
	Flow table spread	175	171	163
	Air void content [%]	10	17.5	16.5
	Bulk density [g/cm³]	2.0	1.8	1.9
Hardened mortar	Compressive strength [N/mm²]	13.5	11.0	20.9
	Flexural tensile strength [N/mm²]	4.2	2.5	5.3
	Porosity [vol. %]**	24.1	31.0	29.5
	Bulk density [g/cm³]**	1.9	1.79	1.7
	Air void content [vol. %]***	4.4	5.2	8.8
	Air void content < 300 µm [vol.%]***	2.3	3.4	7.4

* From X-ray diffractometry methods with calculation using Rietveld refinement
** Determined by mercury intrusion porosimetry in accordance with DIN 66133 [12]
*** Determination of air void characteristics based on DIN EN 480-11 [13]



4 Scaling of the different mortars with the CIF method (cumulative)



5 Scaling of the different mortars with the CDF method (cumulative)

6 Test specimens made of M 10 mortar after the CDF test

However, no internal damage, which is actually the decisive criterion in the CIF method, was established for any of the mortars. The reason for this favourable behaviour is presumably the air void system present in the mortars. Experience shows that air voids effectively prevent internal damage in concrete.

In principle, the CDF method provides the best illustration of the quality differences between the mortars during exposure to frost attack. However, application of this method is primarily recommended for mortars that are subject to environmental stresses similar to exposure class XF4 for concrete (freeze-thaw cycles with high level of saturation, de-icing salt). The CDF method is too severe for testing mortars with less saturation in conjunction with de-icing salt (vertical components, e.g. external rendering in splash water zones, corresponding to XF2 for concrete). Its results lie on the safe side but failure of a corresponding mortar in the CDF test does not imply that this mortar would not have adequate resistance to freeze-thaw with de-icing salt under exposure similar to XF2. Easing the test method would also be conceivable here to achieve an exposure for vertical components that meets the requirements. However, experience with concrete shows that such modifications are not automatically possible without adversely affecting the reliability of the method [16].

It should be noted, however, that there is no evaluation background for application of the CIF and CDF methods for mortars. A link to practical experience would be essential for this. However, it can be assumed that both methods give results that lie on the safe side.

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This study is intended to assess the ability to counter chloride diffusion of concrete applied with inorganic coating modified with different additives including fly ash (FA), silica fume (SF) and nano-SiO_2 (NS). Experimental results reveal that the resistance against penetration of chloride is improved in the concrete specimens coated with special mortar coating compared to the non-coated specimen. Especially, concretes with NS modified mortar coating exhibit the most remarkable performance. Then the influence mechanisms of mortar coating mixed with different additives on the anti-chloride ion permeability of concrete are investigated by X-ray diffraction (XRD), differential scanning calorimetry (DSC), scanning electron microscope (SEM) and mercury intrusion porosimetry (MIP). The results of the analyses indicate that the micro-aggregate filling effect of FA increased the density of the mortars, and thus reduced the chloride diffusion coefficient of the concrete. Three effects of SF and NS, including the heterogeneous nucleus effect, the high pozzolanic activity and the micro-aggregate filling effect, together increased the resistance to the chloride ion permeability of cement-based materials.

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Chloride penetration resistance of micron-nano materials modified mortar used as a concrete coating

1 Introduction

In the field of construction, the 21st century is considered to be the century of the ocean [1]. In recent decades, with the steady development of the marine economy, the construction scale of ocean engineering became larger, the fields expanded, and scores of seaport buildings, coastal power plants, embankments, marine bridges and tunnels, land terminal and treatment facilities for offshore oil and gas fields as well as installation of subsea wires, pipelines and equipment are still being built. According to the State Oceanic Administration, the building industry of marine engineering continued to maintain the momentum of rapid growth in 2015, reaching 504.4 billion RMB, approximately 7.8 % of the total ocean output value.

In the marine environment, reinforced concrete structures suffer from the superimposition of wind, fog, waves, currents, tidal range, ice, storm surge and organism corrosion, which cause corrosion damage and performance degradation and shorten the service life of materials and buildings [2], not only resulting in enormous waste of materials and energy, but also leading to a lot of sudden-onset disasters and triggering leakage of oil and gas, environmental pollution, as well as a great number of personal injuries. According to the survey of American corrosion loss, the direct cost to the United States in 2002 was about $ 276 billion, accounting for about 3.1 % of its annual GDP [3]. In the earthquake in Turkey in 1999, 15 000 people were killed and 50 000 houses collapsed, whereby

the use of unwashed sands was the main cause of costly construction damage [4]. In terms of the corrosion loss accounting for 3% of the national economic output [5], the corrosion loss was over 2 trillion RMB in 2015, a large proportion of which was for marine corrosion.

Professor Sitter's "The Law of Fives" visually reveals the seriousness of the corrosion [6]. This means that if 1 dollar of steel protection costs was saved, 5 dollars would be spent at the beginning of the corrosion time, an additional 25 dollars for concrete cracking and 125 dollars for serious damage. This terrible amplification effect meant that governments and enterprises around the world should spend a lot more money for the research into concrete structure durability and safeguards. So the study of corrosion prevention materials and technology have a profound importance for extending the security service life of marine engineering structures as well as for guaranteeing the rapid development of the marine economy.

The major failure modes of reinforced concrete structures in a marine environment are the rebar corrosion induced by chloride that damages the concrete structures. A lot of research has shown that coating can form a barrier layer on the concrete surface, preventing the chloride ion from seeping into the concrete and improving its ability to counter chloride diffusion [7, 8]. So far, various surface coatings are used to prevent the chloride ions from penetrating into the internal part of the concrete [9–11]. Most of them consist of organic coatings using volatile organic compounds. However, such organic coatings could have the decisive shortcoming of being air-polluting during the manufacturing process as well as during the coating work. Moreover, in a natural environment, the aging-resistant performance of the polymer coating cannot meet the requirements of durability, especially under the conditions of dry-wet circulation and ultraviolet light, the cracking and peeling phenomena occur much more easily, and thus the protection effects are severely reduced and the coating requires continuous repair, which brings numerous practical difficulties to ocean engineering construction.

As the research moved along, more attention was paid to the application of superfine powders and nano-technology in cement-based materials. Especially in the last ten years, scientists have done quite a lot in terms of changing the microstructure and properties of hardened pastes by using superfine powder and nano-technology. Superfine particles like fly ash microspheres that can fill up the interstitial voids in cement, effectively increase the packing density and decrease the voids volume [12]. Silica fume can refine the pore diameter and make the matrix densification, it can also be used as pozzolanic materials to react with calcium hydroxide, and optimize the interface transition zone between cement and aggregates [13]. Nano-particles have the best potential as accelerators for cement hydration as a result of the nucleation effect and they make the microstructure and interface transition zone of hardened pastes much denser, resulting in lower permeability [14]. All in all, the micro-aggregate effect and the nucleation effect of micron-nano-sized particles promoting the formation of the hydration product help strengthen the permeability-resistance and further increase the durability of cement-based materials. In addition, the durability of cement pastes mixed with nano-silica with high pozzolanic activity was found to be much higher and this is attributed to the increase of high stiffness C-S-H gel in the pastes, which has been well documented [15–17]. Although a lot of research has been done on cement-based materials modified with micro-nano-sized materials, the lack of clear results for the effect of inorganic coating incorporation with superfine powders on the durability of concrete leads to the necessity to perform systematic research on performance evaluation of surface coating materials. It can be deduced that a compact surface mortar layer can not only significantly reduce the chloride ion diffusion coefficient, improving the concrete durability, but also compensate for the disadvantage of organic coatings at the same time.

This study is intended to assess the durability of concrete with denser surface mortar layer modified with micron-nano materials. The diffusivity of chloride has been evaluated using concrete specimens under steady state, and X-ray diffraction (XRD), differential scanning calorimetry (DSC), scanning electron microscope (SEM), and mercury intrusion porosimeter (MIP) are used to explain the mechanism of a denser surface mortar layer modified with micron-nano materials to improve the chloride–penetration resistance of concrete.

2 Experiment

2.1 Materials

Ordinary Portland cement (OPC) CEM I 42.5 has been used with a specific gravity of 3.13 and a surface area of 350 m^2/kg. Fly ash (FA) conforming to GB1596–91 [18] was obtained from the Yangluo power plant. Silica fume (SF) with a specific gravity of 2.31 and a surface area of 21 m^2/g according to the national standard of GB/T 27690-2011 [19]. Nano-SiO_2 (NS) with the average particle size of 20 nm is purchased from the Degussa Company. The chemical composition of cement, FA and SF are

summarized in Table 1. XRD patterns of cement, FA, SF and NS are shown in Figure 1. The dispersing X-ray diffraction peaks of SF and NS show that they are amorphous in structure.

Fine aggregates are medium sand from the Xiangjiang River in the Hunan Province of China with a fineness modulus of 2.5 and a maximum size of 5 mm, and the coarse aggregate is limestone rubble ranging in size from 5 to 25 mm that is obtained from the China Construction Third Engineering Division Co. Ltd.. They have been utilized in all mix proportions. Liquefied SDS (sodium dodecyl sulfate)-type polycarboxylate superplasticizer at a solid content of 10 % has been admixed to secure entrained air and reduce the specific volume of water.

2.2 Mix proportion and sample preparation

In order to evaluate the resistance to penetration of chloride, a concrete specimen has been mixed with a water-binder ratio of 0.472, a fly ash-cement ratio of 0.286, a cement-fine aggregate ratio of 0.341 and a sand-ratio of 0.441. Its mixture proportion is given in Table 2.

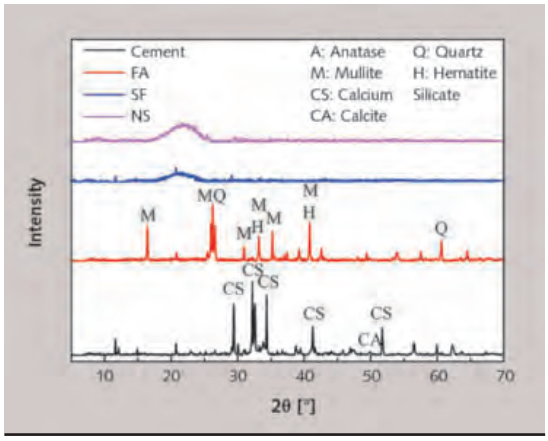
Cement mortars have been mixed at a sand-binder ratio of 1.5 and a water-binder ratio of 0.35. Different dosages of FA (20 wt% of binders), SF (5 wt% of binders) or NS (from 1 wt% to 5 wt% of binders) were added to the mixes. Before the mix preparation, NS was added to deionized water, stirred and dispersed by ultrasonication at 325 W for 30 min to obtain the uniform suspensions. Their mixture proportions are given in Table 3. In order to prepare the samples for SEM and MIP, the small fragments obtained from the middle part of mortars cured to the test age were put into acetone solution for 3 days, and then were dried at 80 °C for 8 h.

All specimens for XRD and DSC were molded into a square with a size of 40 mm × 40 mm × 40 mm using cement pastes, which have the same ratio as mortars except without sand. After curing to the test age, the hydration of the pastes was stopped by submerging the center part of the crushed samples in acetone solution, the samples were oven-dried at 80 °C for 4 h and hand ground in the agate mortar so as to pass the 100 mesh size sieve.

Besides the control sample, other samples for the rapid chloride migration (RCM) test were all covered with a mortar coating. The specimen with coatings was produced as follows. Firstly, concretes and mortars mixed well, respectively, then the mortars were poured into the bottom of molds, and finally the concretes were placed above the mortars. The fabrication of specimens adopted molds of Φ100 mm × 100 mm. After molding, the specimens were put into a standard curing room, and 24 hours later the form stripping was carried out, then the specimens were immersed in the sink of the standard curing room. The specimens should be cut into pieces, with a diameter of 100±1 mm and a height of 50±2 mm 7 days before the rapid chloride migration (RCM) test, and then continued curing to the test age of 28 days. The control sample is pure concrete with the size of Φ100 mm × 50 mm. With the other samples, the concrete thickness is 45 mm, and the mortar coating is 5 mm.

Table 1 Chemical composition of cement, fly ash and silica fume

Chemical analysis	Cement [wt%]	SF [wt%]	FA [wt%]
SiO_2	21.99	96.6	56.30
Al_2O_3	5.92	0.41	24.56
Fe_2O_3	3.26	0.49	8.71
CaO	58.64	0.23	2.99
MgO	1.98	0	1.13
K_2O	0.74	0.70	1.84
Na_2O	0.27	0.26	0.46
TiO_2	0.4	0	1.06
SO_3	2.6	0	0.95
Loss on ignition(LOI)	3.5	0.7	1.58



1 XRD patterns of cement, FA, SF and NS

All authors

2.3 Test procedure

2.3.1 RCM test

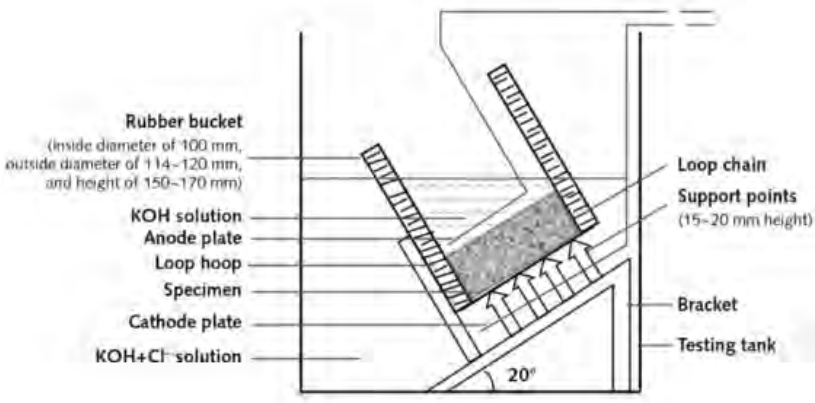
RCM-installation is shown in Figure 2. Before the specimens were installed in the tester, the practi-

Table 2 Mix proportions of concrete

Cement	Water	FA	Sand	Stone	admixture
280	170	80	820	1040	5.00

Table 3 Mix proportions of mortars

Sample	Cement	Sand	FA	SF	NS	Water	admixture
C	900	1350	0	0	0	315	0
FA20	720	1350	180	0	0	315	0
SF5	855	1350	0	45	0	315	0
NS1	891	1350	0	0	9	305.82	10.20
NS3	873	1350	0	0	27	292.32	25.20
NS5	855	1350	0	0	45	279	40.00

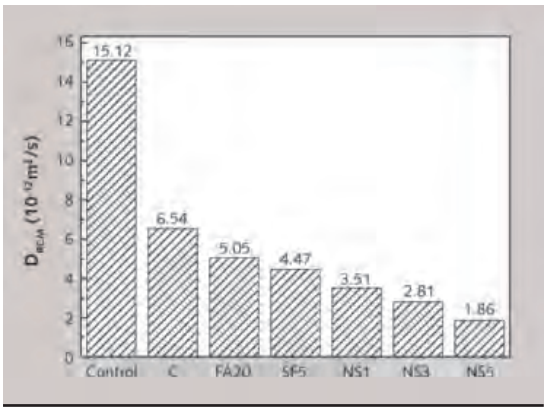


2 The sketch map of RCM-installation

cal diameter and height of these standard specimen was first measured. The cathode is 0.2 mol/L KOH with 5 wt% sodium chloride solution as dissolvent while the anode is 0.2 mol/L KOH solution without sodium chloride and the inside and outside liquids are at the same level. The RCM tester was powered with a direct current of 30 V at a constant temperature of 25 °C. The initial temperature and current of the anode solution should be measured, and the conduction time is determined by the initial current. At the end of experiment, the final temperature of the anode solution should be measured.

2.3.2 Chloride diffusion depth test

By the end of RCM test, the specimens were removed from the rubber buckets and all of them were split into two halves by the press machine. After the specimens were dried in the air, the 0.1 mol/L $AgNO_3$ solution was spray-painted on the split surface. About 15 minutes later, white silver chloride precipitation could be observed in areas with the chloride ion. Vernier caliper was used to measure the distance from the boundary of with and without white precipitation to the bottom of the specimen. For each specimen, the test was run ten times for different locations to eradicate any discrepancies and the mean was the chloride diffusion depth.



3 Chloride diffusion coefficient (D_{RCM}) of concretes with different mortar coatings

The chloride diffusion coefficient (D_{RCM}) of concrete was calculated using the following Equation (1) [20]:

$$D_{RCM} = \frac{0.0239(273+T)L}{U-2t}\left(X_d - 0.0238\sqrt{\frac{(273+T)LX_d}{U-2}}\right)$$

Where T represents the average values of the initial and final temperatures of the anode solution, L represents the height of the specimen, X_d represents the chloride diffusion depth, t represents the electrolytic time, and U represents the absolute value of voltage used in the test.

2.3.3 XRD analysis

The mineral composition of the samples was confirmed using a Bruker D8 Advance XRD device with a Cu k_α X-ray source at 40 kV and 40 mA. During data collection the step-length was 0.02°, scanning rate was 2°/min and 2θ range was 5–70°.

2.3.4 DSC analysis

DSC analysis was conducted with a STA449c/3/G thermal analysis instrument at a heating rate of 15 °C/min from 20 °C to 800 °C in the atmosphere of nitrogen.

2.3.5 SEM analysis

Quanta 200 FEG-SEM from FEI Company in low vacuum mode was used to determine the morphology of the hardened cement pastes.

2.3.6 MIP analysis

Quantachrome Autoscan-60 mercury intrusion porosimetry (MIP) was used for testing the pore structures of the cement mortars. The measurable aperture ranged from 3 nm to 360 µm and in the measurement process the highest pressure was 300 MPa and the contact angle was set to 130°. After testing, Excel software was used to process the data.

3 Result and discussion

3.1 RCM analysis

The concrete with no protective coating was selected as the control sample and the chloride diffusion coefficient (D_{RCM}) of concretes with different mortar coatings are shown in Figure 3.

It is observed that D_{RCM} of the control sample was 15.12×10^{-12} m²/s, which was the highest in all samples. When the protective coatings were added, the D_{RCM} decreased significantly. For example, the D_{RCM} of sample C, FA20, SF5, NS1, NS3 and NS5 were 6.54×10^{-12} m²/s, 5.05×10^{-12} m²/s, 4.47×10^{-12} m²/s, 3.51×10^{-12} m²/s, 2.81×10^{-12} m²/s and 1.86×10^{-12} m²/s, respectively, which were 56.7 %, 66.6 %, 70.4 %, 76.8 %, 81.4 % and 87.7 % lower than that of the control sample.

According to the measured D_{RCM}, the relative resistance to chloride ion of concretes with different coatings was outlined below, from best to worst: sample NS (including NS1, NS3 and NS5), sample SF5, sample FA20 and sample C. For coating with 5 % NS weight fraction, the ability to counter chloride diffusion achieved its best result. It is obvious that, the chloride resistance of concrete with mortar coatings were better than that of the control sample, which is chiefly because the water binder ratio of the mortar surface coating was relatively small, and the compactness of the coatings was better than that of the concrete. As for the comparison of chloride resistance of concrete coated with FA, SF and NS modified mortar coatings, the mechanism will be discussed in the section below by XRD, DSC, SEM and MIP.

In addition, according the reference standard of Tang et al. [21], the resistance chloride ion performance of sample NS5 is categorized very good ($D_{RCM} < 2\times10^{-12}m^2/s$), sample NS3, NS1, SF5, FA20 and C as good ($2\times10^{-12}m^2/s < D_{RCM} < 8\times10^{-12}m^2/s$), and the control sample as mediocre ($8\times10^{-12}m^2/s < D_{RCM} < 16\times10^{-12}m^2/s$).

3.2 XRD analysis of the hydrated cement pastes

The influences of additives on the resistance chloride ion performance of cement-based materials can be reflected by the hydration products and microstructure changes. Figure 4 shows the XRD spectra of different cement pastes at 28 days.

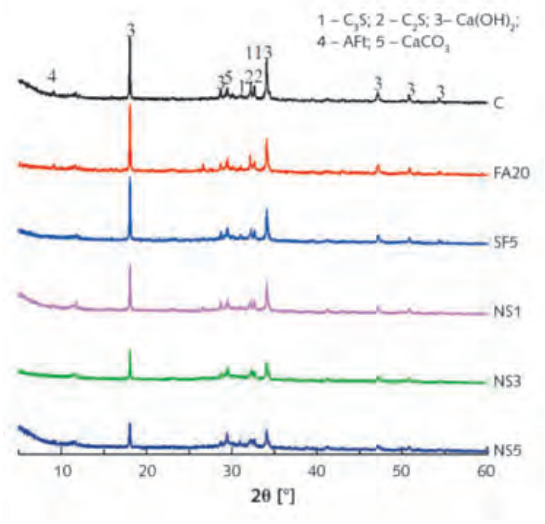
As can be seen from Figure 4, the hydration products of all samples are basically the same, including ettringite (AFt), calcium hydroxide (CH), calcium carbonate ($CaCO_3$) and unhydrated tricalcium silicate (C_3S) and dicalcium silicate (C_2S). Simultaneously, it is also found that the diffraction peak intensity of CH significantly reduced with the addition of 20 % FA, 5 % SF, 1 % NS, 3 % NS and 5 % NS. In addition, the change tendencies of the diffraction peak intensity of C_3S and C_2S were similar to that of CH.

For samples with SF and NS, the decrease of CH, C_3S and C_2S diffraction peaks was related to pozzolanic activity and heterogeneous nucleus effect of SF and NS. The superfine particles of SF and NS can provide a lot of heterogeneous nucleus sites to promote the cement hydration in varying degrees. Moreover, the high pozzolanic activity of SF and NS accelerated the rate of secondary hydration, consuming a lot of CH and accordingly the content of C-S-H increased. All of these speeded up the clinker depletion, decreasing the content of C_3S and C_2S. The increased hydration products introduced a dense hardened paste, which would effectively obstruct the invasion of chloride ions and improve the chloride resistance of concrete, echoing the result of the chloride diffusion coefficient in 3.1. In addition, one can still see that the decline of the CH peak was especially evident with the addition of NS, and as the amount increased, the downtrend was more prominent. Although the CH peak could be decreased by mixed SF, the reduce degree was not as obvious as the samples with NS. This is due to the fact that the reaction activity of the smaller NS particles was higher than that of SF.

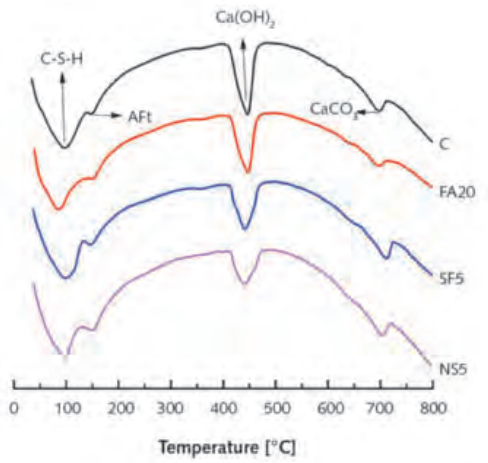
For the sample with FA, the contents of CH, C_3S and C_2S were lower than that of the control sample, but higher than that of sample SF5, NS1, NS3 and NS5, for reasons that the CaO content in FA is far lower than that in cement, and accordingly, using 20 % FA partial replacement of cement would decrease the CH and unhydrated clinker (C_3S and C_2S) content in the mixture. In addition, plenty of network ions ($[SiO_4]^{4-}$, $[AlO_4]^{5-}$) in FA vitreous may lead to the formation of a structure with strong stability, therefore, the pozzolanic activity of FA at 28 days is relatively low [22], going against to the consumption of CH, which result in more CH content in sample FA than that in sample SF5, NS1, NS3 and NS5. Although the addition of FA would lead to a reduction in the amount of hydration products compared with that of sample C, the good micro-aggregate filling effect [23] of FA caused by its smaller particle size than that of cement and the smooth surfaces was able to reduce the pore space between the hardened pastes, resulting in the structure densification, which plays a positive role in hindering the chloride erosion. This is also consistent with the aforementioned results of the chloride diffusion coefficient.

3.3 Thermal analysis of the hydrated cement pastes

In general, quantitative analysis of C-S-H cannot be achieved by XRD because amorphous C-S-H is



4 X-ray diffraction (XRD) patterns of samples hydrated for 28 days



5 Differential scanning calorimetry (DSC) spectra of samples after hydration for 28 days

not able to be directly reflected by XRD patterns. In order to get the information of the main hydration product C-S-H intuitively, the DSC test was done and the results are shown in Figure 5. Because the addition amount has no effect on the acting mechanisms of NS, so only sample C, FA20, SF5 and NS5 were selected for testing.

It can be seen from this figure that the four samples have virtually identical hydration products, including C-S-H gels (about 100 °C), AFt (about 150 °C), CH (about 450 °C) and $CaCO_3$ formed by the carbonation of CH (about 700 °C).

According to DSC curves, the first endothermic valleys caused by dehydration of C-S-H gel of the four kinds of sample varied with the addition of admixture. The first valleys of the sample with SF and NS were deeper than that of sample C, mainly due to the high pozzolanic activity and nucleation effect of SF and NS promoting the generation of hydration products of C-S-H gel. In addition, it is obvious that more C-S-H gel generated by the addition of NS, indicating smaller NS particles with high surface activity is more likely to accelerate the cement hydration. However, the first endothermic valley of sample FA20 are lower than that of sample C, which is largely driven by that FA partial replacement of cement decreased the content of clinker that could react to form C-S-H gels and the pozzolanic activity of FA did not emerge at 28 days.

For the third endothermic valleys caused by dehydration of CH, that of sample C is the deepest, sample FA20 is next, sample SF5 is the third and sample NS5 is the shallowest, indicating that the addition of NS and SF decreased the content of CH, which is attributable to their high pozzolanic activity. Also, because the smaller NS particle has higher chemical activity, so the pozzolanic reaction of NS could consume more CH, resulting in the shallowest endothermic valley. In terms of sample FA20, high addition of FA greatly reduced the clinker content in binders, which caused the decreasing CH content compared with sample C. All of these are also certified by the result of XRD.

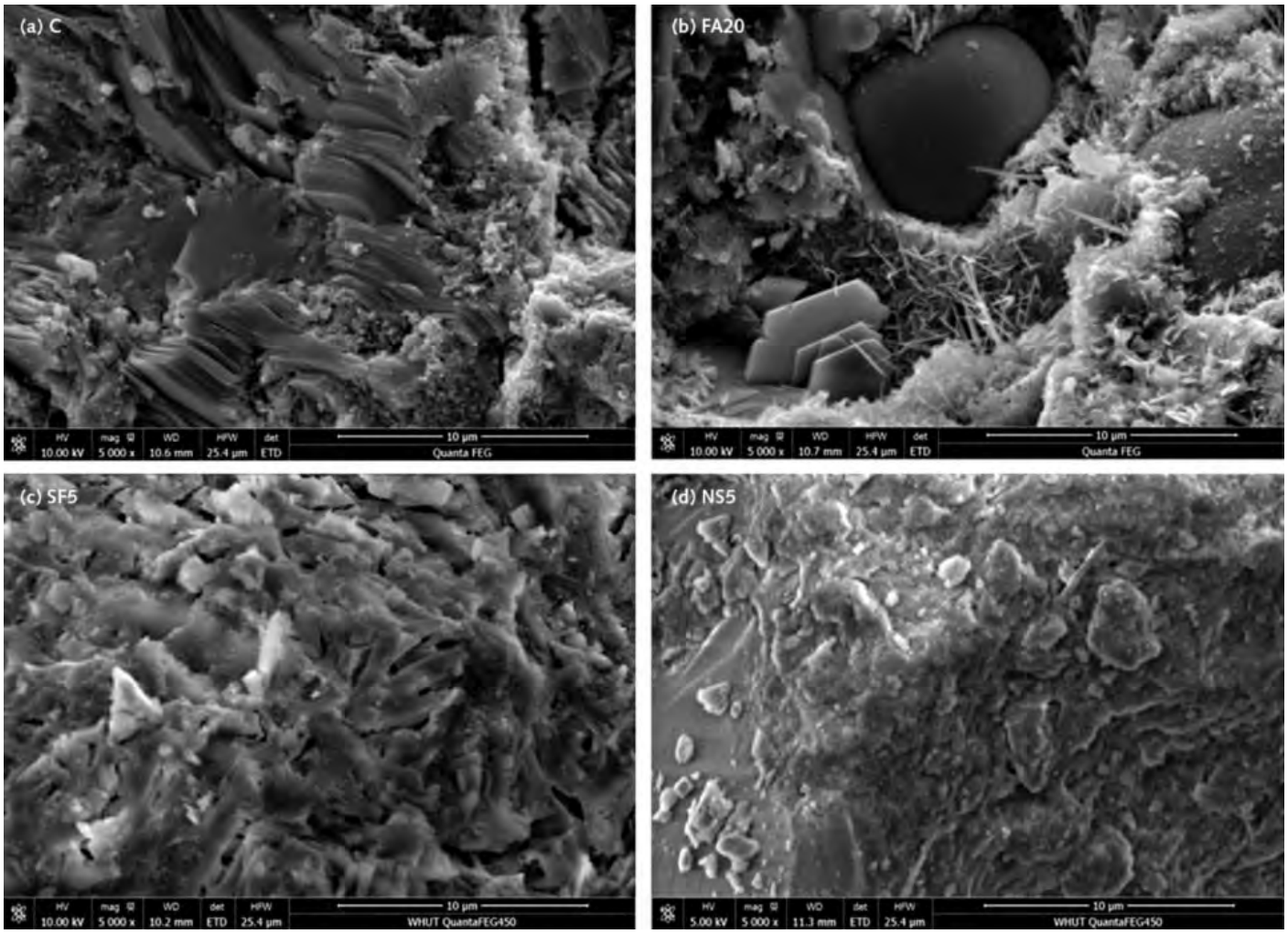
The decrease of CH and the increase of C-S-H caused by SF and NS would help enhance the compaction degree of the hardened cement paste, which could effectively obstruct the penetration of corrosive substances to some extent and improve the ability to resist chloride erosion. This result is consistent with the conclusion derived from the chloride diffusion coefficient test. However, although the hydration products of sample FA20 were fewer than that of sample C, it showed more resistance to chloride corrosion, which is probably because the smaller and smooth FA particles could fill the space between hardened pastes, resulting in higher density.

3.4 SEM analysis

In order to intuitively observe the microstructure of samples modified with different admixtures, separate SEM analyses were carried out on sample C, FA20, SF5 and NS5 at 28 days, as shown in Figure 6.

With comparison and analysis, it can be found out that there were many lamellar CH crystals and some unhydrated cement particles involved in the hardened cement pastes of sample C and lots of micron dimension spaces existed between the lamellar CH crystals, all of which would reduce the density degree of the cement matrix. When FA was added, some hexagonal lamellar CH crystals were present, and the amount of CH also reduced. Besides that, a round FA particle with a relatively clean and smooth surface could be remarkably observed, indicating that the FA particle did not show its pozzolanic activity perfectly at 28 days and it simply acted as a fine aggregate to fill the space between the hardened pastes. While for sample NS and SF, the hydration products appeared gel structure, and the distinct CH crystals could not be found. The gelatiniform hydration products were not independent and dispersed distribution, presenting integration structure, which made their structures more compact. In addition, a small amount of AFt could be detected in Figure 6 (a) and (b), but AFt was not found in Figure 6 (c) and (d), which is possibly because the AFt crystals in sample SF5 and NS5 were too small that covered by the mass of C-S-H gels..

SEM photographs show that the density degree of the hardened cement paste varied with the addition of different admixtures. Accordingly, the higher is the hardened paste density, the stronger is the ability to resist chloride erosion, which coincides with the data from the chloride diffusion coefficient test.



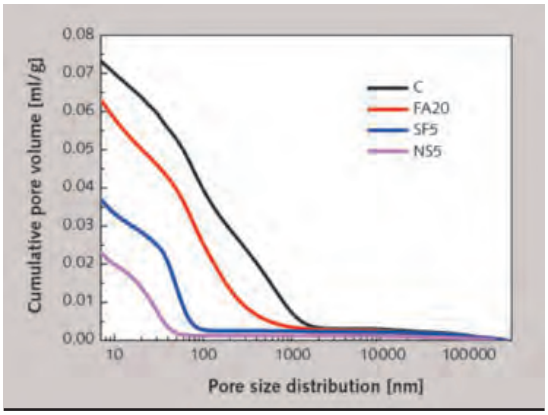
6 Scanning electron microscope (SEM) photographs of samples C, FA20, SF5, NS5 hydrated for 28 days

3.5 Pore structure analysis of hardened cement paste

The pore structure is one of the important characteristics of mortars, which has a great influence on the physical properties and permeability of mortars. Mercury intrusion porosimetry (MIP) is one commonly used method to characterize the pore structure. The influence of different additives on the pore structure of mortars was studied by mercury injection experiment and the parameters are shown in Table 4. In general, mortars with higher porosity have poorer permeability resistance. The data from Table 4 show that, compared with sample C, the porosities decreased by 13.7 %, 50.6 % and 69.8 % when the content of FA, SF and NS was 20 %, 5 % and 5 %, respectively. The average pore size is another important parameter of pore structure, and is used to characterize the overall condition of the pore structure. There is a strong correlation between the average pore diameter and the chloride ion permeability coefficient. Some research has shown that, the chloride ion permeability coefficient increased with the average pore size, which was closely related to the penetration property of mortars [24]. The incorporation of FA, SF and NS significantly reduced the average pore size of mortars, and thus improved the performance of their resistance to chloride ion penetration, among which NS5 had the best function of reducing the average pore size, and thus had the greatest resistance to chloride ion penetration, SF5 was the second one and FA20 was the third one. The performance of cement-based material is not only related to the parameters such as porosity and pore diameter, but also closely connected with the pore size distribution, which is also another important factor that affects the physical mechanical properties and durability of cement-based material. The integral curves of pore size distribution

Table 4 Pore structural parameters of mortars with different additives

Sample	Total porosity [%]	Total pore volume [ml/g]	Average pore size [nm]
C	12.2017	0.0731	65
FA20	10.5251	0.0628	48
SF5	6.0325	0.0367	30
NS5	3.6816	0.0228	18



7 Pore size distribution by mercury intrusion method of mortars with different additives

of hardened cement pastes are shown in Figure 7. Based on the hazardous property for the physical and mechanical performance, pores can be classified into four grades, including harmless pores (smaller than 20 nm), less harmful pores (between 20 and 100 nm), harmful pores (between 100 and 200 nm) and more harmful pores (bigger than 200 nm). However, in all types of pores that influence the chloride ion diffusivity of mortars, the size ranging from 5 to 200 nm has the most adverse effect [25], because in these pores, not only the phenomenon of capillary condensation can occur, enhancing the hygroscopicity of pores, but also larger capillary pressure and osmotic force are generated, increasing the autogenous shrinkage stress of mortars [26], and simultaneously accelerating the rate of surface and normal pressure permeation, which make the overall reduction of surface and normal pressure anti-permeability. In terms of Figure 7, the pore volume of sample C and FA increased quickly with the aperture ranging from 0 to 200 nm, specifically expressing the slope of this part of the curves increased sharply, which indicates that the apertures of the mortars were mainly distributed in that range. While for sample SF5 and NS5, the pore size was mainly distributed in 0~50 nm. Compared with sample C, when the sample was mixed with FA, the amount of capillary pores decreased, which shows that the addition of FA could reduce the porosity and improve the pore-size distribution of the mortars, increasing the ability of the mortars to hinder the chloride penetration, thus dramatically improving the resistance to chloride ion permeability of the matrix. When the sample is mixed with SF, the amount of the capillary pores further reduced, making the mortar more resistant to chloride ion permeability. The greatest reduction of capillary pores was with the sample mixed with NS, which had the greatest resistance to chloride ion permeability. All of these are consistent with the aforementioned results of RCM analysis, XRD analysis, thermal analysis and SEM analysis.

4 Conclusion

In this research, on the basis of the obtained experimental results, the main results are as follows:

(1) Chloride diffusion coefficients of concretes varied with different mortars coating from high to low the order was: concrete with no coating, concrete with pure mortars coating, concrete with FA modified mortars coating, concrete with SF modified mortars coating and concrete with NS modified mortars coating. And the ability to counter chloride diffusion increased along with the dosage of NS.

(2) The diffraction peak intensity of CH decreased along with the addition of 20 % FA, 5 % SF, 1 % NS, 3 % NS and 5 % NS.

(3) The sample with NS has the highest amount of C-S-H at 28 days, and its endothermic valley of CH is the shallowest. While the sample with FA has the lowest amount of C-S-H at 28 days.

(4) There were many lamellar CH crystals and some unhydrated cement particles involved in the hardened cement pastes of the sample without additives and lots of micron dimension spaces existed between the lamellar CH crystals. For the samples mixed with NS, the gelatiniform hydration products appeared integration structure, and the distinct CH crystals could not be found.

(5) Compared with pure cement mortar, the porosities decreased by 13.7 %, 50.6 % and 69.8 % when the content of FA, SF and NS was 20 %, 5 % and 5 %, respectively. The average pore size had similar changing trends. Also, the greatest reduction of capillary pores ranged from 5 to 200 nm was among sample mixed with NS.

(6) The micro-aggregate filling effect of FA reduced the chloride diffusion coefficient of the concrete with FA modified mortar coating. Three effects of SF and NS, including the heterogeneous nucleus effect, high pozzolanic activity and the micro-aggregate filling effect, together affect the resistance to the chloride ion permeability of the cement-based materials.

5 Acknowledgement

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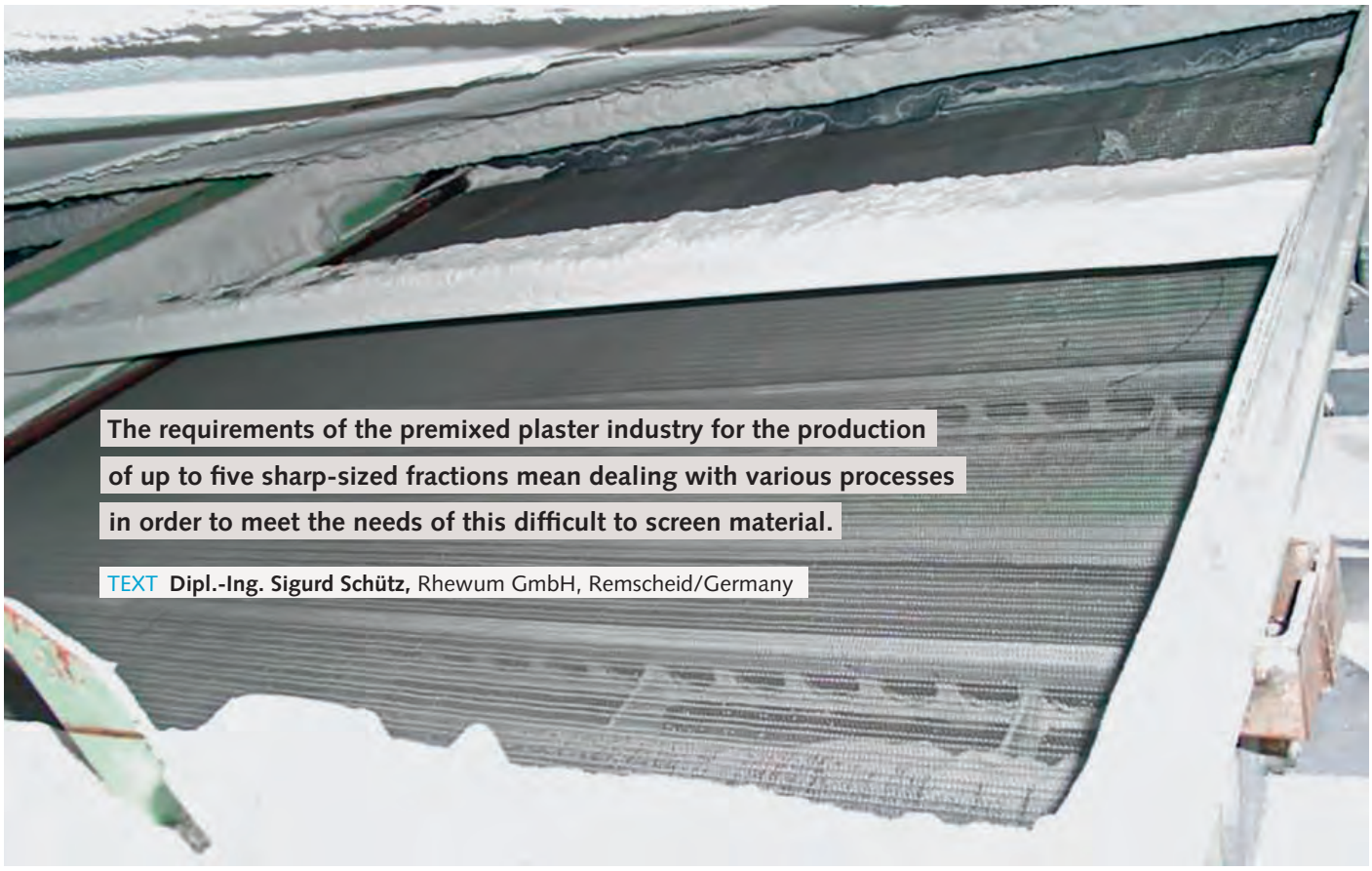


The requirements of the premixed plaster industry for the production of up to five sharp-sized fractions mean dealing with various processes in order to meet the needs of this difficult to screen material.

TEXT **Dipl.-Ing. Sigurd Schütz,** Rhewum GmbH, Remscheid/Germany

All Rhewum

Screening surface after three months of continuous operation with a magnetic drive

RHEWUM GMBH

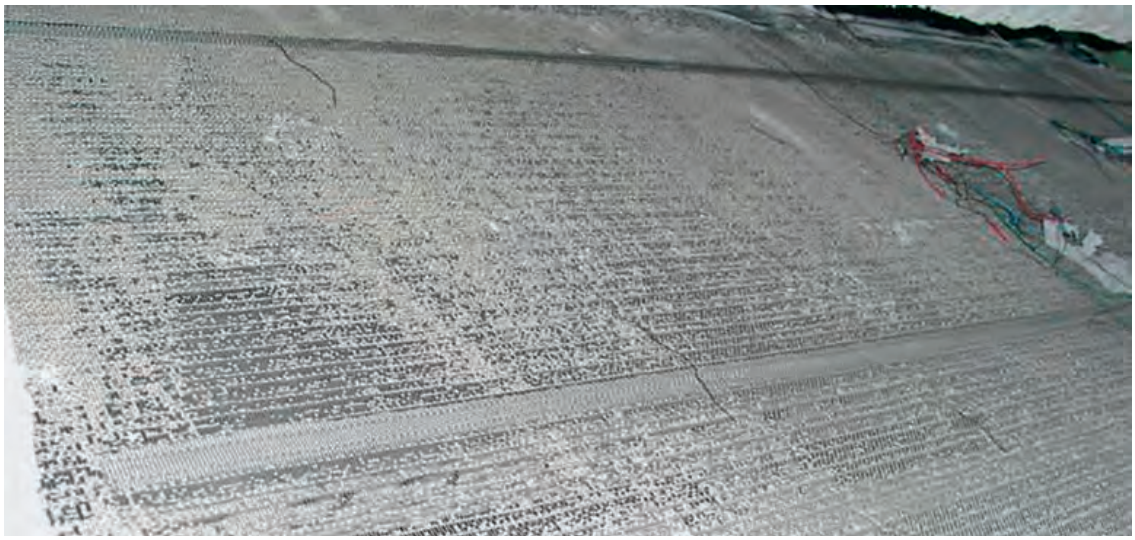
Production of sharp-sized grades from naturally moist sands

An Italian manufacturer of different grain sizes for well-known producers of premixed plasters approached Rhewum with the objective of sizing 80 t/h crushed dolomite flour into the fractions 10.0 mm, 3.5 mm, 2.25 mm, 1.6 mm and 1.0 mm.

The mineral grades contained in premixed plaster are extracted at quarries and then usually crushed in a jaw crusher. After that the bulk materials produced are classified and made available for further production. The moisture of the feed material may vary widely due to rainfall and temperature changes and can be as high as 10 wt% – which makes screening difficult. Also, the concentration of the moisture in the fine fractions and the not inconsiderable clay content cause trouble in the processing.

On linear motion vibrating screens the indicated task led to immediate blinding of the screening cloth. Accordingly, extensive tests were performed in the process circuit plant at Rhewum GmbH. The only practicable screening solution was a screening machine with direct excitation of the screen cloth driven by unbalance motors.

These provide the user with the advantage of an extremely high acceleration of the screening surface. This is achieved thanks to the low masses that must be accelerated. Unlike with linear-motion vibrating screens where the entire machine is set in motion, in this type of screen the machine frame remains static. Only the screening surface is vibrated, but these vibrations are of a higher frequency, leading to higher acceleration at the screening surface. This



1 Screening surface after three months of continuous operation with an unbalance motor

has advantages in the separation of critical materials, in respect of particle size as well as keeping the screening surface open. Furthermore, no dynamic loads are transmitted to the building. The aggregate can consequently be equipped with fixed flange connections and without compensators.

As due to the drive principle no immediate blinding of the screening surface with the naturally moist material was observed, a higher material moisture was simulated artificially with the additional spraying of water. Even at a moisture content of 4.5 wt% the screening surface was still reliably kept clear. But with this water content, chain cleaning was necessary.

Subsequently another test was performed, also with a directly excited screen, but this time with an electromagnetic drive. The background to this drive concept change is the useful inharmonic oscillation of the screening surface by electromagnets. This drive with electromagnets has considerable advantages for materials heavily prone to agglomeration.

In addition, a cleaning impulse ensures that the screening surface remains free. During the cleaning cycle, the magnet draws the hammer to the final position of the screen casing at maximum acceleration, then the hammer hits the casing. This generates additional excitation of the screening surface that keeps the cloth clean.

The motivation behind these tests was the maintenance friendliness of the unbalance motors available today in contrast to the high investment for electromagnetic drives. After three months of continuous operation, the screening surface of the electromagnetically driven machines was open and ready for operation (Lead picture) whereas that of the unbalance driven screen was blind (Figure 1).

The optimal solution in this case was a combination of different processes: The feed material is separated at 10.0 mm in the feed section on co-vibrating strainer bars (Figure 2). The feed is sized at 3.5 and 2.25 mm on a screen driven by an unbalance motor – a simple and cost-effective alternative to electromagnetic drives. Critical cuts at 1.6 and 1.0 mm are performed on a directly excited screen with electromagnetic drive.

An additionally installed electrical screening surface heating with a required maximum power of 30 kW permits the heating of the screening surface to above 100° C. This temperature prevents the caking of moist fines on the screening surface. To adapt the energy consumption to the varying water content of the feed material, the heating system can be switched on or off. As only the critical part of the feed is dried, the consumption of primary energy is lower than with common drying solutions. Additionally, an automatic chain cleaning system was installed. This reduces the inevitable wear on the screening surface to a minimum. Thereby, an optimal solution was found for screening this critical material.

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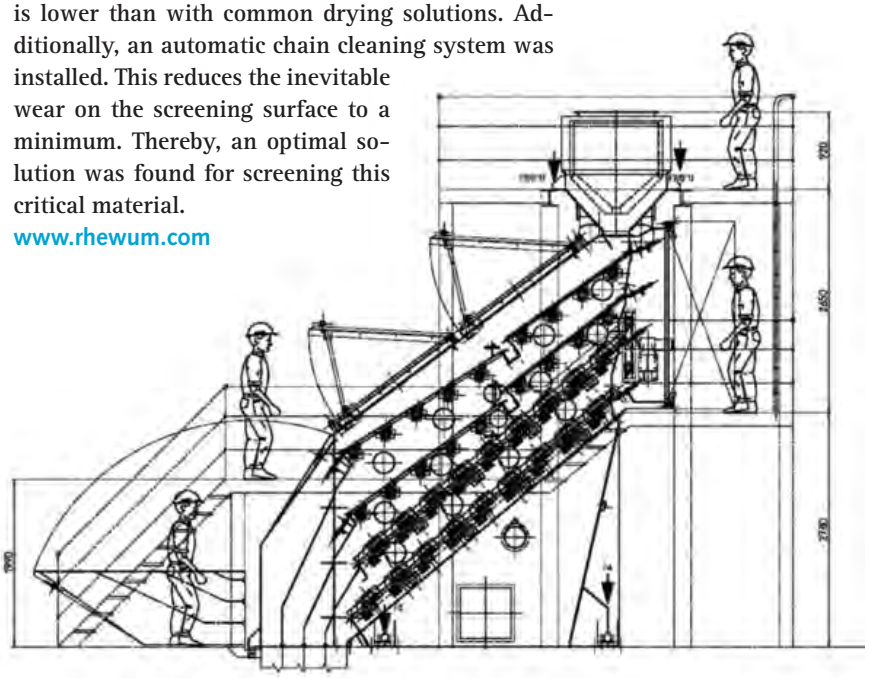
2 Dimensions of the installed machine



Dry premixed mortars as a filling material, for masonry mortars and plasters were developed on a laboratory scale from autoclaved aerated concrete (AAC) rubble which is frequently contained in construction and demolition (C&D) waste. There, the AAC represents a problematic impurity with regard to recycling C&D waste as a secondary construction material due to its physical properties. However, if pure AAC rubble is available either from selective demolition or sorting in a recycling plant, the waste material may offer valuable recycling opportunities in building products. Selected mix formulations for masonry mortars with aggregates from processed AAC rubble have been produced successfully on an industrial scale and are now used in a Bremen building project for the erection of internal walls in combination with masonry blocks produced from recycled AAC as well.

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Recycled autoclaved aerated concrete (AAC) from processed construction and demolition waste for producing dry premixed mortars

1 Introduction

Autoclaved aerated concrete (AAC) for masonry blocks is prepared from fine quartzitic aggregates, binder, gas-forming agent, additives if required, and water by steam hardening in autoclaves. Because of its extremely high porosity the concrete provides a lightweight building material with densities well below 1.0 mg/m^3 [1]. AAC has been used to an increasing extent over the past decades because of its excellent properties with regard to

building physics such as increased requirements for thermal insulation of the building envelope and its easy workability. In the period from 1997 to 2008 the yearly sales of AAC in Germany lay between 2.5 and 4.4 million m^3 [2]. A large proportion of the AAC masonry blocks and larger building elements that have been installed so far are still in service in existing buildings. However, this material now appears to an increasing extent in the building rubble, and a further increase of AAC demolition waste in the future must be expected with a time lag corresponding to the service life of our structures. In parallel, the problem of disposing of this specific waste material will increase since landfilling will further be restricted or closed, and the usual recycling paths for masonry rubble, e.g. applications in road construction, are not suitable for AAC waste because of its low strength and poor freeze-thaw resistance.

Alternative recycling opportunities are needed to accommodate the AAC waste, in which the specific properties of AAC, i.e. the very high porosity, low strength and low resistance to weathering must be observed.

The quantities of AAC that are currently obtained from C&D waste are sorted out from the rest of the building rubble and sent to landfill. However, landfilling is expensive and there is only a limited amount of landfill space available.

Waste from the production of autoclaved aerated concrete which is not contaminated or mixed with other wastes can be processed and returned in small quantities into the production cycle of new blocks or may be used, for example, as loose granulates for thermal insulation or, when finely ground, as absorbers for oil or gasoline spill. However, the quantities that can be utilized in this way are small and the needed volume is covered by the production waste from the AAC plants. Unlike the pure and clean production waste, the waste materials from the demolition of structures usually contain a variety of different substances. These impurities often prevent a recycling of the wastes. Therefore, it is necessary to develop technologies of recycling this demolition material in relevant quantities, not least because of low landfill capacity, high landfill charges and the legal obligations for the recyclability of products and their wastes as well as the conservation of primary materials and the environment.

2 Development of dry premixed mortars from recycled AAC on a laboratory scale

2.1 AAC mortar I – feasibility study

The production of dry premixed mortars was seen as a promising way of returning recycled AAC for high-grade utilization. The intention was to preserve and make specific use of the beneficial properties of the primary AAC, such as low density and low thermal conductivity. Granulates from recycled AAC have an extremely rough particle surface, very high water absorption and comparatively low particle strength. Therefore, an initial project [3] first investigated whether it is at all possible to manufacture mortars with aggregates from recycled AAC with a sufficient workability over a certain period of time for the fresh mortar, and sufficient strength and volume stability of the hardened mortar. The study focused on dry premixed mortars because special knowledge and processing technology is necessary with respect to the sensitive input materials and the use of admixtures.

The granulates of recycled AAC used in the feasibility studies were obtained from a recycling plant for C&D waste. After sorting of the waste materials, larger masonry blocks and building elements were crushed in a jaw crusher and subsequently classified according to different grain sizes.

1 Processed AAC granulates from production waste (left: crusher sand with a particle size of 0/2 mm; right: coarse granulates with a particle size of 2/8 mm)

Table 1 Properties of the used AAC granulates

Property		Recycled AAC from [3]		Recycled AAC from [4]		Granulates from production waste from [4]		Recycled AAC from the demonstration project	
		0/2	2/8	0/2	2/8	0/2	2/8	0/2	2/8
Apparent particle density	[mg/m³]	1.2	0.9	1.3	0.9	1.1	0.8	1.3	1.1
Bulk density	[mg/m³]	0.7	0.4	0.6	0.4	0.5	0.3	0.7	0.6
Water absorption after 24 hours	[% by mass]	42	53	38	51	52	65	38	41
Sulfate content	[% by mass]	1	2	1	2	2	2	3	3

2 Fracture surface of a hardened mortar prism made with recycled AAC aggregates

In the production of the primary AAC closed spherical macro voids with sizes from 0.5 to 1.5 mm, which are separated from each other by thin microporous cell walls, are formed by the gas-forming agent used. When the aerated concrete is crushed in the recycling process the coarse porous structure is reflected in the granulates. The surface of these particles is correspondingly large and rough as it is formed by widely opened macro voids.

There are coarse pores present in the coarse granulates but the crusher sand, i.e. the fine grained material, consists predominantly of the previously mentioned cell walls (Figure 1). This difference between the AAC crusher sand in grain sizes 0/2 mm and the 2/8 mm granulates is also reflected in the physical properties of the particles of the recycled materials used (Table 1). The apparent particle density of the crusher sand was 1.2 mg/m^3, while the coarse granulates exhibited an apparent particle density of only 0.9 mg/m^3. After storage in water for a period of 24 h the water absorption by the crusher sand was 42 percent by mass while it was 53 percent by mass for the coarse grains. The water absorption takes place very quickly. Over 90 % of the quantity of water measured after 24 hours storage was taken up by the recycled material in the first 10 minutes of water storage.

Gypsum/anhydrite may also be used in the production of autoclaved aerated concrete. Moreover, gypsum plaster for internal masonry walls can also adhere to the demolition material. Therefore, the recycled AAC aggregates may contain relevant quantities of calcium sulfates that can interfere with the hardening of cementitious binders and have a negative effect on the volume stability of the mortars produced with these recycled aggregates. The recycled materials used here contained a maximum of 2 percent by mass of sulfate.

The composition of the mortars with respect to granulometry, the ratio of recycled aggregates to binder, the type of binder and the consistency of the fresh mortars were varied within wide limits in a comprehensive series of tests. The grading of the aggregates was initially based on the apparent particle density of the granulates in the different grain size fractions. Grading curves with very high proportions of coarse grains without any fine sand were tested in order to achieve low dry bulk densities in the hardened mortar. In fact very stiff and stiff mortars could be produced without fine sand. However, these mortars exhibited a moderate workability. The workability of plastic and soft mortars was very poor.

Mortars containing fine sand, but without ultrafine constituents, were tested in further trials. These mortars also exhibited only moderate workability. In general, however, an improvement in workability was observed with increasing fineness of the particle mix.

The workability of the fresh mortars was improved further in the next step by an increased binder content and by the use of fine sands rich in ultrafines, using the recycled materials as delivered. With a ratio of binder to AAC crusher sand of 1:3 parts by volume even soft mortars had good workability. However, the adhesion to mineral substrates was poor.

Table 2 Properties of the industrially produced mortars

Property		Mix formulation 1	Mix formulation 2	Requirements for LM36 acc. to DIN V 18580: 2007-03
Dry bulk density	[mg/m³]	0.95	0.92	≤ 1.00
Flexural strength	[N/mm²]	2.7	2.0	---
Compressive strength	[N/mm²]	11.1	7.5	≥ 5.0
Modulus of elasticity	[N/mm²]	3400	4200	≥ 3000
Joint compressive strength (KS-4) a) Joint compressive strength (RC-10) b) Joint compressive strength (RC-30) c)	[N/mm²]	6.5 7.0 6.5	5.4 5.4 not measured	≥ 3.5
Bond strength (KS-4) a) Bond strength (RC-10) b) Bond strength (RC-30) c)	[N/mm²]	0.58 0.91 1.39	0.36 0.36 d) not measured	≥ 0.20
Shrinkage in standard climate (20/65) after approx. 3 years	[mm/m]	-2.4	-2.3	---
Swelling in moist climate (20/95) after approx. 3 years	[mm/m]	0	0	---

a) The test was carried out with reference blocks acc. to DIN V 18580 (Calcium silicate masonry units with a moisture content of 4 % by mass)
b) The test was carried out with masonry blocks produced with aggregates from recycled AAC with a moisture content of 10 % by mass)
c) The test was carried out with masonry blocks produced with aggregates from recycled AAC with a moisture content of 30 % by mass)
d) 4 of 10 samples failed as soon as the initial load was applied

After optimization of the particle size distribution and the content of binder and ultrafines an attempt was made to improve the workability and adhesion with chemical admixtures. The addition of air entraining agent and methylcellulose proved successful for these new recycled aggregate mortars. It was even possible to achieve very good workability and appropriate adhesive properties up to a maximum grain size of 8 mm. However, fine-grained mortars tended to have better workability than coarse-grained mortars. The mortars optimized with admixtures could be applied not only manually with a trowel but also mechanically using dry and wet spraying methods. The feasibility study provided an impressive demonstration that mortars with good workability can be produced with recycled AAC granulates as aggregates.

2.2 AAC mortar II – properties and possible applications

The physical properties of the mortars prepared with recycled AAC were determined in a subsequent project [4] and an indication was given for possible areas of application. Processed AAC granulates from production waste was used in addition to recycled AAC from processed demolition waste. Both materials were crushed in a jaw crusher. The apparent particle density of the recycled material from the demolition waste was 1.3 mg/m^3 (crusher sand with particle size 0/2 mm) and 0.9 mg/m^3 (granulates with particle size 2/8 mm) and its water absorption after a storage of 24 hours in water was 38 and 51 percent by mass, respectively. The granular material from production waste had apparent particle densities of 1.1 (0/2 mm) and 0.8 mg/m^3 (2/8 mm) and its water absorption was 52 and 65 percent by mass respectively. The granulates had a maximum sulfate content of 2 percent by mass.

The experimental investigations were carried out on mortars with 2 mm and 8 mm maximum particle sizes in plastic and stiff consistencies with and without admixtures, respectively. The consistency, the change in workability with time, the fresh mortar bulk density and the water retention capacity of the fresh mortars were determined. The hardened mortar was tested for flexural strength, compressive strength, dry bulk density, capillary water absorption and volume stability with time under different climatic conditions. The modulus of elasticity, the water vapour diffusion characteristics and the thermal conductivity of selected mixes were investigated. Figure 2 shows an example of the fracture surface of a hardened mortar prism made with recycled AAC aggregates.

The investigated mortars exhibited dry bulk densities between 0.7 and 1.1 mg/m^3, compressive strengths between 2.5 and 18 N/mm^2 and moduli of elasticity between 1400 and 4600 N/mm^2. The thermal conductivity varied between 0.17 and 0.24 W/(m·K). No expansion phenomena were observed in the durability investigations, even when using cement with a high tricalcium aluminate (C_3A) content.

Good workability could be achieved even for mortar mixes without admixtures, however, with the help of admixtures very good workability could be installed and maintained for at least one hour.

3 Industrially produced dry premixed lightweight masonry mortar including recycled AAC

Mortars with very low densities were produced by using stable foam. The observed properties of the fresh and hardened mortars indicate that these mortars may be used as filling mortar in masonry cavities or ducts, as normal and lightweight masonry mortar and as plastering mortar, especially as base plaster in renovation mortar systems.

3 From laboratory scale to industrial production

In order to promote the use of recycled materials and highlight their potential application in the construction sector, the developed lightweight masonry products will be used for the first time in a real building project in Bremen, where internal separating walls are made of masonry blocks and jointing mortars, both on the basis of recycled AAC aggregates. In preparation of this demonstration project which is currently under construction, it was necessary to transfer the techniques and results from the laboratory scale to industrial production processes so that the recycling products will be available in the required quantities and homogeneous properties. Dry premixed masonry mortars were therefore developed in the project entitled "Scale up of AAC recycling" [5] and their production was tested in the industrial production plant of a project partner. The investigations aimed at producing a lightweight masonry mortar LM36 according to DIN V 18580:2007-03 [6]. After extensive laboratory investigations two selected mix formulations, consisting of dried aggregates from recycled AAC, Portland cement and small additions of admixtures, were mixed in the industrial dry mixer and packed in bags of about 16 kg each (Figure 3).

The dry mixes of the mortars were designed to provide a plastic consistency and exhibit good workability after addition of water. The spread on the flow table remained substantially stable over a period of one hour, the water retention capacity was higher than 90 % and the fresh mortar bulk densities lay between 1.3 and 1.4 mg/m^3.

After 28 days the mortars showed a compressive strength of up to 11 N/mm^2 with dry bulk densities of less than 1.0 mg/m^3. The modulus of elasticity lay between 3400 and 4200 N/mm^2, the joint compressive strength was higher than 5 N/mm^2 and the bond strength lay between 0.4 and 1.4 N/mm^2 (Table 2). Calcium silicate masonry units with a moisture content of 4 percent by mass as reference blocks and also blocks produced with aggregates from recycled AAC with a moisture content of 10 percent by mass (equilibrium moisture) and 30 percent by mass (possible moisture content at delivery) were used to determine the joint compressive strength and bond strength.

4 Industrially produced masonry blocks including recycled AAC

Shrinkage deformations of the masonry mortars of up to 2.4 mm/m were recorded after a period of about three years during storage in a standard climate of 20 °C/65 % relative humidity, and the observed shrinkage was virtually completed after 6 months. Samples stored in a moist climate (20 °C/90 % relative humidity) did not exhibit any measurable swelling.

The aforementioned properties meet the requirements for LM36 lightweight masonry mortar according to [6].

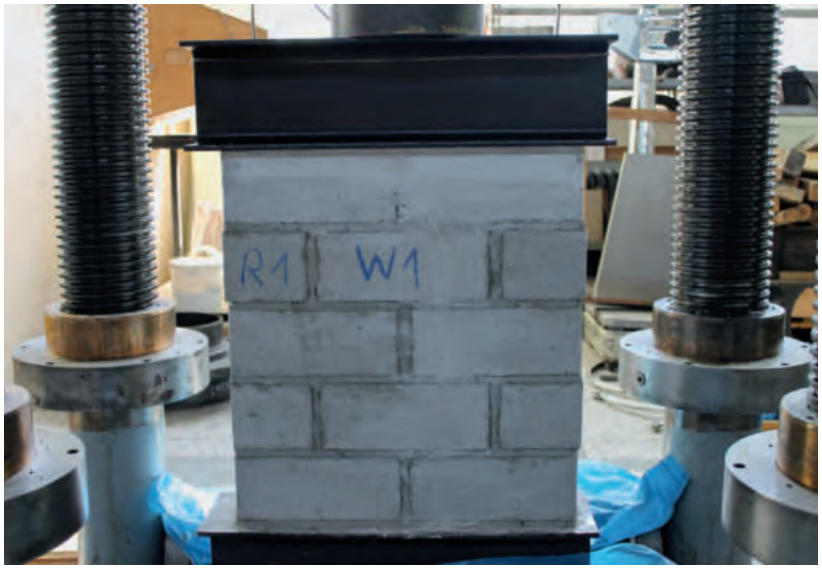
4 Bremen demonstration project

In the demonstration project which is currently under construction the dry premixed lightweight masonry mortar is used for laying masonry blocks (Figure 4), which also contain recycled AAC granulates as aggregates, in order to erect internal separating walls in the "Borgfeld recycling station", a new single-storey structure with a floor area of about 80 m^2. Demolition waste was collected for this purpose and the AAC rubble was sorted and processed, pilot batches of the recycling products were produced industrially and their properties were determined. Figure 5 shows a test wall during the compressive strength testing.

The formulation of the mortar mix was further improved during the on-going project. As aggregates recycled AAC granulates in the 0/2 mm particle size range, Portland cement and very small quantities of methylcellulose as well as air entraining agent were used. The ratio of binder to aggregates was approximately 1:5 parts by volume.

The masonry blocks were produced with even lower cement contents. In this case the ratio of cement to recycled aggregates was 1:11 parts by volume.

It is expected that the recycling products will be applied in the building project in early 2017. After erection the walls will be monitored for a period of about one year to check their behaviour under practical conditions.



5 Wall consisting of recycled AAC products during compressive strength testing

5 Funding note

The IGF projects [3, 4] of the Forschungsvereinigung Recycling und Wertstoffverwertung im Bauwesen e.V. (RWB) were supported by the Bundesministerium für Wirtschaft und Technologie through the AiF within the programme IGF (Support of Collaborative Industrial Research) based on a decision of the German Bundestag.

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The production of drymix mortar aggregate requires effective interaction of suitable comminution and sizing machines. For this purpose, experimental tests on pilot or large-scale are essential. Of considerable importance for the design of the plant configuration is also consideration of the influence of mineralogical-petrographic rock properties of the raw material deposit, in order to develop for the plant operator a flexible equipment concept for long operating lifetime with high equipment availability.

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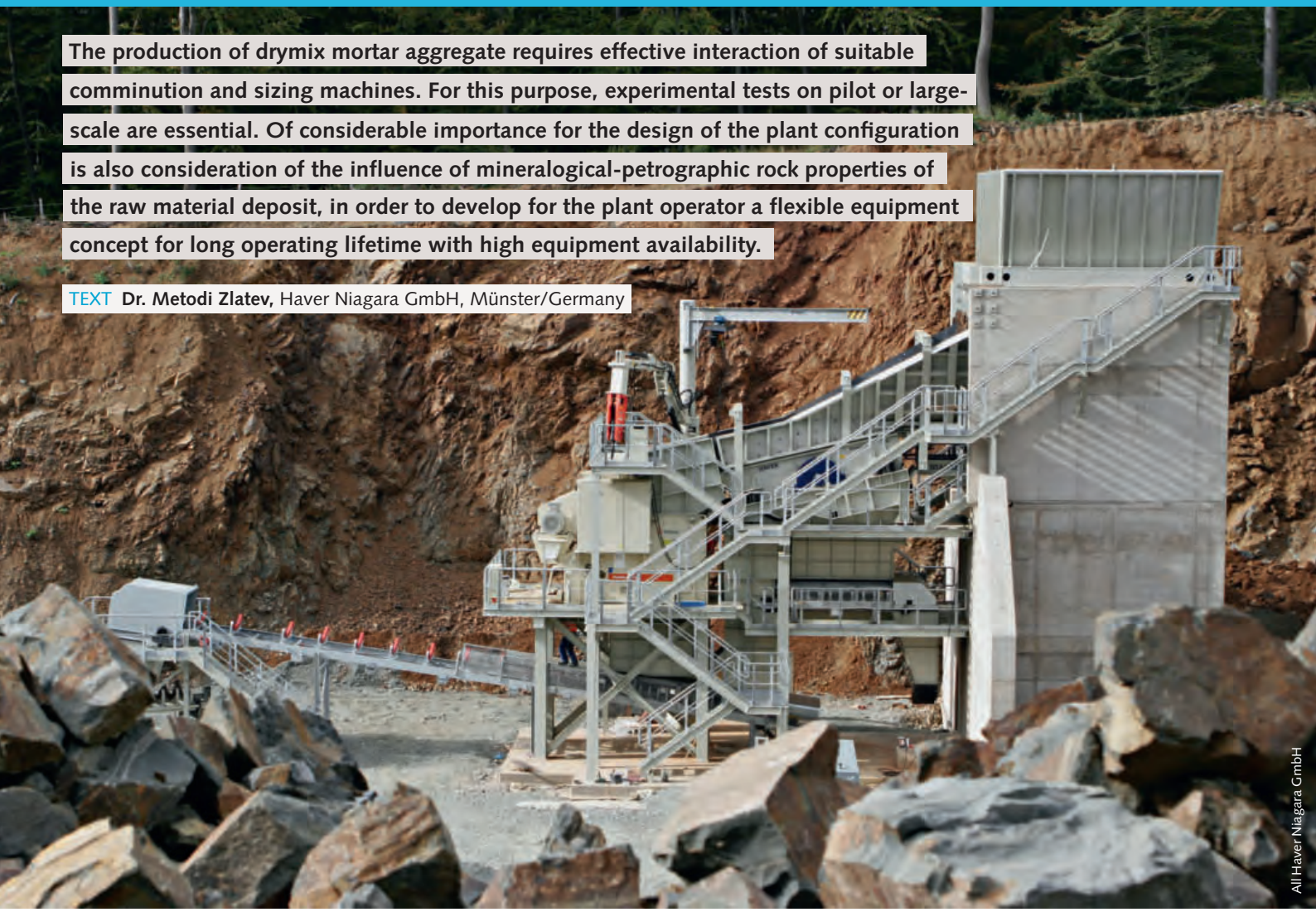


All Haver Niagara GmbH

Precrushing plant

HAVER NIAGARA GMBH

Optimizing the production of crushed sand for drymix mortar industry

1 Introduction

"Mortar" is a building material that can be described as a mix consisting of a binder (e.g. cement, lime), mineral aggregate with a maximum particle size d = 4.0 mm, and any necessary additives together with mixing water. The wide range of mortar types and their uses means that especially the mineral aggregates have to meet high requirements with regard to quantity and quality. The demand for mortar aggregate can be covered either with available natural sands or mechanical processing of solid rock.

The disadvantage of using natural sands is that the sands are only available in a particle size distribution specific to the deposit. Another disadvantage are the impurities consisting of loamy and clayey fines, alkali-reactive constituents and brittle rock components that have to be removed in complex washing and sorting processes. While the production of mortar aggregate from suitable solid rocks, which is explained more closely in the following, does require relatively high processing effort entailing the application of multi-stage, stationary comminution and sizing equipment, it offers the advantage that the required aggregate can be flexibly produced in line with demand depending on changing market conditions.

2 Requirements for drymix mortar aggregate

For the production of crushed sands, usually soft to medium-hard sedimentary rocks, e.g. limestone, dolomites, medium-hard gypsum and anhydrites, are preferred. The properties of the aggregates and flours produced from these play a big part in production of mortar. For characterization of the rocks, the following properties and requirements, which, for example, are recommended in DIN EN 13139 for the European region, are of great importance.

2.1 Petrographic rock characterization

The mortar aggregates produced from solid rock by means of mechanical processing are described on the basis of their petrography (rock characterization). In most cases, the current mineralogical-petrographic rock characterization allows only a verbal rock description. The "quantitative rock analysis" developed at Freiberg University of Mining and Technology permits the determination of quantitative rock characteristic values that enable an evaluation of the rocks with regard to their crushability, particle size and shape distribution of the crushed products, the wear on the working components of processing machines and equipment and the energy input required for comminution [1].

2.1 Geometric requirements

According to DIN EN 13139, the following particle size fractions are preferred: 0/1 mm, 0/2 mm, 0/4 mm, 0/8 mm, 2/4 mm and 2/8 mm. The drymix mortar producers usually demand an even finer subdivision of the particle size fractions. The particle size distribution of an aggregate is, like the particle shapes, crucial for the packing density of the material, which in turn determines the usage properties and water requirement of the mortar. For mortar aggregates, generally a nominal particle content of approx. 85 mass% is required. Oversize should not exceed 15 mass% while undersize should not exceed approx. 6...8 mass%. With regard to particle shape, for aggregate < 4 mm no requirements are specified.

2.3 Chemical requirements

Depending on the origin of the aggregates and the intended use, individual chemical components of the aggregates can have detrimental effects on the mortar produced with them. EN 12620 and EN 13139 therefore specify limits for components that are detrimental to the solidification and hardening of the mortar, lower its strength or density, lead to staining and discoloration or impair the corrosion protection of any reinforcements. In EN 13139 the following requirements are specified: chloride content ≤ 0.04 mass%; water-soluble sulphate content SO_3 ≤ 0.8 mass%; sulphur content ≤ 1.0 mass% and content of organic impurities ≤ 0.5 mass%.

For the characterization of the chemical composition of the rocks, usually the most important major and minor elements in oxide form are specified. These are: SiO_2, TiO_2, Al_2O_3, Fe_2O_3, FeO, MnO, MgO, CaO, K_2O and Na_2O. Although the chemical composition is of minor importance for immediate processing (e.g. machine selection and operation), increased values, especially of the components SiO_2, Al_2O_3, Fe_2O_3 and MgO of the typical chemical composition of, for example, a limestone can indicate that, on account of thermal processes that have taken place in deeper-lying parts of the deposit, SiO_2 has been dissolved out of acidic rocks, then transported with the solution to parts of the deposit near the surface and deposited there as SiO_2. Such deposit variations result in changing comminution properties (e.g. with regard to strength and hardness, abrasiveness) of the rock from the deposit and therefore increased wear on machines and equipment.

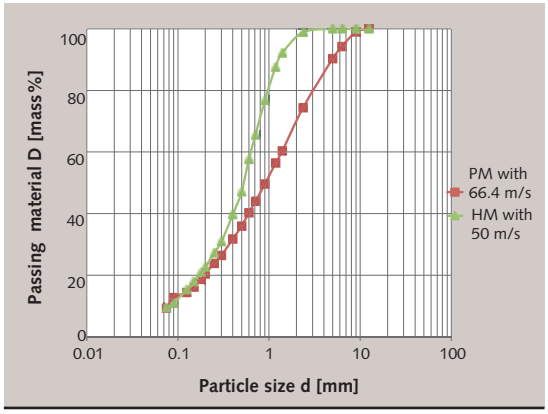
2.4 Physical-technical characterization

This includes the apparent density of the rock and the bulk densities of the drymix mortar aggregate, the surface moisture and the water absorption capacity, rock strength and hardness (e.g. Mohs hardness of calcite 3, feldspars 6 and quartz 7), the abrasiveness (limestone, for example, is only mildly abrasive, feldspars and quartzites are abrasive to very abrasive), the fracture toughness (the higher this is, the higher the energy input required for comminution; limestone has, for example, values of 0.2...0.7 $N/mm^{3/2}$ and quartz from 1.8...2.2 $N/mm^{3/2}$).

3 Production of drymix mortar sands

For the production of mortar aggregates < 4 mm, rock must be extracted from suitable deposits by means of drilling and blasting [2]. The large

1 Comminution and screening plant for sand grades



2 Selected particle size distributions of the crushing tests

lumps of blasted rock with a particle size of around 0/1500 mm are then processed in a precrushing installation (Lead picture) by means of multistage comminution and sizing processes. For the production of mortar aggregate 0/2 mm (0/4 mm), the particle fraction 0/22.4 mm from the precrushing installation is comminuted further in a downstream drymix mortar plant (Figure 1) and the crushed material separated into particle fractions, which then, depending on the mortar quality, are combined to defined particle size curves. For realization of the "comminution" and "sizing" processes, a wide range of machines and equipment is available from different manufacturers. For optimum selection of the necessary comminution and sizing technology, various criteria must be taken into consideration, e.g.:

- The properties of the material to be comminuted and sized (e.g. mineralogical and chemical composition, feed size, abrasiveness, strength properties and hardness, apparent and bulk density, surface moisture, etc.)
- Granulometric aspects, e.g. the number and particle ranges of the required particle fractions as well as their yield (quantities). The particle shape is not a factor in mortar aggregates < 4 mm with regard to the product quality. However, particle shape variations in fine and very fine sizing influence the quality and product quantities of the aggregates
- Stress and separation conditions and the possibilities for their mechanical realization in the design and selection of the working tools (e.g. size and shape of the comminution and sizing tools; stress type and velocity, etc.)

To define the plant configuration for the production of the mortar aggregates, extensive experimental comminution and sizing tests are therefore necessary.

3.1 Comminution tests

The raw materials usually used in the production of mortar aggregates require the use of suitable machines for medium-hard comminution (Mohs hardness of 2...5). For this, mainly machines with impact stresses, e.g. impact and hammer crushers, are used [3]. The following comminution systems were tested:

- Rotor impact crusher with vertical drive shaft
- Twin-rotor hammer crusher with grinding path and 4 mm grate
- High-pressure piston-die press for pressure comminution

For the comminution tests, pre-screened limestone in the size 0/22 mm (impact crusher) and 0.7/10 mm (hammer crusher and high-pressure piston-die press) was used. During comminution in the two types of crusher, especially the influence of changes of the rotor circumferential speed on the fineness of the product discharged from the crusher was tested. In the tests on pressure comminution, the pressure was changed in the range from 100 MPa to 200 MPa. After sampling and sample division, the particle size distributions of the crushed products were determined by means of sieve analysis with a Haver & Boecker EML-200-T analysis sieve [4]. From the particle size distribution, the product percentages of the fractions 0.15/0.5 mm, 0.5/0.71 mm, 0.71/1.2 mm and 0/1.2 mm required by the mortar producers were determined (Table 1). In addition, the content of flour 0/0.075 mm, which is relevant for the properties and usage of the mortar, is listed.

Table 1 Listing of the crushed product contents of relevant mortar grades (extract)

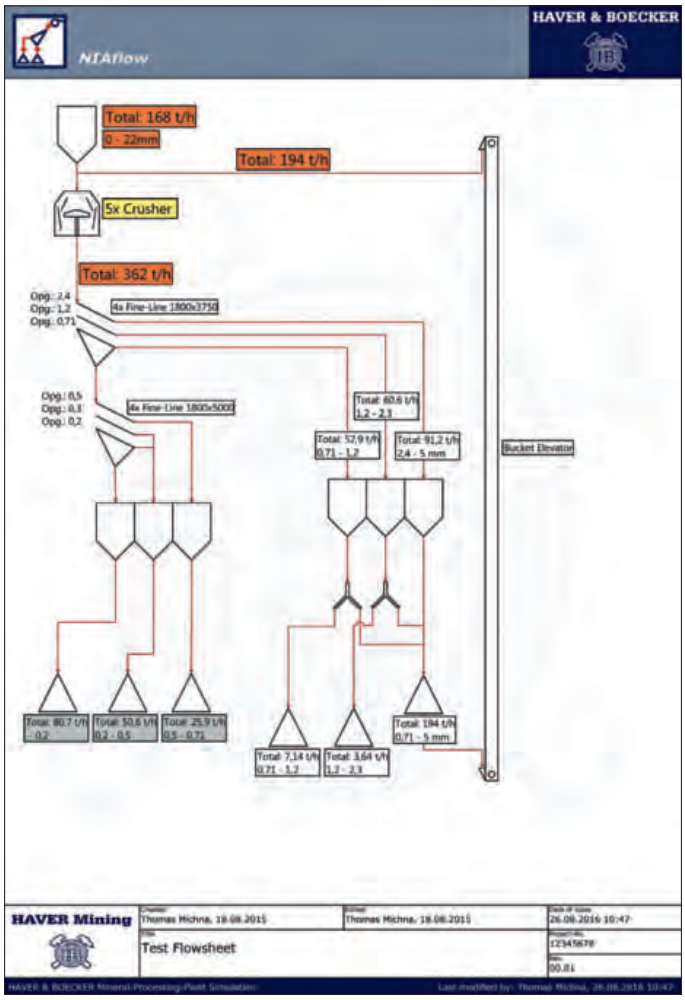
Circumferential speed of rotor [m/s]	Impact crusher (grain fractions in mm)				
	Percentage of selected product fractions [M.-%]				
	0/0.075	0.15/0.5	0.5/0.71	0.71/1.2	0/1.2
V_u = 57.9	10.9	20.5	7.9	11.8	57.9
V_u = 62.2	9.7	18.5	7.7	12.1	55.3
V_u = 66.4	7.7	19.3	8.3	12.9	55.0
V_u = 70.7	14.3	21.3	8.7	12.9	63.3
	Hammer crusher (grain fractions in mm)				
V_u = 30.0	4.6	14.8	14.9	28.4	66.4
V_u = 40.0	5.6	21.4	18.1	28.9	79.6
V_u = 50.0	9.6	29.2	18.5	22.0	87.4
	Piston-die press (grain fractions in mm)				
100...200 MPa (Average values)	20.5	8.1	6.8	12.2	57.5

3 Fine-Line screens

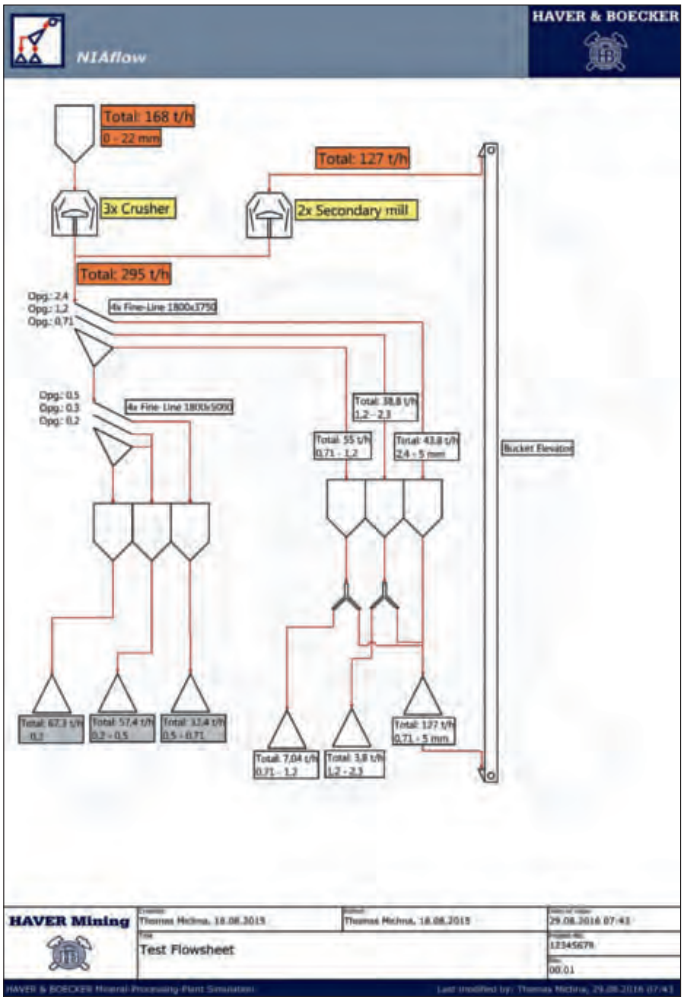
In respect of the rock flour content, the data of the pressure comminution tests show very high values, however, the product percentages in the relevant mortar aggregate sizes are too low and therefore these data are not of interest for further plant design [5]. From the many particle size distributions from impact comminution in the impact and hammer crushers, the machine-

Table 2 "Screening technology" of Haver Niagara GmbH Münster (extract)

Screening system	Feed particle size (max.) [mm]	Feed rate (max.) [t/h]	Screening rate per deck [m²]	Number of decks [–]	Cut size range [mm]	Screen deck inclination [°]	Drive power [kW]	Total weight [t]	Application areas
Eccentric – SM (F – CLASS)	≦ 500	≦ 1500	3…18	1…3.5	2…125	13…25	7.5…90	2.5…30	Product screening Scalping Impurity separation
Free- vibrating screening – SM (T – CLASS)	≦ 300	≦ 800	0.3…24	1…3.5	0.5…150	6…25	3…75	0.2…25	Product screening (dry, wet) Impurity separation
Linear – SM (L – CLASS)	≦ 300	≦ 1500	0.9…19.2	2…3.5	0.3…125	-3…10	45…150	0.5…25	Product screening (dry, wet) Dewatering
Multideck – SM M – CLASS)	≦ 10	≦ 75	5.6	≦ 11	0.08…8	0	15…30	5…10	Product screening Industrial minerals Foodstuffs Synthetic and chemical products
FINE-LINE	≦ 8	≦ 100	4.5…11.25	1…3	0.1…3.0	30…45	2.64…26.4	2…14.5	Product screening (dry) Filler removal Reject removal



4 Flowsheet of a drymix mortar plant without a secondary crusher



5 Flowsheet of a drymix mortar plant with a secondary crusher

specific product curves shown in Figure 2 were filtered out, which are to be used for later plant design. The use of these crushed material curves for plant design, however, requires not only the adjustment of the machine and operating parameters defined in the preliminary tests, but also assumes that the material is extracted from largely homogeneous raw material deposit and exhibits comparable mineralogical-petrographic rock properties.

3.2 Screening tests

The selection of a screen and the definition of its configuration depend on a number of influencing factors. To guarantee high product qualities and quantities, it is necessary to define:

» A sufficiently large screening area and
» An optimum screen aperture (size and shape) for every cut-point

For high throughput rates, the largest possible screen aperture is advantageous. For accurate screening, relative to the respective cut-point, narrow screen apertures are useful, to keep any misplaced particles in the screen oversize and undersize within the prescribed limits. With the selection of such a mesh width, oversize particles in the undersize can be reduced or even completely excluded, as a result of which, however, misplaced (undersize) particles in the screen oversize can increase to impermissible values. As a result, the yield of fines is reduced considerably.

For the range of fine to ultrafine screening for the production of mortar aggregate, from the range of machines of Haver Niagara, Münster/Germany, especially flat screens and Fine-Line screens (Table 2 and Figure 3) are suitable [6; 7; 11]. For drymix mortar plants with lower throughput rates, alternatively screens of the M-Class (multideck screens) can be used. For the determination of appropriate screen parameters, experimental screening tests are essential. To conduct the screen tests, from the machine range of Haver Niagara GmbH, the Fine-Line screen of the type HE 500 x 1250 was used. Following operating parameters were kept constant during testing:

- Speed of the unbalance drives n_u = 3600 min^{-1}
- Oscillation amplitude a = 0.5 mm
- Dimensions of the screening area: width W = 500 mm; length L = 1250 mm: screen area AF = 0.635 m^2
- Inclination of the screening area β = 33°

The test programme entailed the change or variation of the following parameters:

- Cut-point-specific mesh sizes and shapes
- Specific screening rate in [t/(h · m²)]
- Screening duration t_S in [s]

Used was a limestone mix, which was screened on a Fine-Line screen with 1 mm square mesh [8]. With the undersize material, on the above-described Fine-Line screen, screening tests were performed with cut-point-specific mesh shapes, with variation of the specific screening rate. Selected results of the tests are summarized in Table 3. On the basis of the sizing tests, for the screening part of the drymix mortar plant, the following was determined:

- Cut-point w = 0.71 mm: the setting with the specific screening rate of 8.9 t/(h · m²) is recommended
- Cut-point w = 0.5 mm: The specific screening rate should not exceed 10.2 t/(h · m²)
- Cut-point w = 0.2 mm: Suitable for this cut-point is the test setting with a specific screening rate of 3.2 t/(h · m²)

For the second screening stage, relief of the load of material <0.5 mm is planned. For the downstream cut-points, the following test settings were selected:

- Cut-point w = 0.3 mm: For this cut-point, good results were obtained at a screening rate of 4.0 t/(h · m²)

After the load relief, the screening tests were performed with the cut-points w = 0.2 mm and w = 0.15 mm, which led to the following recommendations:

- Cut-point w = 0.2 mm: Good screening results were obtained to screening rates of 2.4 t/(h · m²). With an increase of the specific screening rate to >2.5 t/(h · m²), already slight overfilling of the screening area was registered
- Cut-point w = 0.15 mm: This is a specific cut-point that should only be realized on customer request. Up to a screening rate of 1.2 t/(h · m²), good screening results could be obtained. With an increase of the specific screening rate to values of 1.4 t/(h · m²), considerable overfilling of the machine was observed

The necessary screening areas of the Fine-Line screens used (Figure 3) were defined with consideration of the specific screening rates depending on the respective cut-point. For the first screening stage, four screens of the size 1800 x 3750 mm (screening area 6.25 m²) were selected. For

Table 3 Summary of the most important screening results (extract)

Cut sizes without load relieving (for first screening stage)									
Cut sizes w [mm]	w = 0.71			w = 0.5			w = 0.2		
Mesh type/Mesh dimension (category)	1	2		3	4a	4b	5	6	
Spec. screening performance m_{sp} [t/(h · m²)]	5.4	**8.9**	9.5	6.4	6.7	**10.2**	2.7	**3.2**	4.0
Oversize [mass%]	–	**7.6**	–	–	–	**2.7**	–	**9.2**	–
Undersize [mass%]	–	**5.2**	–	–	–	**2.8**	–	**4.1**	–

Cut sizes with load relievingrelieving w < 0.5 mm (for second screening stage)										
Cut sizes w [mm]	w = 0.3			w = 0.2			w = 0.15			
Mesh type/Mesh dimension (category)	7			8a			8b (Sandwich)			
Spec. screening performance m_{sp} [t/(h · m²)]	**3.6**	5.1	6.1	2.0	**2.4**	3.7	0.7	**1.2**	1.4	1.9
Oversize [mass%]	**7.5**	–	–	–	**9.1**	–	–	**9.2**	–	–
Undersize [mass%]	**7.3**	–	–	–	**3.2**	–	–	**6.1**	–	–

Table 4 Chemical composition of selected solid rocks (customer data and specifications from the references)

	Customer details (Average values)		Comparative values based on technical literature [9],[10]		
Selected Oxides [%]	Limestone (Planning)	Limestone (Repeat sampling)	Limestone	Dolomite	Quartzite
SiO_2	2.87	19.87	0.10	0.21	93.16
TiO_2	k.A.	k.A.	0.00	0.00	0.03
Al_2O_3	1.09	0.24	0.10	0.02	1.28
Fe_2O_3	0.51	0.06	0,27	1.73	0.47
FeO				0.22	3.12
CaO	51.48	43.50	54.60	30.35	0.70
MgO	1.48	0.59	0.68	20.46	0.07
K_2O	0.10	0.03	0.00	0.00	0.39
Na_2O	0.03	0.04			

the second screening stage, screens of the type 1800 x 5000 mm (screening area 9.0 m²) were foreseen.

4 Plant configurations

The drymix mortar aggregates are generally produced in stationary crushing and sizing plants. As raw materials, suitable soft to medium-hard rocks (e.g. limestones, dolomites, anhydrites and gypsums) are used, which can be comminuted with relatively low energy input and machine wear. For the comminution part of the drymix mortar plant, usually machines with impact and percussion-type stresses (e.g. impact and hammer crushers) are used [3]. In the selection of the crushing system, it is necessary to consider advantages and disadvantages in respect of

- Yield of product grades
- Production of excess grades
- Specific work requirement
- Wear of relevant plant components
- Guarantee of a stable throughput rate

For the development of suitable plant configurations, extensive comminution and screening tests were therefore performed, the results of which and recommendations for plant design are shown in Tables 1 and 3.

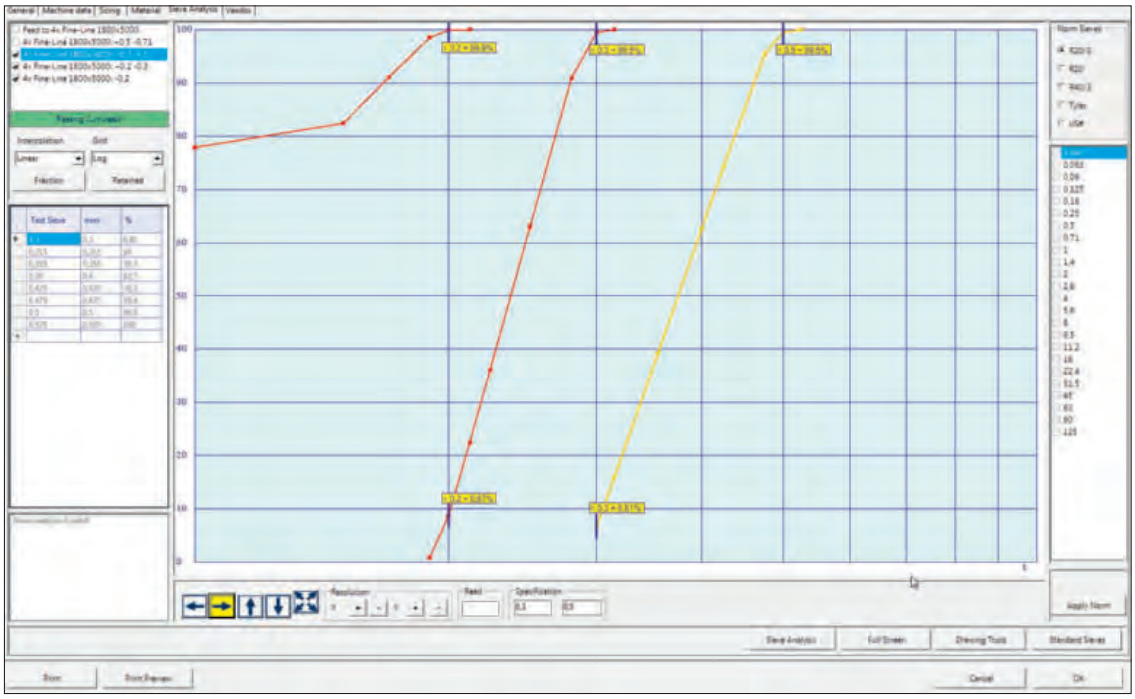
The goal of the comminution tests was in particular to determine suitable operating parameters for the crushing systems tested, i.e. parameters at which a maximized percentage of product grades of the tested limestone can be realized with reasonable energy input and minimized machine and equipment wear. After this, the crushed product is separated by means of suitable screening equipment into a customer-specific number of more or less narrow particle size fractions, which are stored in separate bins. Any excess sizes produced are recirculated to the comminution machine and there recrushed together with the fresh feed material. From the stored product fractions, the required grading curves are mixed for the specific drymix mortar application. The quantity of recirculated material is crucial for the throughput rate of the entire plant. The less material that needs to be recirculated, the higher the plant throughput rate is.

For the process design of the crushed sand plant, calculation of the mass flows with consideration of the machine-specific operating parameters of the selected comminution technology and the calculation of the particle size distributions of the mortar products, the "NIAflow" process simulation software developed by Haver & Boecker was used.

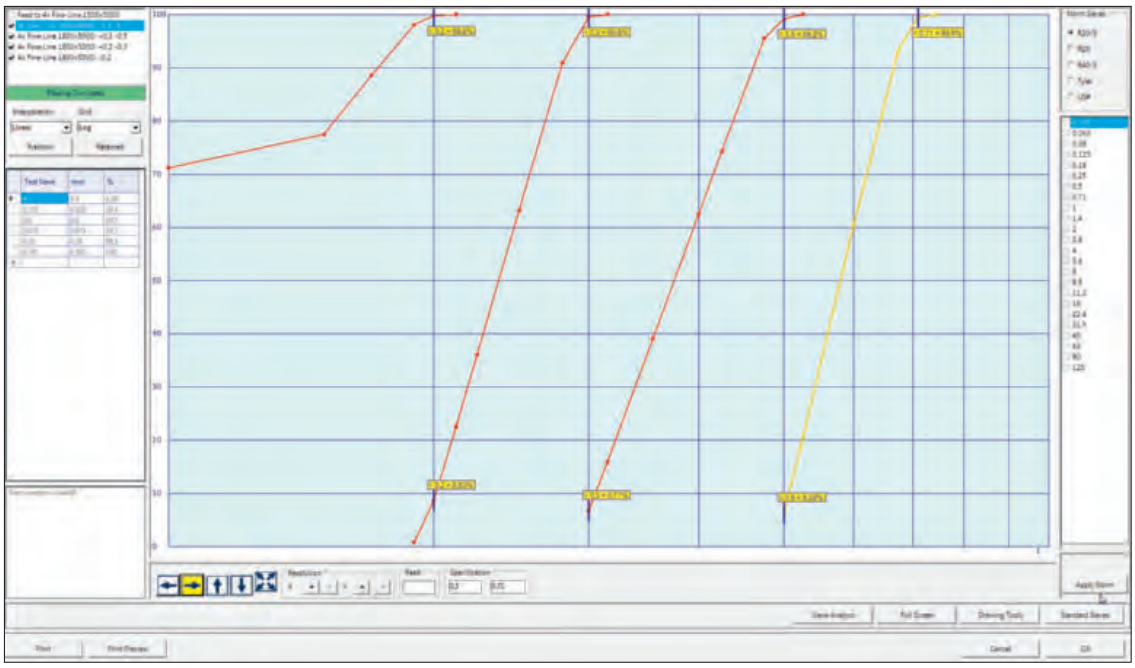
Figure 4 shows as a basic variant the flowsheet of a plant for the production of mortar aggregate with an impact crusher with vertical drive shaft as the comminution machine. The comminuted material is fed to the first screening stage, which is equipped with Fine-Line screens of the size 1800 x 3750 mm. Here the crushed material is separated into the sizes 0.71/1.2 mm, 1.2/2.4 mm und 2.4/5 mm. The screen undersize 0/0.71 mm is fed to a second screening stage with Fine-Line screens of the size 1800 x 5000 mm and sized into the fractions required by the customer, that is 0/0.2 mm, 0.2/05 mm und 0.5/0.71 mm. The excess grades from the first screening stage 0.71/1.2 mm and

1.2/2.4 mm are stored in small quantities in bins for further use. The large part of the two fractions is combined with the size 2.4/5 mm and fed as the excess size 0.71/5 mm by means of a bucket conveyor to the impact crusher and recrushed together with the fresh feed material.

As no comprehensive mineralogical-petrographic deposit evaluation was available for the design of the plant, it was necessary to refer to the chemical analysis of the limestone deposit to be extracted. The chemical rock analysis provided for the design phase corresponded, apart from the slightly increased SiO_2 values, to a usual limestone composition (Table 4). A further analysis that was provided at a later point in time, however, showed considerable deviations, especially in respect of the components SiO_2, Al_2O_3, CaO and MgO. It could therefore be presumed that the limestone deposit from which material is to be extracted has variations with regard to the mineralogical-petrographic composition. Obviously parts of the sedimentary "limestone" deposit had undergone a metamorphic



6 Particle size distribution of the crushed products (without secondary crusher)



7 Particle size distribution of the crushed products (with secondary crusher)

process under the influence of pressure and temperature, as a result of which the original crystal structure and mineral composition were changed. Such transformation processes can lead to the formation and intercalation of metamorphic rock components (e.g. quartzites, feldspars).

As a reaction to the changed deposit conditions, as a result of the occurrence of selective comminution effects, an increased content of hard, abrasive rock component in the circulated material has to be expected. Therefore, for the separate comminution of the excess size 0.71/5 mm enriched with hard materials, two secondary comminution machines (hammer crushers with grinding track and 4 mm grate) were included in the flowsheet. The number of primary crushers could be reduced to three machines as a result (Figure 5).

With the new plant configuration, the quantity of circulated material could be reduced considerably, the yield of the product sizes 0.2/0.5 mm and 0.5/0.71 mm increased. Moreover. less machine and equipment wear and higher availability of the drymix mortar plant can be expected. The particle size distributions of the mortar fractions calculated with the NIAflow software (Figures 6 and 7) lead to the conclusion that sizing to the load-relieving cut-point w = 0.3 mm does not present any problem. A direct sizing at the cut-point w = 0.2 mm after the cut-point w = 0.5 mm cannot, however, be recommended as the screens with the required specific screening rate could be overfilled. If the drymix mortar producer requires an additional cut-point at w = 0.15 mm, so on the basis of the crushing curve of the planned impact crusher in accordance with Figure 2, the planned screening area should be enlarged. Alternatively, it is possible to compensate for the screening rate obtained in the calculation of the recipe of the drymix mortar. Precondition for this, however, is that the sizing process produces a sized product of uniform quality.

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SIKA DEUTSCHLAND GMBH

New Sika Customer Technology Centre at the Rosendahl site

All Sika Deutschland GmbH

1 On a total area of just under 3000 m², there is ample space for new ideas and branch-oriented solutions

Just over two years since the announcement of plans costing just under € 6 million, Sika's ambitious building project could be completed: Not even 14 months after ground breaking, the new Sika Customer Technology Centre in Rosendahl, Westphalia, was opened on 01.09.2016.

The newbuild at the Rosendahl site represents a forward-looking move for the entire Sika Group, reflecting the innovative drive of the company and Sika AG. The facility opens up new possibilities and perspectives in development, research, application engineering and customer dialogue.

On a total area of almost 3000 m², the new Competence Centre offers ample space for new and branch-oriented solutions. The opening ceremony was held in the presence of the company and group management, customers, employees and local government representatives.

Foundation stone for modern customer dialogue

Following the acquisition of Schönox GmbH by Sika AG in 2013, this is now being integrated into its subsidiary, Sika Deutschland GmbH. The Schönox brand will be managed and further expanded as part of the Construction Adhesives and Sealants business unit. The range comprises tile adhesives, flooring adhesives, joint sealants, fillers, fast screeds, primers and sealants.

As a new Competence Centre, from the Rosendahl site Sika is taking on global responsibility for laying materials within the entire corporate group. Already before the acquisition, over the last few years Schönox GmbH had brought new impulses to the market with innovations such as the very low-emissions Schönox iFloor rollable adhesive, the 2-component Schönox iFix rollable sealing adhesive or the Schönox aDeco spackling non-woven system. In future, it will be possible to introduce more impulses in floor, tile and wall systems. Moreover, responsibility now resides with Rosendahl for development of the formulas and technologies for the "Interior Finishing" target market – not only for Germany, but also for other Sika companies around the world. In addition, support will be provided for local and regional technology centres within the group. For this purpose, a special local competence team for speciality mortar products has been put together, which, for example, deals with grouting and concrete repair mortars for very challenging applications like building wind farms or bridges. Accordingly, the Rosendahl laboratory centre is becoming more important and acting as a global technology centre for the Sika Group.

Making the working life of construction professionals better every day

Behind the Schönox brand is the promise to make the working life of construction professionals better every day. With the multimillion euro investment of the Swiss parent group Sika in the Rosendahl site, the company is again delivering on this promise. The investment has been made in the generation of knowledge and the creation of conditions to assure a sustainable future. A large part of the facility is made up of new laboratories and offices for research and development. Moreover, an industrial hall has been erected over two levels for application engineering. The brand promise will also be better fulfilled with the new training facilities: in spacious and modern seminar rooms equipped with state-of-the-art technology, the advantages and application of the Schönox products and systems can now be presented to larger groups in a more demonstrative, practice-oriented and individual way. Field orientation based on training is not only a priority in Rosendahl. Sika has training centres all over the world, confirming its closeness to the building trades and allowing them to experience the handling of its efficient system solutions on a practical level. The goal is to continue offering the best solutions with products and services for customers in the branch and consequently to permanently improve their working life.

www.sika.de

2 Opening ceremony for the new customer technology centre

3 An area of 900 m² is available for training and events

All Sofraden

Since its foundation in 1991, Actemium has been specializing in the design engineering and the manufacturing of turnkey dry mortar mixing plants – either new installations or the revamping of existing facilities – with flexible and scalable layouts.

TEXT **Sofraden Industrie SAS,** Saint-Étienne/France

ACTEMIUM SAINT-ÉTIENNE PROCESS SOLUTIONS | SOFRADEN INDUSTRIE SAS

Turnkey processing solutions for dry mortar mix plants

Actemium has over the past decades developed a strong reputation in the building chemicals industry and long-term relationships with key manufacturers of dry mortar worldwide. The company provides sustainable and innovative process engineering solutions and equipment for mixing, dosing, conveying and handling products made from powder, granules, bulk solids, pasty products and liquids.

Since the company joined the Vinci Energies group, Actemium has taken advantage of an exceptionally dense network of 300 subsidiaries in 38 countries.

Actemium operates all around the world and has built strong partnerships with local suppliers. Co-activity on site is managed by the company's highly experienced site managers.

The company's expertise covers the entire industrial life cycle from design engineering through to project management, equipment supply, installation and service management.

During the design phase, the company's engineers strictly follow a method organized into three steps in order to identify customer's needs and expectations (see three info boxes).

The design activities and construction phase of the installation are led by highly skilled project management professionals.

Installation commissioning is jointly managed by Actemium's site manager who supervises the erection phase and by the electrical and automation manager. This phase also includes the operators training.

CHARACTERIZATION OF RAW MATERIALS

- Powders: density, grain size, granular flow of powder products
- Liquids: viscosity and density parameters
- Compatibility of raw materials
- Atex requirements

TRIALS

To determine the most appropriate technology

Mixers for bulk solids, reactor/dispersers for liquids and pasty products, dosing systems, mechanical and pneumatic conveying systems in dense and dilute phase are available in-house or at customer's site. Following parameters can be tested:

» Definition of loading mode
» Selection of dispersion tools required (cutting or simple stirring) ...
» Calculation of energy required
» Discharge mode (gravity, pump, pressurized tank)
» Management of final stages of transfer
» Cleaning procedure

To pilot and optimize the plant industrial performance, Actemium can integrate a MES (Manufacturing Execution System) which has been specifically designed to manage and control mix batch plants.

MES solution Prodose

This software is a suite of different modules including planning, piloting, monitoring and traceability of the overall production process. Prodose is multilingual and installed worldwide. Any installation from all around the world which is piloted by Prodose can benefit from remote technical assistance 24/7.

For over 25 years Actemium has been developing expertise in mixing technologies. Under the brand name Sofraden, Actemium proposes a wide range of industrial continuous and batch mixers for dry products as well as dispersers for liquids and pasty products.

FEASIBILITY AND CAPACITY STUDIES

Basic Engineering Design
Front End Engineering Design

Definition of installation dimensions:

» Storage volume determined as a function of consumption and supply characteristics
» Volume of semi-finished product storage (premix)
» Volume of transfers and dosing
» The mixer(s) are scaled up based on the requested production capacity

Assessment to customers' specific security and safety constraints (ATEX, CMR, FDA…)

Assessment of physical restrictions linked to the location (for example: seismic consideration), study of ergonomics, evaluation of expected flexibility and future evolution of the installation

Ensuring installation compliance with local laws and regulations

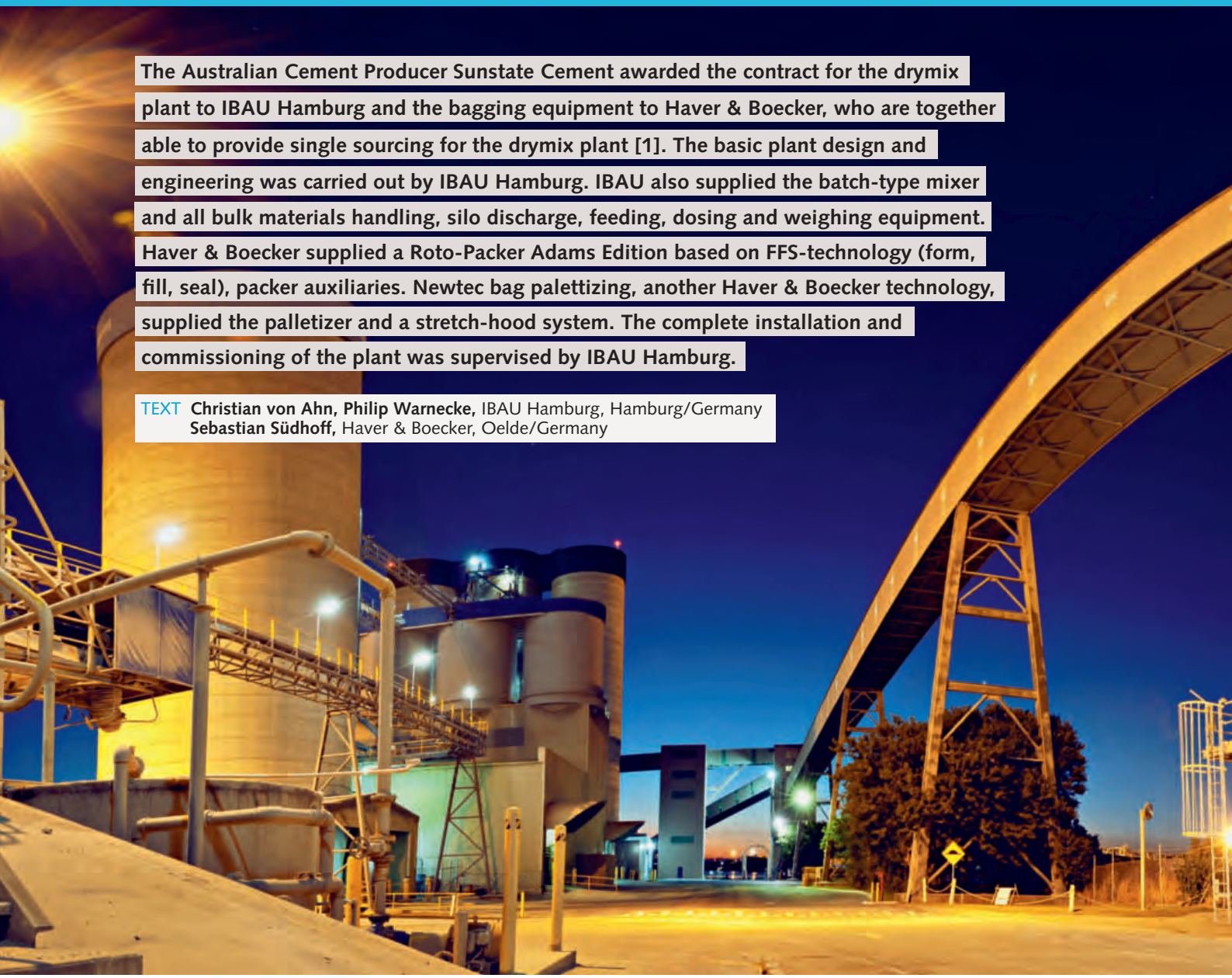
MIB intensive batch mixers for powder, granules, bulk solids

These mixers consist of a horizontal tank equipped with a simple shaft and PHR blades (patented): their reversed helical profile ensure the actions of projection as well as vertical and horizontal circulation to ensure high quality dispersion. For a quick discharge and to reduce the risks of cross contamination between batches, the mixers are available with full discharging doors. MIB mixers are designed for durable, reliable and continuous duty in mixing applications. When abrasive materials are involved, the MIB mixers are delivered with special wear-resistant alloys and tank armouring. Depending on the customer's needs, the mixers can be fitted with high speed choppers, samplers, liquid spraying nozzles, an auxiliary discharge outlet.

To reduce the time for cleaning operations and get the best cleaning results, Sofraden mixers and dispersers can be delivered with a fully automated and efficient Cleaning-In-Place (CIP) system. When processing thermal sensitive products, the mixing vessel is designed with a double jacket for heated or cooled mixing or drying operations. The vessel can also be designed to work under a vacuum. MIB mixers can also be designed to mix explosive materials and to comply with the Atex directive.

www.mixing-process.actemium.com
www.sofraden.com

Turnkey (including civil engineering) dry mortar mixing plant (Location: Northern Europe)



The Australian Cement Producer Sunstate Cement awarded the contract for the drymix plant to IBAU Hamburg and the bagging equipment to Haver & Boecker, who are together able to provide single sourcing for the drymix plant [1]. The basic plant design and engineering was carried out by IBAU Hamburg. IBAU also supplied the batch-type mixer and all bulk materials handling, silo discharge, feeding, dosing and weighing equipment. Haver & Boecker supplied a Roto-Packer Adams Edition based on FFS-technology (form, fill, seal), packer auxiliaries. Newtec bag palettizing, another Haver & Boecker technology, supplied the palletizer and a stretch-hood system. The complete installation and commissioning of the plant was supervised by IBAU Hamburg.

TEXT **Christian von Ahn, Philip Warnecke,** IBAU Hamburg, Hamburg/Germany
Sebastian Südhoff, Haver & Boecker, Oelde/Germany

Sunstate Cement plant in Port of Brisbane

IBAU HAMBURG | HAVER & BOECKER

Latest drymix plant concept and technology

1 Introduction

Sunstate Cement Ltd. is one of Australia's leading producers and suppliers of high quality cementitious products. With a capacity to supply more than 1.5 million t of cement per year it is a contributor to some of the largest and most impressive infrastructure projects in Queensland, West Australia and northern New South Wales. The company is jointly owned by two of Australia's largest cement manufacturers, Adelaide Brighton Cement Ltd. and Boral Cement (a division of Boral Limited).

Sunstate operates a cement production and distribution terminal (Lead picture) at the Port of Brisbane. Cement and additives mainly arrive by

All IBAU Hamburg/Haver & Boecker

ship and are unloaded at the terminal's own berth. The company, who produces a large range of bulk and bagged cement products, including blended slag and fly ash cements, decided to complement its product range by introducing a number of ready to use drymix products. At the same time, Sunstate Cement wanted to offer its clients the advantages to store these products outside and to optimize logistic expenses.

Therefore, Sunstate Cement awarded IBAU Hamburg and Haver & Boecker the contract to supply the main components, design and commission of their new drymix production plant. After starting off with the technical discussion and consulting in November 2015 and the contract award in January 2016, the fabrication, acceptance and testing were carried out in July, followed by the plant installation which began in October and ended with the successful commissioning in November 2016. In comparison to similar plants with an average time of two years from order to operation, the complete project was realized in fourteen months.

2 Sunstate Cement and their major requirements

With the uptrend in the Australia's Do-it-Yourself markets Sunstate Cement decided on a new and state-of-the-art drymix production facility. The main proposed products were a high-performance concrete mix, a special mortar mix blend, a special post mix, a rapid set mix as well as a paver sand mix. These products, which are designed to be ready to use, have proportionately different blends of ingredients, including cement, lime, gravel, sand and additives. The company decided to shift from the more traditional paper packaging to plastic bags (PE) and this was done for a number of reasons:

» PE bags are dust-free, waterproof and UV resistant
» PE bags allow for high-quality, eye-catching and colourful printing
» PE bags have no spillage during transport
» PE bags can be stored outside, all year long
» PE bags are tear-resistant and flexible

Accordingly, Sunstate's drymix products in PE bags increase the company's own storage capacity and those of the clients, reduce overall logistics expenses and offer an essential advantage at the point of sale. Sunstate Cement decided on PE bags of 10, 20 and 30 kg, to be palletized and equipped with a stretch-hood system for maximum load integrity.

The technical requirements were complex. The new facility had to be installed taking into account storage silos, a bag filter and the building that already existed. The major equipment including the mechanical mixer, packer and palletizer were to be delivered from a single source as was all auxiliary equipment such as the silo extraction, material transports, feeding/dosing and weighing systems, all packer and palletizer auxiliaries, the stretch-hood system as well as plant automation and control. The new plant's requirement was to be easily expandable to future market demands. However, the footprint of the plant was very limited. The main requirements were:

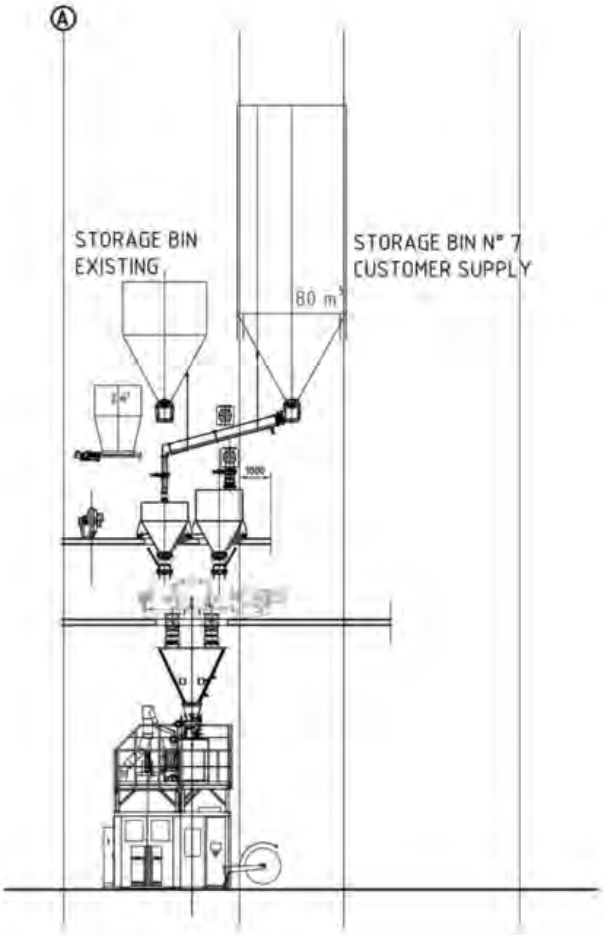
» small footprint of the plant,
» state-of-the-art technology
» integration of new silos and existing buildings
» easy possibility for expansion
» short delivery time
» customer support

1 Drymix building with storage silos

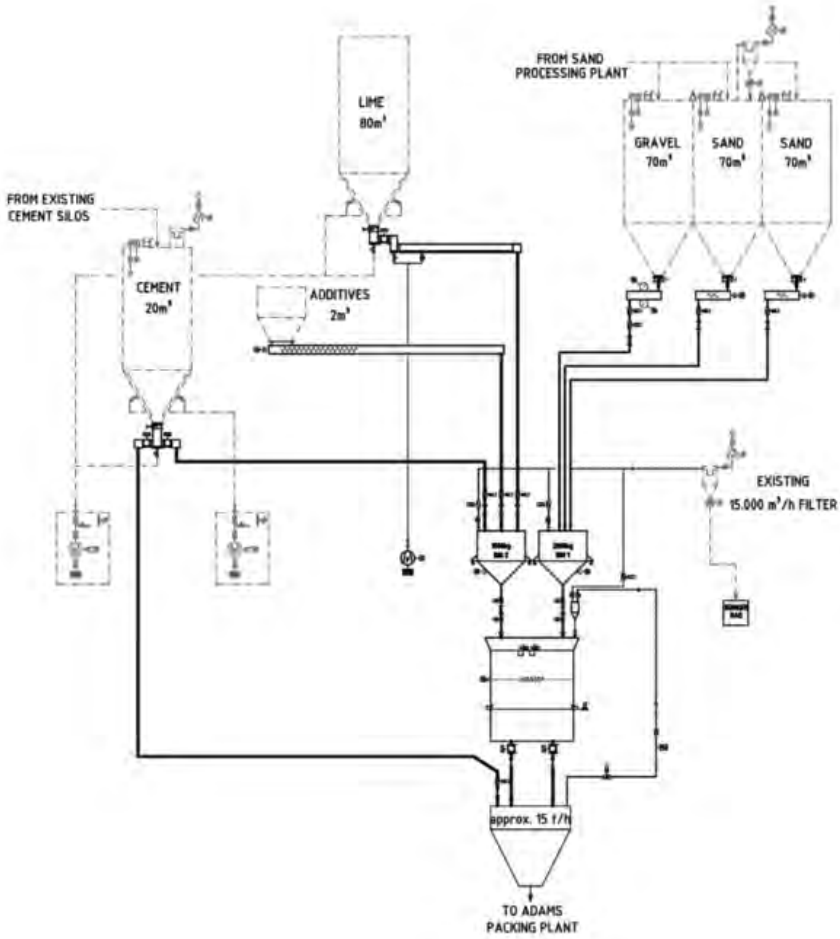
3 Drymix plant design and major components

Figure 1 shows the building of the new drymix plant with the storage silos. The larger silos are for the storage of cement and blended cements, which is part of the cement production plant. In total the drymix plant has five storage silos, one for cement, one for lime/flyash, one for gravel and two for sands. The storage capacity of the individual silos range from 20 to 100 m³. Furthermore, the plant has one bin for additives. Figure 2 shows the layout of the plant. The mixing tower only has a height of about 25 m. Sunstate's building is very compact – integrating the mixing plant, packing plant, palletizer and stretch hood system. No dryer and separation equipment was necessary for the sand and gravel, because these products were all delivered separately.

Figure 3 illustrates the flow sheet of the mixing plant. The key component is the IBAU Batch-type mixer IBAU M 2500 (Figure 4), which has a 45 kW drive. The mixer has a gross volume of 2.5 m³ and allows, with 12 mixing cycles per hour, a guaranteed throughput of 15 t/h. With discontinuous mixing a very large quantity of recipes is possible [2]. Sunstate has the ability to produce special drymix or cement recipes according to individual customer requirements. The mixing cycle of a batch-type mixer consists of the filling time, mixing time and discharge time. During the mixing process the next batch is prepared.



2 Drymix plant layout



3 Flow-sheet of the mixing plant

4 IBAU Mechanical mixer

5 Dosing and feeding equipment

The mixing plant has two weighing bins: the larger one with 2000 kg weighing range and 2.6 m^3 gross volume is for sand and gravel, the smaller one with 1000 kg weighing range and 1.6 m^3 gross volume is for cement, lime and additives. The feeding and dosing of the material to the weighing bins is done either by fluidslides, screw feeders or vibrating feeders (Figure 5). State-of-the-art micro-processor-controlled electronics are used for automated weighing, dosing and mixing. The quality of all production batches can be monitored and documented. From the mixer the finished products are transported directly to the packing plant. No intermediate storage of finished products is necessary.

The heart of the packing and palletising plant is the Roto-Packer Adams Edition (Figure 6). The packer is equipped with two filling modules for a capacity of 600 bags/hour, but can easily be upgraded to four filling spouts with 1200 bags/hour. The FFS technology (form, fill, seal) is the latest high-performance packing technology for powdery products [3]. The bags are formed in the packing machine from a continuous PE plastic tube. Then the formed bag is filled on one of the filling modules, compacted during filling and hermetically sealed via pulse-welding technology.

Each filling module is equipped with the MEC electronic weighing system with touch panel and leading weight accuracy, which have made Haver & Boecker the well-known specialist for bagging systems. Anyhow, for maximum customer safety the bag discharge line is equipped with a bag flattening device, checkweigher and bag rejecting system, in case bags with under- or overweight should be detected. The complete system is designed for PE bags with 10 kg, 20 kg and 30 kg weights and can easily be adapted to bigger and smaller bag sizes. Haver & Boecker has also supported the customer in the bag size calculation, so that with this "start-up" right from the start all the bags can be sold.

The bagging plant comprises a Newtec Batipal S1200 palletizer for a bag capacity of 1200 bags and a Lachenmeier T1 stretch-hood system. The automatic bag palletizer (Figure 7) is characterized by reliable operation and layer stacking which ensures an excellent palletising quality. Based on the principle of simple sequential actions, the Batipal allows all required different patterns and bags of

6 Haver & Boecker Adams4 rotary packer

7 Newtec bag palletizer

8 Bagging spout in filling position

9 Bag transfer to the conveying line

various weights and dimensions. The stretch-hood system completes the bagging line. The stretch hood is made from a continuous transparent film which is stretched over the pallet for load integrity. The machine automatically adjusts to the pallet height and allows easy maintenance.

4 Latest PE packing technology

One of the plant's highlights is definitely the PE packing technology. Sunstate Cement recognized from Haver & Boecker's other references in the building material industry the benefits of using PE bags not just for themselves but also for their customers. Retailers and wholesalers can increase their stock level as additional undercover storage is not required, while construction companies can leave their bags outside in the open on work-sites, even under harsh weather conditions. The bags are cleaner, waterproof and tear resistant and emit no dust during handling and transportation.

The FFS technology is fully automated and makes bag applicators for the packer unnecessary. The PE tubular film, from which the bags are formed in the bagging machine, are simply supplied from a reel. The bags are formed from a flat film by welding the side seams and bottom seam and then cutting off the produced bag from the plastic film tube. This allows a very compact bag design, which is perfect for storage and also possible with a handle punch. Gripper units accurately transfer the bags to the filling spouts. During filling procedure external and internal bag vibrating units ensure the required de-aeration and compaction of the dry powder products.

The main advantage of this mechanical vibration system (Figure 8) is its high availability and that in contrast to vacuum systems, this micro vibration does not exhaust any fine particles, which could lead to inhomogeneous products. The filled bags are 100 % closed – sealed with a low maintenance pulse-welding device. The bags are transferred to this device in their upright position (Figure 9). If required, a head seam cleaning and cooling systems can easily be integrated. The modular configuration of the Haver Adams makes it possible to use between one to ten filling modules. The complete machine is fully enclosed, to fulfill all safety standards like "Lototo" and others.

In another option, remote support of the packer is available with a HPS system (Haver Service Pad). The system consisting of a touchpad (Figure 10), an integrated camera and software, enables operators, service technicians and other service staff to communicate directly with the packer via a high-speed internet connection. This allows short response

times, when issues occur and ensures a higher machine availability.

5 Outlook

Sunstate Cement installed a drymix plant concept, which is a state-of-the-art example for other prospective drymix producers around the world. The concept shows, that drymix plants only need a small footprint and can easily be implemented. Drymix producers just need the market know-how and the availability of the raw materials for the drymix products, while the plant can be installed on a turnkey basis, even when sub-sections of the plant such as silos and buildings are existing. The PE bag technology offers even more opportunities to enter markets, because of its many advantages in comparison to conventional bags. Examples prove that some cement producers even completely shift to PE bags.

10 Touchpad for packer

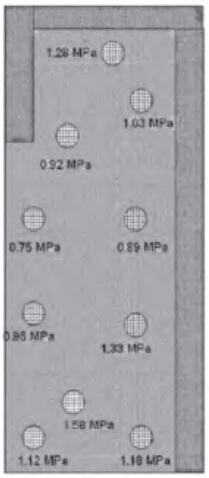
REFERENCES

[1] Rämmele, M.: The cement plant of the future. IBAU's silo of tomorrow – generating perfect flow, evolving into a work of art and providing new functions. ZKG International, 6/2016, pp. 40–47

[2] von Ahn, C.: Advanced Turnkey Dry Mortar Plants. Presentation at AFCM Conference (ASEAN Federation of Cement Manufactures), 21–24 April 2015, Hanoi/Vietnam

EP 3 078 646 A1

Multi-purpose mortar or cement compositions for construction applications



(22) 13.08.2013
(43) 12.10.2016
(57) The present invention relates to a multi-purpose mortar or cement composition for (i) inhibiting the corrosion of steel in mortar or cement structures, (ii) repairing, filling and/or spraying damages, cracks, flaws and cavities in mortar or cement structures and/or (iii) surfacing, coating and/or protecting mortar or concrete surfaces.

The present invention further relates to methods of preparation and use of the multi-purpose mortar or cement composition.
(71) Sika Technology AG, 6340 Baar (CH)
(84) Designated Contracting States: AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR

EP 3 115 346 A1

Cement dispersant, method for preparing same, and mortar concrete

(22) 16.02.2015
(43) 11.01.2016
(57) The present invention relates to a polycarbonic acid-based cement dispersant, a method for preparing the same, and a mortar concrete admixture using the polycarbonic acid-based cement dispersant.

The cement dispersant of the present invention and the mortar concrete admixture using the cement dispersant are applied to a cement composition such as a cement paste, mortar, concrete, etc., enhance a dispersion and retention force between cement molecules, have excellent fluidity due to the suppression of slump loss, and have an effect of improving workability, such as shortening a concrete mixing time by 20 % or more. Further, the mortar concrete admixture using the cement dispersant of the present invention has an effect of providing a very good concrete condition and an appropriate compressive strength over time.
(71) San Nopco Korea Ltd. Pyeongtaek-si, Gyeonggi-do 451-852 (KR)
(84) Designated Contracting States: AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR; Designated Extension States: BA ME

EP3107877 (A1)

Dry mortar, mortar slurry and method for producing semi-rigid coatings

(22) 20.02.2015
(43) 28.12.2016
(57) Summary of corresponding patent W02015124313 (A1): The present invention relates to a dry mortar and a mortar slurry, and a method for producing semi-rigid coatings. In one embodiment, the dry mortar and/or mortar slurry comprises a cement, a very fine component, and a superplasticizer and is free of silica fume, wherein the mortar slurry can be applied at an asphalt framework temperature between 55 and 80 °C, and a compressive strength of at least 100 N/mm² is reached after 28 days. In a further embodiment, the dry mortar and/or mortar slurry additionally contains a gelling agent to reduce the propensity of the mortar slurry to flow out.
(71) HeidelbergCement AG

ZKG PATENT RESEARCH

Dr. Ralf Giskow, Mainz/Germany
Phone: +49 6131 682625
E-Mail: ralf.giskow@aol.com

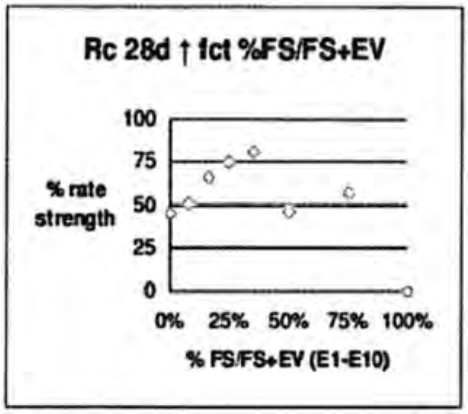
PATENT CODING SCHEME

(22) Date (dates) of application
(43) Date of publication of the patent application
(45) Date of publication of a patent document
(57) Summary or claim
(71) Name applicant(s)
(73) Name(s) of holder
(84) Contracting states named in accordance with regional patent agreement

AU 2016266029 A1

Process for the preparation of cement, mortars, concrete compositions containing a calcium carbonate-based filler containing an organosiliceous material, the said "filler(s) blend" being treated with a superplastifier, cement compositions and cement products obtained, and their applications

(22) 30.11.2016
(43) 22.12.2016
(57) Process for the preparation of cement/mortar/concrete compositions or systems, (for simplicity hereafter „cement" compositions or systems), featuring an improved compressive strength Rc namely at 28 days and 90 days, containing at least a „carbonate-based filler", comprising at least one step where the said at least one „carbonate-based filler" is mixed or blended with at least one aluminosiliceous material, and the obtained „fillers blend" is treated with an efficient treating amount of at least one treating agent consisting of or comprising superplastifier(s); product comprising at least a „carbonate based „filler" „as defined and at least an aluminosiliceous material, what provides a „fillers blend"; cement compositions, use of the said „Fillers(s) blends" and cement composition; cement elements or cement products" obtained from the said „cements compositions", such as construction or building blocks.
(71) Omya International AG



AU 2016250504 A1

Process for the preparation of cement, mortars, concrete compositions containing a calcium carbonate-based filler treated with an ultrafine filler and a superplasticizer, compositions and cement products obtained and their applications

(22) 31.10.2016
(43) 17.11.2016
(57) Process for the preparation of cement/mortar/concrete compositions or systems, (for simplicity hereafter "cement" compositions or systems or even "cements"), of a generally known type containing low or medium (standard) „filler(s)", and/or optionally HP filler(s), as carbonate-based filler(s), namely coarse low or medium calcium carborate(s), namely coarse marble(s); Product comprising, or consisting of, the pre-blend (A) of coarse, low or medium (or optionally HP) „calcium carbonate-based filler" pre-blended with at least an UF; Aqueous compositions (B) obtained by mixing the above pre-blend (A) of coarse filler(s) with UF(s) with an aqueous system such as mix water, aqueous mix fluid; Product (C) consisting of, or comprising, the pre-blend (A) or the compositions (B), treated or pretreated with at least one superplastifier or aqueous system containing superplastifier(s); Cement and use of cement.
(71) Omya International AG

KR20160113882 (A)

Dry mortar composition comprising blast furnace slag

(22) 23.03.2015
(43) 04.10.2016
(57) The present invention relates to a mortar composition, and more particularly, by including the slag debris having a particular specific gravity and the average particle size of the slag processed sand obtained by processing the polishing in a wet state with aggregate, dry exhibits excellent workability and physical properties of the premix type mortar composition will be.
(71) Shin Myeong Top Construction Co., Ltd.; Cho, Sung Kwang

JP2016179912 (A)

Polymer cement composition, polymer cement mortar composition and polymer cement concrete structure

(22) 23.03.2015
(43) 13.10.2016
(57) Problem to be solved: To provide a polymer cement composition capable of providing a polymer cement concrete structure which has excellent balance among on-site work efficiency, initial curability and concrete characteristics after curing, is excellent in heat resistance, water resistance and flame retardancy, and has high strength, and to provided a polymer cement mortar composition, and a polymer cement concrete structure. Solution: The polymer cement composition of the present invention contains a phenolic resin, a curing agent and cement. The phenol resin can be cured at ordinary temperature. The polymer cement mortar composition of the present invention contains the polymer cement composition of the present invention and aggregate. The polymer cement concrete structure of the present invention contains the polymer cement composition of the present invention and/or the polymer cement mortar composition of the present invention.
(71) Sumitomo Bakelite Co Ltd

PL412011 (A1)

Method for producing thermally insulating plaster mortar on the basis of aerogel solutions of inorganic acid salts

(22) 16.04.2016
(43) 24.10.2016
(57) The present application is a method for producing a plaster mortar for thermal insulation and/or sound from a material comprising mineral fibers and cellulose. The method is characterized in that with a mixer, biaxial mixed particulate material comprising mineral fibers and cellulose, the previously prepared airgel structure as a tenth of a 20-hundredfold foamed aqueous solution of inorganic acid salts, preferably sodium silicates and/or potassium and expanded mineral fillers and/or polymer to obtain a foamed insulating plaster mortar, followed by actuation of hydrodynamic devices and/or mechanical or hand threads previously prepared mortar to the place of application.
(71) Majewski Leszek (PL)

TN2015000152 (A1)

White or colored cementitious mixture for manufacture of concrete, mortar and pastes with thermochromatic properties

(22) 20.04.2015
(43) 03.10.2016
(57) The present invention relates to a white or colored cementitious mixture for the manufacture of microconcrete or normal concrete, mortar or pastes with thermochromatic properties, i.e., changing its color depending on the temperature at which the material is exposed. This color change is reversible after some rime of exposure to another level of temperature. This cementitious mixture comprises the following components, in percentage in weight of the components relative to the total weight of the composition: a) 35-80 % of white or gray Portland cement; b) 0.1-30 % of finely ground limestone filler; c) 0.01-3 % of powdered super-plasticizer; d) 0.01-3 % of modified polyvinyl resins; e) 0.01-5 % of dispersant of vinyl acetate and ethylene copolymers; f) 0.3-15 % of encapsulated photochromic copolymers; and also one or more components selected from: g) 1-10 % of binding regulator; h) 0.1-4 % of zinc stearate; i) 1-20 % of metakaolins; j) 5-60 % of artificial pozzolans; k) 0.1-15 % of inorganic pigments.
(71) Secil, S.A., Companhia Geral Decale Cimento (PT)

US 2017/0001910 A1

Hydraulic mortar with glass

(22) 21.04.2014
(43) 05.01.2017
(57) Hydraulic mortar with glass, mainly formed by: Cullet to which is added pure white or gray Portland clinker, gypsum and optionally alumina; extra-fine glass subsequently added to the milled product; and natural crushed stone and natural calcareous or siliceous soil, or a mixture of both, or milled glass as a substitute for the natural, calcareous or siliceous stone fines.
(71) Envirocem, S.L., Madrid (ES)
(73) Envirocem, S.L., Madrid (ES)

US 2016/0304399 A1

Pulverulent mortar composition having improved adhesion

(22) 12.05.2016
(43) 20.10.2016
(57) Pulverulent mortar composition comprising a mineral binder, an inert material in the form of aggregate capable of being agglomerated in aqueous phase by means of said binder, and 0.2 to 1 % of a fluid additive comprising 25 to 100 % of a linear or branched, saturated or unsaturated hydrocarbon compound (i) which is liquid at room temperature and which includes one or more –COO– ester groups, the total weight of which, relative to the molar mass of said compound, is between 20 and 50 %. Use for preparing an adhesive mortar for fixing ceramic tiles.
(71) Bostik S.A., Colombes Cedex (FR)
(73) Bostik S.A., Colombes Cedex (FR)

WO 2016/174009 A1

Use of a composition made from silylated polymers as jointing mortar for a surface coating

(22) 26.04.2016
(43) 03.11.2016
(57) The present invention concerns the use of a joint mortar composition comprising at least one silylated polymer comprising at least one alkoxysilane group, at least one catalyst and at least one filler for producing tile joints or joints between LVT's (Luxurious Vinyl Tiles).
(71) Bostik SA, 253 avenue du President Wilson, 93210 La Plaine Saint-Denis (FR)
(84) ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG)

WO 2016/174009 A1

Addition for producing thermally conductive mortars and structural concrete

(22) 13.05.2016
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(57) The invention relates to an addition for producing thermally conductive mortars and structural concrete, said addition being a specific powdery formulation in each case, which, when added as an addition to a conventional concrete or mortar, allows the production of a structural concrete or mortar with improved thermal characteristics (thermal conductivity X). If the addition is added to a conventional concrete in a plant, a structural concrete with increased thermal conductivities is produced, which can adapt to the thermal requirements of the building, thereby being highly suitable for the heat activation of structures or the geothermal activation of foundations. The concrete containing the addition takes on special rheological characteristics which, inter alia, allows a self-compacting concrete to be produced. If the addition is added to a conventional mortar in a mixer, a mortar is produced with very high thermal conductivities which make it highly suitable for geothermal probes.
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04.04.–06.04.2017 Nuremberg/Germany	European Coatings Show www.european-coatings-show.com
24.04.–28.04.2017 Hanover/Germany	Hannover Messe www.hannovermesse.de
25.04.2017 Leimen/Germany	7th Open Meeting Nanocem Consortium www.nanocem.org
26.04.–27.04.2017 Frankfurt a.M./Germany	Baustoffanlagentag 2017 http://mining.vdma.org
04.05.–10.05.2017 Düsseldorf/Germany	interpack 2017 www.interpack.de
10.05.–11.05.2017 Dortmund/Germany	Schüttgut/Solids Dortmund 2016 www.solids-dortmund.com
10.05.–12.05.2017 Nanjing/China	The 18th China International Cement Industry Exhibition www.cementtech.org
21.05.–26.05.2017 Calgary, Alberta/Canada	59th IEEE-IAS/PCA Cement Industry Technical Conference www.cementconference.org
30.05.–01.06.2017 Prague/Czech Republic	Refra Prague 2017 www.silikaty.cz
06.06.–08.06.2017 Paris/France	"The Future of Cement" Symposium www.infociments.fr
27.06.2017 Mexico City/Mexico	Second Central American Drymix Mortar Meeting www.drymix.info
11.09.–12.09.2017 London/UK	37th Cement & Concrete Science Conference www.ucl.ac.uk/aim/conference-info/37ccs
26.09.–28.09.2017 Nuremberg/Germany	Powtech 2017 www.powtech.de
27.09.–28.09.2017 Munich/Germany	2nd International Conference on Polycarboxylate Superplasticizers (PCE 2017) www.bauchemie.ch.tum.de
10.10.–13.10.2017 Antalya/Turkey	14th TÇMB International Technical Seminar and Exhibition www.tcma.org.tr
14.11.–16.11.2017 Sharm el Sheikh/Egypt	22nd Arab International Cement Conference and Exhibition (AICCE22) www.aucbm.org
23.11.–24.11.2017 Munich/Germany	Euroconstruct www.euroconstruct.org
05.12.–07.12.2017 Havana/Cuba	2nd International Conference on Calcined Clays for Sustainable Concrete www.lc3.ch/conference-2
05.12.–08.12.2017 New Delhi/India	15th NCB International Seminar on Cement and Building Material www.ncbindia.com
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