INDIA SPECIAL

Cement Lime Gypsum

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ISSUE 1
2015

ZKG INTERNATIONAL

Feeding fine grained materials

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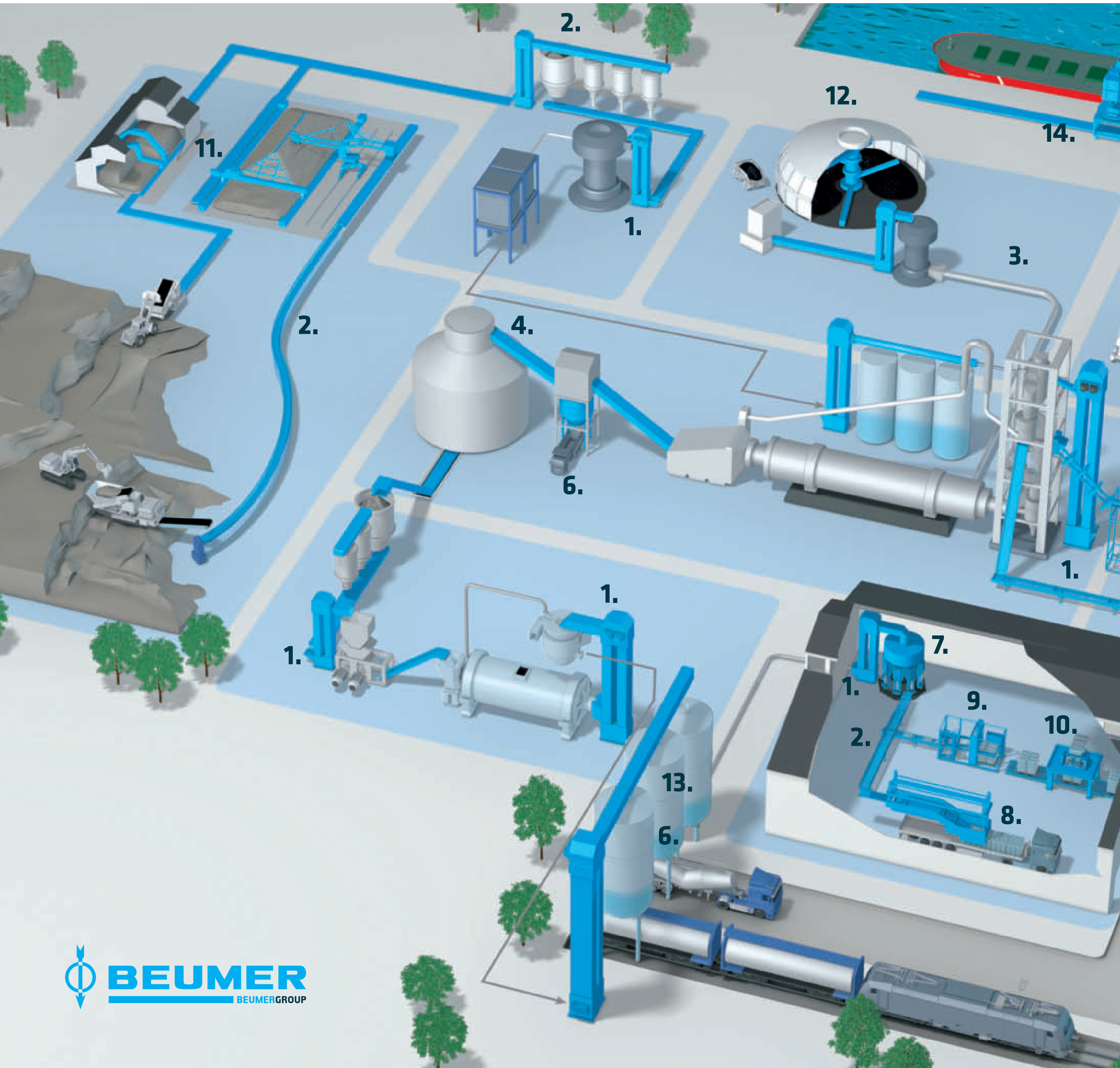
BEUMER: YOUR EXPERT IN CEMENT – FROM QUARRY TO DISPATCH



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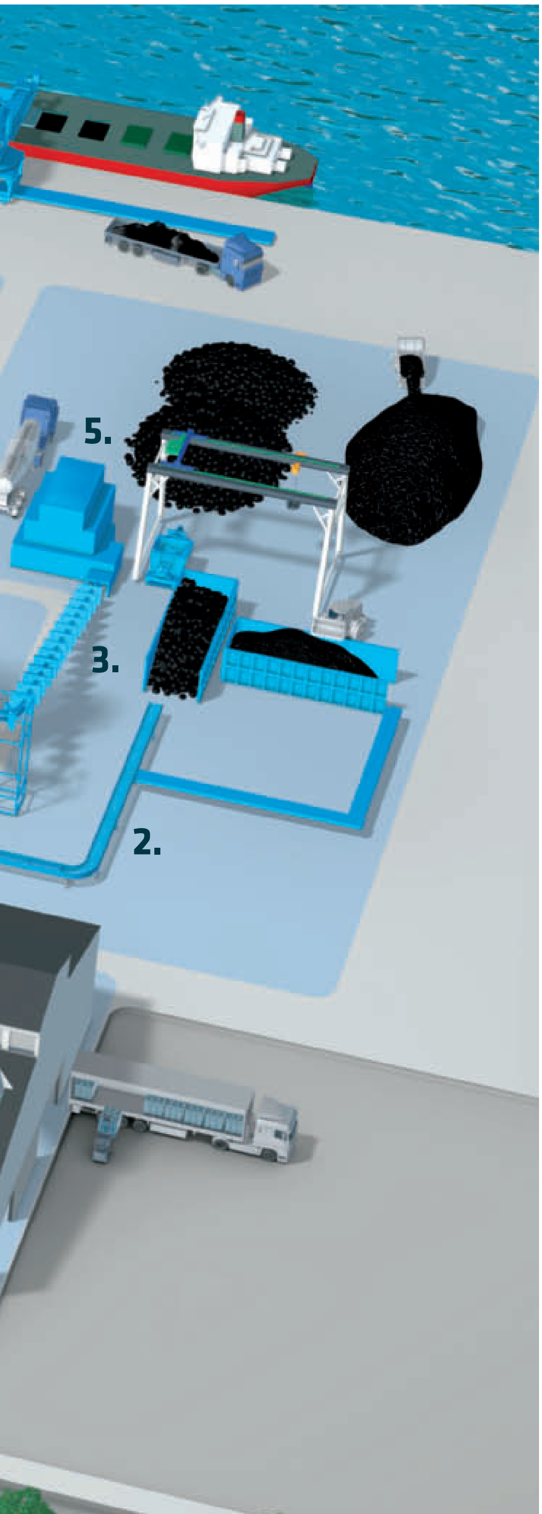

1. BUCKET ELEVATORS

For vertical materials handling, BEUMER Group supplies robust bucket elevators like its heavy duty belt bucket elevator for lump sizes of up to 120 mm and its central chain bucket elevator for hot, abrasive and lumpy bulk material. BEUMER's high-performance belt bucket elevators are conveying bulk material ranging from powder to granular, such as raw meal, cement or gravel to heights of over 200 m, using buckets between 160 and 2,000 mm wide.

2. BEUMER BELT CONVEYOR SYSTEMS

Troughed belt conveyors transport bulk goods quickly across large distances and rough terrain. Large volume flows of heavy and solid materials like limestone and iron ore are transported via these systems.

3. PIPE CONVEYORS

BEUMER pipe conveyors protect sensitive materials, e.g. coal, alternative fuels and cement, against environmental influences during transportation, or conversely, protect the environment against the dust from these substances. Two different materials can be conveyed parallel in upper and lower strand. Flexible conveyor routing is possible due to small curve radii.

4. APRON CONVEYOR

Hot and abrasive materials such as cement clinker can be transported safely and at low cost using the BEUMER Group's heat-resistant apron conveyors, even at an inclination of up to 60°. As traction element either belt or chain are used.

5. ALTERNATIVE FUELS FOR KILN FIRING

BEUMER Group provides special system technology – proven and installed many times – to make use of a wide range of alternative fuels in cement factory kilns.

6. LOADING TECHNOLOGY FOR BULK MATERIALS

BEUMER's loading technology for bulk materials such as cement and clinker makes it possible to load trucks and railway wagons in a way that is safe, clean and environmentally friendly.

7. FILLPAC I/R FILLING TECHNOLOGY

For free-flowing, coarse or fine-grained products, BEUMER fillpac I/R inline and rotary filling machines ensure reliable and efficient bagging.

8. BAG LOADING TECHNOLOGY

Mechanised and partial or fully automatic bag loading machines are a speciality of the BEUMER Group. These enable maximum loading volumes to be combined with careful handling.

9. PALLETISING TECHNOLOGY

BEUMER palletising technology considers both the characteristics of the individual packed materials and the desired packing patterns and pallet sizes. This means that all bags are handled carefully and palletised to best advantage. Also newest palletless packing is possible.

10. STRETCH HOOD PACKAGING TECHNOLOGY

The BEUMER stretch hood® series is a range of modular packaging systems to secure palletised load units using stretch hoods. The perfect use of film tension ensures maximum protection during transportation.

11. BLENDING BED

Stockpiles with blending bed equipment are used for homogenisation and storing of raw materials. Once the stacker has built up the pile so that its cross-section has the largest possible number of layers of identical material, the bridge reclaimer achieves the maximum homogenisation effect when reclaiming material from the front of the pile.

12. COAL STOCKPILES

These are usually fed by a slewing stacker. Reclaiming from the inside slope of the pile can be performed by a portal, semi-portal or lateral reclaimer. Optimum utilisation of stockpile capacity is achieved by simultaneous but independent storing and reclaiming.

13. SILO EXTRACTION TECHNOLOGY

Fluidisation beds enable fine, powdery bulk products to be discharged easily without lump formation. The silo bottom is divided into sectional and symmetrical aerated parts, which ensures a minimum of air and energy to be used. The robust construction ensures an even and optimised material extraction.

14. LOADING SYSTEMS FOR SHIPS

Coarse bulk materials, such as clinker or lumpy ores, are loaded into bulk carriers via BEUMER Group belt conveying systems and a vertical telescopic loading head, efficiently and without dust. Swivelling and telescopic ship loaders ensure filling most of the cargo space without shifting the ship. The loading of powdered goods is handled by fully enclosed loading machines. This, in connection with the required filter systems, reduces the environmental impact to a minimum.

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SPECIAL INDIA
Cement Lime Gypsum

This issues front cover …
… shows rotor weighfeeder Pfister® FRW which was designed for powerful handling of fine grained materials such as raw meal, fly ash, bypass dust or cement products with high dosing constancy and precision. Whether kiln feeding or additive feeding to the raw or finish mill: The robust dosing system integrates material extraction, weighing and dosing and is extremely reliable. FLSmidth Pfister GmbH/Germany is worldwide acknowledged as an expert for engineering and manufacturing of sophisticated continuous weighing- and dosing systems for all stages of cement production.
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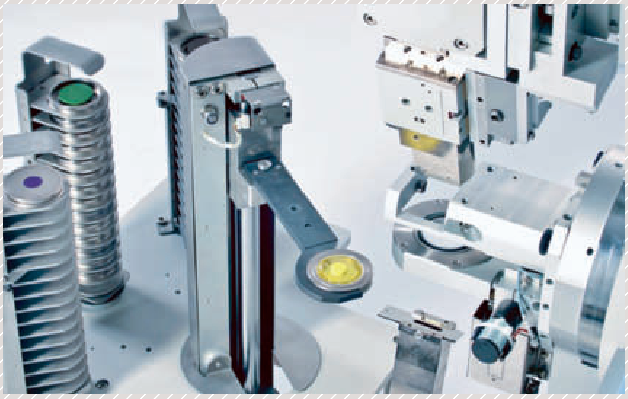
Drive train condition monitoringdeteriorating concrete structures?



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Cement quality control system: application of X-ray diffractometry

BEUMER

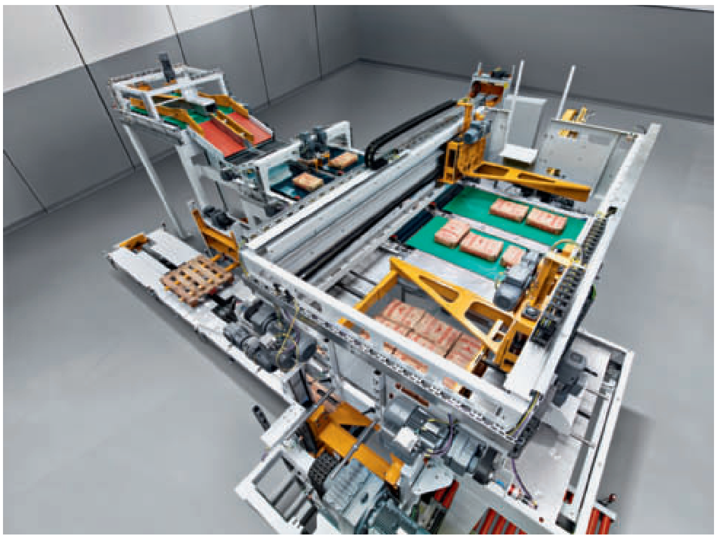
BEUMER offers sustainable systems

Individually tailored and efficient intralogistics solutions

Beumer Group, based in Germany with group companies around the globe, a full-range supplier for customised system solutions that provide increased efficiency in the cement industry. Manageable growth, global market presence and a large range of products in the field of conveying, loading, filling, palletising, packaging technology ensure the long-term success of the company. Beumer Group currently employs about 4100 people worldwide and generated an annual turnover of approximately 680 million Euros in 2014. Beumer offers comprehensive customer support for all products and complete systems. In all developments, the Group focuses on sustainability.

The Beumer portfolio includes curved troughed belt conveyors for fast and cost-efficient transport of large quantities of limestone from the quarry to the plant. Beumer Group develops stackers and bridge scrapers, the essential components of blending beds, which stack bulk material reliably and guarantee a maximum blending effect. As the production of cement is highly energy-consuming Beumer Group offers systems to use so-called AFR (alternative fuel and raw materials) energy sources and has therefore established its new business field AFR systems.

In order to load the finished cement quickly and without dust in bulk transporter vehicles, Beumer offers bulk loading heads and loading systems for trucks, ships and waggons. Thus, the single-source provider is offering equipment and systems for packaging lines from one source: Beumer has expanded its product portfolio with the Beumer fillpac® for filling cement into most different types of bags. The layer palletiser series, Beumer paletpac®, palletises the cement bags allowing the formation of accurate and stable stacks. Additionally, Beumer offers the Beumer stretch hood® for the stretch film packaging of full cement pallets for a safe transportation and outside storing secured against humidity, UV-radiation and dust.



Beumer has equipped the rotating filling machine fillpac® with extensive features

The Beumer paletpac® enables the formation of accurate and stable stacks

The increasing performance requirements of cement producers led to rethink the further developments in drive technology for vertical roller mills. Particularly for larger mill outputs, LOESCHE favours a drive system with multiple motors and gearboxes with milling force decoupling.

In order to meet these demands, LOESCHE will use for future projects with high and medium grinding capacity the COPE gearbox developed in cooperation with Renk, which offers a redundancy of up to 8 motors at the motor end. Only 4 models of the COPE gearbox, equipped with 6 to 8 motors, allow for a classification in a range of capacities from 3 up to 14 MW and thus an application within up to 17 different mill types.

For a constant output speed the COPE drive does not require any variable speed drive for the maintenance-free drive motors and moreover can be operated with a reduced number of motors. This new type of drive concept allows for an operation with for example 7, 6 or simply 4 of the 8 existing motors. Even in operation with only 7 motors, 100% mill output can be attained by activating the design reserves installed. The compact design of COPE gearbox is also of advantage as it does not require any additional modification of the mill foundation.

As this drive train can be put into operation with the common gearbox dimensions, this system can as well be considered for any retrofit at existing Loesche Mills.

For more info contact us:

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Hansaallee 243
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Email: marketing@loesche.de

THE NEW COPE DRIVE IS ON THE MARKET

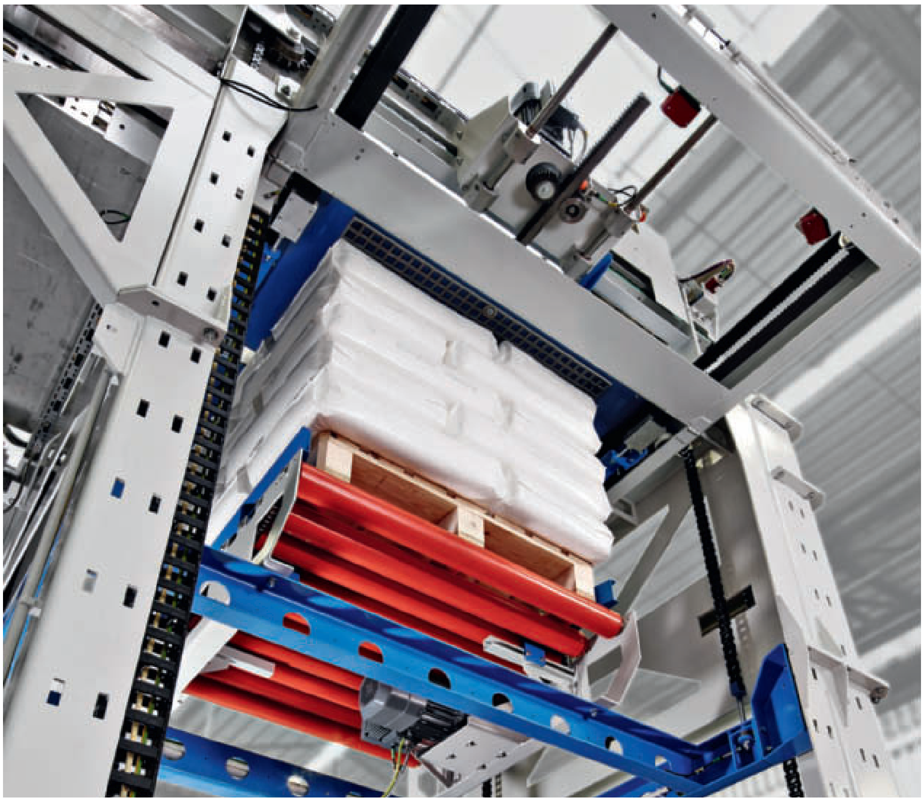
LOESCHE®

All Beumer Group GmbH & Co. KG

1 The Beumer Group has incorporated the fillpac rotary filling machine in its product portfolio, and has equipped it with extensive features

BEUMER GROUP

Warehouse management systems as part of system competence



2 The Beumer paletpac produces stable, precisely dimensioned and therefore space-saving stacks of bags

The Beumer Group rigorously gears the development of its equipment and systems towards providing customers with single-source, sustainable solutions for all their applications. To control, coordinate and visually represent these processes, the specialist company from Beckum, Germany includes warehouse management systems (WMS) in its range of products. Beumer tailors these system solutions to the individual requirements of customers.

For companies in widely differing industries, such as the building materials industry, the subject of safety during the transportation and storage of products stacked on pallets is becoming increasingly important. Products have to be reliably filled, palletized and securely packaged to ensure undamaged delivery to customers. As an intra-logistics specialist, Beumer has expanded its product portfolio to include the Beumer fillpac filling machine, thus becoming a full-range supplier of equipment and systems for complete packaging lines. The fillpac can be flexibly integrated into existing packaging lines, ensuring optimal adaptation of the machine to the situation at the customer's plant.

For palletizing systems, Beumer provides a graded and comprehensive range of high performance layering palletizers. These produce secure loading units. The geometric accuracy and stability of the palletized stacks allow easy storage and ensure safe transportation to the downstream packaging line. These units and systems, together with the conveyors that are also included in the Beumer range of products, are carefully matched and achieve extremely long service lives. They are perfectly adapted to the customer's requirements, such as machine capacities, production output rates or storage area.

To control all these processes reliably and efficiently, Beumer additionally provides Warehouse Management Systems (WMS), which can also be tailored to the individual needs of users. It is a web server application enabling optimal control and coordination of the entire packaging process, as well as product storage and shipping preparation. The material flow control, warehouse management and the interface to the higher-level ERP system of the customer are all integrated into the Beumer WMS. All the data from the packaging line, labelling, storage, and shipment are brought together here. This ensures full and complete transparency of all products and processes throughout manufacturing.

Everybody involved in the production process – from materials require-

3 The WMS controls and coordinates such manufacturing and storage processes as bag-filling, palletizing and load securing

4 The Beumer WMS efficiently controls the complete packing line

ments planners to warehouse employees or forklift drivers – can access the system. The system's functionality and graphical user interface can be configured to suit the customer's specific needs. Overall, the Beumer WMS ensures that processes are cost-effective, makes the flow of goods more transparent and shortens the delivery times.

When the ERP system receives a picking order, it sends the information to a distributed control system and to the WMS. The distributed control system monitors and controls the flow of material from the silo, controls the product quantities, the bagging, the palletizing and the load securing. The packaged unit loads are then provided with a barcode. The WMS performs these functions in constant data interchange with the ERP system.

When the loading units are delivered by the conveyor, the palletising system stacks the boxes, bags or trays safely and space-savingly on pallets. These pallets are then transported on roller conveyors to the Beumer stretch hood high-performance packaging machine. The hood stretching unit wraps the loaded pallets in special transparent foil. This extremely sturdy and weather-resistant packaging ensures the safety of the goods during storage and shipment. The packages are finally provided with a barcode.

The WMS additionally includes a forklift control system. This system ensures that the palletized and packaged goods are loaded for despatch without long interim storage. The WMS also checks whether the pallet is available for pickup at the belt conveyor, reads the barcode, assigns the pallet to a storage space and controls the respective forklift truck. These functions are also performed by the Beumer WMS in constant communication with the ERP system.

Thus, the WMS avoids errors that can occur between production, storage and shipping and time-consuming searches are prevented. The time definition of all processes enables automatic material reservation and delivery in a time- and need-oriented manner. The controlled storage and supply process also makes production significantly faster and more efficient.

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FLSMIDTH/MANIKGARH CEMENT

New pyro system and cement mills for Manikgarh Cement

TEXT **Razal Ali,** Project Manager, FLSmidth, Kopenhagen/Denmark

Manikgarh Cement Limited, owned by India's BK Birla Group of Companies, has successfully commissioned a three million t/a cement plant. The cement producer first announced its plans to build a brownfield integrated cement plant in 2010. Located in Gadchandur, a town in the Chandrapur District in the State of Maharashtra, Manikgarh Cement (Fig. 1) is a division of Century Textiles & Industries Ltd., owned by the BK Birla Group, which operates within a variety of industries, including textiles, rayon, chemicals, paper & pulp, and cement.

Following a lengthy series of technical and commercial negotiations, during which many different solutions were weighed up, Manikgarh Cement awarded the contract for supply of pyro processing system and cement mills to FLSmidth. The project kicked off immediately after the signing of the contracts for both projects in May 2010.

The scope of the 8000 t/d pyro processing system (Fig. 2, 3) includes the design, engineering, manufacture and supply of the complete array of equipment to build up a modern pyro processing system. It features a CF silo for homogenising and storing raw meal with a capacity of 24000 t and bulk density of 0.9 t/m³. With a six-stage twin string Inline Calciner (ILC), its preheater was designed to optimise fuel and power consumption and minimise emissions. The rotary kiln was lit up on 17.08.2014 and was soon producing the desired clinker output of 8000 t/d.

Scope of supply – pyro process:
» CF silo – 22.4 m in diameter, 55 m in height
» Kiln feed system
» ILC preheater – 8 m in diameter, 160 m in height
» 3-base rotary kiln – 5.5 m in diameter, 87 m in length
» SF Cross Bar® 5 x 7 F clinker cooler, with heavy-duty roller breaker MF 418
» Coal dozing and firing system
» Clinker transport to storage

1 The Manikgarh Cement plant at Gadchandur, Maharashtra/India

All FLSmidth

2 The preheater tower with the new silo

The cement mill contract included the complete design, engineering, manufacturing and supply of equipment. The UMS ball mills supplied as part of the contract grind at the rate of 150 t/h. All three mills have been commissioned and are currently running at the expected production rate, while performance guarantee tests are currently in progress.

Scope of supply – Cement grinding:

- UMS Ball mill – 4.6 m in diameter, 15.5 m in length
- Dynamic separator Sepax 500 M-22

Razal Ali, Project Manager, was responsible for the project delivery from FLSmidth. He is very pleased that the project ran smoothly, saying, “There was no delay in deliveries, which is one of the most essential aspects of completing a project on time and at the expected level of perfection.” He adds that the cooperation between FLSmidth and Manikgarh’s cement execution teams was highly efficient.

3 Preheater tower and rotary kiln in closer view

Filter bag house of a Korean cement plant

Reliable dedusting with fabric filters makes a significant contribution to improve the environmental conditions. Today, the industrial dust has a significant importance. Modern technologies for efficient dust removal are a hot topic due to environmental pollution, climate change, increasing energy consumption and the conservation of resources of non-renewable raw materials.

TEXT **Thomas Carius, Jürgen Lauer, Sabine Kreiser**, BWF Envirotec, Offingen/Germany

BWF ENVIROTEC

Reduced emissions by optimizing the efficiency of filter bags

1 Introduction

It is a fact that with NESHAP, the new environmental rules, life will be changing for almost all cement plant operators in the USA and perhaps also around the world. Environmental compliance issues may become tougher to achieve. As a first step this may also be an opportunity to look at fixing what you have instead of immediately planning on replacing the dust control units with more expensive equipment.

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1-7 BWF Envirotec

1 Measuring probes inserted into filter bags

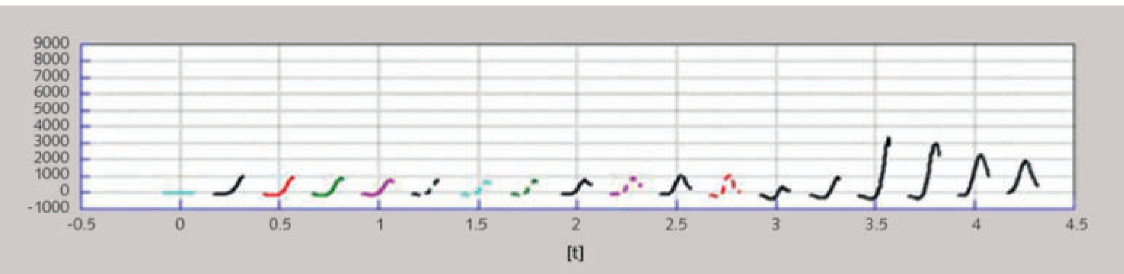
One way of improving existing dust control units is to operate the cement kiln and all associated equipment with optimized parameters – making the kiln dust control units function better in all aspects of their operation.

2 The importance of proper cleaning

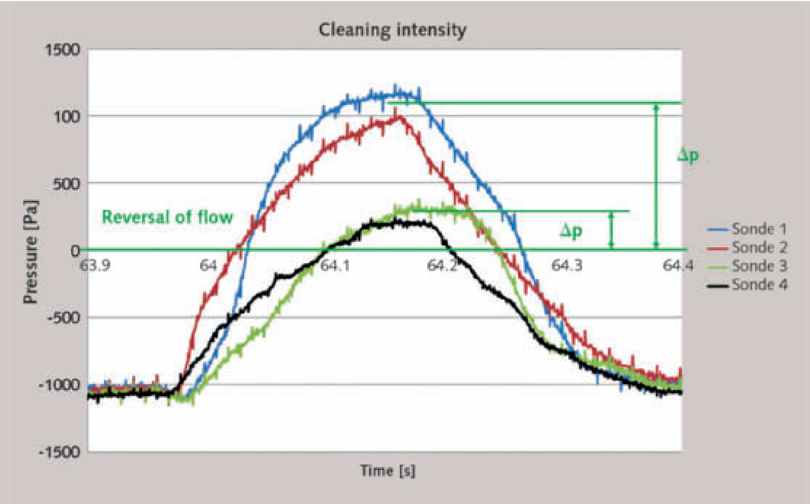
Cleaning the fabric filter bags in a pulse-jet baghouse is a dust control function that does not occupy highest priority in the cement manufacturing process. Dust control units will not produce any cement clinker and therefore these issues are shifted to an area of lower management focus. However, sometimes these minor details have a significant effect on the overall performance of the entire cement clinker production line. Optimizing cleaning of the filter bags in dust control units for example will make kilns run smoother, provide potential for optimized production at lower cost and reduce emissions.

3 Performance upgrading

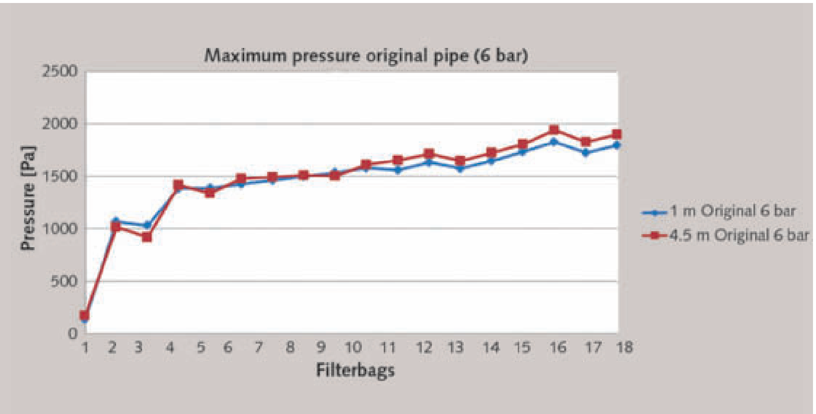
BWF Envirotec has been highly active in providing a new service that detects the current performance of the pulse-jet dust control system. Using CFD (Computational Fluid Dynamics) technology and pressure/flow analysis, the efficiency of filter bag cleaning is being measured off-line and on-line. Probes that work based on the Prandtl principle are inserted into the filter bags (Fig. 1) measuring the actual cleaning pressure and gas velocity. Offline measurements will detect the distribution of the cleaning air (Fig. 2). Online measurements will detect whether the cleaning pressure and velocity are sufficient for bag cleaning by overcoming the operational process pressure.



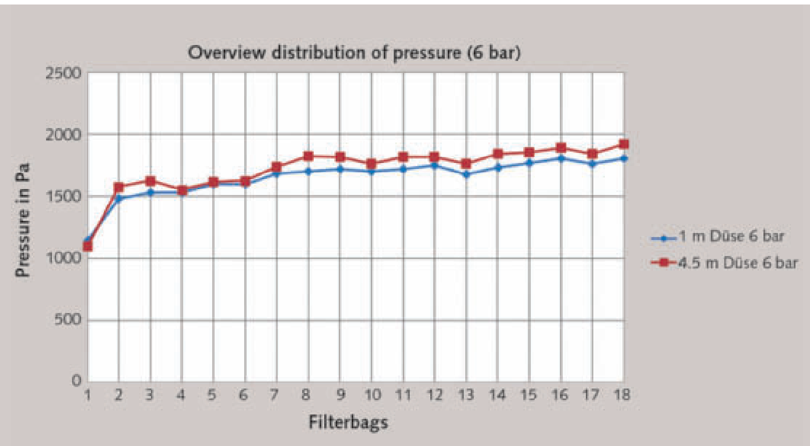
2 Example of uneven distribution of cleaning air (CFD model)



3 Example of cleaning air intensity, showing the measured values of max. pressure within filter bag during operation



4 Measured values of original cleaning device



5 Measured values after modification

By means of its analytical approach, the measured values can be recorded with sampling rates of up to 2000 Hz. Even the smallest changes in the filter system can be reliably detected and detailed information is provided about the condition of the filter medium and the pulse-jet dust control unit.

Figure 3 shows an example of four bags being measured simultaneously on-line. Only two of the bags receive sufficient cleaning air. For the other two bags (black and green color in the graph) the cleaning air pressure just overcomes the process pressure, but is not enough to remove all the dust from the filter bags.

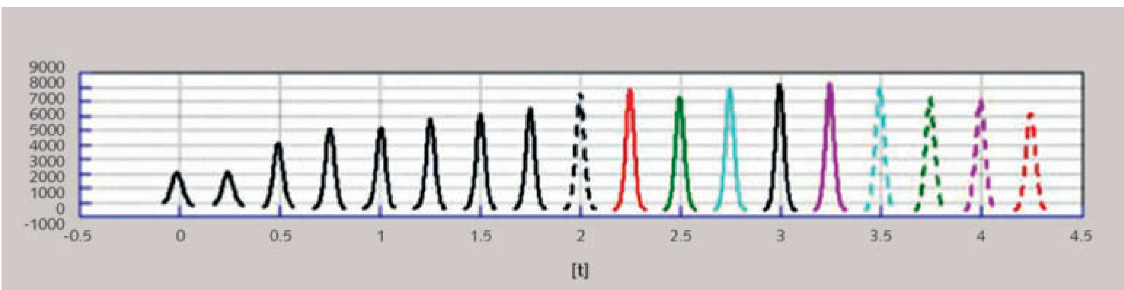
4 CFD in practice

Based on this analysis of the CFD analysis results, the operator will be offered physical modifications that help to make bag cleaning more effective. This CFD analysis and modifications were performed at a large number of European plants. In Figure 2 and Figures 4-6 the comparison of the cleaning air distribution before and after the modifications is visible. As can be seen, the distribution of the cleaning air in its original configuration is very poor.

A significant improvement is observed after implementation of the modifications. Those modifications are site specific. However, depending on the results of the CFD analysis, the blow pipe may become the focal point. The design of the holes will be altered in such a way that the cleaning air is being directed into the center of the venturi as well as the quantity of air for each bag will be the same. After those modifications have been made and with an extended operating period a reduction in cleaning pressure may be possible. Post probe measurements are recommended to assist in each step of the improvements.

5 Improvement in bag service life

Although different from one plant to another, improvements in bag cleaning may often amount to more than 20 %. In most cases, this would enable operators to reduce cleaning pressure, which will increase bag life. Maintaining the integrity of the filter bag over a longer period of time will subsequently reduce emissions. This may be sufficient in order to comply with the new NESHAP rules in the USA.



6 CFD model after modifications

CEMENTABILITY

SICEMENT – Reliability that enables you to reach the top

Companies in the global cement industry are facing major challenges: If they are to improve productivity while simultaneously decreasing costs, they need high-performance products that are also energy-efficient and offer maximum availability and flexibility. These products also need to comply with environmental regulations while providing maximum safety for employees, machines, and material.

In order to tackle all these competing challenges, we have developed SICEMENT – the world's most comprehensive range of products and solutions for the cement industry. Tap into the potential of modern cement production – while maintaining maximum reliability. SICEMENT Drives are best example for Siemens Integrated Drive Systems.

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This question might be best answered by means of an example of two reinforced concrete pre-heater towers, one is located in Europe and the other one in Asia. These cases may at first seem to be special however similarities to plants wordwide can be found and may be of interest for many cement producers. This article will share the experience of Scherr + Klimke AG gained through the inspections of main production buildings of several cement plants from the structural point of view such as crusher and mill buildings, pre-heater towers, silos, kiln supports, cooler buildings, packing plants etc.

TEXT **Dr.-Ing. Tarek Nasr**, Consultant Engineer, Scherr+Klimke AG, Neu-Ulm/Germany

SCHERR+KLIMKE AG

Does it make sense to think about extending the design lifetime of deteriorating concrete structures?

1 Presentation of the subject

In general reinforced concrete production buildings should have a design lifetime of 50 years. This means with regular maintenance the construction should sustain its structural integrity throughout this period without showing severe deterioration. However, in cement plants with heavy duty operation and frequent times changing of equipment loading during the years, the buildings suffer greatly and often show serious damages by the end of their design lifetime. This can be observed in many plants built in the 1960s and -70s (Fig. 1 and Fig. 2). The owner often sees no way other than to demolish these buildings which will lead to high

ZKG

investment costs – not to forget the severe consequences of operational interruption. To avoid demolition of constructions and reduce the risk of operation stop, professional repair, strengthening and/or monitoring is a good option.

In order to achieve the design lifetime of any building, regular maintenance has to be performed similar to the maintenance of the equipment. The regular maintenance can normally be performed by the owner himself as long as the measures to be taken are not of structural relevance such as removing excess dust accumulation, cleaning of drainage, repair of minor cracks etc.

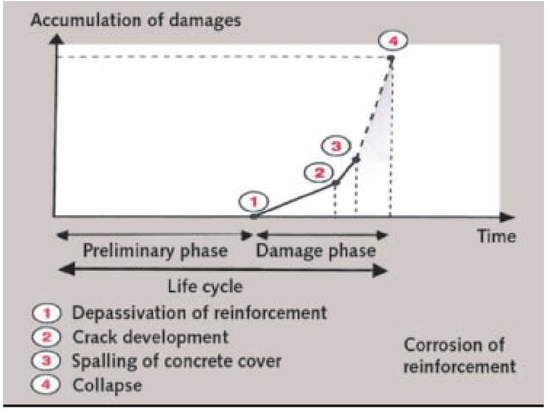
Figure 3 shows the time-depending process of cumulative deterioration of reinforced concrete structures due to corrosion of reinforcement. At the beginning the reinforcement is protected due to the chemical reaction of the cement resp. concrete hardening:

» Phase 0 – 1 Preliminary phase, no carbonization contamination.
  After several years of operation minor cracks develop and the "natural" protection of reinforcement vanishes:
» Phase 1 – 2 Depassivation of reinforcement, carbonization contamination and rusting of reinforcement is most likely present.
  Then cracks become larger and increase in width due to rusting of reinforcement and spalling of concrete will be the consequence:
» Phase 2 – 3 Crack development and spalling, structurally critical stage, repair is inevitable.

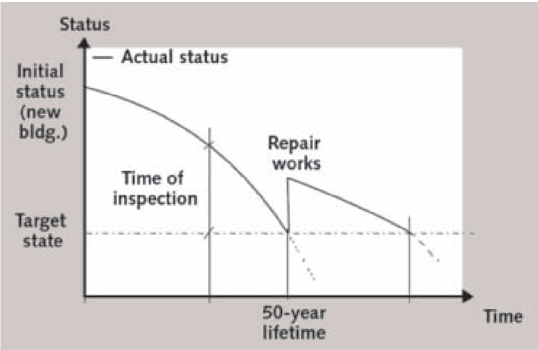
1-19 Scherr + Klimke

1 Preheater tower in Europe

2 Preheater tower in Asia



3 Accumulation of damage to an RC-structure



4 Comparison between present status of a building with its target state

Finally the damage exceeds the structural stability status resulting in a collapse of the structure:

» Phase 3 – 4.
Considering these facts it is strongly recommended to consult an expert in Phase 1 – 2 at the latest in Phase 2 – 3, when spalling of the concrete cover occurs. It should be here underlined that spalling of the concrete cover is not only a matter of structural stability but reflects a safety issue for the workers at the plant as well. Roughly it can be stated that repair work starting from Pt. 2 is structurally required and needs a repair design provided by an expert.

A comparison between the present state of a construction with the target state is shown in Figure 4. It is clearly seen that at the latest overall repair work has to be performed by the end of the design lifetime of the construction. However, if regular maintenance of the structures is performed over the years, the scope and therefore the investment of time and money for overall repair work will be generally much less than in the case where regular maintenance was not undertaken.

The following pictures given in Figure 5 show randomly some typical damages in cement plants during site inspections done by the author over the years. It was noticed during site inspections done, that the most common issues causing damage to the concrete structure are as follows:

1. Drainage of the roofs not functioning well
2. Columns are not protected against impact
3. Dust accumulation → additional heavy load on structural elements
4. Spalling of the concrete cover leads to deterioration of the reinforcement bars
5. Drainage system especially for underground buildings is insufficient
6. Humidity behind technical installations such as cables, tranches, pipes ... etc.
7. Insufficient concrete cover

On the other hand the expert for repair and structural engineering must be aware that the design codes and standards developed over the years. Hence the repair design of 40 to 50 years old structures cannot be performed in a straight forward matter. Special thoughts must be considered and discussed with the owner in order to take the right decisions. For example if the repair design should follow Eurocode the following issues should be taken into account. The existing damaged structures were mostly designed according to local standards 40 to 50 years ago. At that time the safety of a concrete construction was defined by only one global safety factor for the material resistance (R). The design was relatively simple based on deterministic values and should fulfill the following condition:

$R/E > S.F. > 1.0$
Where:
R = Resistance of material
E = Actions and loads
S.F. = Global safety factor

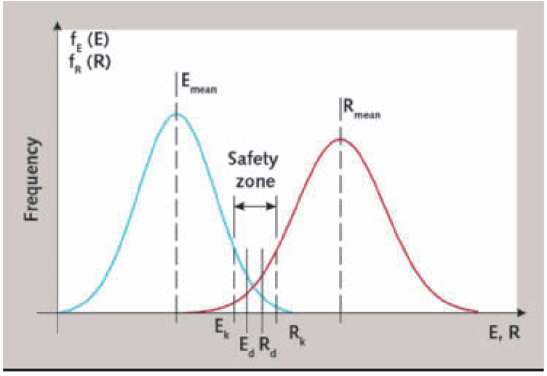
Hence the safety reserves in safety factor for each reinforced concrete structural element could be easily determined in such a way by comparing the required to the as-built reinforcement, i.e.:

As-built reinforcement > required reinforcement

The present safety concept according to Eurocode is based on a semi-probabilistic theory. The relevant parameters are evaluated based on statistical evaluation for the material resistance (R) as well as the actions (E). The 'safety factor' becomes a variable safety zone as given in Figure 6. Even the load assumptions (actions, such as wind, earthquake, snow ... etc.) have been changed since imposing the Eurocode.

Therefore a comparison between the concepts of the former standard of as-built structures years ago with the present Eurocode is not really possible or reasonable. The main differences to be considered between former design standards and present codes such as Eurocode are: load and actions, material properties, design philosophy and approach.

5 Typical damage detected by the author during site inspections over the years



6 Eucrocode design concept

7 Preheater tower in Europe prior to repair

2 Project preparation, site assessment and repair

Before starting the repair works of structural relevance a repair design must be prepared. In order to prepare the repair design several investigations should be carried out as follows:

2.1 Preliminary investigation

2.1.1 Gathering and review of the main structural key data and existing overview drawings of the building of interest prior to the field trip → as-built data is often missing (calc. note, reinforcement drawing ... etc.).

2.1.2 Prepare a scheme for site assessment

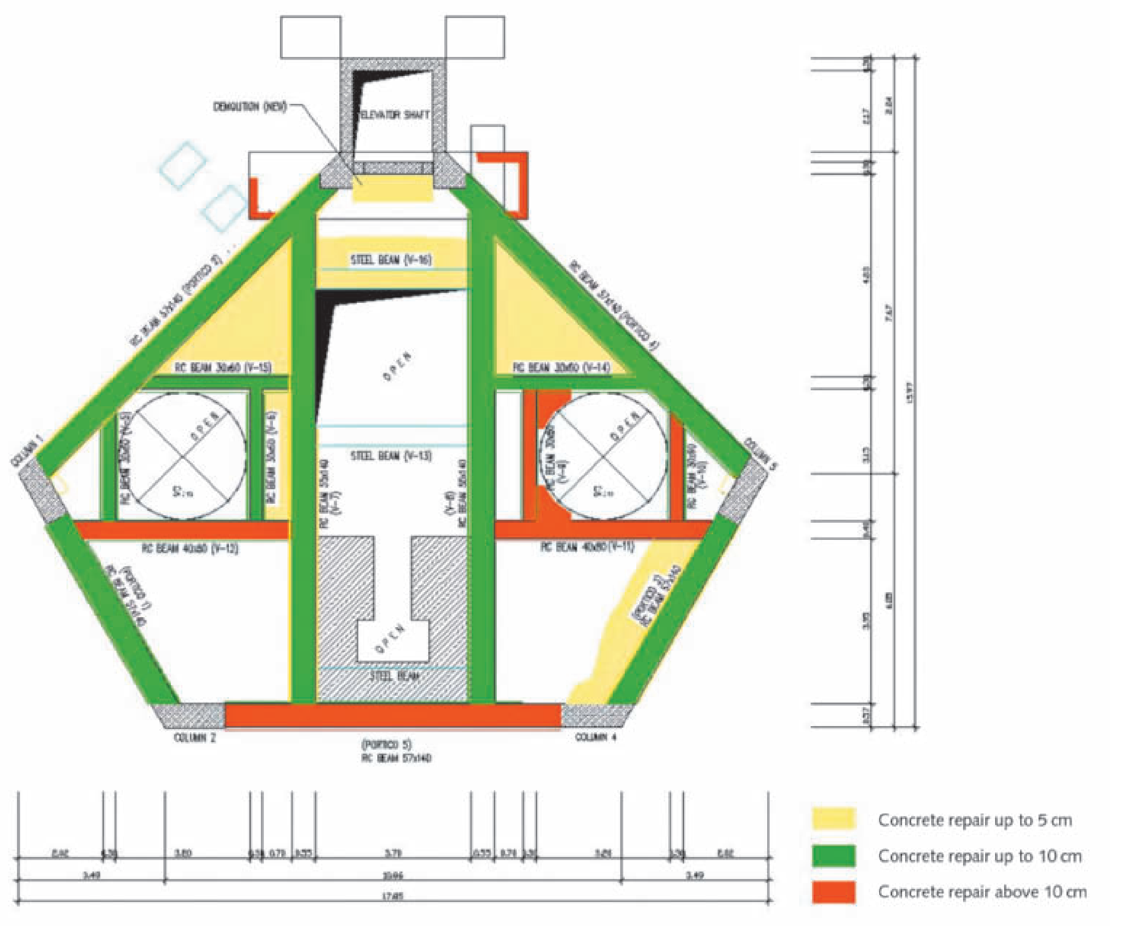
2.1.3 Preliminary inspection on site

2.2 Main investigation

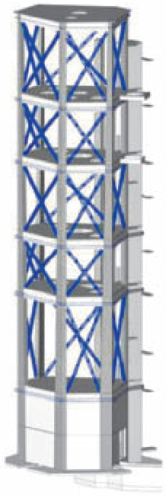
2.2.1 Detailed visual inspection on site incl. photo documentation. If necessary breaking open the concrete up to the main reinforcement to detect the status of reinforcement bars

2.2.2 Preparing a plan for sampling and taking samples by local laboratory (Core testing (f_c), Chloride testing (Cl^-), carbonation testing (CO_2), pull-off testing (T) ... etc.)

2.2.3 Review the utilization of structurally relevant elements by means of the existing calculation notes and reinforcement drawings. If reinforcement drawings are not available, then as-built reinforcement shall be assessed by professional scanning



8 Extract of repair concept for preheater showing the areas to be repaired with respect to demolition depths



9 Strengthening measures of preheater tower

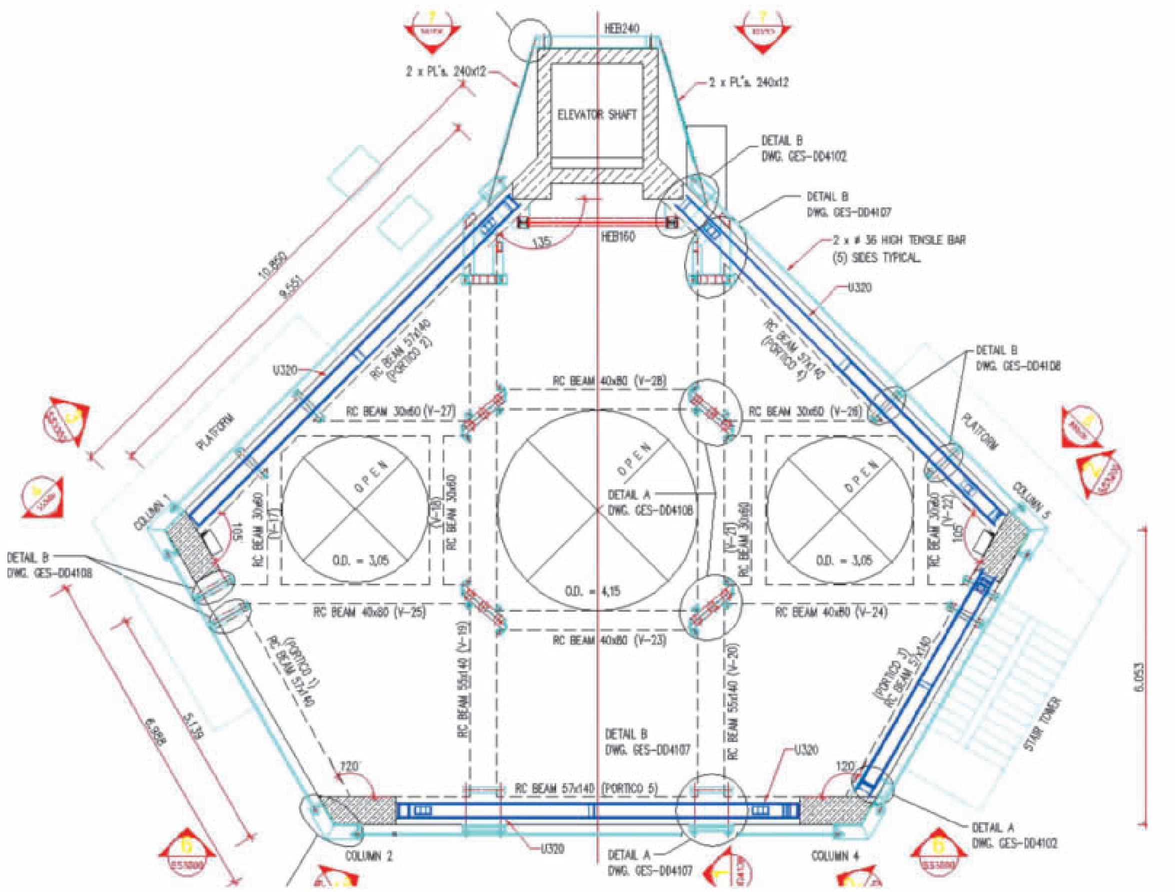
10 Additional structural steel cross-bracings

(e.g. by ferro scan)
2.2.4 Categorizing the structures into risk classes, e.g.:
Extreme risk → cordon off area, immediate action by stabilizing the main structural elements, repair within the following months
High risk → repair within 1 year
Medium risk → repair within 3 years
Low risk → repair within 10 years
2.2.5 Preparing of the inspection report and presenting the outcome to the owner
2.2.6 Discuss with the owner possible options in terms of operation needs, available time and budget

2.3 Repair and strengthening

2.3.1 Repair and strengthening design
2.3.2 Tendering and awarding
2.3.3 Repair and strengthening works, site supervision
2.3.4 Option: Install monitoring systems

One of the main handicaps for repair design is the missing as-built documents such as calculation note, formwork and reinforcement drawings, design criteria ... etc. Without having information about the existing structure it is very hard to develop a reliable repair design especially if strengthening of structural elements is the essential.



11 Post tensioning of main ring beams, plan view

12 Anchor for post tensioning of main ring beams

Furthermore the real status of structure and its degree of damage can only be determined during repair works when the concrete cover is removed and the reinforcement is exposed. Not till then can the real degree of rust be determined. This means the repair design is always an estimate and consequentially the cost estimate and time schedule for repair works as well. Unforeseen hidden damage cannot be excluded prior to proceeding with the repair work. Therefore professional site supervision and regular communication with the repair expert designer is inevitable.

3 Repair and strengthening of two preheater towers

As examples of the repair two reinforced concrete preheater towers of similar ages will be presented.

3.1 Preheater tower in Europe

Figure 7 shows the preheater tower prior to the repair and strengthening work. The preheater tower is located near a coastal area and therefore chloride contamination was expected. During the site investigation serious damage was detected although the construction was continuously repaired over the years. However the repair method used did not show good results, so that spalling of repaired material after a few years could not be avoided. A structural analysis was then performed based on Eurocode and local wind load conditions. The outcome of the analysis clarified that the preheater tower was underdesigned against wind action. Therefore minor cracks developed surely to wider ones over the years due to excess swaying of the tower.

Hence a repair concept was developed taking the strengthening measures into account (Fig. 8). The following strengthening measures were taken to reduce horizontal deformation of the structure (Fig. 9):

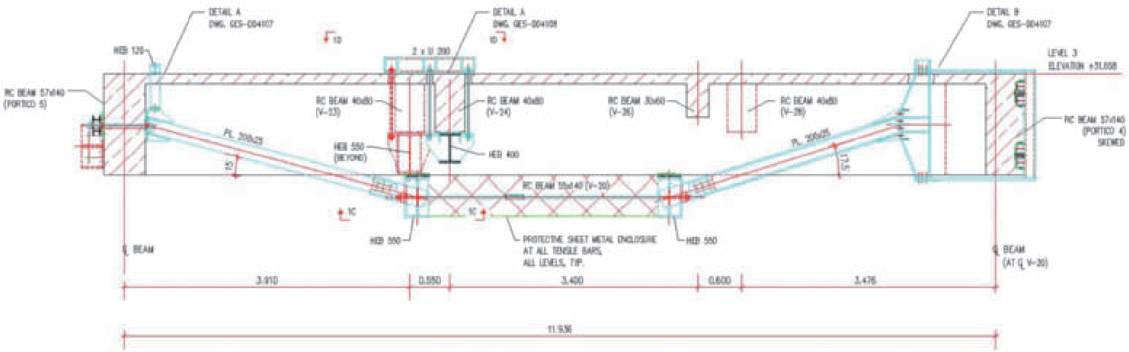
- RC shear walls
- Cross-bracings
- Removal of the top level
- Post tensioning of beams

The additional reinforced concrete shear walls and structural steel cross-bracings (Fig. 10) are installed mainly to reduce the horizontal deformation of the preheater tower. The removal of top level was done to reduce wind action and repair costs. The main purpose of post tensioning of the main ring beams was to increase the general stability of the preheater tower (Fig. 11 and Fig. 12). However post tensioning of secondary beams was necessary to increase local stability of the beams by increasing their carrying capacity toward vertical loads (Fig. 13 and Fig. 14).

Due to optimized and collegial cooperation between owner, designer and contractor the repair and strengthening works were completed on time on the exact day as planned. The following day the kiln started operating as desired. Finally the repaired and strengthened preheater tower is shown in Figure 15.

3.2 Preheater tower in Asia

The preheater tower in Asia had similar boundaries as the one in Europe. The structure is located near a coastal area and therefore chloride contamination was expected. Figure 2 (on 2nd page) shows the preheater tower (twin towers) prior repair and strengthening works. Regular repair work was performed over the life cycle of the structure. The lifetime of the building was reached although some of the equipment changed and new load cases were planned. Hence a repair and strengthening of the preheater tower was essential. Furthermore, during the site assessment various more damage was detected.



13 Post tensioning of secondary beams, sectional view

14 **Anchor for post tensioning of secondary beams**

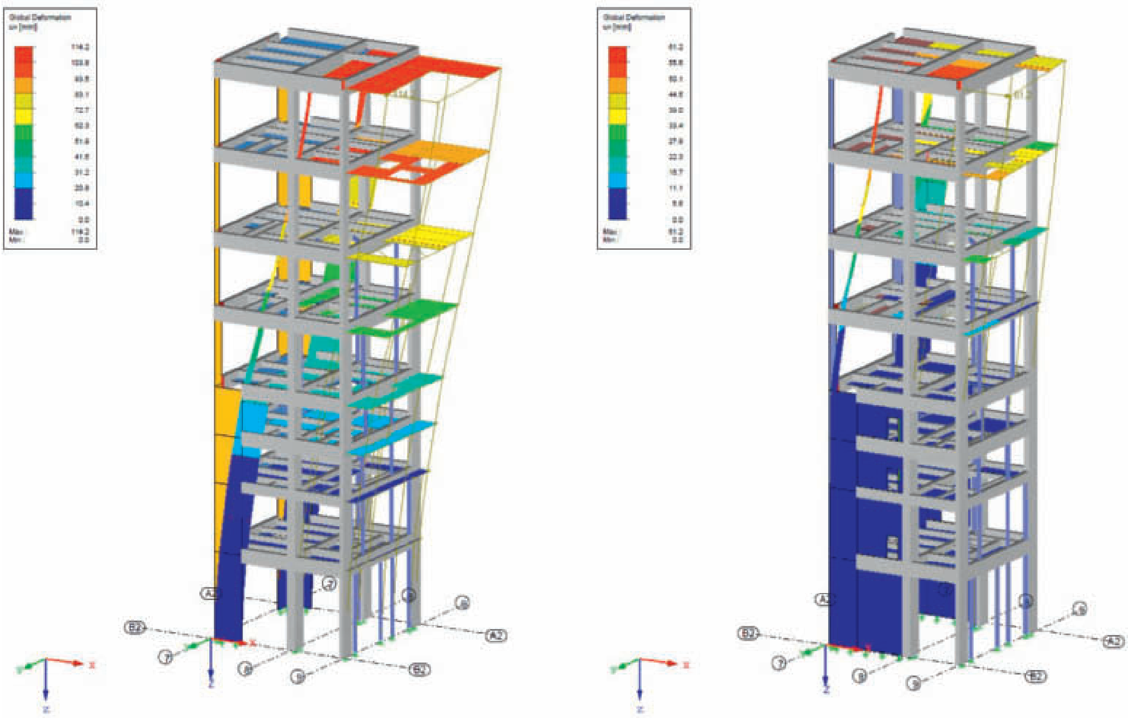
A structural analysis was then performed based on Eurocode and local wind load conditions. The outcome of the analysis clarified that due to wind action the horizontal displacement is above allowable limits (**Fig. 16**). Therefore minor cracks developed surely to wider ones over the years due to excess swaying of the tower. Hence a customized repair concept was developed taking the following strengthening measures into account (**Fig. 17**) to reduce horizontal deformation:

» Install RC shear walls
» Install structural steel beams

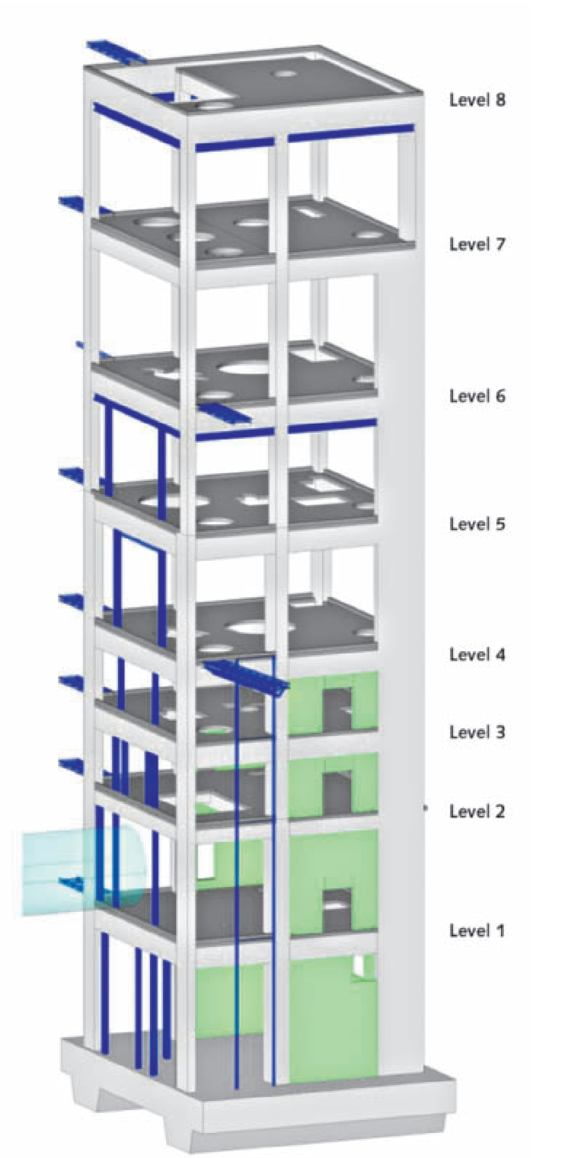
The reinforced concrete shear walls are installed mainly to reduce horizontal deformation and increase global stability. Structural steel beams were installed underneath the main concrete beams to increase local stability and increase their carrying capacity towards vertical loads.

Also in this case due to optimized and collegial cooperation between owner, designer and contractor the repair and strengthening works were completed on time. Finally the repaired and strengthened preheater tower is shown in **Figure 18**.

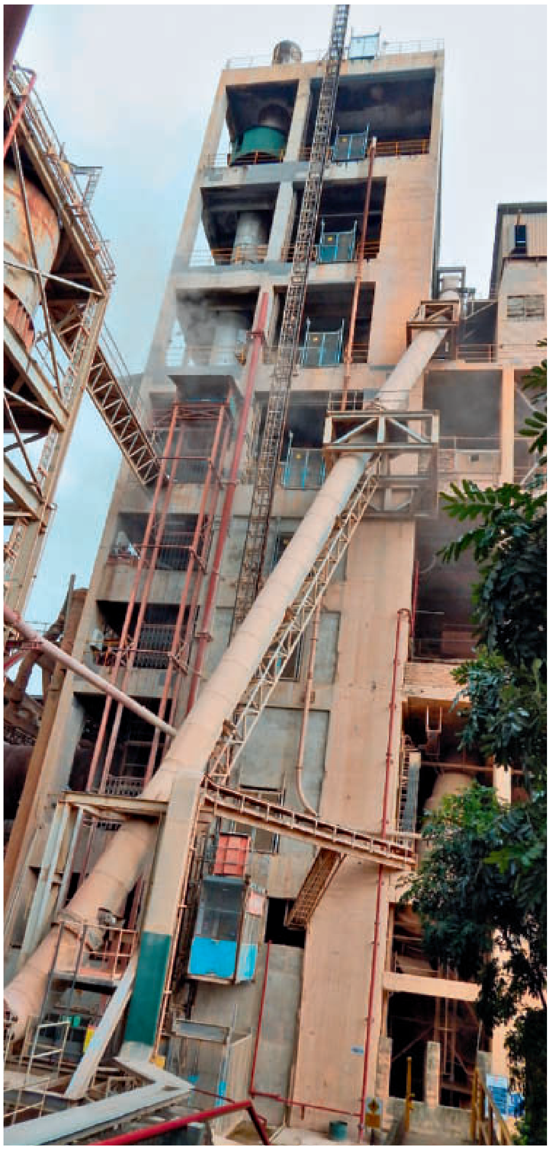
15 **Repaired and strengthened preheater tower**



16 **Deformation of preheater tower under wind action (left: without strengthening, right: with strengthening)**



17 Stengthening of preheater tower, RC shear walls (green) and SS beams (blue)



18 Repaired and strengthened preheater tower

4 Summary and conclusion

In order to achieve a 50-year lifetime of concrete structures regular maintenance must be performed in a professional manner. In case the structure shows wider cracks and spalling of the concrete cover resp. excess deflection, experts are to be consulted.

To avoid demolition of constructions and reduce the risk of operation stop, professional repair, strengthening and/or monitoring is surely a good option.

One of the main difficulties and challenges is to gather information about the existing status of structures of interest. The as-built documentation such as calculation note, equipment load and structural drawings are very important to have for requirements of repair and strengthening projects. The owner should always be keen on having and archiving the as-built documents.

Unforeseen situations and uncertainties will most likely arise during a repair project as hidden damage can only be detected during repair work. A 100 % planning of all kinds of scenarios in advance can hardly be accomplished. Professional site supervision is therefore a must.

Hence to achieve the best results for repair projects, owner, designer and contractor must work in a collegial in manner as one team.

Acknowledgments

At this point we would like to thank our clients for giving us the opportunity to show our ability in developing special solutions for sophisticated and challenging projects. Further special thanks go to following employees of Scherr+Klimke AG. Mostly involved in these two projects were:

» Structural design: Messes Hecht, Brück, Barros
» Repair design: Mr. Seifert
» Site supervision: Mr. Gaspard
» Drafting: Ms Manzer, Mr. Stastny

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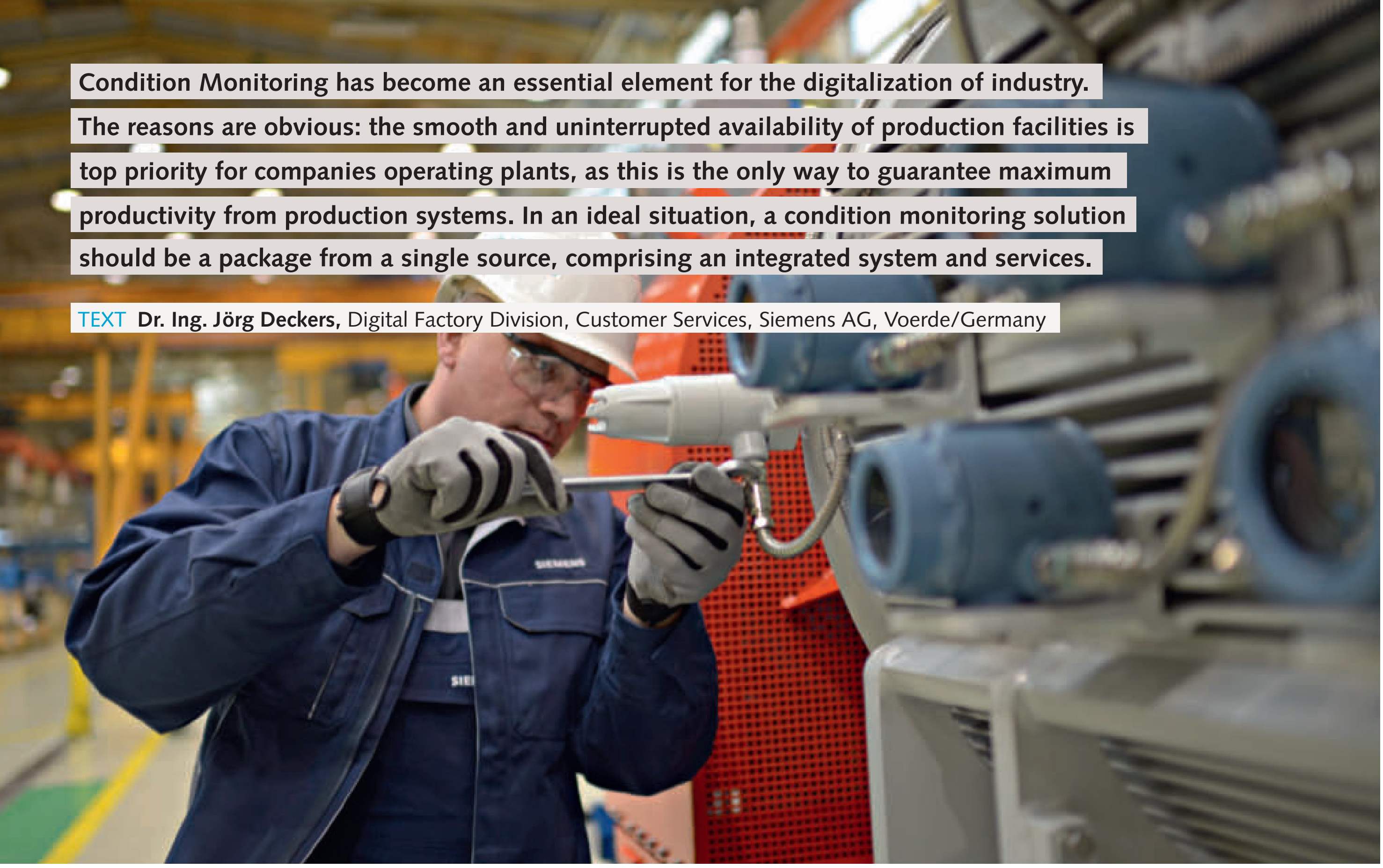
Condition Monitoring has become an essential element for the digitalization of industry. The reasons are obvious: the smooth and uninterrupted availability of production facilities is top priority for companies operating plants, as this is the only way to guarantee maximum productivity from production systems. In an ideal situation, a condition monitoring solution should be a package from a single source, comprising an integrated system and services.

TEXT **Dr. Ing. Jörg Deckers,** Digital Factory Division, Customer Services, Siemens AG, Voerde/Germany



All Siemens

Even after 22 years of continuous operation, only the basic maintenance is required

SIEMENS AG

Drive train condition monitoring

1 Introduction

An efficient condition monitoring solution such as Siemens' Drive Train Condition Monitoring (DTCM) is integrated into the automation system and monitors the entire drive train. The main focus is on motors and mechanical transmission systems, to ensure that potential damage is identified and rectified – or averted – at an early stage. This monitoring system also carefully analyzes how individual components operate together. The monitoring data is combined within a single system and is evaluated in detail by experts in the form of condition reports. This means that plant operators are kept constantly up to date and can take any necessary action without delay. This avoids costly plant downtimes, reduces maintenance costs and enables service intervals to be optimized.

2 Still perfect after 22 years of continuous operation

The case of a cement factory in southern Germany demonstrates how well a DTCM system can pay off. The factory has used a Flender KMP590 gear unit for 22 years, and years of reliable operation can still be expected, not least thanks to the many years during which its condition was continuously monitored.

The condition monitoring system was installed on the gear unit of the vertical mill drive in 1998 – and just in time, since a damaged motor bearing was diagnosed when the very first measurements were taken. This was quickly rectified during a brief, scheduled downtime.

A cost-efficient retrofit was performed in 2009: the main component of the CMS was replaced, however the sensors and cables were kept. A further milestone was reached in 2013 with the conversion from analog to broadband remote connection technology: the system can now be conveniently parameterized using the faster data transfer technology; when necessary, even large data volumes can be transmitted at lightning speed for diagnostics. The online signals can be viewed in the remote diagnostics center in what is essentially real time.

The DTCM system definitively proved its worth in early 2014: as part of the regular six-monthly reporting process, there were the first clear signs of damage to the inner ring of the roller bearing at the motor end of the gear unit input shaft. The experts involved recommended repairs over the long term. The customer hoped to continue production through to the scheduled winter downtime in February 2015. This meant that the best possible use of the remaining roller bearing service life had to be made, with condition-based maintenance helping to mitigate the risk. The damage that had already begun was then closely monitored to ensure a swift response if the condition of the bearing worsened –

or if there were any signs of consequential damage (Fig. 1).

And the strategy worked: the maintenance work ran smoothly on the scheduled date as the long lead time had been fully utilized to organize spare parts and experts in advance. The replaced bearing revealed exactly the damage that was expected: no substantial consequential damage had occurred, and the repairs could be performed on site. This allowed the actual downtime to be kept to a minimum, and the plant was able to quickly resume operation.

3 DTCM on Multiple Drive

The example provided by an Indian cement manufacturer also shows how a DTCM system can make a noticeable difference to service and lifecycle costs. The special aspect to this case was that development, construction, setup, service and condition monitoring for the drive train were procured from a single source in the form of a Siemens Integrated Drive System (IDS).

With the novel drive design for vertical mills, known as "Multiple Drive," four separate drive units mesh with a ring gear on the drive train, which means that the appropriate load balancing is crucial. If the drives work against each other or oscillate uncontrollably because the controller parameters were incorrectly set, for example, in a worst-case scenario, this would damage the teeth or bearing. This is why the DTCM system installed in the factory focuses on monitoring mechanical drive torque values. To achieve this, for each drive unit the torques of the various drive shafts in the auxiliary gear unit are monitored using strain gauges. Torque values are monitored against limit values and dynamic rates of change; deviations from specified limits trigger an alarm or the events are recorded with a high resolution. The frequency converters also transmit the calculated motor torque signals to the DTCM system.

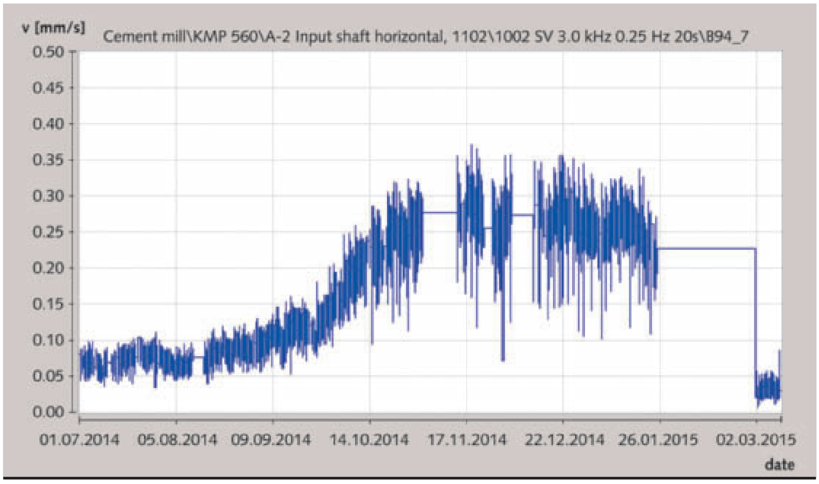
To monitor the sleeve bearings on the reduction gear unit input shafts and the roller bearings on the intermediate and output shafts, oil, temperature and vibration are all monitored for each drive unit. The roller bearings on the driven end and non-driven end of the modern drive motors are also monitored for vibration. The DTCM system also monitors hydraulic pressure in the hydrostatic axial friction bearings and the temperature of the friction bearings on the ring gear and grinding plate flange on the mill center body. Position measuring systems are used to monitor radial and axial runout errors and also the connection holding the split ring gear together.

To minimize wiring costs during commissioning, in each case, all of the sensors are installed in the factory and wired through to the intermediate terminal box attached to the steel frame. The intermediate terminal boxes also contain the interface nodes that digitalize all of the analog signals already after short signal cable lengths. The prewired control boxes mounted on the mechanical drive units with the interface nodes are networked using fiber-optic cables during commissioning onsite. Despite high sampling frequencies of vibration signals and a large number of channels, this allows a large bandwidth to be achieved to transfer the synchronously sampled signals to the PC used for analysis, even over considerable distances

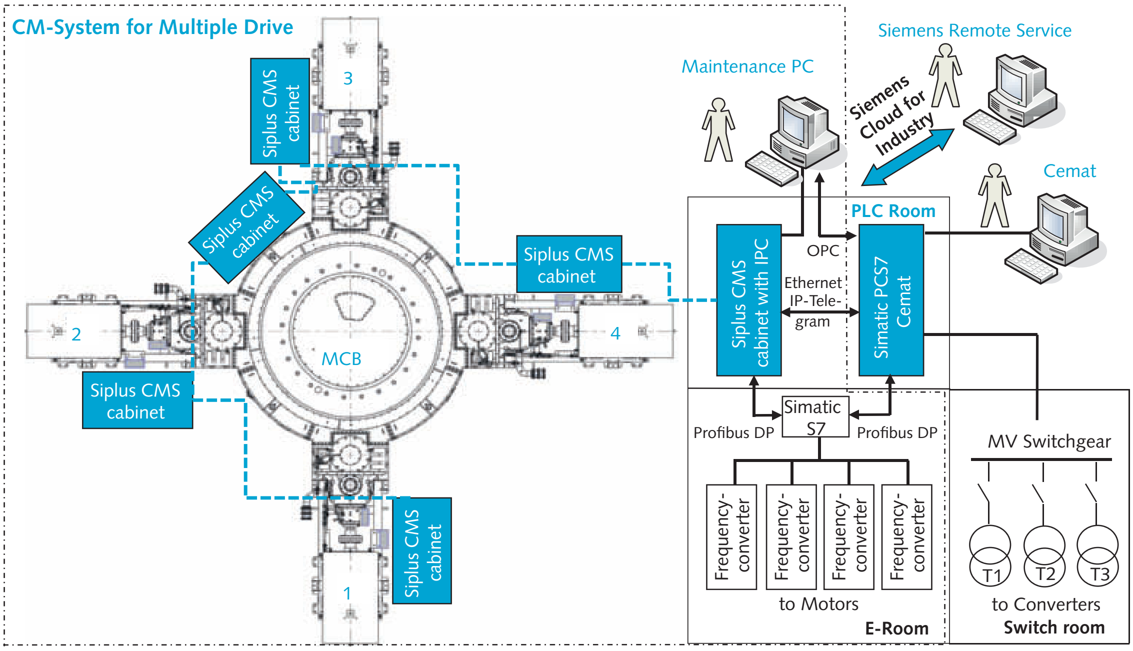
In addition, data from the frequency converters – e.g. active power levels and speed signals from the incremental encoders – is also fed into the DTCM system for each software interface. The higher-level process control system records essential process data such as material volume flows, temperatures and pressure. If gear unit vibration occurs, correlation with process statuses makes it easy to distinguish damage-related from process-related vibration events.

Overall, a total of 115 signals are recorded from the electromechanical drive train using the Siplus CMS monitoring system and saved on the local RAID hard drive system on the PC used for analysis. The computer is connected to the Siemens Cloud for Industry platform; diagnostic experts in Germany are responsible for the parameterization and monitoring (Fig. 2).

Continuous monitoring by the DTCM solution is based on an operational class plan. What this means is that different, frequently occurring load statuses are defined, for which threshold values are monitored together with the alarm values set in accordance with the process conditions in question. Fourier spectra are used to monitor periodic parameters that could indicate damage. The DTCM system thus continuously monitors the high-speed and variable-load system with a clear focus on identifying possible bearing and tooth damage, and as higher-level early warning system, prevents costly machine failures and plant downtimes.



1 Increasing vibration amplitude trend indicates bearing defect growth



2 Signals from different sensors in the field, from frequency inverters and from the automation system are networked in the DTCM System

4 The key to efficient plant operation

Both of these case studies show that Siemens DTCM systems provide a permanent, transparent picture of plant conditions, reducing risks of outages and also the costs associated with downtimes and maintenance. But there are additional advantages: comprehensive analysis results enable the best possible maintenance strategies to be developed, along with a much more cost-effective logistical setup for companies operating plants.

In both case studies, preventive maintenance strategies were able to be transitioned into condition-based ones that brought costs down. Unplanned and costly plant downtimes are things of the past, in the plants in southern Germany and India. By analyzing the data recorded by the DTCM system, damage can be quickly identified and located, even in the early phases. In the best case scenario, damage – and potential consequential damage – can be avoided in the first place. If damage is subsequently identified, then it can be quickly resolved. The damage analysis precisely determines which spare parts and tools are needed. This significantly reduces outage costs as well as repair costs.

If, as in the case of the plant in India, Siemens supplies the entire drive train as part of Integrated Drive Systems, the company also provides training for technicians, who will then be able to service both the electrical and the mechanical drive train components; this is another way in which service costs can be substantially reduced. A further contributing factor is that a long-term service contract means that there are no coordination and interface problems, as there is just one contact person who is responsible for all of the interests of the company operating the plant.

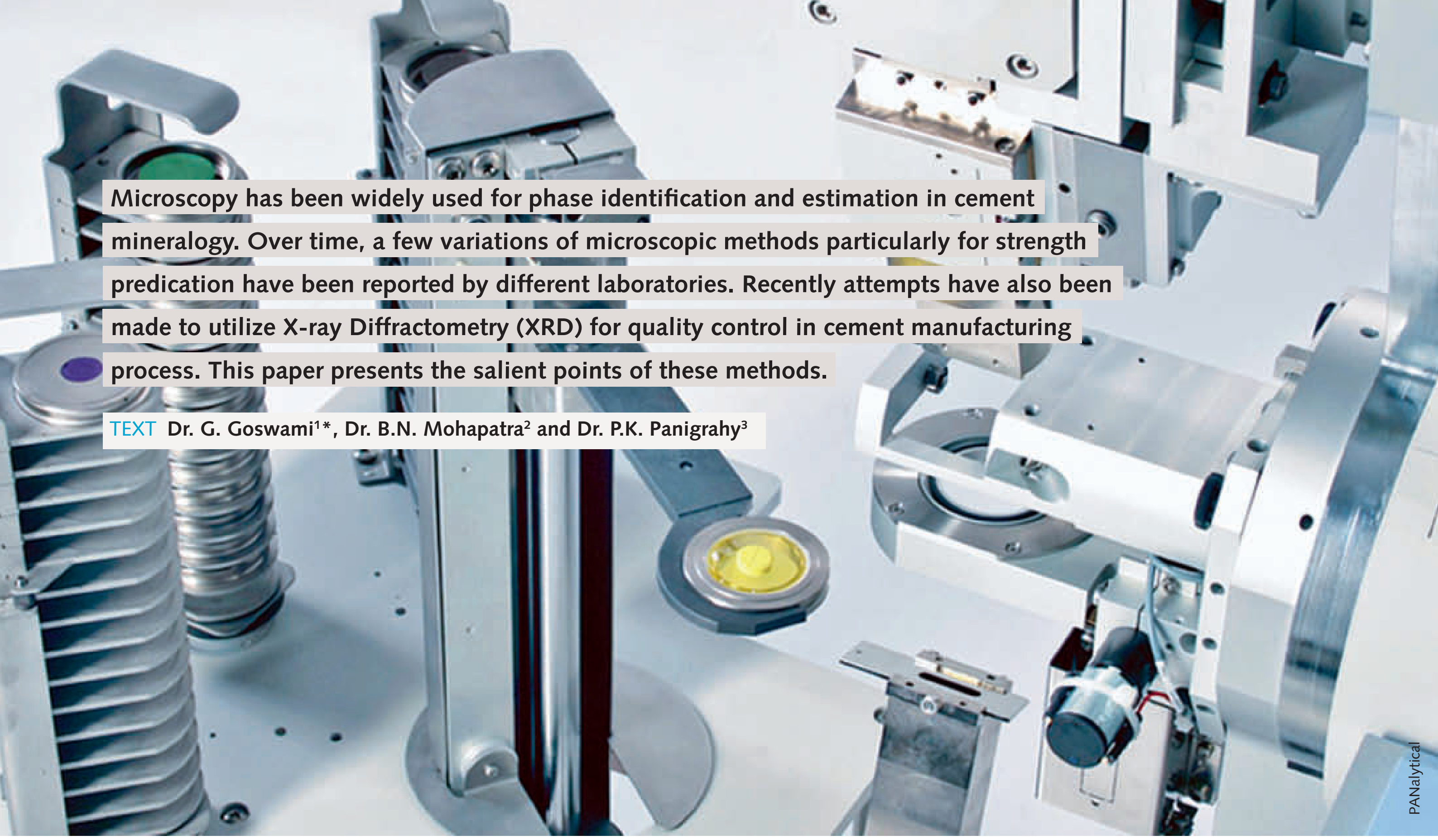
The example of the gear unit in the plant in southern Germany also clearly underscores the impact that a full DTCM system has on a maintenance strategy: analysis results enable risk-free, purely condition-based maintenance of the individual components. This means that components that are still intact are not replaced and it is avoided that highly-stressed components unexpectedly fail before the end of their useful service life. In other words, intelligent maintenance safeguards investments over the long term.

The data recorded in the DTCM system also provides a statistically sound basis for estimating which spare parts will be needed, and how often. Pools of spare parts for these components can then be created at logistically practical locations. This ensures that they are available quickly in the event of a breakdown and it also keeps warehousing costs to a minimum; in other words, stock inventory can be optimized, which is another area where major savings can be achieved.

DTCM systems can be used to cost-efficiently retrofit older condition monitoring systems. If an existing plant or system is modernized, as in the case of the cement factory in southern Germany, the advanced DTCM solution significantly extends the service life of the production machinery: continuous monitoring minimizes the risk that the older components will fail, and condition-oriented maintenance can optimize the service life of individual components.

5 Conclusion

In a nutshell: an efficient DTCM solution takes over the whole job of monitoring the drive train from a single source and significantly increases plant availability and productivity, while reducing maintenance and repair costs. As a result, companies operating plants can fully concentrate on their core business.



Modern X-ray powder diffractometer with pneumatic shutters and beam attenuators

Microscopy has been widely used for phase identification and estimation in cement mineralogy. Over time, a few variations of microscopic methods particularly for strength predication have been reported by different laboratories. Recently attempts have also been made to utilize X-ray Diffractometry (XRD) for quality control in cement manufacturing process. This paper presents the salient points of these methods.

TEXT **Dr. G. Goswami[1]*, Dr. B.N. Mohapatra[2] and Dr. P.K. Panigrahy[3]**

Cement quality control system: application of X-ray diffractometry

1 Introduction

The main features of a cement quality control system involve raw mix composition, burning of the cement clinker, fineness and finally the strength of the cement produced. The ultimate quality of cement primarily depends on the quantity and characteristics of different mineral phases present in it, which in turn are controlled by the raw mix composition and burning process. Identical raw mix compositions even with a more or less similar burning process may not be expected to produce the same mineral assemblages. Hence evaluation of the clinker mineral phases is regarded as very crucial for the quality control of cement.

Microscopy and X-ray Diffractometry (XRD) are widely used in the field of cement mineralogy, particularly for phase identification and estimation. Prof. Ono of Japan was the first to introduce clinker microscopy for characterization of the clinker burning condition and prediction of 28-days cement strength [1, 2]. Since then, a few variations of microscopic methods particularly for strength predication have been reported by different laboratories.

Recently attempts have also been made to utilize XRD for quality control in the cement manufacturing process. Free CaO content in the cement clinker is still regarded as an index of clinker quality. A very rapid estimation of free CaO in clinker by XRD is possible [3] and quite a number of cement plants are known to adopt this method [4]. Aldridge [5] used XRD for quantitative estimation of cement phases for prediction of cement strength applying the equation earlier formulated by Alexander [6]. Beilmann and Bruggemann have developed a method for on-line determination of clinker phases using XRD, which can be incorporated into the POLAB system for cement quality control [7].

However quantitative estimation of clinker phases by XRD is a complex and time consuming method and on-line determination has not yet been perfected [8]. Keeping this in view, attempts were made in the Dalmia Institute of Scientific and Industrial Research, Rajgangpur to develop some rapid XRD methods for quality control of cement clinker which do not necessitate quantitative estimation of the phases. The salient points of the methods developed are presented in this paper.

2 Characterization of the burning condition

Examination of a large number of clinker samples from different plants and of laboratory fired

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Table 1 'Cn' Indices of laboratory fired clinkers

Firing conditions			
	Retention time (h)	Temperature (°C)	'Cn' Index
1	1		
	1.1	1350	1.6
	1.2	1400	1.4
	1.3	1440	1.2
2	2	1350	1.0

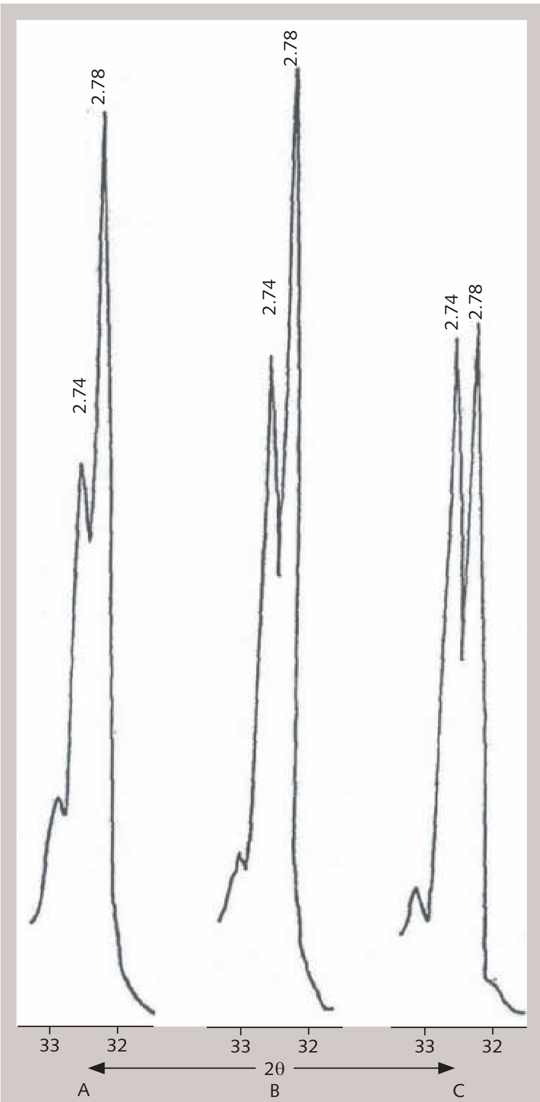
clinkers demonstrate that the ratio between the XRD pulse counts (Cu-K_{α}) corresponding to 'd' 2.78 (2 θ = 32.2) and 'd' 2.74 (2 θ = 32.7) bears a distinct relationship with the clinkering process (9). Laboratory experiments show that this ratio (termed as 'C_n' index) is dependent on the burning temperature and retention time (Table 1, Fig. 1).

From the examination of industrial clinkers from different plants it is observed that, to achieve normal cement properties, the 'C_n' index must not be above 1.5 [9]. The two 'd' values taken for calculation of 'C_n' index belong to alite (C_3S) and belite (C_2S) and it is to be noted that in the case of perfect crystallization, both alite and belite should have 'C_n' index around 1.0 to 1.1 only [10]. Thus 'C_n' index reflects the degree of crystallization, and the higher the 'C_n' values the less is the degree of crystallization. Accordingly there exists a distinct relationship between the 'C_n' index, burning condition and degree of crystallization of cement phases. As the burning condition determines the cement quality, the 'C_n' index can be used directly for predicting the cement properties. For example, during the production of the clinker 1.1 with 'C_n' index ranging from 1.6 to 3.7 (Table 2) the kiln atmospheres was very dusty, and the cement produced showed abnormal properties.

3 Prediction of cement strength

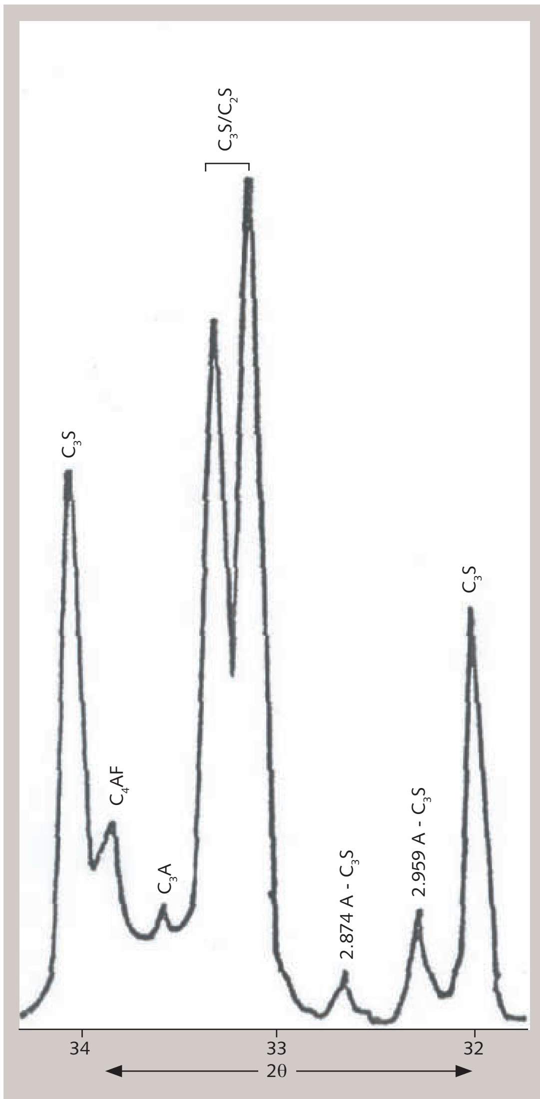
3.1 3-days strength

From an examination [11] of a large number of cement samples, a relationship has been established between the 3-days compressive strength (CCS) of cement mortar and an XRD index 'X_n' of the corresponding clinker derived from the ratio of the XRD pulse counts (Cu-K_{α}) at 2 θ = 30.2 (d = 2.959 A) and 31.1 (d = 2.874 A) corresponding to alite (hkl = 202) and belite (hkl = 120) respectively (Fig. 2).



1-4 Dalmia Institute

1 XRD spectra of laboratory fired clinkers, A = 1350°C – 1 hour, B = 1400°C – 1 hour, C = 1350°C – 2 hours



2 XRD pattern (Cu-Kα) of cement clinker, showing the diffraction peaks (d = 2.959 and 2.874 A) taken for X_n Index (common cement notations are used)

The regressive equations derived for a particular plant:

» 3-days-CCS- X_n x 240 kg/cm², when $X_n \leq 1$
and 240 + 26 (X_n – 1) kg/cm², when $X_n > 1$,
and X_n maximum = 5.5

The correlation co-efficient between the conventionally tested CCS values of the cement mortar cubes and the calculated CCS values bases on X_n index for 42 samples of the particular plant was found to be 0.88 (Fig. 3).

The average tested and calculated CCS values of 42 samples were 296.4 and 294.7 kg/cm² respectively. In average calculated CCS values varied from tested values by +5.9 to –5.4 percent only. Root mean square error was 6.33. In spite of having a wide variation in tested values (195 to 360 kg/cm²), predicted strength values for 80 % samples were within 10 kg/cm².

3.2 Increase of strength from 3 days to 28 days curing

It is found that the Index X_n, as defined in 3.1 also bears a distinct relationship with the strength development of cement mortar cubes in the period between 3 and 28 days [12]. In an examination of 37 samples from a particular plant, the correlation co-efficient between the X_n and I_n, (the latter being the increase of CCS from 3 to 28 days curing, expressed as the percentage of the 3-days-CCS) was found to be 0.88. From this relationship a regressive equation was derived to calculate the possible increase in strength (I_n) from the index X_n:

» $I_n = 90 - 10\, X_n$,
where X_n maximum is 5.5

Actual I_n, derived from the tested 3 days and 28 days cement strength, bear a high degree of positive linear correlation with the calculated I_n bases on X_n (Fig. 4).

3.3 28 days strength

As I_n, derived from X_n-(3.2) is the increase of CCS from 3 to 28 days curing, expressed as the percentage of the former, it is conceivable that:

$$\text{28-days-CCS} = \text{3-days-CCS} + \frac{\text{3-days-CCS x } I_n}{100}$$

where 3-days-CCS is derived from the index X_n (3.1)

Determination of 28 days CCS of 35 industrial samples on the basis of the index X_n, showed that the calculated CCS values were on average within +3.8 % and –3.5 % of the tested values [13]. The predicted CCS values for 50 % of the test samples were within 10 kg/cm² or about ± 2 % of the tested values (Table 3).

3.3 Modification of the equation

As each kiln and the kilns in each plant are known to have their individual characters, which control the clinker quality, it is accepted that any regressive equation for strength prediction based on clinker analysis is limited

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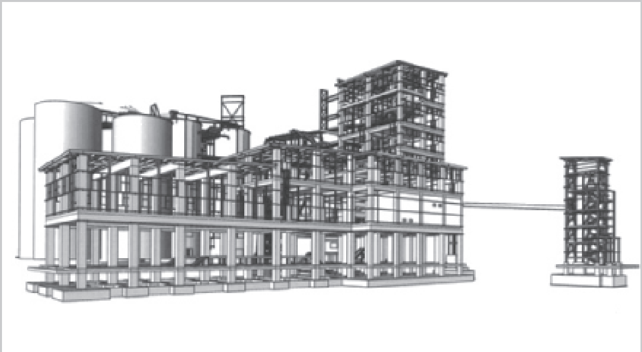

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			'C_n' Indices	
	Sample sources	No. of samples analyzed	Range	Average
1.	Kiln-I			
1.1	Early stage	15	1.6-3.7	2.5
1.2	Later stage	35	1.2-2.4	1.5
2.	Kiln-II	20	1.1-1.7	1.4
3.	Kiln-III	25	1.0-2.1	1.2

Table 2 'Cn' Indices of cement clinkers from different sources

to one kiln only [2]. Furthermore, a number of studies have shown that none of the proposed regressive equations, without any modification is universally acceptable. Keeping this in view the applicability of the present method was further examined by testing clinkers and corresponding cement samples from a second plant. It is found that while the basic principle of the equation remains the same, co-efficients are to be changed [14]. For example, the equations derived for the second plant were:

Table 3 Tested and calculated 3 and 28 days CCS (kg/cm²) of cement mortar cubes

(1) when $X_n \leq 1$, 3-days-CCS = X_n x 276 kg/cm² and when $X_n > 1$, 3-days-CCS = 276 + 90 (X_n – 0.5) where X_n maximum = 2.0

X_n	I_n	3 days		28 days	
		Calculated	Tested	Calculated	Tested
1	2	3	4	5	6
0.8	82	192	195	349	359
1.2	78	245	260	436	437
1.3	77	248	271	439	447
1.5	75	253	255	443	450
2.0	70	266	282	452	457
2.2	68	271	287	455	483
2.2	68	271	289	455	451
2.3	67	274	264	457	453
2.5	65	279	301	460	451
2.5	65	279	301	460	468
2.7	63	284	285	461	451
2.8	62	287	307	464	434
2.9	61	289	308	465	484
2.9	61	289	285	464	446
3.0	60	292	308	467	461
3.2	58	297	312	469	458
3.2	58	297	258	469	447
3.4	56	302	285	471	431
3.5	55	305	302	473	483
3.6	54	308	331	474	481
3.6	54	308	296	474	470
3.7	53	310	356	474	508
3.9	51	315	281	476	470
4.0	50	318	302	477	454
4.0	50	318	359	477	518
4.5	45	331	329	480	508
4.7	43	336	336	480	481
4.9	41	341	360	480	474
4.9	41	341	343	480	474
5.5	35	357	338	482	498
5.5	35	357	357	482	513
5.5	35	357	372	482	466
5.5	35	357	357	482	462
5.5	35	357	321	482	444

(2) $I_n = 65 - 10\ X_n$

where X_n maximum = 2.0

As the 28-days-CCS is derived from the calculated 3-days-CCS and I_n, the equation for 28-days-CCS does not need any modification.

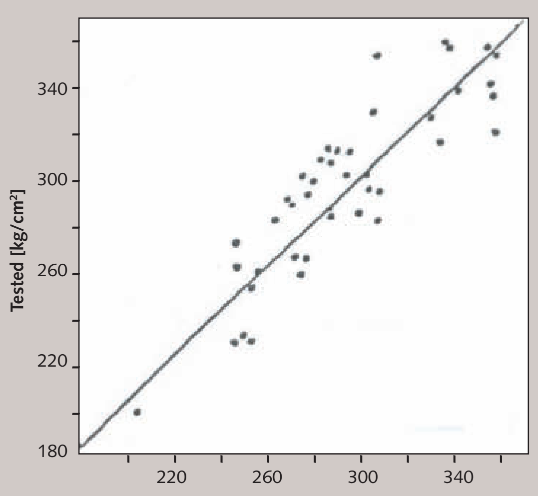
4 Advantage of the XRD metods

Determination of burning condition and prediction of both 3-days- and 28-days-cement-strengths can ensure the quality of the cement produced. In the developed method, XRD of a single representative clinker sample can provide the data for both the burning condition and CCS values. Both the XRD indices, C_n and X_n can be derived within a period of around 20 minutes. The data are collected from the display of the XRD unit and thus the methods avoid any element of personal judgment involved in the microscopic method. As the test results are achievable within a very short time, the two XRD indices C_n and X_n, combined together can be used for any corrective measures that may be necessary in the kiln for the control of the clinker quality.

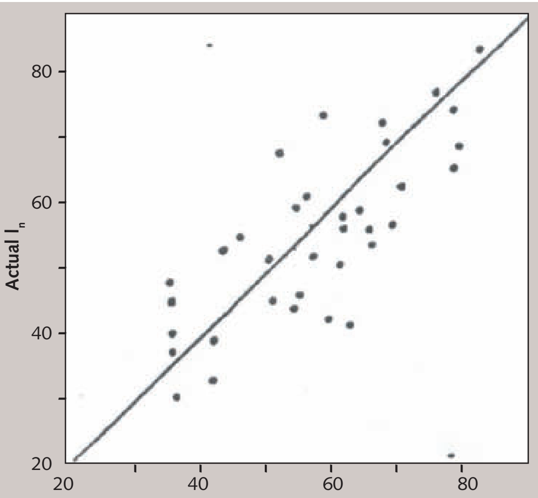
5 An observation

At present, most of the cement manufacturers possess sophisticated analytical instruments like the X-Ray Fluorescence (XRF) for the elemental analysis, but not often instruments for the phase analysis. This is because of the fact that the cement technologists generally intend to control the cement quality based on the chemistry of the raw meal. However in recent years it is being widely realized that in order to make the process control effective, it is necessary to combine it with the quality control system and that it is not the chemistry of the raw mix, but the clinker phase assemblages and their crystallography that determine the ultimate cement properties. No doubt, potential phases of the clinker could be estimated from chemical analysis. But it is well known that contents of actual clinker phases, as determined by physical methods, always differ from the chemically estimated potential phase contents.

Both microscopy and XRD are widely used for physical estimation of clinker phases and clinker microscopy has already been in use for characterization of the clinker burning condition and prediction of cement strength. However the drawbacks of the clinker microscopy lie in the method of sample preparation and in the microscopic visual evaluation. Determination of different microscopic indices is a complex process, which involves some personal judgments also. Accordingly the method needs an analyst with a significantly wide experience in the application of petrological microscopy. On the other hand, in the XRD method, the required data are collected



3 Relationship between the tested and calculated 3 days CCS (kg/cm²)



4 Relationship between the actual an d calculated I_n

from the display unit of the XRD system and thus it avoids any element of personal judgment and does not need any highly qualified analyst. Furthermore part of the sample prepared for chemical analysis can be used for the XRD.

The only hindrance to a wide application of the XRD system is the relatively high cost of the instrument. Even then, many cement manufactures are reported to procure XRD units only for rapid estimation of free CaO [4]. XRD systems are powerful analytical instruments with many and varied capabilities and in the cement manufacturing process they can be used for evaluation of raw materials and final products, and in addition for fundamental studies for understanding different cement characteristics [15]. So it is natural that with the increased quality consciousness, the XRD system will be more and more popular amongst cement technologists. Because of its rapidity and lack of ambiguity, the XRD method is expected to play the most crucial role in the field of cement quality control system in the coming years.

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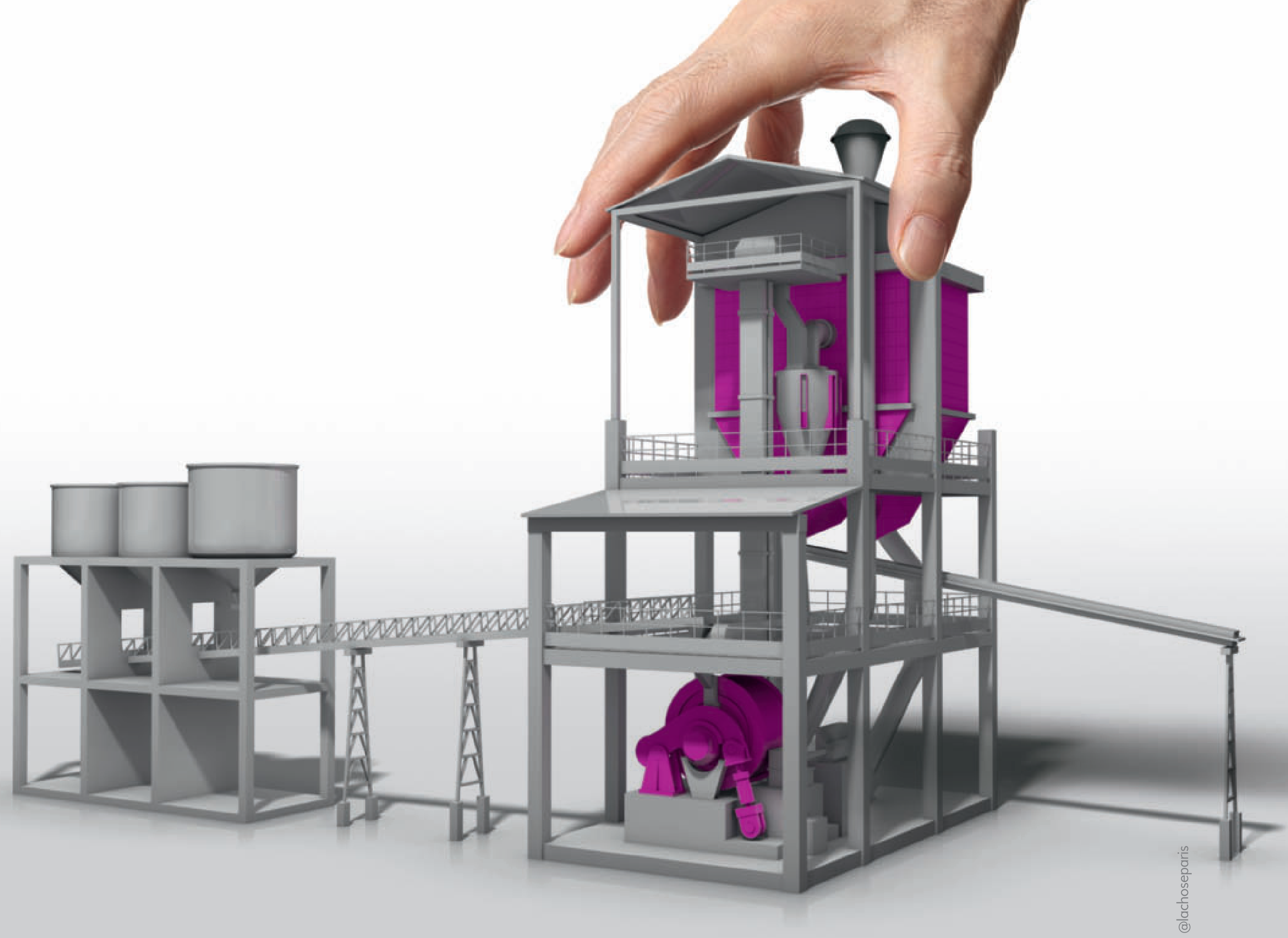

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