Cement Solutions I:

From the Research Lab to the Production Plant –

Cost Savings with Automated Quantitative X-ray Diffraction
Welcome

Speakers

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Today’s Topics

- New challenges in cement production
- Use of powder X-ray Diffraction (XRD) in controlling cement production
New Challenges in Cement Production

- Accurate clinker phase determination using alternative fuels
- Mill control
- Additive control in blended cements
- Quantification of Lime stone additions
- Quantification of Pozzolan admixtures, such as flyash, blast furnace slags, and silica fume
- Quantification of raw materials
Why X-ray Diffraction?

- Example: TiO$_2$ (Anatase / Rutil)

Anatas (black)  Rutil (yellow)

BOTH ARE 100% TiO$_2$
Why X-ray Diffraction?

Phase

- Anatase
- Rutile

Structure

- Tetragonal TiO₂
- Trigonal TiO₂

XRD Pattern
Why X-ray Diffraction?

- Each crystalline phase has a distinctive pattern ("fingerprint")
  ⇒ QUALITATIVE PHASE ID

- Intensity of the reflections from a phase are proportional to the concentration of the phase in the mixture
  ⇒ QUANTITATIVE PHASE ANALYSIS

- The width of the reflection is a function of the crystallinity of the phase

WHY DO WE NEED TO KNOW THIS?
## Important Phases/Components: Clinker

<table>
<thead>
<tr>
<th>Clinker phase</th>
<th>Name</th>
<th>Relevance</th>
</tr>
</thead>
<tbody>
<tr>
<td>C3S/C2S</td>
<td>Alite/Belite</td>
<td>Hardness</td>
</tr>
<tr>
<td>C3A</td>
<td>Aluminate</td>
<td>Setting time</td>
</tr>
<tr>
<td>C4AF</td>
<td>Brownmillerite</td>
<td>Color, Fe-content</td>
</tr>
<tr>
<td>CaO</td>
<td>Free Lime</td>
<td>Kiln temperature control</td>
</tr>
<tr>
<td>Ca(OH)2</td>
<td>Calciumhydroxide</td>
<td>Kiln temperature control</td>
</tr>
</tbody>
</table>
### Important Phases/Components: Cement

<table>
<thead>
<tr>
<th>Cement phase</th>
<th>Name</th>
<th>Relevance</th>
</tr>
</thead>
<tbody>
<tr>
<td>CaSO4·xH2O</td>
<td>Gypsum Phases</td>
<td>Dehydration / setting time</td>
</tr>
<tr>
<td>CaCO3</td>
<td>Calcite</td>
<td>Limestone addition 3%</td>
</tr>
<tr>
<td>Mg phases</td>
<td>Periclase / Dolomite</td>
<td>Mg-rich quarries</td>
</tr>
<tr>
<td>Glass</td>
<td>Amorphous Phase</td>
<td>CEM III / Reactivity</td>
</tr>
</tbody>
</table>
## Important Phases/Components: Raw Materials

<table>
<thead>
<tr>
<th>Material</th>
<th>Name</th>
<th>Relevance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ca,Mg (CO3)</td>
<td>Limestone</td>
<td>Kiln Fuel dosage</td>
</tr>
<tr>
<td>SiO2</td>
<td>Quarz</td>
<td>Grind ability</td>
</tr>
<tr>
<td>BF Slag</td>
<td>Blast Furnace Slag</td>
<td>CEM III / Cost</td>
</tr>
<tr>
<td>CaSO4x XH2O</td>
<td>Gypsum Phases</td>
<td>Dosage for blend</td>
</tr>
<tr>
<td>Bypass/Dust</td>
<td>Sulfide, Spurrite</td>
<td>Dosage and Deposits</td>
</tr>
</tbody>
</table>
Please use your mouse to answer the question on the right of your screen:

What methods are you currently using for phase determination? (Check all that apply):
- Freelime by titration only
- XRD channel in system
- Powder X-ray Diffraction
- Microscopy
- Bogue calculation
- None
XRD... Why Not More?

- XRD has been used on cement, clinker and minerals since the 1950’s
- Qualitative phase identification and standard-based quantification were the early applications.
  - Initially all these tasks were very cumbersome and difficult and needed either manual evaluation or expensive computer hardware.

- With the first fully shielded X-ray diffractometer (PDP controlled), our D500, Bruker started the move from University to Industry.

- Introducing PC-based diffraction software and developing a very intelligent search match for phases enabled non-PhD users to get meaningful results.
Quantitative XRD in the past could only be done using either internal standards (RIR) or by calibration with reference material.

Standard (reference) based approach
- Very similar to XRF approach
- One or more peaks are unique to a phase and are not overlapped
- Relationship between Intensity and Concentration is developed by measuring characterized reference samples using the same parameters

This works very well for simple systems such as CaO Freelite or the limestone addition or Respirable Quartz
- Characteristic peaks are available and not overlapped
- Reference materials can be characterized (titration) or mixed
X-ray Diffraction Systems for Powders

D8 ADVANCE: modular, expandable research system

D4 ENDEAVOR: compact system, high throughput, quality control, automation ready
Methods for Quantitative XRD
Classical Reference Material Based
Quantitative XRD Phase Analysis
Conventional Quantitative Analysis

measurement range
Solid Solution Effects
Schematical Representation
NIST RM's 8486, 8487, 8488
Solid Solution Effect for C3S
Preferred Orientation Effects
Schematical Representation

Randomly oriented powder

Highly textured sample
NIST RM 8486
Preferred Orientation Effects

Bruker AXS
Conclusions

- Alite (C3S) exhibits strong peak shifts due to changes in chemical composition and varying intensities due to changes in both chemical composition and preferred orientation effects
  - **C3A and C4AF clearly remain at the same positions**
- The various background of the patterns is directly related to the various iron content of the clinkers
  - **Abundance of C4AF**

**Reliable clinker quantification is impossible using traditional XRD methods**
Can a “Classical” Approach Work Here?

NIST RM's 8486, 8487, 8488
Solid Solution Effect for C3S
Quantification Without Standards

- The Rietveld method generates a calculated diffraction pattern from the phase list and their structures, that is compared with the observed data.
- The differences between observed and calculated diffraction patterns are minimized using least-squares procedures.
The Rietveld method:

- A **direct standardless** full-pattern approach to quantitative phase analysis
  - No standards
  - No calibration

- Independent of equipment and sample properties such as tube aging, solid solution effects, and preferred orientation
  - No drift correction required
More and More.

- Lots of calculations required, as well as many parameters, limited the application to mainframes and Unix workstations (1994)
  - (none to be found in a cement plant)
  - Time to result for a sample > 120 minutes best case
- The Rietveld “Refinement” uses many parameters; turn-on sequence and values need to be constrained to create meaningful results
  - Solid background in crystallography is required
  - Interactive type approach
  - Refinement needs to be tuned to instrument to empirically determine the instrument response function to constrain some refinement parameters
- Faster and faster PC’s allowed this technique to mature (e.g. ZEROQUANT on 1997, WINRIET), but still an expert was needed to control it, with time to result still > 15 minutes
Breakthrough. . . Changed the Industry

- Using the PC platform and adapting the code to utilize Fundamental Parameters to describe the instrument function, new software was born.
- Instead of a parameter turn-on sequence and pure interactive approach, it uses a phase list and recipe and does not require ANY user input during its run.

TOPAS
The unique TOPAS allows fully automated quantitative phase analysis from XRD data without any user input.

Typical calculation times are << 30s for a Pentium III

<table>
<thead>
<tr>
<th></th>
<th>Time</th>
<th>C3S</th>
<th>C2S</th>
<th>C3A</th>
<th>C4AF</th>
<th>MgO</th>
</tr>
</thead>
<tbody>
<tr>
<td>NIST</td>
<td></td>
<td>58,47</td>
<td>23,18</td>
<td>1,15</td>
<td>13,68</td>
<td>3,21</td>
</tr>
<tr>
<td>D8 Standard</td>
<td>38 min</td>
<td>57,14</td>
<td>22,39</td>
<td>2,13</td>
<td>14,31</td>
<td>4,03</td>
</tr>
<tr>
<td>D5000Matic PSD</td>
<td>38 min</td>
<td>57,00</td>
<td>23,08</td>
<td>2,00</td>
<td>14,13</td>
<td>3,78</td>
</tr>
<tr>
<td>D5000Matic PSD</td>
<td>19 min</td>
<td>57,08</td>
<td>22,95</td>
<td>2,05</td>
<td>14,16</td>
<td>3,75</td>
</tr>
<tr>
<td>D5000Matic PSD</td>
<td>3,8 min</td>
<td>58,02</td>
<td>22,06</td>
<td>1,99</td>
<td>14,20</td>
<td>3,72</td>
</tr>
</tbody>
</table>
Quantitative Clinker Analysis
No Standards, No Calibration (TOPAS!)

- NIST RM 8488 – analytical performance
- Mean results plus precision (10 measurements)
  D4 ENDEAVOR, measurement time: 4 min (PSD)
  Benchmark in 2003

<table>
<thead>
<tr>
<th>Compound</th>
<th>TOPAS (wt%)</th>
<th>NIST (wt%)</th>
<th>Bogue (wt%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alite C3S</td>
<td>64.77 (0.36)</td>
<td>64.97 (0.56)</td>
<td>57</td>
</tr>
<tr>
<td>Belite C2S</td>
<td>19.51 (0.28)</td>
<td>18.51 (0.58)</td>
<td>22</td>
</tr>
<tr>
<td>Aluminate C3A</td>
<td>4.04 (0.44)</td>
<td>4.34 (1.35)</td>
<td>7</td>
</tr>
<tr>
<td>Ferrite C4AF</td>
<td>11.71 (0.43)</td>
<td>12.12 (1.50)</td>
<td>12</td>
</tr>
</tbody>
</table>

Very Easy...
Quantitative Phase Analysis of Cements: Quality and Process Control

- **Clinker**
  - actual clinker composition
  - distinction of different $\text{C}_3\text{A}$ modifications
  - distinction between Free Lime and MgO
  - understanding color changes in clinker by determination of actual $\text{C}_3\text{S}$ and $\text{C}_4\text{AF}$ composition
  - possibility to determine clinker grindability

- **Real phases, no Bogue assumption**

- **Can you get this in 5 minutes by microscopy and with the same accuracy?**
Audience Poll

Please use your mouse to answer the question on the right of your screen:

How do you check the grinding time for your cement?

- Blaine/Fineness
- DTA/TG
- Fixed Time
- No check...
Quantitative Cement Analysis... Fast

Typical Measurement Data in automated cement plant laboratories

- D4 ENDEAVOR equipped with LynxEye detector (opening angle 3.9°)
- Cu-Tube: 30kV, 40mA
- Divergence slit: 0.5°
- Angular range: 10 to 65 °2θ, Step size: 0.02°
- Measurement time: 4 min 50 sec
- Automated sample preparation
Quantitative Cement Analysis: Direct Calculation, No Interaction!

C3S monoclinic (NISHI) 65.38 %
C2S beta (MUMME) 7.97 %
C3A Na orthorhombic 6.61 %
C3A cubic 1.41 %
C4AF Colville 8.68 %
Periclase 1.73 %
Lime 0.24 %
Arcanite K2SO4 1.82 %
Gypsum 2.53 %
Bassanite Bezou 0.58 %
Portlandite 2.19 %
Calcite 0.88 %

TOPAS... No turn-on sequence, automated!
Mill Control
Real Composition of Gypsum Phases

What happens to the gypsum “additive” during milling?

- Gypsum can loose “water” when ground too long --> dehydration effect
- Too high Bassanite will have detrimental effect
- Too long milling will cost money; mill is a large factor in energy consumption
- All three sulfate phases have a different solubility
- The ratio of the sulfates controls the setting behavior of the cement
- The production process influences the sulfates as cement milling
- Dehydrates gypsum to bassanite or even anhydrite
- Typically in process control only the total SO$_3$ content is monitored by XRF
### Accuracy and Precision (values in wt. %, SD in brackets/1σ)

- Same measurement data as above
- Alite calculated by hkl_Phase

#### DSC/TG:

<table>
<thead>
<tr>
<th></th>
<th>Sample 1</th>
<th>Sample 2</th>
<th>Sample 3</th>
<th>Sample 4</th>
<th>Sample 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gypsum</td>
<td>0,0</td>
<td>1,9</td>
<td>1,4</td>
<td>0,2</td>
<td>1,6</td>
</tr>
<tr>
<td>Bassanite</td>
<td>0,7</td>
<td>0,8</td>
<td>1,8</td>
<td>1,0</td>
<td>0,4</td>
</tr>
<tr>
<td>Anhydrite</td>
<td>1,2</td>
<td>0,8</td>
<td>1,1</td>
<td>1,3</td>
<td>2,9</td>
</tr>
</tbody>
</table>

#### TOPAS

**Hkl approach**

<table>
<thead>
<tr>
<th></th>
<th>Sample 1</th>
<th>Sample 2</th>
<th>Sample 3</th>
<th>Sample 4</th>
<th>Sample 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gypsum</td>
<td>0,1 (0,02)</td>
<td>1,9 (0,03)</td>
<td>1,5 (0,03)</td>
<td>0,2 (0,03)</td>
<td>1,7 (0,02)</td>
</tr>
<tr>
<td>Bassanite</td>
<td>0,8 (0,05)</td>
<td>1,2 (0,07)</td>
<td>1,8 (0,05)</td>
<td>1,0 (0,03)</td>
<td>0,8 (0,07)</td>
</tr>
<tr>
<td>Anhydrite</td>
<td>1,2 (0,03)</td>
<td>0,6 (0,02)</td>
<td>1,0 (0,03)</td>
<td>1,7 (0,04)</td>
<td>2,9 (0,04)</td>
</tr>
</tbody>
</table>

From RR data
Quantitative Phase Analysis of Cements
Quality and Process Control

Cement

- control of CO$_2$ set points
- control of dehydration characteristics in ball mill
- control of amount of amorphous compounds
- prediction of strength development in combination with other results
- keeping a fingerprint of every sample as reference
- check of competitor products
Quantification of Blast Furnace Slag Cements with TOPAS
How to quantify amorphous amounts like blast furnace slag in CEM III by Rietveld analysis?

We can calculate the crystalline phases

But how to handle amorphous humps as indicated by the blue curve?

background
Quantification of Blast Furnace Slag Cements with TOPAS

- Rietveld analysis can only take into account crystalline phases, which are normalized to 100 wt.%
- Using Rietveld analysis, amorphous phase abundances can only be quantified by adding a standard (spiking method)
- In an automated plant laboratory this is not a favored approach or practical at all. It even would be an additional source of error.
- If the amorphous part of the slag could be treated as its own phase, it could be seamlessly integrated into the Rietveld analysis.
Measurement Data: Blast Furnace Slag

- Sample: Slag sample of the VDZ Round Robin (2006): Material 1
- High quality blast furnace slag
In 2006 the VDZ (German Cement Works Association) organized a Round Robin focused on quantitative phase analysis of blast furnace slag cements using XRD methods.

Three different BFSlag Cement samples to be analyzed were distributed to the participants.

In all samples, slags of almost amorphous composition have been used. The pure slags have been made available to the participants as well.
## Results:

### Vorläufige Ergebnisse

<table>
<thead>
<tr>
<th>Material</th>
<th>Untersuchtes Merkmal</th>
<th>Mittelwert</th>
<th>Vergleichs-σ</th>
<th>Wiederhol-σ</th>
<th>Rot.-Methode / Mischwert</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material 1 (CEM II/B-S)</td>
<td>XRD / Untergrund</td>
<td>24,61</td>
<td>1,91</td>
<td>1,49</td>
<td>25,15 / 25,00</td>
</tr>
<tr>
<td></td>
<td>XRD / Spike</td>
<td>23,84</td>
<td>1,13</td>
<td>1,90</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sonstige</td>
<td>24,49</td>
<td>2,18</td>
<td>0,22</td>
<td></td>
</tr>
<tr>
<td>Material 2 (CEM III/B 32,5 N-NW/HS/NA)</td>
<td>XRD / Untergrund</td>
<td>69,24</td>
<td>2,35</td>
<td>1,06</td>
<td>67,01</td>
</tr>
<tr>
<td></td>
<td>XRD / Spike</td>
<td>(67,21)</td>
<td>(1,40)</td>
<td>(1,26)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sonstige</td>
<td>69,33</td>
<td>2,13</td>
<td>0,19</td>
<td></td>
</tr>
<tr>
<td>Material 3 (CEM III/B 42,5 N-NW/HS/NA)</td>
<td>XRD / Untergrund</td>
<td>74,28</td>
<td>4,15</td>
<td>0,99</td>
<td>72,03</td>
</tr>
<tr>
<td></td>
<td>XRD / Spike</td>
<td>72,32</td>
<td>1,01</td>
<td>0,74</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sonstige</td>
<td>72,28</td>
<td>1,71</td>
<td>0,49</td>
<td></td>
</tr>
</tbody>
</table>

Wiederhol-Standardabweichung: - bis 5 % (Untergrund Methoden)  
- bis 3 % (Spike Methoden)

---

Results reference method
Application to the VDZ Round Robin
Samples: Results

Accuracy and Precision (values in wt. %, SD in brackets/1σ)

- Every sample was measured 5 times (D4 ENDEAVOR, LynxEye Detector)
- The same empirical value for the mass of the hkl_phase was used for all samples
- Reference values:
  - sample 1: 25,0 wt.%
  - sample 2: 67,0 wt.%
  - sample 3: 72,0 wt.%

<table>
<thead>
<tr>
<th></th>
<th>Sample 1</th>
<th>Sample 2</th>
<th>Sample 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measurement 1</td>
<td>25,0</td>
<td>67,2</td>
<td>71,7</td>
</tr>
<tr>
<td>Measurement 2</td>
<td>25,1</td>
<td>67,3</td>
<td>71,9</td>
</tr>
<tr>
<td>Measurement 3</td>
<td>24,7</td>
<td>67,0</td>
<td>71,6</td>
</tr>
<tr>
<td>Measurement 4</td>
<td>25,1</td>
<td>67,3</td>
<td>71,9</td>
</tr>
<tr>
<td>Measurement 5</td>
<td>25,3</td>
<td>67,0</td>
<td>71,5</td>
</tr>
<tr>
<td>Mean</td>
<td>25,1</td>
<td>67,2</td>
<td>71,7</td>
</tr>
<tr>
<td>SD</td>
<td>0,2</td>
<td>0,2</td>
<td>0,2</td>
</tr>
</tbody>
</table>
TOPAS Improves Process and Quality Control

- Effects can be seen which other methods do not detect at all (Bogue) or only after long analysis (microscopy)
- Control of the alkali mass flow (C3A cubic/orthorhombic, Alkalisulphates) – very important for Cement Setting Behavior
- Closer operation to the limits of the process (saving of energy and expensive raw materials) – instead of blind following of traditional LSF (Lime Saturation Factor), Silica and Alumina module
- Freelime analysis can be done more reliably with TOPAS – interference stability!
- Control of the cement milling – dehydration of the sulphates
TOPAS
(Total Pattern Analysis Solutions)

Benefits:
- Reliable results
- Does not break down when sample composition changes like other packages
- Best available reproducibility

Latest generation Rietveld software
The Time for XRD is Now. . .

- From pick-up to result in less than 5 minutes! As fast as XRF
- Quantitative XRD enhances ability for process and quality control. Real phases equals real information.
- Cost savings will cover instrument investment
  - High margin cement is no accident. . . or luck. . .
- Push-button approach brings XRD to the control room
Automation Software AXSLAB
Push Buttons to Start Routine Jobs

- Simply click a button to start a sample or a batch job
- Configurable by the user
Automation Software AXSLAB
User Interface with Color-coded Results Table

```
<table>
<thead>
<tr>
<th>Sample</th>
<th>Position</th>
<th>Method</th>
<th>Preparation</th>
<th>State</th>
<th>XRF</th>
<th>State</th>
<th>XRD</th>
<th>State</th>
</tr>
</thead>
<tbody>
<tr>
<td>1020A4003</td>
<td>ard_1 100E</td>
<td>Freetime</td>
<td>FREP4</td>
<td>completed, removed</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Freetime active</td>
</tr>
<tr>
<td>1020A4016</td>
<td>ard_1 100E</td>
<td>Freetime</td>
<td>FREP4</td>
<td>completed, removed</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Freetime loaded</td>
</tr>
<tr>
<td>1020A4007</td>
<td>prep_1_press</td>
<td>Freetime</td>
<td>FREP4</td>
<td>completed</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Freetime</td>
</tr>
<tr>
<td>1020A4009</td>
<td>prep_1_2mill</td>
<td>Freetime</td>
<td>FREP4</td>
<td>active</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Freetime</td>
</tr>
</tbody>
</table>
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### Result Table

- **Template:** Cement not Validated

```
<table>
<thead>
<tr>
<th>MeasuringDate/Time</th>
<th>SampleID</th>
<th>Operator</th>
<th>Device</th>
<th>Method</th>
<th>Al2O3</th>
<th>Fe2O3</th>
<th>MgO</th>
<th>SiO2</th>
<th>Al2O3</th>
<th>Fe2O3</th>
<th>MgO</th>
<th>SiO2</th>
</tr>
</thead>
<tbody>
<tr>
<td>18.04.2002 11:29:10</td>
<td>CM1</td>
<td>Barde</td>
<td>xrf_1</td>
<td>Cement</td>
<td>6.26</td>
<td>5.68</td>
<td>0.114</td>
<td>18.0</td>
<td>3.35</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18.04.2002 13:15:12</td>
<td>CM1</td>
<td>Barde</td>
<td>xrf_1</td>
<td>Cement</td>
<td>6.26</td>
<td>5.68</td>
<td>0.114</td>
<td>18.0</td>
<td>3.35</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18.04.2002 13:01:10</td>
<td>CM1</td>
<td>Barde</td>
<td>xrf_1</td>
<td>Cement</td>
<td>6.26</td>
<td>5.68</td>
<td>0.114</td>
<td>18.0</td>
<td>3.35</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18.04.2002 11:08:23</td>
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<td>Granacher</td>
<td>xrf_1</td>
<td>Cement</td>
<td>6.27</td>
<td>5.68</td>
<td>0.114</td>
<td>18.0</td>
<td>3.35</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
```

---

- **Average:**
  - Al2O3: 6.26%
  - Fe2O3: 5.68%
  - MgO: 0.114%
  - SiO2: 18.0%
  - Result: 3.35%

- **Standard deviation:**
  - Al2O3: 0.0013
  - Fe2O3: 0.0003
  - MgO: 0.00015
  - SiO2: 0.008

- **Maximum:**
  - Al2O3: 6.28
  - Fe2O3: 5.68
  - MgO: 0.116
  - SiO2: 18.0

- **Minimum:**
  - Al2O3: 5.26
  - Fe2O3: 1.00
  - MgO: 0.112
  - SiO2: 14.4

---

- **1017114 Items**
  - Options
  - Refresh
  - Save

- **Cement not Validated**
  - Days last 7 days
  - Last 50 not validated

---

Bruker AXS
```
Quantitative Rietveld Analysis
Cement Industry

Milestone reference:

The cement industry is currently the fastest growing application area for quantitative Rietveld analysis.

_The question is not IF, but WHEN the Rietveld method will be implemented for quality optimization and process control in ALL cement plants._

Sample Preparation – Key to Success

- Ring and puck mill traditionally used will
  - Dehydrate the cement
  - Destroy crystal structure -> amorphous
  - Settings for XRF usually too long for XRD
  - Easy to automate

- Mortar mills
  - Too slow
  - Fine for XRD
  - Cannot be automated

- Mortar and pestle
  - Too slow x 2
  - Operator dependent

- Powder mounts
  - too operator dependent
  - Not reproducible
Sample Preparation

**Pressed pellets (steel rings)**
- Gentle grinding: free lime, sulfate phases, calcite
- Uniform pressure: preferred orientation effects
- Automation: Application in routine analysis
Automatic Preparation Module
Features:

- Grinding with or without bind sample
- Predefined procedures for typical materials (RM, CLI, CM)
- Simple entry of individual parameters
- One button operation
- Predefined special programs (only grinding, only pressing)
- Manual sample input
- Fine grinding mill
- Grinding aid dosing
- Tablet press
- Tablet cleaning
- Steel ring magazine
Compact module for automatic sample preparation
POLAB® APM: Automatic Sample Preparation Module

new machine with sample changer
Lab Automation – AXSLAB
Configuration: D4 with APMplus

Transfer of results via LAN,
e.g. to plant control system, LIMS system, Blending Software

APMplus
D4 ONLINE
AXSLab User Interface
Automation Control

Lan network
Thank you for attending!

Please provide feedback by completing our brief survey.

Also, please type any questions you may have in the Q&A panel.
Upcoming events:

Apr 20-24  ICMA, Reno, NV
May 7  Cement Solutions II Webinar: Improved C-114 Qualification with WDXRF
May 18-22  IEEE/PCA, Miami, FL
Oct 5-9  MS&T, Pittsburgh, PA