Quality Assurance of Cement from Production to Construction

Presented by: K.K. Choi
14th February 2006
Content

- Cement Standard in HK
- Cement Manufacturing Process
- Quality Assurance Planning
- Quality Control Schemes
Quality Planning

QUALITY PLANS:
- Product Specification
- Process Specification
- Procedures
- Sampling & Testing Plans
- Work Instruction/Records
- Testing Data QA

National Standards
Customer Requirements
Market Positioning
Raw Material Constrains
Process Constrains
## Cement Standard Migration

<table>
<thead>
<tr>
<th>Portland Cement Standard</th>
<th>HK Adoption year</th>
</tr>
</thead>
<tbody>
<tr>
<td>BS12:1989</td>
<td>1992</td>
</tr>
<tr>
<td>BS12:1991</td>
<td>-</td>
</tr>
<tr>
<td>BS12:1996</td>
<td>2003</td>
</tr>
<tr>
<td>BSEN197-1:2000</td>
<td>2005</td>
</tr>
</tbody>
</table>
### Major Changes since BS12:1991

<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td><strong>Test method</strong></td>
<td>Mortar and Concrete cube tests to BS4550</td>
<td>Mortar prism test to EN196</td>
</tr>
<tr>
<td><strong>Classification</strong></td>
<td>By Fineness and early strength, into CFPC, OPC and RHPC</td>
<td>4 major Strength Classes in BS, and 3 major strength classes in BSEN197:2000</td>
</tr>
<tr>
<td><strong>Minor constituents</strong></td>
<td>Not permitted</td>
<td>Up to 5%</td>
</tr>
<tr>
<td><strong>Compliance</strong></td>
<td>Based on single sample and single test. Compliance based on absolute limits</td>
<td>Employs statistical method in strength class classification, and Single Sample Acceptance based on deviations.</td>
</tr>
</tbody>
</table>
Conformity Criteria

For class 52.5 N

- 2 days strength: 18.0, 20.0
- 28 days strength: 50.0, 52.5

P <= 5%

LL_{SS} > LL_{AutoControl} + K_A \times S

P <= 10%

K_A is no. of test dependent
S is standard Deviation
### Target 28 days’ Strength

<table>
<thead>
<tr>
<th></th>
<th>SD = 2.5</th>
<th>SD = 1.8</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of test = 310</td>
<td>57.00</td>
<td>55.74</td>
</tr>
<tr>
<td>(P_k = 1.80)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. of test = 55,</td>
<td>57.68</td>
<td>56.23</td>
</tr>
<tr>
<td>(P_k = 2.07)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Reduce SD = Reduce target 28 d strength
= Reduce production cost
= Improve operation stability
What is Cement?

- Cement - A finely ground powder which has hydraulic properties when mix with water.
- It is the most essential element in concrete for civil structures.

**Typical C40 Concrete Composition**

- Cement: 18%
- Water: 7%
- Aggregates: 75%
- Admixture: 0%
What’s Inside the Cement

Clinker

Inter-grinding

Additives
- Such as Flyash, Limestone
- Performance modifier

Gypsum

Cement Clinker
- Major strength contributor

Gypsum
- Regulate the setting properties
Typical Type I Cement Clinker

**C₃S & C₂S**
- Calcium Silicates, \(xCaO.SiO_2\)
- Amount up to 72-78%
- Strength contributor

**C₃A & C₄AF**
- \(3CaO.Al_2O_3\), \(4CaO.Al_2O_3.Fe_2O_3\)
- Flux for the pyroprocess

Such as free lime, MgO, Alkali, sulphates
Composition

Type I cement clinker

<table>
<thead>
<tr>
<th>Element</th>
<th>Composition</th>
</tr>
</thead>
<tbody>
<tr>
<td>C₃S</td>
<td>45 - 65 %</td>
</tr>
<tr>
<td>CₓS</td>
<td>72 - 78 %</td>
</tr>
<tr>
<td>C₃A</td>
<td>8 - 12 %</td>
</tr>
<tr>
<td>C₄AF</td>
<td>10 - 11 %</td>
</tr>
</tbody>
</table>

Elementary Composition

<table>
<thead>
<tr>
<th>Element</th>
<th>Composition</th>
</tr>
</thead>
<tbody>
<tr>
<td>CaO</td>
<td>63 66 %</td>
</tr>
<tr>
<td>SiO₂</td>
<td>20 23 %</td>
</tr>
<tr>
<td>Al₂O₃</td>
<td>4 6 %</td>
</tr>
<tr>
<td>Fe₂O₃</td>
<td>3 4 %</td>
</tr>
</tbody>
</table>

Bogue’s formulas for calculating potential composition

<table>
<thead>
<tr>
<th></th>
<th>CaO</th>
<th>SiO₂</th>
<th>Al₂O₃</th>
<th>Fe₂O₃</th>
</tr>
</thead>
<tbody>
<tr>
<td>C₃S</td>
<td>+4.071</td>
<td>-7.602</td>
<td>-6.719</td>
<td>-1.430</td>
</tr>
<tr>
<td>C₂S</td>
<td>-3.070</td>
<td>+8.602</td>
<td>+5.068</td>
<td>+1.079</td>
</tr>
<tr>
<td>C₃A</td>
<td></td>
<td></td>
<td>+2.650</td>
<td>-1.692</td>
</tr>
<tr>
<td>C₄AF</td>
<td></td>
<td></td>
<td></td>
<td>+3.043</td>
</tr>
</tbody>
</table>
# Cement Processes

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td><strong>I</strong></td>
<td>Quarrying</td>
<td>Provide raw material</td>
</tr>
<tr>
<td></td>
<td>Proportion of Raw Material</td>
<td>Provide correct chemistry</td>
</tr>
<tr>
<td><strong>II</strong></td>
<td>Raw Grinding</td>
<td>Provide surface area for heating process</td>
</tr>
<tr>
<td></td>
<td>Precalcination</td>
<td>Decomposition of $\text{CaCO}_3$ to $\text{CaO}$</td>
</tr>
<tr>
<td></td>
<td>Sintering</td>
<td>Formation of Clinker mineral</td>
</tr>
<tr>
<td><strong>III</strong></td>
<td>Finish Grinding</td>
<td>Provide surface area for cement hydration and properties modification</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Clinker</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cement</td>
<td></td>
</tr>
</tbody>
</table>
Quarrying

△ Most limestone quarry are not uniform
△ Origin from organisms like corals, algae in “Shallow marine carbonate platform”
△ Complex structure due to formation mechanism, faults, foldings.

Quarry planning

- Resource conservation – Overburdens, Low Ca layers, High MgO layers, Gypsum
- Controls of harmful elements, such as Alkali, Chloride, MgO
Pre-blending & Homogenizing

- Further reduce quality variation from quarry
- Applicable to limestone, clay, coal
Raw Meal Proportioning

- **Raw Mix design**
  - Clinker performance – Bogue’s formulas
  - Burnability – Free lime VS temperature
  - Coal ash correction
  - Cost
- **Control parameters** – LSF, S/R, A/R
- **Material dosing, drying and grinding**
Impact Flowmeter

- Total enclosure, ideal for powder
- Less accurate
Belt Weight Feeder

Flow (tph) = Weight x Speed

Accuracy: Better than 1%

Suitable for very high flow rate
Coriolis Flowmeter

Flowrate * Angular speed * Radius^2 = Torque
Totally enclosure, ideal for powder
Very accurate: For Coal, Cement Additives Dosing
Typical Close Circuit Raw Grinding with High Efficiency Separator

Main Components
- Limestone
- Clay, Flyash

Correctives
- Si
- Fe

Components
- Raw mill
- Belt analyzer
- XRF analyzer
- Product
- KilnFeed
- Homo Silo

Correctives
- Si
- Fe

Main Components
- Limestone
- Clay, Flyash
# Raw Mill Controls

<table>
<thead>
<tr>
<th>Processes</th>
<th>Objectives</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw Material Dosing</td>
<td>✷ Ensure correct potential clinker chemistry</td>
</tr>
<tr>
<td>Raw meal fineness</td>
<td>✷ Ensure proper heat transfer in Preheater</td>
</tr>
<tr>
<td>Coal ash analysis</td>
<td>✷ Provide data for ash correction</td>
</tr>
</tbody>
</table>
Typical Precalciner-Kiln System

100-400 °C: Escape of adsorbed water

600-900 °C: Decomposition of clay, metakaolinites & others, with formation of reactive oxide mixture

800-1000 °C: Decomposition of CaCO₃, with formation of CS, CA, CA + 2C \rightarrow C₃A, C₂S + C \rightarrow C₃S

CA + 3C + F \rightarrow C₄AF

CS + C \rightarrow C₃S

2C + S \rightarrow C₂S
Cement Kiln Controls

**Combustion air control**
- Reduce excess air
- Prevent reducing atmosphere (Fe²⁺ formation)

**Precalciner temperature control**
- Provide reactive oxide for sintering
- Reduce kiln thermal loading

**Burning zone temperature control**
- Reduce residue free lime
- Complete transform C₂S to C₃S

**Clinker cooling rate**
- Control crystal and glass formation
- Control of alite size
- Control periclase (MgO) crystal

Kiln Feed
- 380°C
- 80°C
- 600°C
- 750°C
- 870°C
- 1000°C
- 900°C
- 1450°C

To Clinker Silo 110°C
Typical Close Circuit Finish Grinding
With High Efficiency Separator

Gypsum dosing
- Control hydration reaction
- Obtain optimal dosing

Cement Cooling
- Control false setting during storage

Cement Silo

Additives dosing
- Reduce strength deviation
- Regulate strength

Mill temperature control
- Control false setting during grinding
Comparison of Size distribution on Separator product

![Graph showing size distribution comparison](image-url)
## Comparison of Separator

<table>
<thead>
<tr>
<th></th>
<th>Blaine, cm²/g</th>
<th>45um residue, %</th>
<th>Specific Power Consumption, kWh/t</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open Circuit</td>
<td>3800</td>
<td>14%</td>
<td>-</td>
</tr>
<tr>
<td>Mechanical</td>
<td>3600</td>
<td>14%</td>
<td>49</td>
</tr>
<tr>
<td>Separator</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>H. E.</td>
<td>3200</td>
<td>8%</td>
<td>45</td>
</tr>
<tr>
<td>Separator</td>
<td></td>
<td></td>
<td>(-8%)</td>
</tr>
</tbody>
</table>
## Conflict between BS12:1989 & HE Separator

<table>
<thead>
<tr>
<th>Test items</th>
<th>BS12:1989 Limits</th>
<th>2002 Average</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>OPC</td>
<td>RHPC</td>
</tr>
<tr>
<td><strong>Fineness, m²/kg</strong></td>
<td>&gt;275</td>
<td>&gt;350</td>
</tr>
<tr>
<td><strong>Mortar Strength</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 days, MPa</td>
<td>&gt;25</td>
<td>&gt;25</td>
</tr>
<tr>
<td>28 days, MPa</td>
<td>&gt;47</td>
<td>&gt;52</td>
</tr>
<tr>
<td></td>
<td>&lt;67</td>
<td></td>
</tr>
</tbody>
</table>
Standards & Cement Process

- Auto-Control scheme of BS12:1991 provides incentives to reduce SD through QA.
- Provision of 5% additive enables better control of strength variation and cost saving.
- End-users are benefit from the addition of 5% pozzolanas.
Thank You