VCCTL at SCG

Pichet Sahachaiyunta
Wilasa Vichit-Vadakan, Ph.D.

3rd June 2013
Outline

• A little about our company...

• VCCTL Verification
  – On various different cements
  – On concrete with and without fly ash

• Use of ultrafine limestone to decrease cement content
SCG was established in 1913 following a royal decree of His Majesty King Rama VI to produce cement, a main building material for infrastructure projects that greatly contributed to the progress of the country during that period. The Group has diversified into five core businesses which include SCG Chemicals, SCG Paper, SCG Cement, SCG Building Materials, and SCG Distribution.

SCG, the sustainable development role model, has been ranked as Sector Leader in DJSI Building Materials & Fixtures by SAM. SCG has been in 'Gold Class', the highest group, for 4 consecutive years.
Business Units of SCG

Cement and Building Materials
Net sales: US$ 5.8 billion

Paper
Net sales: US$ 1.7 billion

Chemicals
Net sales: US$ 4.8 billion

Data from Annual Report 2010
<table>
<thead>
<tr>
<th>Product</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grey cement</td>
<td>24 Million tons</td>
</tr>
<tr>
<td>Ready-mixed concrete</td>
<td>19.00 Million cubic meters</td>
</tr>
<tr>
<td>Mortar</td>
<td>1.35 Million tons</td>
</tr>
<tr>
<td>White cement</td>
<td>0.16 Million tons</td>
</tr>
<tr>
<td>Refractory</td>
<td>0.15 Million tons</td>
</tr>
</tbody>
</table>
Outline

• A little about our company...
• VCCTL Verification
  – On various different cements
  – On concrete with and without fly ash
• Use of ultrafine limestone to decrease cement content
Measured vs. Modeled

**Data Input**
- Particle size distribution of cement, limestone & gypsum
- Surface area fraction & volume fraction
- Mass fraction of gypsum & limestone, alkali
- Air content
Phase Distribution

Input data: Cement

- Phase Distribution
- Cement Composition
- Particle Size Distribution

What? (Qualitative)

How much? (Quantitative)

Where?

XRF, XRD

SEM & EDS

Quantitative (%)
Measured vs. Modeled

Data Input
- Particle size distribution of cement, limestone & gypsum
- Surface area fraction & volume fraction
- Mass fraction of gypsum & limestone, alkali
- Air content

VCCTL Parameters
- Curing conditions
  - isothermal
  - adiabatic, etc.

ASTM C215
“Impact Resonance Method”

- Young’s modulus (E)
- Shear Modulus (G)
- Bulk modulus (K)
- Poison’s ratio (μ)
- Setting time [ASTM C191]
Modulus of Type I Cement
Moduli from Different Plants

SKK

STL

STS

wilasav@scg.co.th
Error in Modulus Prediction

More accurate when degree of hydration more than 40% (or 2 days)

+10% error

-10% error
## Setting Time

**Concept:** predicted by average solid fraction connected in system

<table>
<thead>
<tr>
<th>Sample</th>
<th>Initial Setting time (min)</th>
<th>Final setting time (min)</th>
<th>error in initial time (min)</th>
<th>error in final time (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SKK</td>
<td>Measured 113</td>
<td>225</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Modeled 123</td>
<td>223</td>
<td>+10</td>
<td>-2</td>
</tr>
<tr>
<td>STL</td>
<td>Measured 113</td>
<td>225</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Modeled 123</td>
<td>223</td>
<td>+10</td>
<td>-2</td>
</tr>
<tr>
<td>STS</td>
<td>Measured 98</td>
<td>240</td>
<td>-7</td>
<td>-17</td>
</tr>
<tr>
<td></td>
<td>Modeled 91</td>
<td>223</td>
<td>-7</td>
<td>-17</td>
</tr>
</tbody>
</table>


wilasav@scg.co.th
Type III Cement

Setting time

<table>
<thead>
<tr>
<th>Sample</th>
<th>Initial Setting time (min)</th>
<th>Final setting time (min)</th>
<th>error in initial time (min)</th>
<th>error in final time (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type III</td>
<td>Measured</td>
<td>65</td>
<td>150</td>
<td>4</td>
</tr>
<tr>
<td>Modeled</td>
<td>61</td>
<td>157</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>


wilasav@scg.co.th
Concrete mix design

- **Problem:** How about concrete?
- Thailand consistently use fly ash in 80-90% of commercially available concrete mixes and the inclusion
- Commercial grade concrete uses: Ready mixed concrete, precast (non-prestressed) units, precast prestressed concrete
- Use of modeling
  - Optimization of mix design
  - Impact of raw materials variation
  - Threshold for acceptability testing
From Past to Present...

- Mid 2010: Started implementing VCCTL to SCG
- 2011: Successfully used to predict properties of cement for us in cement and mortar plants
- 2012: Verification and exploration on concrete
NIST Target

1. C-S-H, nm
2. cement paste, μm
3. concrete, mm
4. structure, m
Bigger Scale, More Complicated

Data Inputs
- Cement
- Coarse aggregate
- Fine aggregate
- SCM: pulverized fly ash
- Admixture

Mix Conditions
- Mix design, w/b & gradation
- Curing condition
Data Inputs: Aggregate

1. Shape data

Coarse aggregate  Fine aggregate

(cubic & slab)

Data: length, width, thickness
Ratio: mean & range of L/T, W/T,

X-ray tomography “SkyScan”

50 pictures each of limestone
8,971 pictures of sand
Data Inputs: Aggregate

2. Modulus data

<table>
<thead>
<tr>
<th></th>
<th>Specific gravity</th>
<th>Bulk modulus (GPa)</th>
<th>Shear modulus (GPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Limestone (SKK)</td>
<td>2.70</td>
<td>67.3</td>
<td>31.5</td>
</tr>
<tr>
<td>Sand (refer to ASTM C33)</td>
<td>2.64</td>
<td>36.4</td>
<td>31.1</td>
</tr>
</tbody>
</table>
Data Input: Pulverized Fly Ash

- Power Plant: Mae-moh, Lampang, THA

Characterization
- Specific gravity
- Phase analysis
- Particle size distribution
Experiment

<table>
<thead>
<tr>
<th>Mix No.</th>
<th>Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mix#1</td>
<td>No fly ash</td>
</tr>
<tr>
<td>Mix#2</td>
<td>30% fly ash</td>
</tr>
</tbody>
</table>

Data from impact resonance apparatus

![Waveform Analyzer or Frequency Counter](image-url)

**FIG. 2 Schematic of Apparatus for Impact Resonance Test**
Mix#1: No fly ash
Mix#2: 30% Fly Ash
Error

<table>
<thead>
<tr>
<th>Mix No.</th>
<th>Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mix#1</td>
<td>No fly ash</td>
</tr>
<tr>
<td>Mix#2</td>
<td>30% fly ash</td>
</tr>
</tbody>
</table>

![Graph showing error over time for Mix#1 and Mix#2 with different markers for Young's modulus.](image-url)
Another Case Study

Utilization of superfine limestone in concrete fence

• Quality improvement
• Cost reduction
Modeling

- Simulation using VCCTL for concrete mix design of precast elements
  - ASTM C 150 Type I OPC ($X_{50} = 20 \, \mu m$)
  - Coarse aggregate (nominally 1”)
  - River sand
  - Superfine limestone ($X_{50} = 5 \, \mu m$)
- Superfine limestone replacement range of 5%, 10%, 15% and 20%

wilasav@scg.co.th
Results: Young’s modulus Index

Optimum point is 10% replacement

Note: fixed w/c (0.67)
Upcoming Applications

SCG conglomerate

• Optimization of mix design
• Impact of raw materials variation
• Etc.

wilasav@scg.co.th
Questions?