Reactivity analysis of high calcium fly ash as raw material for non-traditional, fly ash-based binders

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CeraTech, Inc.
Technology overview

Cement Manufacturing Process Comparison
(To Produce One Ton of Cement)

CO₂

Ordinary Portland Cement

Raw Material Mining 3500 Lbs.
6,000,000 BTU’s Required

Coal Burning Utility
Waste Stream (Coal Ash)

CERATECH Admixtures

CERATECH
Rapidly Renewable Resource
Liquids Blender

Concrete Producer
Construction Project
Quality control

QC Tools

• Beyond pass-fail
• Deliver concrete with consistent set time and strength
• Quantify reactivity and relate to the effect in the concrete mix. Quantify reactivity-quantify adjustments
• Deliver green concrete, quality and consistency
HC Fly ash

- Silica, calcium oxide, alumina and iron oxide
- Mostly amorphous
- Crystalline components can be considered relatively inert
- MPS: 20 microns on avg
- Reactivity depends on glassy phase content and composition
Reactivity study

- 20 Fly ash samples

- Fly ash variables: XRF, XRD, PSD

- ASI and NBO/T calculated from the total oxide content as measured by XRF

- Response: Compressive strength @ 1 day
## Chemical analyses

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| min     | 1.49   | 4.68 | 15.5       | 29.3   | 0.64     | 1.1    | 0.27  | 23.9  | 1.12   | 4.84    | 0.05 | 0.33 | 0.04   | 0.61| 0.3 |
| max     | 4.43   | 9.29 | 20.1       | 37.4   | 1.18     | 2.94   | 0.53  | 30.1  | 1.57   | 7.68    | 0.07 | 0.54 | 0.05   | 0.92| 2.5 |
| Avg     | 2.28   | 5.90 | 17.79      | 34.14  | 0.94     | 1.82   | 0.42  | 27.33 | 1.35   | 5.91    | 0.06 | 0.40 | 0.04   | 0.71| 0.66|
XRD
PSD
Compressive strength
Stepwise regression
Glass science basics

**Network Formers**
Si, Al, Fe

**Network Modifiers**
K, Na, Ca, Mg
ASI and NBO/T

\[
ASI = \frac{Al_2O_3}{Na_2O + K_2O + CaO + MgO}
\]

\[
\frac{NBO}{T} = \frac{2(Na_2O+K_2O+CaO+MgO-Al_2O_3)}{SiO_2+Al_2O_3+Fe_2O_3}
\]
ASI and NBO/T

\[ ASI = \frac{Al_2O_3}{Na_2O + K_2O + CaO + MgO} \]

\[ \frac{NBO}{T} = \frac{2(Na_2O + K_2O + CaO + MgO - Al_2O_3)}{SiO_2 + Al_2O_3 + Fe_2O_3} \]

Compressive strength @ 1 day (psi)

ASI

NBO/T
ASI and NBO/T

\[
ASI = \frac{Al_2O_3}{Na_2O + K_2O + CaO + MgO}
\]

\[
\frac{NBO}{T} = \frac{2(Na_2O + K_2O + CaO + MgO - Al_2O_3)}{SiO_2 + Al_2O_3 + Fe_2O_3}
\]
ASl and NBO/T

\[
ASl = \frac{Al_2O_3}{Na_2O + K_2O + CaO + MgO}
\]

\[
\frac{NBO}{T} = \frac{2(Na_2O+K_2O+CaO+MgO-Al_2O_3)}{SiO_2+Al_2O_3+Fe_2O_3}
\]
Assumptions and restrictions

- No Crystalline phases (100% Glass)
- Free energy of hydration not considered
- Constant physical characteristics
- Homogeneity
- Compositional range
- Fe is always acting as a network former
Other sources of variability

• Redox state or Fe — Fe (II) has much lower FEH than Fe (III)

• P2O5 in concentrations near as low as 1% can have profound effects on liquidus phase relations and transport properties [Willie an Tuttle, 1964; Toplis et al., 1994; Wolf and London, 1994]

• TiO2 can occur in a 4-fold coordination and substitute Si to act as a network former, it can also be coordinated with more than 4 oxygens and act as a network modifier
Despite the assumptions
In practical terms
Questions??