US Experience and Future Potential Use of Local Clay Materials as an SCM

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NEED FOR CALCINED CLAY

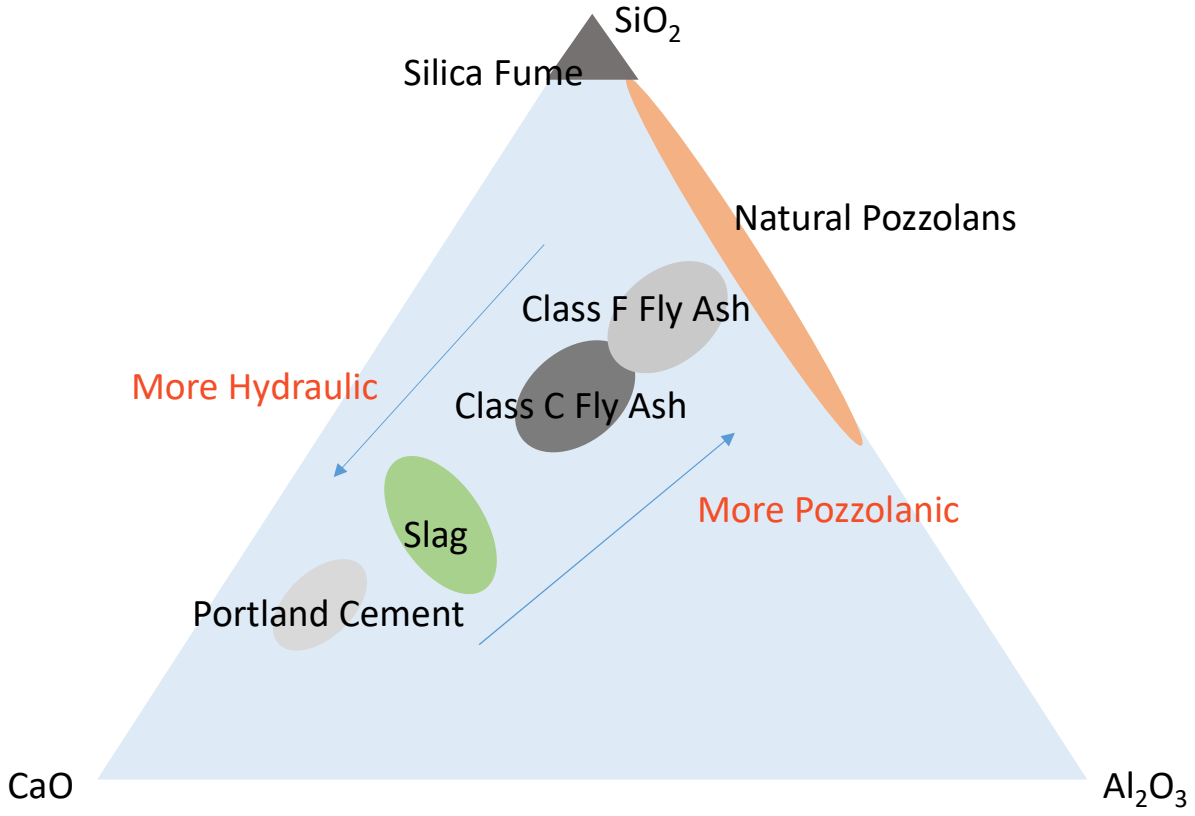
HISTORICAL USE

CALCINED CLAY AVAILABILITY

DURABILITY

MARKET STRATEGY

SCM Options



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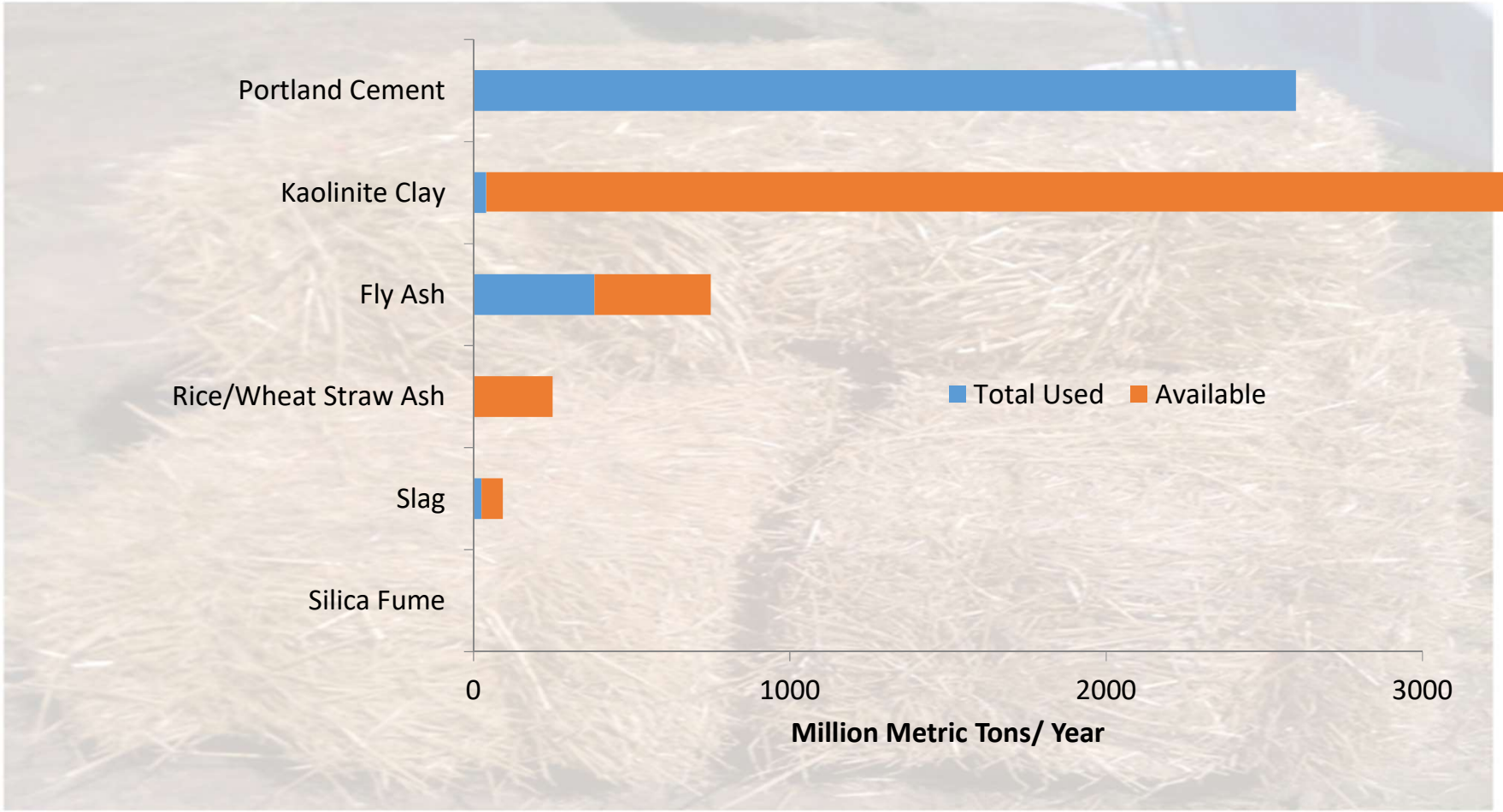

Golden Gate Bridge (1933-1937)

- Santa Cruz Portland Cement Co. – starting in 1932 produced a calcined Monterrey Shale blended cement.
- 336,500 barrels used in Golden Gate Bridge and San Francisco-Oakland Bay Bridge
- Selected for use because of sulfate resistance and lower heat generation (Meissner 1950)

Davis Dam

Built in 1950

From Elfert 1974:

Clays and shales used were:

- Superior with reactive expansion and permeability
- Moderate effect on strength and temperature rise
- Had high water requirement
- Used calcined opaline shale because of cost and reactive expansion

Historical Data – Heat of Hydration (Elfert 1974)

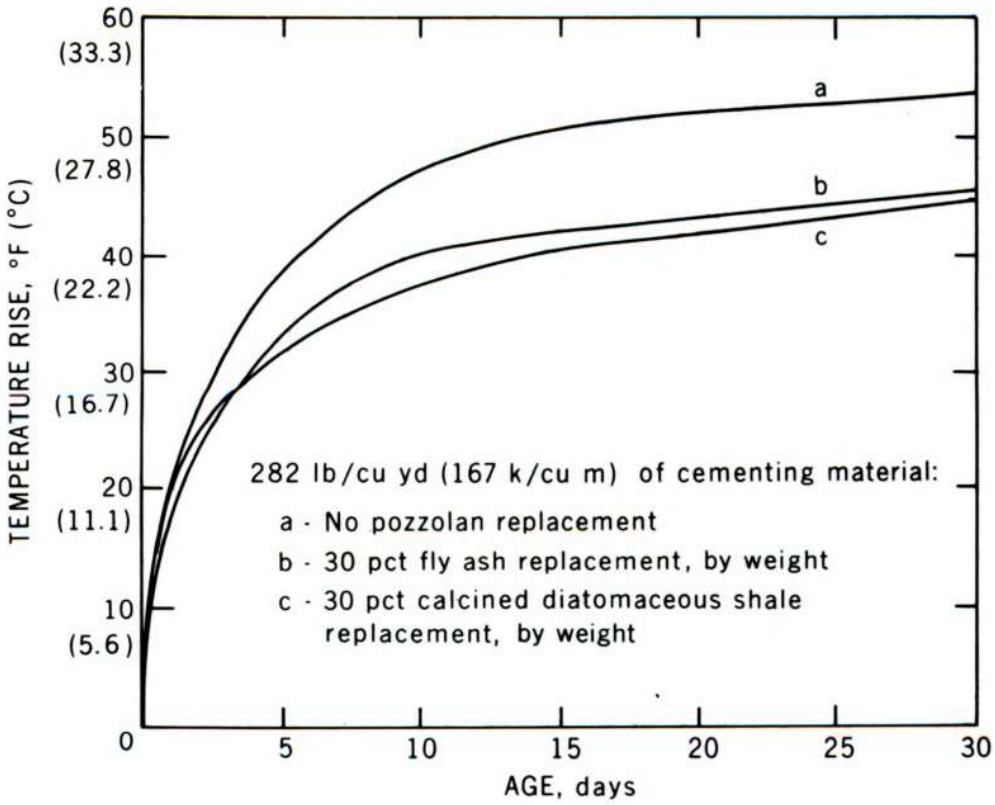

FIGURE 10. - Effect of pozzolan on temperature rise of concrete.

Historical Data: ASR Reactivity (Elfert 1974)

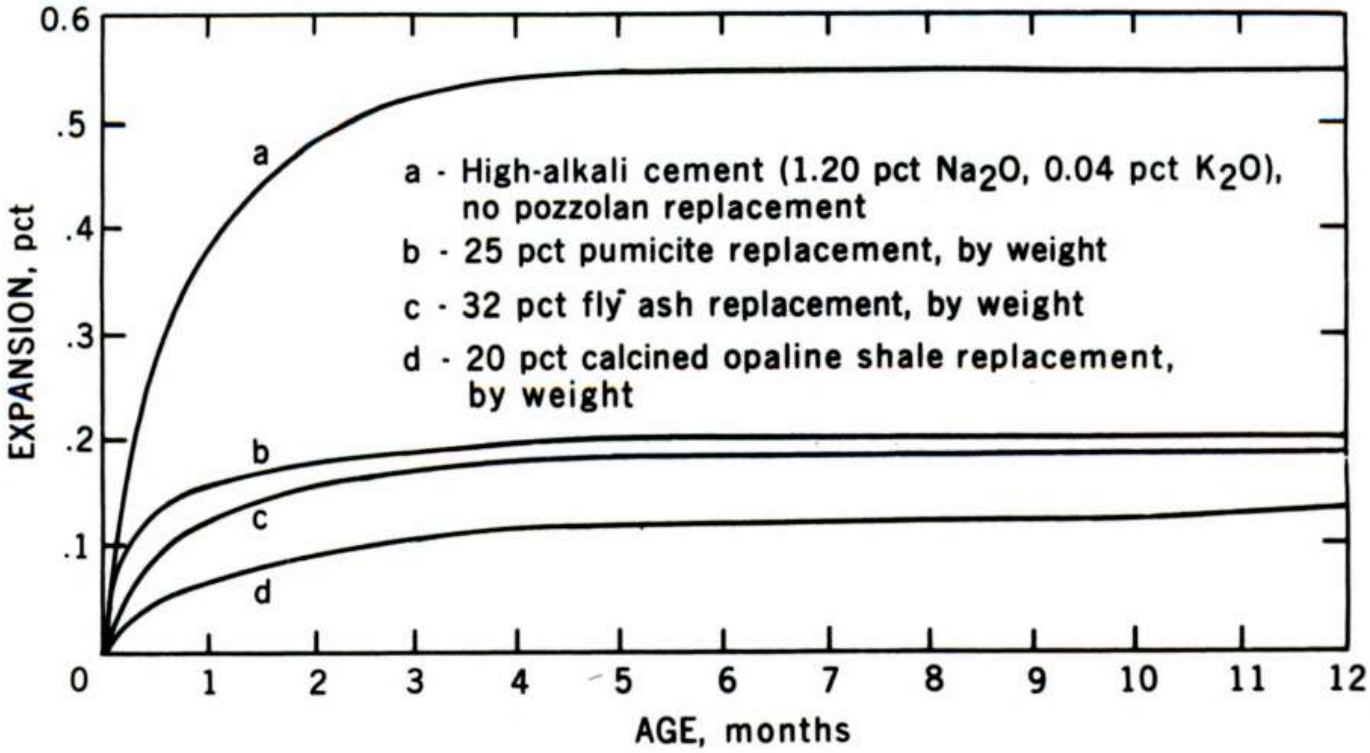

FIGURE 14. - Effect of pozzolan on reactive expansion of mortar made with alkali cement and crushed Pyrex glass sand.

Hungry Horse Dam (1948-1952)

- First major structure built with fly ash in U.S.
- Able to ship fly ash from Chicago to Montana for half the cost of portland cement (Meissner 1950)
- Cheap fly ash reduced demand for natural pozzolans in United States

Calcined Pozzolans: More Recent Use

- Calcined shale use in Virginia and Pennsylvania 1996-2004 (stopped making it because of plant issues, not because of material) (ACI 232.1R-12)
- Ashgrove cement produced a calcined clay with 85-90% metakaolin content beginning in 1993 and lasting several years[1]
- Most companies focused however on making very highly reactive metakaolin for high performance applications
- Some “metakaolins” are actually 60-70% kaolinite
- Get synergistic reaction when used in conjunction with limestone – higher strengths, better durability with lower clinker/portland cement use and lower GHG footprint

[1]Barger, G., Hansen, E., Wood, M., Neary, T., Beech, D., and Jaquier, D., "Production and Use of Calcined Natural Pozzolans in Concrete," *Cement, Concrete and Aggregates*, Vol. 23, No. 2, 2001, pp. 73-80, https://doi.org/10.1520/CCA10478J. ISSN 0149-6123

Kaolinite Availability in U.S.

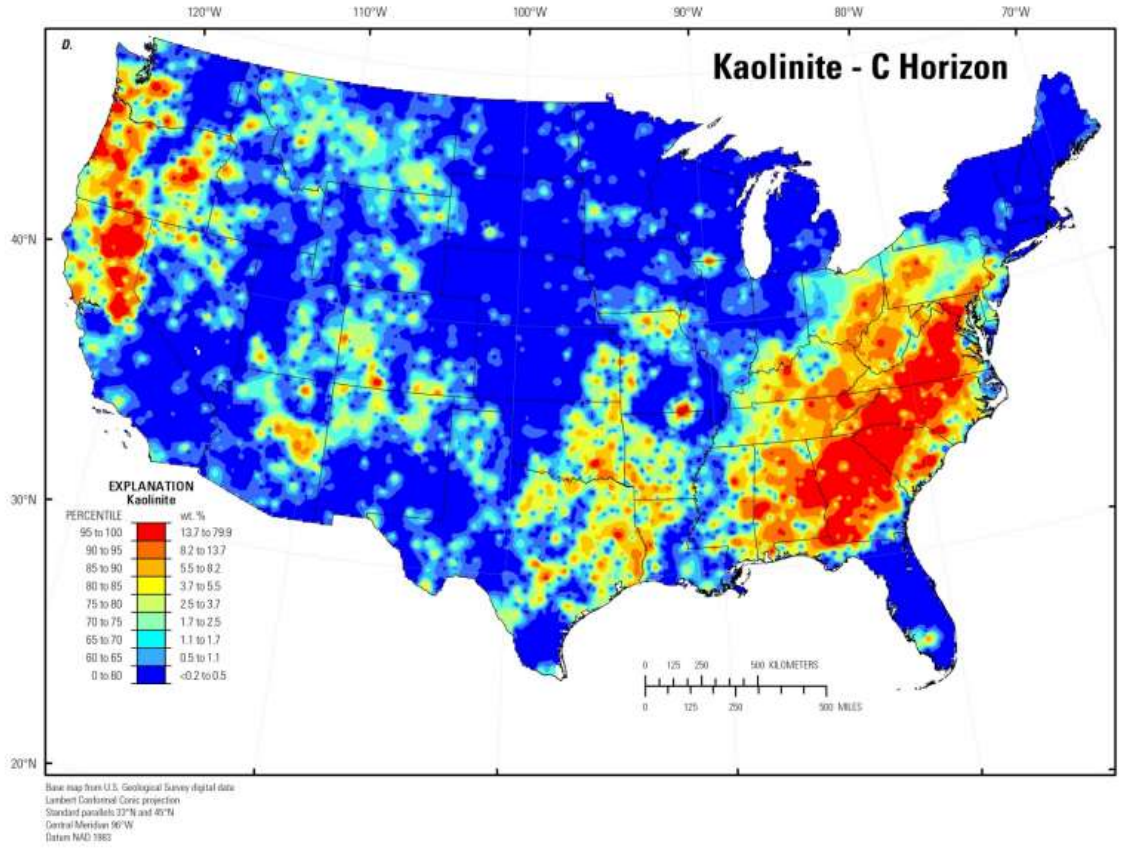

Figure 153. *A*, Histogram and summary statistics; *B*, Boxplot; *C*, Empirical cumulative distribution function; and *D*, Distribution of kaolinite in the soil C horizon, conterminous United States (LLD, lower limit of determination; wt. %, weight percent).—Continued

Figure from USGS, 2014 "Geochemical and Mineralogical Maps for Soils of the Conterminous United States"

Kaolin Clay Sources

- Florida survey performed by USF last year
- Samples from 9 mines taken and analyzed
- Sand content (% > 45 µm sieve) between 65 and 90%
- Of the fraction passing 45 µm sieve, 75 – 94% kaolinite
- Study found that clays can pass strength activity index

Figure from A. Zayed, N. Shanahan, A. Sedaghat, Y. Stetsko, and B. Lorentz "Development of Calcined Clays as Pozzolanic Additions in Portland Cement Concrete Mixtures"

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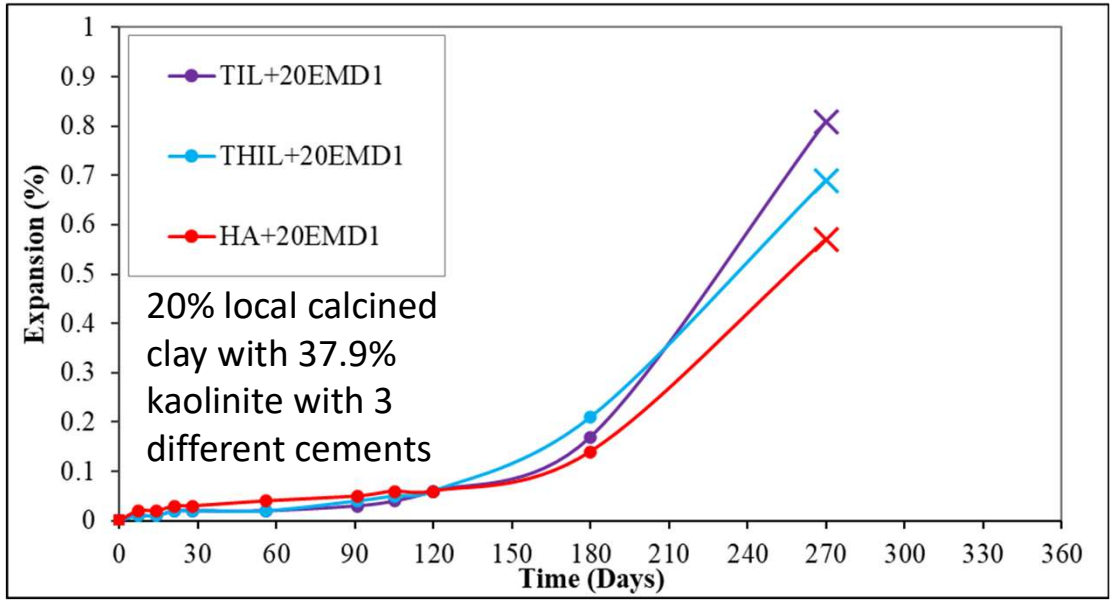
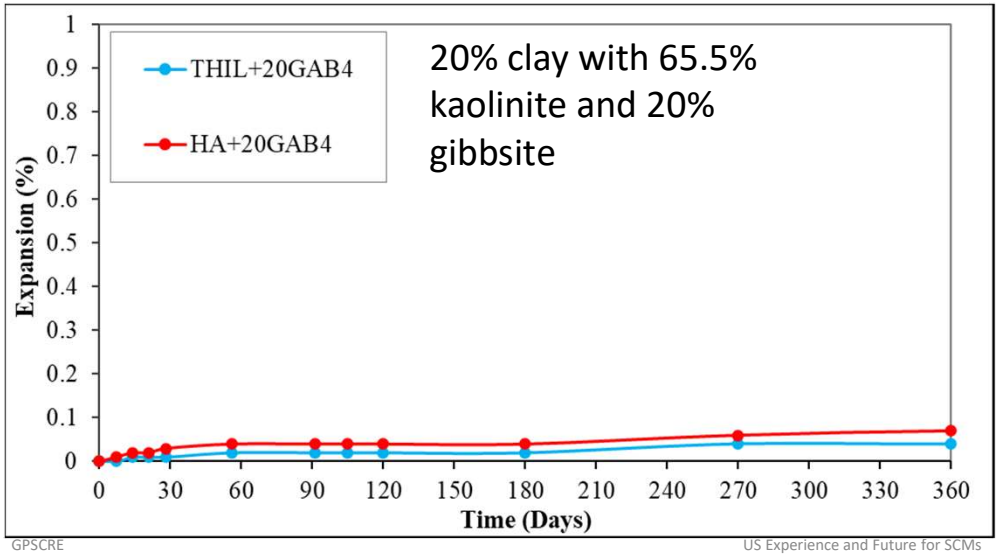
Kaolin Quality

Durability

ASTM C1012 Sulfate Attack Mortar Bars in 5% Sodium Sulfate Solution





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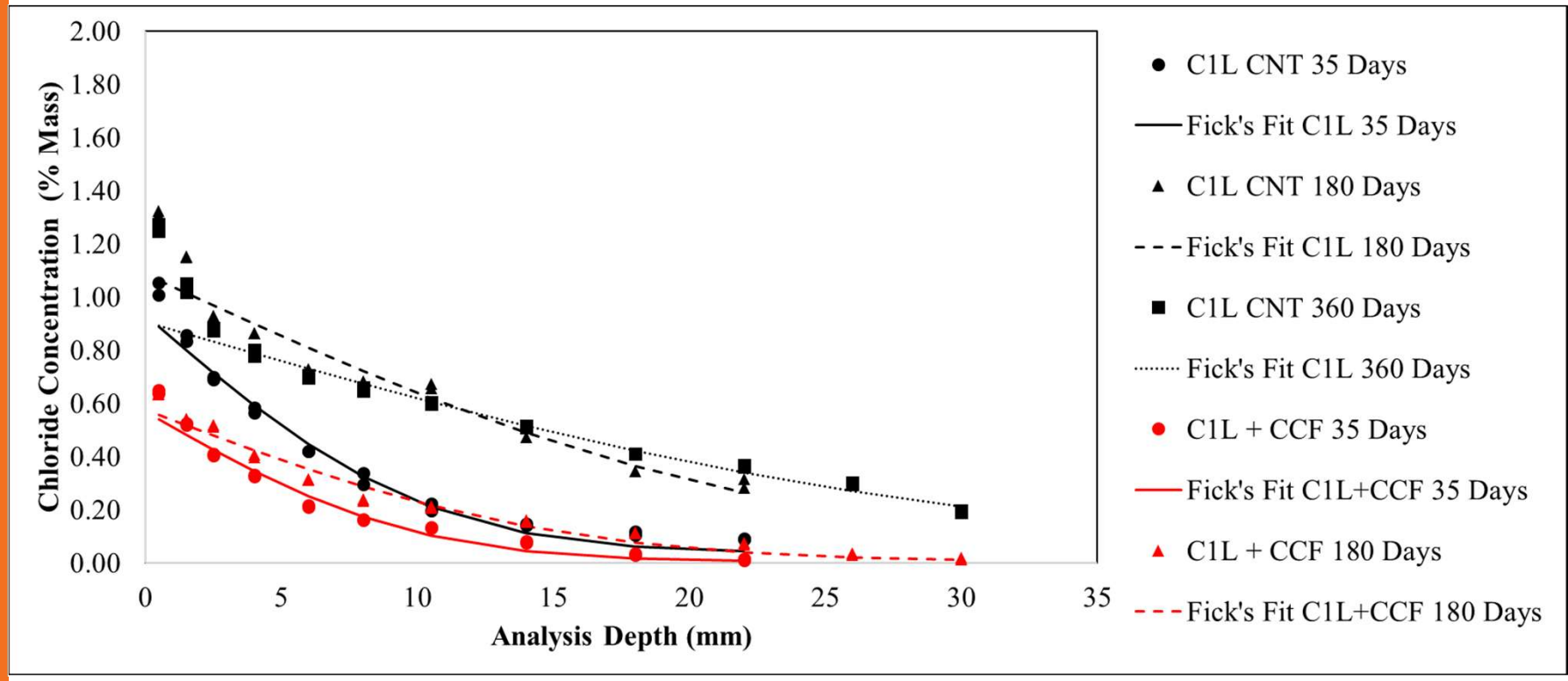
Chloride Penetration Resistance



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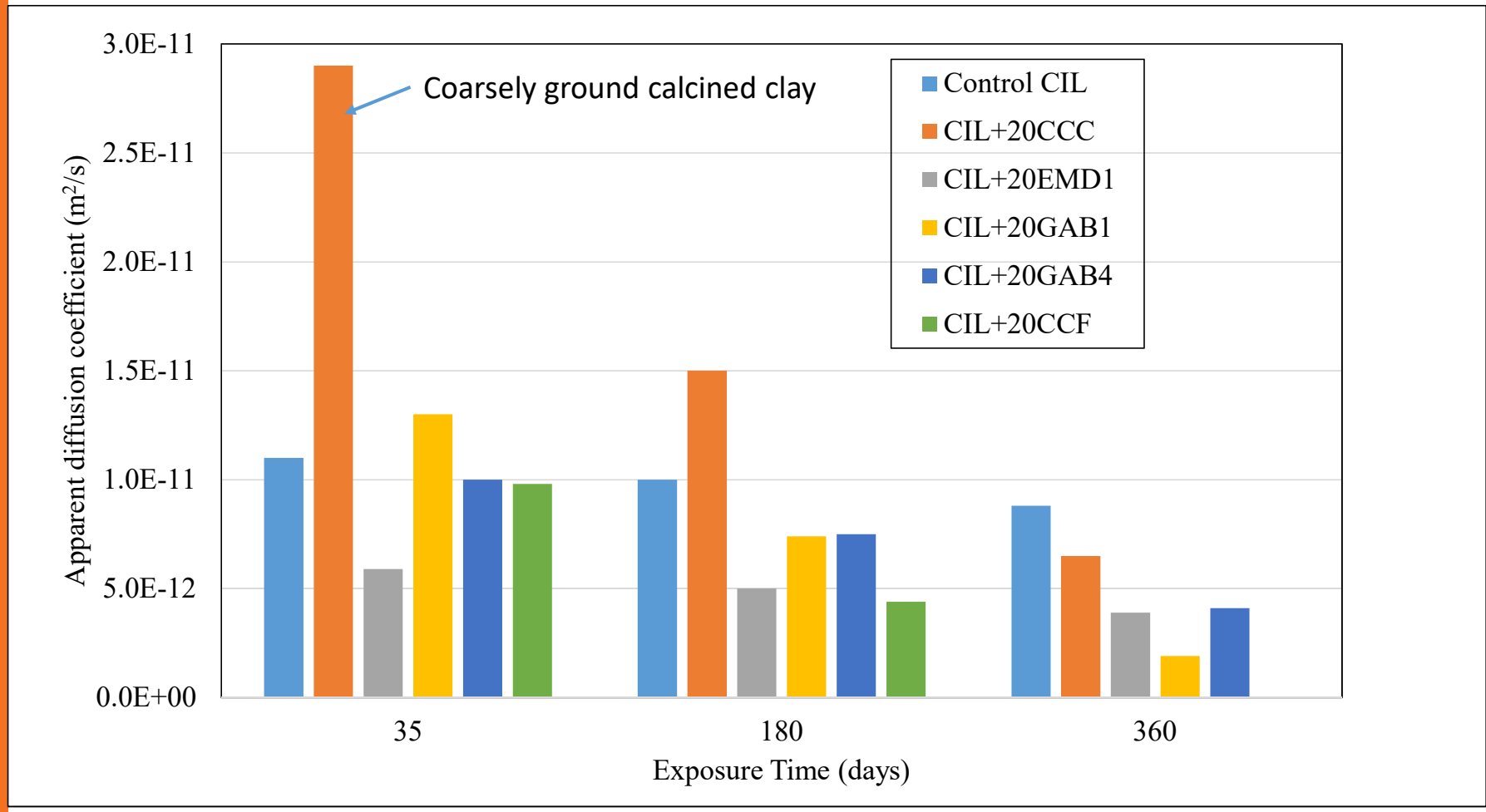


Considerations For Manufacture

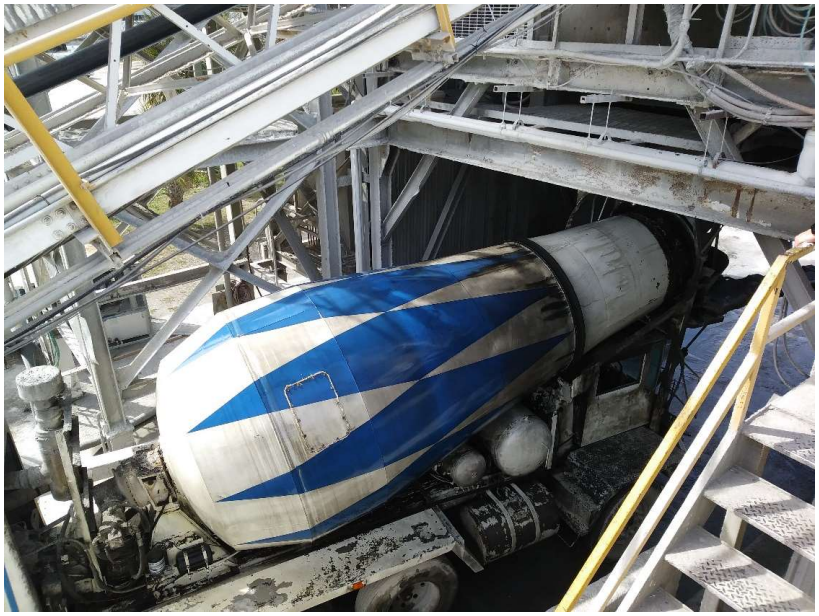
- While calcined clay manufacture can cost 1/3 to ½ that of Portland cement, need to overcome the inertia of several things:
- Capital costs of kiln
  - Can repurpose unused cement kiln with some modifications (need to control oxygen content to control color for example)
- Grinding
  - Cement plant grinding limited?
  - Co-grinding with cement?
  - Grinding aids? Can utilize superplasticizer as grinding aid, but raises cost
- Storage silo at cement plant?

Ready-Mixed Concrete Impacts

- Calcined clay could be sold as a blended cement (ASTM C595) or natural pozzolan (ASTM C618 Class N), could also be sold as ASTM C1709 alternative SCM
- CCIL – blend calcined clay at the ready-mixed plant with Type IL cement
- CCIL Example:
  - Type IL cement: 82% clinker, 14% limestone fines, 4% $CaSO_4$
  - ASTM C618 Class N pozzolan: 95 clay, 5% $CaSO_4$
  - For a 75% Type IL, 25% Class N mix:

Final CCIL Cementitious Contents
When Mixed @ Ready-Mixed Plant

Material	%
clinker	61.5
limestone	10.5
gypsum	4.25
clay	23.75



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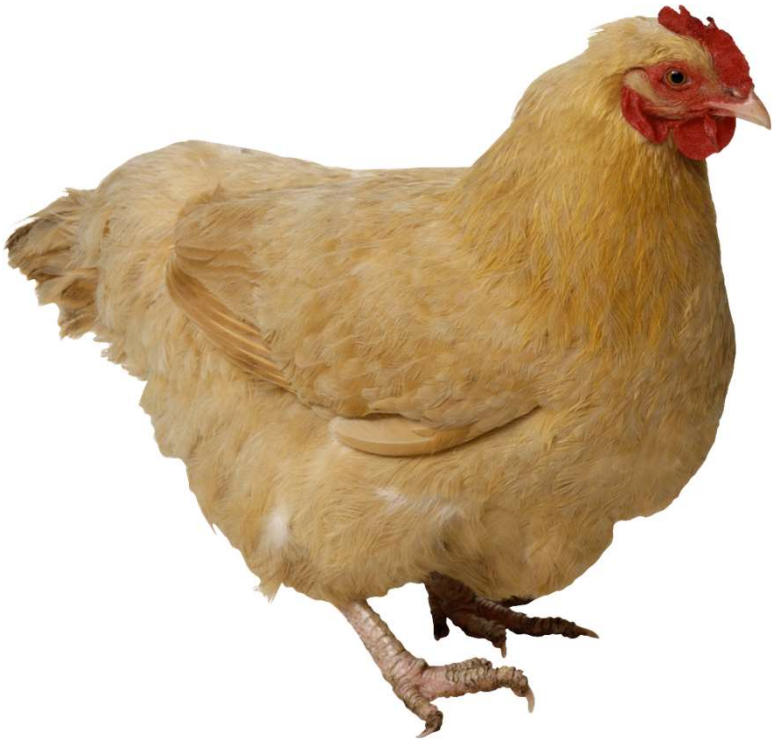
Ready-Mixed Concrete Impacts

- Whether blended, or added as an SCM at the plant, material will occupy a silo at the ready-mixed concrete plant
- Mix design for specialty cases may require additional blending depending on clay dosage (ie. mass concrete applications, UHPC, etc.)

Path Forward

- Demonstration projects needed to familiarize contractors, reduce risk & project cost



CCIL vs LC^3

CCIL advantages

- Customizable blends for the application
- US market prefers blending at the ready mixed plant
- Avoid patent issues (although license costs are low)
- Extend distance calcined clay can be transported profitably

LC^3 advantages

- Sulfate balance optimized
- Inter-grinding at plant thought to provide some strength benefits
- More optimum limestone – clay balance – could give slightly higher strength than CCIL

Acknowledgements

- FDOT, FHWA for funding work