Strength. Performance. Passion.

Laboratory Paste Mixtures as a Concrete Mix Design Tool

Proportioning Concrete Mixtures for use in the 21st Century

ACI 2013 Spring Convention, Minneapolis

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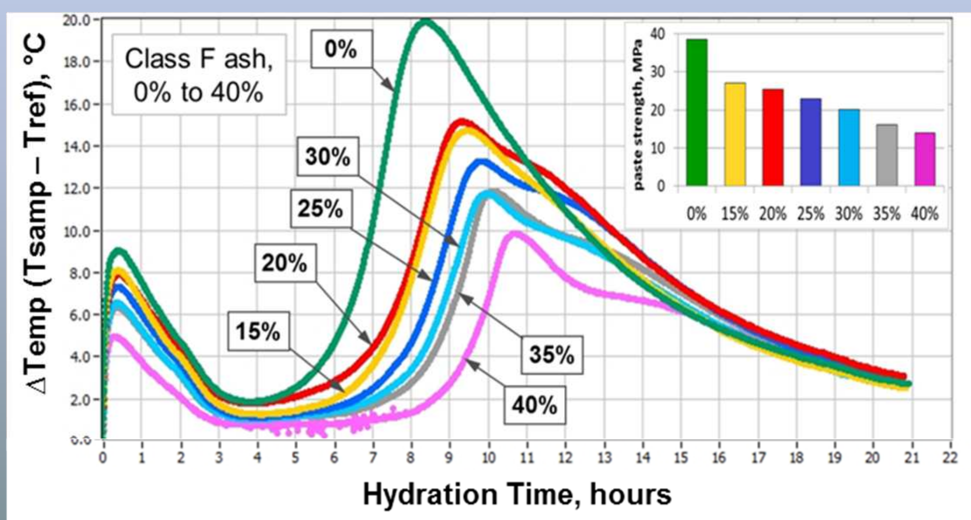

Laboratory paste mixtures as a concrete mix design tool

- ***Paste = cementitious materials + water + admixtures***
- ***Concrete = paste + aggregates***
- Premise: *paste* setting & strength development trends compare well to those of *concrete* for typical mixtures & performance ranges
  - Can be used to evaluate multiple component variables to guide proportioning & materials selection
  - Within certain bounds may be used to predict approximate concrete performance, develop preliminary mix designs
- Also useful for finding & fixing incompatibility potential
- Advantage: <u>much</u> less time & resources needed than for lab concrete mixtures to answer the same questions

Laboratory paste mixtures as a concrete mix design tool

- Approach: small batches of lab paste proportioned according to the paste fraction of envisioned concrete mixtures, batched using simple mixing protocols
  - Paste strengths at ages of interest
  - Thermal profiles for setting & hydration info
- How do the time and resource requirements compare (paste mixtures vs. lab concrete batches)?
  - Paste batches: - dozens can be done in a single morning
    - no penetrometer monitoring
    - modest equipment costs
    - thermal data can be processed using spreadsheets or special software

Are there ASTM standard methods for this? (pending…)

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Standard practice for

Evaluating early hydration of hydraulic cementitious mixtures using thermal measurements

1. Scope

1.1 This practice describes the apparatus and procedure for evaluating relative differences in early hydration of hydraulic c those containing chemical adı and other finely divided mater

1.2 Calorimetry is the mea cement hydration; calorimetri evaluate hydration and related under isothermal conditions (a adiabatic conditions. This pra made to measure the heat evo be used for similar evaluation application of this practice are

Designation: X XXXX-XX

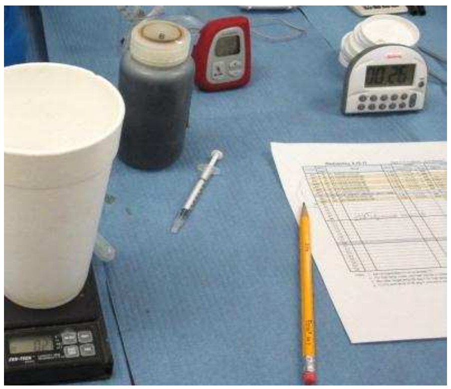
Work Item Number: 21221

Date: 12/4/2012

Standard Practice for indication of early-age mechanical properties of cementitious mixtures by temperature measurements[1]

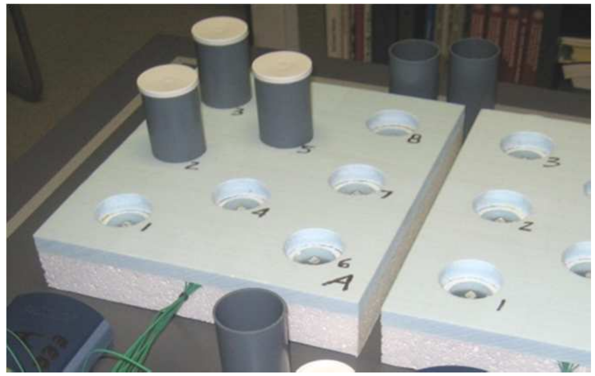
This standard is issued under the fixed designation X XXXX; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

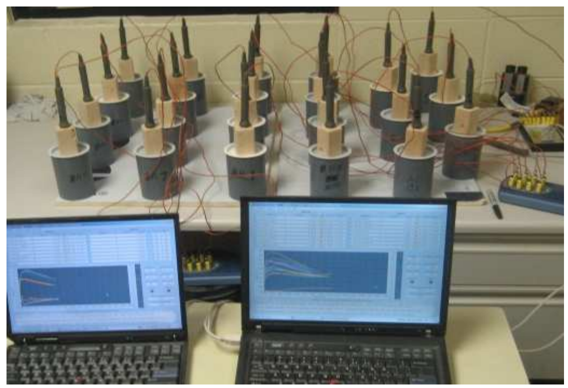
Lab paste mixture batches – equipment and procedures



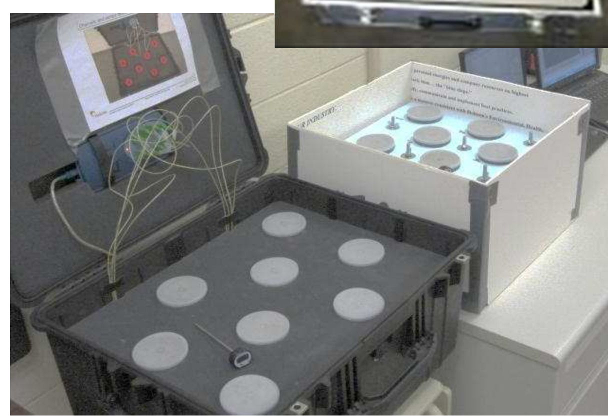
With two technicians working: one mix every 4-5 minutes = 48 mixes in a morning (3-1/4 to 4 hours)

Some equipment variations, manufactured and adapted

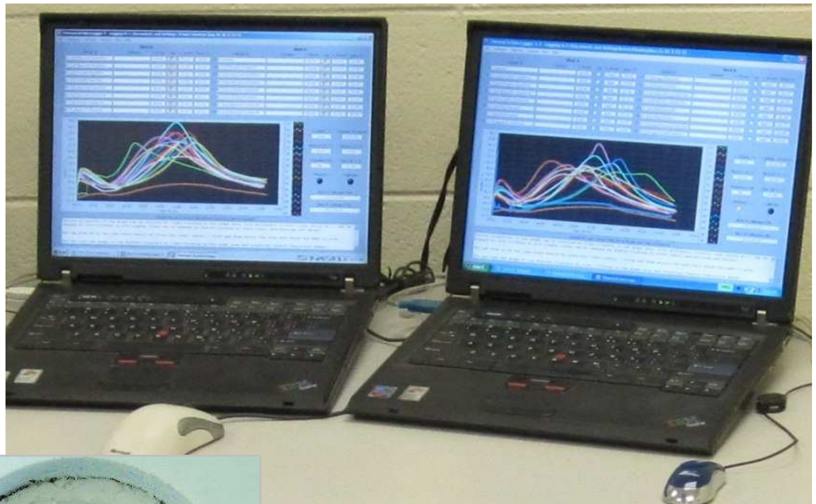



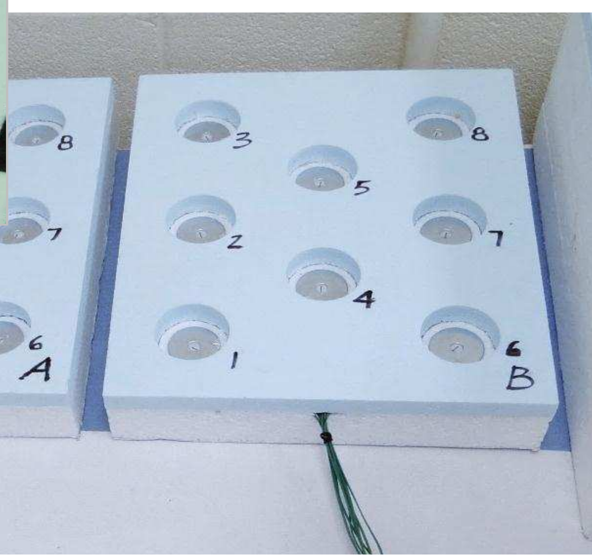







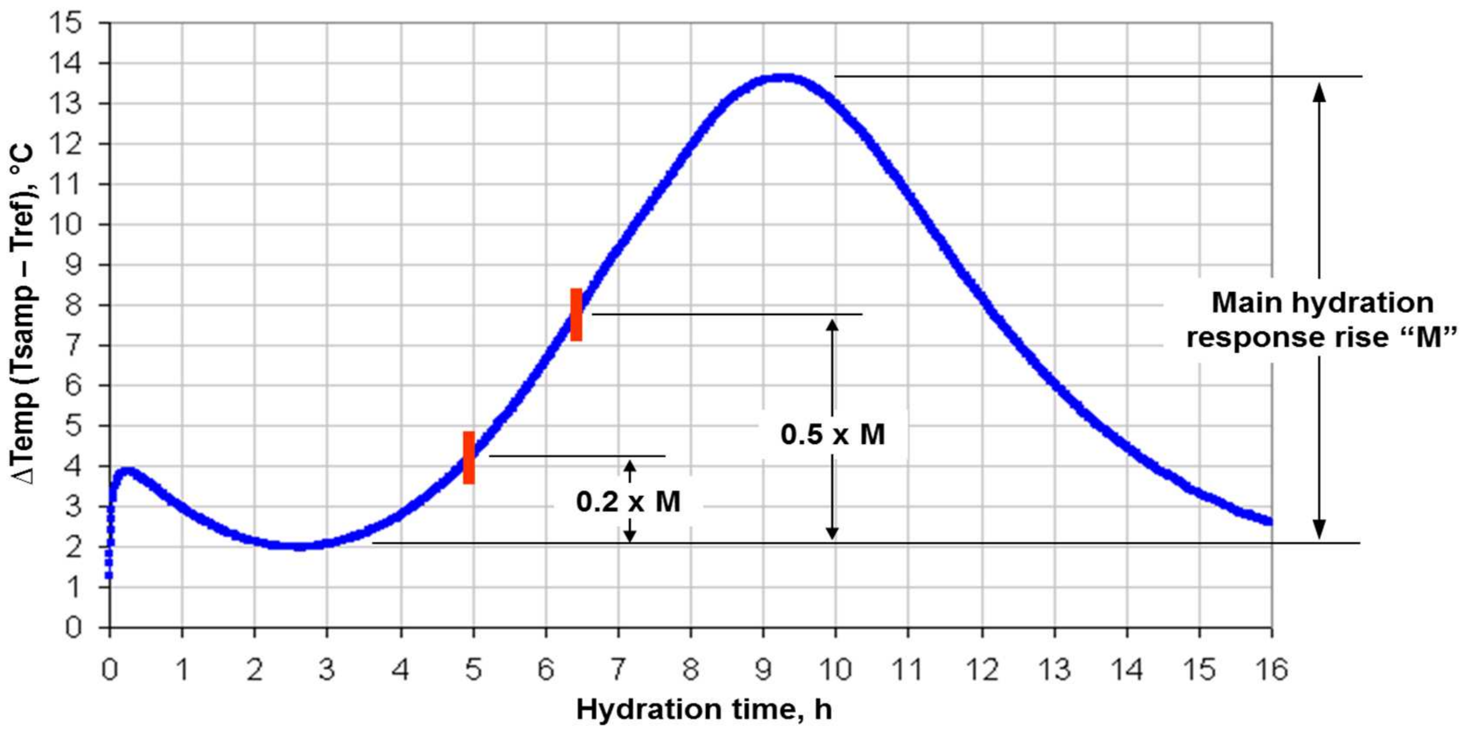
Data collection setups currently used





Comparing setting influences using thermal profiles

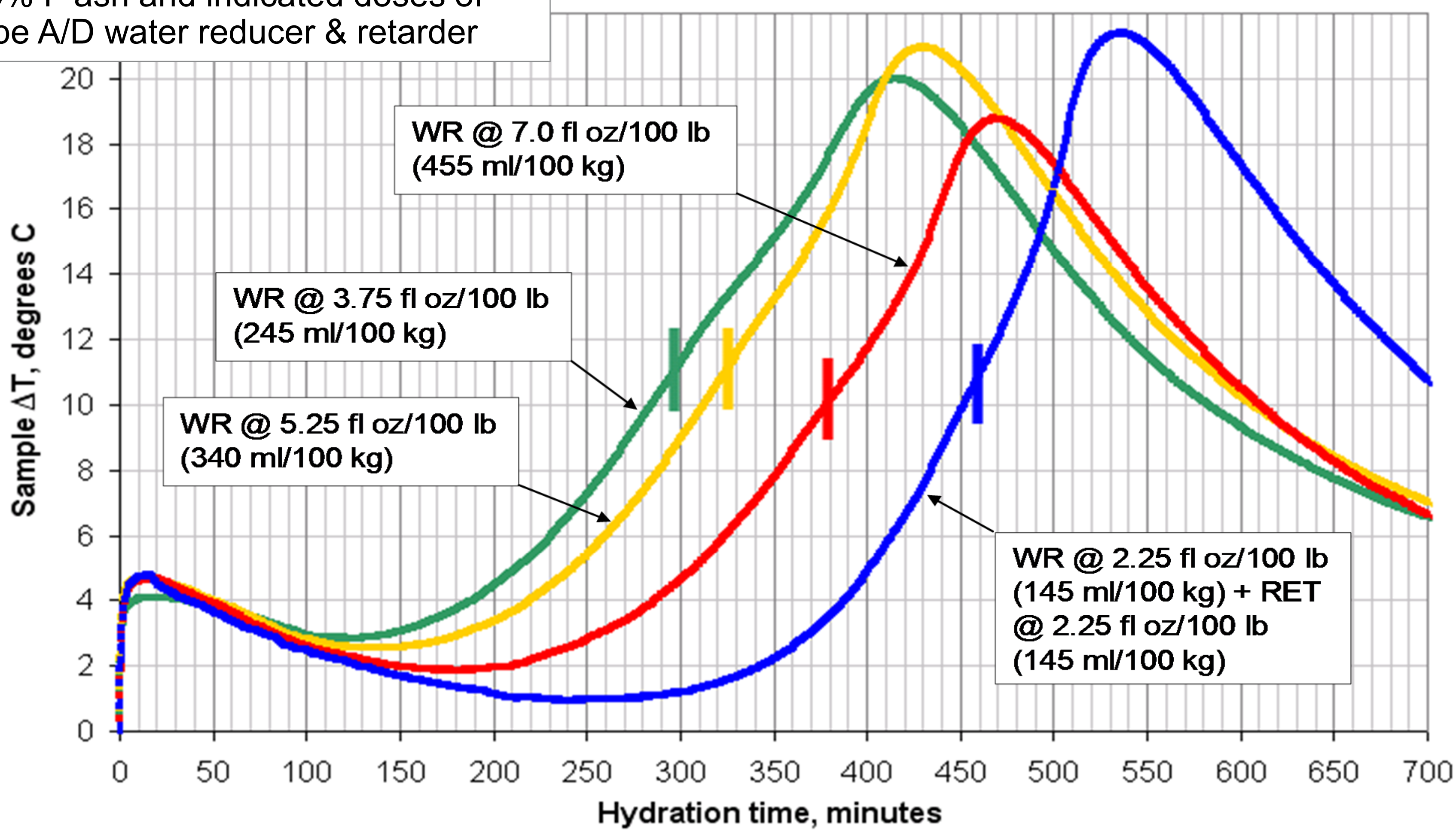
- Relative time-of-set comparisons can be made using the hydration times determined at some constant % (or "fraction") of the main peak heat rise for each thermal profile (paste, mortar, or concrete)
- A 50% fraction works well with paste mixtures – this hydration time is easily found and trends are consistent with parallel concrete times of set
  - 50% fraction values can be spreadsheet-calculated or estimated (visually)



Example: relative set times via paste thermal profiles

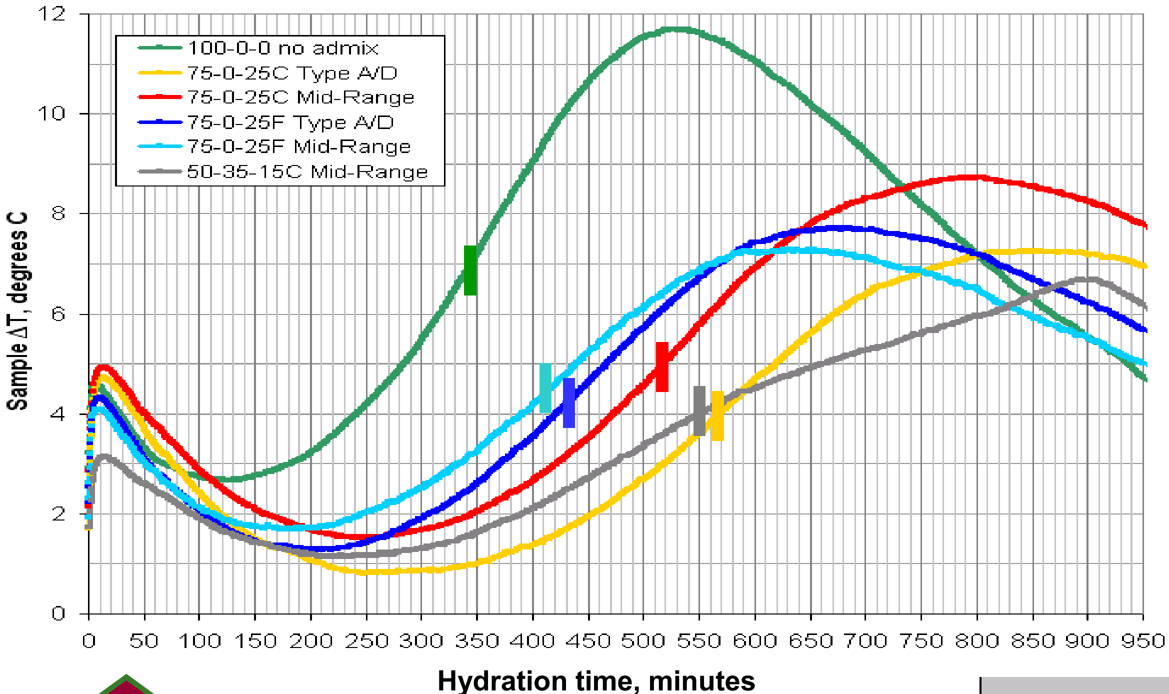
Thermal profiles with 50% fraction markers, all mixtures @ 90°F with 25% F ash and indicated doses of type A/D water reducer & retarder

Influence of admix dose & retarder



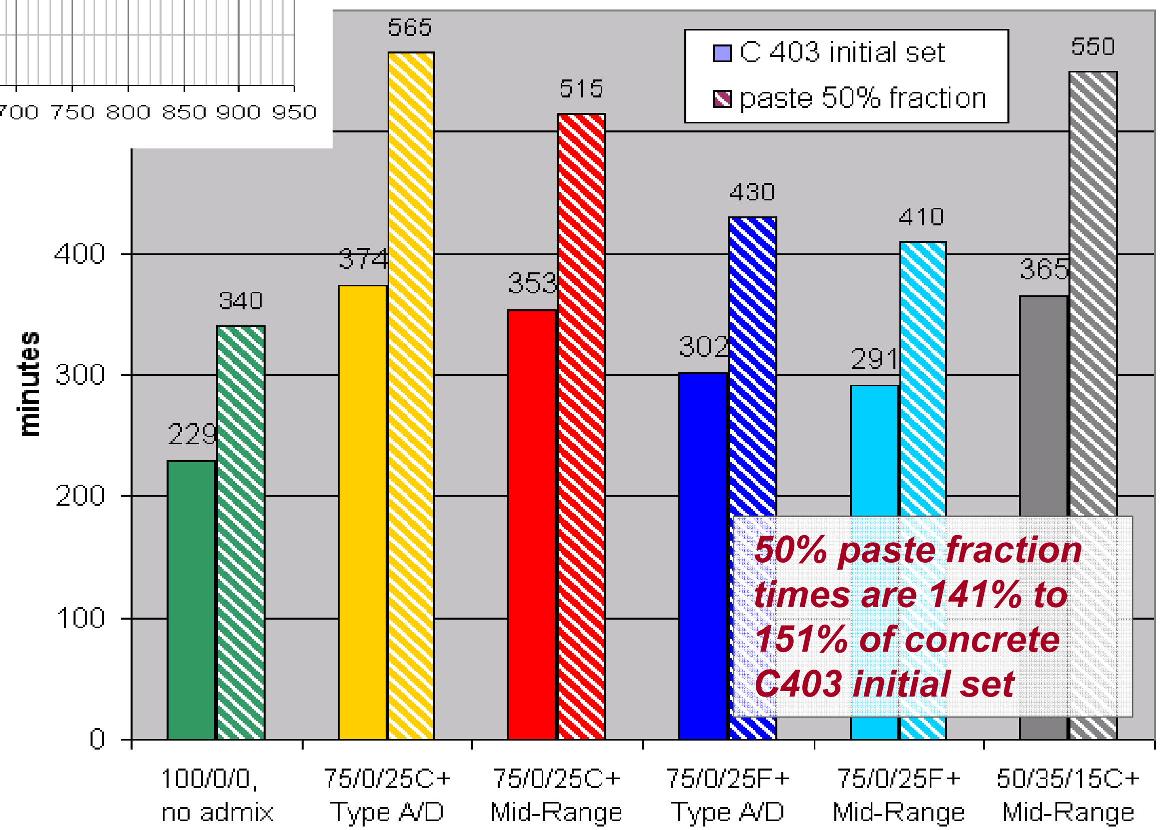
Example: paste and concrete trends compared – setting

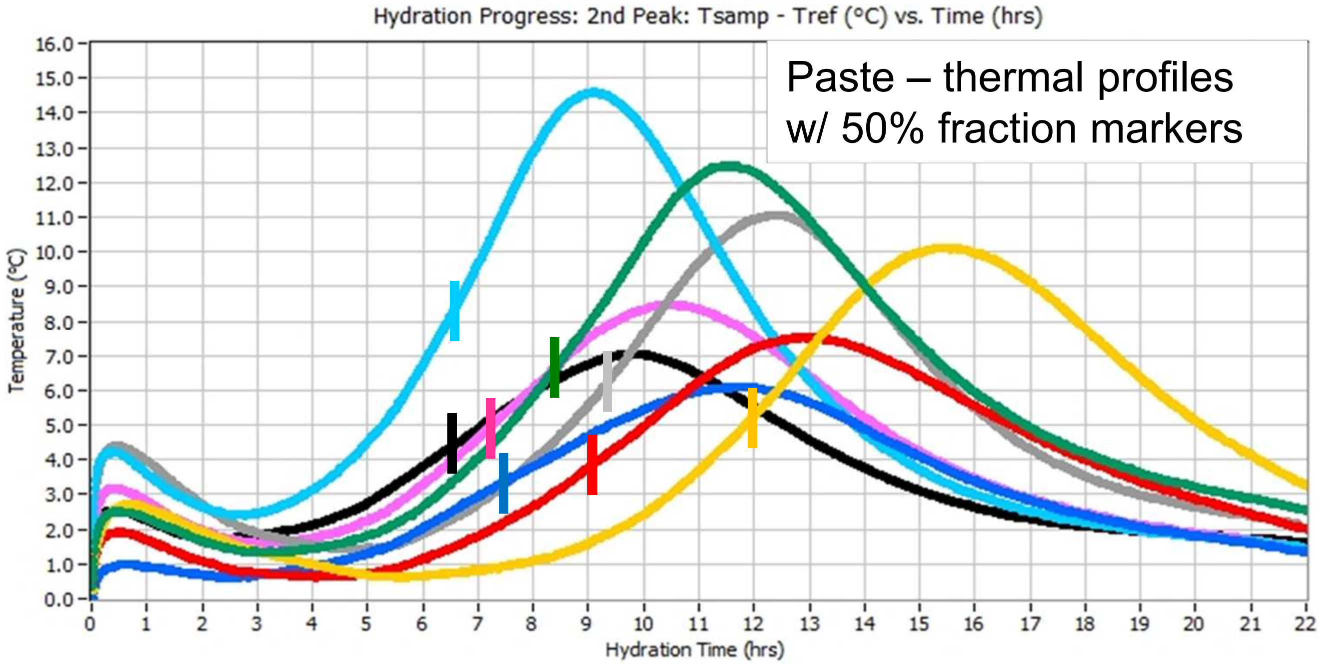
- 50% fraction times for paste vs. C403 time of set for parallel concrete batches
- Mixtures using various SCM's and admixtures, with the same sample of Type I/II cement

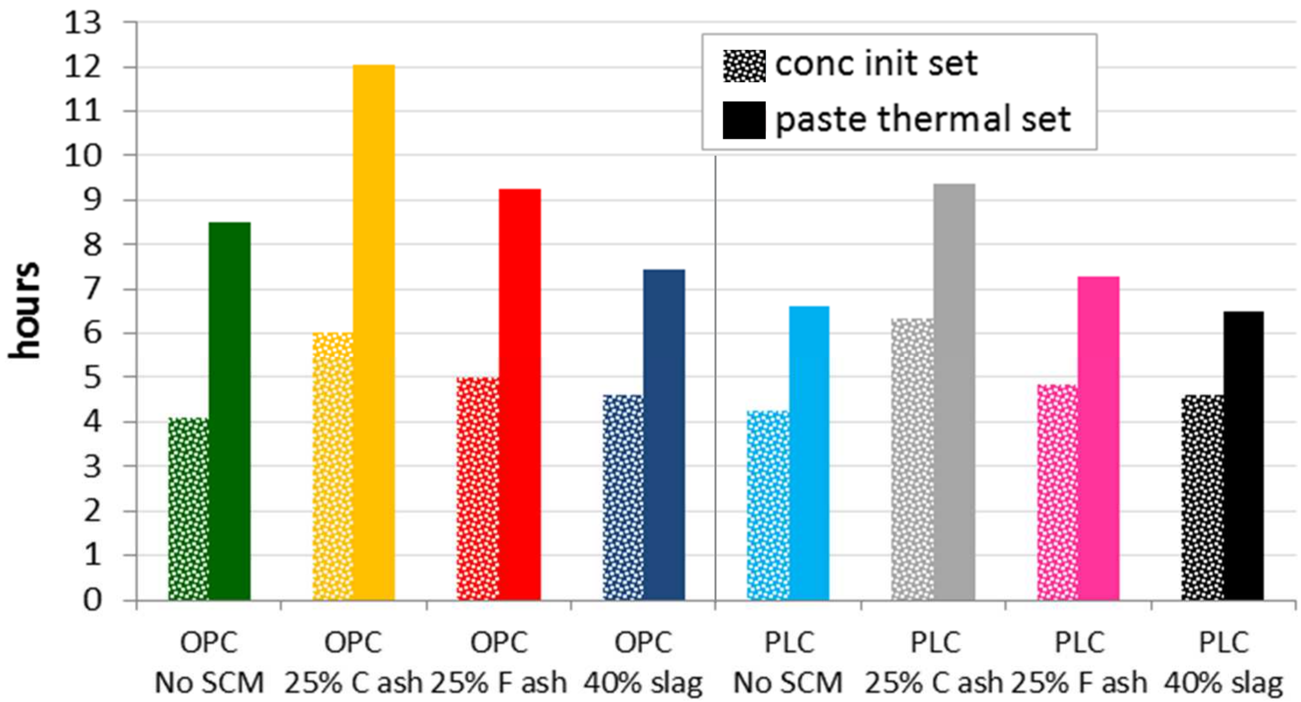


Thermal profiles with indicated 50% fractions, lab paste mixtures

Paste 50% fractions compared with concrete C403 initial set times

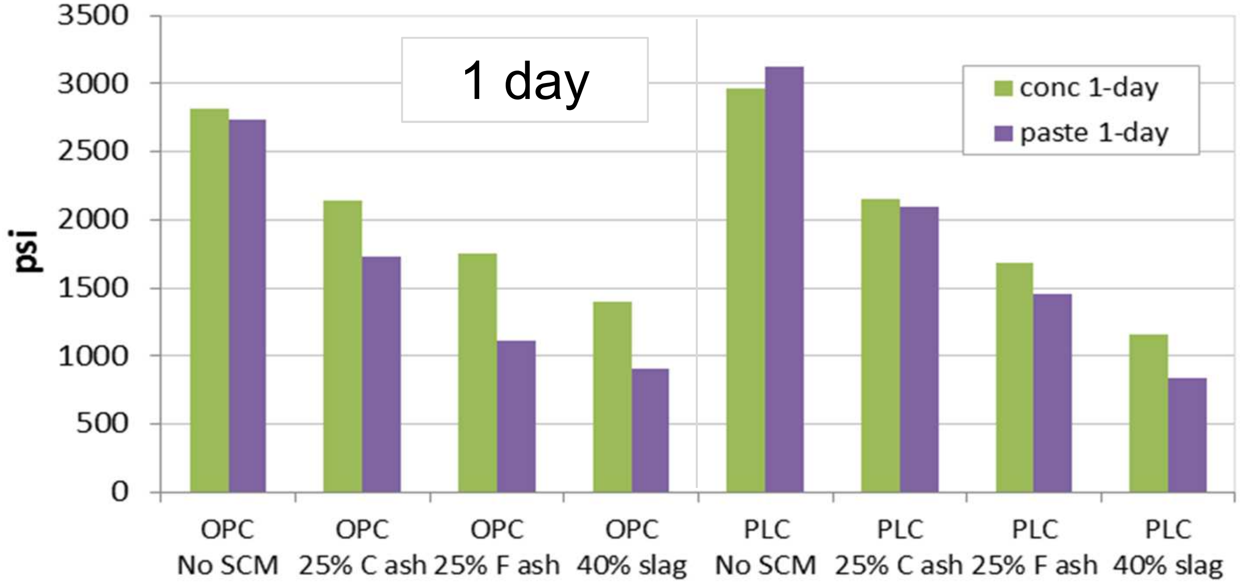


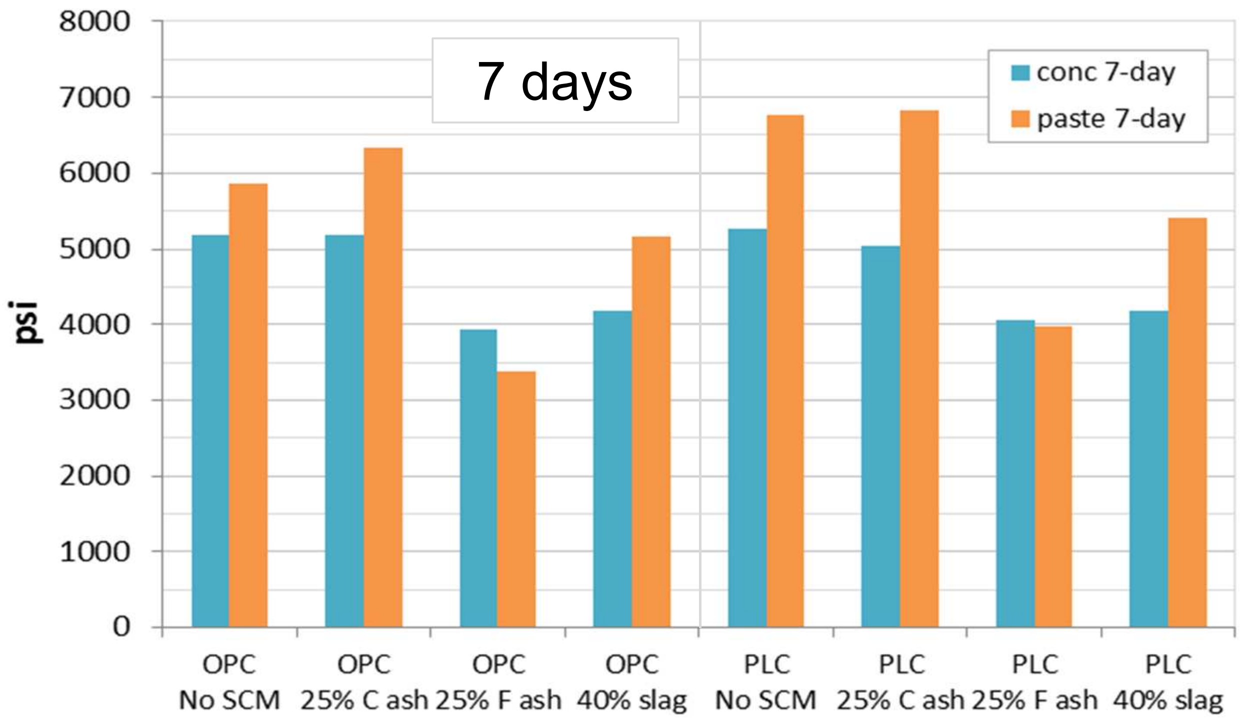




Example: *Paste and concrete trends compared –* ***setting***

- 50% fraction times for paste vs. C403 time of set for parallel concrete batches
- Comparing OPC vs. PLC for four different mixture conditions with different SCM content:
  - No SCM
  - 25% C ash
  - 25% F ash
  - 40% slag cement
- Paste is of exactly the same proportions as concrete, without any aggregates





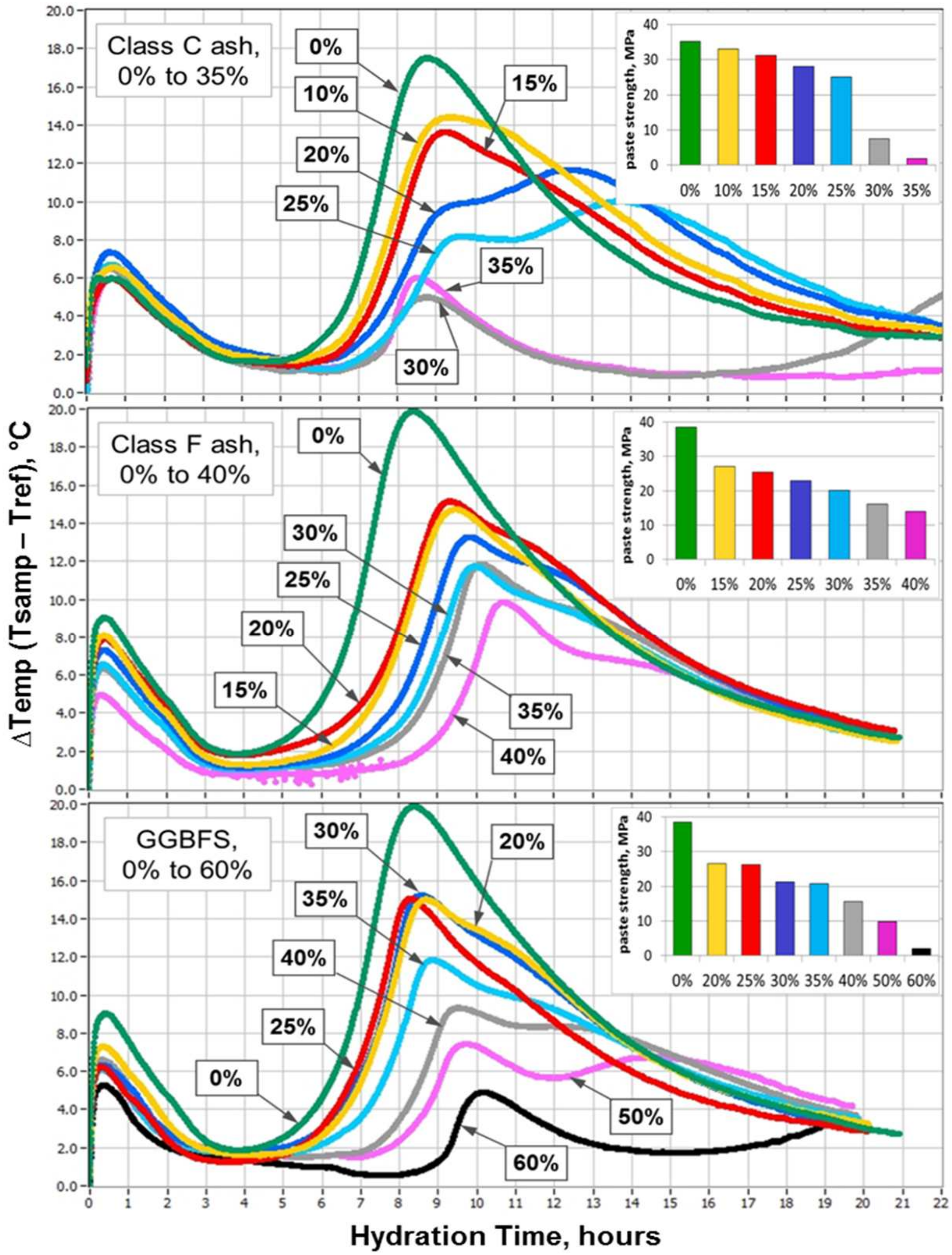
Example:

*Paste and concrete trends compared – **strengths***

- Paste vs. concrete compressive strengths, C39* testing using neoprene caps
- Comparing OPC vs. PLC for four different mixture conditions with different SCM content:
  - No SCM
  - 25% C ash
  - 25% F ash
  - 40% slag cement
- Paste is of exactly the same proportions as concrete, without any aggregates

Example paste mixture use in development of a mix design

- Project & objectives:
  - Mix design for a large slab project is needed using 50% replacement of cement
  - Setting and early (1-day) strength performance must be similar to familiar, traditional slab mix designs
  - A single SCM must be selected from 3 available types
  - HRWR and accelerator dosages need to be adjusted as per performance needs and selected materials



Performance trends of the 3 SCM's compared using incremental replacement

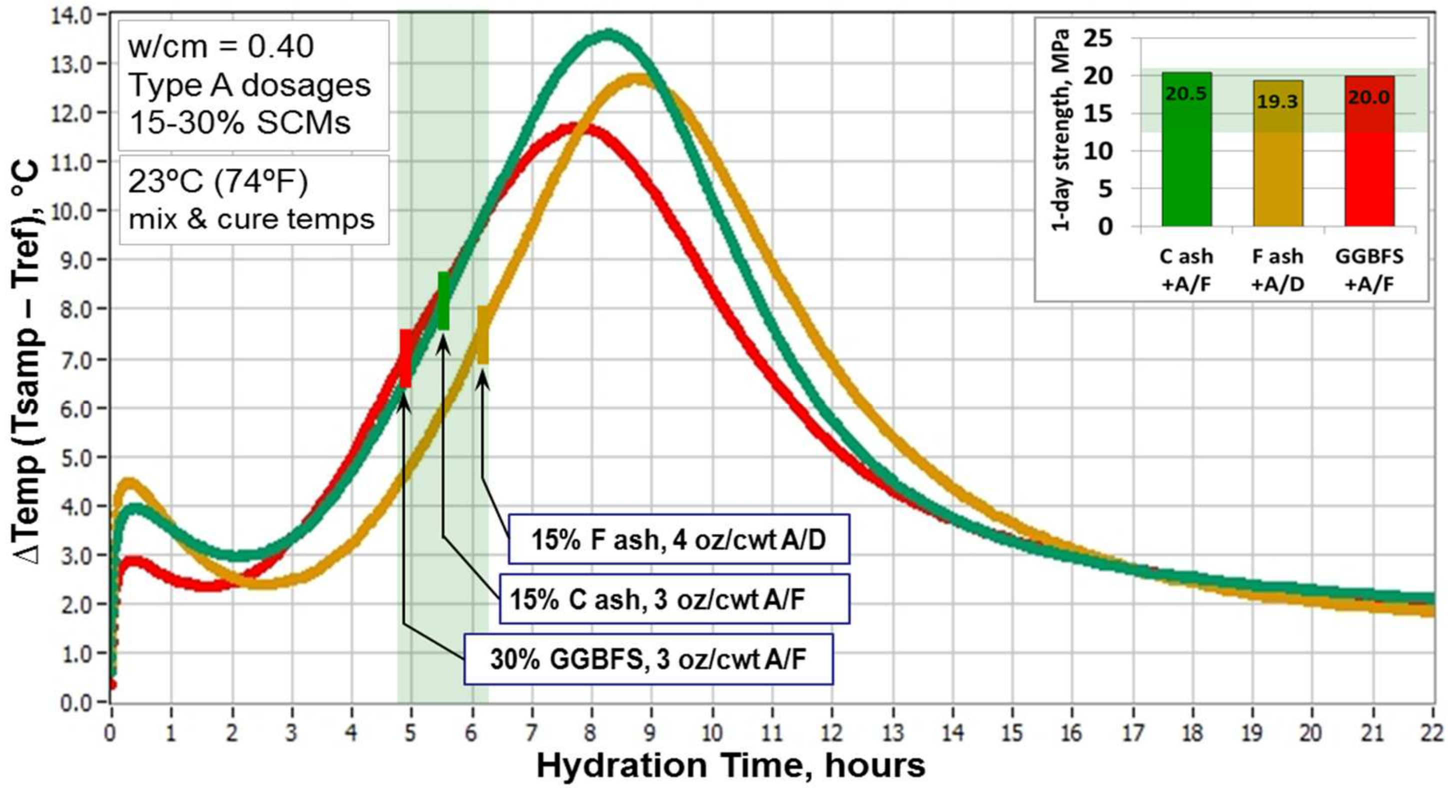
At left, thermal profiles and 1-day strengths comparing 3 SCM's (C ash, F ash, and slag cement) in otherwise identical mixtures, with incremental cement replacement rates. The Type A/D WR admix was selected because of its known high sulfate-demand tendencies.

A single sample of Type I/II cement was used, w/cm = 0.40, upper-limit dosage of admixture, 32ºC (90ºF) mix and cure temps.

C ash mixtures – incompatibility detected at higher replacement rates – symptoms at 20%-25%, true incompatibility beyond 25%.

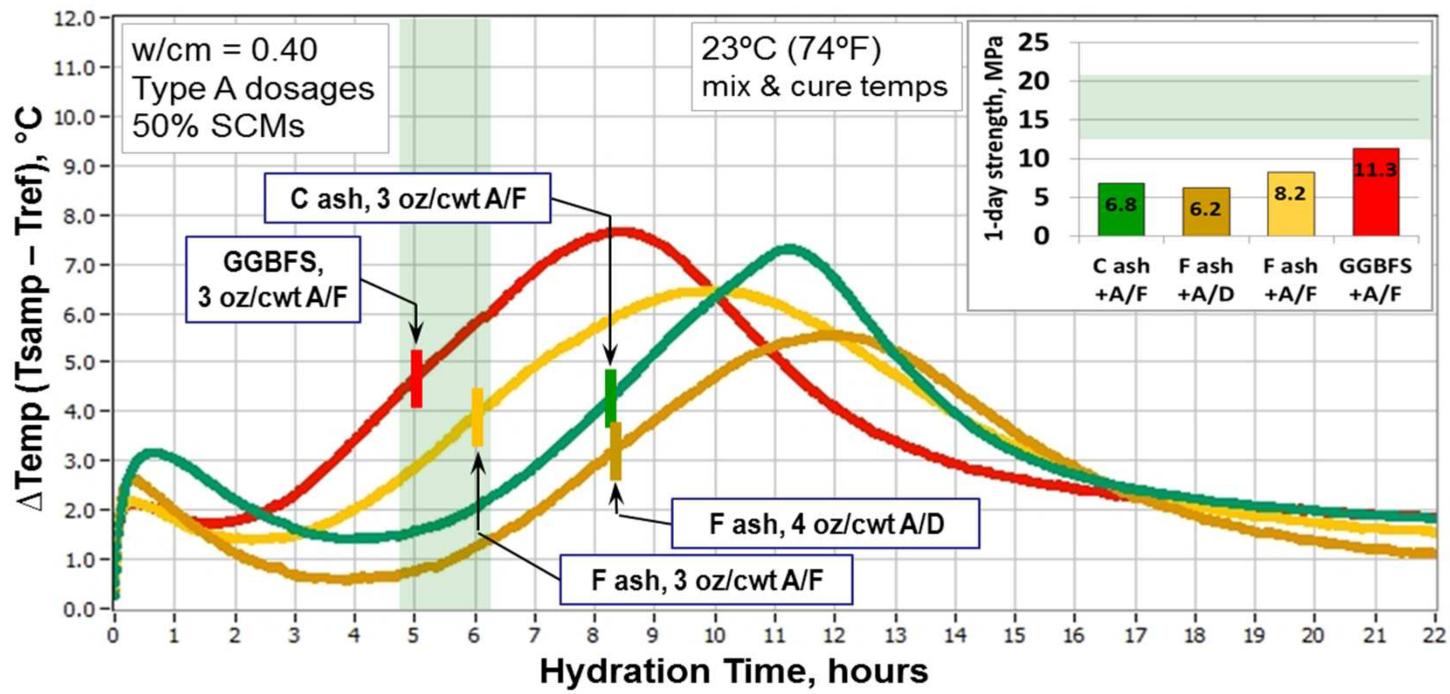
Paste performance for traditional low-SCM mixtures

- “Reference” mixtures to establish performance targets for mix development
- 15% C ash, 15% F ash, 30% slag cement with mild WR dosages
- For these examples, criteria to be based on these mixtures (green bands), 50% fraction thermal set indications and 1-day strengths in bar charts



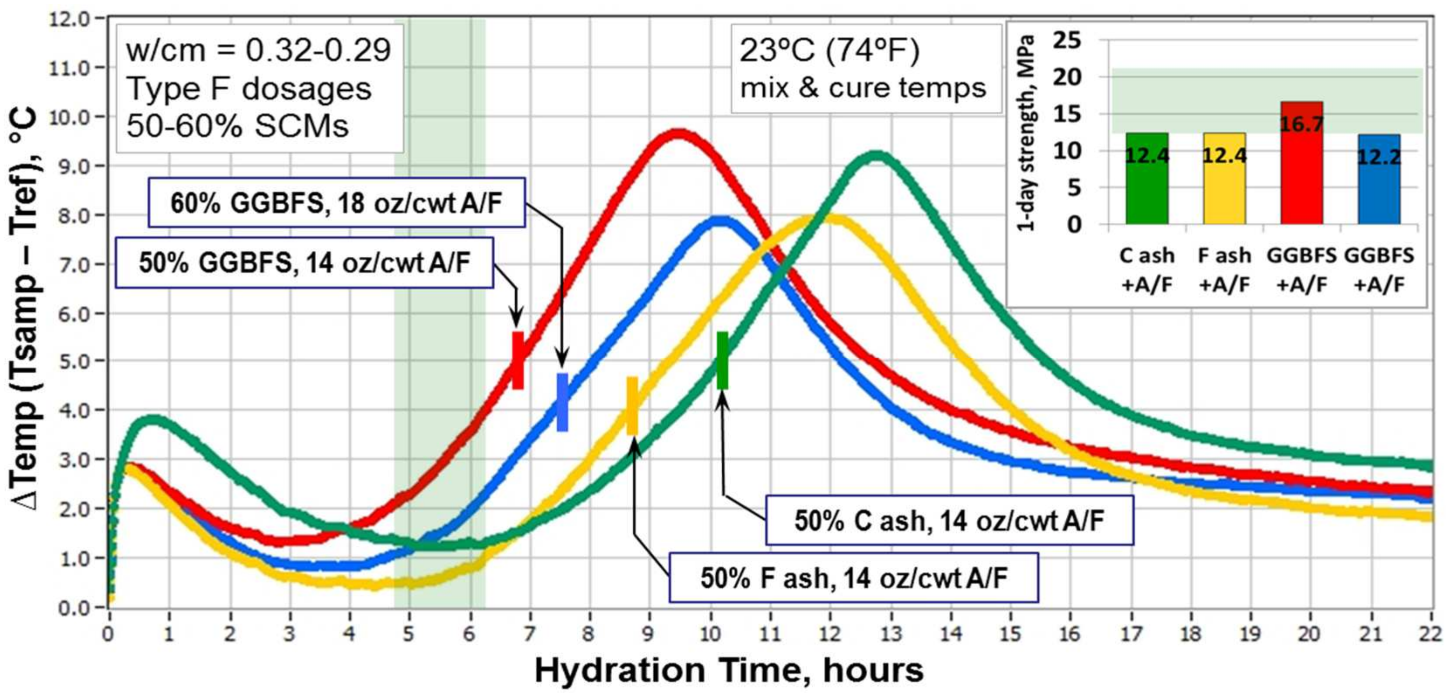
Effects of increasing SCM replacement rates to 50%

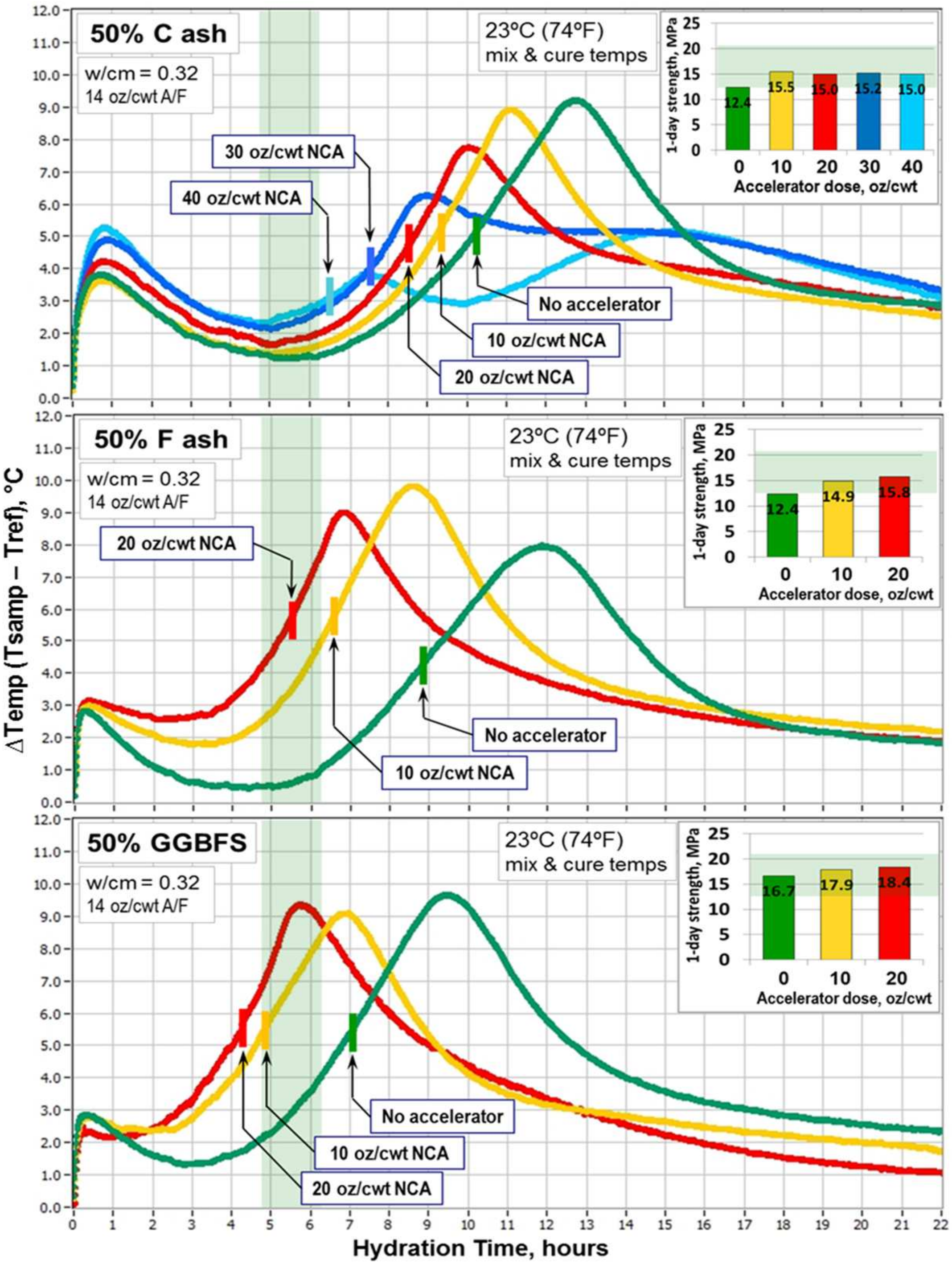
- Same temps & admix dosages, with the addition of an F ash mix w/ A/F WR
- Set time with F ash and A/D WR driven by admix
- Good set performance with slag and F ash + A/F
- C ash set time goes quite long (indication of potential issues)
- 1-day strengths all now unacceptable



Effects of lower w/cm using HRWR dosages

- Lower w/cm needed to restore early strengths, A/F WR dose increased
- All 1-day strengths now marginally acceptable, slag mix healthiest
- 60% replacement mix with slag added, still acceptable strength
- All set times now unacceptable, need help from accelerators (esp. C ash)





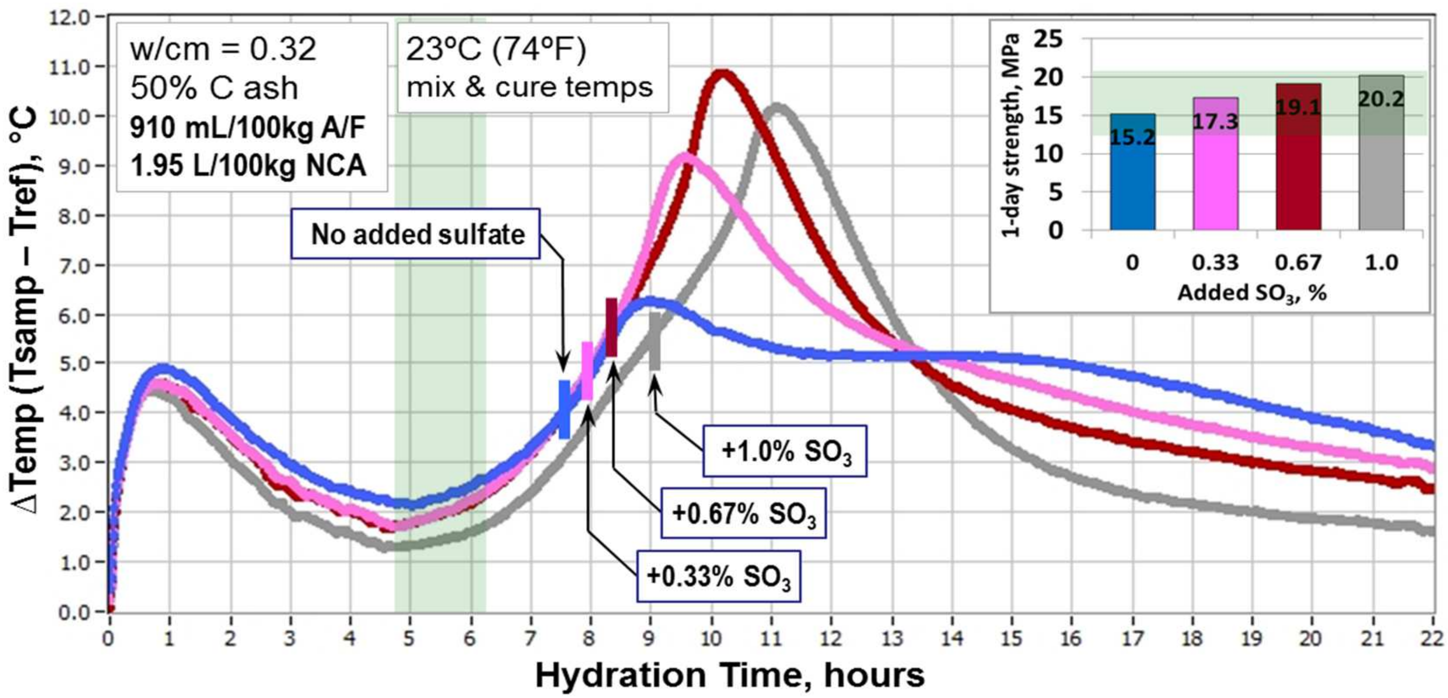
Restoring time of set

Effects and needed dosage of NCA for setting performance

- All mixtures repeated with varying & incremental dosages of non-chloride accelerator (NCA)
- Moderate dosages restore acceptable set for F ash and slag
- NCA less effective with C ash and seems to create sulfate balance issues (incompatibility) at higher dosages (in pursuit of restored set)
- 1-day strengths benefit from NCA

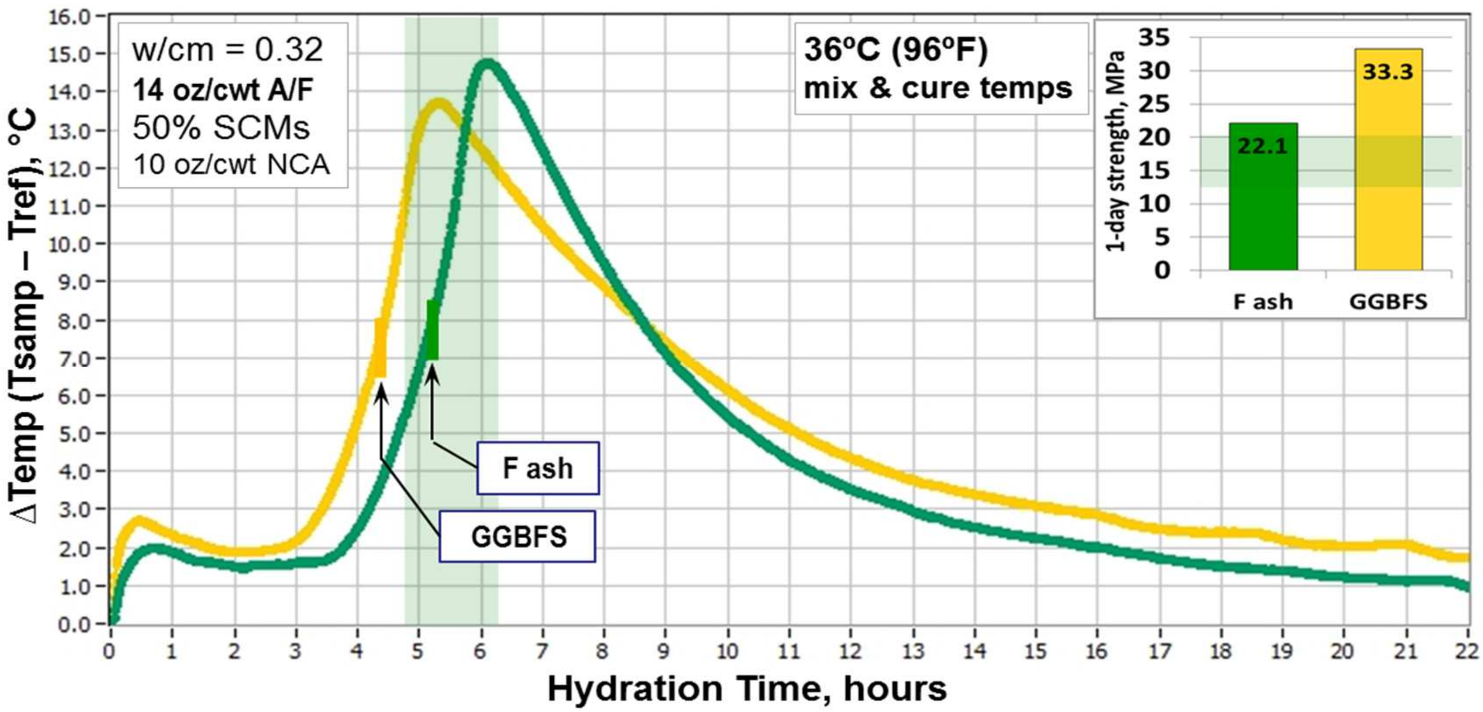
Sulfate balance evaluation of the C ash mix w/ NCA

- An affected mixture using NCA repeated with incremental $CaSO_4$ additions
- Profile shapes and 1-day strengths improve with additions, but not set time
- Confirms sulfate balance (incompatibility) issues
  - ***C ash not considered a candidate for 50% replacement mix design!***
  - Lower replacement mix could be developed



Verification of proportions at extreme field temps

- F ash and slag mixtures with same A/F dose & max NCA dose repeated at highest envisioned concrete field temps: 36ºC (96ºF) mix and cure temps
- No sulfate balance issues indicated; NCA dosages could be reduced
- ***OK to proceed to trial concrete mixtures!***



Questions?

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