




Allowing higher cement replacement by class C fly ashes: A new method

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Construction Products

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Growth Drivers & External Factors for Use of Fly Ash in Concrete

Better Economics

- **Concrete Producer**
  In most cases cost of Fly Ash is significantly less than cement (approx $100/ton for cement and $50/ton for Fly Ash)
- **Power Plant**
  Disposal cost for Fly Ash ~ $10/ton. Cost will rise significantly if Fly Ash is classified as toxic waste.

Environment

- Pressure on cement producers to reduce overall CO2 footprint.
- Cement manufacturing is one of the top 5 largest CO2 producers in the world

GREEN: LEED

- LEED credits for high volume fly ash concrete (50% Fly Ash)

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Classes of Fly Ash (ASTM C618)

C or F?

Defined by coal composition.

Class F	***Class C***
$SiO_2 + Al_2O_3 + Fe_2O_3 \geq 70\%$	***$SiO_2 + Al_2O_3 + Fe_2O_3 \geq 50\%$***
~1 – 12% CaO	***> ~12% CaO***
('low calcium')	***('high calcium')***
Coarser	***Finer***
Low water reactivity	***Highly reactive in water***
More worldwide available	***~40% US production***

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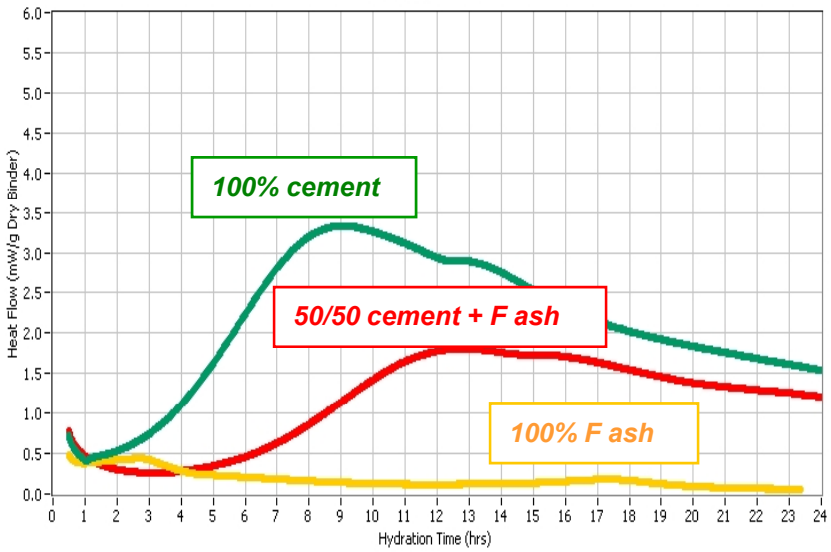
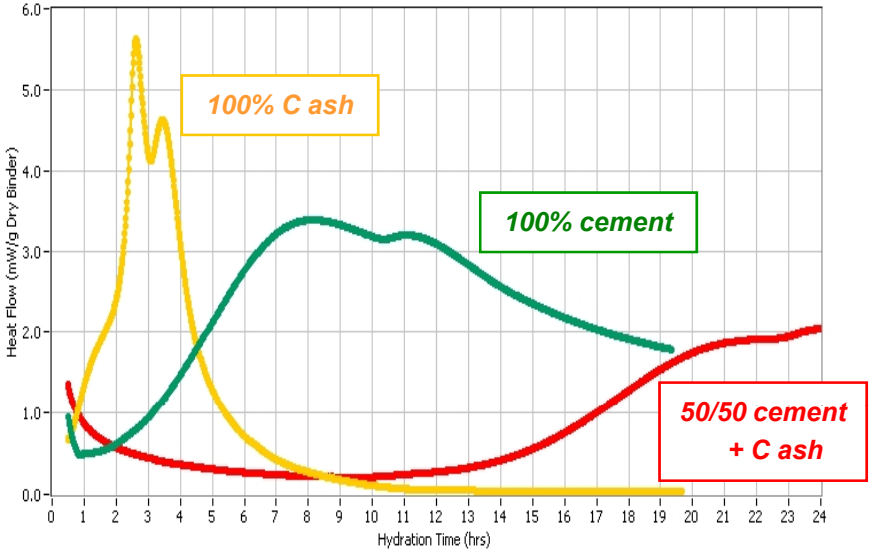
Calorimetry profiles of class F and C fly ash





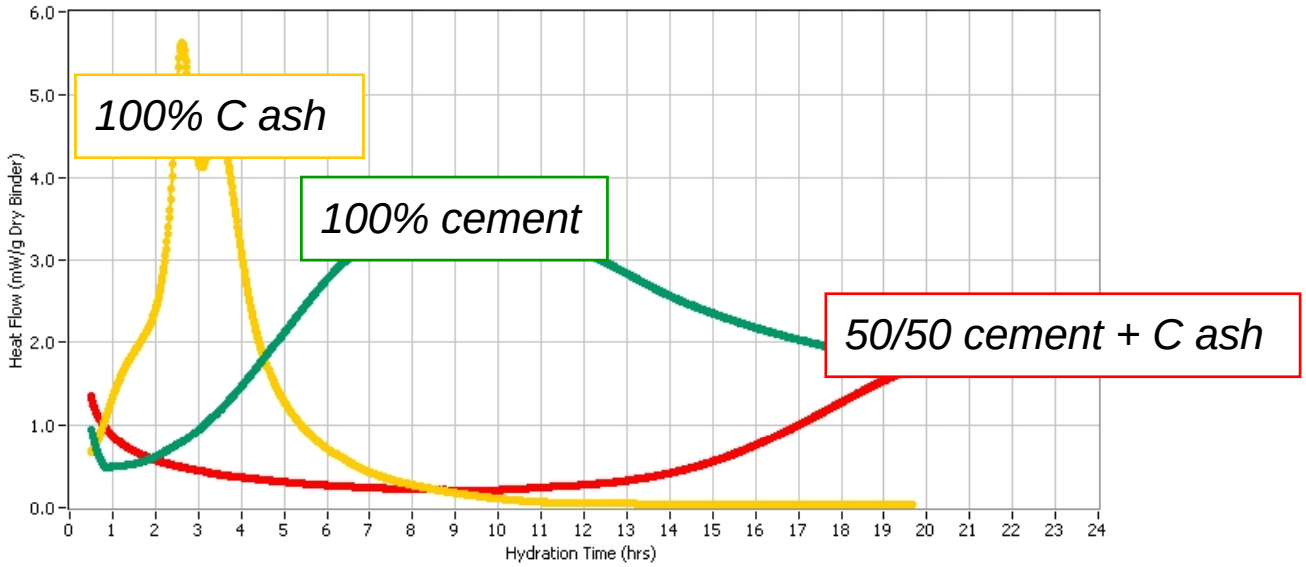
Low Ca ashes (Class F)

- Low Ca (Class F) ashes are **not reactive** in water
- Retardation of blended system due to cement **'dilution'** effect

High Ca ashes (Class C)

- High Ca (Class C) ashes are **highly reactive** in water
- **Strong** retardation of blended system indicating **antagonistic hydration** between the cement and fly ash

Hypothesis



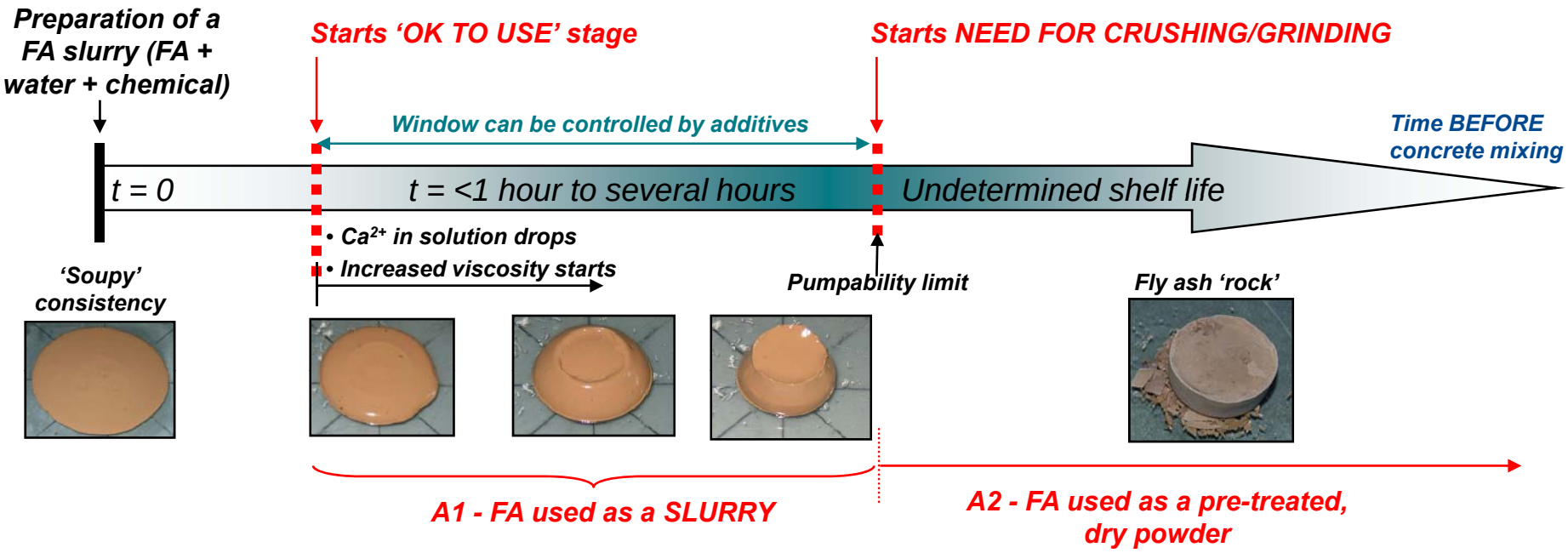
Why so much set retardation and strength decrease?

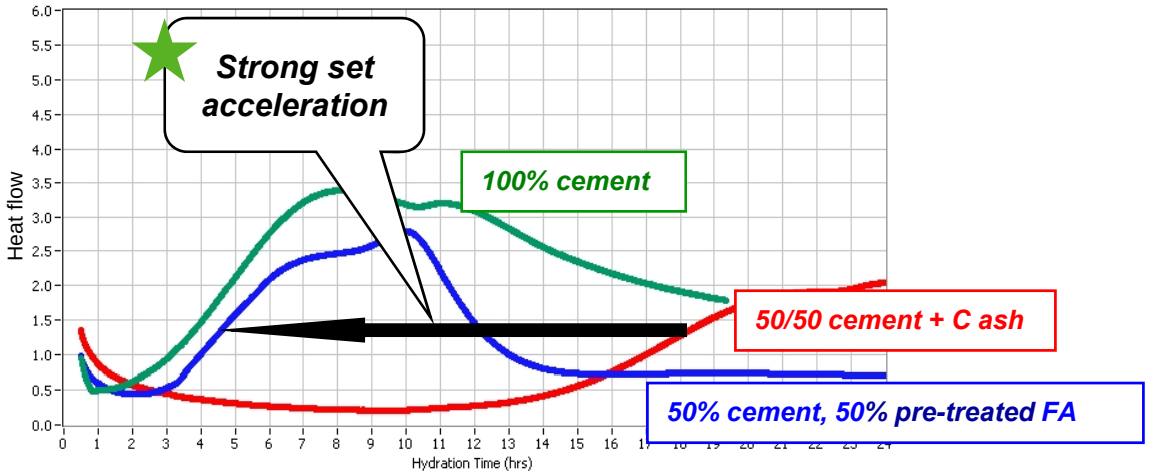
Antagonistic hydration between cement and fly ash

Would promoting hydration of cement and fly ash at different times address the problem ?

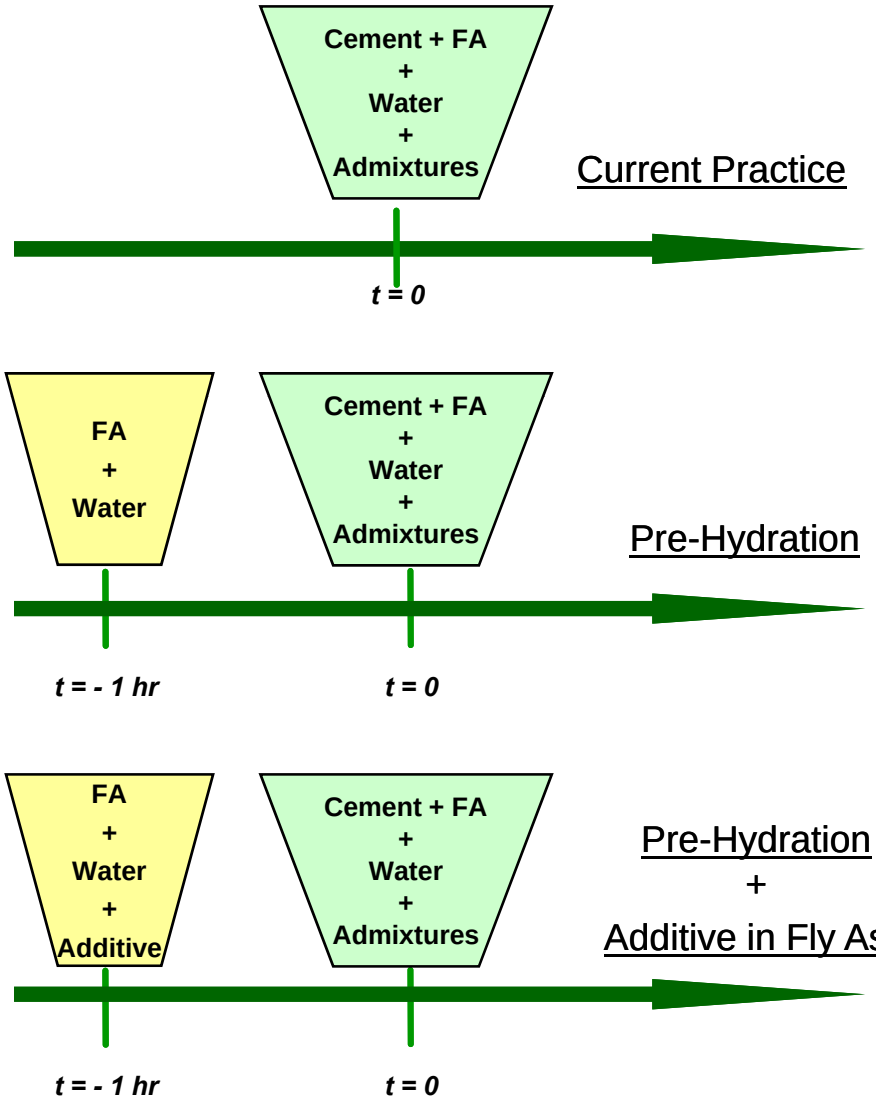
Would addition of suitable chemicals help?

Solution: Pre-Hydration + Chemical Treatment of High Ca fly ash



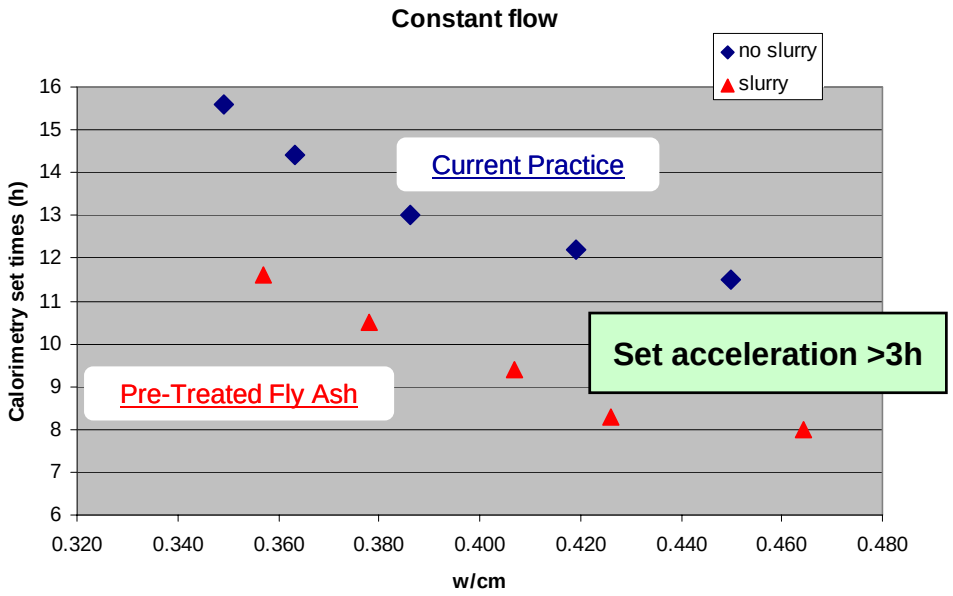


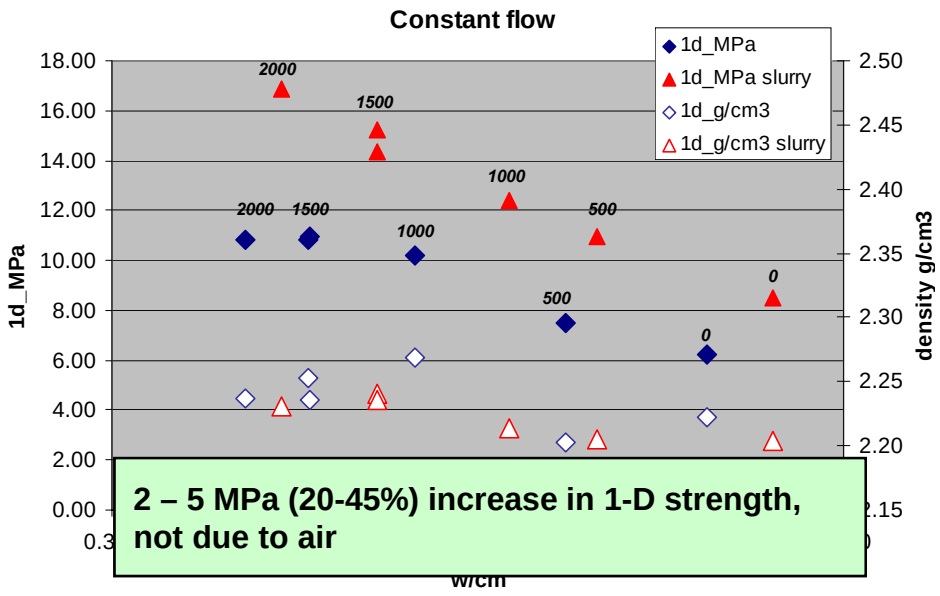
Impact of Treatment method



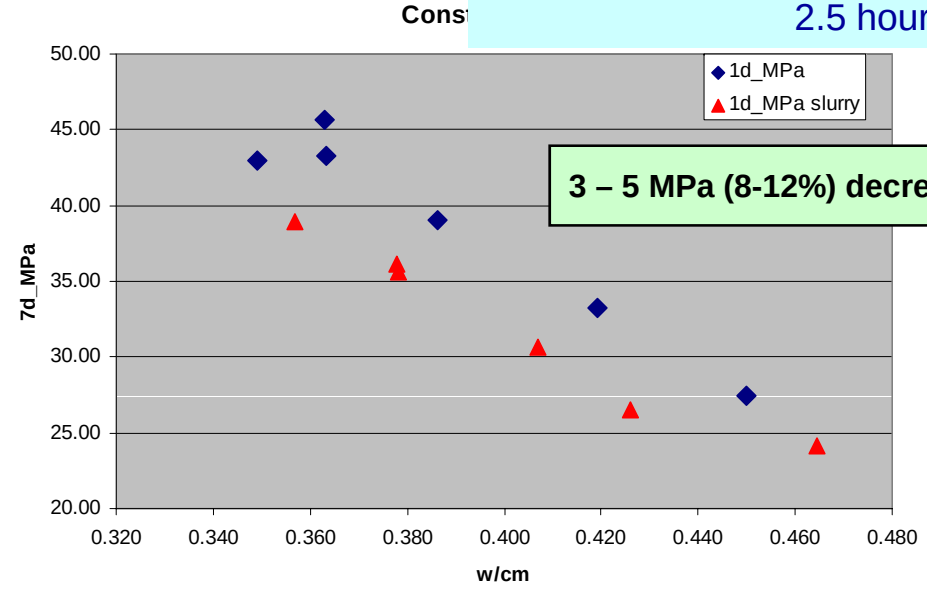
	Workability (mm)	Strength (MPa)	Set (Hr)
Current Practice	+	-	-
Pre-Hydration	-	+	+
Pre-Hydration + Additive in Fly Ash	+	+	+

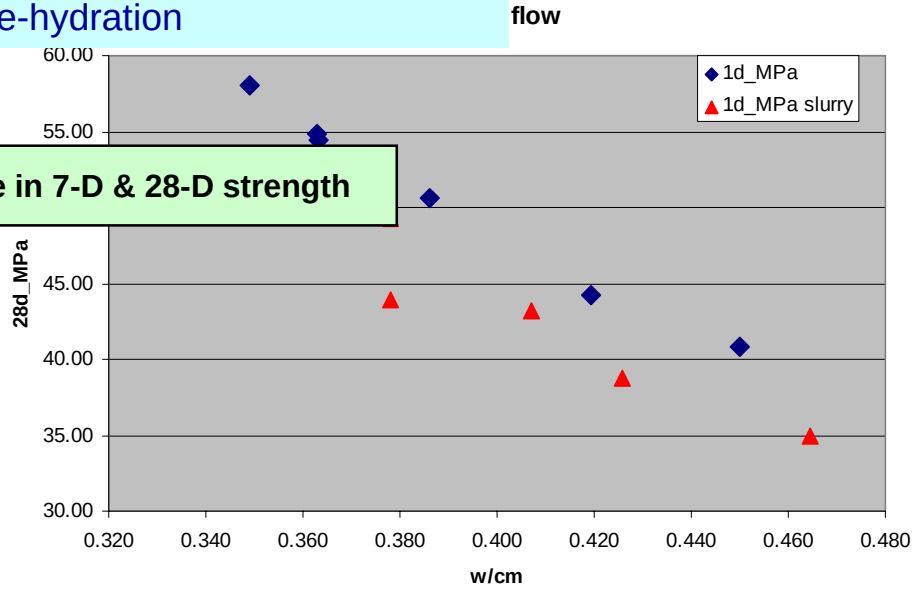
A1 - High Ca Fly Ash Slurry (Fly Ash #1 + Cement A)



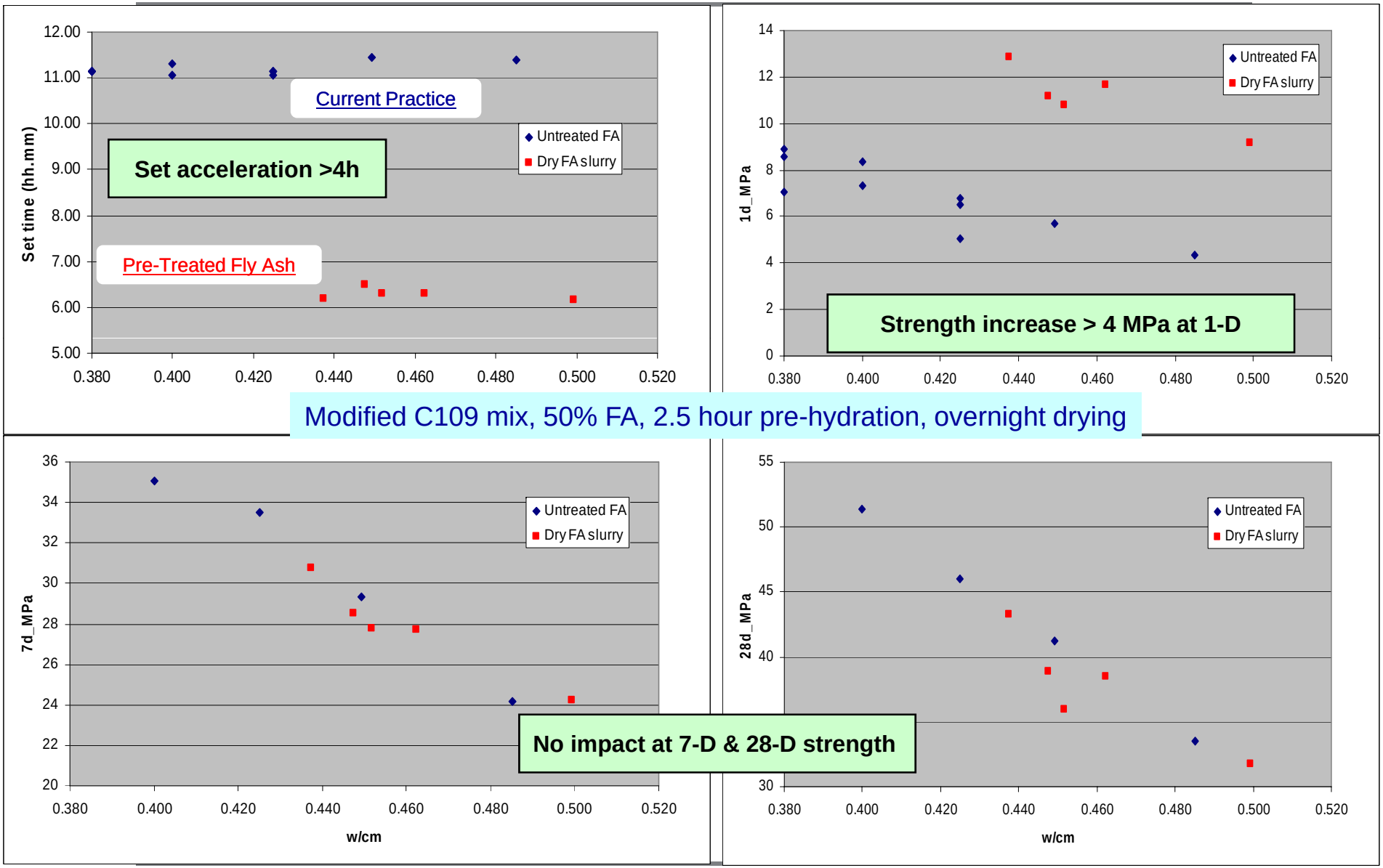


Modified C109 mix, 50% FA, constant flow by adding PCE, 2.5 hour pre-hydration



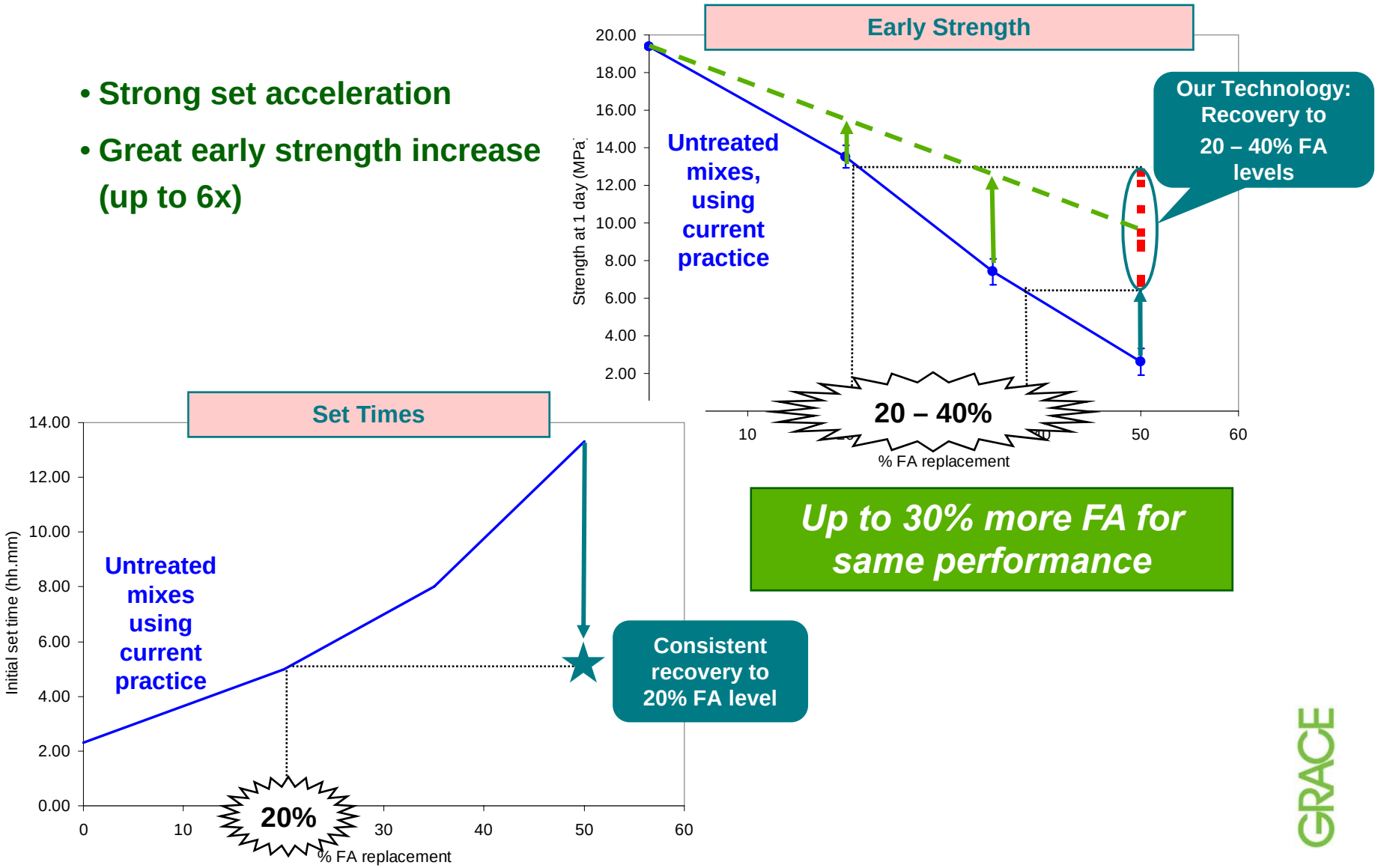


A2 – Pre-Treated High Ca Fly Ash Dried Powder (Fly Ash #1 + Cement A)



Result Summary of 8 High Ca Fly Ashes

- **Strong set acceleration**
- **Great early strength increase (up to 6x)**

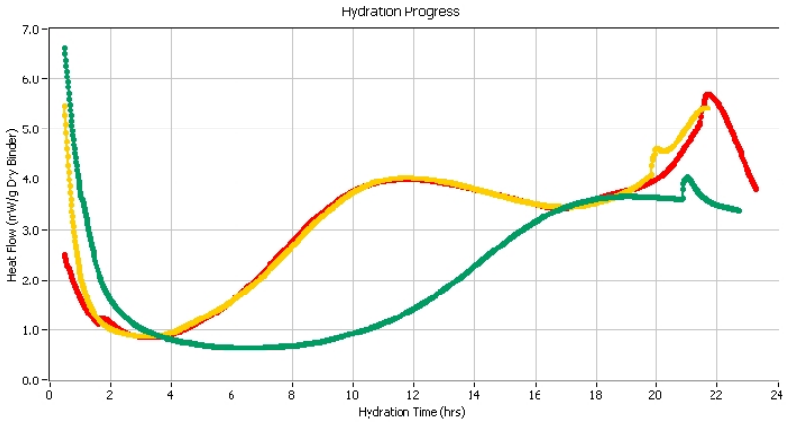


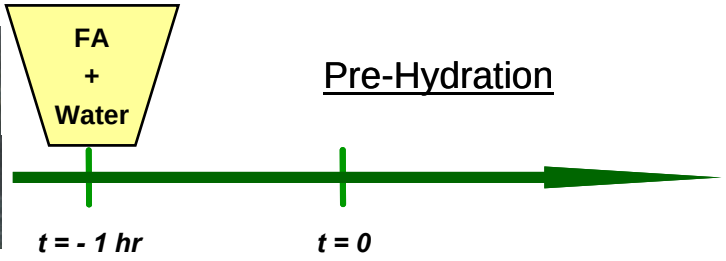
Up to 30% more FA for same performance

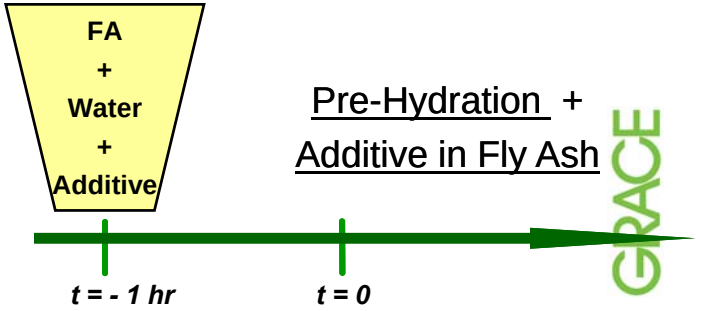
Impact of Treatment Methods : Mortar with FA #2 + Cement A

	Workability (mm)	Strength (MPa)			Set (hr)
		1D	2D	28D	
Current Practice	200	2.7	15.0	37.3	13
1 hr Pre-Hydration	43	9.1	16.8	39.5	7
1 hr Pre-Hydration + Additive	128	9.0	17.7	40.4	7

50% FA #2 + 50% Cement A ; w/fa = 0.4; w/c=0.5







Impact of Treatment Methods : Concrete with FA #2 + Cement A

	Slump	Strength (PSI)				Set	Air
	(inches)	1D	2D	7D	28D	(Hr)	(%)
Current Practice	8 1/4	299	741	2479	3700	13:43	2.3
0.5 hr Pre-Hydration + Additive	8	1088	1689	3226	4350	10:38	2.2

50% FA #2 + 50% Cement A ; CF = 611;
w/fa = 0.4; w/c = 0.5; 3.5 oz AC 575

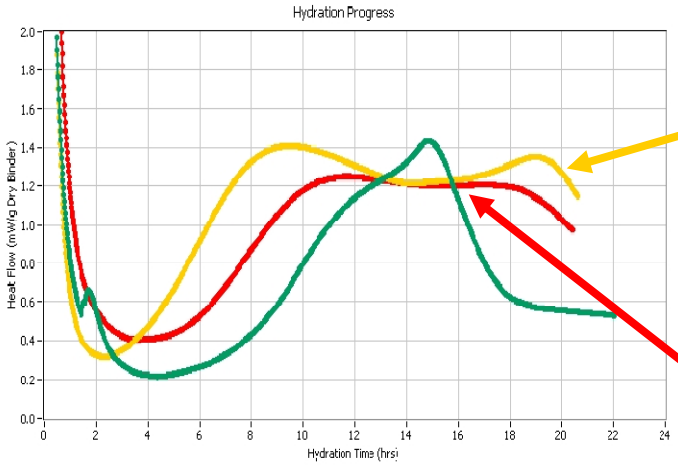
Pre-treatment of FA

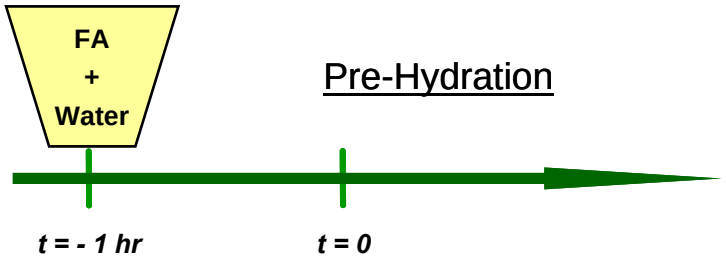
- ***accelerates set***
- ***increases strength***
- ***corrects workability issues***
- ***provides proper hydration development***

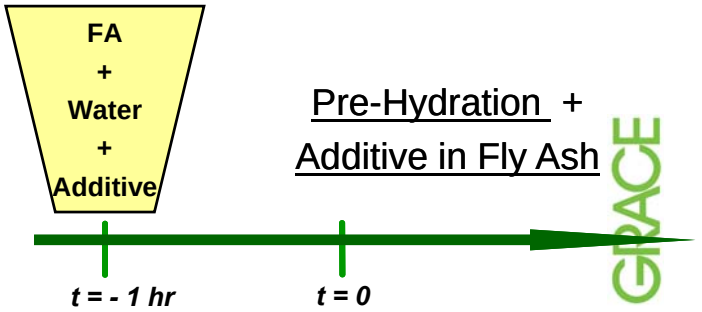
Impact of Treatment Methods : Mortar with FA #3 + cement A

	Workability (mm)	Strength (MPa)			Set (Hr)
		1D	2D	28D	
Current Practice	226	3.1	8.5	35.0	10
1 hr Pre-Hydration	2	12.7	21.4	44.7	7.8
1 hr Pre-Hydration + Additive	81	11.2	18.7	44.7	5.3

50% FA #3 + 50% Cement A ; w/fa = 0.4; w/c=0.5







Different Fly Ash gives different reactivity
→ Different treatment times

Conclusion

- **High Ca fly ash gave long set retardation and poor strength development when blended with cement, making the material not useable in concrete**
- **Pre-treatment of High Ca fly ash suppresses the antagonistic hydration reactions between high Ca fly ash and cement, making the material useable**
  - Good workability
  - Faster set time
  - Good strength development (50 % FA levels = 20 – 40% FA levels)
- **Treatment time is dependent on**
  - Chemistries of High Ca Ash
  - Chemistries of Cement
  - Mixing Conditions
- **Patent Application filed**

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