Design and Construction of Sustainable Concrete Pavements in Desert Environments

Our workshop objectives

1. Share knowledge about recent research and best practices for concrete pavements.
2. Provide guidance for improving the outcomes of concrete pavement projects in desert climates.
3. Provide a forum for sharing pavement project successes and challenges.

Design and Construction of Sustainable Concrete Pavements in Desert Environments

1. **Concrete Mixtures for Pavement** – This session will present the "How's & Why's" of specifying and proportioning cements, SCMs, admixtures, and aggregates for desert pavements. Peter Taylor, CP Tech Center	***Tuesday, April 19th*** ***9:00 to 10:15 am***
2. **Pavement Design and Critical Properties** – Designing and specifying pavements for desert environments requires a solid understanding of how design relates to placement and performance. Tom Van Dam, NCE	***Tuesday, April 26th*** ***9:00 to 10:15 am***
3. **Concrete Pavement Inspection and Testing** – Pavement quality is controlled through comprehensive inspection and testing requirements. Desert environments present added paving risks that should be accounted for. Mike Praul, FHWA	***Tuesday, May 10th*** ***9:00 to 10:15 am***
4. **Pavement Construction and Performance** – Successful paving in desert environments requires attention to key construction processes. Pavement condition data indicates excellent performance in desert environments. Angel Mateos, UCPRC; Dave Rath, Southwest Concrete Paving Company; and Matt Fonte, Fonte & Company	***Tuesday, May 24th*** ***9:00 to 10:15 am***

Thank You to our Workshop Supporters

Our Presenter Today

Peter Taylor, Ph.D., P.E
Director, Concrete Pavement Technology Center

Dr. Taylor leads internationally recognized research at the National Concrete Pavement Technology Center. His high-impact work has resulted in the development of specifications such as the *AASHTO PP 84: "Developing Performance Engineered Concrete Pavement Mixtures."*.

Additionally, his research has helped transportation agencies save millions of dollars by preventing premature joint failures, and improving the performance of concrete mixtures.

Design and Construction of Sustainable Concrete Pavements in Desert Environments

Session 1: Concrete Mixtures for Pavements

Dr Peter Taylor

Iowa State University
Institute for Transportation

National Concrete Pavement Technology Center
CP Tech Center

Mixtures for Desert Environments

- What's special about the desert
- Materials
- Mixture

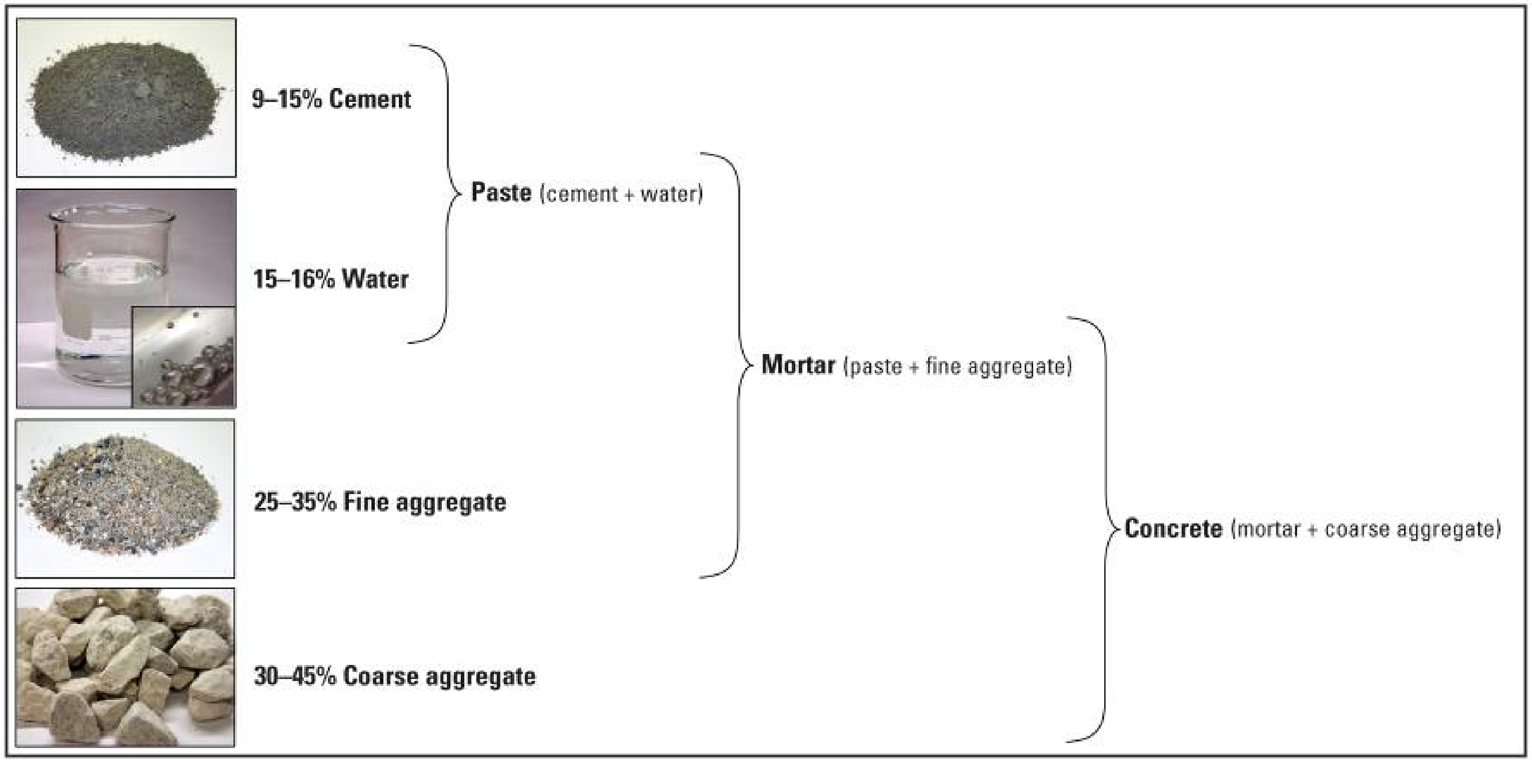
What's special about the desert?

- Its dry
- Temperatures swing

Concrete and Water

- At mixing – less water is better
- After setting – more water is better
- Later on – less water is better

Concrete Materials



What controls performance?

Aggregates

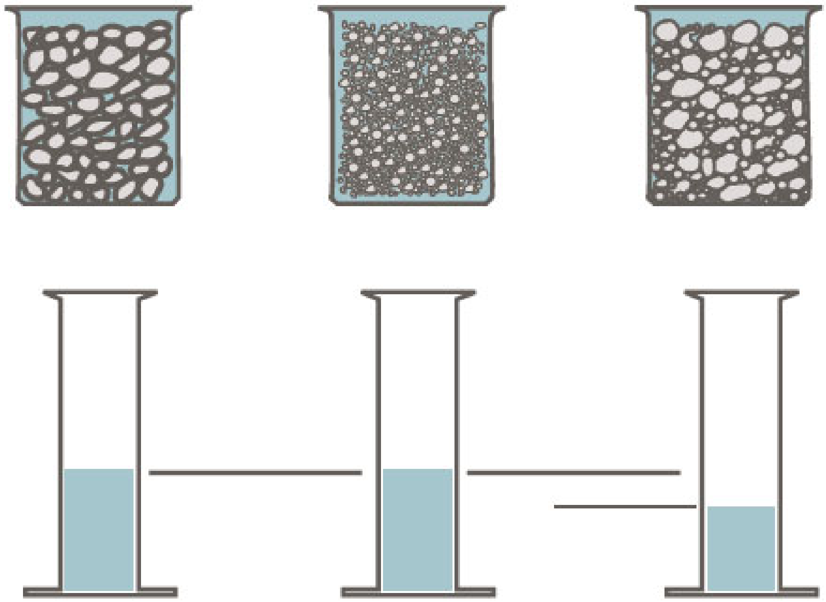
- Aggregates comprise ~70% of the volume of a concrete mix.
- Aggregate properties influence :
  - Water demand
  - Durability
  - Workability
  - Dimensional changes

Aggregates in Concrete

- Physical properties to consider:
  - Contamination
  - Gradation
  - Absorption
  - Surface texture
  - Particle shape

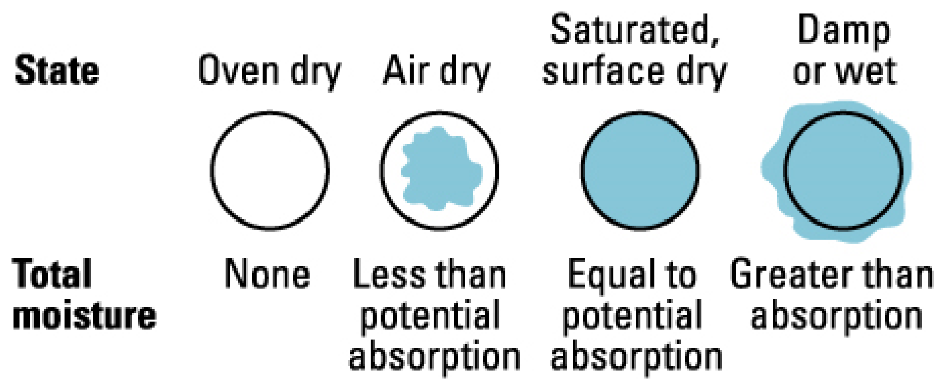
Aggregate Gradation

- Combined gradation controls
  - Workability
  - Volume of paste needed



Moisture State

- Uniformity

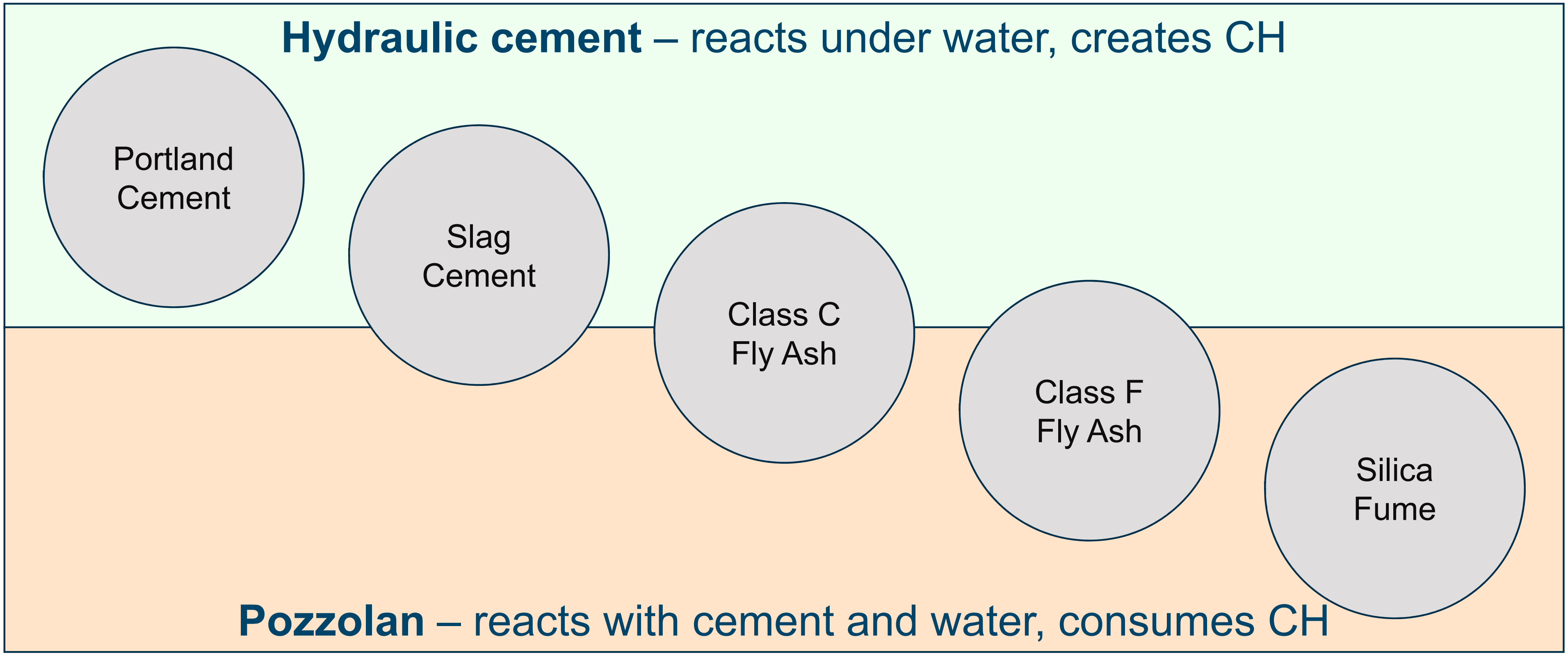


Aggregate Durability

Aggregate-related distresses include the following:

- Alkali-aggregate reactivity (ASR / ACR)
- D-cracking
- Surface popouts
- Polishing

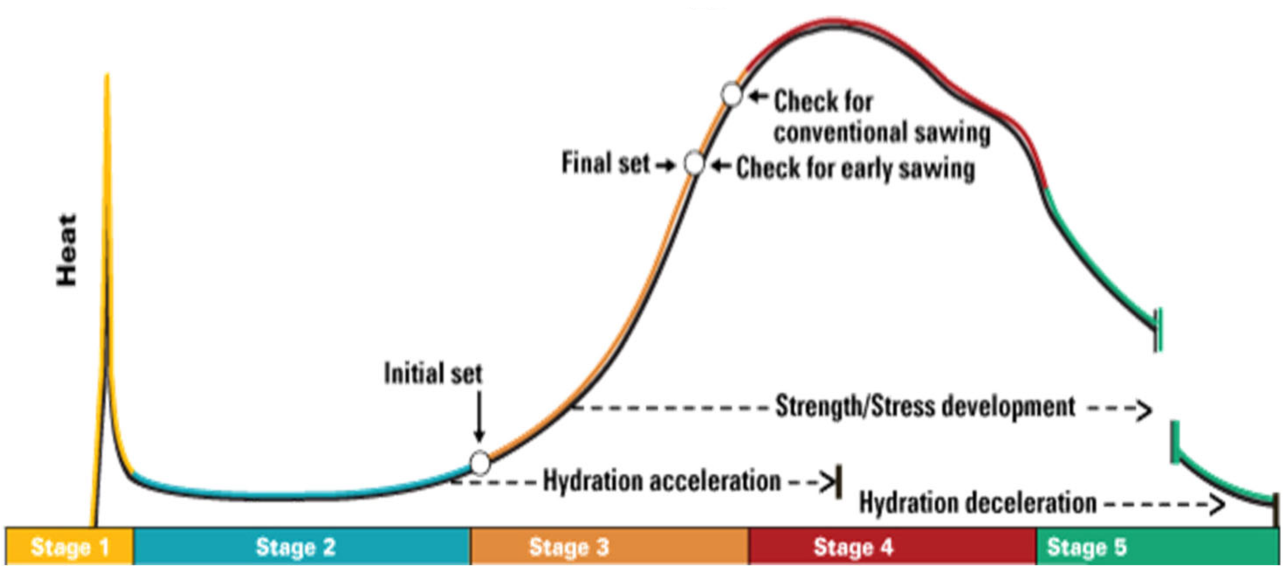
Cementitious Materials



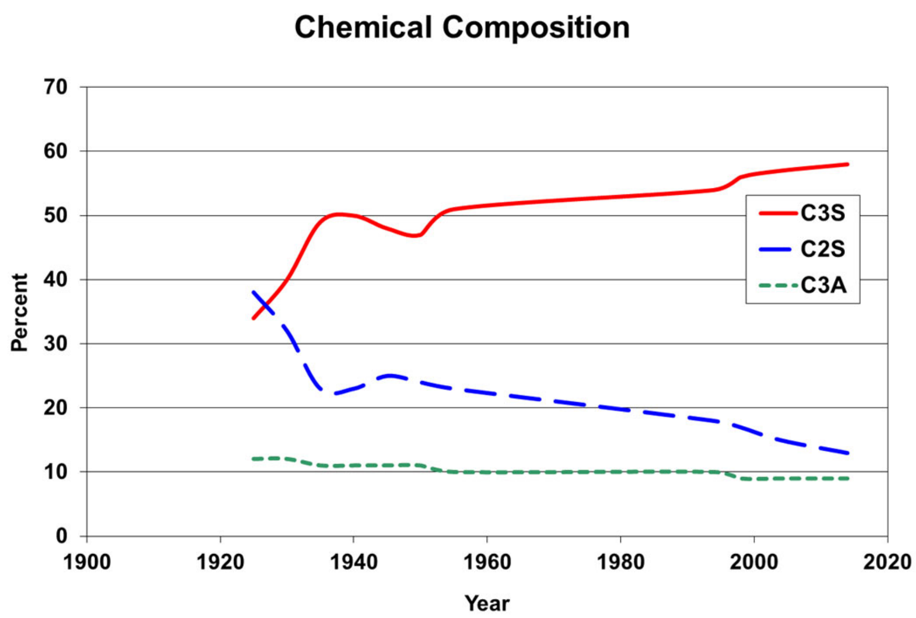
Not to scale

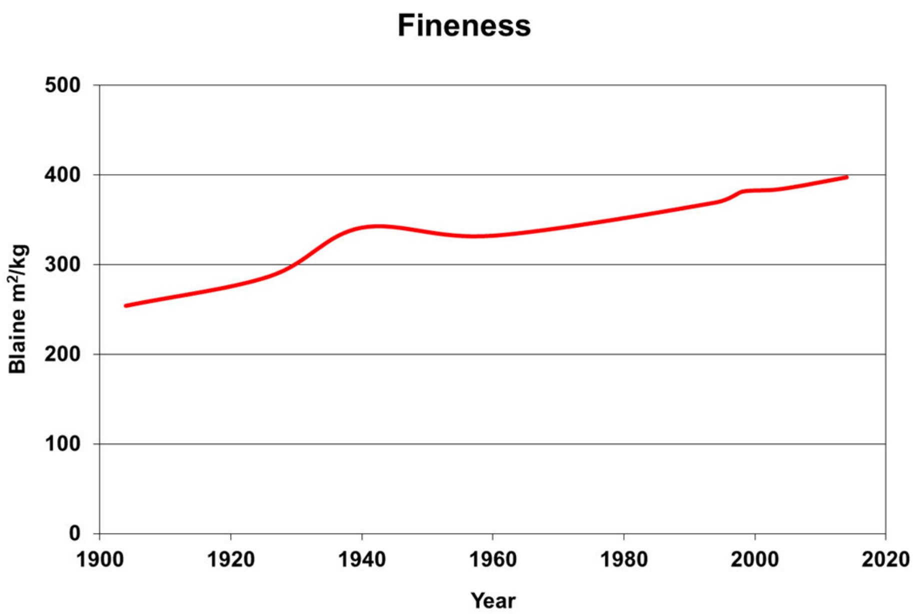
Portland Cements

- Type I – general use (ASTM C 150)
- Type IL – general use (ASTM C 595)



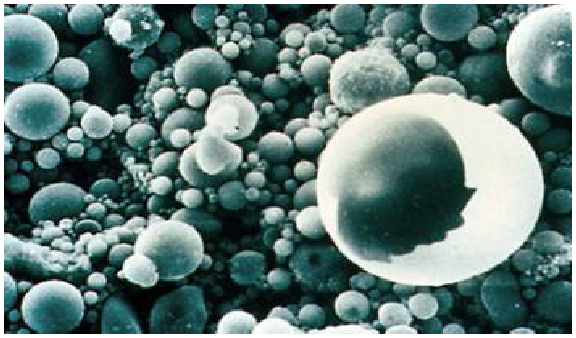
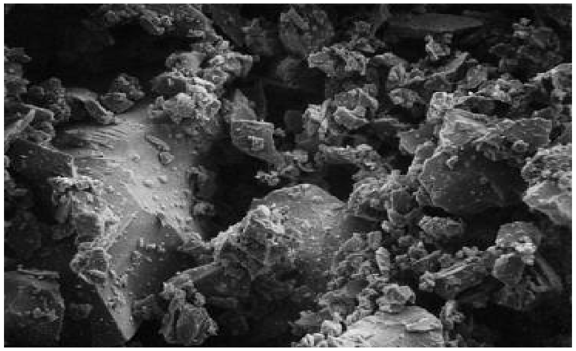
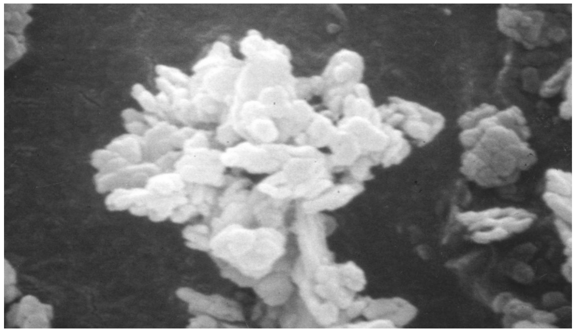
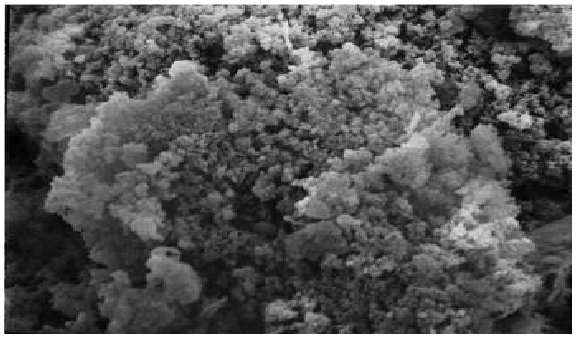
Cement is Changing





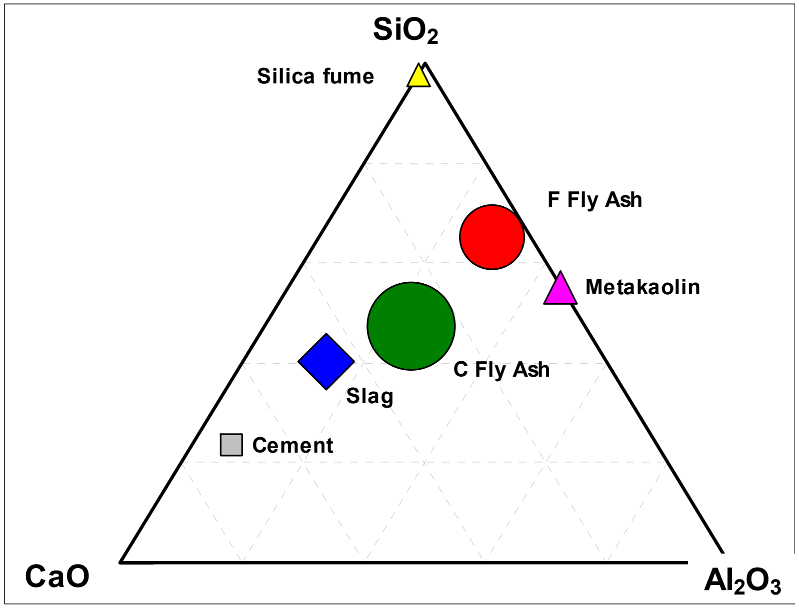
Supplementary Cementitious Materials

- Fly ash
- Slag
- Natural pozzolan
- Silica fume

Sources

- Fly ash – coal fired utilities
- Slag – iron making
- Silica fume – ferro silicon
- Metakaolin – partially calcined clay



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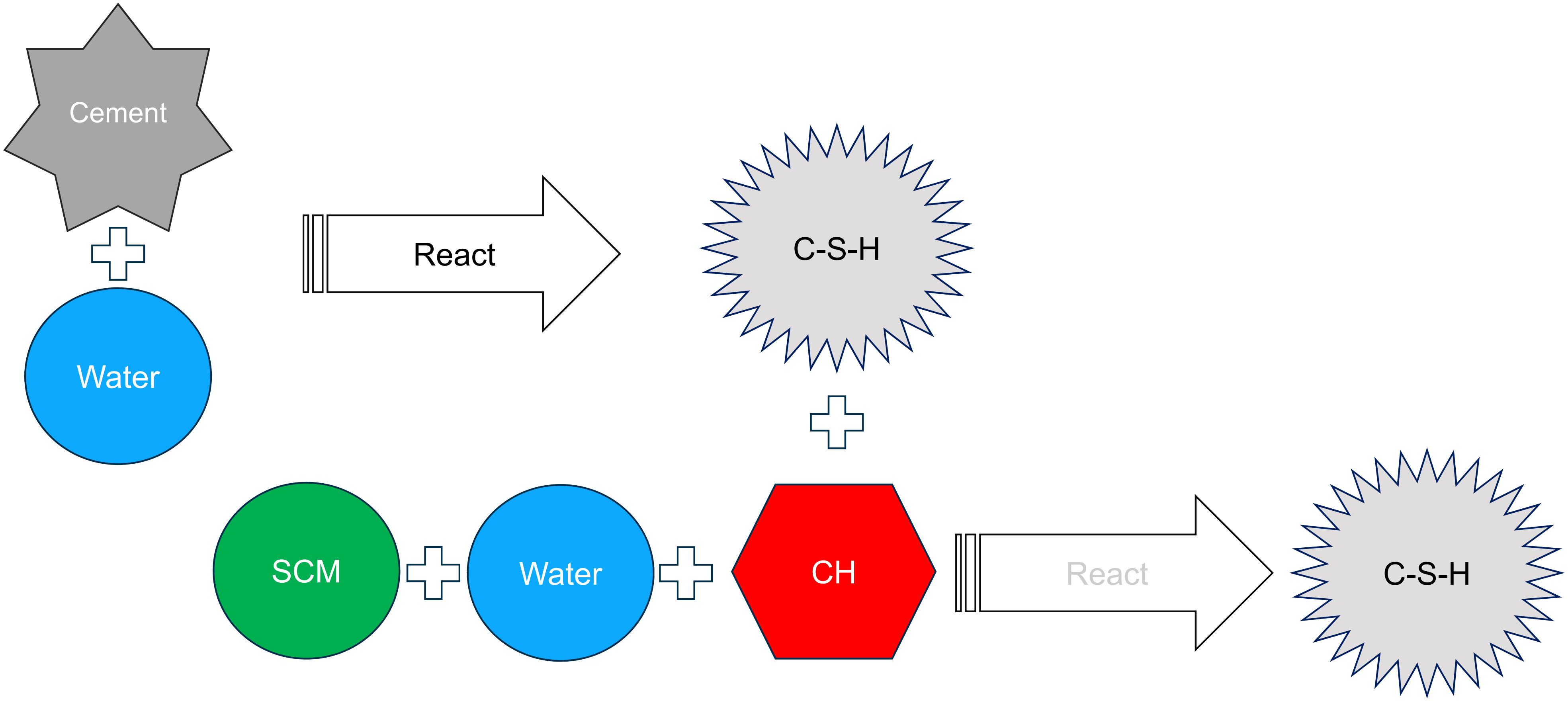
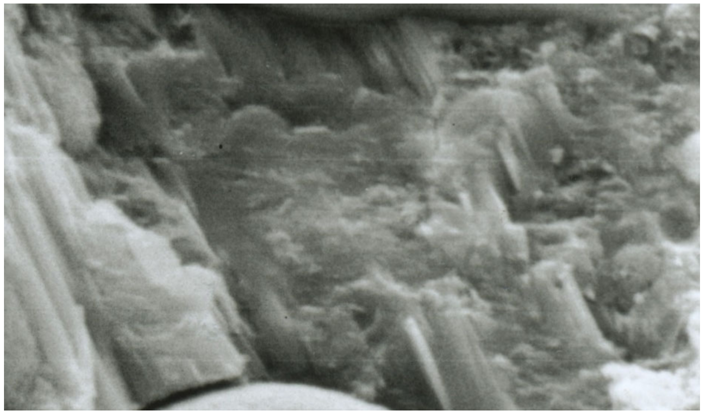
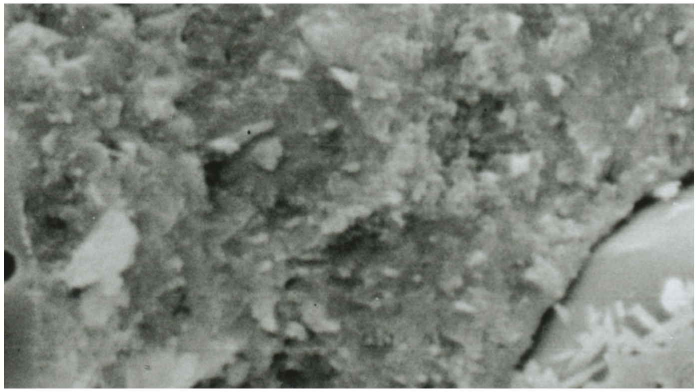


So What Do They Do?

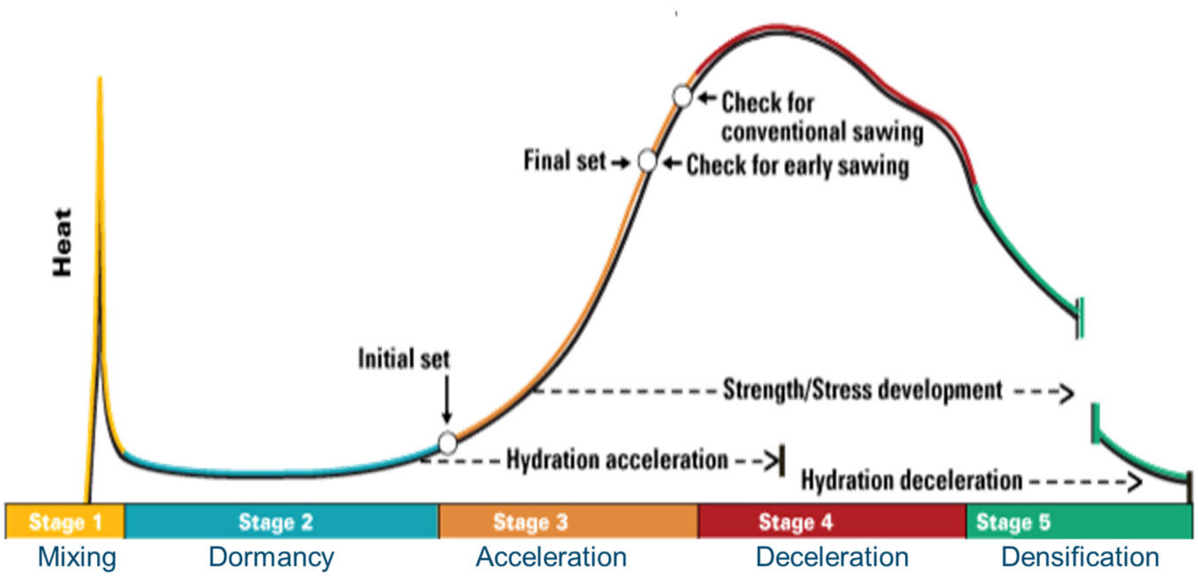
- SCM's change properties
- Means we have to allow for them
- Cracking risk changes
- Finishing and curing needs change
- Strength rate slows
- Permeability decreases (good)



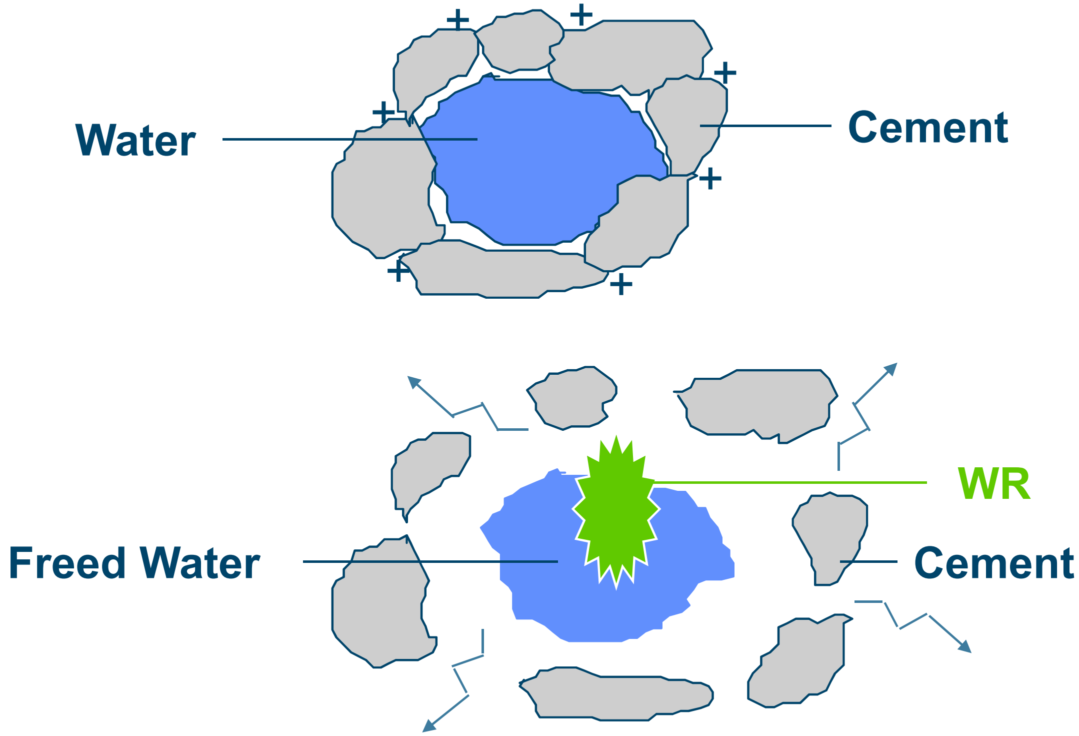


Water

- Potable or
- Free of organics & contaminants

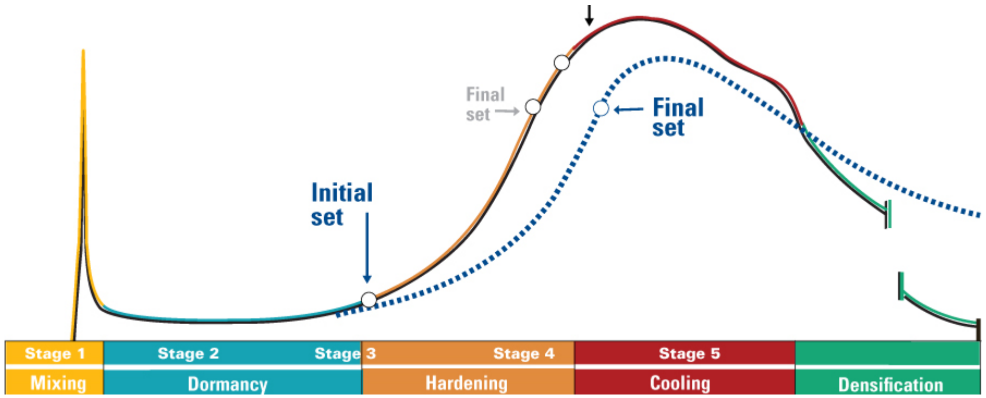


Water Reducers



Retarders

- Slow hydration
  - Slows need for sawing in hot weather
  - Reduces heat of hydration peak
  - May reduce slump loss
  - May improve long-term strength
  - May increase risk of plastic cracking
- Often based on sugars



Accelerators

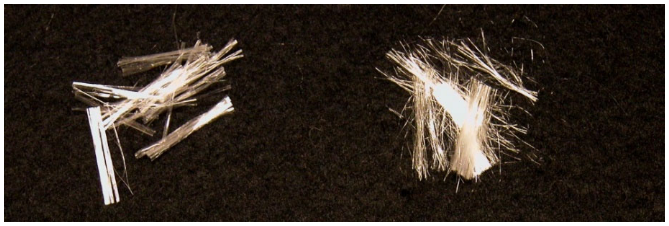
- Increase rate of hydration
  - Setting time decreased in cold weather
  - Increased early strength
  - May increase risk of shrinkage cracking
- Avoid chloride based products if steel is in the concrete

Fibers - Critical Properties

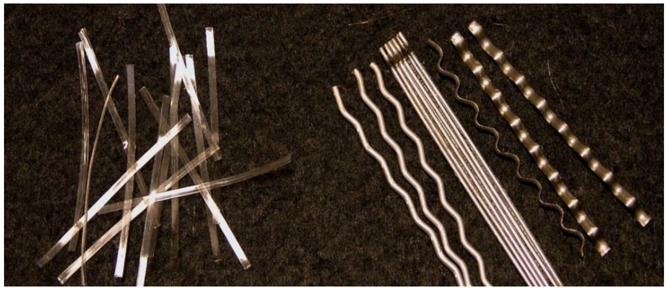
- Stiffness
- Bond
- Strength
- Size
- Durability

“Micro” vs. “Macro” Fibers

- Micro (Low Volume Addition) Fibers
  - Diameters < 0.004”
  - Polypropylene, Nylon, Carbon, Cellulose
  - 0.03 – 0.1% volume (0.5-1.5#/cy)

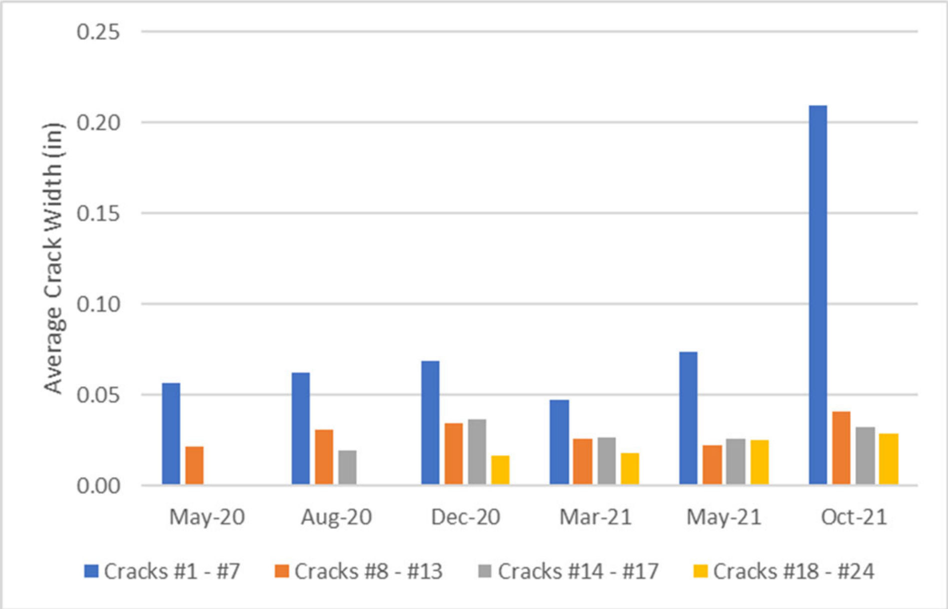


- Macro (High Volume Addition) Fibers
  - Diameters: 0.008 – 0.03”
  - Synthetic, Steel 0.2 – 1.0% volume [3 - 15#/cy (Synthetic) or 20-100#/cy (Steel)]



Effects of Fibers

- Do not affect strength
- Do increase toughness / strain capacity



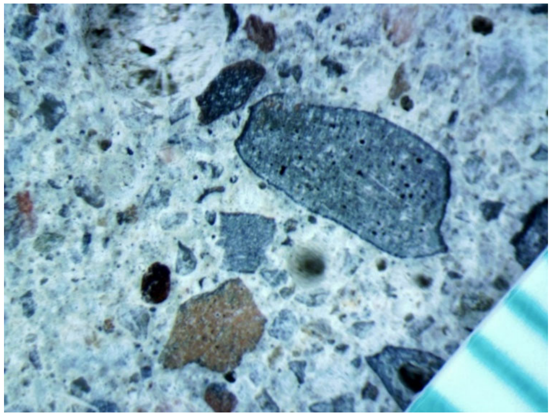
Curing

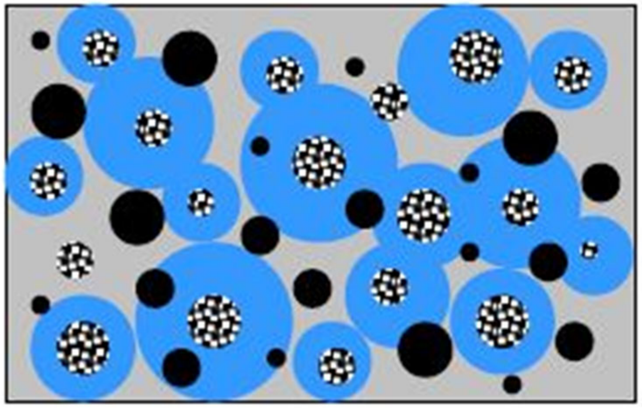
- Keep the water in…
- Curing compound should be applied as soon as practical after finishing
- Should be white
- Poly-alpha-methylstyrene is effective
- Alternatives are water fogging, plastic sheeting, ponding

- How do we know it is good?

Internal Curing

- Provide curing water uniformly through the section
- Material should
  - Hold sufficient water
  - Hold the water until needed and not effect w/c
  - Give up water at high RH (desorption)
  - Not adversely effect the concrete quality





Proportioning

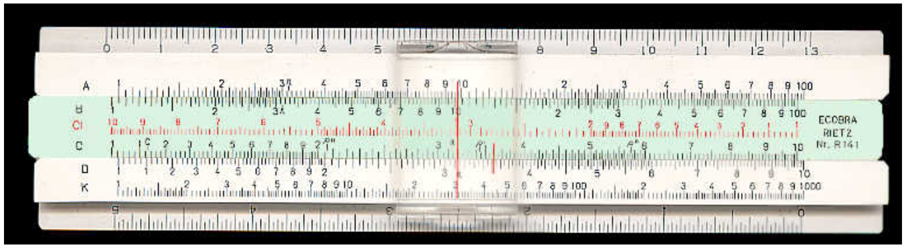
Proportioning Approaches Past

- Structural concrete 1:2:4
- Other concrete 1:3:6
- Waterproof concrete Add salt

- No chemicals
- No SCMs
- Precision was ugly
- Bulking made it worse

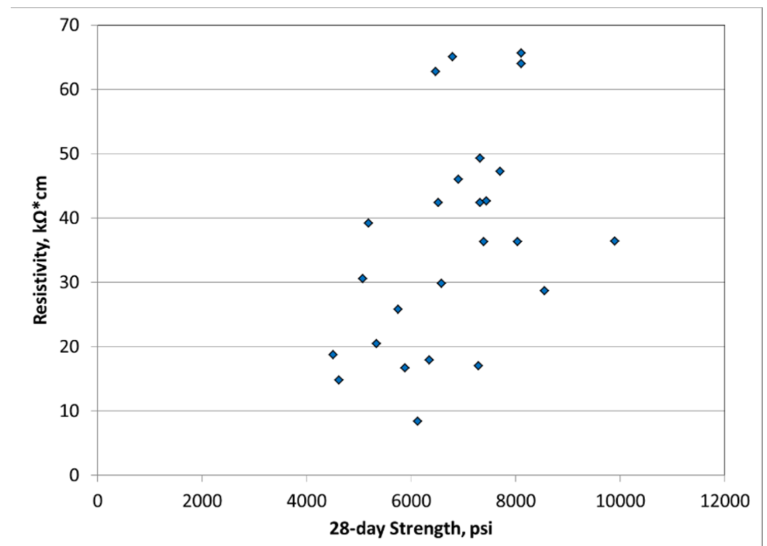
Proportioning Approaches Present

- ACI 211
  - Last revised in 1991
  - Linear
- Developed
  - Before water reducers
  - Before supplementary cementitious materials
- Primarily focused on structural concrete
  - 100 mm (4”) slump
  - 30 MPa (~4000 psi)



Preconceptions

- More cement = more strength
- Strength is everything
- Slump indicates quality
- Gradations of individual fractions are critical



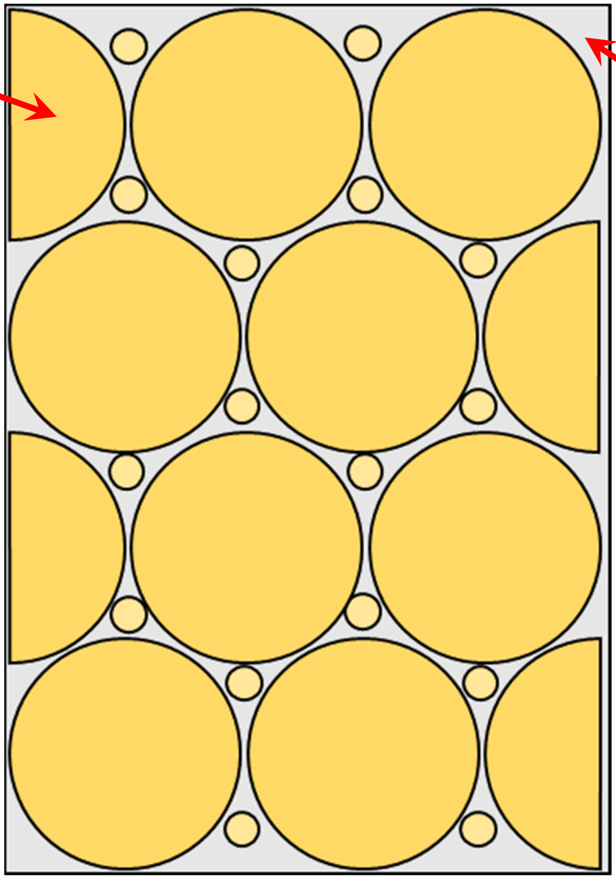
What do we need?

- Transport properties (everywhere)
- Aggregate stability (everywhere)
- Strength (everywhere)
- Cold weather resistance (cold locations)
- Shrinkage (dry locations)

- Workability (everywhere)

Proportioning

Filler
Gradation



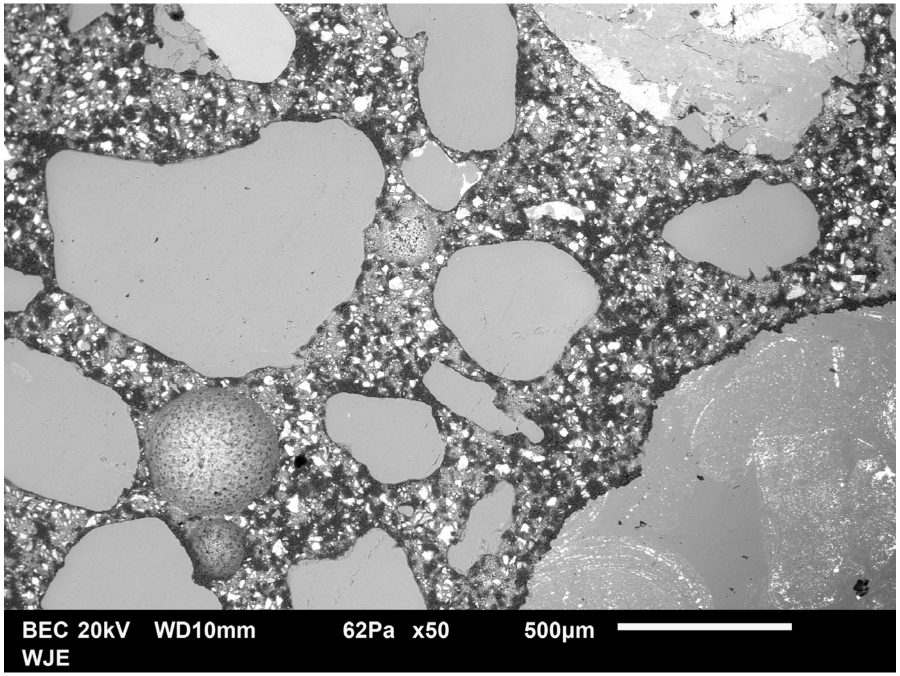
Glue
What sort
How much

How do we proportion to achieve design goals?

		Workability	Transport	Strength	Cold weather	Shrinkage	Aggregate stability
Aggregate System	Type, gradation	✓✓	-	-	-	-	✓✓
Paste quality	Air, w/cm, SCM type and dose	✓	✓✓	✓✓	✓✓	✓	✓
Paste quantity	Vp/Vv	✓	-	-	-	✓✓	-

Step 1 Paste Quality

- Binder type
  - Cement type
  - SCM type and dosage
- w/cm
  - ~0.38-0.42
- Air void system
  - <0.2 SAM
  - <0.008 in. spacing factor
  - >5% in place
  - Stable

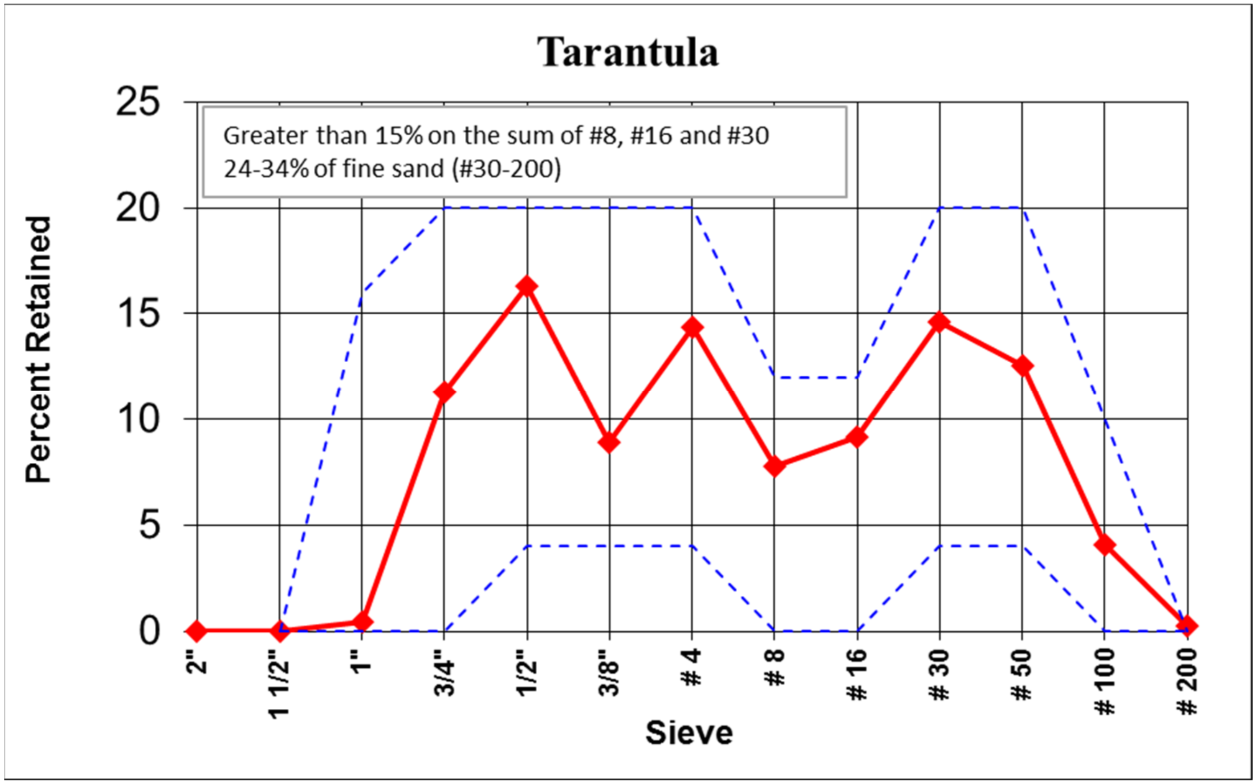


Step 2 Aggregate system

- Choices…
  - 2 bins or 3?
  - ASTM C33
  - Or combined:
    - Haystack
    - Shilstone Plot
    - Power 45
    - Tarantula

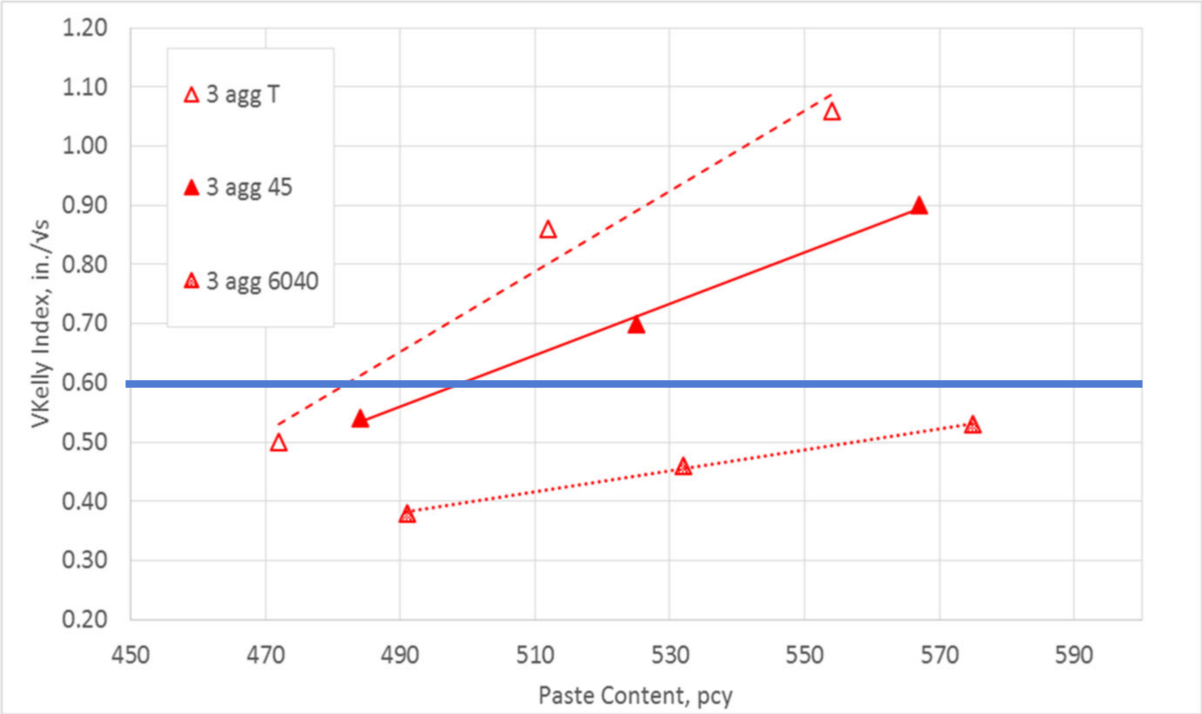
Step 2 Aggregate system

- Tarantula Curve

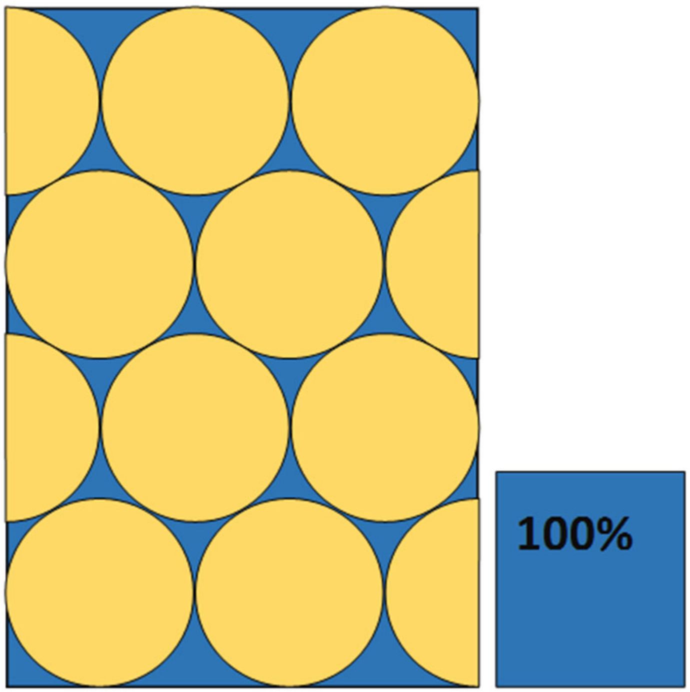


Step 2 Aggregate system

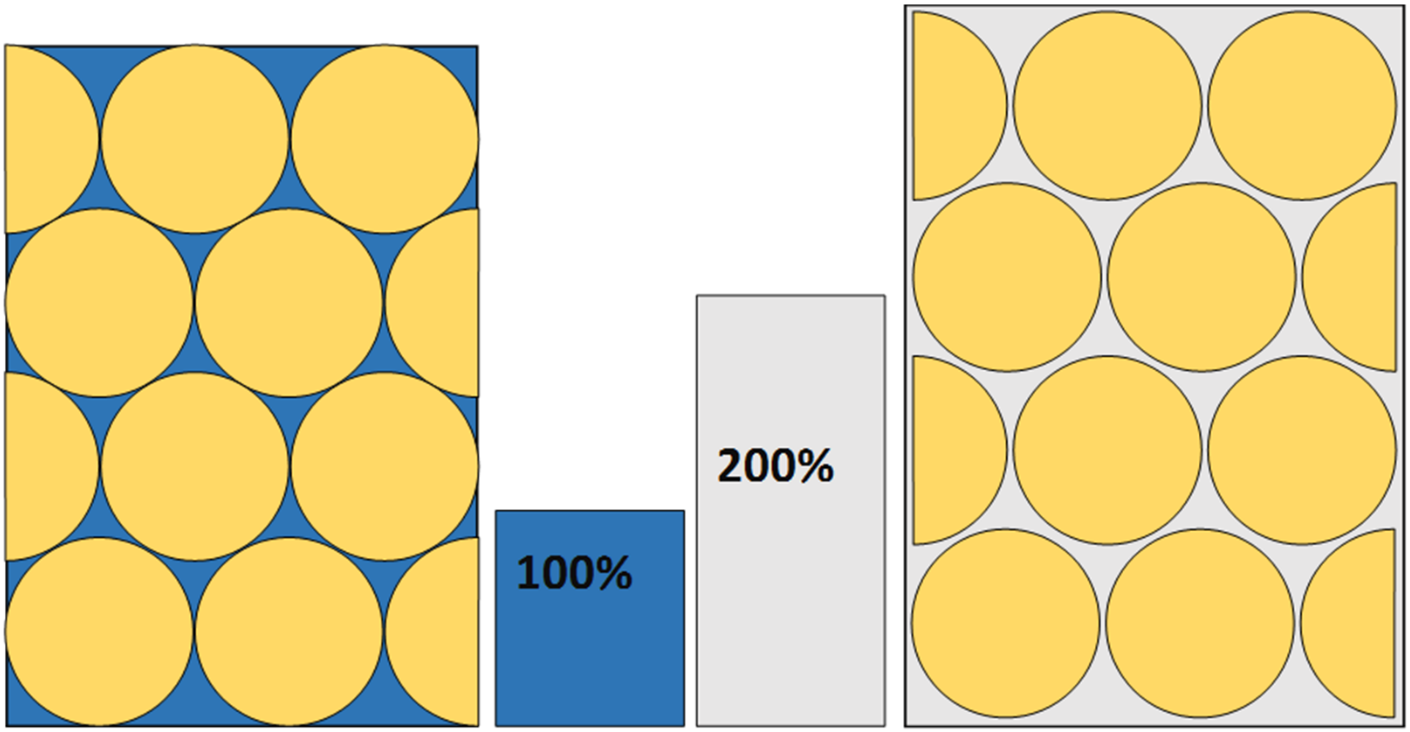
- Choose an aggregate system…



Step 3 Paste Content



Step 3 Paste Content



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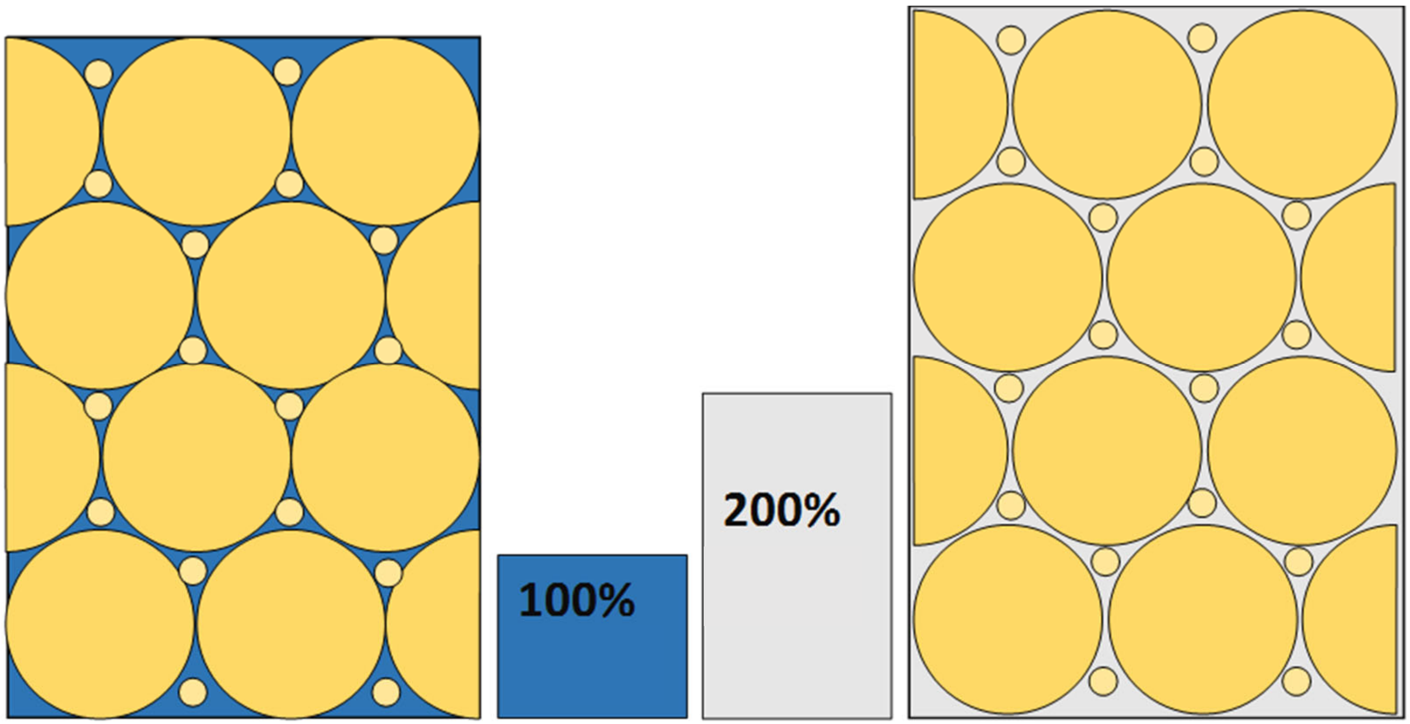
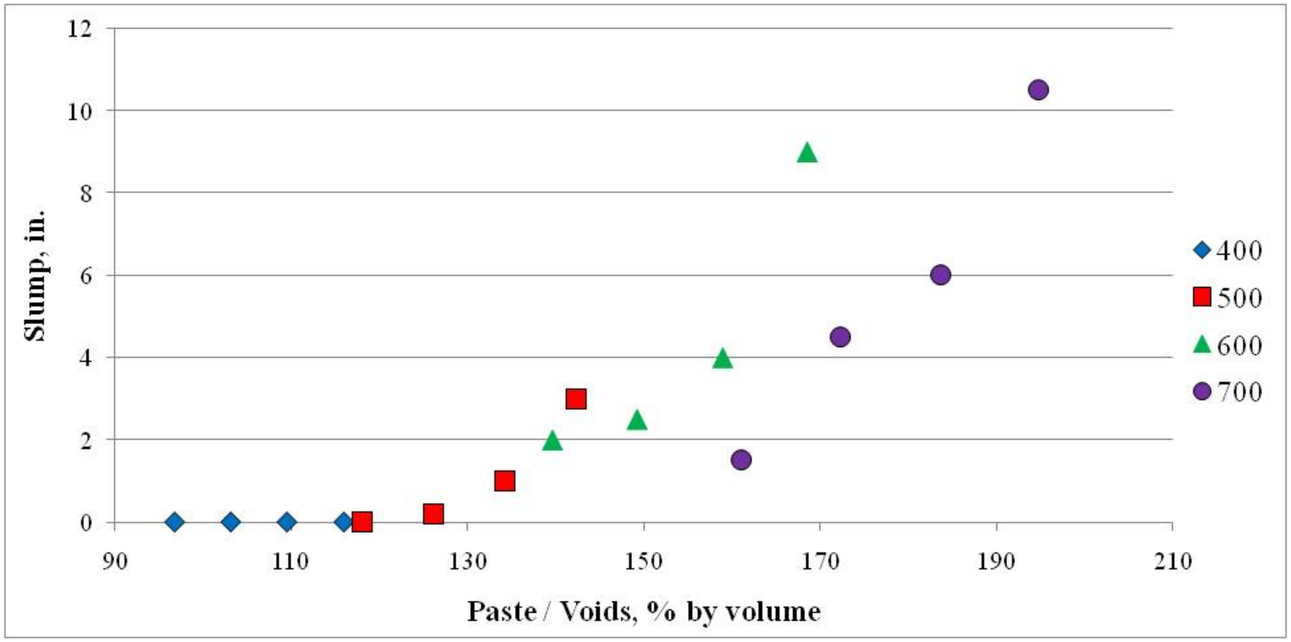
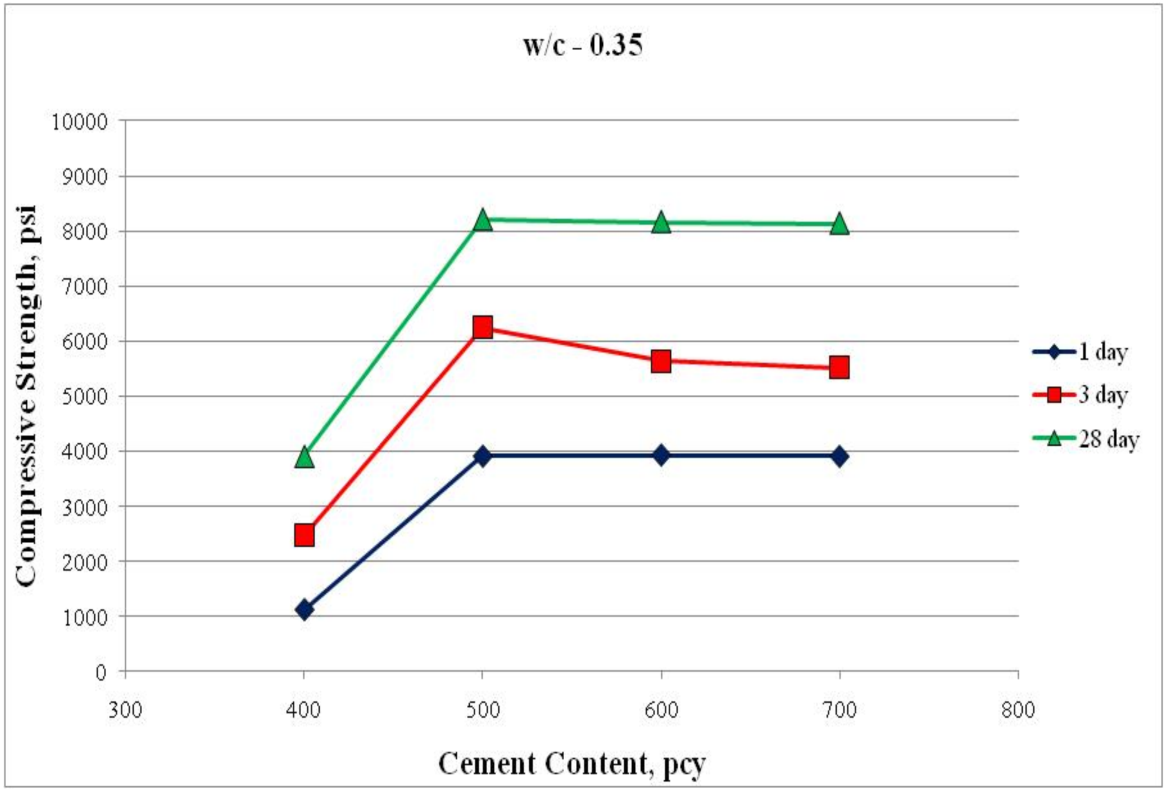


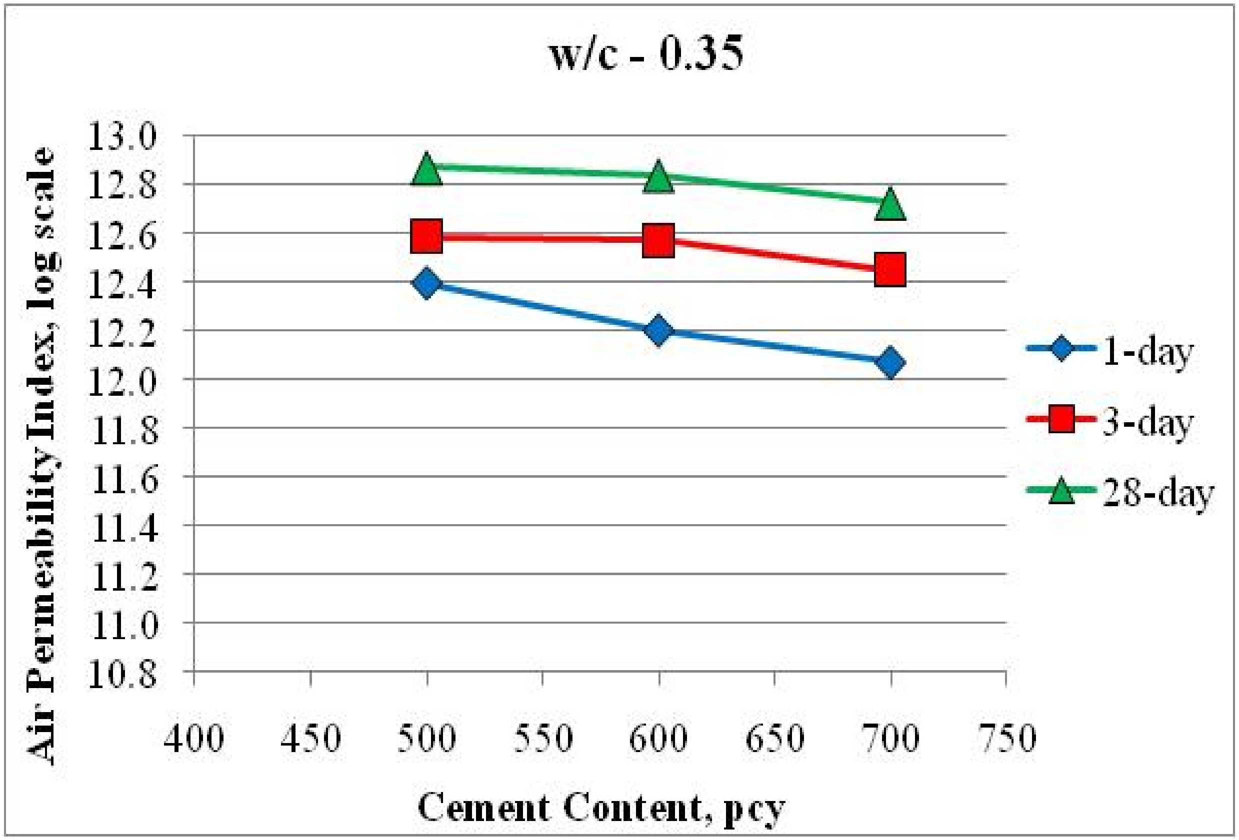
Workability



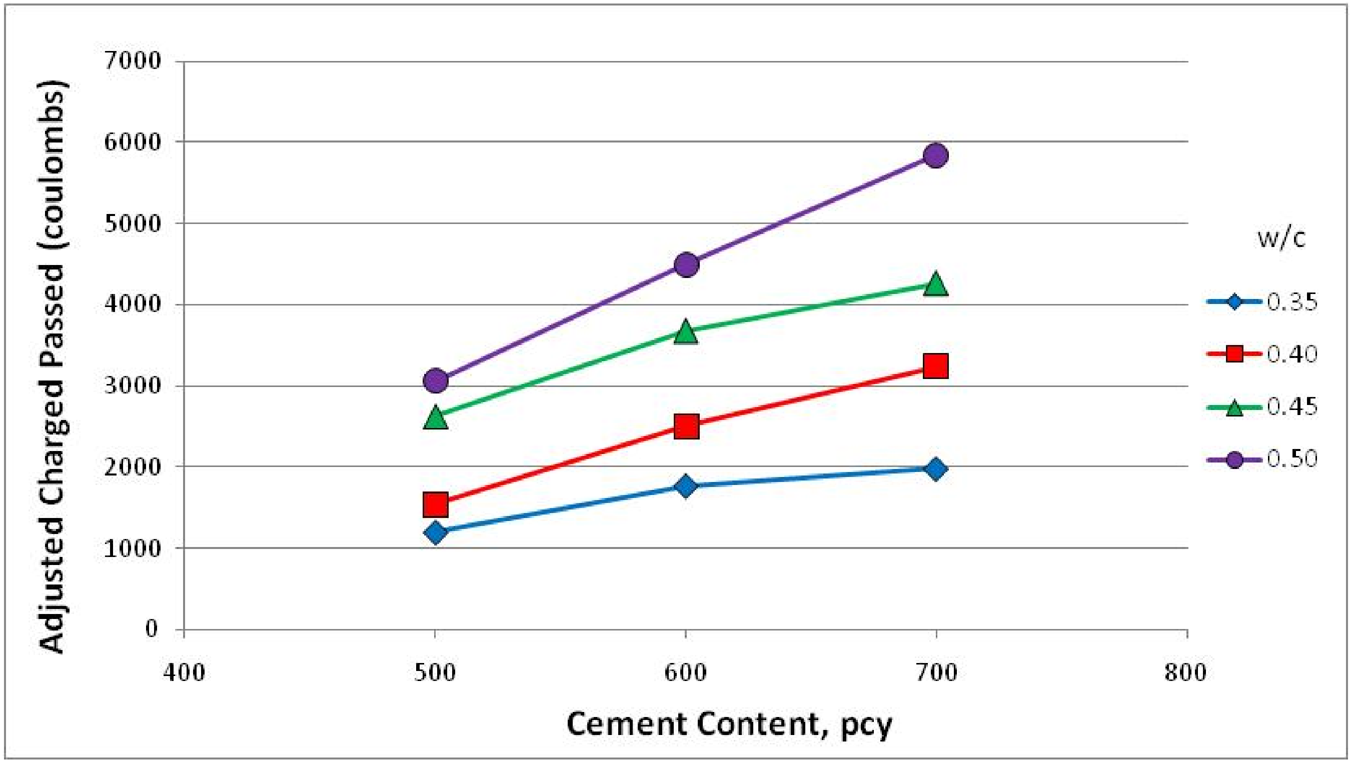
Strength


w/c - 0.35
Compressive Strength, psi
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
300
400
500
600
700
800
Cement Content, pcy
1 day
3 day
28 day

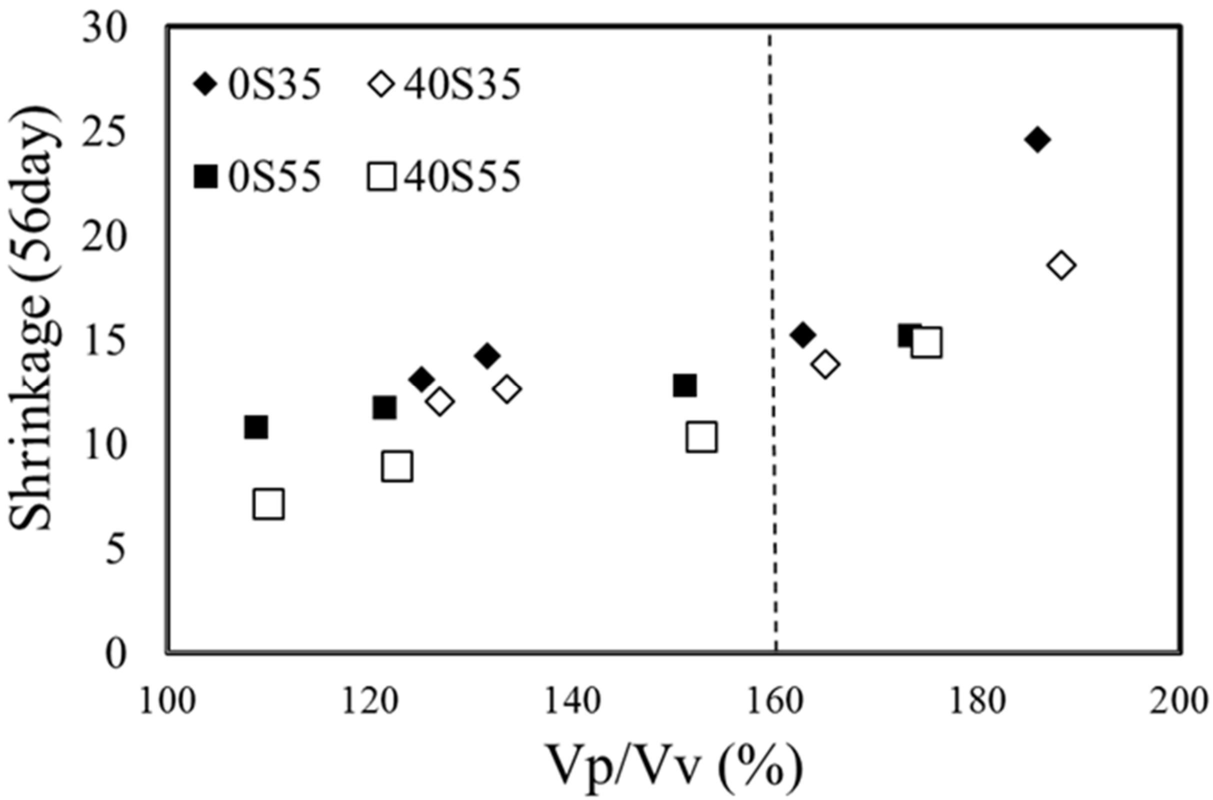
Air Permeability



Rapid Chloride Penetration

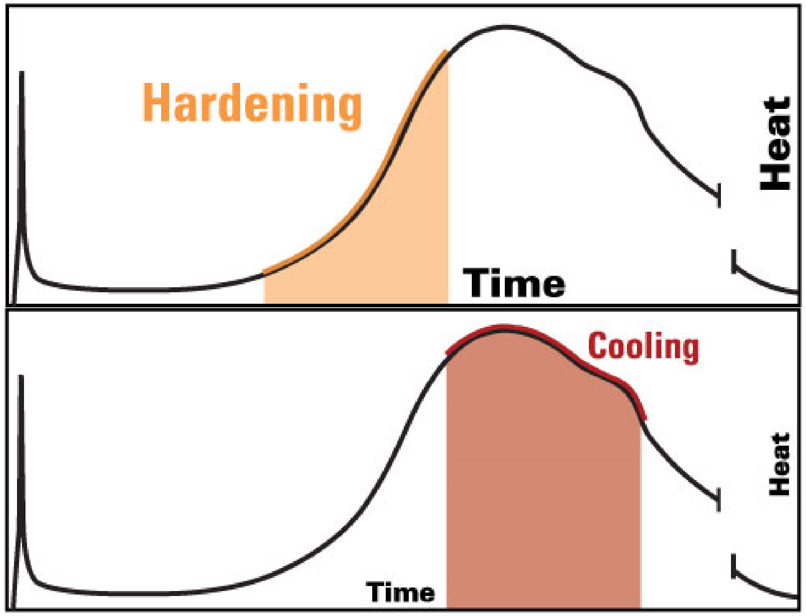


Shrinkage


◆ 0S35
◇ 40S35
■ 0S55
□ 40S55
Shrinkage (56day)
30
25
20
15
10
5
0
100
120
140
160
180
200
Vp/Vv (%)

Step 3 Paste Content

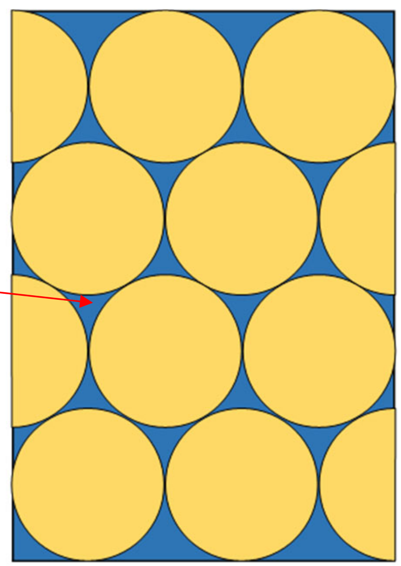
- Need a minimum paste for workability
- Excess has a:
  - Small negative effect on strength
  - Negative effect on permeability, shrinkage, cost
  - Negative effect on heat
- "Optimum" depends on:
  - Aggregate type
  - Gradation
  - Binder type
- Typically Vv ~125-200%

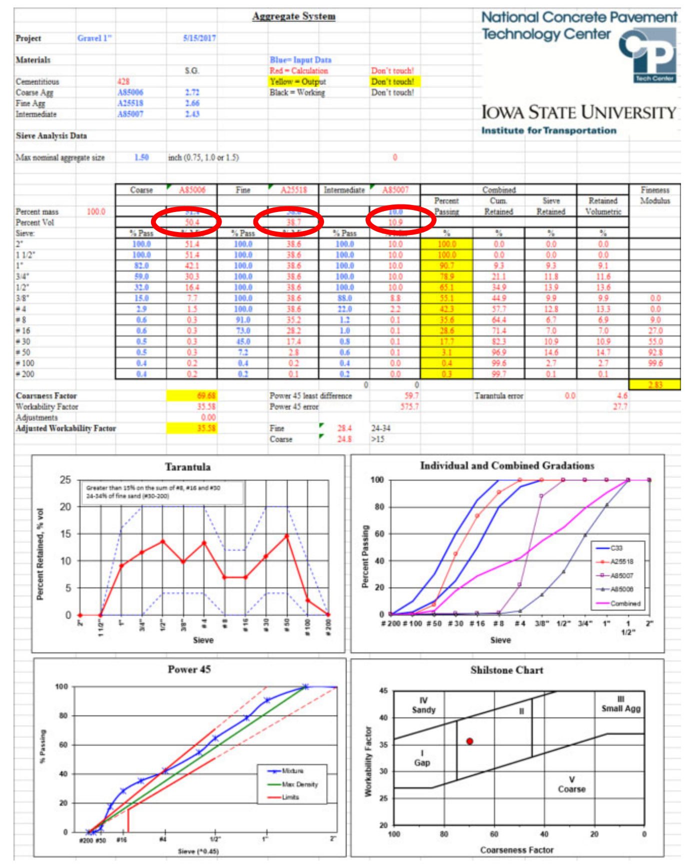


Doing the Sums

The wonders of a spreadsheet and a solver function…

Measure V_a





Doing the Sums

The wonders of a spreadsheet…

Paste Quality

Project	**Gravel 1"**		**5/15/2017**	
Materials				
		Targets		
			R.D.	
Cement	Type I		3.15	
SCM 1	F Ash		2.65	
SCM 2	Slag		1.00	
Coarse Agg	**A85006**		2.72	
Fine Agg	**A25518**		2.66	
Intermediate	**A85007**		2.43	
Water			1.00	
Cementitious		428	pcy	
w/cm		0.42		
Air %		5.0	%	
% SCM 1		20	%	
% SCM 2		0	%	
Voids in aggregate		25.3	%	
Required Vp/Vv		125	%	
Strength		4000	psi	7 days
RCP		1500	coulomb	56 days
Wenner		27	kΩ-cm	28 days

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Blue= Input Data	
Red = Calculation	Don't touch!
Yellow = Output	Don't touch!
Black = Working	Don't touch!

Doing the Sums

The wonders of a spreadsheet…

Mixture Proportions

Project	**Gravel 1"**		**5/15/2017**		
Mixture Proportions					
		Targets	**Actual**		
			Pounds	R.D.	Volume
Cement	Type I		342	3.15	1.74
SCM 1	F Ash		86	2.65	0.52
SCM 2	Slag		0	1.00	0.00
Coarse Agg	A85006		1753	2.72	10.33
Fine Agg	A25518		1318	2.66	7.94
Intermediate	A85007		340	2.43	2.24
Water			180	1.00	2.88
Air %			5.0		1.35
			4019		27.00
Cementitious		428	428	pcy	
Volume of paste			24.0	%	
Volume of aggs			76.0	%	
Volume of voids			19.2		
vp/vv		125	125.0		
w/cm		0.42	0.42		
% SCM 1		20	20	%	
% SCM 2		0	0	%	
Mass aggs		3411	3411	pcy	
Excess paste, %			4.8	%	

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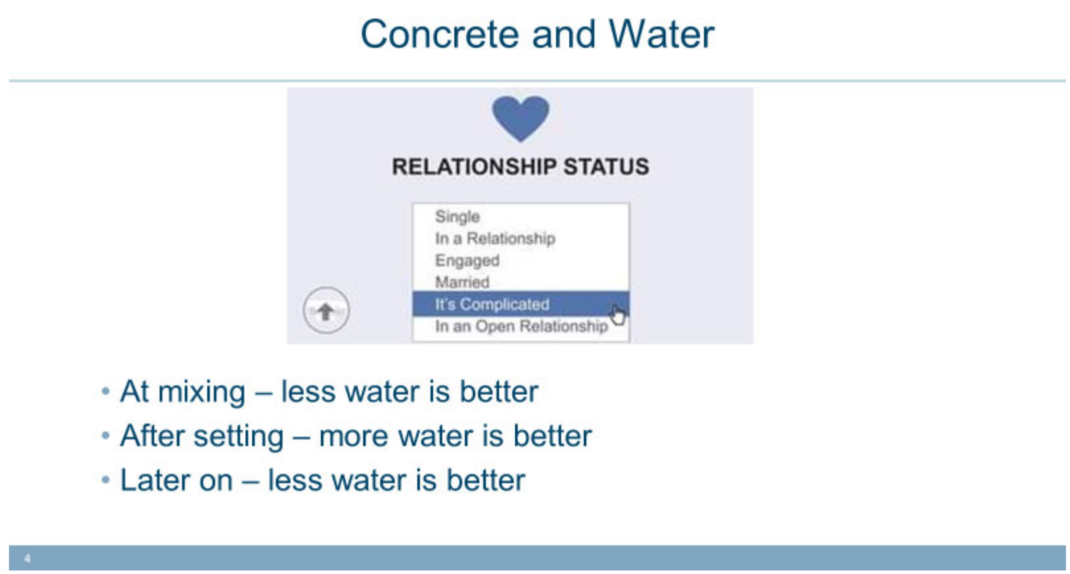
Trial Batches

- Workability
- Air void system
- Setting
- Strength gain
- Permeability

So

- Its all about the water…
  - The right amount
  - At the right time

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