Design and Construction of Sustainable Concrete Pavements in Desert Environments

Tech Center

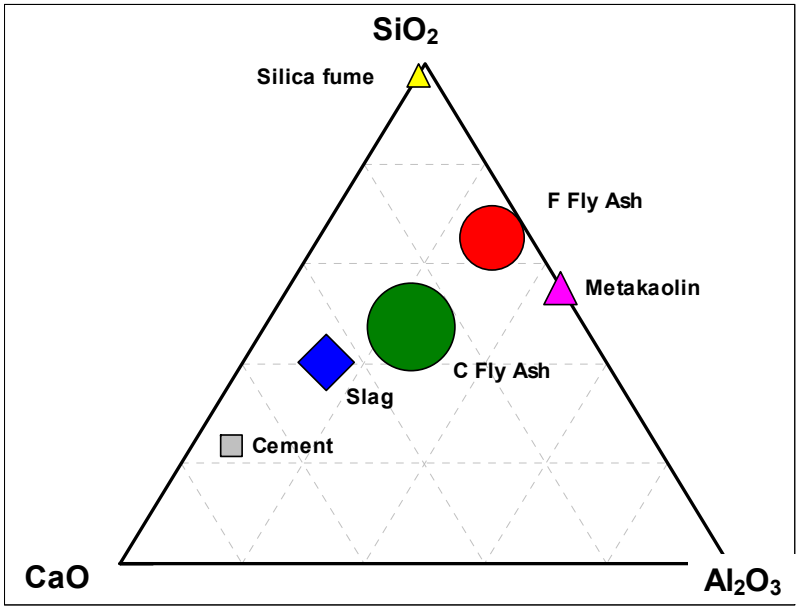
DEPARTMENT OF TRANSPORTATION
UNITED STATES OF AMERICA

NEVADA DOT
SAFE AND CONNECTED

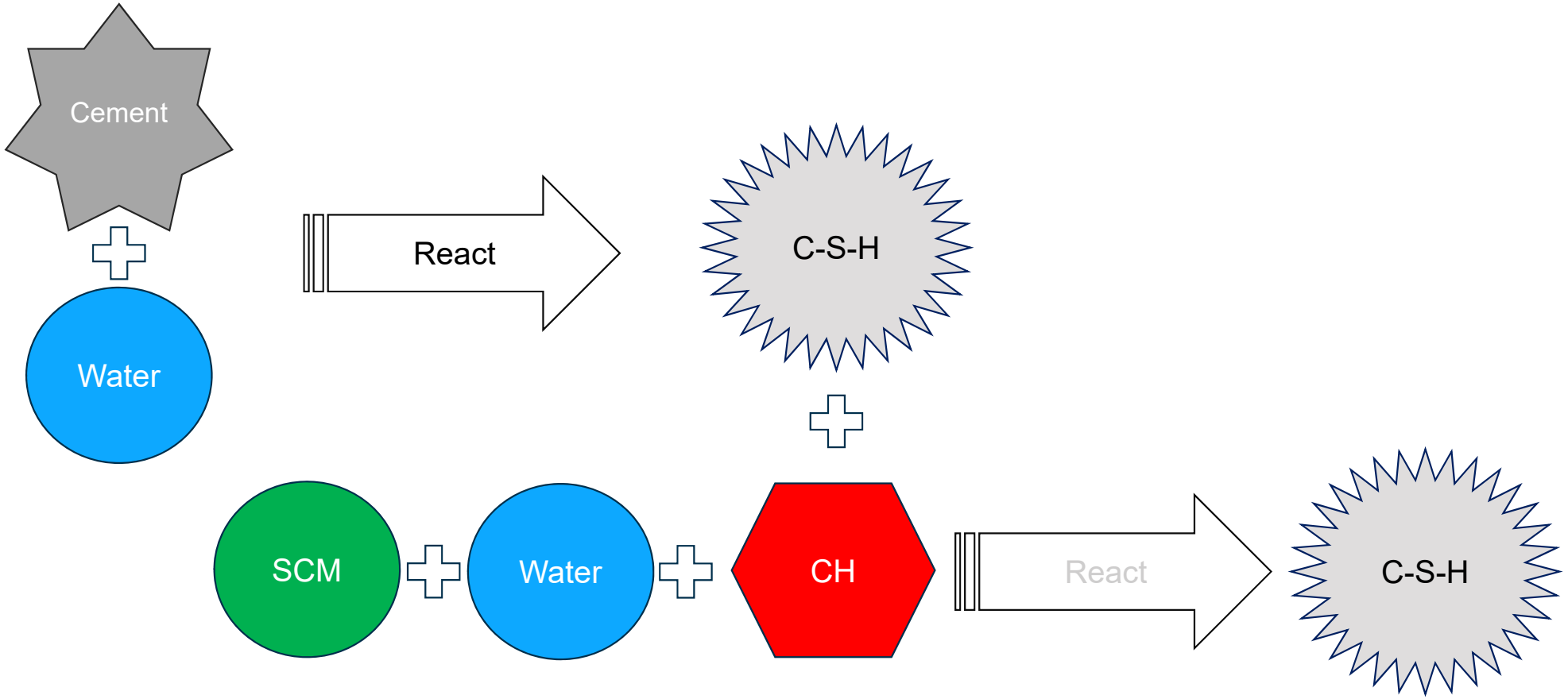
CNCA

Sources

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

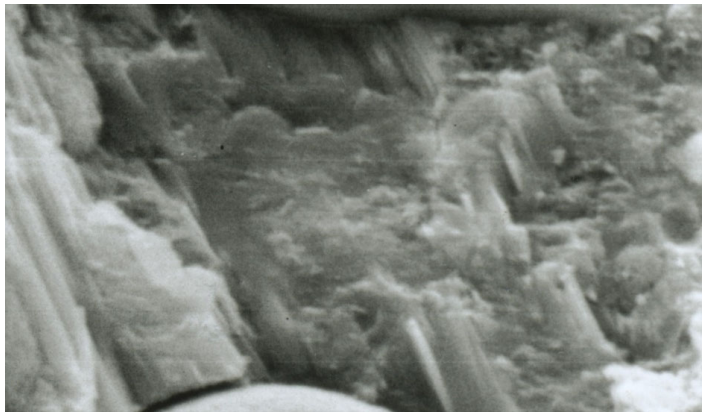


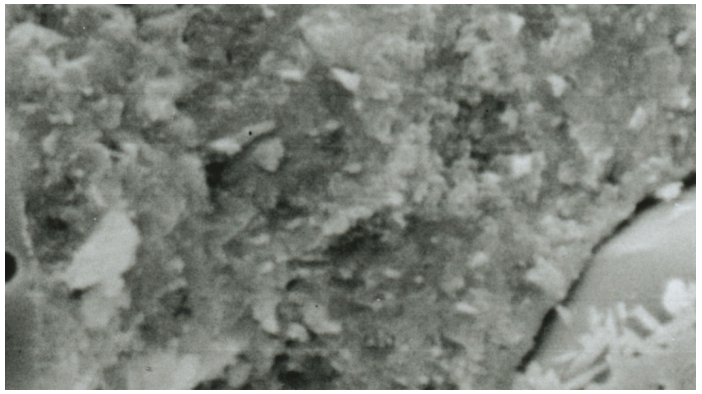
Supplementary Cementitious Materials



So What Do They Do?

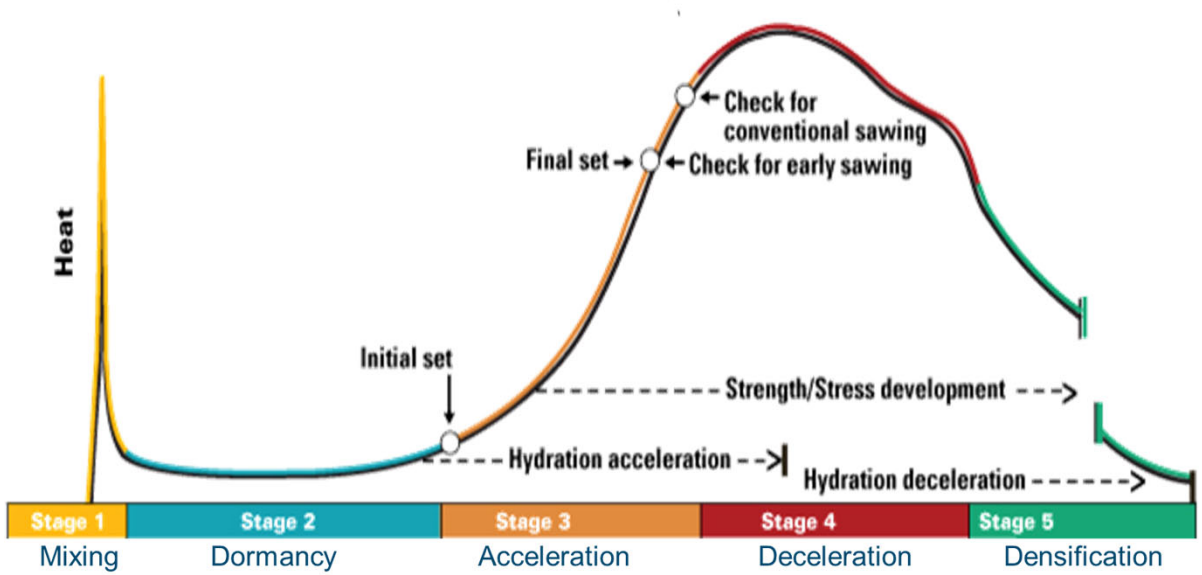
- SCM's change properties
- Means we have to allow for them
- Cracking risk changes
- Finishing and curing needs change
- Strength rate slows
- Permeability decreases (good)



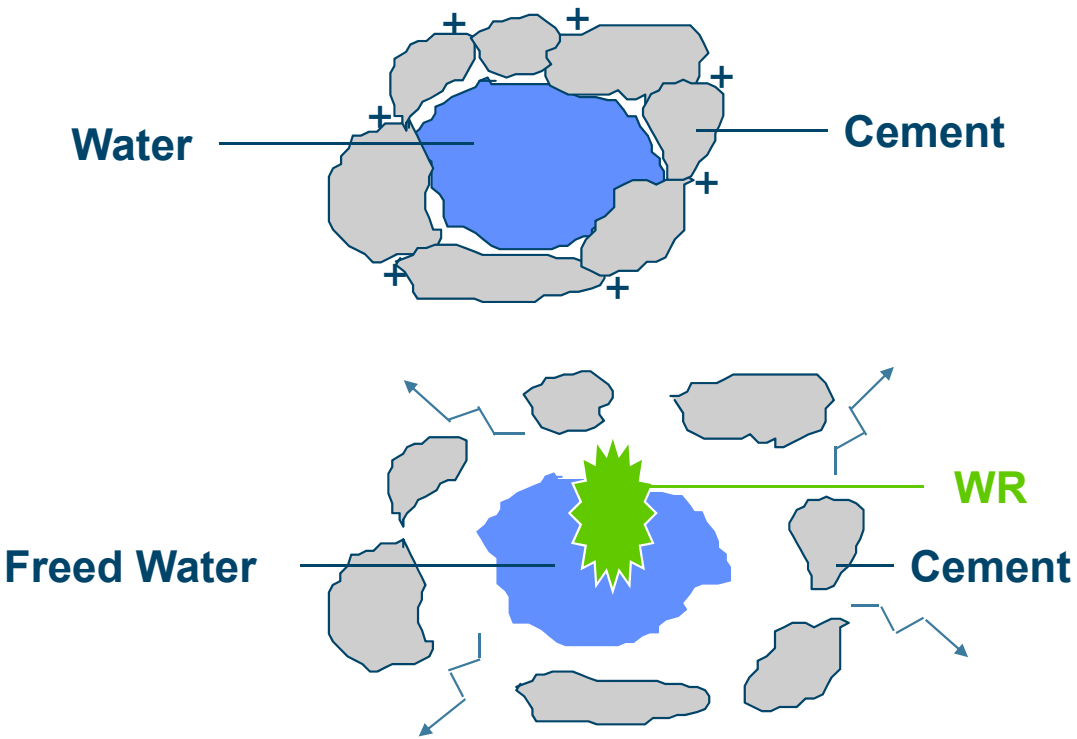


Water

- Potable or
- Free of organics & contaminants

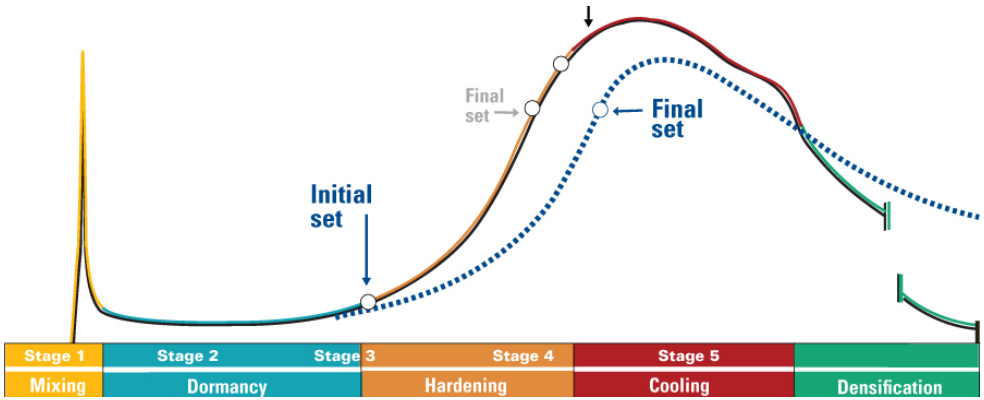


Water Reducers



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

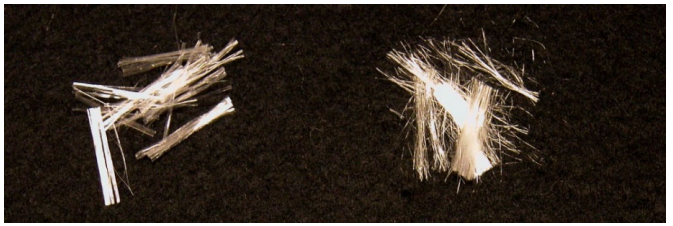
- Increase rate of hydration
  - Setting time decreased in cold weather
  - Increased early strength
  - May increase risk of shrinkage cracking
- Avoid chloride based products if steel is in the concrete

Fibers - Critical Properties

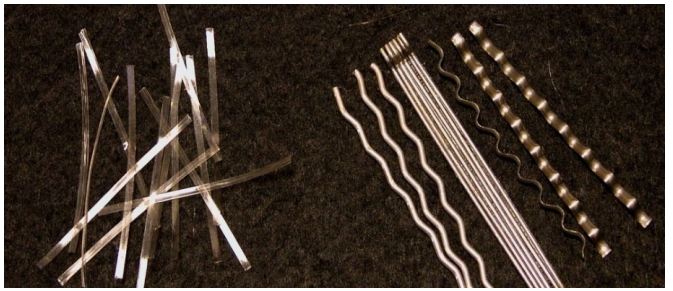
- Stiffness
- Bond
- Strength
- Size
- Durability

“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)

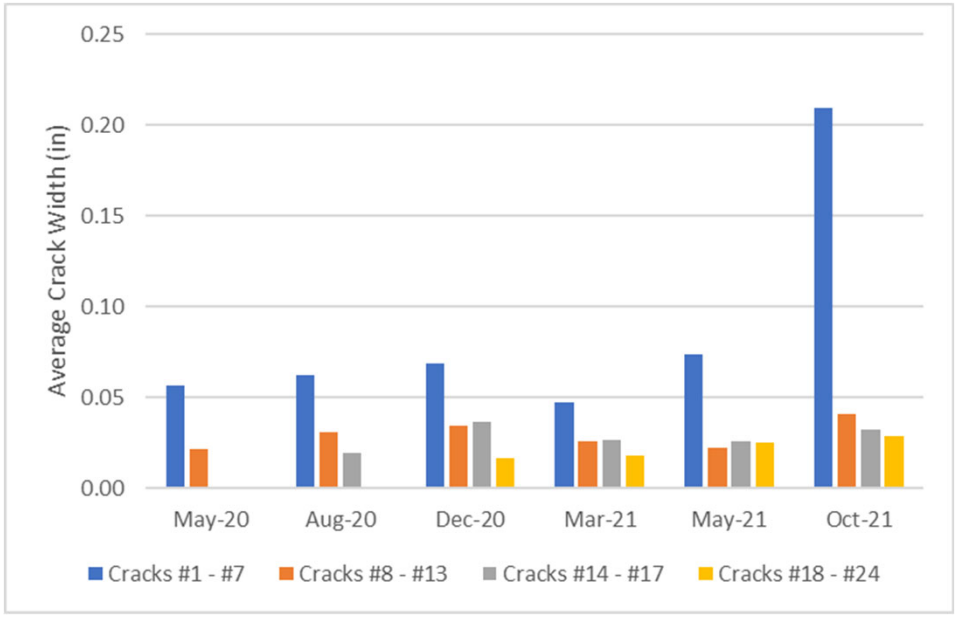


- Macro (High Volume Addition) Fibers
  - Diameters: 0.008 – 0.03”
  - Synthetic, Steel 0.2 – 1.0% volume [3 - 15#/cy (Synthetic) or 20-100#/cy (Steel)]



Effects of Fibers

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



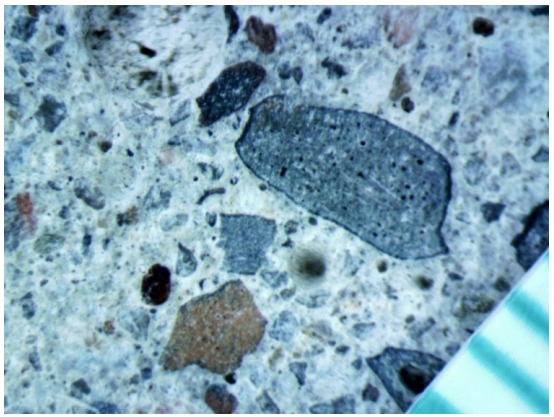
Curing

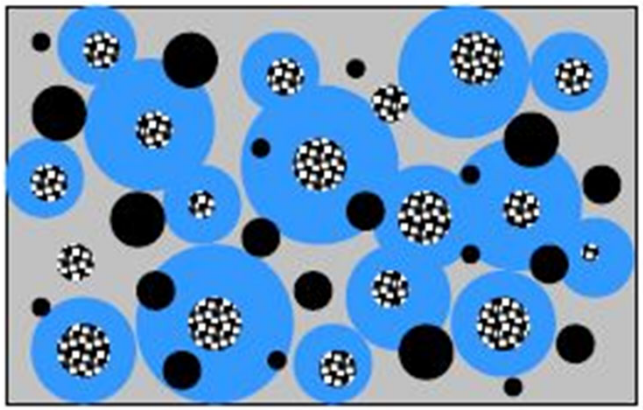
- Keep the water in…
- Curing compound should be applied as soon as practical after finishing
- Should be white
- Poly-alpha-methylstyrene is effective
- Alternatives are water fogging, plastic sheeting, ponding

- 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

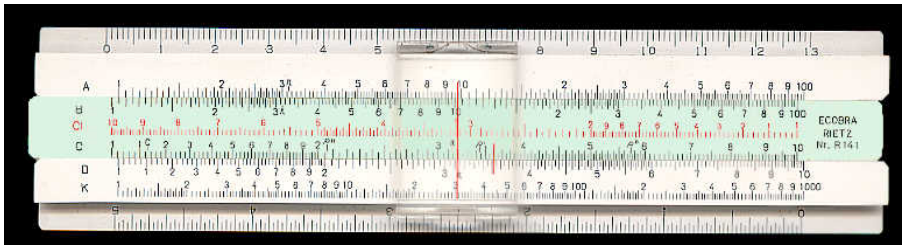
Proportioning Approaches Past

- 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

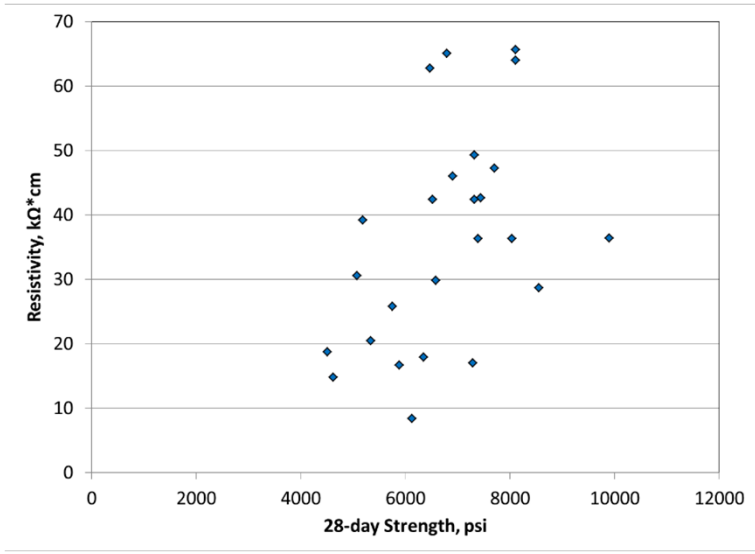
Proportioning Approaches Present

- 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



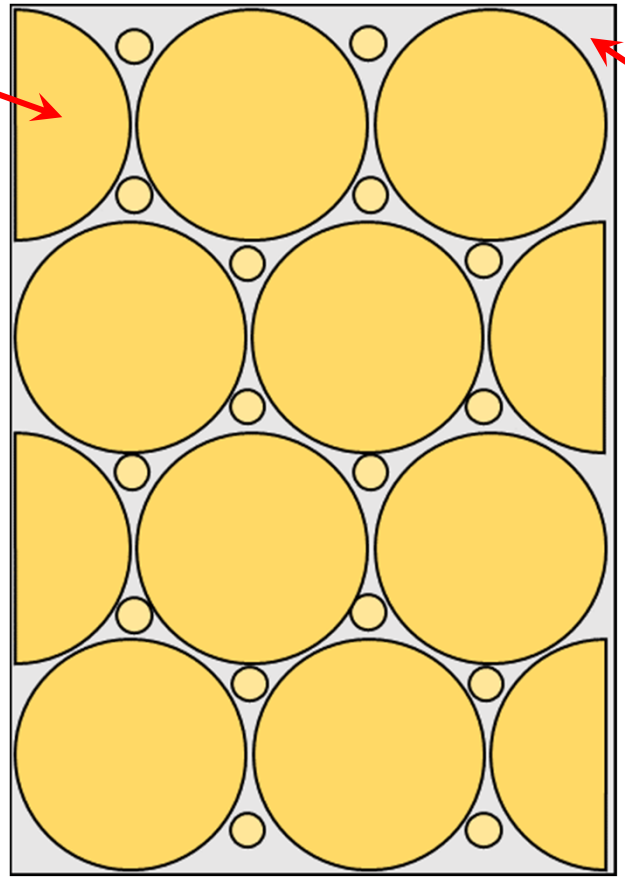
What do we need?

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

- Workability (everywhere)

Proportioning

Filler
Gradation



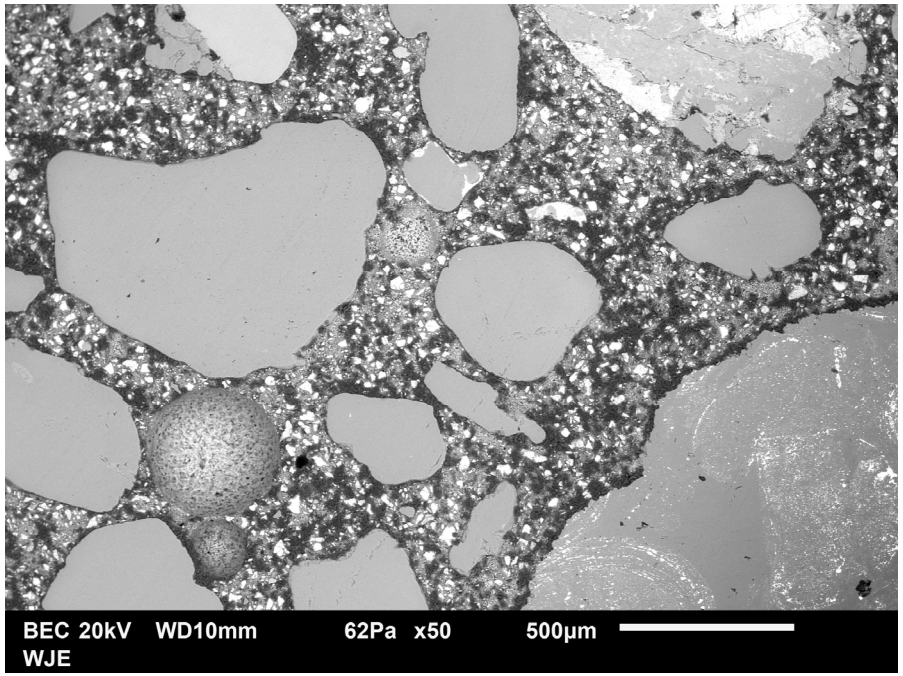
Glue
What sort
How much

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

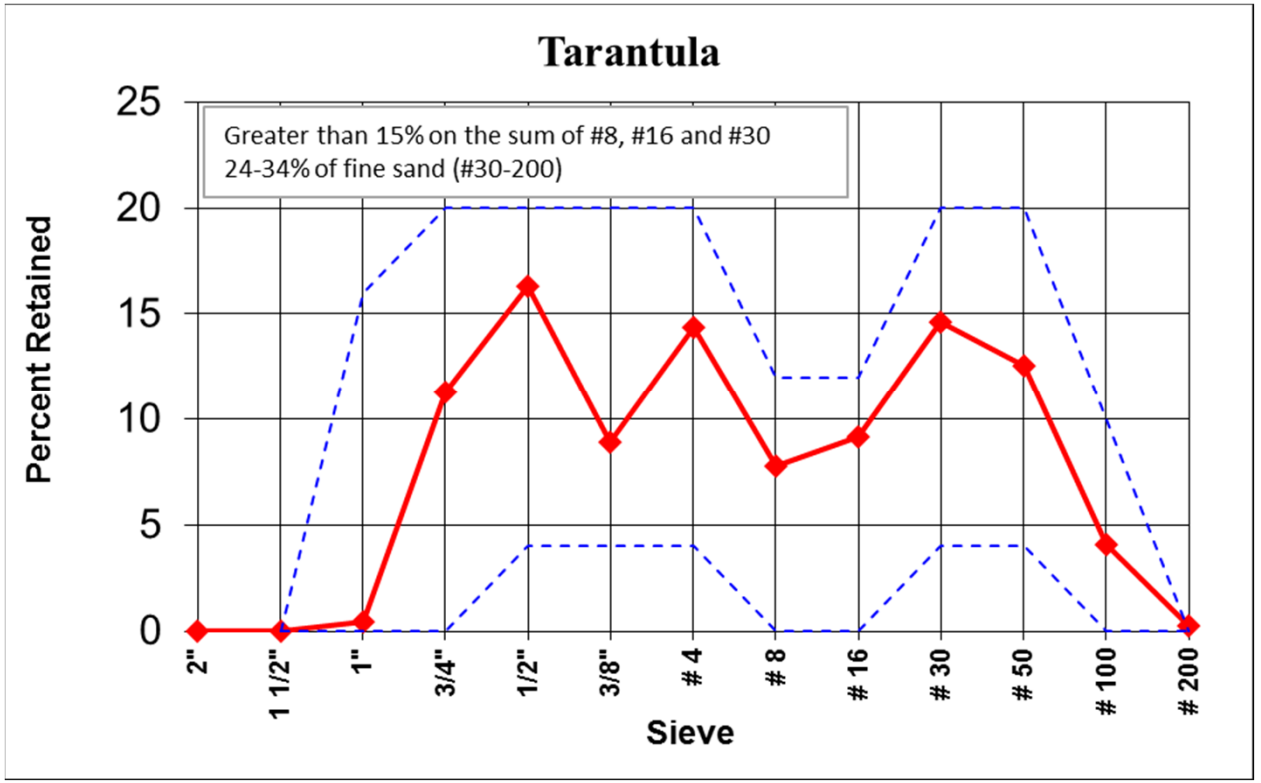


Step 2 Aggregate system

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

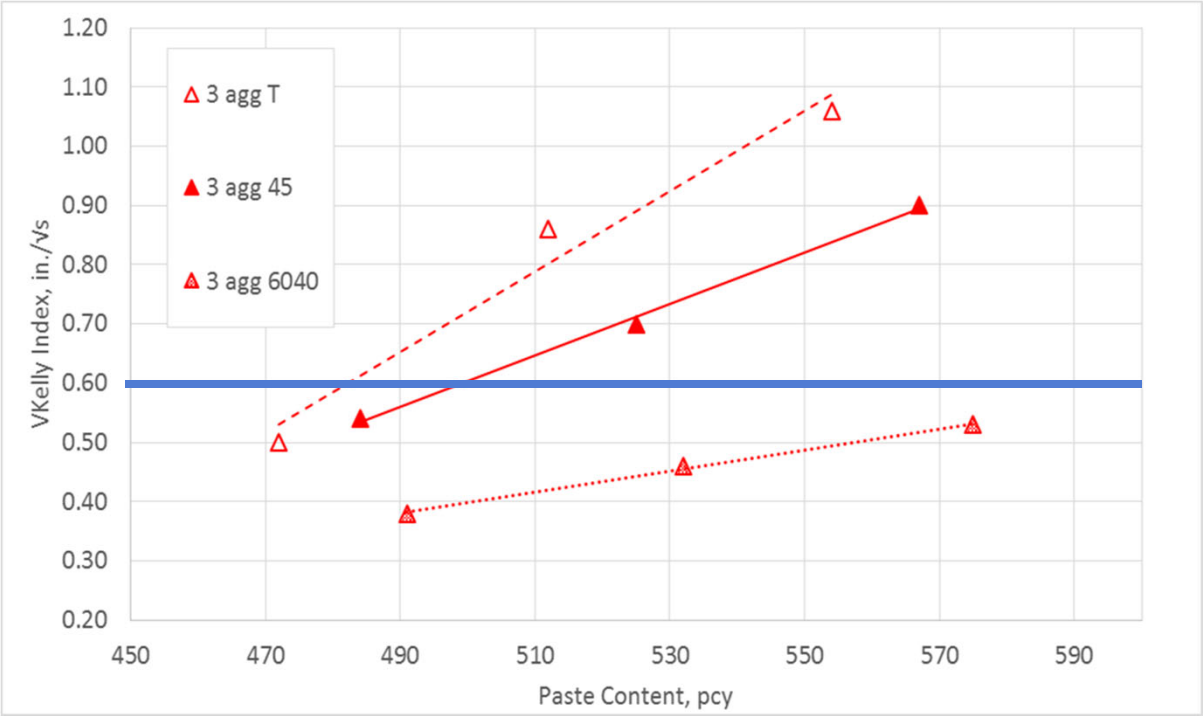
Step 2 Aggregate system

- Tarantula Curve

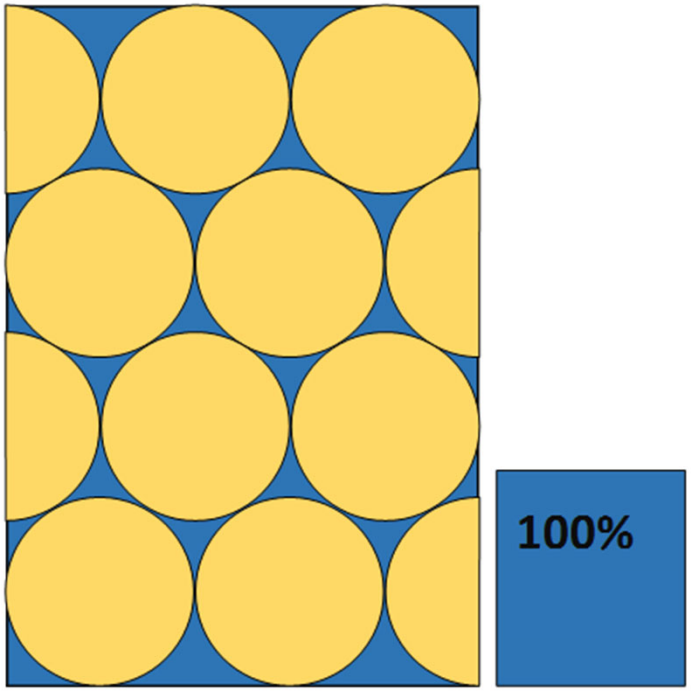


Step 2 Aggregate system

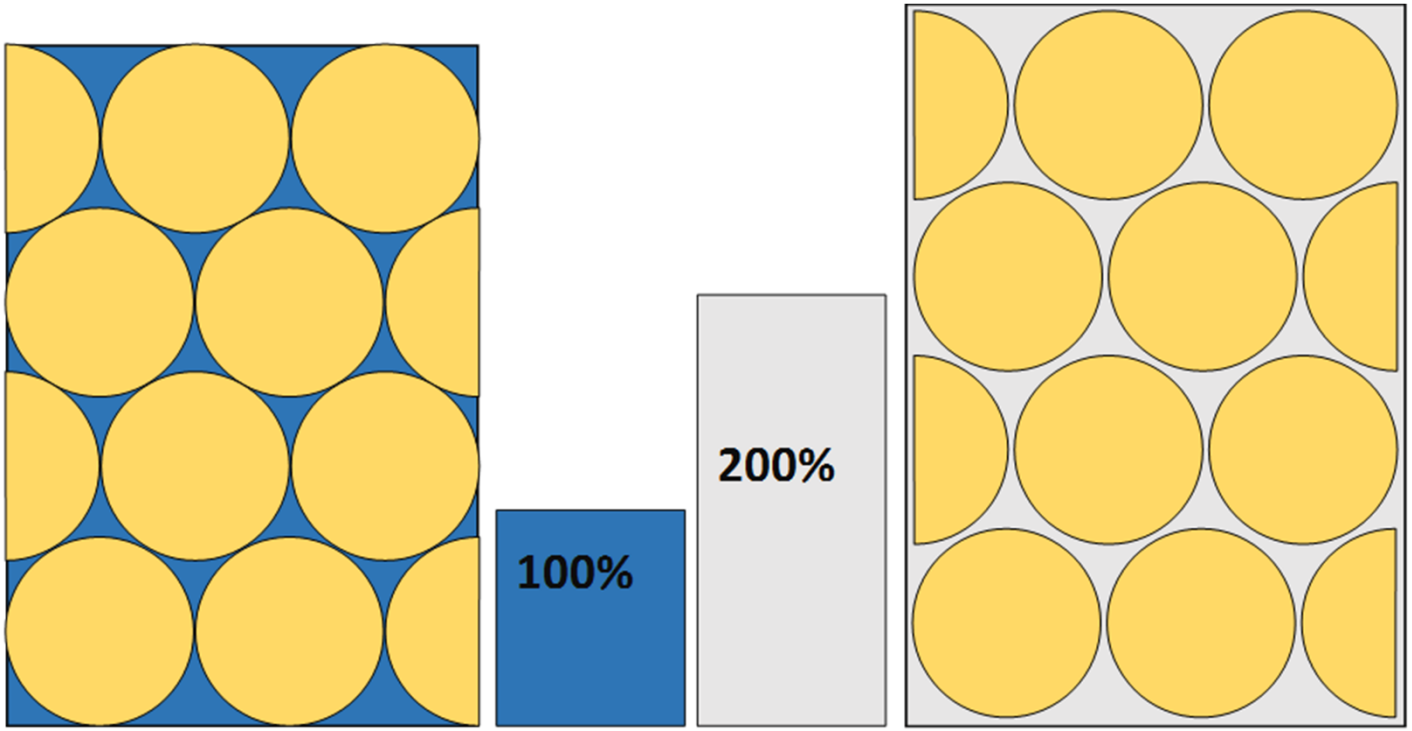
- Choose an aggregate system…



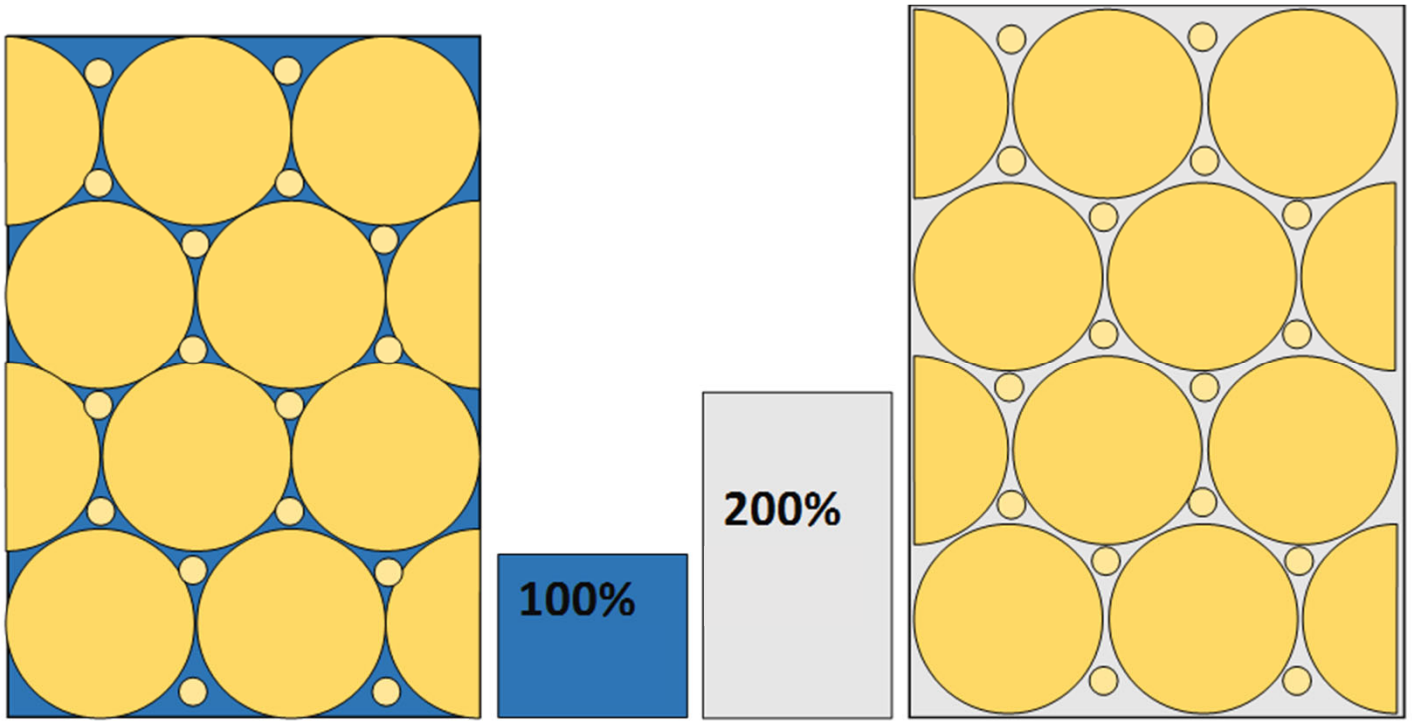
Step 3 Paste Content



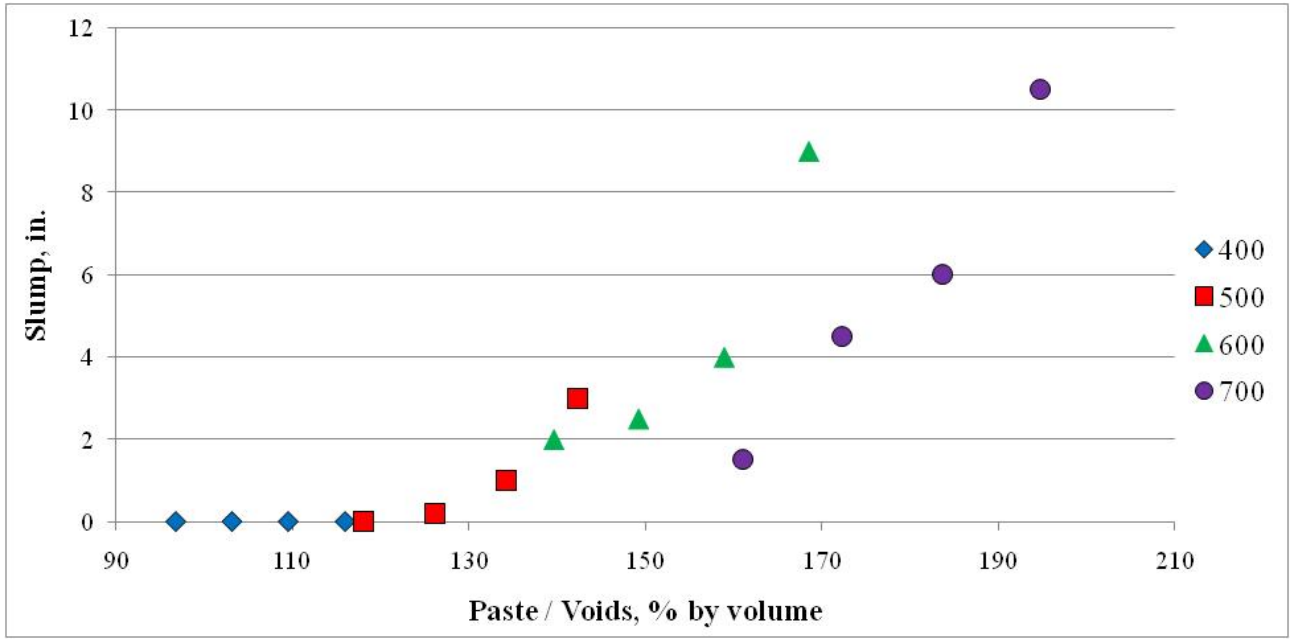
Step 3 Paste Content



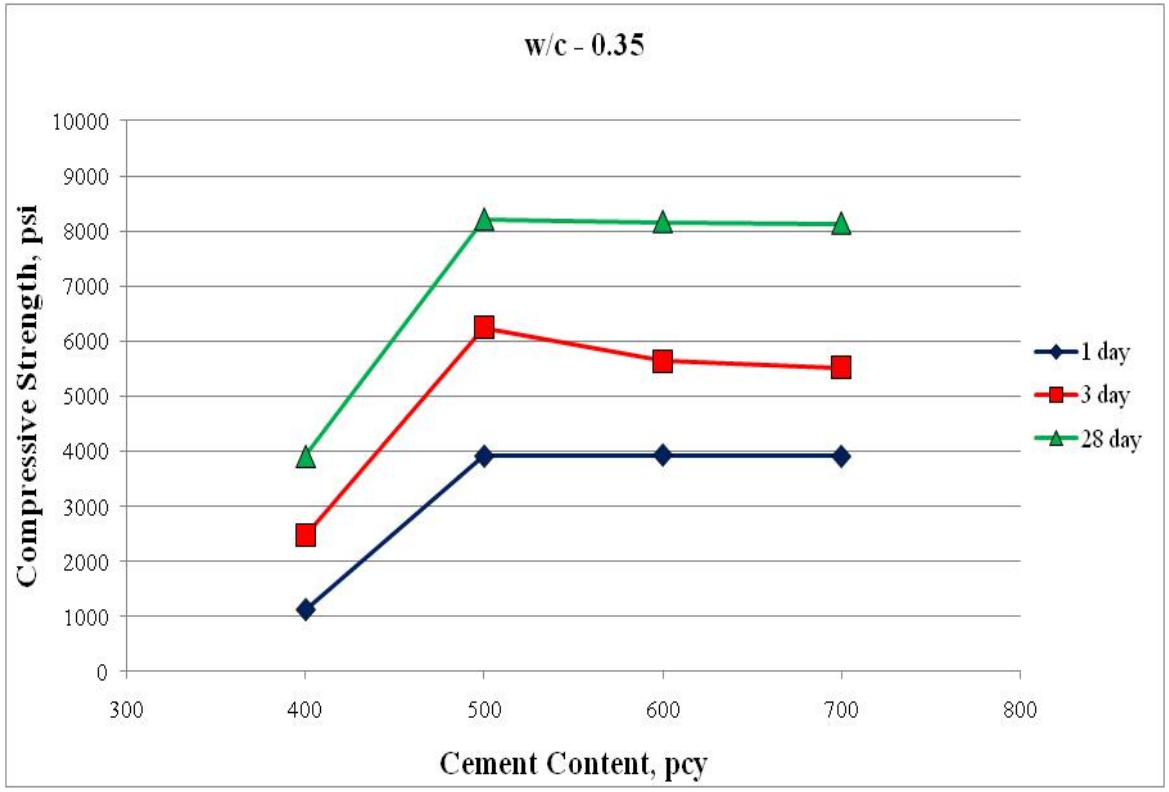
Step 3 Paste Content



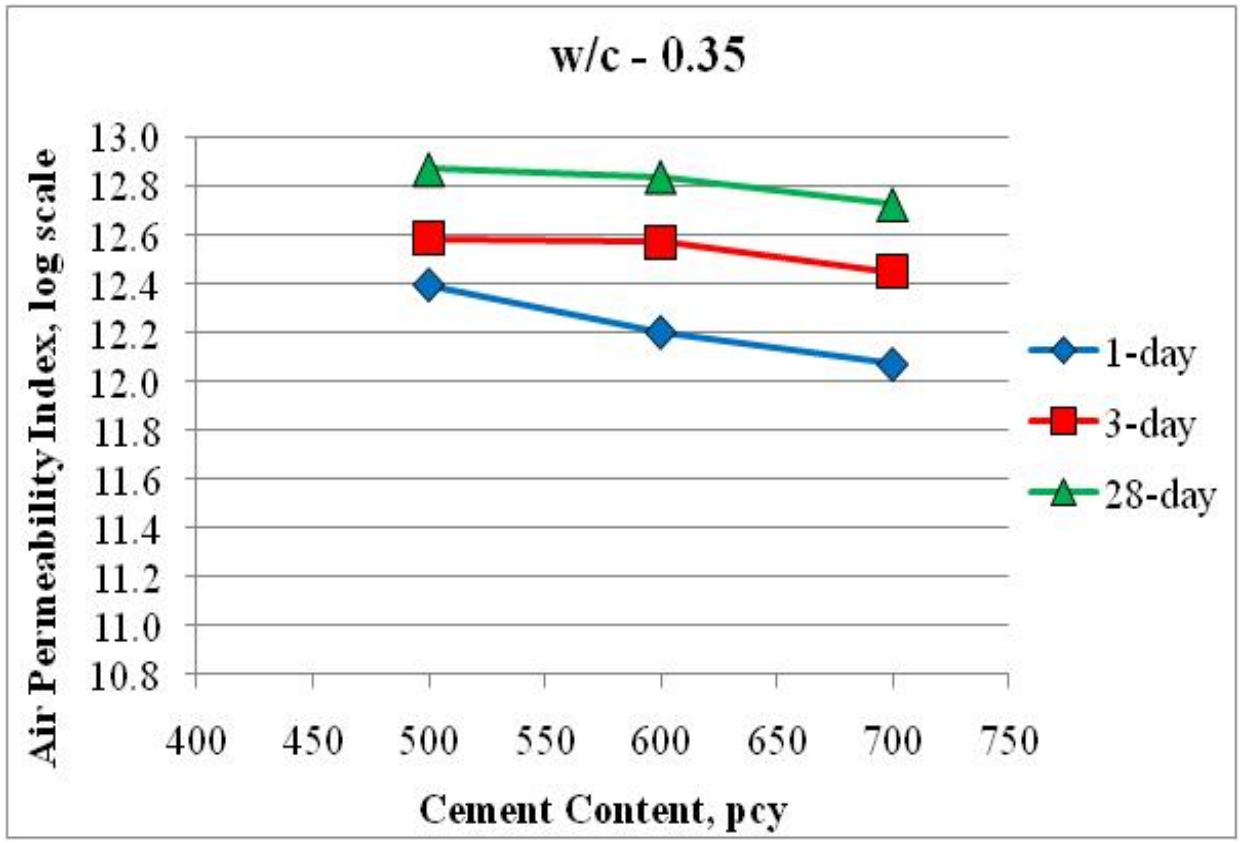
Workability



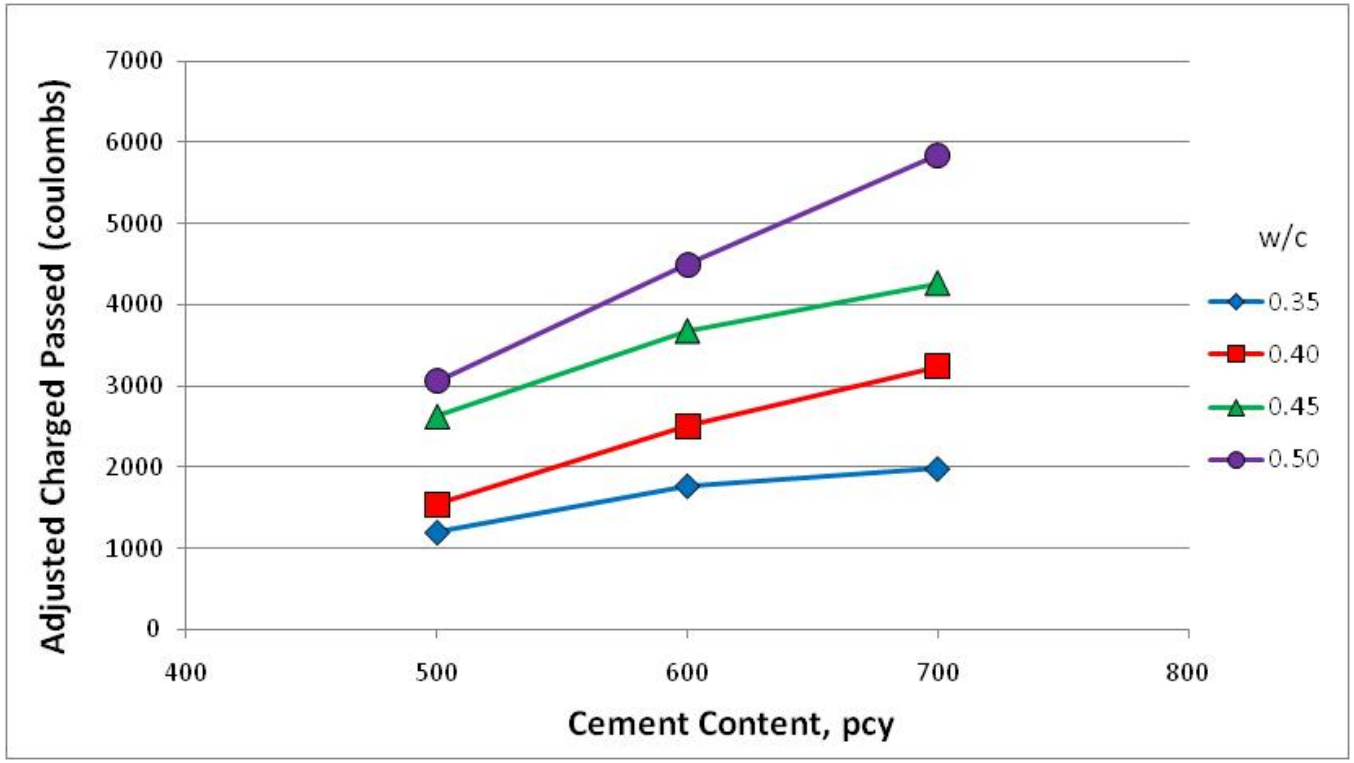
Strength


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

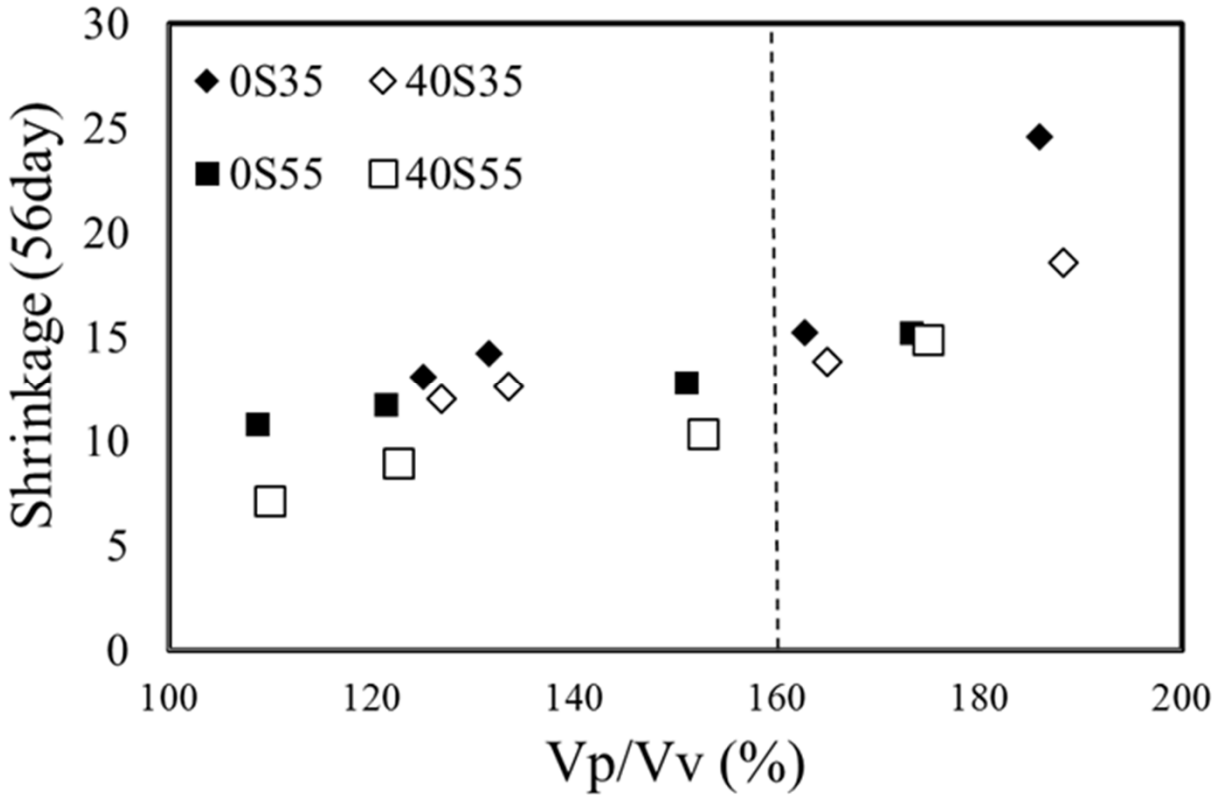
Air Permeability



Rapid Chloride Penetration

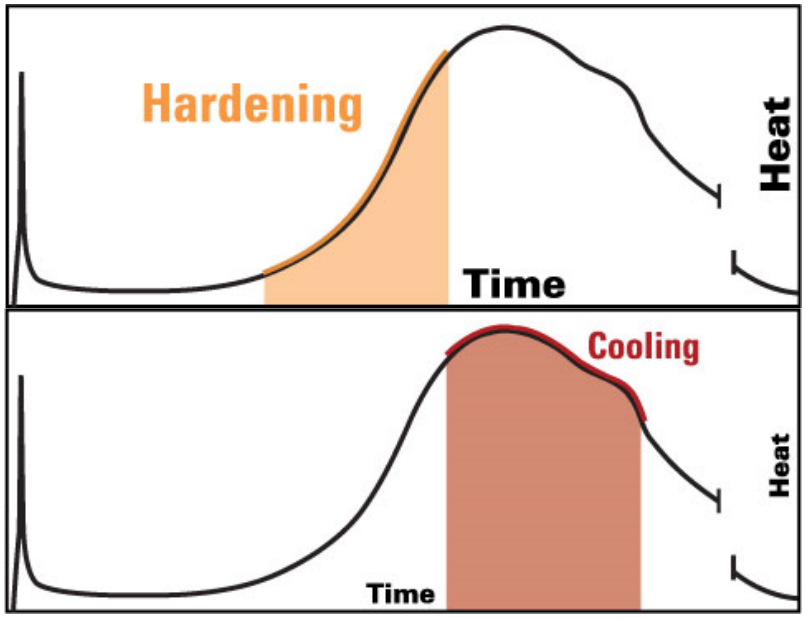


Shrinkage


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

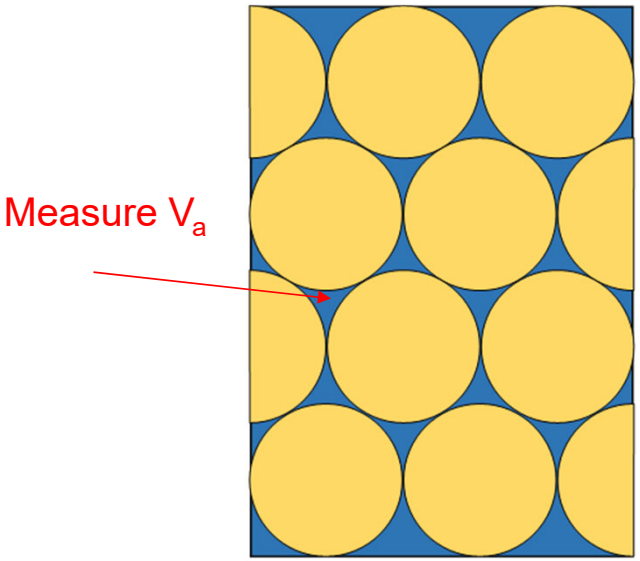
Step 3 Paste Content

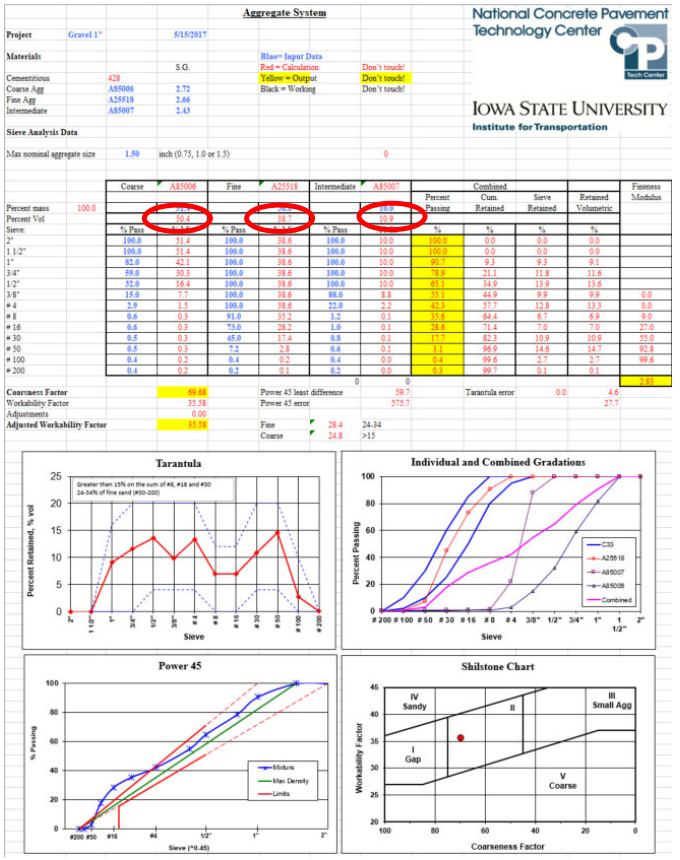
- Need a minimum paste for workability
- Excess has a:
  - Small negative effect on strength
  - Negative effect on permeability, shrinkage, cost
  - Negative effect on heat
- “Optimum” depends on:
  - Aggregate type
  - Gradation
  - Binder type
- Typically Vv ~125-200%



Doing the Sums

The wonders of a spreadsheet and a solver function…





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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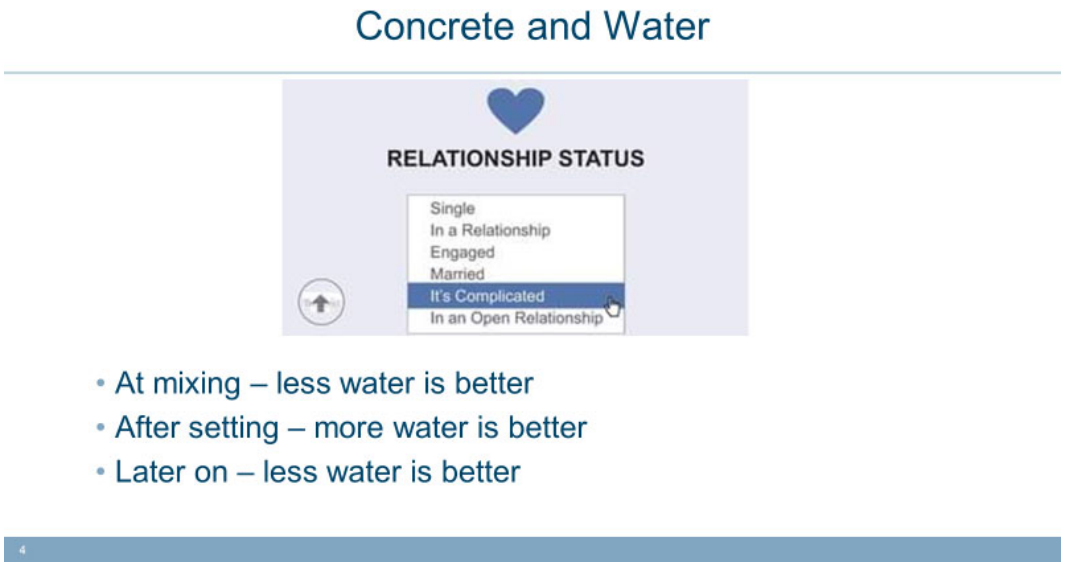
Trial Batches

- 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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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***