Concrete Mixtures for Pavements

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With thanks to
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National Concrete Pavement Technology Center
Tech Center

Design

- Choosing what you need
  - All concrete:
    - Workability, strength development
  - Pavements / slabs on grade
    - Durability, cracking risk
  - Airfields
    - FOD, edge slump

Proportioning

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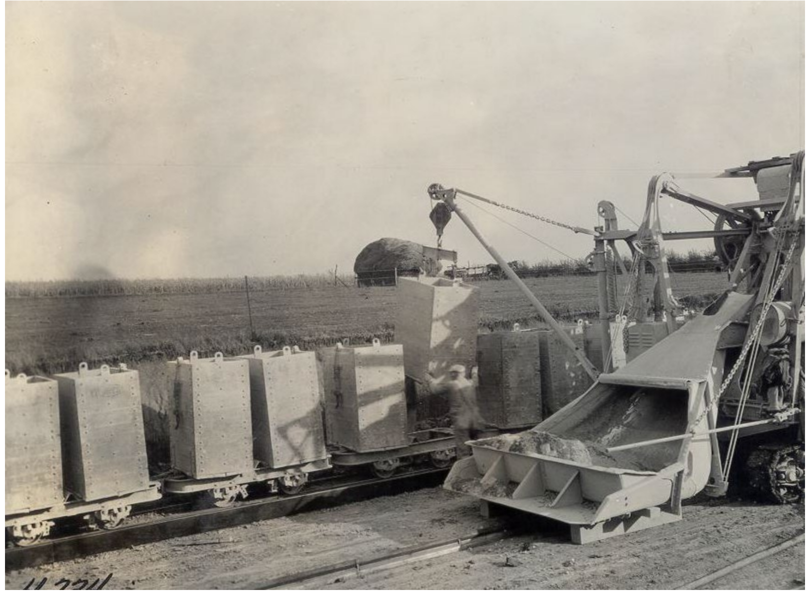
Proportioning Approaches: Past

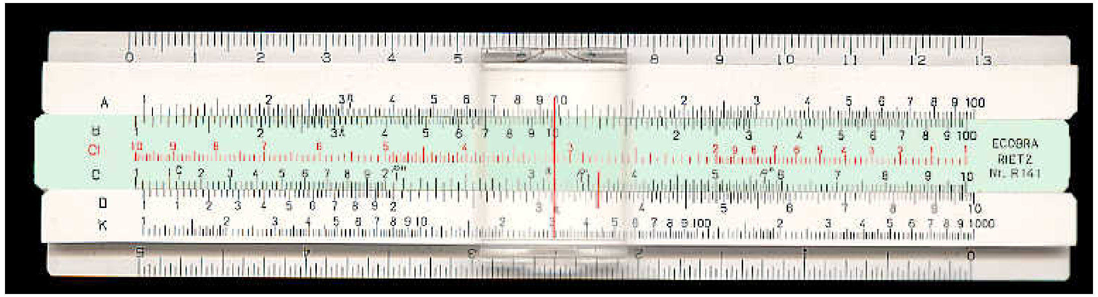
• Structural concrete	1:2:4
• Other concrete	1:3:6
• Waterproof concrete	Add salt

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

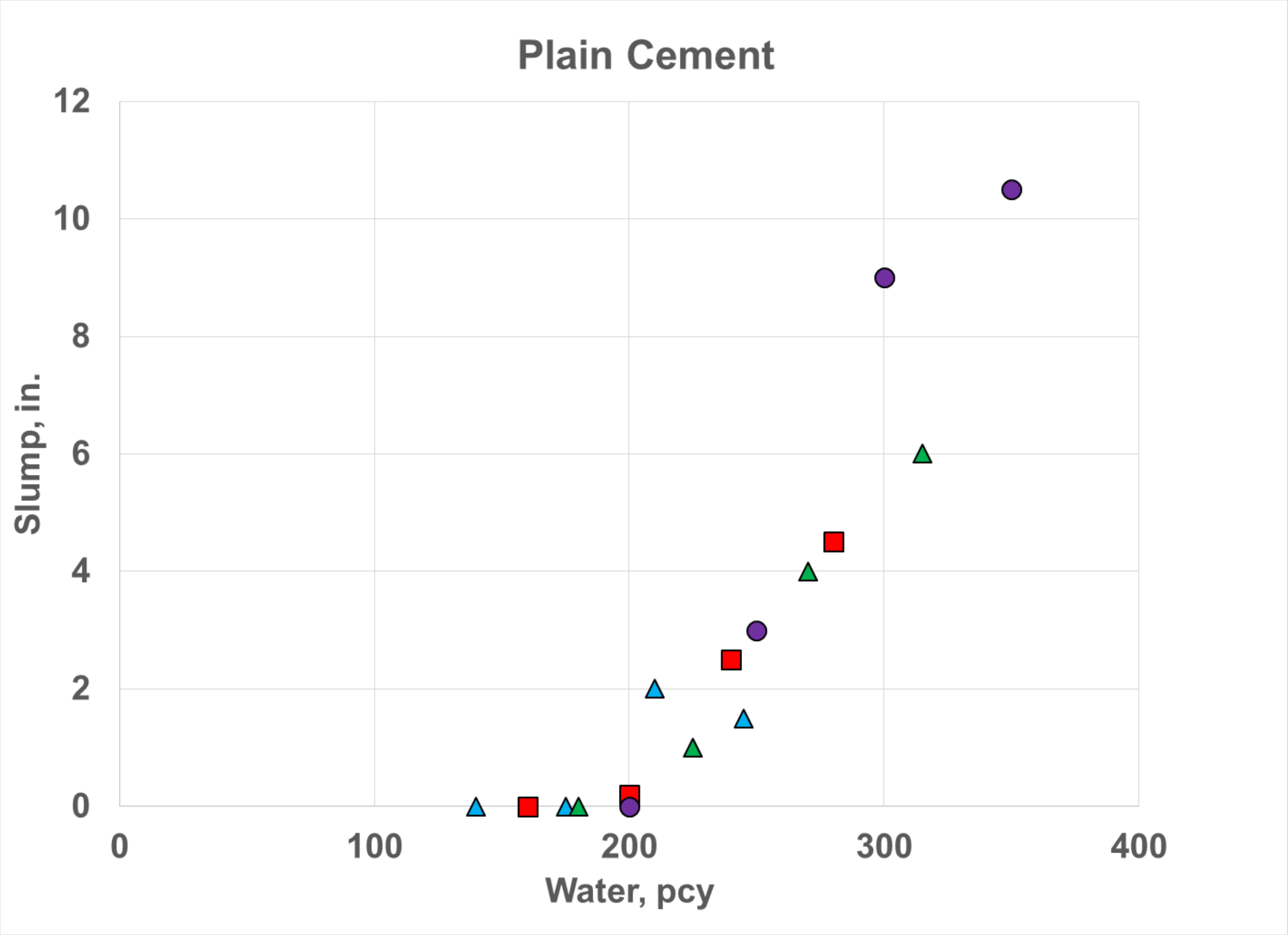


Proportioning Approaches
Present

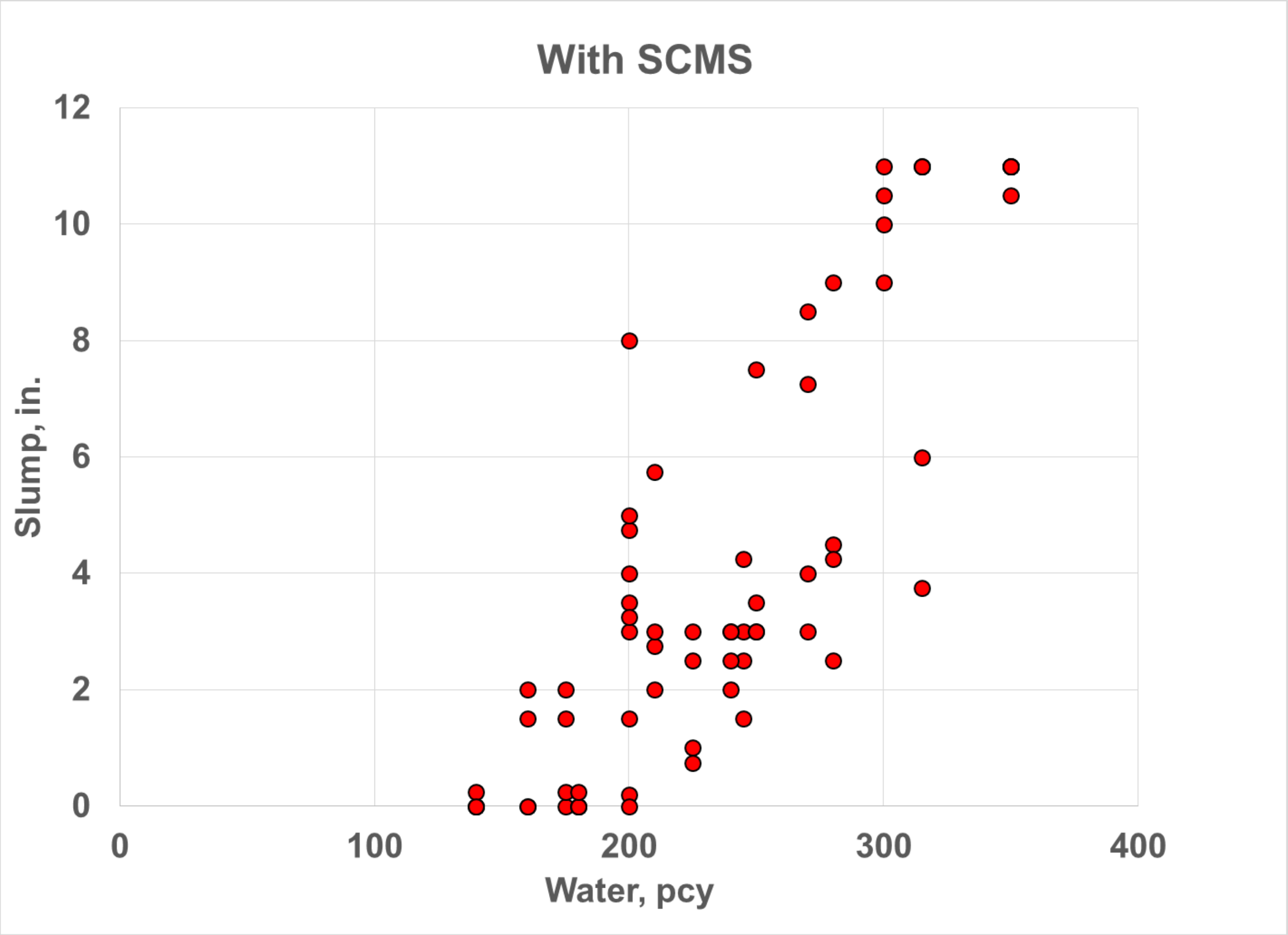
- ACI 211
  - Last revised in 1991
  - Linear
- Developed
  - Before water reducers
  - Before supplementary cementitious materials
- Primarily focused on structural concrete
  - 100 mm (4”) slump
  - 30 MPa (~4000 psi)



Workability

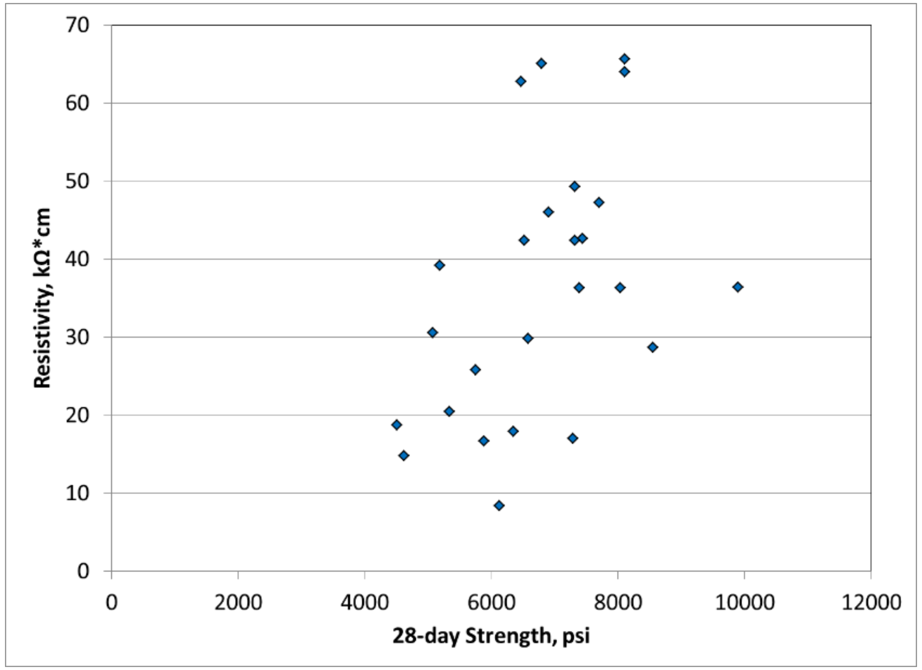


Workability



Preconceptions

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

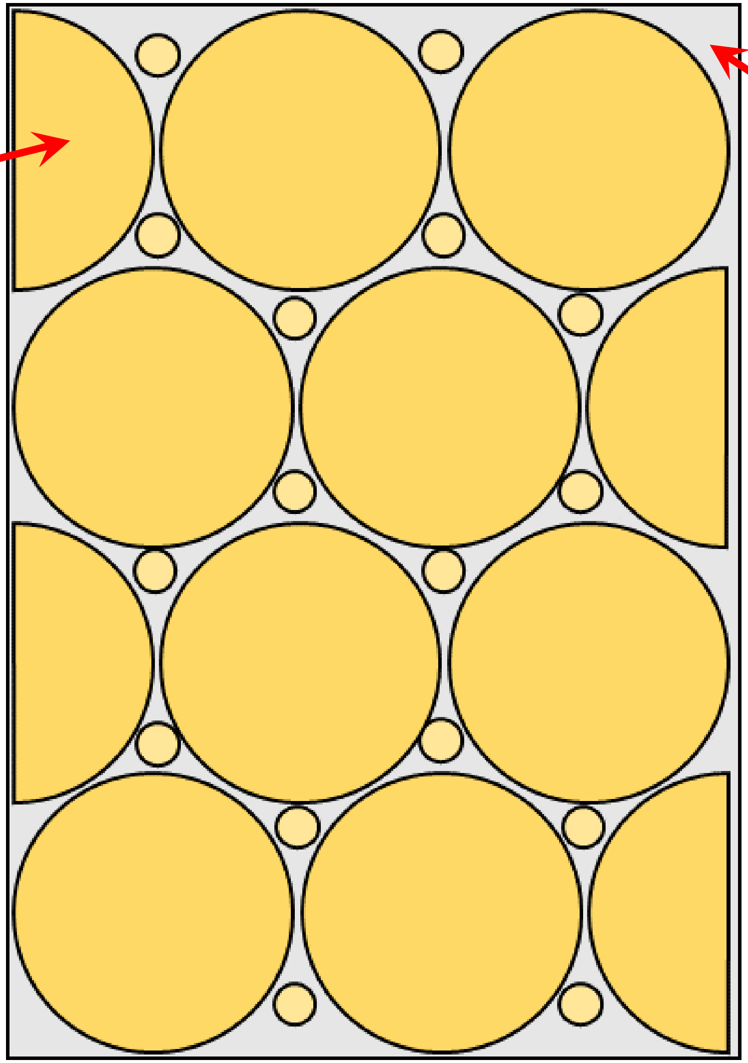


How do we proportion to achieve design goals?

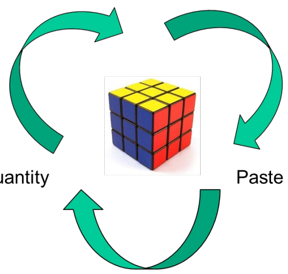
		Workability	Transport	Strength	Cold weather	Shrinkage	Aggregate stability
Aggregate System	Type, gradation	✓✓	-	-	-	-	✓✓
Paste quality	Air, w/cm, SCM type and dose	✓	✓✓	✓✓	✓✓	✓	✓
Paste quantity	Vp/Vv	✓	-	-	-	✓✓	-

Proportioning

Filler
Gradation



Glue
What sort
How much



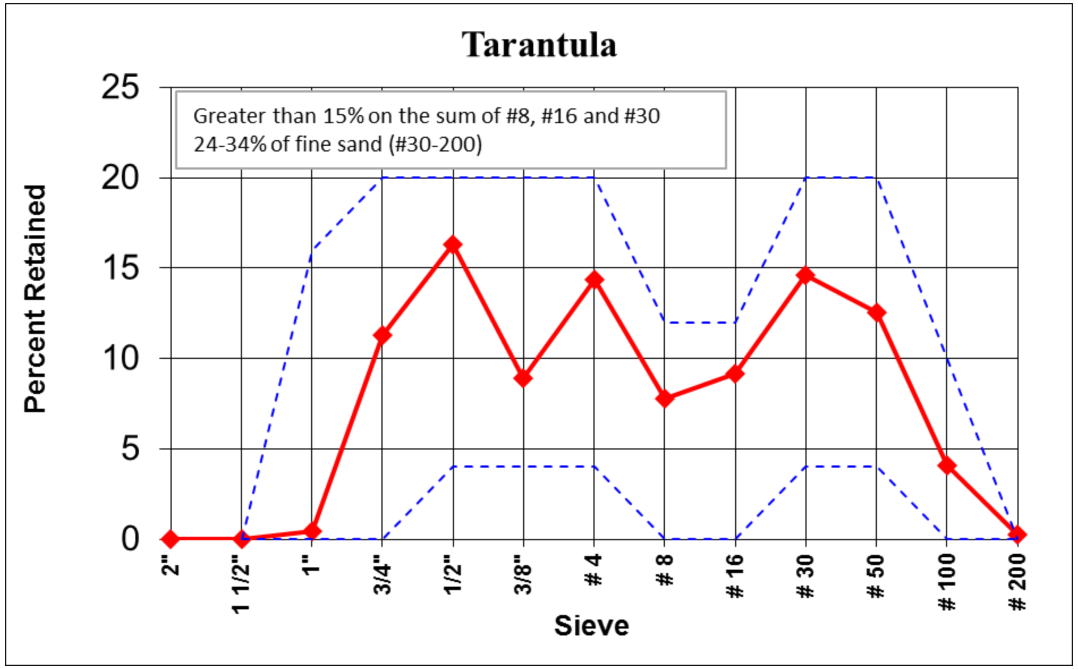
Step 1 Paste Quality

- 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

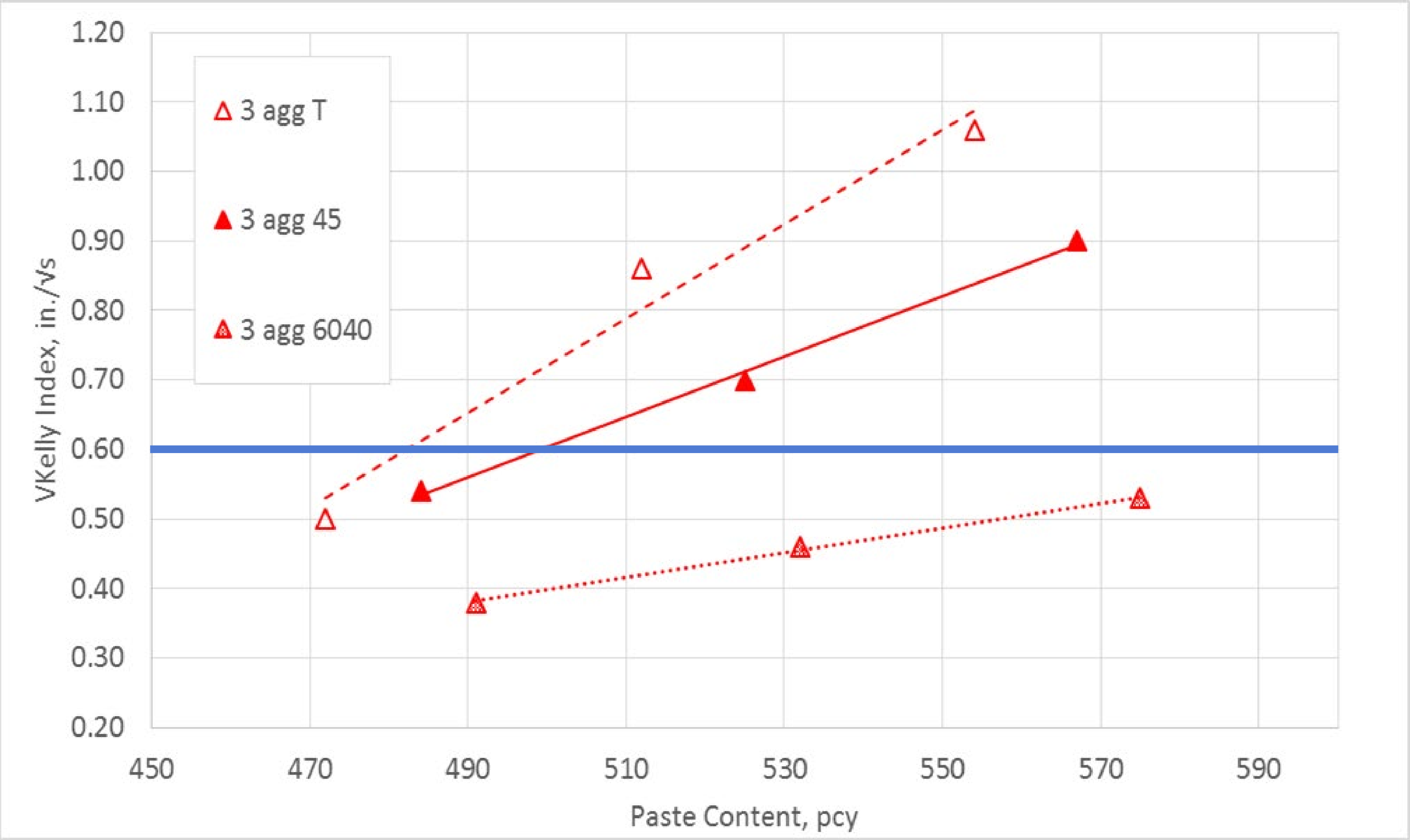
- Choices…
  - ASTM C33?
  - Or combined?:
    - Haystack
    - Shilstone Plot
    - Power 45

    - Tarantula

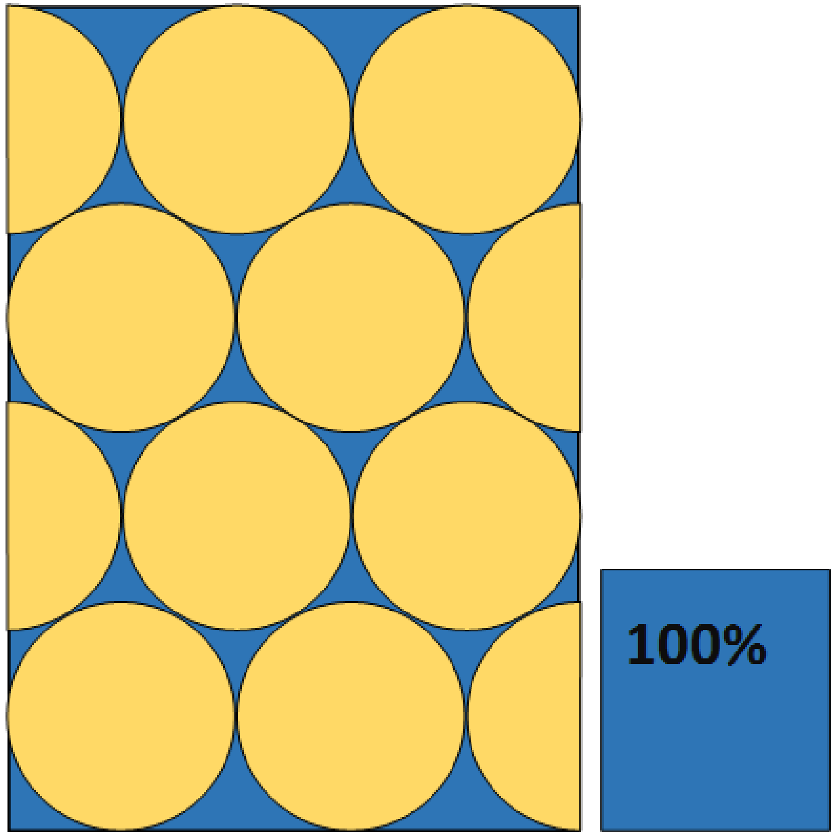


An Experiment

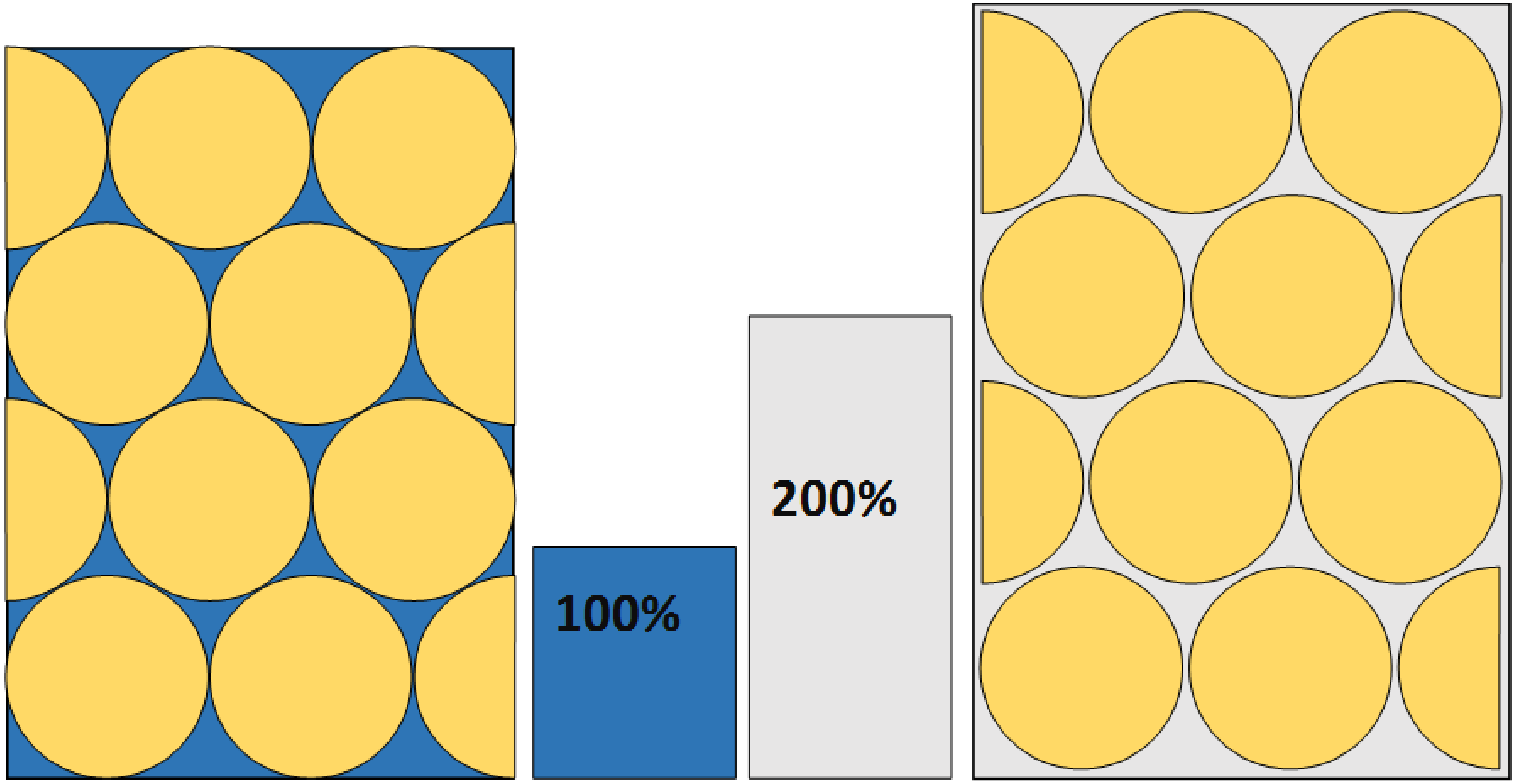
- Combined gradation matters



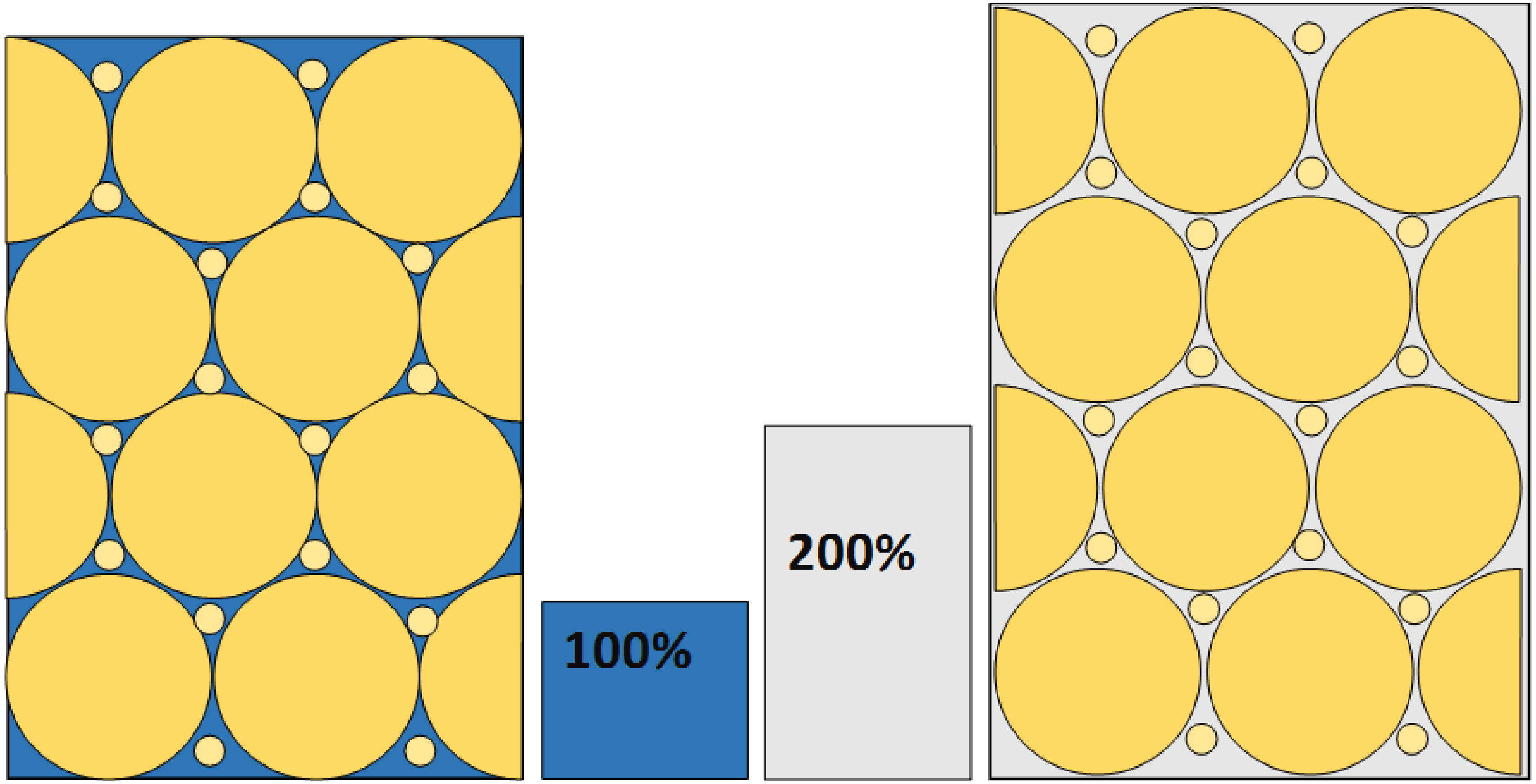
Step 3 Paste Content



Step 3 Paste Content



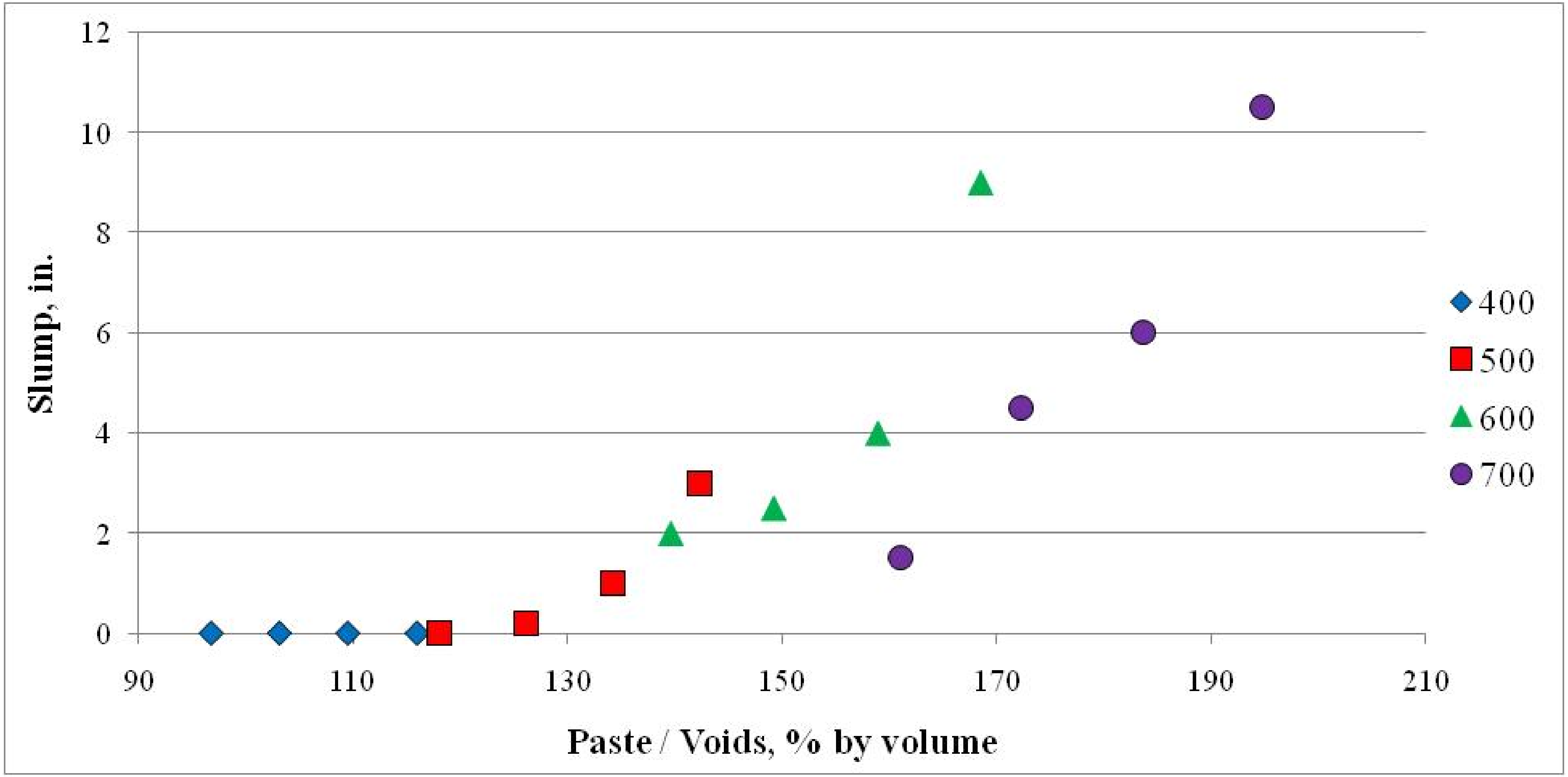
Step 3 Paste Content



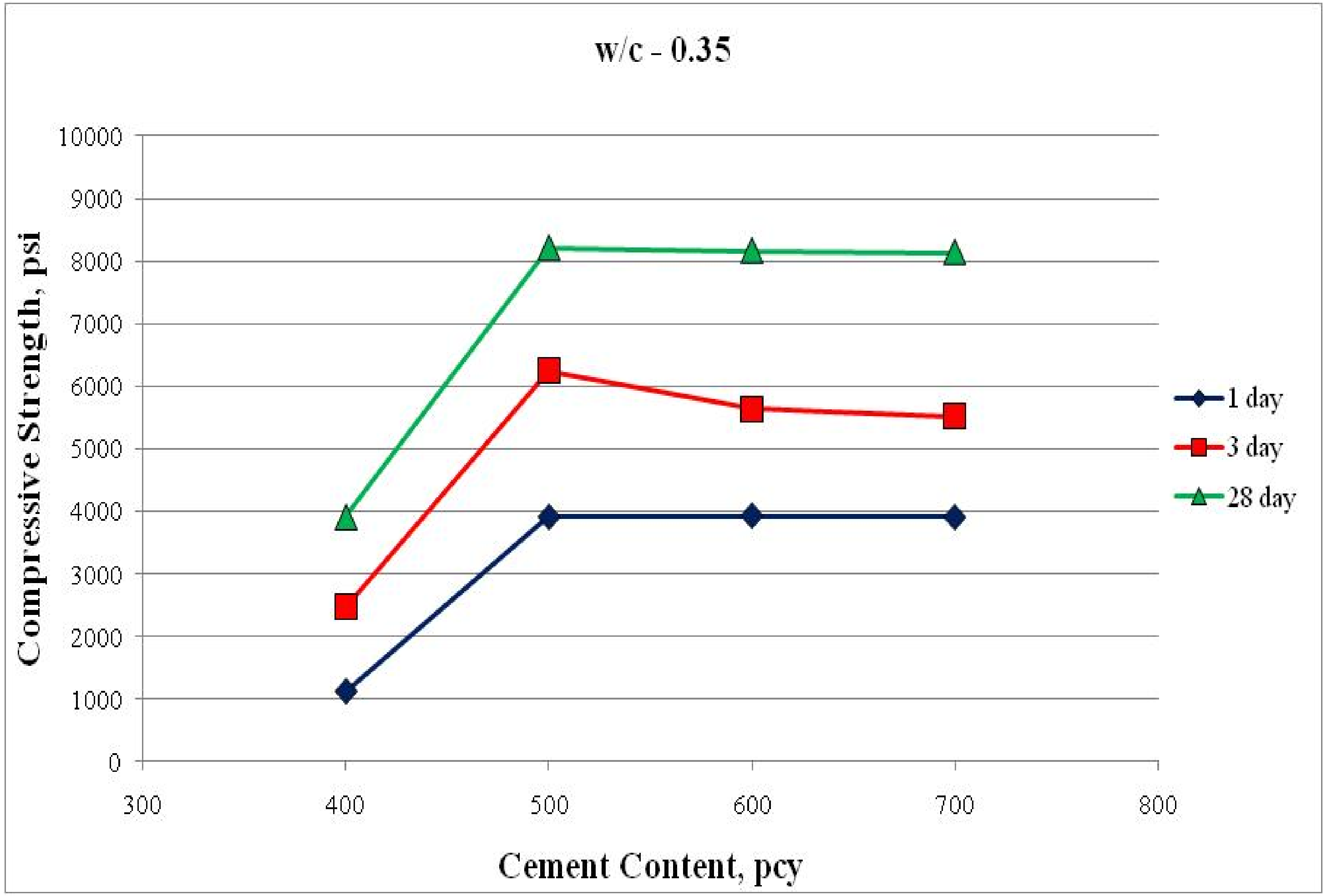
Step 3 Paste Content

- Need a minimum paste for workability
- Excess has a:
  - Small negative effect on strength
  - Negative effect on permeability, shrinkage, cost
- “Optimum” depends on:
  - Aggregate type
  - Gradation
  - Binder type
- Typically Vv ~150-200%

Workability

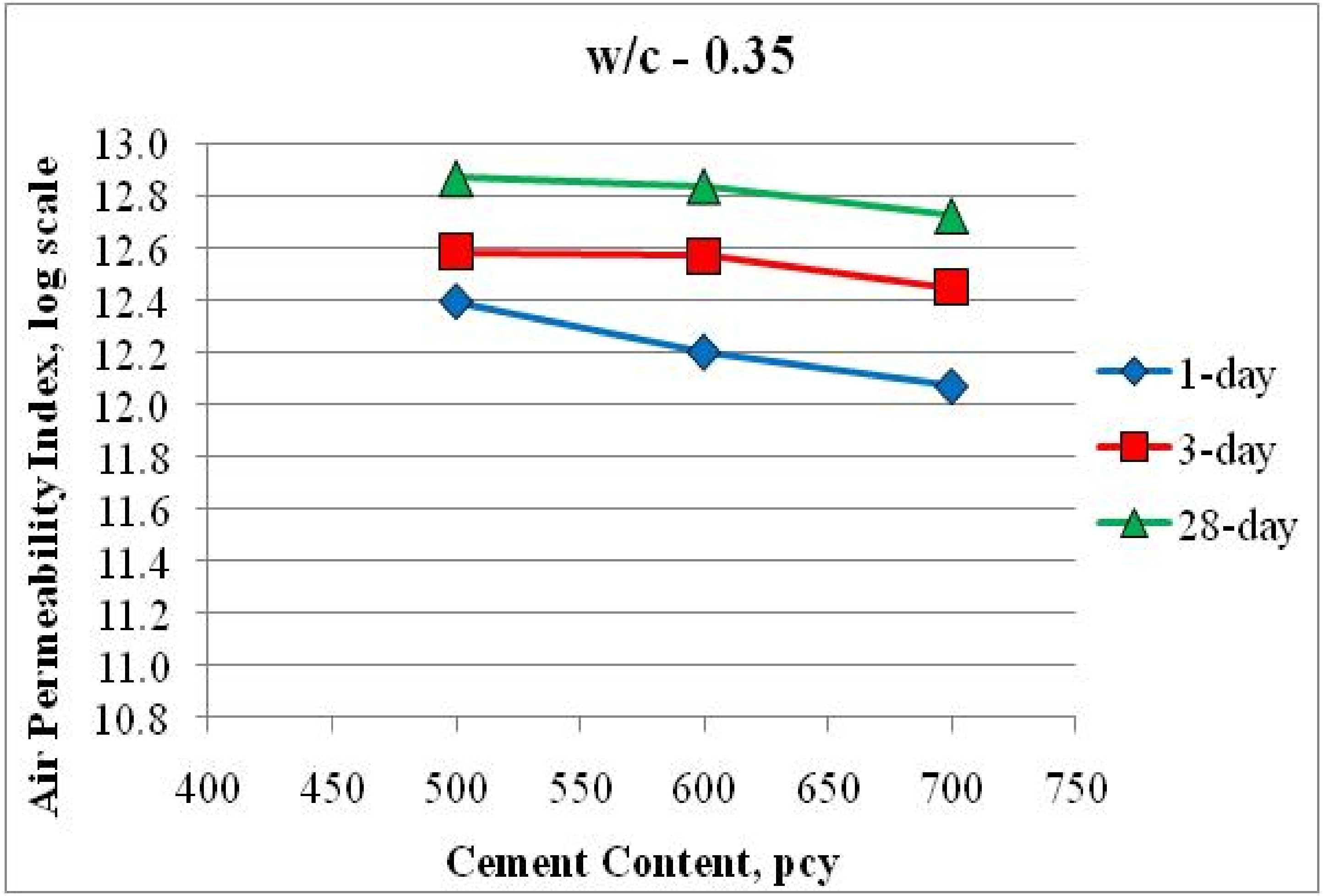


Strength

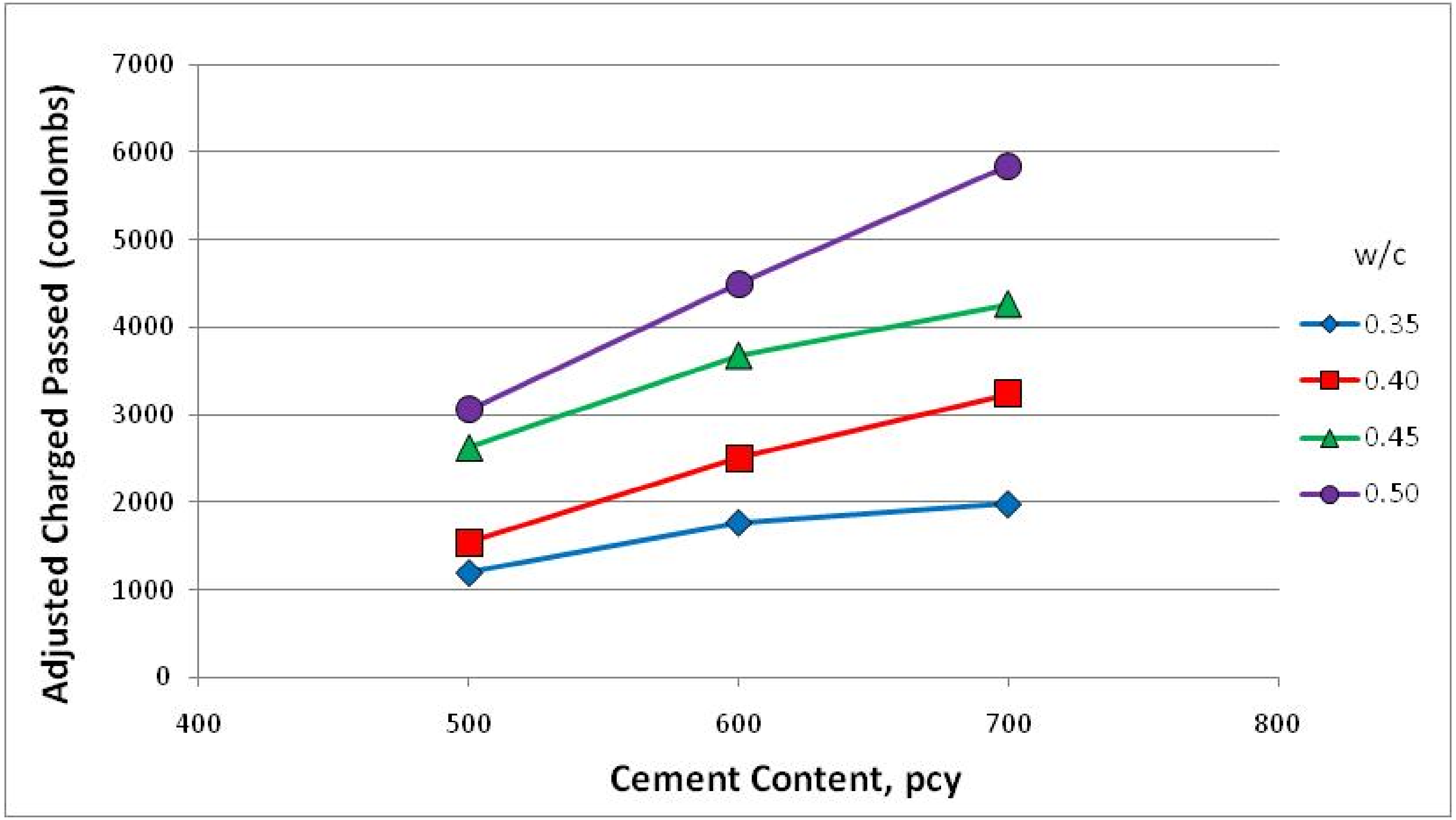


w/c - 0.35
Compressive Strength, psi
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
300
400
500
600
700
800
Cement Content, pcy
1 day
3 day
28 day

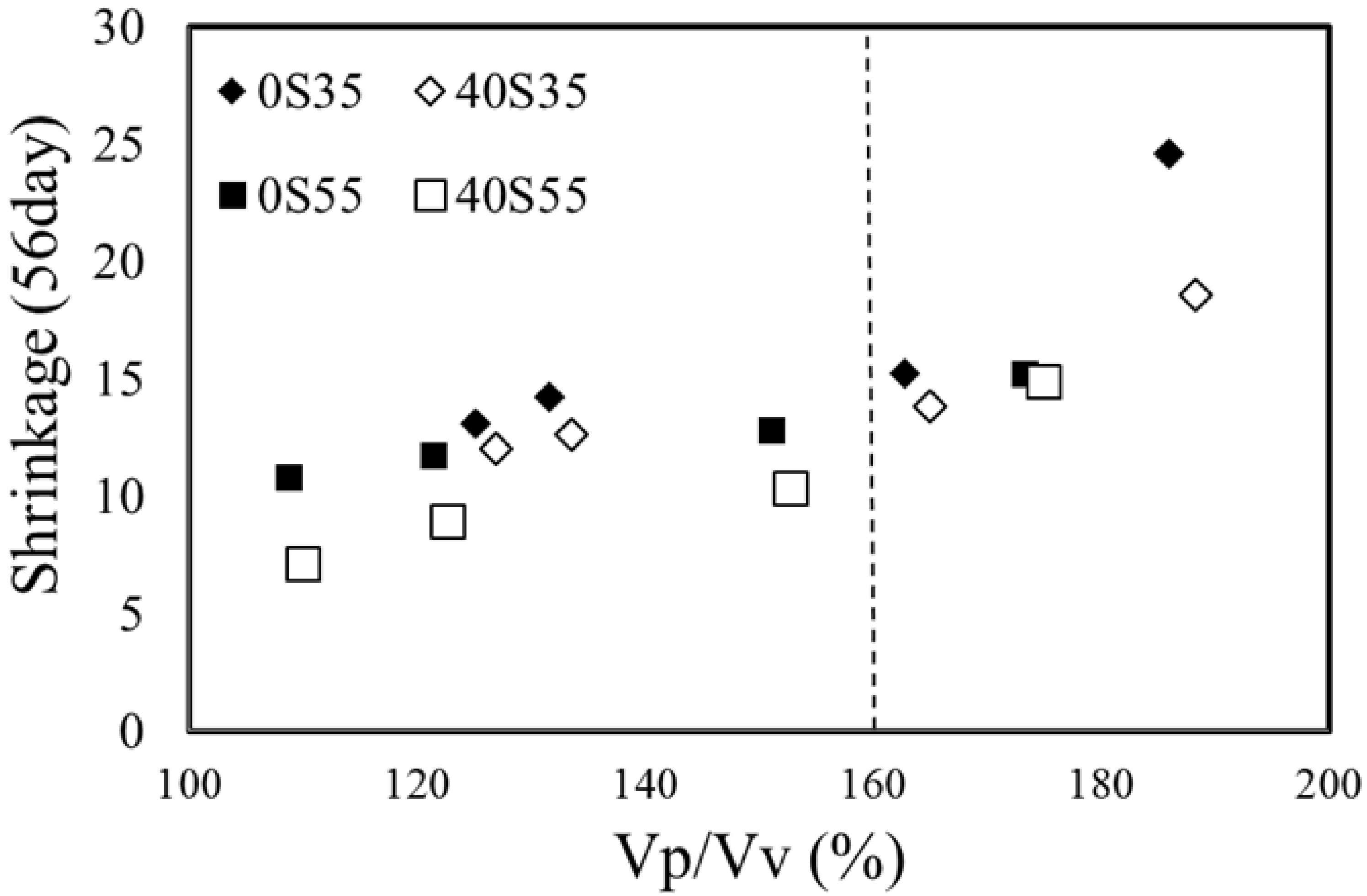
Air Permeability



Rapid Chloride Penetration



Shrinkage

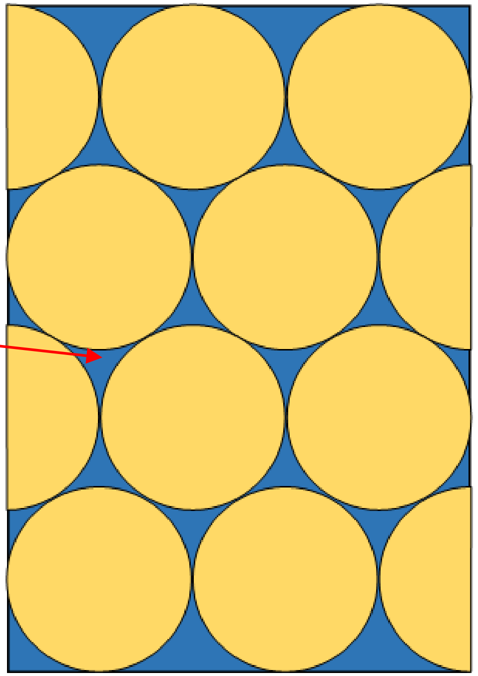


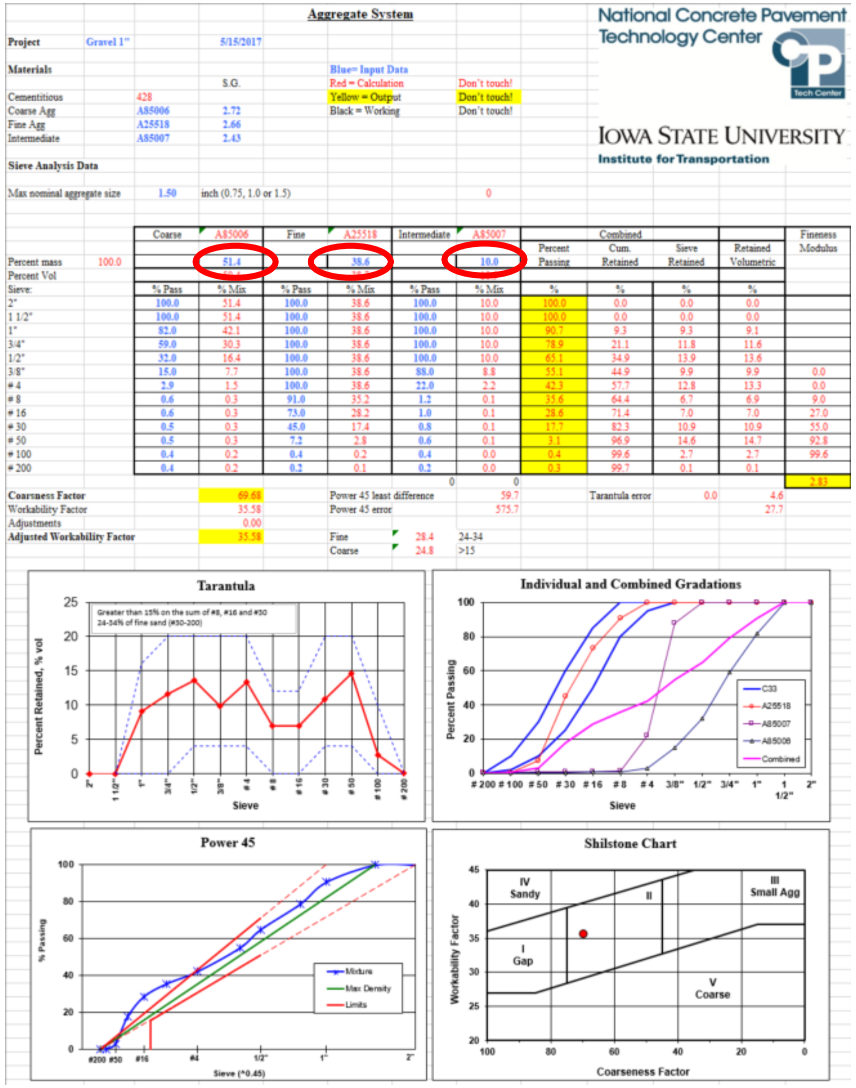
0S35
40S35
0S55
40S55
Shrinkage (56day)
0
5
10
15
20
25
30
100
120
140
160
180
200
Vp/Vv (%)

Doing the Sums

- The wonders of a spreadsheet and a solver function…

Measure V_V





Aggregate System

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Project Gravel 1" 5/15/2017

Materials

		S.G.
Cementitious	428	
Coarse Agg	A85006	2.72
Fine Agg	A25518	2.66
Intermediate	A85007	2.43

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

Sieve Analysis Data

Max nominal aggregate size 1.50 inch (0.75, 1.0 or 1.5) 0

	Coarse	A85006	Fine	A25518	Intermediate	A85007	Combined				Fineness Modulus
							Percent Passing	Cum. Retained	Sieve Retained	Retained Volumetric	
Percent mass 100.0		51.4		38.6		10.0					
Percent Vol											
Sieve:	% Pass	% Mix	% Pass	% Mix	% Pass	% Mix	%	%	%	%	
2"	100.0	51.4	100.0	38.6	100.0	10.0	100.0	0.0	0.0	0.0	
1 1/2"	100.0	51.4	100.0	38.6	100.0	10.0	100.0	0.0	0.0	0.0	
1"	82.0	42.1	100.0	38.6	100.0	10.0	90.7	9.3	9.3	9.1	
3/4"	59.0	30.3	100.0	38.6	100.0	10.0	78.9	21.1	11.8	11.6	
1/2"	32.0	16.4	100.0	38.6	100.0	10.0	65.1	34.9	13.9	13.6	
3/8"	15.0	7.7	100.0	38.6	88.0	8.8	55.1	44.9	9.9	9.9	0.0
# 4	2.9	1.5	100.0	38.6	22.0	2.2	42.3	57.7	12.8	13.3	0.0
# 8	0.6	0.3	91.0	35.2	1.2	0.1	35.6	64.4	6.7	6.9	9.0
# 16	0.6	0.3	73.0	28.2	1.0	0.1	28.6	71.4	7.0	7.0	27.0
# 30	0.5	0.3	45.0	17.4	0.8	0.1	17.7	82.3	10.9	10.9	55.0
# 50	0.5	0.3	7.2	2.8	0.6	0.1	3.1	96.9	14.6	14.7	92.8
# 100	0.4	0.2	0.4	0.2	0.4	0.0	0.4	99.6	2.7	2.7	99.6
# 200	0.4	0.2	0.2	0.1	0.2	0.0	0.3	99.7	0.1	0.1	
					0	0					2.83

Coarsness Factor	69.68	Power 45 least difference	59.7	Tarantula error	0.0	4.6
Workability Factor	35.58	Power 45 error	575.7			27.7
Adjustments	0.00					
Adjusted Workability Factor	35.58	Fine	28.4	24-34		
		Coarse	24.8	>15		

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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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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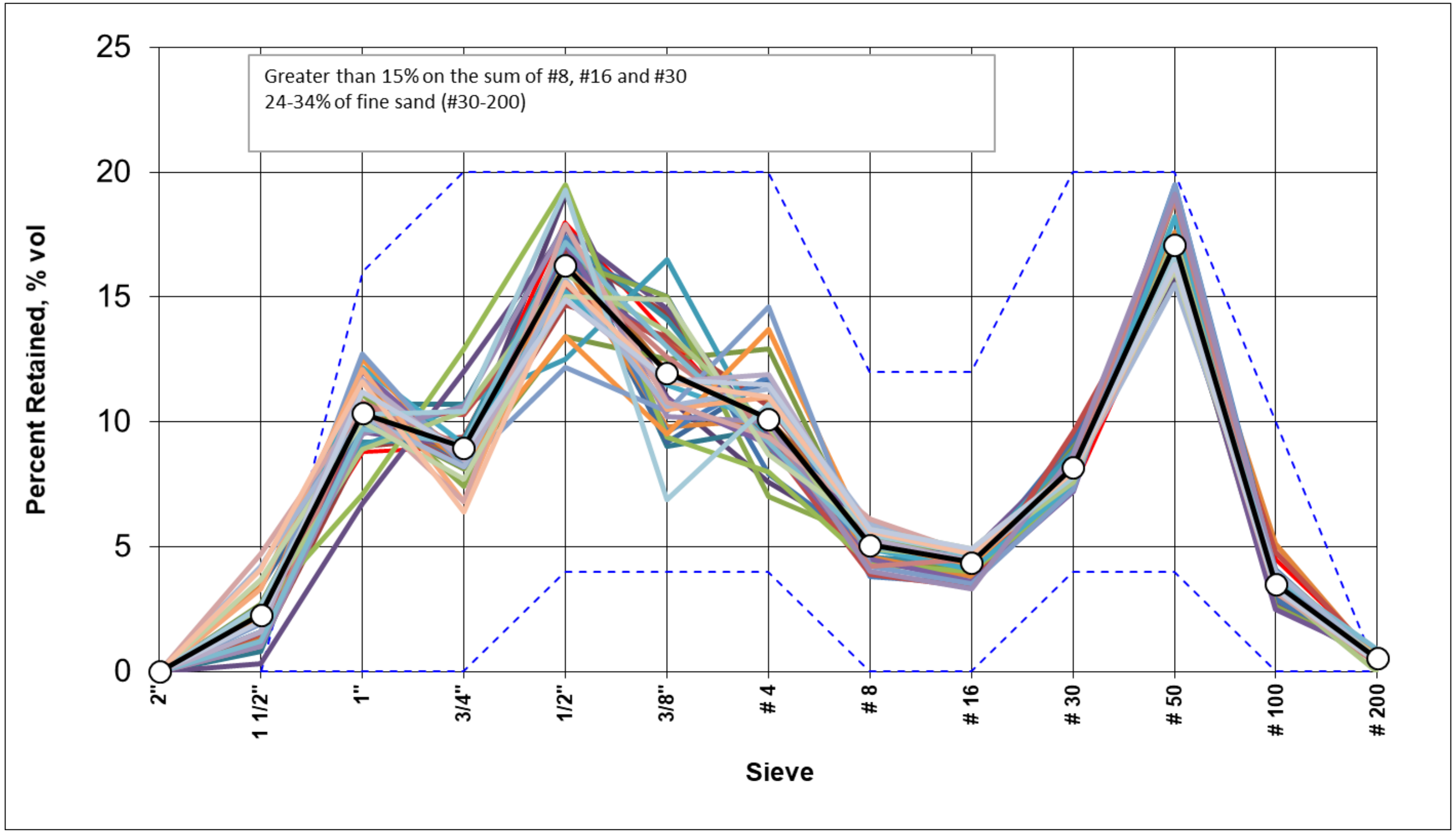
Trial Batches

- Workability / Admixture dosages / Void ratio
- Air void system
- Setting
- Strength gain
- Permeability

What about uniformity?



Does it Work?

- Before and after reworking the proportions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