



# Concrete Mixture Proportions

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National Concrete Pavement  
Technology Center



## Outline

- Introduction
- Proportioning:
  - Paste quality
  - Aggregate system
  - Paste quantity
- In reality...





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### Proportioning Approaches Past

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

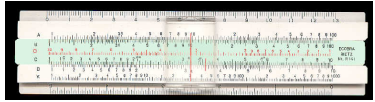
- No chemicals
- No SCMs
- Precision was ugly
- Bulking made it worse



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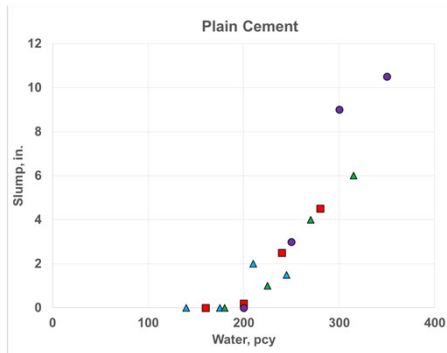
### Proportioning Approaches Present

- ACI 211 - 1991
- Developed
  - Before water reducers
  - Before supplementary cementitious materials
- Primarily focused on structural concrete
  - 100 mm (4") slump
  - 30 MPa (~4000 psi)
- Modified 2022 – not much change



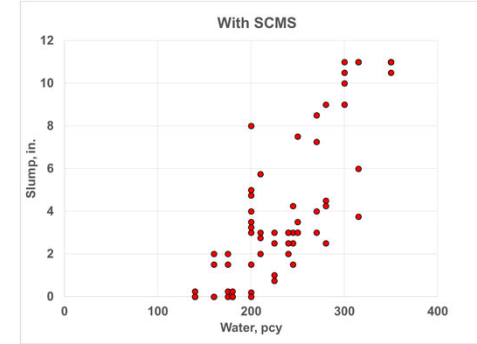
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### Workability



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### Workability



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### What do we need?

- Transport properties (permeability)
- Aggregate stability
- Cold weather resistance
- Strength
- Shrinkage
- Workability



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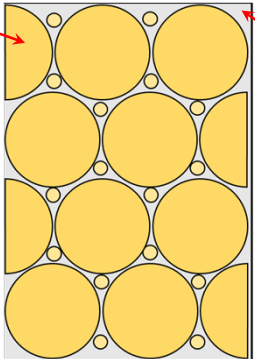
### Proportioning



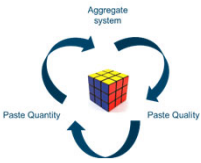
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## Proportioning

**Filler**  
Gradation




**Glue**  
What sort  
How much



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## 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	✓	-	-	-	✓✓	-



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## Step 1 Paste Quality

- Binder type
  - Cement type
  - SCM type and dosage
- w/cm
  - Choose for durability (~0.42)
- Air void system
  - <0.008 in. spacing factor
  - Stable



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## Step 2 Aggregate system

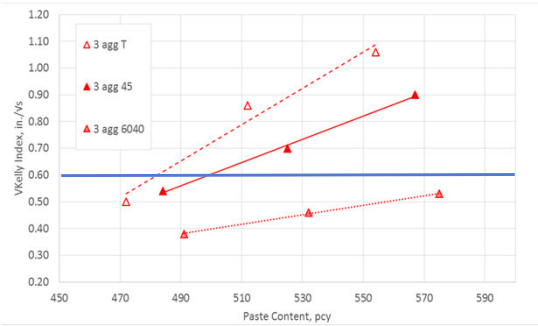
- Choices...
  - ASTM C33
  - Or combined:
    - Haystack
    - Shilstone Plot
    - Power 45
  - Tarantula



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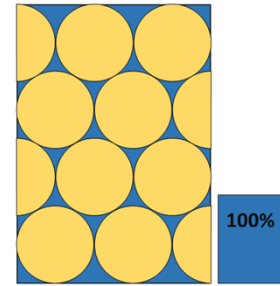
### Step 2 Aggregate system

- Choose an aggregate system...



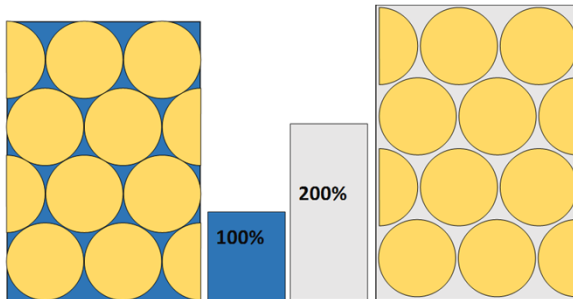
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### Step 3 Paste Content



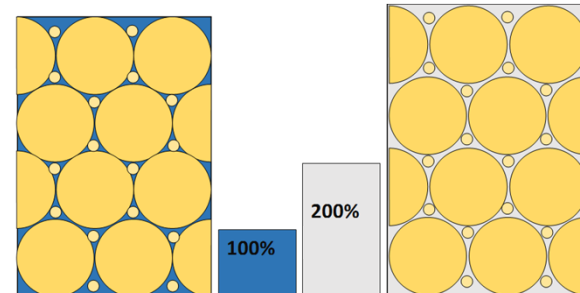
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### Step 3 Paste Content



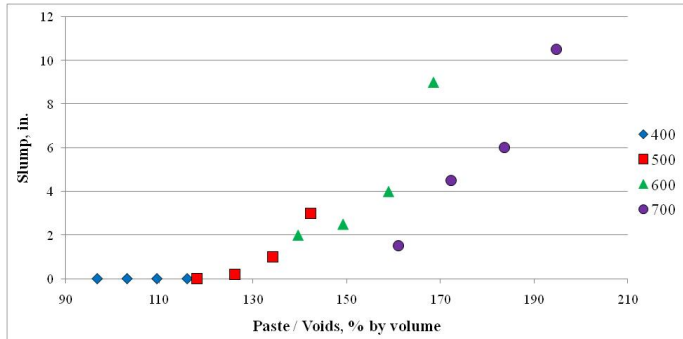
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### Step 3 Paste Content



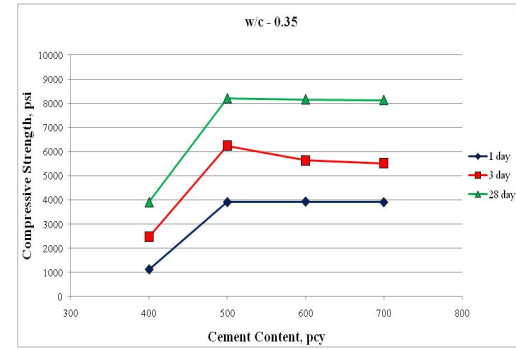
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### Workability



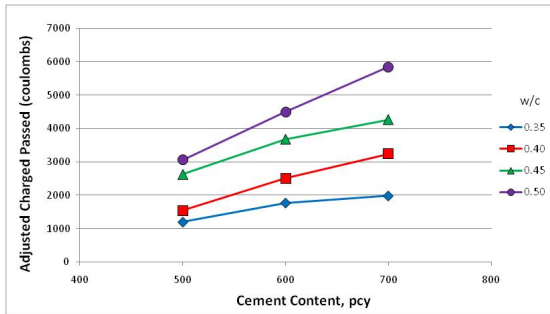
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### Strength



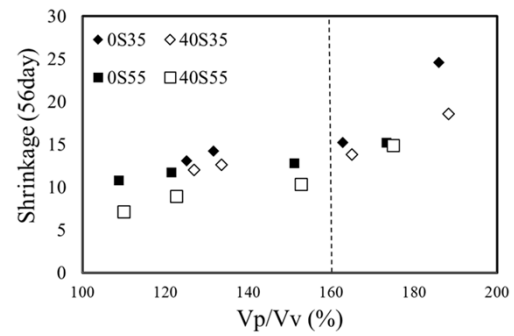
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### Rapid Chloride Penetration



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### Shrinkage



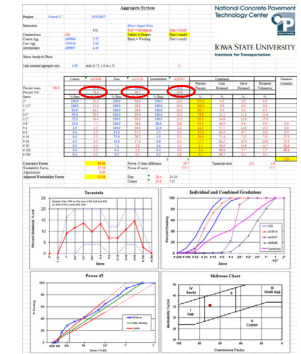
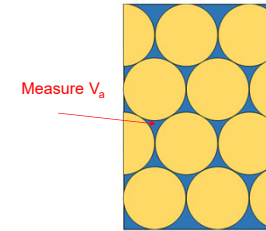
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### Step 3 Paste Content

- Need a minimum paste for workability
- Excess has a:
  - Small negative effect on strength
  - Negative effect on permeability, shrinkage, cost
  - **Negative effect on sustainability**
- “Optimum” depends on:
  - Aggregate type
  - Gradation
  - Binder type
- Typically  $V_v \sim 150\text{-}175\%$

### 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
<b>Materials</b>			
		<b>Targets</b>	<b>R.D.</b>
Cement	Type 1		3.15
SCM 1	F Ash		2.65
SCM 2	Slag		1.00
Course Agr	AR5006		2.72
Fine Agr	AR5518		2.66
Intermediate	AR5007		2.43
Water			1.00
<b>Comminutions</b>			
w/cm	0.42	pcf	
Air %	5.0	%	
% SCM 1	20	%	
% SCM 2	0	%	
<b>Void in aggregate</b>			
Required Sp.Vv	125	%	
Strength	8000 psi		7 days
RCF	1500 cfm/mb		56 days
W/cmm	27.50-cm		28 days

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

### Doing the Sums

The wonders of a spreadsheet...

Mixture Proportions			
Project	Gravel 1"		5/15/2017
<b>Mixture Proportions</b>			
		<b>Targets</b>	<b>Actual</b>
		<b>Pounds</b>	<b>R.D.</b> <b>Volume</b>
Cement	Type 1	362	3.15 1.74
SCM 1	F Ash	280	2.65 0.52
SCM 2	Slag	0	1.00 0.00
Course Agr	AR5006	1751	2.72 10.33
Fine Agr	AR5518	1816	2.66 7.94
Intermediate	AR5007	740	2.43 2.24
Water		300	1.00 2.68
Air %		5.0	1.35
		<b>4019</b>	<b>27.00</b>
<b>Comminutions</b>			
	428	pcf	
Volume of paste	21.0	%	
Volume of aggs	76.0	%	
Volume of voids	10.2		
sp/vv	125	125.0	
w/cm	0.42		
% SCM 1	20		
% SCM 2	0		
Mass aggs	3411	3411	pcf
Excess paste, %		1.8	%

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### Trial Batches

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



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### Does it Work?

• MNRoad

	MNDOT	Optimized		MNDOT	Optimized
Cement	400	351	Slump	2.0	2.0
SCM 1	170	150	HRWRA	2.0	2.3
SCM 2	0	0	Air content	6.8	7.0
Coarse Agg	457	662	Box	1 - 0	1 - 0
Fine Agg	1171	1303	Initial set	6:27	6:12
Intermediate 1	1167	954	Strength at 7	3,340	3,650
Intermediate 2	244	254			
Water	228	200			
Air	7.0	7.0			
Total	3837	3874			
Cementitious	570	501			
vp/vv	208	180			
w/cm	0.40	0.40			
% SCM 1	30	30			

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### Ongoing Work

- What void ratios are needed for:
  - Varying aggregate mineralogy
  - Varying aggregate form
  - Varying gradation



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