The Perfect Specification…
(and other myths)

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Why do we write specifications?

- To establish expectations
- To make sure we get what we want
- To decide whether to pay
- To set up remedial actions

What do we want?

- Sustainable and resilient
- The right dimensions
- Stable
  - Support system
- Long lasting for the:
  - Environment
  - Loading
- Value for money

What do we want?

- All of the above from a material that:
  - Is manipulated on site
  - Changes properties over time
  - Moves with water and heat
  - Is abused all through its life

Source unknown

What then is important?

- Design and details
- Materials and mixture
- Workmanship

- Inspection and testing

The art of specifications

- Allowing freedom to the trustworthy
- Protecting from the unreliable
- Delivering “nominal” pavements

- Discuss…

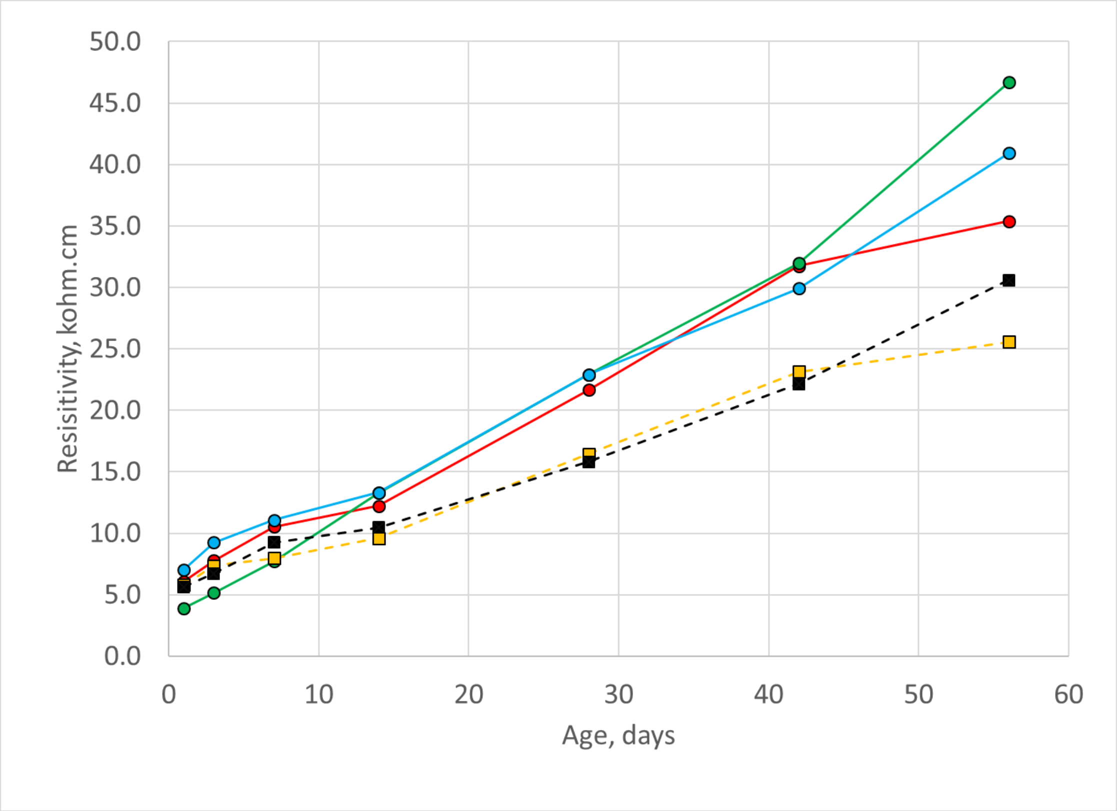
Materials and mixture

- Materials and Proportions
  - Constructability
  - Long life

- Performance Engineered Mixtures
  - Workability
  - Transport
  - Aggregate stability
  - Cold weather
  - Strength
  - Shrinkage

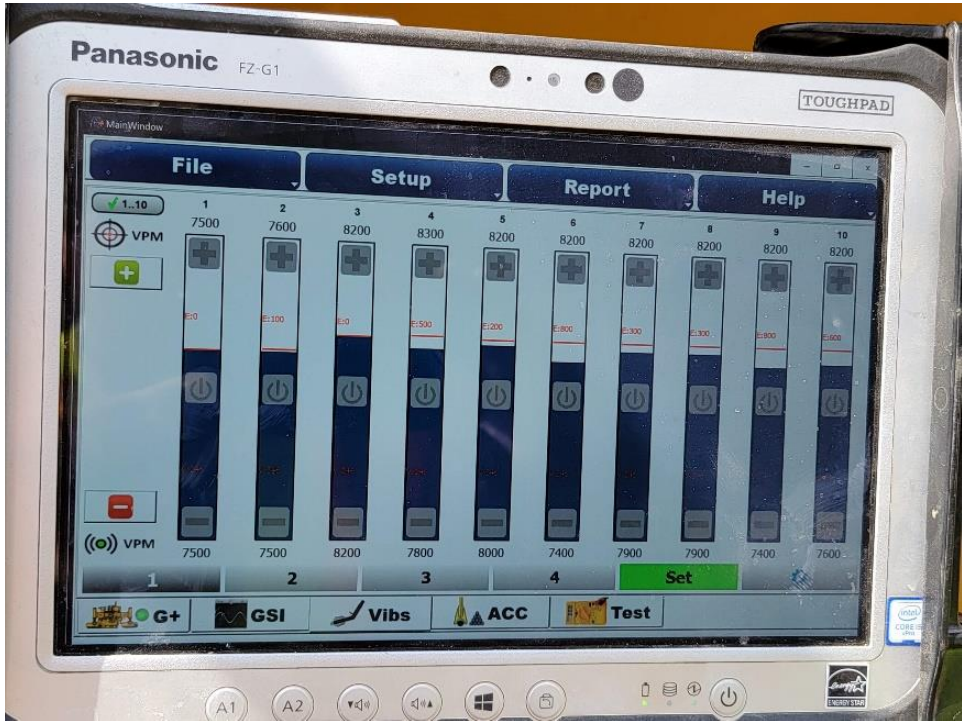
Philosophy of testing

- Pre-construction
  - Will this mixture survive?
    - Extrapolation
    - Calibration
    - Sensitivity to variation
  - Can we get it in place?
    - “Workability”



Philosophy of testing

- During construction
  - Is this the same stuff
    - Ingredients
    - Dosage
  - What do we measure?
    - Air
    - Water
  - Is the sample representative?
  - What about construction activities?



Philosophy of testing

- Post-construction
  - Did we get what we wanted?
  - What about effects of:
    - Sawing
    - Smoothness
    - Curing

The perfect test

- Fast
- Cheap
- Representative
- Repeatable
- Right

- Meaningful

Inspection

- Because process matters

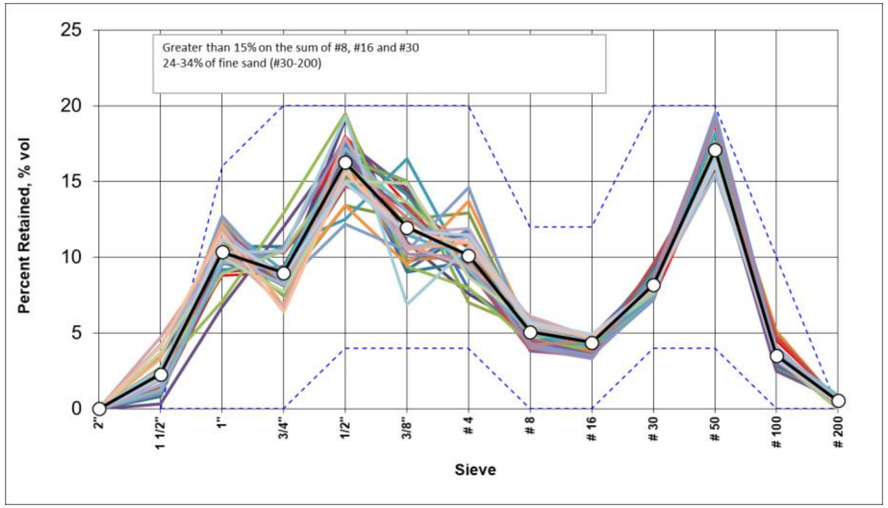
- Or is there a test?
- And is it worth it?

Performance/Prescriptive

- We want performance
- But sometimes prescriptive is more cost / time effective
  - e.g. w/cm
- Don’t do both!
  - e.g. fixed water, cement, admixture dosage and slump

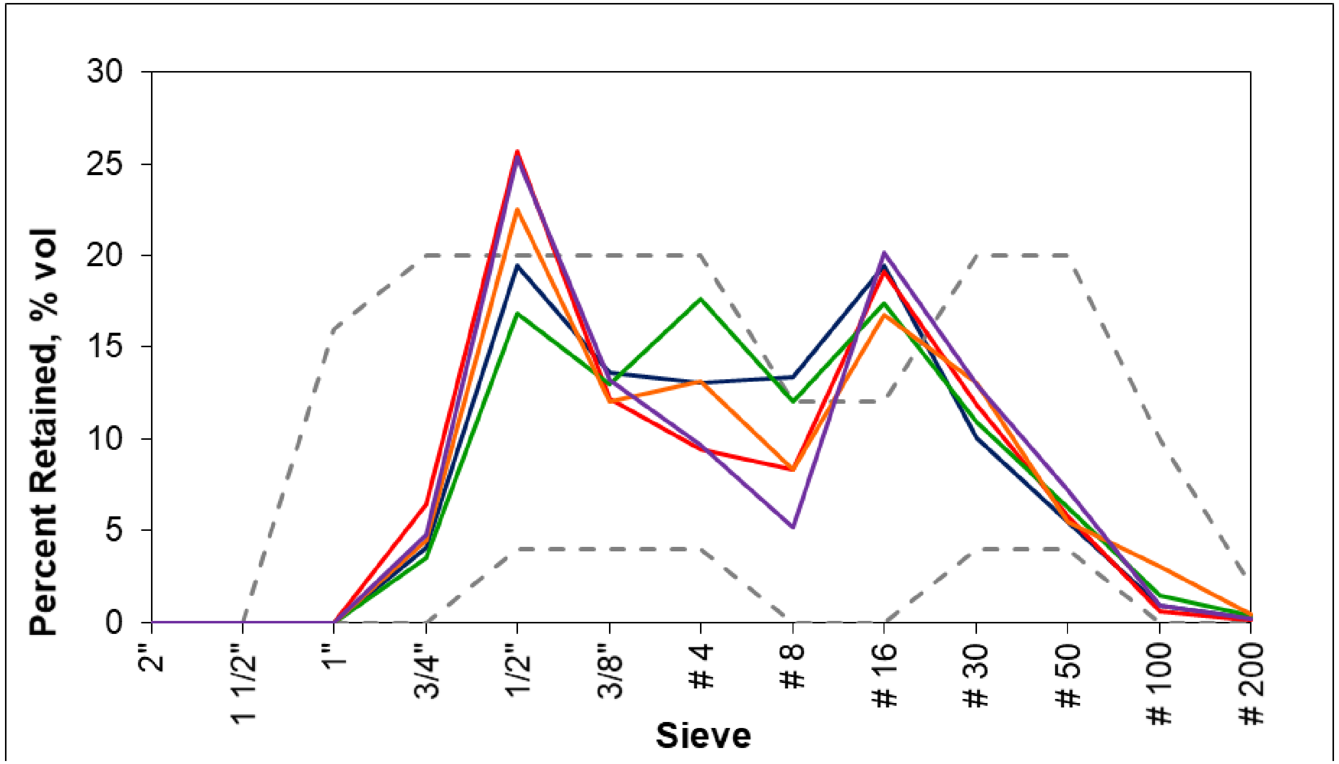
Performance/Prescriptive

- Do we monitor everything?
- Who owns the risk?
- Is "good enough" good enough



Performance/Prescriptive

- Do we monitor everything?



Traditional Test Methods

- Slump
- Strength
- Thickness

- Poor correlation with durability…

Current Test Methods

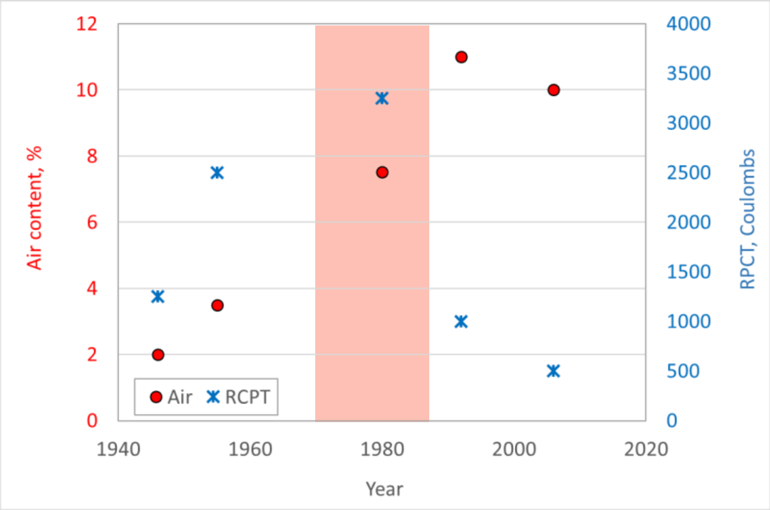
- Quality Assurance
  - Slump
  - Strength
  - Thickness
  - Air

But What Do We Need?

- Performance Engineered Mixtures
  - Understand what makes concrete “good”
  - Specify the critical properties and test for them
  - Prepare the mixtures to meet those specifications
- Ask for what is needed, and no more

What is Good concrete?

- Constructible (Workable)
- Dimensionally stable
  - Aggregates
  - Shrinkage
- Impermeable (Transport properties)
- Cold weather resistant
  - Freeze thaw
  - Salt attack
- Strong (enough)



Workability

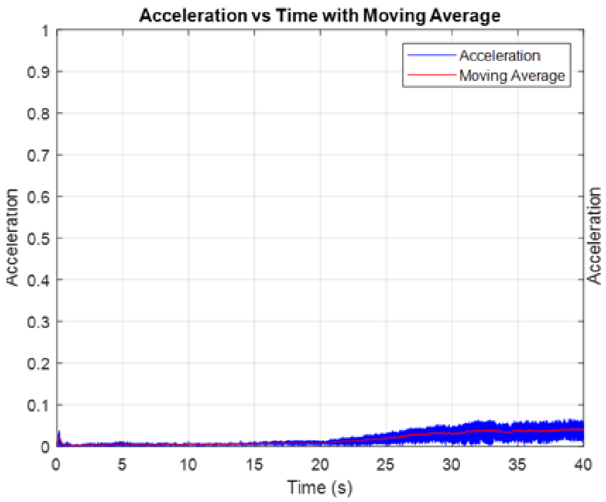
- Not too wet / Not too dry
- Right for the equipment you are using
- Response to vibration
- Thixotropy
- Prequalification

Workability

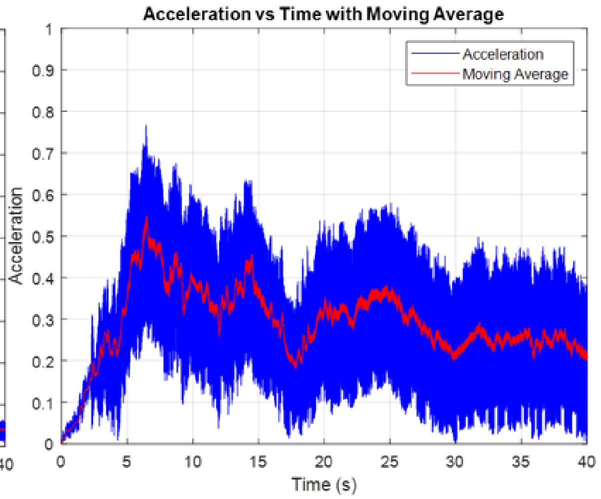
- VKelly and Box

Workability

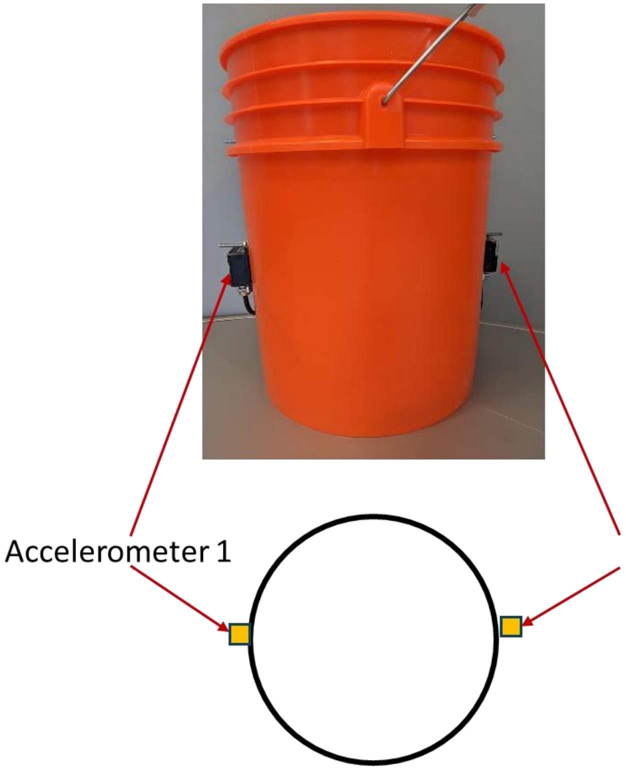
- Quake



Slump: 1.0 inch



Slump: 2.5 inches



Top View of bucket

Ley

Workability

- Segregation
  - No test

Workability

- Finishability

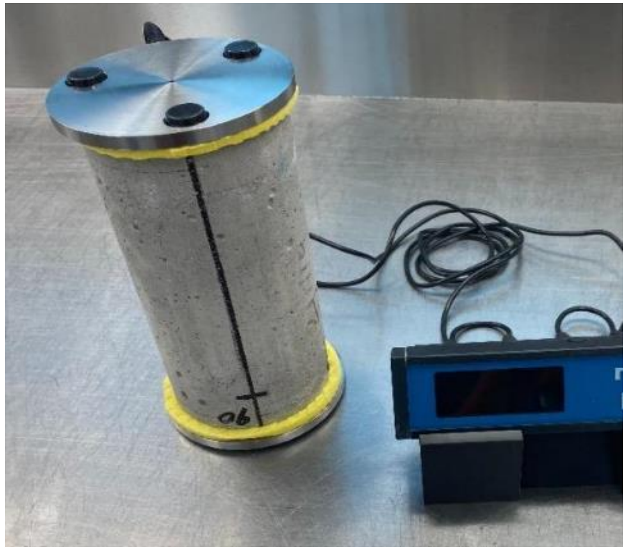
Transport properties (permeability)

- All deterioration mechanisms involve fluid movement
- Keep water out = longer life
- Measurement has been difficult

- Prequalification
- QC
- Acceptance

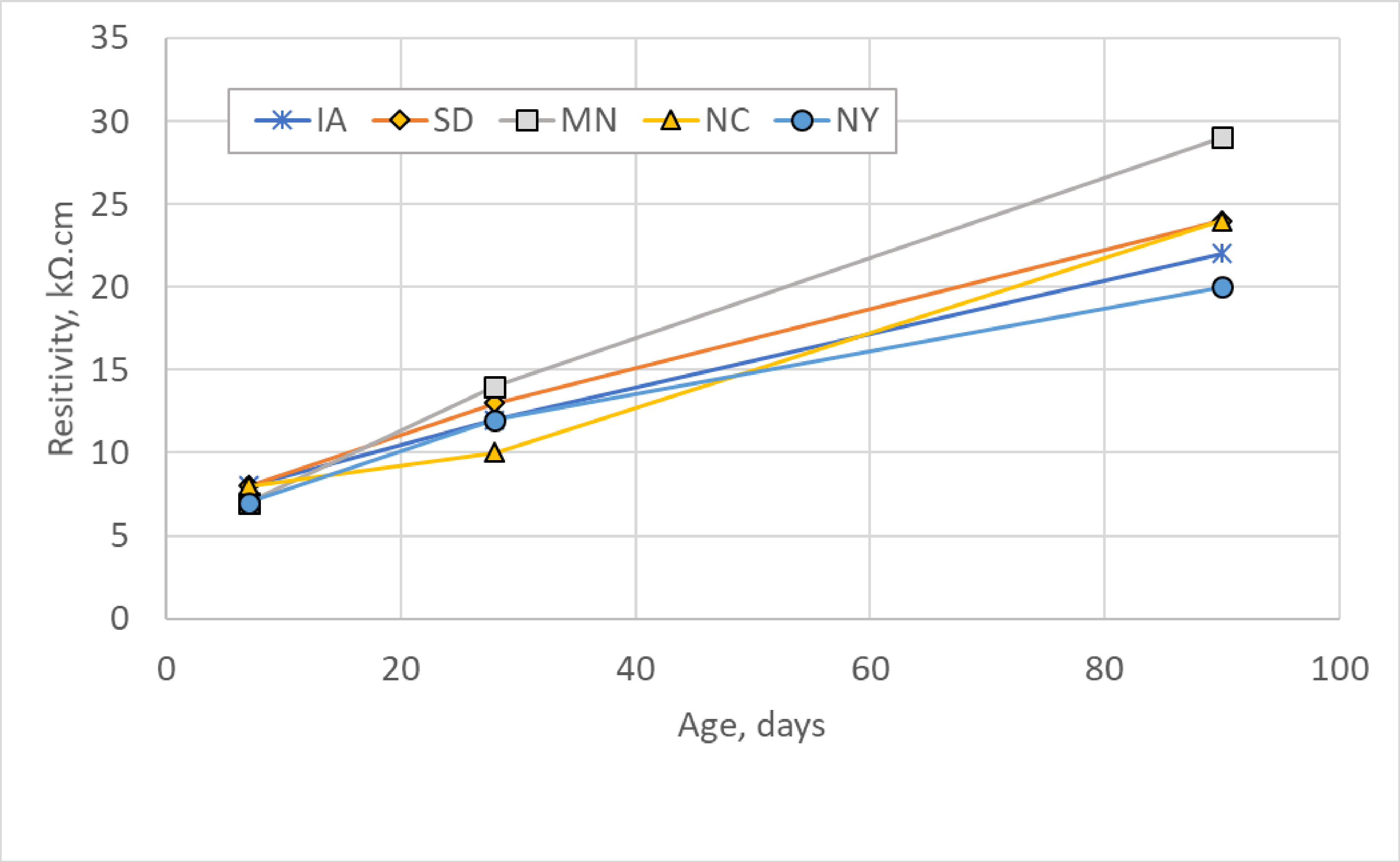
Resistivity

- Resistivity
  - Curing: Fog room
  - Pull out at desired age
  - Read and put back
  - Repeat



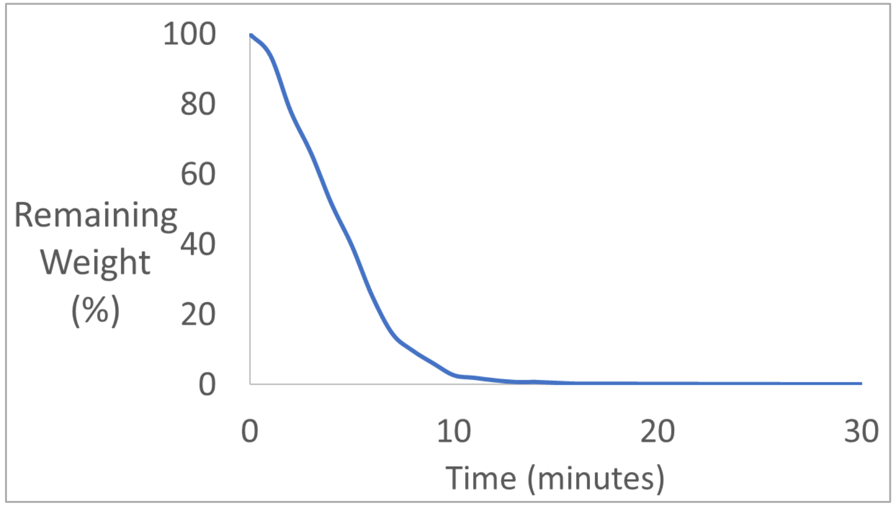
Classification	Resistivity (kΩ · cm)	Formation Factor
High	<5.2	<520
Moderate	5.2–10.4	520–1,040
Low	10.4–20.8	1,040–2,080
Very low	20.8–207	2,080–20,700
Negligible	>207	>20,700

Resistivity



Phoenix (w/cm)

- Record batch ticket and aggregate properties
- Make and weigh 6”x 3.75” cylinder (1640 cm3)
- Dump cylinder into pan and weigh
- Heat for 15 min
- Weigh pan



Cold Weather

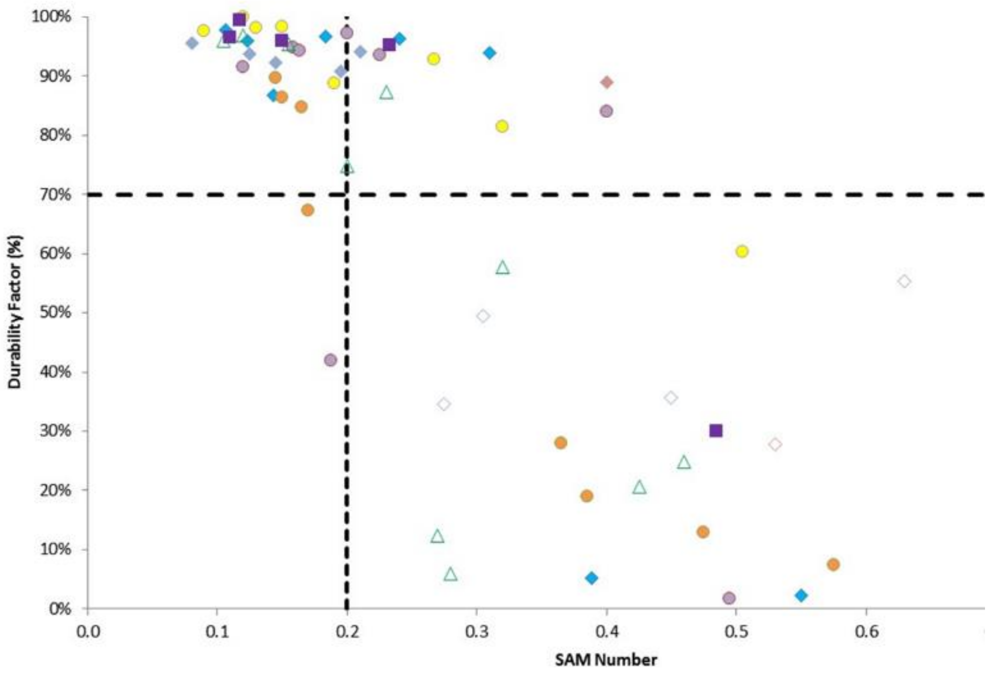
- Saturated Freeze-thaw
- De-icing salts
- Scaling

- Prequalification
- QC
- Acceptance

Super Air Meter

- Reports an index that correlates with F/T performance
- Training and machine maintenance are critical

- Prequalification
- QC
- Acceptance (later)



Salts can cause chemical attack

- Calcium oxychloride
  - Reaction between $Ca(OH)_2$ and calcium or mag chloride
  - Expands more than ice
  - Forms above 32F

- Prevention
  - Enough SCM

$CaCl_2$ @ 40° F

Tests for Oxychloride

- Low temperature differential scanning calorimetry (LT-DSC)
- Expansion

- Prequalification

Aggregate Stability

- Aggregate growing due to
  - Alkali silica reaction
  - (Alkali carbonate reaction)
  - D-Cracking

- Prequalification

Shrinkage

- Influences cracking risk
- Controls warping
- Takes time

- Prequalification

Shrinkage

- Paste content (read the batch sheet)
  - Easy
  - Fast

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	%	

Strength

- Strong enough to carry loads
  - (and not much more)

- Prequalification
- QC
- Acceptance

Other Parameters

- Consolidation and Segregation
  - Unit Weight
  - Resistivity
  - GPR
  - MIRA

Other Parameters

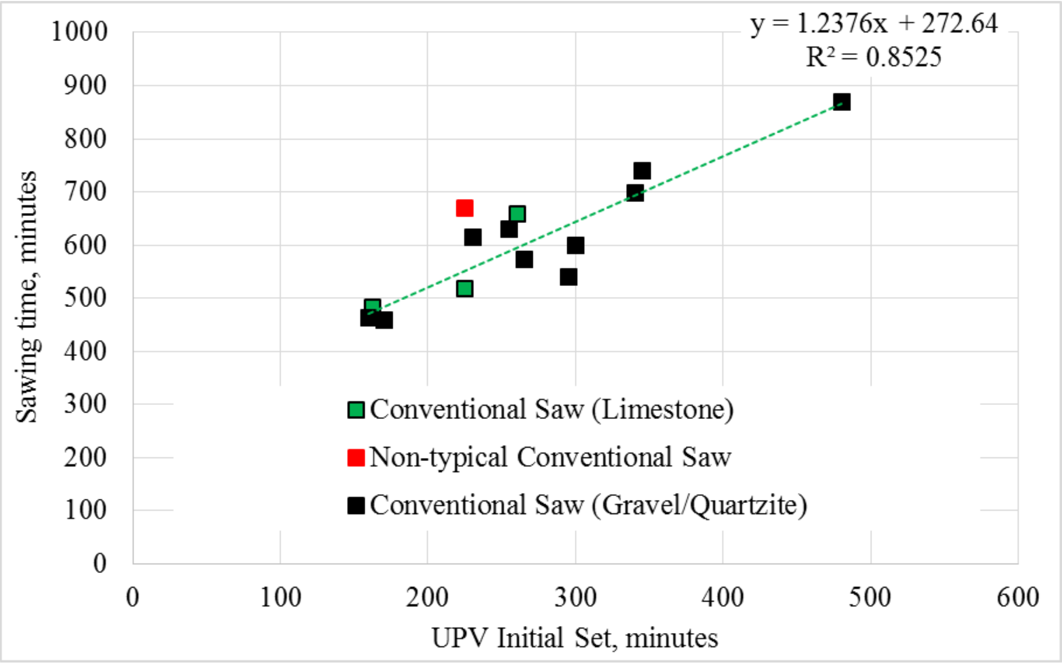
- Smoothness

Other Parameters

- Curing

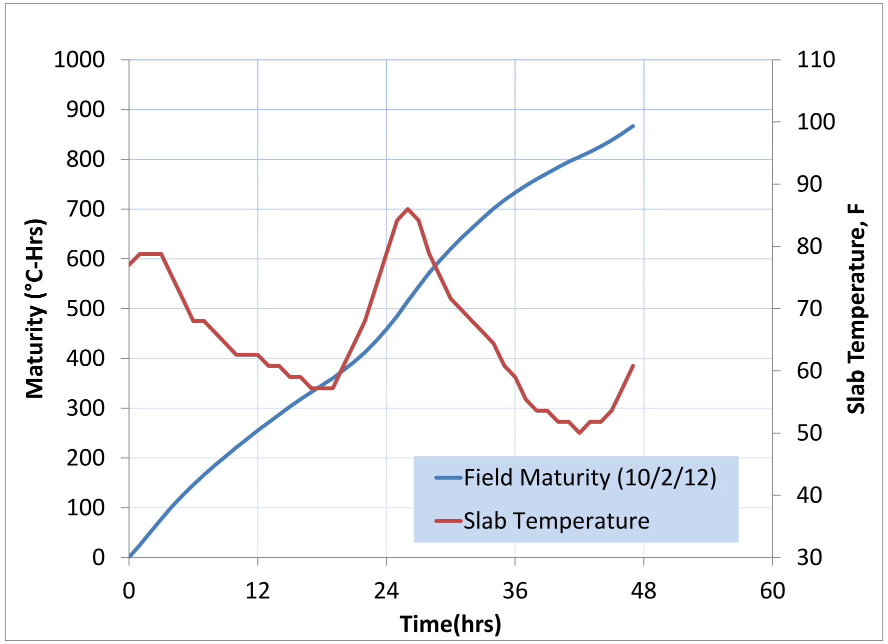
Other Parameters

- Saw timing



Other Parameters

- Maturity
  - AASHTO T 413



The mixture

- How do we prepare mixtures that meets these needs?

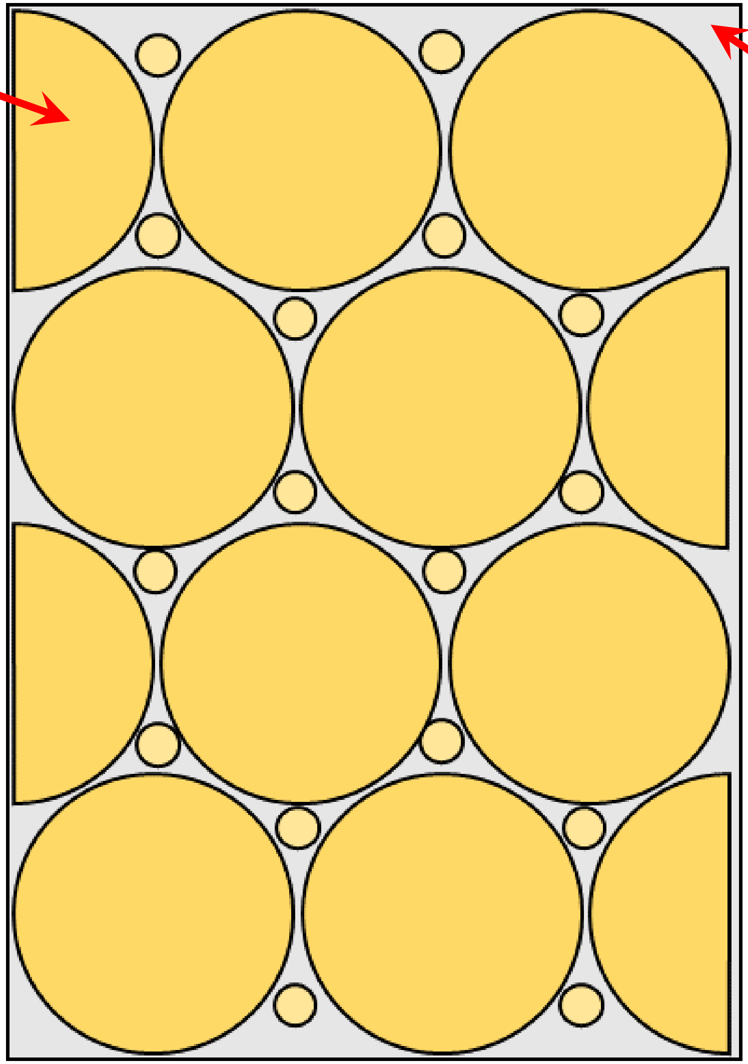
The mixture

- How do we prepare mixtures that meets these needs?

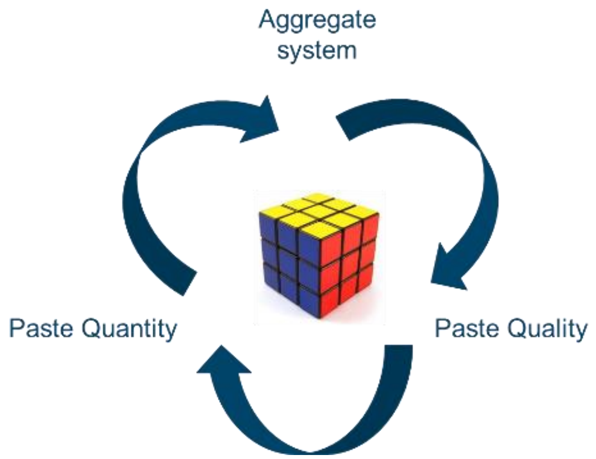
		Workability	Transport	Strength	Cold weather	Shrinkage	Aggregate stability
Aggregate System	Type, gradation	✓✓	-	-	-	-	✓✓
Paste quality	Air, w/cm, SCM type and dose	✓	✓✓	✓✓	✓✓	✓	✓
Paste quantity	Vp/Vv	✓	-	-	-	✓✓	-

The mixture

Filler
Gradation



Glue
What sort
How much



Does it Work?

- MNRoad

	MNDOT	Optimized
Cement	400	351
SCM 1	170	150
SCM 2	0	0
Coarse Agg	457	662
Fine Agg	1171	1303
Intermediate 1	1167	954
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

	MNDOT	Optimized
Slump	2.0	2.0
HRWRA	2.0	2.3
Air content	6.8	7.0
Box	1 - 0	1 - 0
Initial set	6:27	6:12
Strength at 7	3,340	3,650

Where Next?

- Adapt the thought process for airfields!
- Work underway at Oklahoma State University

What About PLC?

- What is being discussed
  - Variability between plants is likely higher
  - Water requirement is likely higher
  - Strength development is different
  - Finishing practices are different (set, bleed)
  - Admixture interactions are different

What About PLC?

- Where next?
  - Research
    - Measure critical properties in a variety of systems
    - Hahn Ready-mix project
    - Rigorous review of pavements in a city
  - Correlate properties with practices in the field
  - Develop protocols for specifiers, and crews

What About PLC?

- What do I do today?
  - Follow best practices as we know them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