Performance Engineered Mixtures
So what…

National Concrete Pavement Technology Center

CP Tech Center

Iowa State University

Institute for Transportation

An Emphasis on Durability

- What do I want?
- How do I get what I want with what I have?
- How do I know?

What Do We Want?

- The pavement owner wants:
  - ✓ Strong enough
  - ✓ Crack free
  - ✓ Ability to resist the environment
  - ✓ Safety
  - ✓ Cost effective

What Do We Want?

- The contractor wants:
  - ✓The right workability for his machine (water content, agg gradation)
  - ✓Control of the setting time (SCM type)
  - ✓Cost effective

What do we measure now?

- Slump
- Strength
- Air
- Thickness

What do we measure now?

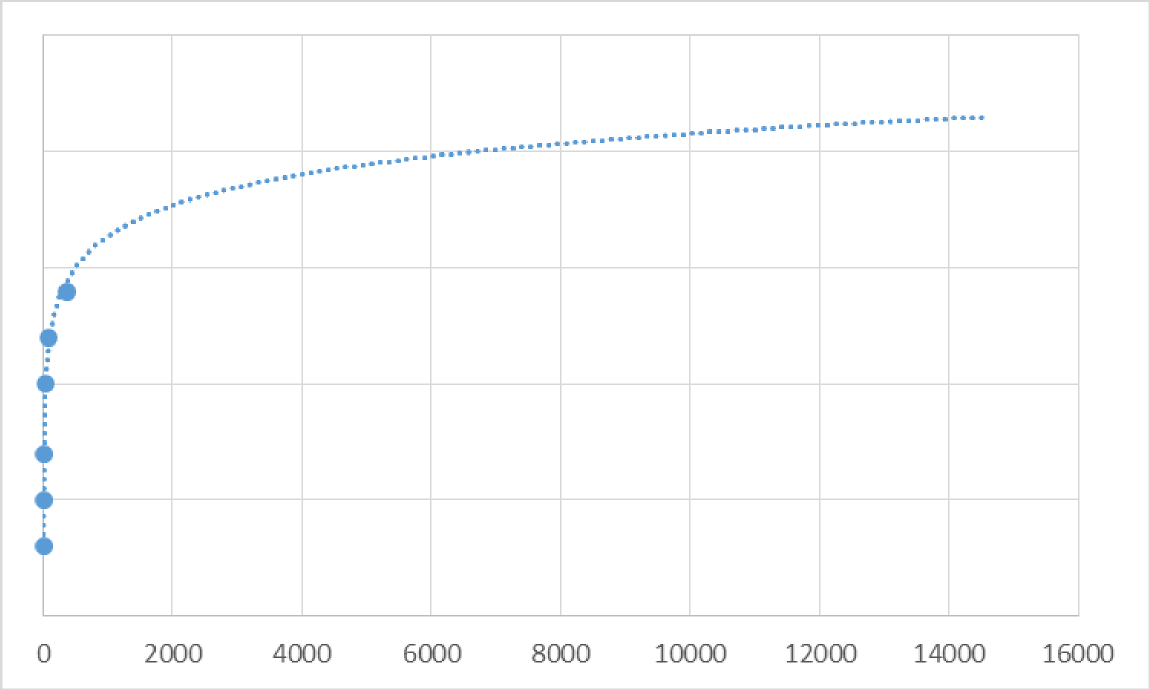
- How are these related to potential distress?
  - ✓ And tougher environments
  - ✓ And new materials
  - ✓ And new practices

What do we need to assess?

- Materials quality
- Mixture <u>in place</u>

Complications

- Reactions are slow
  - ✓ Attack takes time
  - ✓ Accelerating the test changes it
  - ✓ Extrapolation or interpolation



Complications

- Concrete changes over time
  - ✓Hydration may continue
  - ✓Cracking
  - ✓Moisture state / temperature

Complications

- The environment is not constant
  - ✓ Yearly / daily changes
  - ✓ Local effects

Complications

- Workmanship issues
  - ✓Fabricated on site
  - ✓Incoming variability
  - ✓Mixing
  - ✓Transporting
  - ✓Finishing
  - ✓Curing

Complications

- Tests
  - ✓Time
  - ✓Precision
  - ✓Cost

When do we measure?

- Mixture design
  - Most critical properties
  - Accept mixture(s)
- Field trials
  - Workability and uniformity
- Acceptance
  - Is the mixture the same?
- QC
  - Are we going to get there?

AASHTO Guide Specification

- Based on existing specs
- Add new thinking
- Take out some stuff

Materials

- Cement – M85, M240
- Slag cement – M302
- Fly ash – M295 (ASTM C 1709)
- Admixtures – M154, M194 (others?)

Materials

- Aggregates
  - ✓ M80 for contaminants
  - ✓ PP65 for ASR
  - ✓ ?? For d-cracking

  - ✓ Continue with current individual fraction gradation
  - ✓ Address combined gradation in proportioning

  - ✓ ASTM C 1761 for IC

Prescriptive

Property	Value	AASHTO Test Method	When Test Must be Conducted*
Combined Aggregate Gradation	Within Tarantula Curve	T27	All
	#8 - #30 >15%		
	24% < #30 - #200 < 34%		
Cementitious content	450 lb/yd^3, minimum	Batch records	Mixture design
	658 lb/yd^3, maximum	Batch records	Mixture design
Portland cement content	50% of cementitious, minimum	Batch records	Mixture design
Class C Fly Ash**	30% maximum cement replacement	Batch records	Mixture design
Class F Fly Ash**	25% maximum cement replacement	Batch records	Mixture design
GGBFS**	50% maximum cement replacement	Batch records	Mixture design
w/cm ratio	[0.42] […] maximum	Batch records	All
Entrained air	4% after placement, and	T 152, T 196M/T 196,or T 199	All
	0.2 SAM number	Super-air-meter	All
	2% maximum loss during placement	T 152, T 196M/T 196,or T 199	All

Performance

Property	Value	AASHTO Test Method	When Test Must be Conducted
Electrical Resistivity	[27] […] kΩ-cm minimum at [28] […] days	TP 95	All
Compressive strength	[4000] [3500] […] psi minimum at [28] [90] days	T 22	All
Freeze thaw resistance	RDM > [80] […] %	C666	Mixture design
Shrinkage	Crack free at [14] […] days	ASTM C 1581 Ring	Mixture design
	<0.06 %	ASTM C 157 mod**	Mixture design

Report

Property	AASHTO Test Method
Modulus of elasticity at 28 days	ASTM C 469
Drying shrinkage	ASTM C 157
Coefficient of thermal expansion	T 336
Rate of strength development to 90 days	T 22
Rate of development of electrical resistivity	TP 95
Unit weight	T 121
Slump	T119

QC

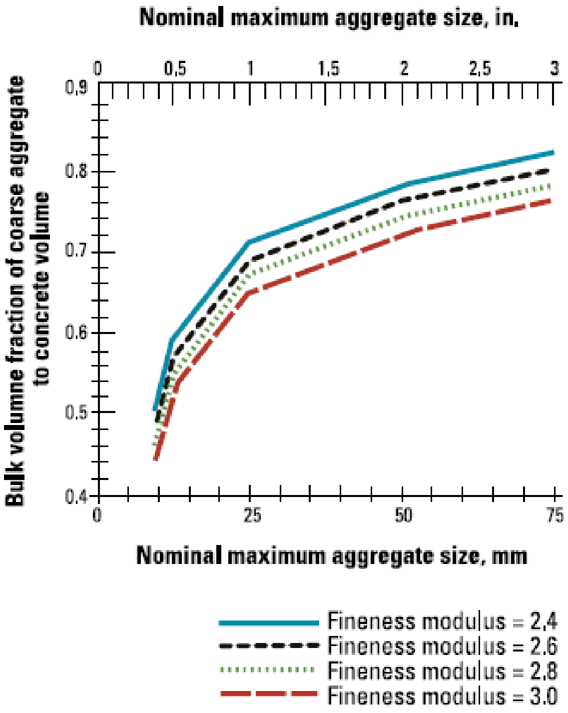
Property	AASHTO Test Method	When Test Must be Condu
Air void system	Foam Drainage	Mixture design
Slump	Within 1” of design mix	T 119M/T 119
Unit weight	Within 3 pcf of design mix	T 121
Calorimetry	Adiacal	Construction
Maturity	ASTM C 1074	Construction
Strength development	T 22	Construction
Resistivity Development	TP 95	Construction

Current Proportioning Technologies

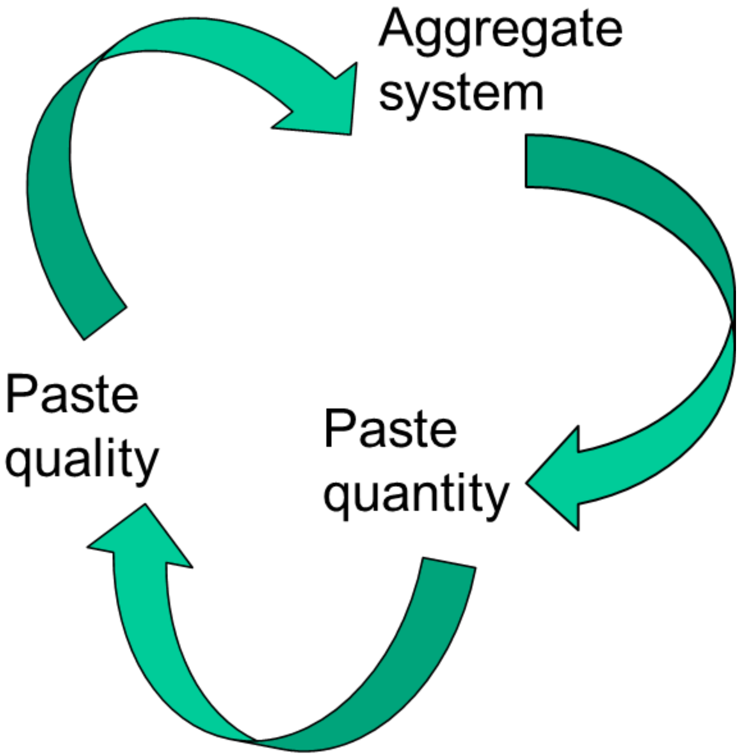
- Developed
  - ✓Before water reducers
  - ✓Before supplementary cementitious materials
- Primarily focused on structural concrete
  - ✓100 mm (4”) slump
  - ✓30 MPa (~4000 psi)
- ACI 211 last revised in 1991

Absolute Volume Approach

- Paste volume based on coarse aggregate size
- Coarse aggregate volume based on subtracting the fineness modulus (FM) of sand from a fudge factor
- Fill the remaining volume with sand



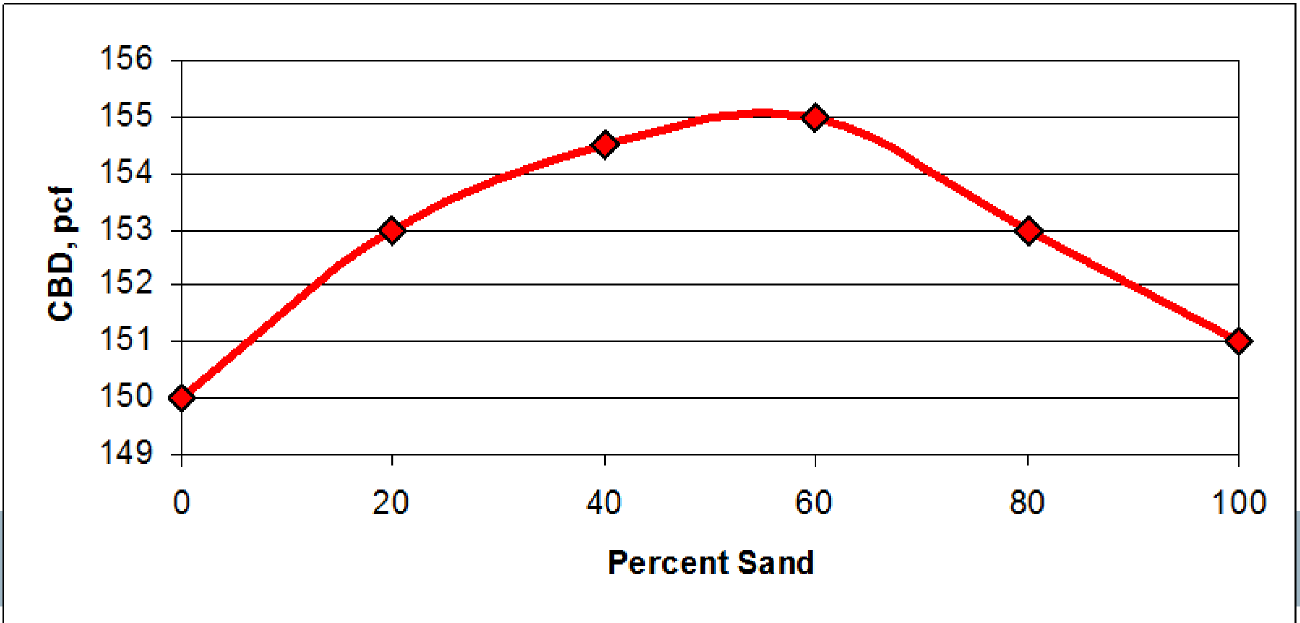
Proposed Mixture Proportioning Procedure



Proposed Mixture Proportioning Procedure

<u>Choose the Aggregate System</u>

- Combined gradation
- Determine void ratio

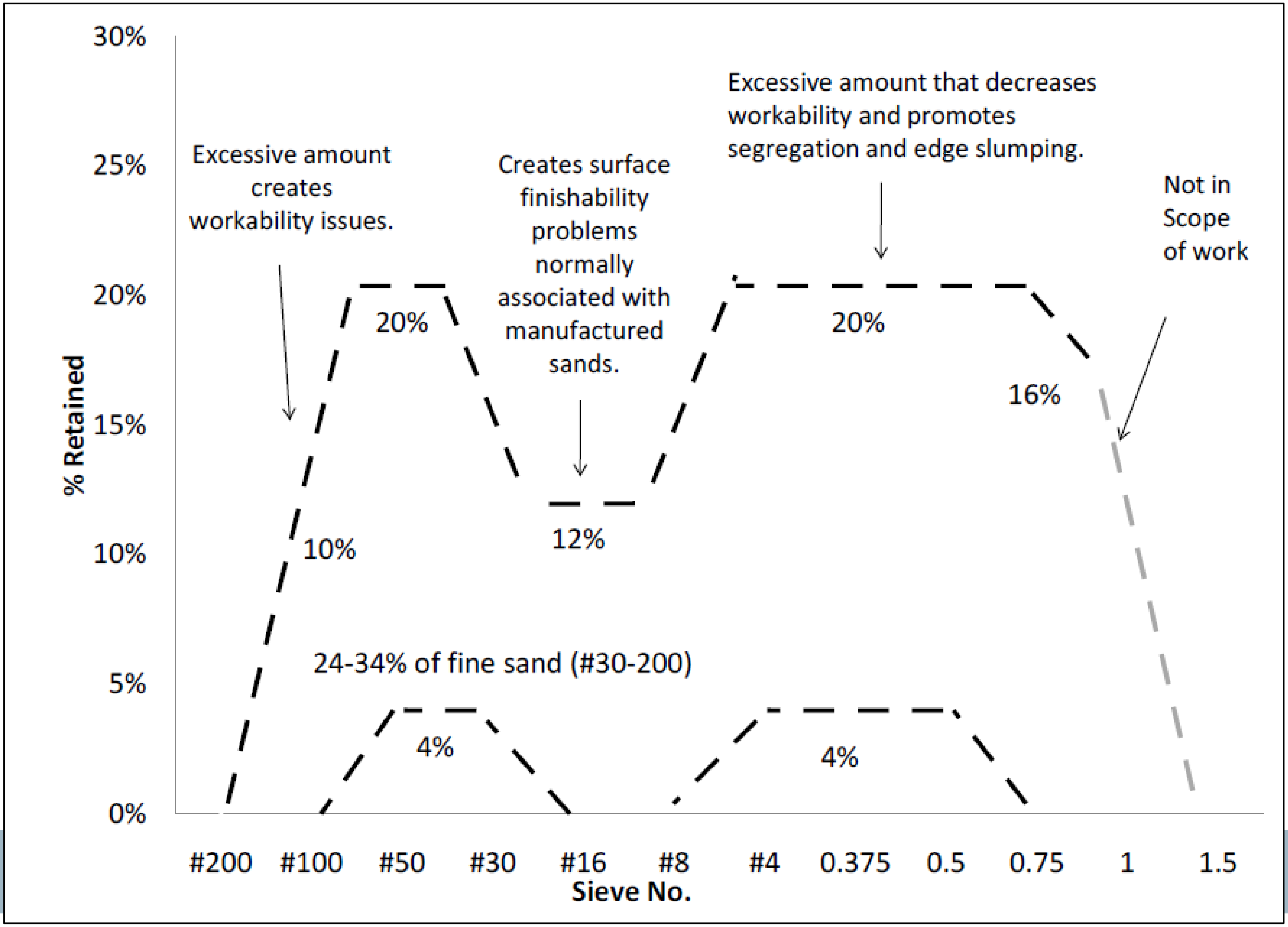


Aggregate System

- Aggregate Contents
  - ✓Target good combined gradation
- Aggregate Quality
  - ✓D-Cracking
  - ✓ASR – AASHTO protocol – use blended cements)
  - ✓Use DOT approved sources

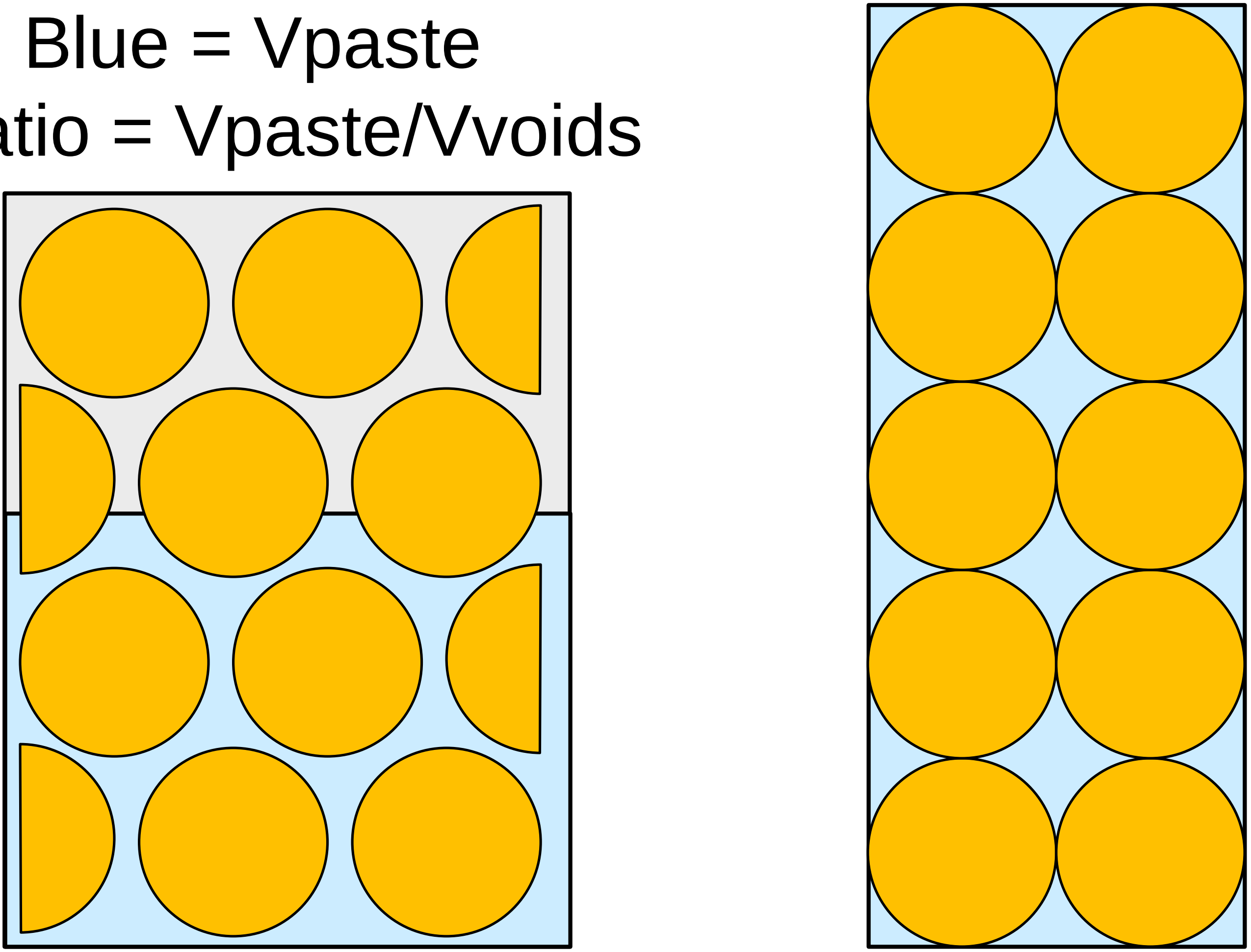
Aggregate System

- Tarantula Curve (Ley)



Definitions…

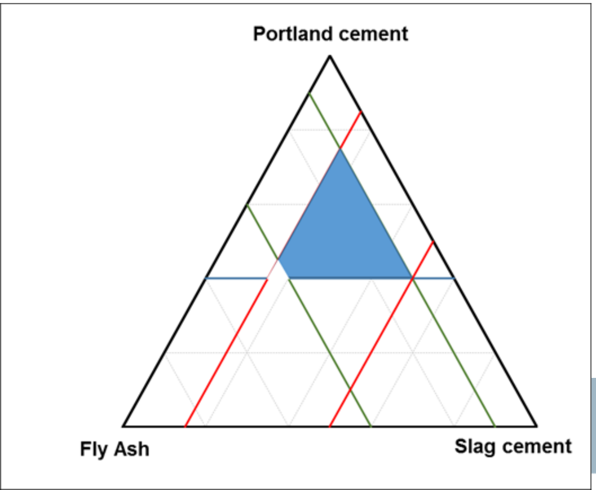
- Blue = Vvoids (C29)
- Grey + Blue = Vpaste
- Void ratio = Vpaste/Vvoids



Proposed Mixture Proportioning Procedure

<u>Choose a paste system for performance</u>

- Cementitious blend
- W/Cm
- Air content
- Chemical admixtures

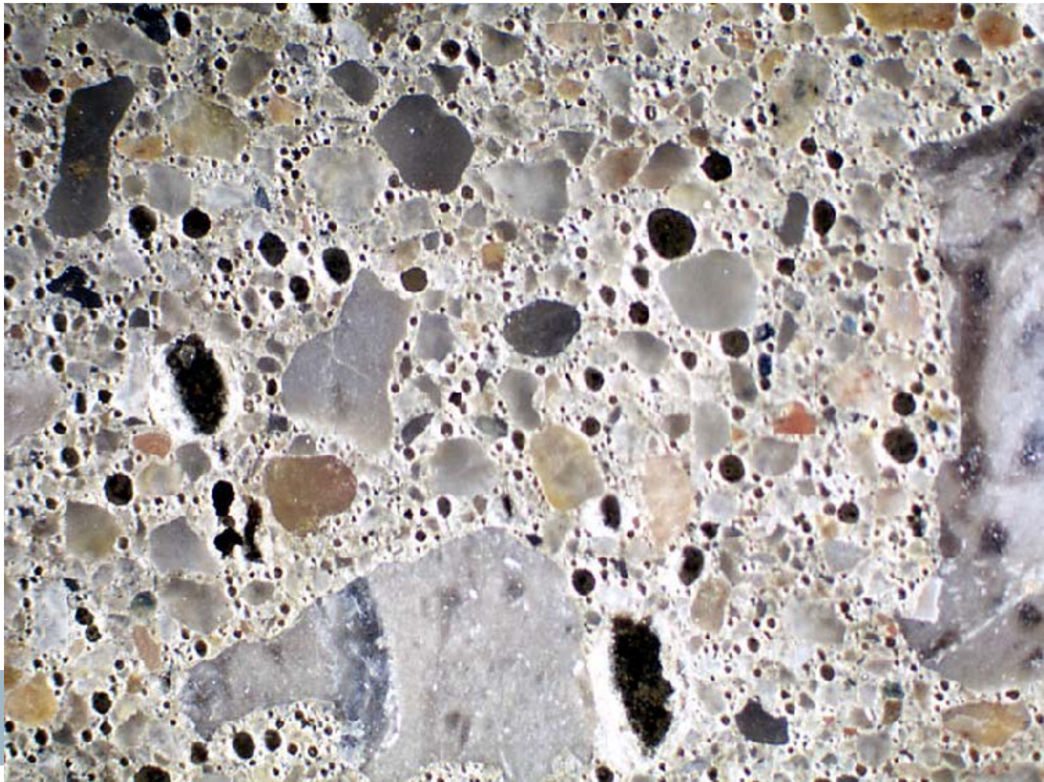


Paste System

- w/cm
  - ✓ Concrete exposed to the weather = 0.38 to 0.42
  - ✓ Interior = 0.45 to 0.50
  - ✓ Don't care = >0.50

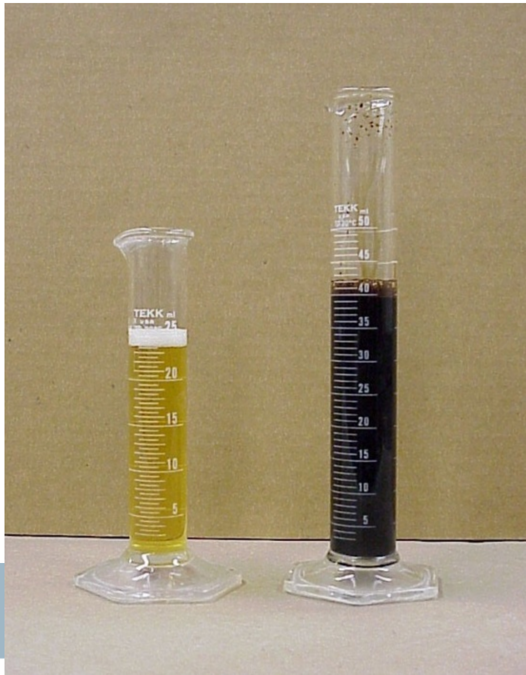
Paste System

- Air Void System
  - ✓Spacing factor <0.008 inch
  - ✓Air content >5% behind the paver



Paste System

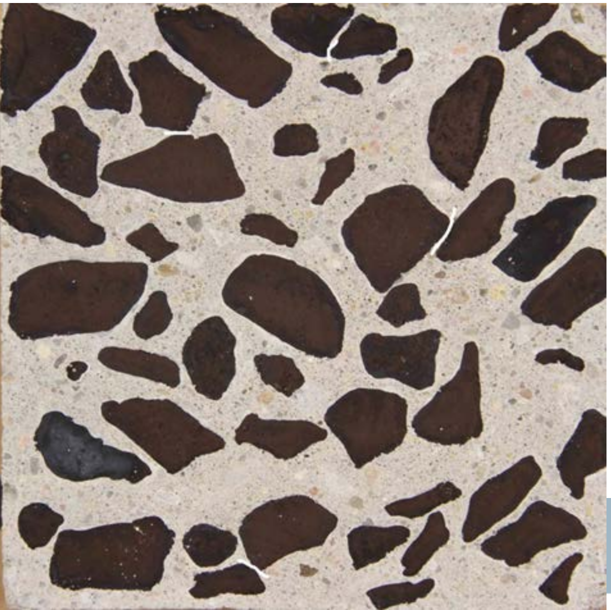
- Admixtures
  - ✓ Will vary depending on weather
  - ✓ Do not specify dosage
  - ✓ Compare with manufacturers' guidelines

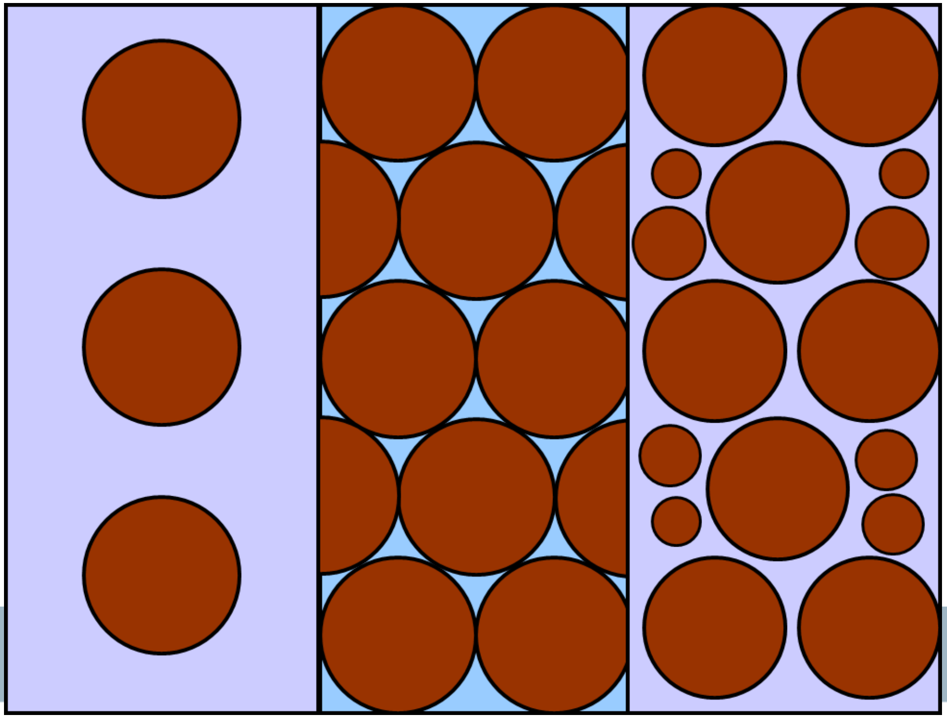


Proposed Mixture Proportioning Procedure

Choose Paste Volume

- All voids must be filled with paste
- And a bit more to coat the particles for workability

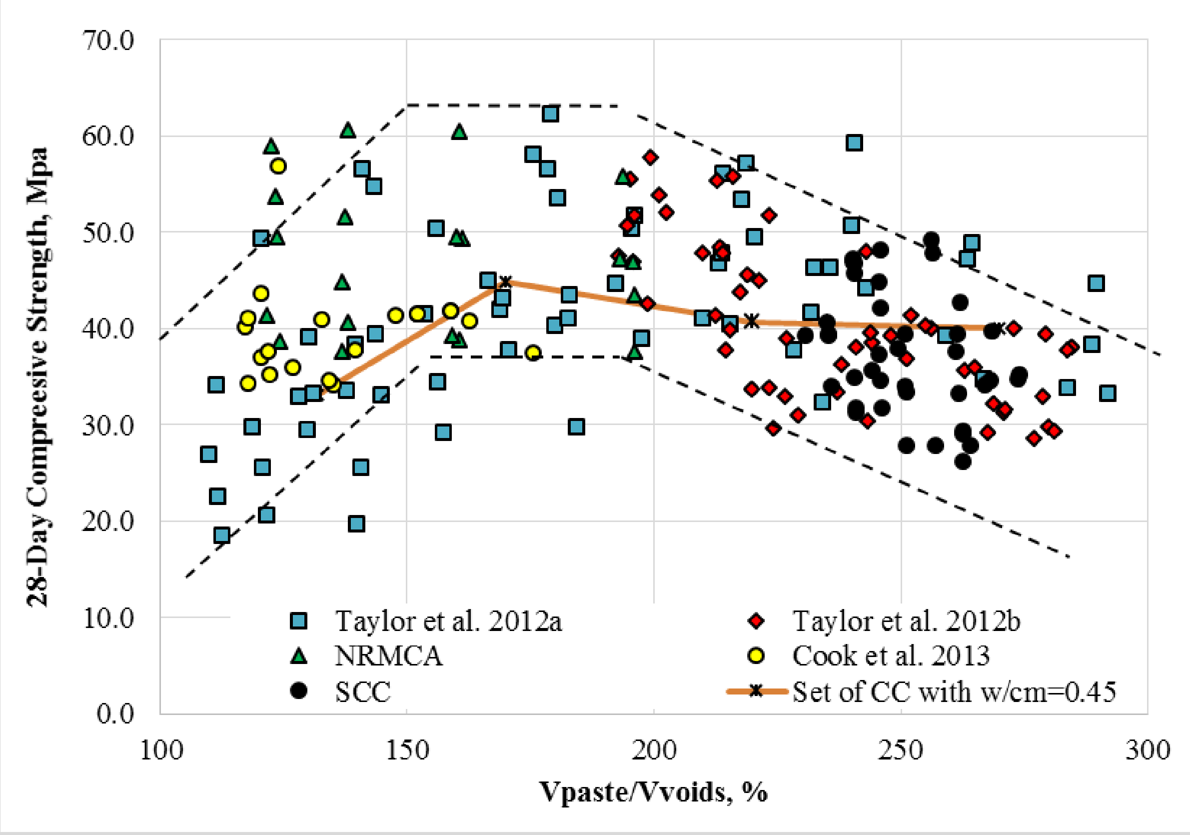




Proposed Mixture Proportioning Procedure

Choose Paste Volume

- Need enough paste for mechanical properties ~175% of voids



Closing

- Did you get what you thought you paid for?
- Did you measure what you really want?
- Concrete can last a long time…

Chicago Sun Times

Discussion…