CP5 – Troubleshooting Precast Production

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DEAR BOSS

I'M AFRAID THAT I WILL NOT BE ABLE TO MAKE IT IN TO THE OFFICE TODAY.

I OPENED THE FRONT DOOR AND THERE ARE 20 INCHES OF SNOW OUTSIDE.

I'VE ATTACHED THE ABOVE PHOTO TO PROVE IT.

YOUR HONEST EMPLOYEE

P.S. IF I DON'T ANSWER THE PHONE I'LL PROBABLY BE OUTSIDE SHOVELING. - TRUST ME

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THE PRECAST SHOW

Houston, We Have a Problem – Now What?

Why is it so Challenging to Solve Some Problems?

Overview

Need = Expectations → Design → Project

Overview

Raw Materials

Batch/Mix

Transport

Cast/Place/Consolidate

Set-Up Forms/Molds

Overview

Remove/Handle/Store

Ship and Install

Owner = Happy

Overview

- Every step matters!
- Every step in the process is a chance to improve quality or degrade it
- Consistency matters!

What Are Some of Your Challenges?

Troubleshooting/Problem Solving

When is the best time to have a problem?

- At the plant before batching?
- At the plant after batching?
- At the bed before casting?
- At the bed after casting?
- Before you ship?
- After you ship to customer?
- When you get a call from a lawyer?

Troubleshooting, Problem Solving & Process Improvement

Troubleshooting
- Designed for “Somebody is mad at me” situations
- Time is of the essence
- Problems that can be solved in a few minutes, hours, or before the next batch

Problem Solving
- Used for more complex problems
- Typically require data analysis and team approach
- May involve processes, products, services or more

Process Improvement
- Ongoing activity
- Typically involves small changes in order to improve output or performance
- Recognized Programs:
  - Total Quality Management (TQM)
  - Six Sigma

Trouble Shooting

- Time-sensitive (often need a decision/remedy quickly)
- Have an internal plan (e.g. fire, medical emergency, concrete emergency)
  - Plant-Specific Quality Control Manual (NPCA)
  - Quality Systems Manual (PCI)
- Clear chain of decision makers
- SOP for high-potential issues
- Reach out to your Precast Specialist or Admix rep

Problem Solving vs. Process Improvement

Problem Solving

- Identify and quantify the problem
- Assign project team
- Gather and analyze data, and establish measures
- Diagnose cause(s) and ascertain whether cause is sporadic (special) or endemic (common)
- Address cause(s)
- Develop action plan
- Implement plan and prevent recurrence
- Start another problem-solving project

Process Improvement

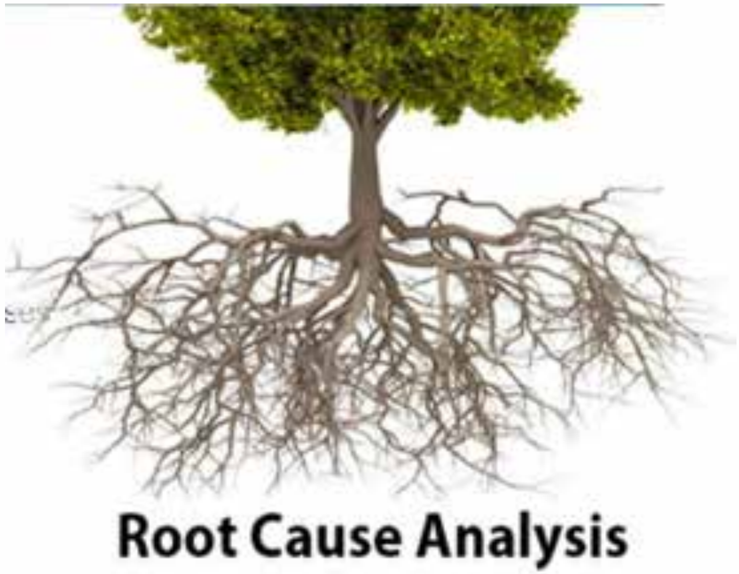
- Identify and quantify the opportunity
- Define the process and the scope of the project
- Analyze the current process
- Think about future process(s)
- Generate and assess alternatives and recommend changes
- Try out and verify effectiveness of changes
- Implement changes, standardize
- Hold the gains!

Using a Process-Driven Method

Six Sigma Methodologies

- ➢ Intended for existing process - DMAIC
  - □ Define
  - □ Measure
  - □ Analyze
  - □ Improve
  - □ Control

- In other words…ROOT CAUSE ANALYSIS



Defining The Problem

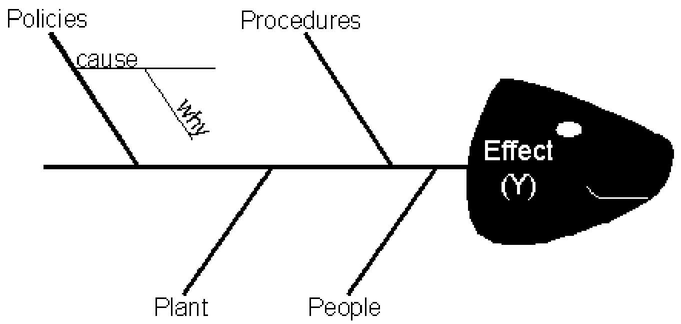
- This is the most important part of the procedure, but also sometimes the most difficult to truly ascertain
- The “real” problem is often different from what is initially described
  - Communication difficulties
  - Language barriers
  - Different “slang” terminology
- Develop the problem statement and review it with the appropriate person
  - “The Problem appears to be…
    - low strength” (cylinder strengths were low)
    - retardation” (couldn’t strip forms in the morning)
    - high air content” (strength was low and concrete felt “spongy”)

Measurement

- The “True” Process is identified and documented
  - Process steps and corresponding inputs and outputs are identified
- Establish baselines
  - Determine what should be measured and how it will be measured
  - Collect data (internal, external)
  - Identify gaps between current and required performance
- Development of a map of all interrelated business processes
  - Look to clarify areas of possible performance enhancement

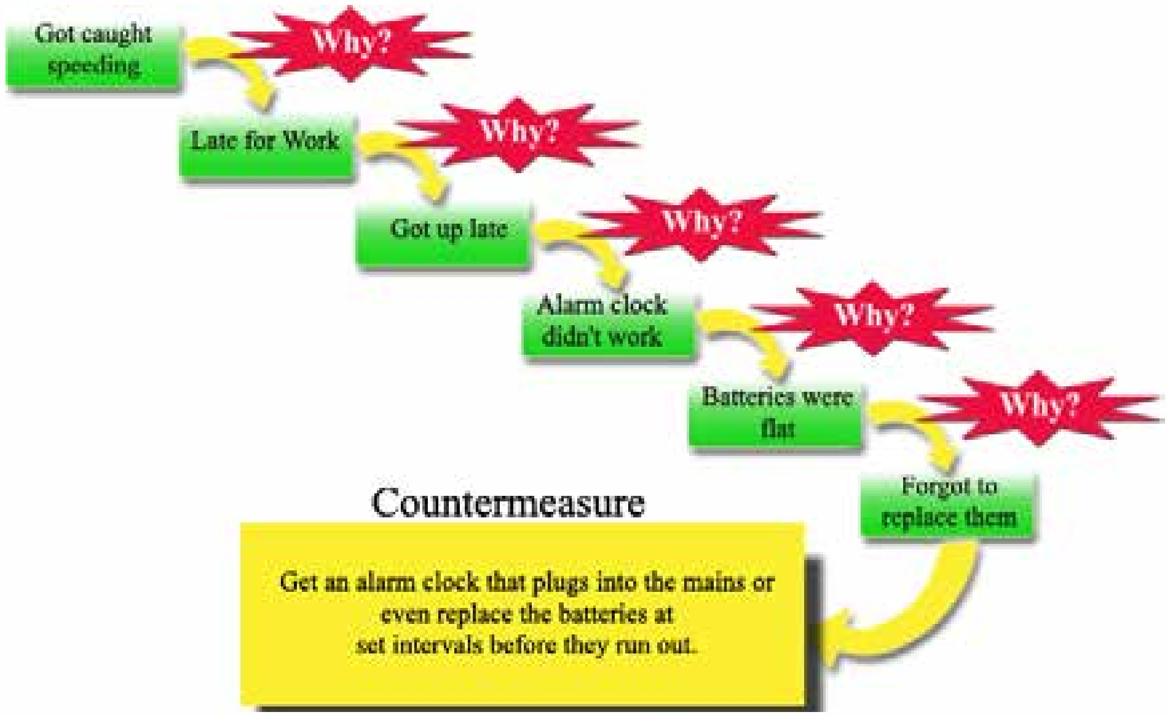
Analysis

- Primary Objective: Identify the root cause of the Problem
  - 5 Whys
  - Fishbone Diagram
  - Others?
- Multiple root causes may be identified via root cause analysis



When 5 Whys is Most Useful

- When problems involve human factors or interactions
- In day-to-day business (or personal) life
  - ➢ 5 Whys can be used with or without a project



Several Considerations

Materials
OPC
SCM
Aggregates
Fibers
Admixtures
Water

Equipment
Material Haulers
Yard Equipment
Batch Plants
Mixers
Jobsite Equipment

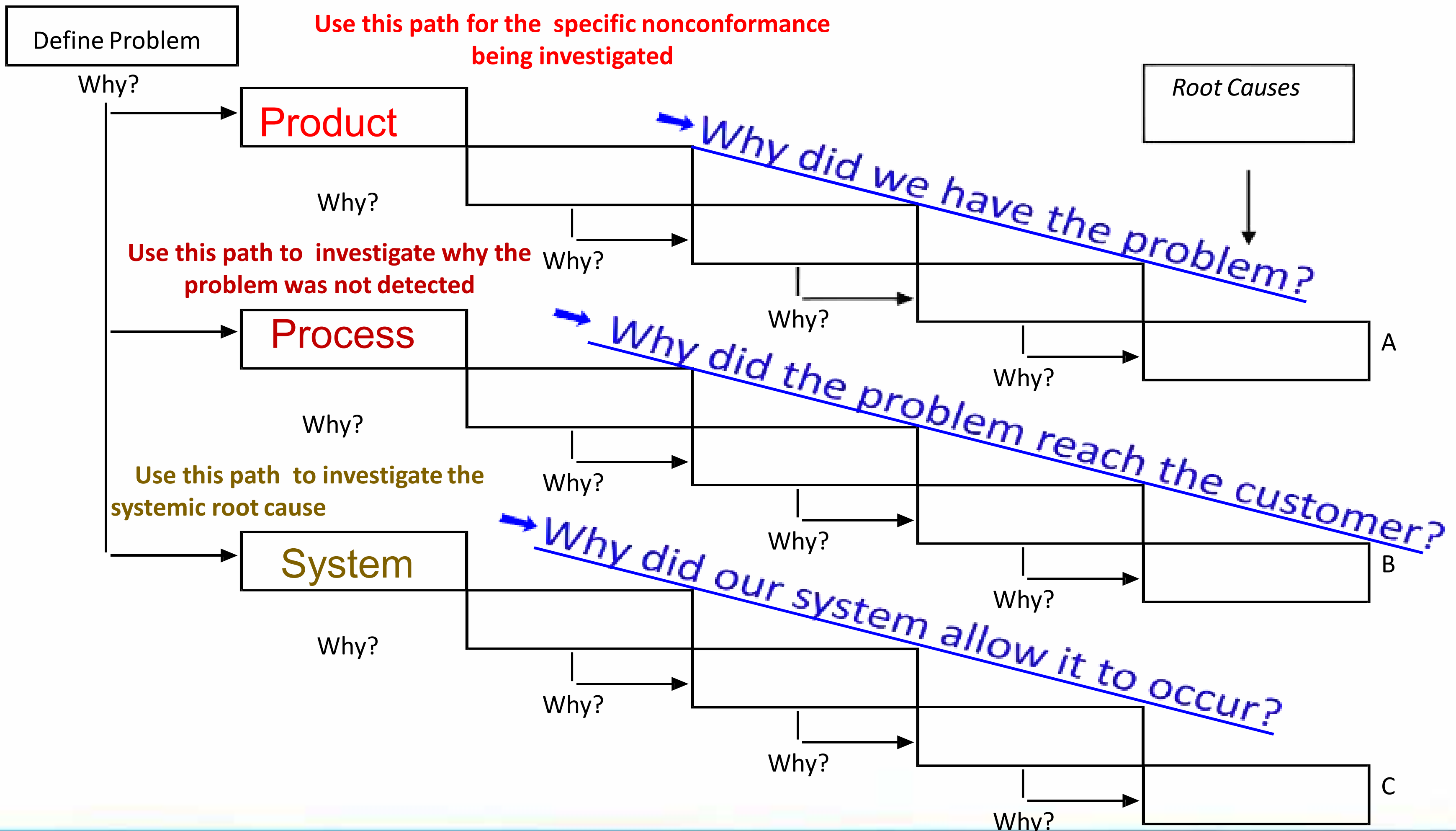
Processes
Material Handling
Material Sequence
Batching
Transporting
Placing
Finishing
Curing

People
Managers
Equip. Operators
Batch Operators
Drivers
Production
Finishers
Testing Labs
Engineers
Owners

Multiple-Legged 5 Whys

Now we know what happened to the concrete, but how did it get to the customer?

Multiple-Legged 5 Whys



5 Whys Concrete Example:

Background: While testing concrete on a large project, QC reports that the mixture's slumps are "all over the place"

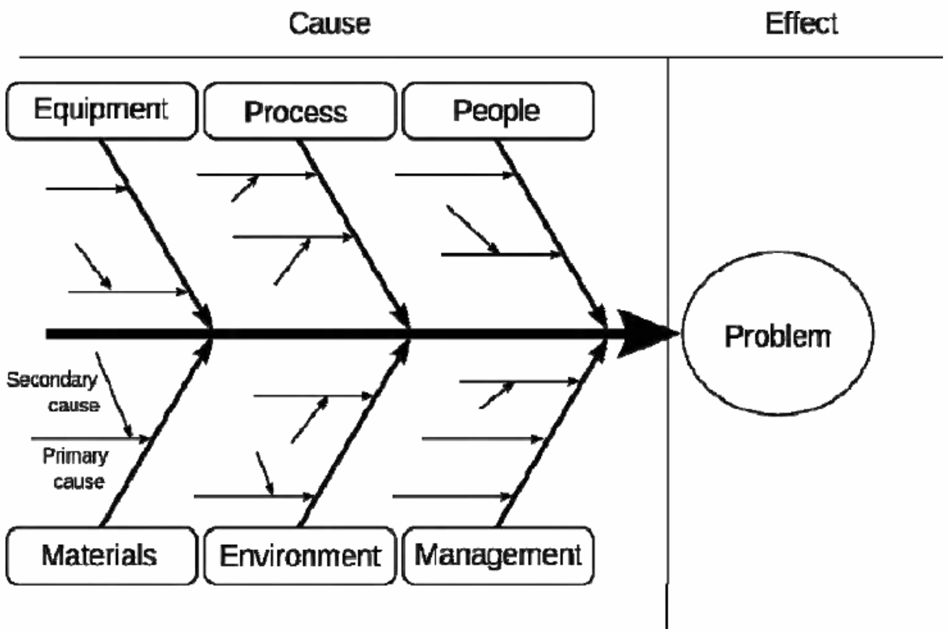
- Question: Why is the concrete performing inconsistently?
  - Answer: I don't know. (they rarely do)
  - Note, the question is vague, may be too open ended, and posed to the wrong person.

Meanwhile at the batch plant…

- Q1: Why is the slump inconsistent?
  - A: Because there are different amounts of water in the mix.
- Q2: Why is the water content changing?
  - A: Because the batchman has to adjust the water content manually by the load.
- Q3: Why does the batchman have to adjust the water manually by the load?
  - A: Because the moisture probes are broken and haven't been fixed/replaced?
- Q4: Why have the moisture probes not been fixed?
  - ➢ A: Because we haven't had enough time to fix the probes.
- Q5: Why haven't we had the time to fix the probes?
  - ➢ A: Because we have to meet Production goals.

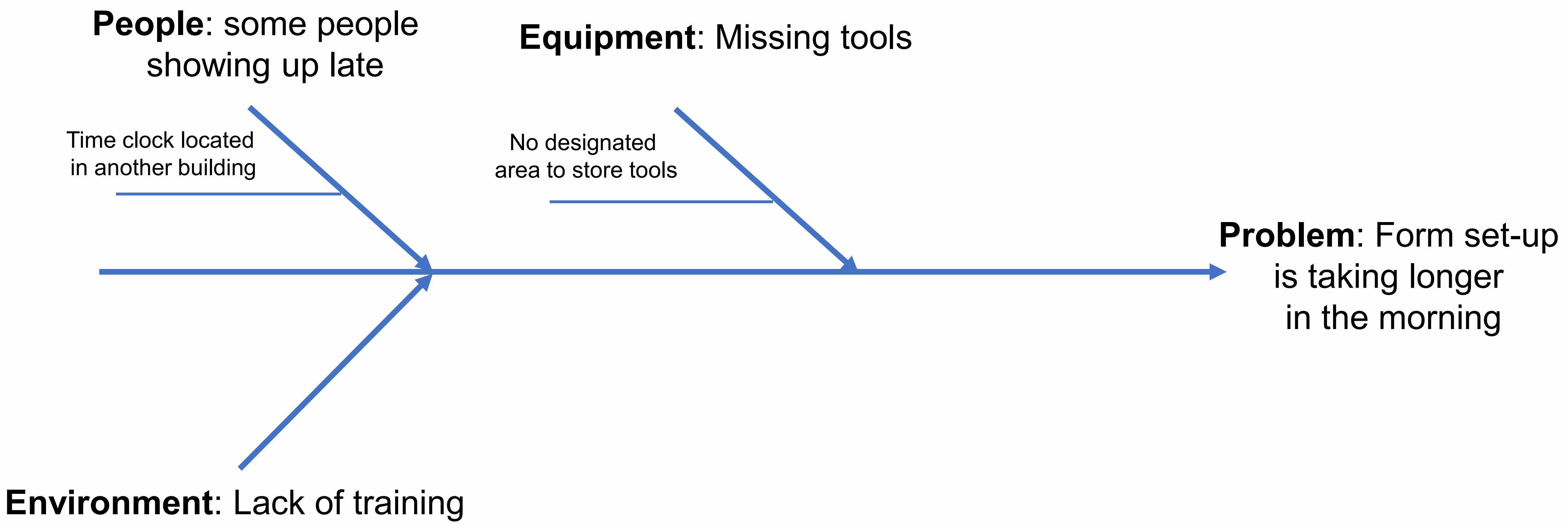
Fishbone Diagram (Cause and Effect)

- Help to identify the likely causes of the problem(s)
  - Helps user to think through causes more thoroughly
  - Major benefit: it pushes user to consider all possible causes of the problem(s), rather than the ones that are more obvious, the ones the user "wants", or that of "opinions"
- Helpful in identifying problems with more than one significant root cause



Promotes "System Thinking" through visual linkages.

Using the Fishbone



The End Game - Process Control

In Summary:

- A systematic approach to solving problems
- Identify and Define the real issue
- Use the tools to determine cause and effect
- Develop a plan for measurable improvements
- Make adjustments one at a time
- Sometimes experimentation is in order
    - Alternate Materials
    - Alternate Equipment
    - Alternate Process
    - Alternate People

A Few Case Studies

The HRWR isn’t working

- Inconsistent slumps
- Batch the same mix all day
- Dosage is “normal”
- Dispensers are working correctly
- Slumps vary from 3” to 9”
- Moisture is “tested” and recorded every few hours

The HRWR isn't working

- Six Sigma team determines:
  - The moisture testing equipment isn't calibrated

Bleeding Gatorade

- Residential builder experienced extended setting on a project.
- Believes that RMC used fly ash in what is supposed to be straight OPC mixes
- Petrography shows no signs of fly ash
- Contractor convinced they did everything by the book.

Bleeding Gatorade

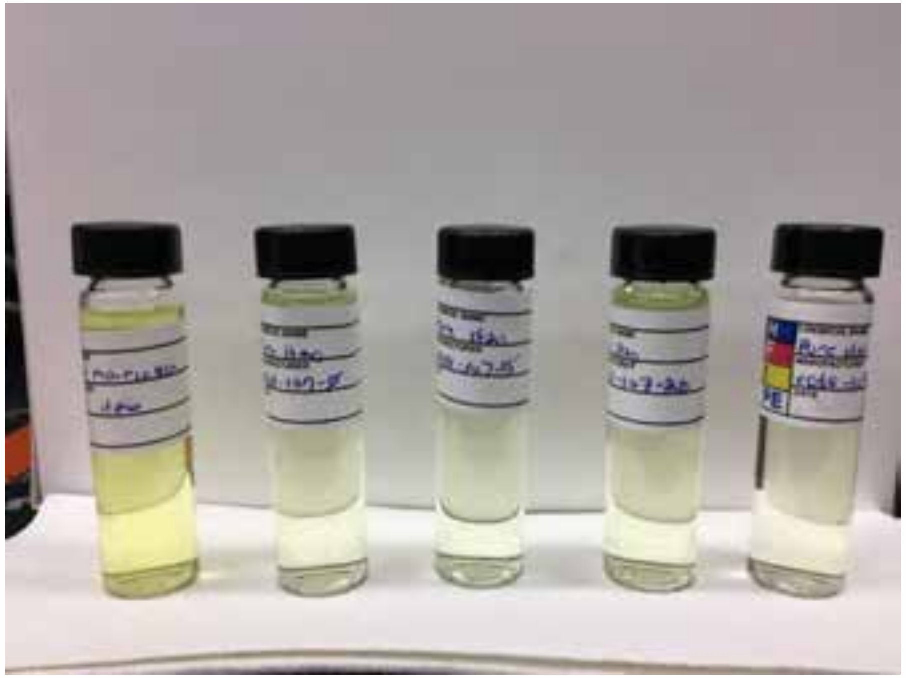
- Contractor noticed that bleeding from the slab was green
- *“We’ve never seen this before”*
- *“It must be what the problem is because…*
- *…We’ve done everything by the book.*

Bleeding Gatorade

The green bleed water 319-0311-1 absorbs in the Ultra violet light at 273 and 371 nm, with the absorption at 371 giving rise to a yellow color. **The measured fluorescence, represents the absorption of light (excitation) at one wavelength and emission at a different wavelength. There are two excitation bands, at 299 and 313 nm** – neither of which are observed in the absorbance spectrum. Likely it is too small to be observed with the UV-vis instrumentation. If the sample is exposed to light at either 299 or 313 (both of which are present in natural day light – but are out of visible range so cannot be seen) the sample emits light at 447, in the blue range. **The combination of absorbing and emitting gives the distinctive fluorescent green/yellow color.**

Bleeding Gatorade

XRF analyses of the cement sample indicated chromium level 0.08%. By comparing this figure with some recent cement clinker analyses (typically 0.01-0.03%) it appears this particular cement has a noticeably higher chromium figure than is typically observed.



Chromium solutions are known to exhibit distinctive fluorescent green/yellow color.

RMC Producer: What's up with the Chromium?
OPC Supplier: Oh yea, it's been running pretty high lately. I meant to call you.

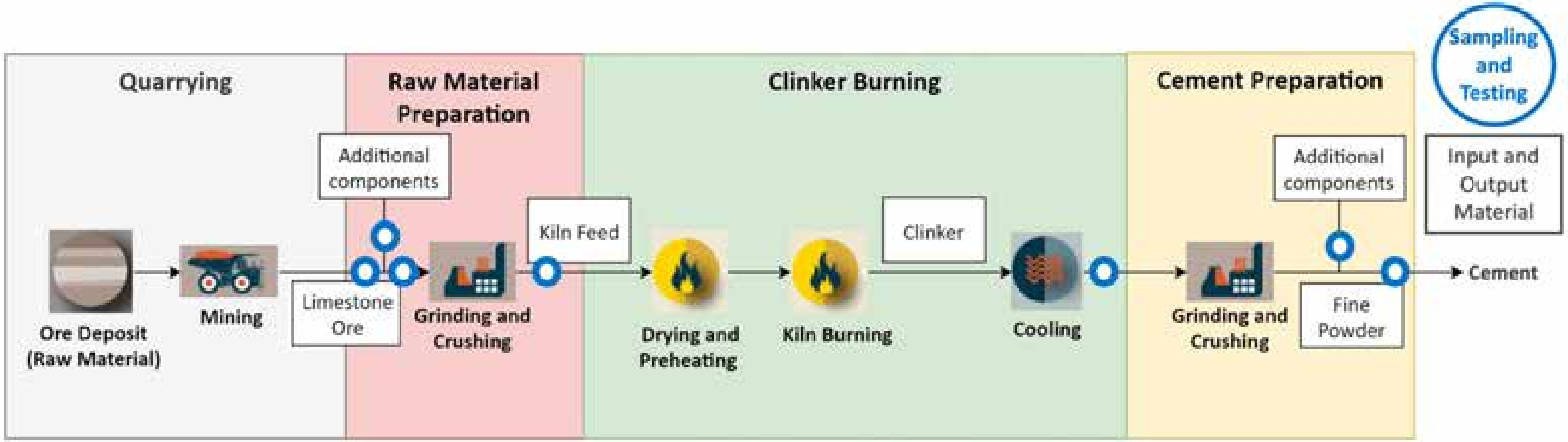
Materials

Cement

What is Cement?

Hydraulic Cement is the binder in concrete

Lime
Iron
Silica
Alumina



CO2 Release

What Happens When Cement and Water are Mixed Together?

Hydration – is an exothermic, chemical process that creates Calcium-Silicate-Hydrate (CSH gel) the binder in concrete.

Hydration

- **Tricalcium Silicate (C_3S)** - Hydrates and hardens rapidly and is largely responsible for initial set and early strength.
- **Dicalcium Silicate (C_2S)** - Hydrates and hardens slowly and contributes largely to **strength increase at ages beyond one week**
- **Tricalcium Aluminate (C_3A)** - Liberates a large amount of heat during the first few days of hydration and hardening. It also contributes slightly to early strength development. Gypsum, which is added to cement during final grinding, slows down the hydration of C_3A. Without gypsum, a cement with C_3A present would set rapidly. **Cements with low percentages of C_3A are especially resistant to soils and water containing sulfates.**
- **Tetracalcium Aluminoferrite (C4AF)**- Reduces the clinkering temperature, thereby assisting in the manufacture of cement. It hydrates rather rapidly but contributes very little to strength. **Most color effects are due to C_4AF** and its hydrates.

Composition & Fineness of Portland Cements (% by mass)

Type	C_3S	C_2S	C_3A	C_4AF	Blaine Fineness m^2/kg
I Normal	57.5 49-62	12.7 9-16	9.3 7-11	7.3 4-11	397.2 375-440
II Sulfate Resistance	59.1 51-68	12.7 7-20	6.4 0-8	10.3 7-13	392.7 305-471
III High-Early	58.0 49-66	13.5 7-20	7.3 4-14	9.1 4-12	560.8 365-723
IV Low Heat	42.2 37-49	31.7 27-36	3.7 3-4	15.1 11-18	339.5 319-362
V High sulfate Resistance	59.2 52-63	14.6 8-22	4.1 2-5	11.7 9-15	401.1 302-551
White	62.7 50.5-72.4	17.8 9.3-25.2	10.4 5.2-12.6	1.0 0.7-1.8	482.4 384-564

Material Certification Report

MILL TEST RESULTS	**Date: June 2022**
Laboratory:	**Cement Type: I Portland**

CHEMICAL DATA			PHYSICAL DATA		
ITEM	LIMIT	RESULT	ITEM	LIMIT	RESULT
Silicon Dioxide (SiO_2) %	***	20.38	% Air Content		7.10
Aluminum Oxide (Al_2O_3) %	***	5.75	Blaine (cm^2/g)	>=2800	3880
Ferric Oxide (Fe_2O_3) %	***	2.05	% Pass 325 Mesh	***	93.60
Calcium Oxide (CaO) %	***	63.38	14 day C1038 Expansion %*	<=0.020%	0.001
Magnesium Oxide (MgO) %	<=6.0	3.58	% Autoclave Expansion	<=0.80	0.35
Sulfur Trioxide (SO_3) %	<=3.5*	3.56			
Loss on Ignition (LOI) %	<=5.0	1.71	Compressive Strength		
Sodium Oxide (Na_2O) %	***	0.13	1 day	***	2955
Potassium Oxide (K_2O) %	***	1.12	3 day	***	3870
Total Alkali %	***	0.87	7 day	***	4615
Insoluble Residue %	<=0.75	0.40	28 day	***	5750
Limestone	<=5.0				
L Color		63.78			
Potential Compounds			Time of set		
C_3S	***	51.0	Vicat		
C_2S	***	20.0	Initial(minute)	45>X<375	97
C_3A	***	12.0			
C_4AF	***	6.0	PFS		77.00

Create a Mill Cert. Control Chart

- Since the raw materials are dug out of the ground, their consistency will vary
- Mixture proportions of the raw materials must be continually adjusted, Therefore, the cement characteristics will vary
- Track your Cement

Cement Certification Control Sheet

Cement Supplier:

Cement Plant Location:

Cement Type:

Date Received	C_3S	C_2S	C_3A	Blaine	Alkali

Mill Cert. Control Sheet

- Alkali content
  - Na_2O and K_2O shown as Equivalent alkalis on the Cert.
  - As alkali content increases, air entraining agents produce more air. If above 0.60%, change of 0.10% significant. If low (0.30%), even 0.05% change significant
  - Less than 0.60% necessary if ASR potential

MILL TEST RESULTS

Laboratory:

CHEMICAL DATA

ITEM	LIMIT	RESULT
Silicon Dioxide (SiO_2) %	***	20.38
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Potential Compounds		
C_3S	***	51.0
C_2S	***	20.0
C_3A	***	12.0
C_4AF	***	6.0

Mill Cert. Control Sheet

- Alkali content
- Blaine fineness
  - Controls early strength
  - Higher the Blaine, higher the water
  - Higher the Blaine, higher the air entrainment admix demand
  - Change in Blaine signals a potential change in concrete performance

Date: June 2022
Cement Type: I Portland

PHYSICAL DATA

ITEM	LIMIT	RESULT
% Air Content		7.10
Blaine (cm^2/g)	*>=2800*	3880
% Pass 325 Mesh	***	93.60
14 day C1038 Expansion %*	*<=0.020%*	0.001
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Compressive Strength		
1 day	***	2955
3 day	***	3870
7 day	***	4615
28 day	***	5750
Time of set		
Vicat		
Initial(minute)	*45>X<375*	97
PFS		77.00

388 m^2/Kg

Mill Cert. Control Sheet

- Alkali content
- Blaine fineness
- C_3S – higher %, higher early strength
- C_2S – higher %, higher long-term strength
- C_3A – lower %, higher sulfate resistance

MILL TEST RESULTS
Laboratory: Bath, Pennsylvania

CHEMICAL DATA

ITEM	LIMIT	RESULT
Silicon Dioxide (SiO_2) %	***	20.38
Aluminum Oxide (Al_2O_3) %	***	5.75
Ferric Oxide (Fe_2O_3) %	***	2.05
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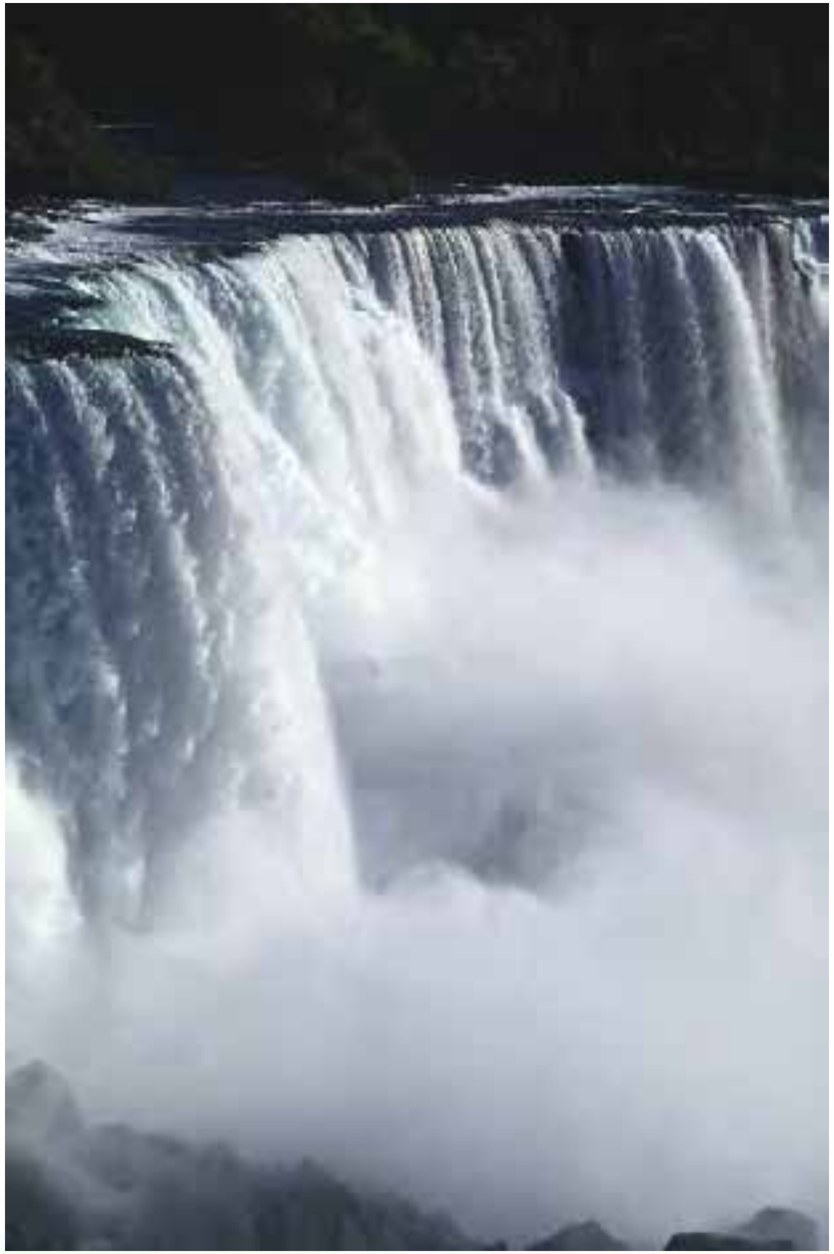
Water

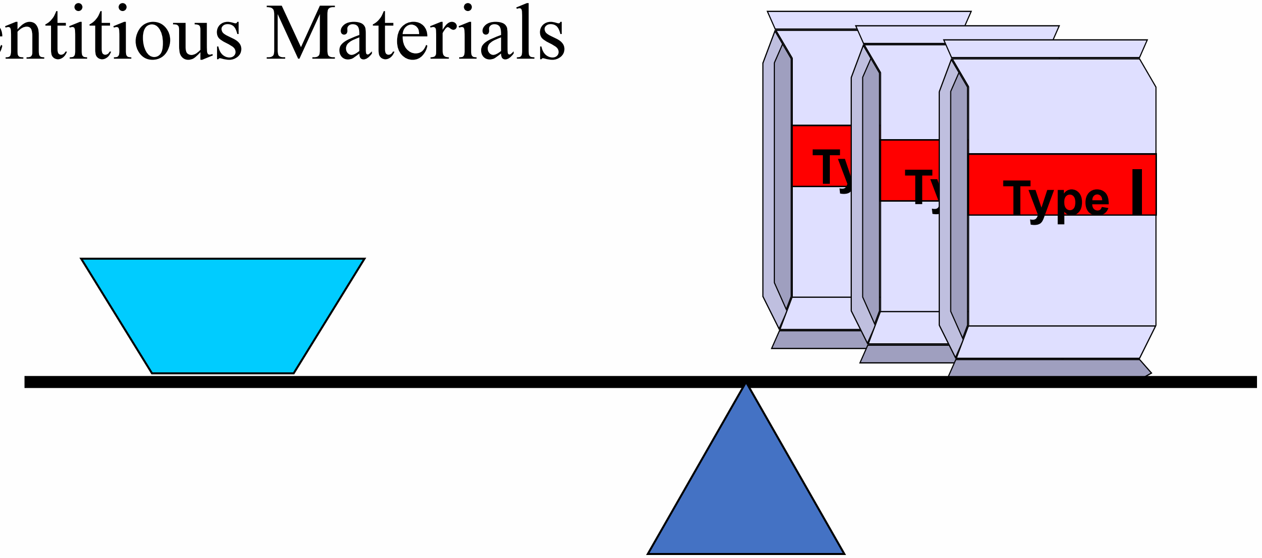


Water

- Purpose
  - Activates hydration
- Specs
  - Potable
  - Non-potable water meeting ASTM C1602 (Standard Specification for Mixing Water Used in the Production of Hydraulic Cement Concrete)
  - Recycled

Water/Cementitious Ratio

$$\frac{\text{Weight of Water}}{\text{Weight of Cementitious Materials}}$$



Precast/prestressed concrete = typical range of w/c ratio is between 0.30 and 0.45

Just Add Water?

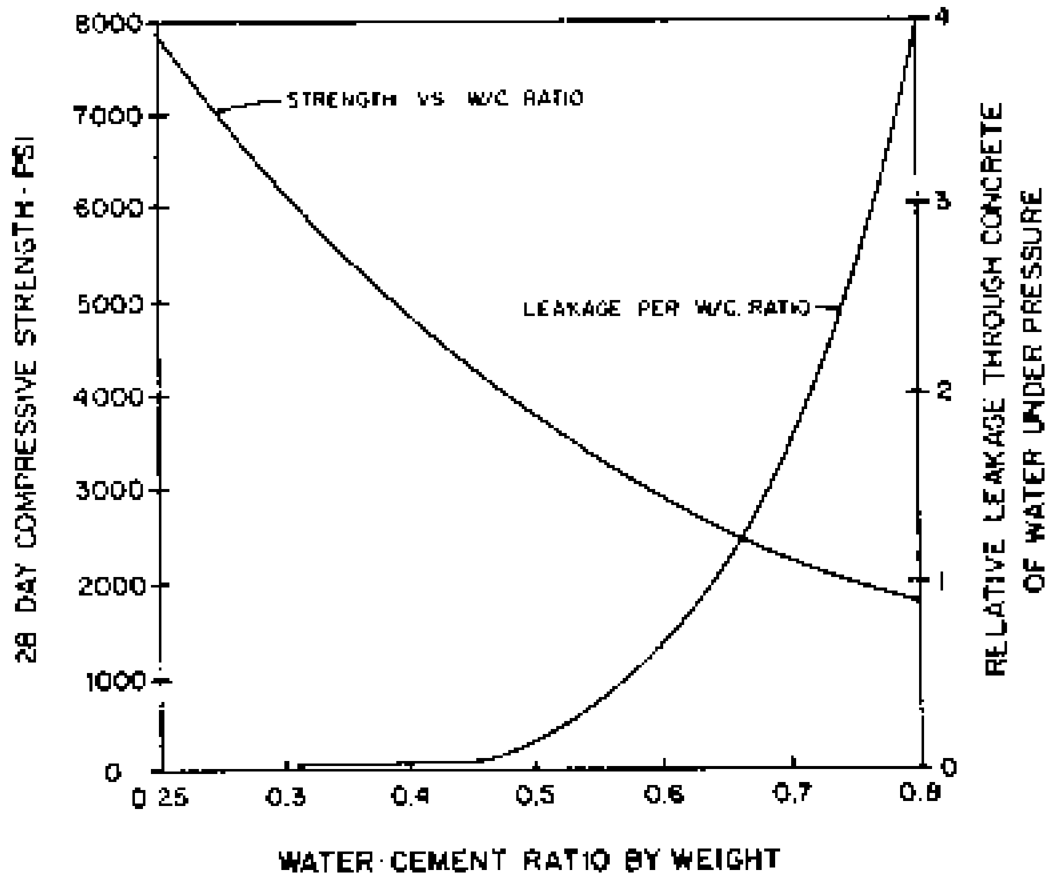
Why Not - Just Add Water?

The addition of one gallon of water to standard 3000 psi mix

- Can increase slump by 1", SCC Spread by 3"
- Increase shrinkage potential by 10%
- Increase potential for seepage up to 50%
- Reduce compressive strength by 200 psi
- Decrease F/T resistance by about 20%
- Waste the impact of ¼ bag of cement

What Happens When We Lower The W/C Ratio?

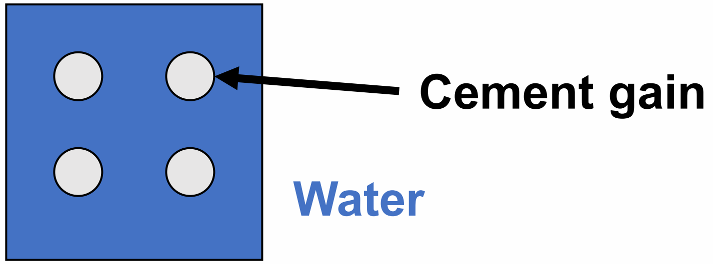
- Greater strengths
- Lower permeability
- Increased durability
- Less color variation
- Why?



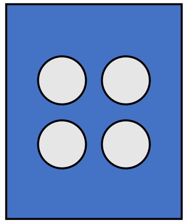
Water/Cementitious Ratio

The answer is in the volume relationship, not mass

$$\frac{\text{Water}}{\text{Cement}} \quad \frac{300\ \text{lbs}}{600\ \text{lbs}} = 0.50 \rightarrow \frac{4.81\ \text{ft}^3}{3.05\ \text{ft}^3}$$



$$\frac{240\ \text{lbs}}{600\ \text{lbs}} = 0.40 \rightarrow \frac{3.85\ \text{ft}^3}{3.05\ \text{ft}^3}$$



Control w/c ratio (this is critical!)

Aggregates

Aggregates

Purpose

- Make up the bulk of the mix (60-70% by volume)
- Often strongest part of the mix (e.g. 10 – 45 ksi)
- Typically, most economical part

Specs

- ASTM C33 - Normal Weight Aggregates – be familiar with the required tests
- ASTM C330 - Lightweight Aggregates
- ASTM C637 - Radiation Shielding Aggregates (Heavyweight – Hematite, steel shot, steel shavings)

Aggregates

Coarse (stone) and Fine (sand) Aggregate

- Angular
- Round
- Avoid flat or elongated particles
- Aggregates should be clean and free from deleterious substances

Gradation

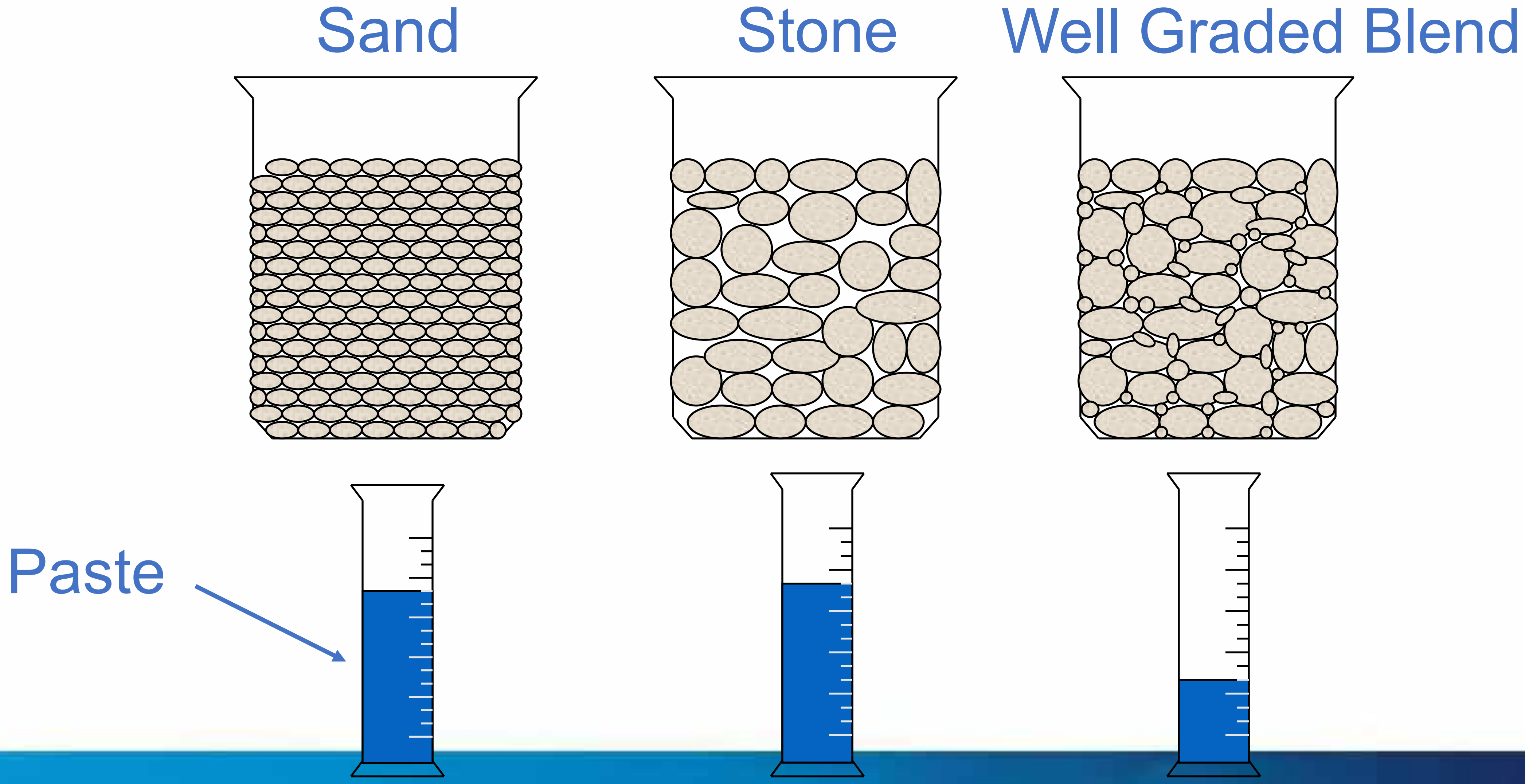
What is aggregate gradation?

- Distribution of particle sizes

Why do we want gradation of our aggregate?

- Well graded concrete aggregates will result in fewer voids between particles = less cement paste demand

Aggregate Gradation



Gradation – ASTM C-136

	Sieve Size	Metric Size	International
Nominal Agg. size	1-1/2"	38 mm	37.5 mm
	1"	25 mm	---
	3/4"	20 mm	19 mm
	1/2"	12.5 mm	---
	3/8"	10 mm	9.5 mm
Number of openings per In. in. (e.g. # 100 has 100x100)	#4	4.75 mm	4.75 mm
	#8	2.50 mm	2.36 mm
	#16	1.12 mm	1.18 mm
	#30	0.6 mm	0.6 mm
	#50	0.3 mm	0.3 mm
	#100	0.15 mm	0.15 mm
	#200	0.075 mm	0.075 mm

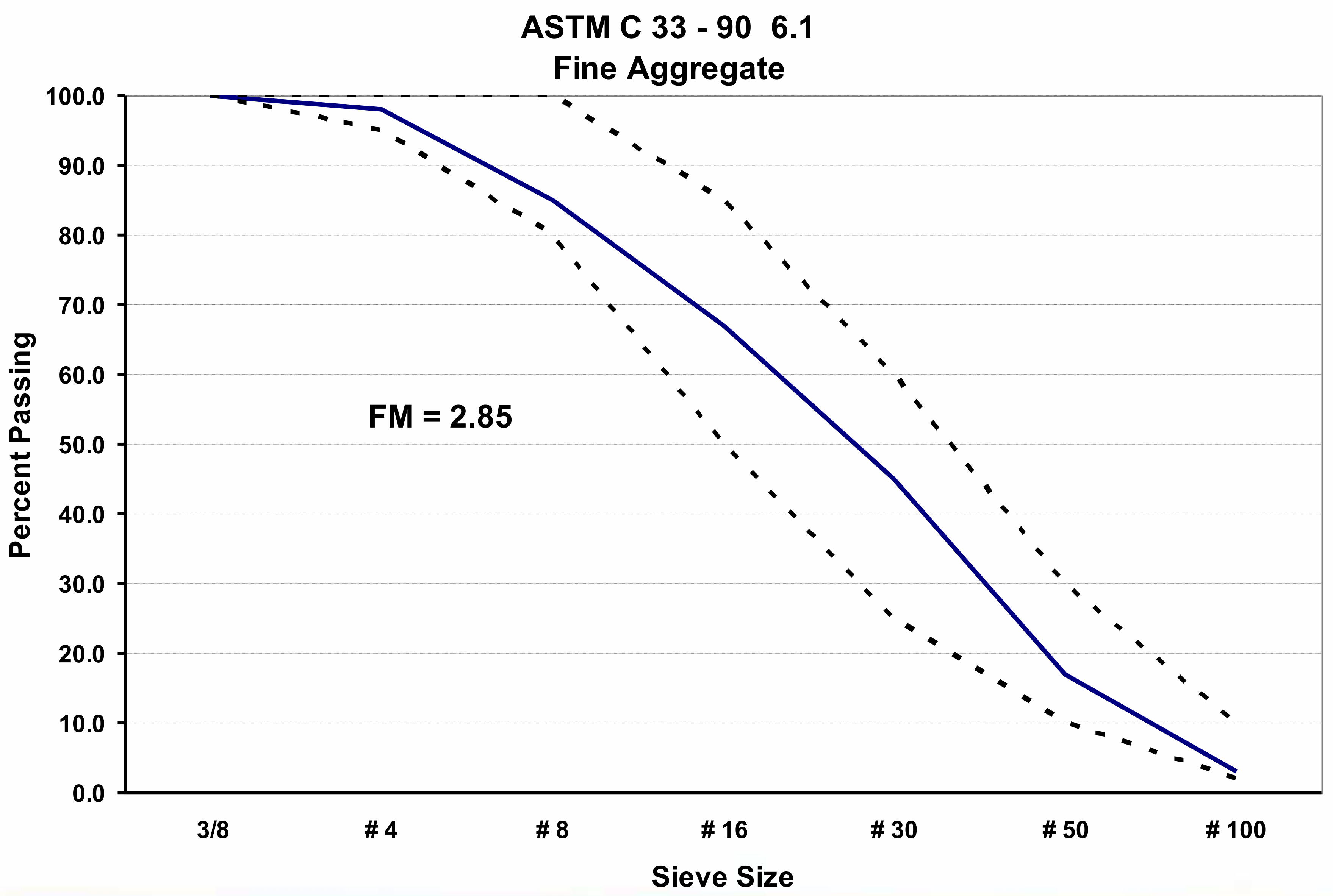
Not used in FM Calculation

Aggregate Screen Shakers

Fineness Modulus (FM)

- A single, index number roughly proportional to the average size of particles in a given aggregate, used to express the fineness or coarseness of an aggregate
- Sum of cumulative % retained on the standard sieves
- C33 specifies that FM of sand be between 2.3 and 3.1, Values can't differ by more than 0.2 for the same mix design
- The coarser the aggregate, the higher the FM
- Several different aggregate gradings can have the same FM

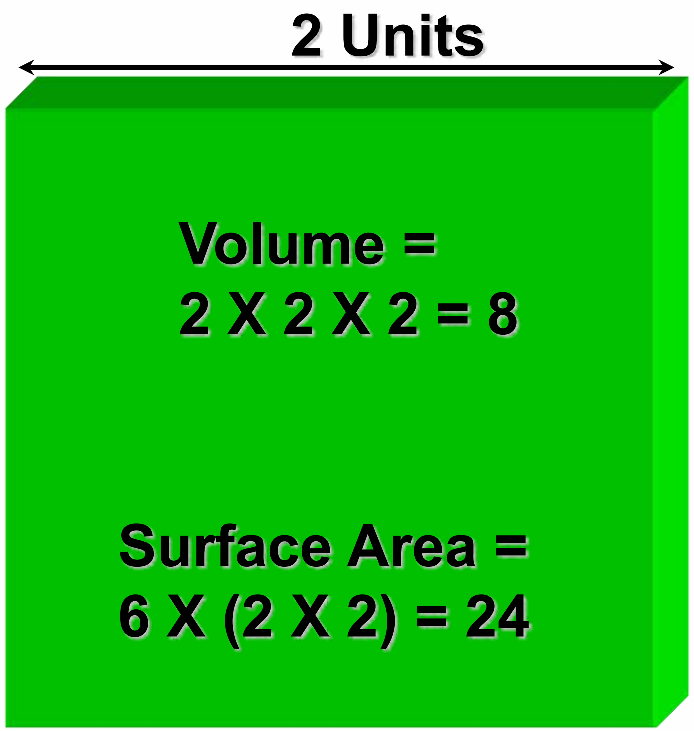
FM & Gradation are NOT the SAME

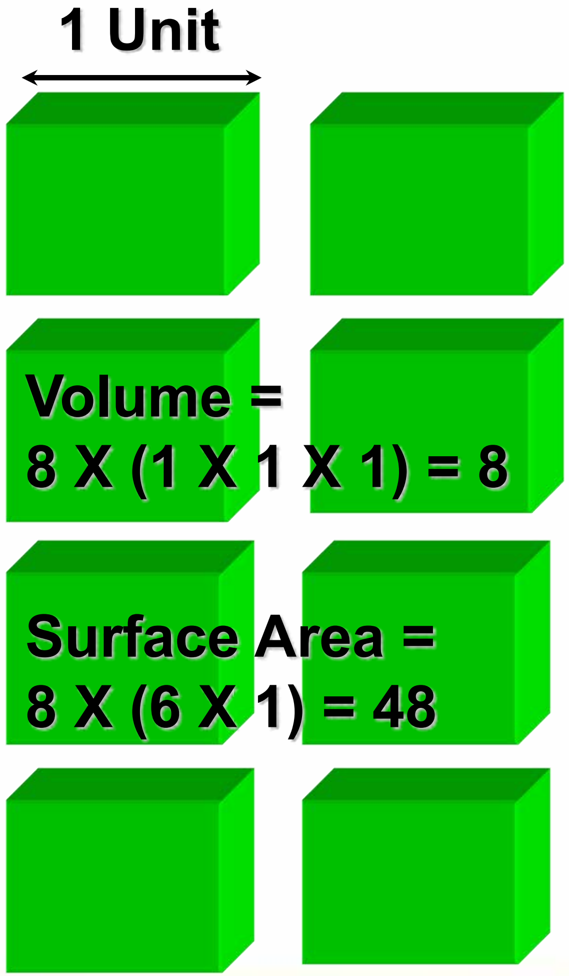

ASTM C 33 - 90 6.1
Fine Aggregate
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
Percent Passing
FM = 2.85
3/8
4
8
16
30
50
100
Sieve Size

Why Are Aggregates Critical to the Water Content of Concrete?

- Aggregates take up the largest amount of volume in concrete.
- Aggregate particle size, distribution, shape, and texture affect the amount of water needed in concrete.
- Therefore, more than any other material, aggregates have the greatest affect on the water needed for a given concrete workability (machine-ability)

Why Aggregates Effect Water Demand

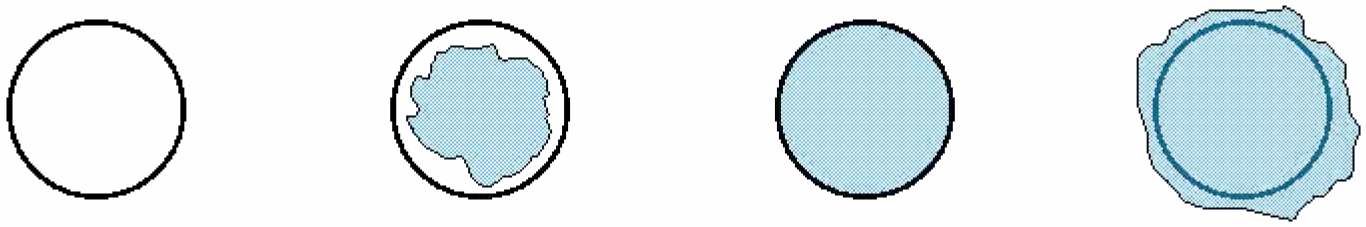




Small boxes have equal volume, but twice the surface area.

Moisture Contents of Aggregate

State	Ovendry (OD)	Air Dry	Saturated Surface Dry (SSD)	Damp or Wet



Total Moisture	None	Less than potential absorption	Equal to potential absorption	Greater than absorption

Adapted from PCA "Design and Control of Concrete Mixtures

Free Moisture Calculation for Batches

$$\text{Total Moisture} = \text{Free moisture} + \text{Aggregate absorbed moisture}$$

$$\%\ \text{Total Moisture Content} = \frac{(\text{Wet Wt} - \text{Dry Wt})}{\text{Dry Wt}} \times 100$$

Example:

Wet Wt = 1000 g

Dry Wt = 980 g

$$\frac{1000 - 980}{980} \times 100 = 2.4\%$$

Never include the weight of the pan!

$$\%\text{Free Moisture} = \text{Total Moisture} - \text{Absorbed Moisture}$$

Admixtures

Admixtures

Two types of admixtures

- Chemical admixtures - non-pozzolanic admixture in the form of a liquid, suspension, or water-soluble solid.

- Mineral admixtures – (supplementary cementing materials, SCMs), contributes to the plastic and hardened properties of the concrete through hydraulic or pozzolanic reaction or both in the presence of water and cement

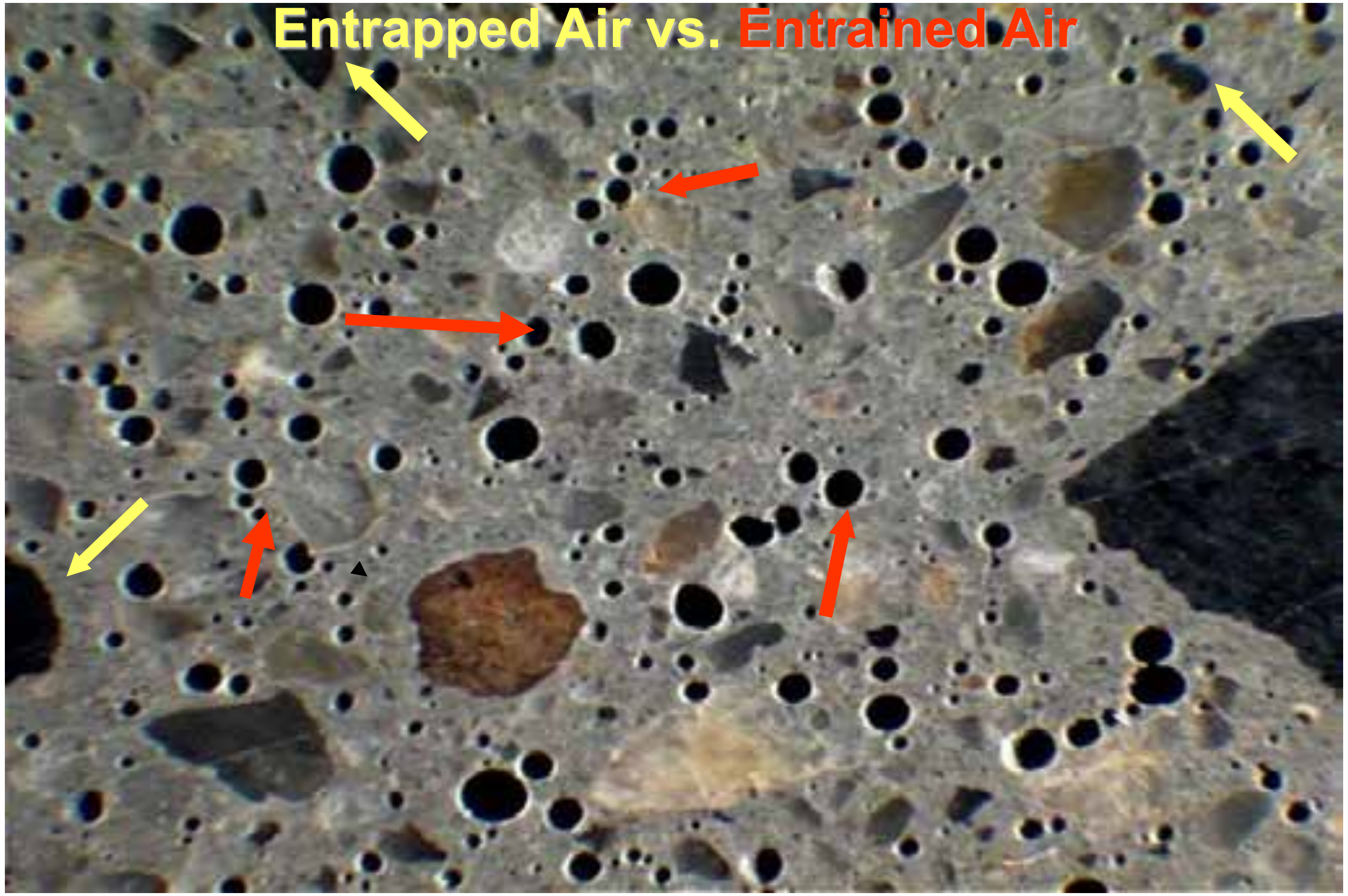
Admixtures

- Air-entraining admixtures
- Water-reducing admixtures (plasticizers)
- Set-controlling admixtures
- Specialty admixtures
- SCMs

Air Entrainment

- **All Concrete has air in it**
  - Entrapped air
  - Entrained air

- **Avg yd^3 of concrete contains 600 billion bubbles.**



Admixtures

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- SCMs

Admixtures

- Air-entraining admixtures
- Water-reducing admixtures (plasticizers)
- Set-controlling admixtures
- Specialty admixtures
- SCMs
  - Pozzolans: Class F Fly Ash, Silica Fume, Metakaolin
  - Hydraulic: Class C fly Ash, Granulated Blast Furnace Slag

SCMs

TABLES 1 AND 2: The following tables present a broad generalization on the use of common supplementary cementitious materials and the effects they have on both the fresh and hardened properties of concrete. (adapted from PCA CD: Supplementary Cementing Materials)

TABLE 1: Fresh Properties

	FLY ASH				NATURAL POZZOLANS		
	Class F	Class C	Slag	Silica Fume	Shale	Clay	Metakaolin
Water Demand	↓↓	↓↓	↓	↑↑	↔	↔	↑
Workability	↑	↑	↑	↓↓	↑	↑	↓
Bleeding	↓	↓	↕	↓↓	↔	↔	↓
Setting Time	↑	↕	↑	↔	↑	↑	↔
Air Entrainment Dosage	↑↑	↑	↔	↑↑	↔	↔	↑
Heat of Hydration	↓	↕	↓	↔	↓	↓	↓

TABLE 2: Hardened Properties

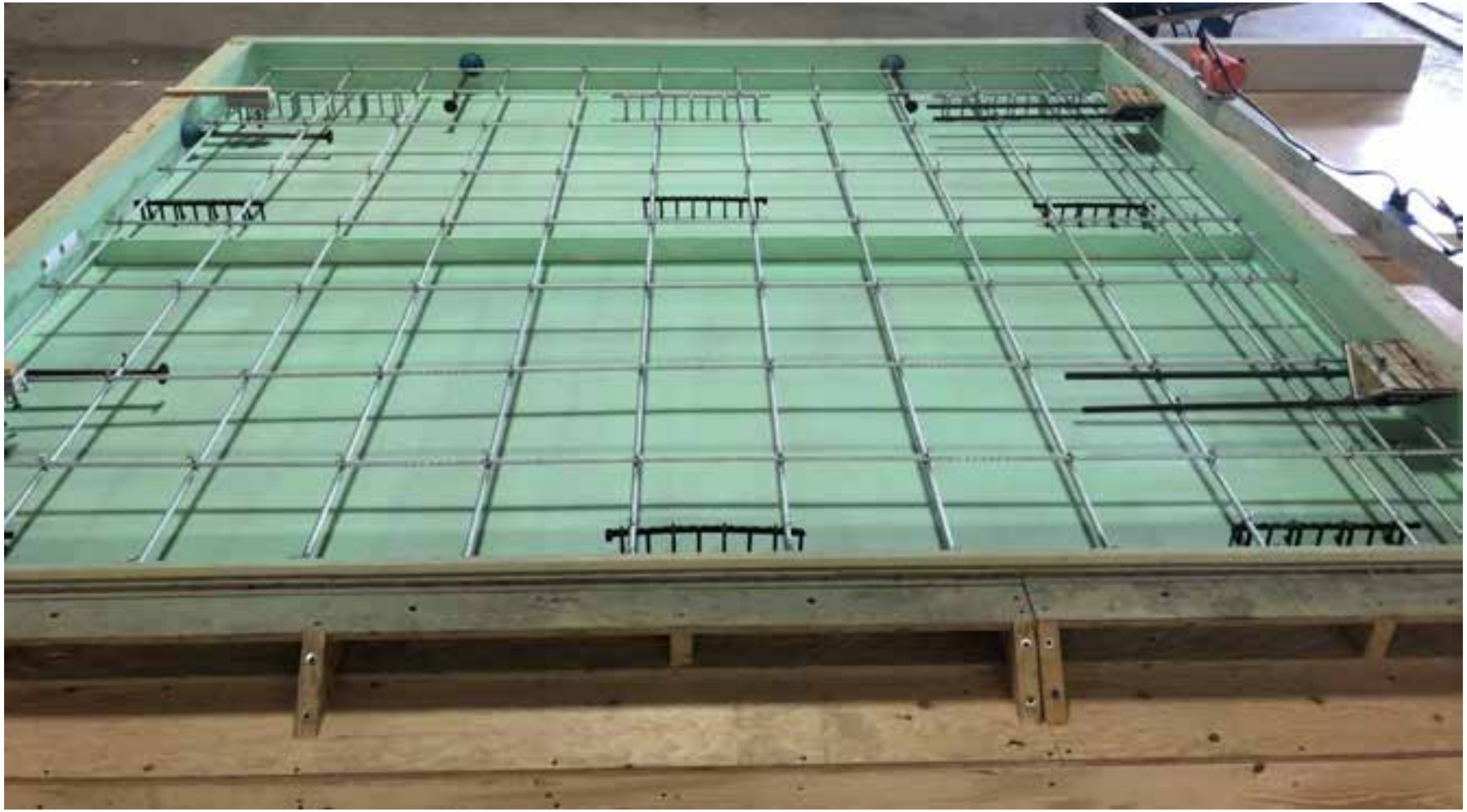
	FLY ASH				NATURAL POZZOLANS		
	Class F	Class C	Slag	Silica Fume	Shale	Clay	Metakaolin
Early Age Strength Gain	↓↓	↔	↕	↑↑	↓	↓	↑↑
Long-Term Strength Gain	↑	↑	↑	↑↑	↑	↑	↑↑
Permeability	↓	↓	↓	↓↓	↓	↓	↓↓
Chloride Ingress	↓	↓	↓	↓↓	↓	↓	↓↓
ASR	↓↓	↓	↓↓	↓	↓	↓	↓
Sulfate Resistance	↑↑	↑	↑↑	↑	↑	↑	↑
Freeze-Thaw	↔	↔	↔	↔	↔	↔	↔

↔ = effects may vary ↕ = effects may increase or decrease depending on material properties ↓ = decrease ↑ = increase

Producing Precast Concrete

Forms & Molds

Timber



Polymer / Polystyrene

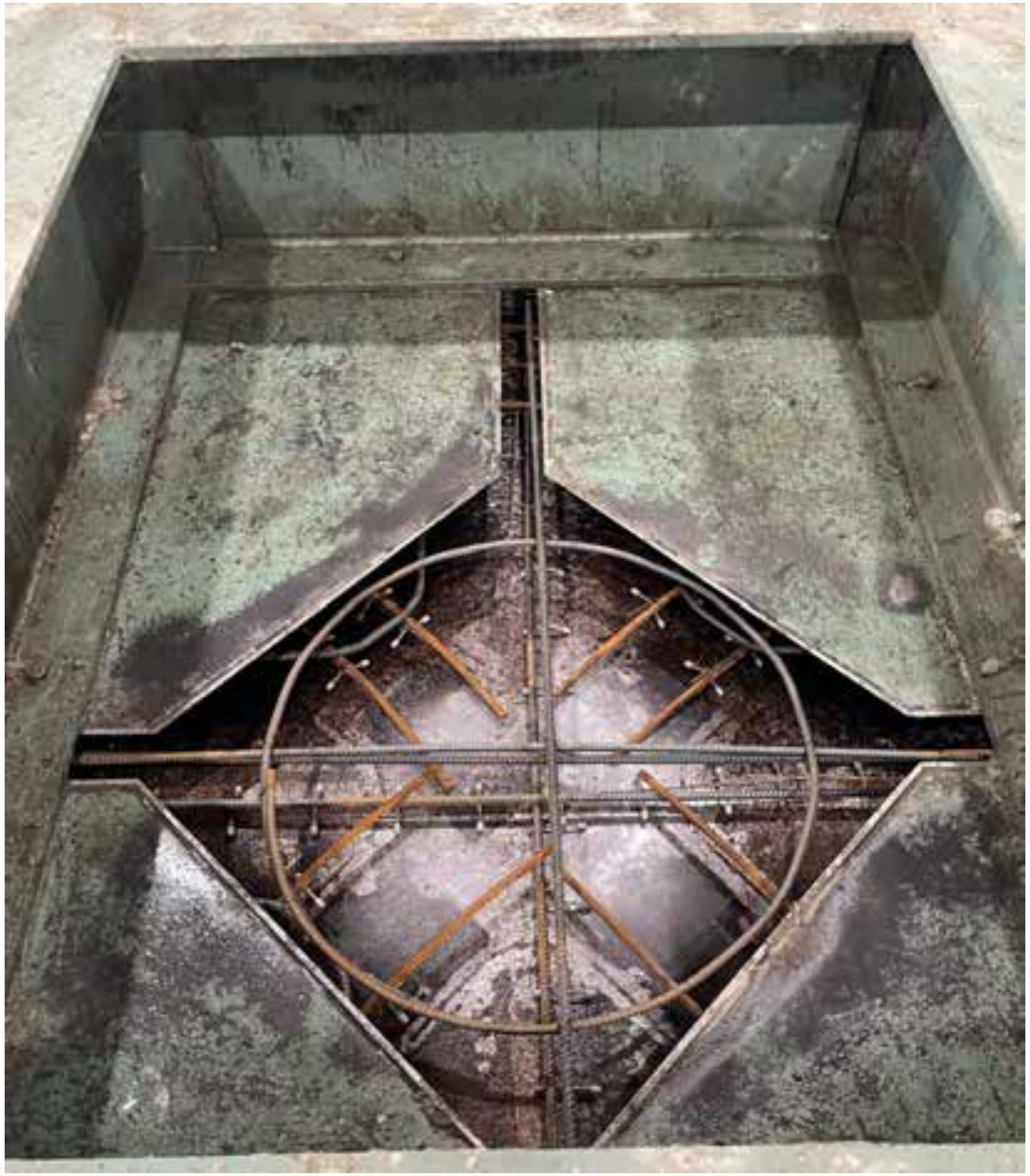
Dry Cast

Dry Cast

Wet Cast

Geometry

Geometry



Cleaning

Leakage

Release Agent

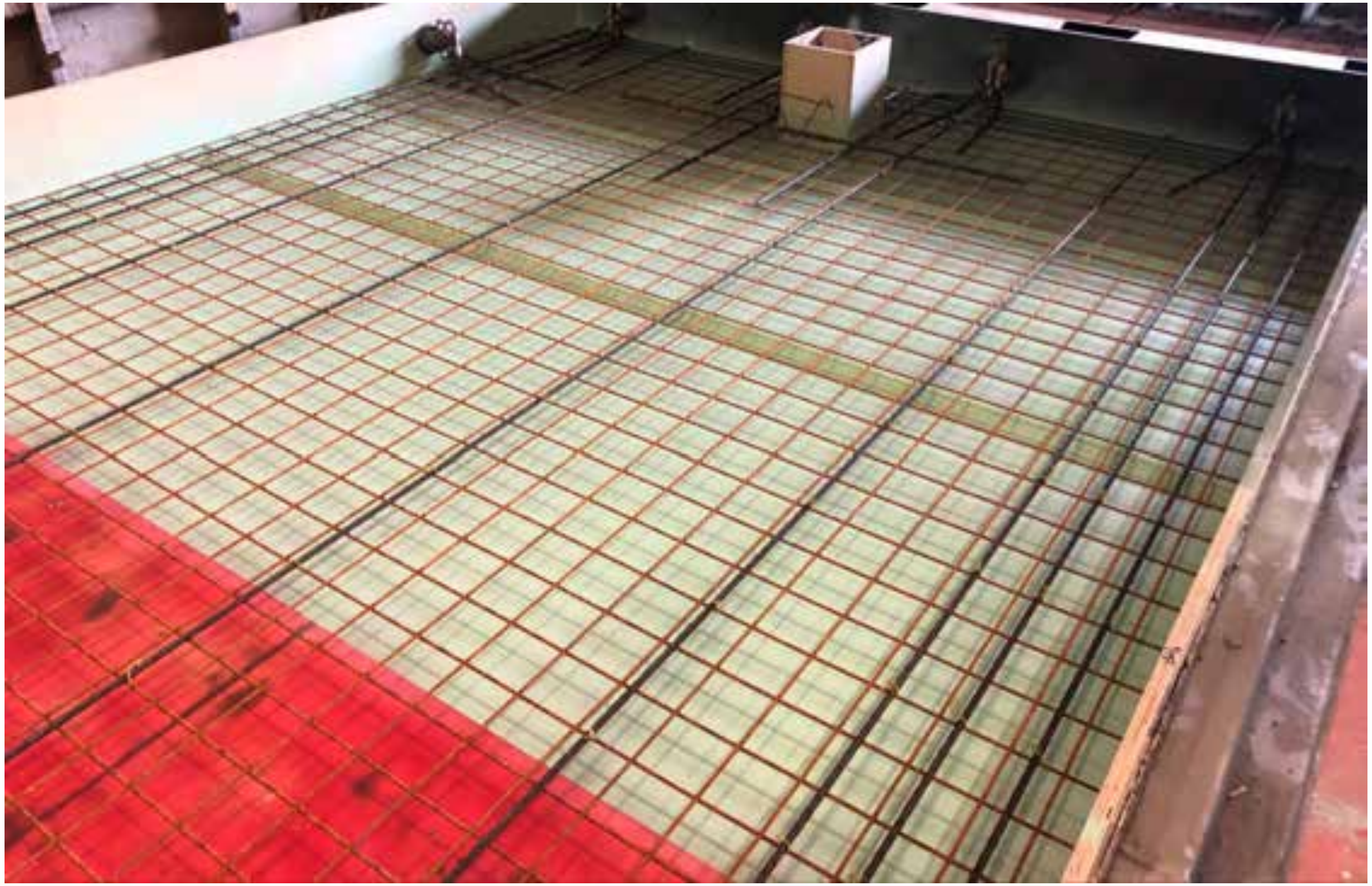
Release Agent

Release Agent

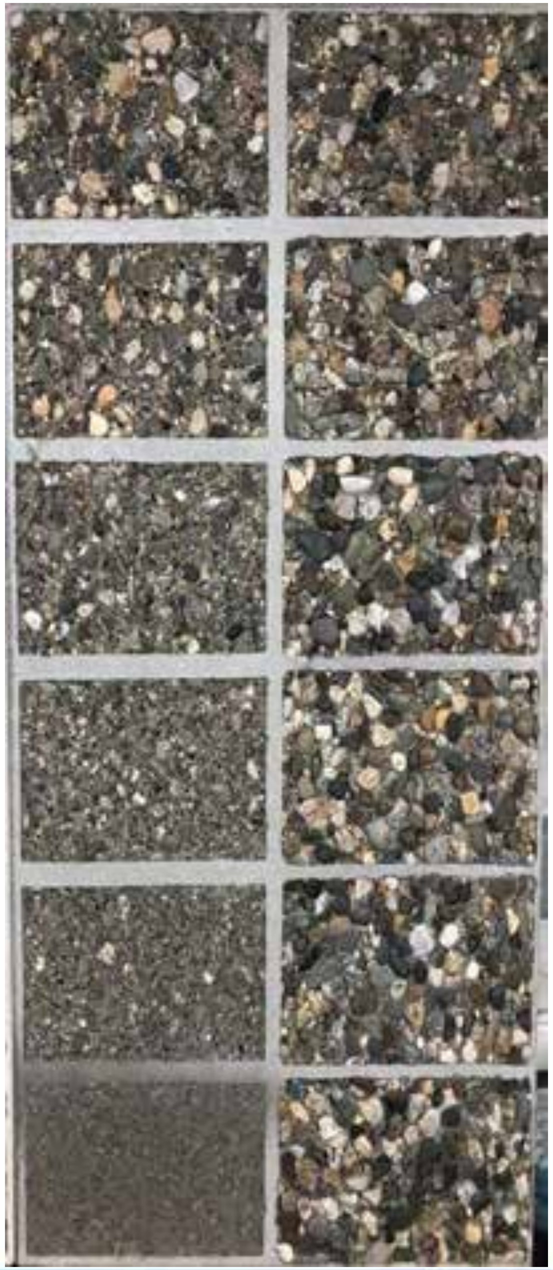
Reinforcement

Liners

Architectural Finishes



Architectural Finishes



Architectural Finishes

Architectural Finishes

Batching & Mixing

Batch Plants

- Horizontal:

Aggregates are held in bins below the central mixer; conveyed or hoisted during the batch cycle

- Vertical:

Aggregates are conveyed to bins that are above the central mixer; gravity to move material downward to scale and mixer

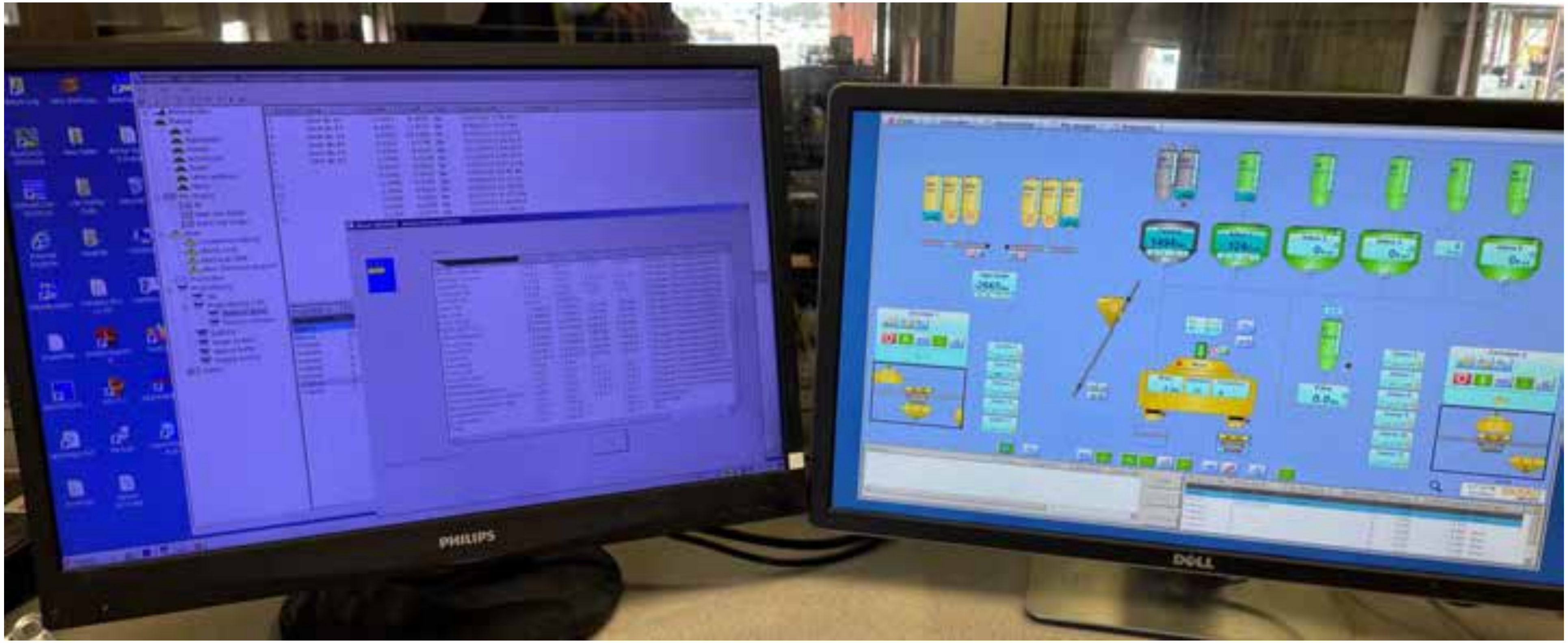
Aggregates

Aggregates

Aggregates

Powders

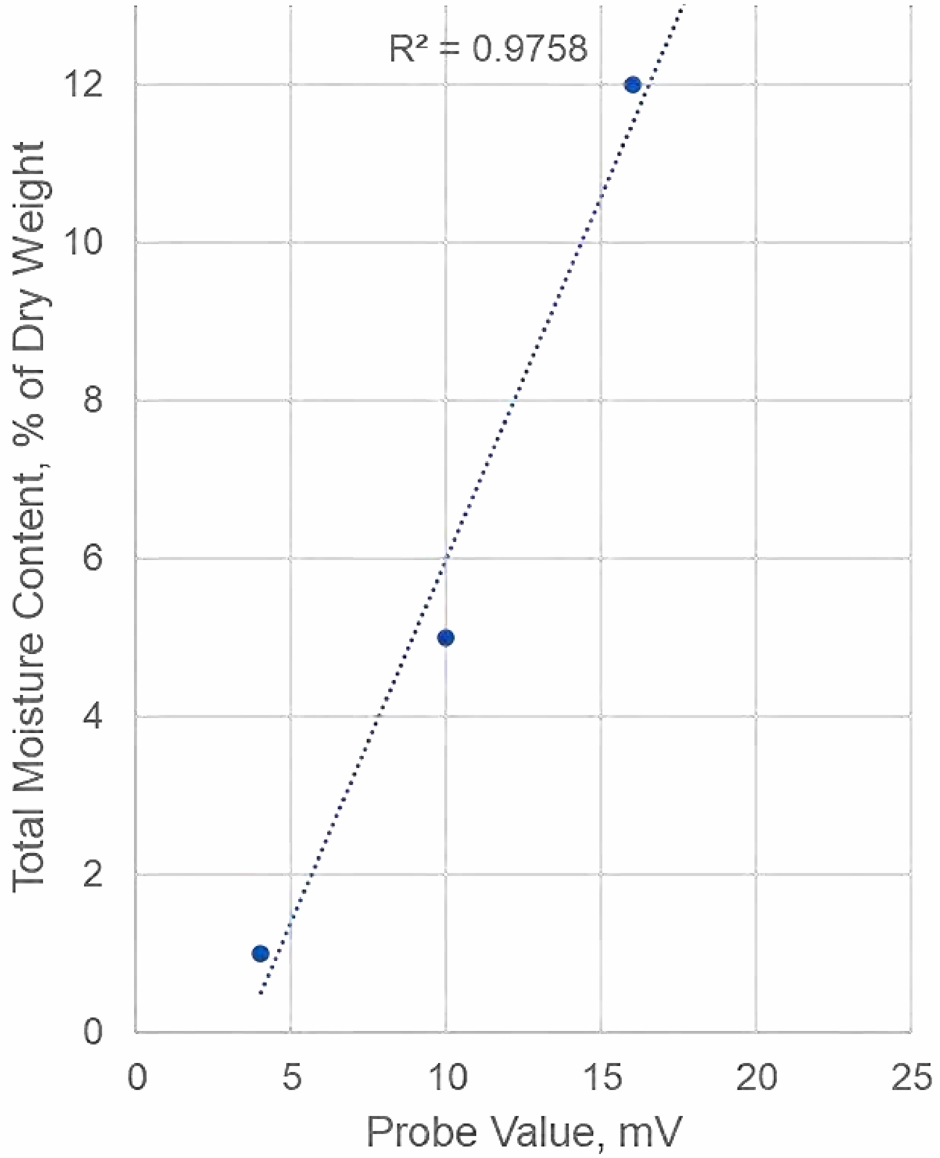
Software



Sensors

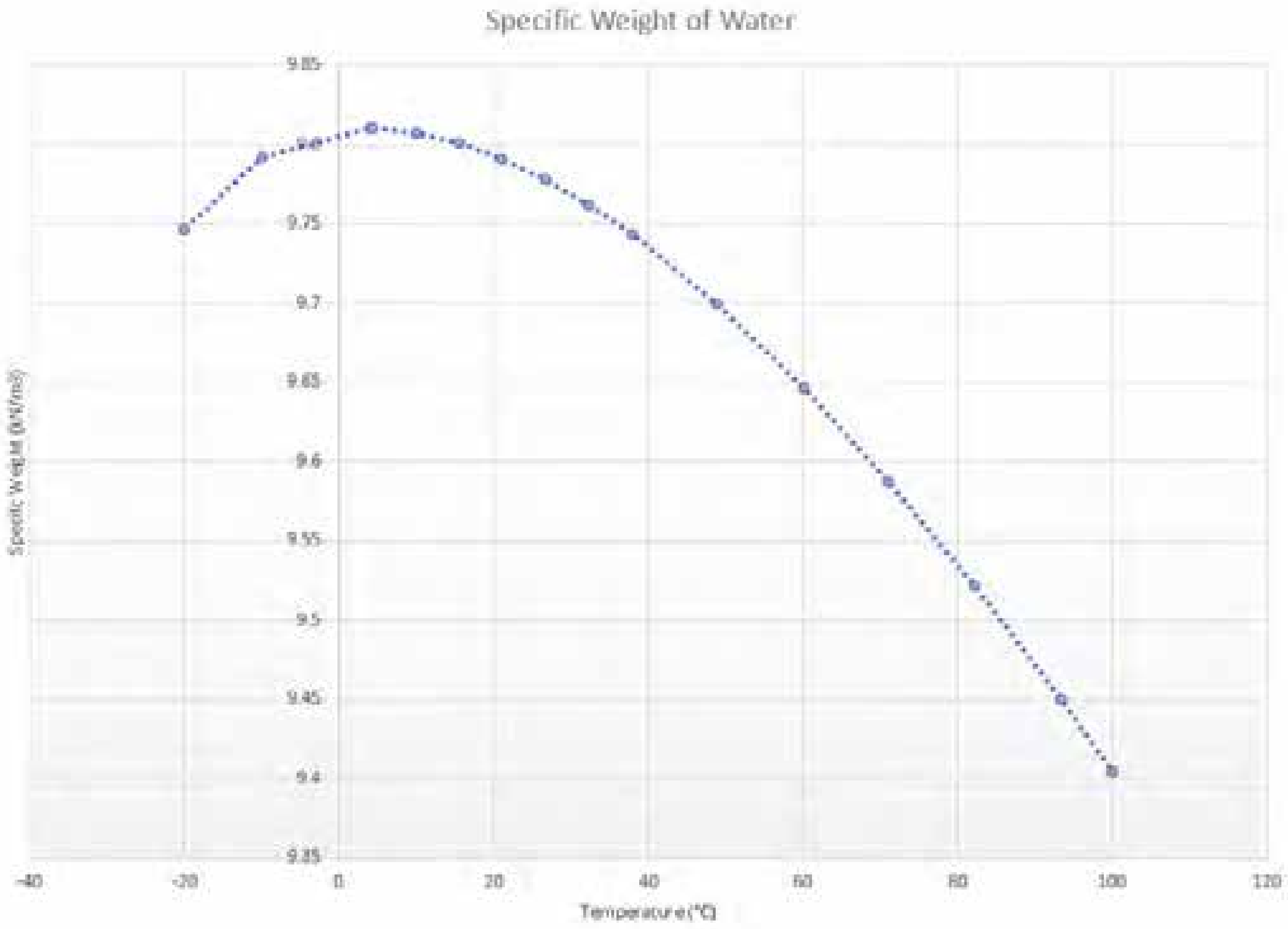
Moisture Control

Batch size	Measured value 1	Water content 1	Measured value 2	Water content 2
0.01 - 0.50	33.05	59.77	49.44	152.77
0.51 - 0.60	0.00	0.00	0.00	0.00
0.61 - 0.70	0.00	0.00	0.00	0.00
0.71 - 0.80	0.00	0.00	0.00	0.00
0.81 - 0.90	0.00	0.00	0.00	0.00
0.91 - 1.00	34.77	95.00	60.88	280.00
1.01 - 1.10	35.50	103.33	61.96	307.08
1.11 - 1.20	36.23	111.67	63.04	334.17
1.21 - 1.30	36.97	120.00	64.12	361.25
1.31 - 1.40	38.10	142.50	65.74	402.00
1.41 - 1.50	39.18	165.00	67.36	442.50
1.51 - 1.60	39.91	176.00	68.44	469.70
1.61 - 1.70	40.65	187.00	69.52	496.83
1.71 - 1.80	41.38	198.00	70.60	524.00
1.81 - 1.90	42.48	214.00	72.22	565.00
1.91 - 2.00	43.58	230.00	73.84	605.00



THE PRECAST SHOW

Water

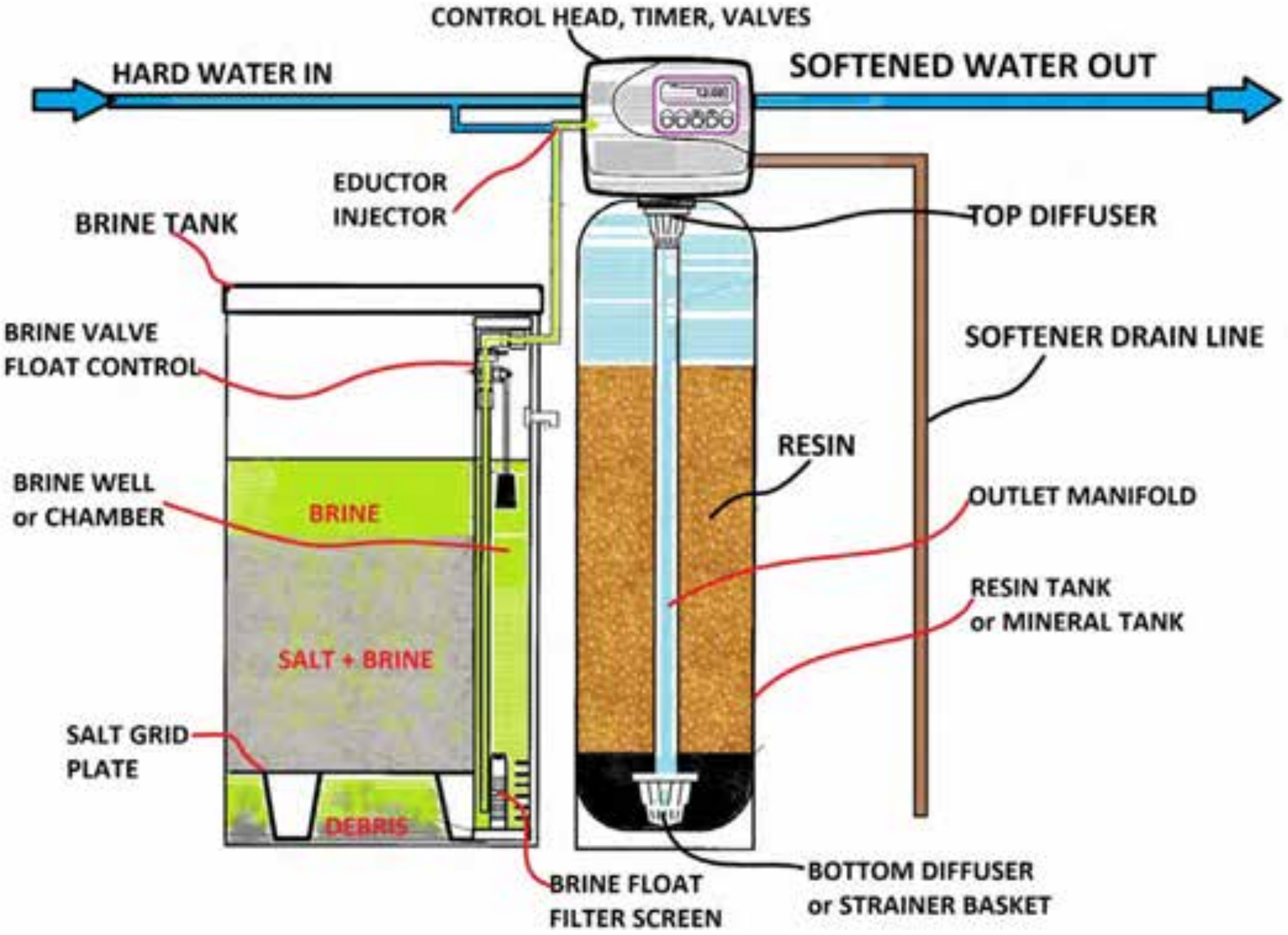


Specific Weight of Water
Specific Weight (kN/m3)
Temperature (°C)
9.85
9.75
9.7
9.65
9.6
9.55
9.5
9.45
9.4
9.35
-40
-20
0
20
40
60
80
100
120

PLEASE KEEP
WATER VALVES
WHERE THEY
ARE SET!
UNLESS
OTHERWISE
INSTRUCTED

Water


Soft water
Hard water


CONTROL HEAD, TIMER, VALVES
HARD WATER IN
SOFTENED WATER OUT
EDUCTOR
INJECTOR
BRINE TANK
TOP DIFFUSER
BRINE VALVE
FLOAT CONTROL
SOFTENER DRAIN LINE
RESIN
BRINE WELL
or CHAMBER
BRINE
OUTLET MANIFOLD
RESIN TANK
or MINERAL TANK
SALT + BRINE
SALT GRID
PLATE
DEBRIS
BRINE FLOAT
FILTER SCREEN
BOTTOM DIFFUSER
or STRAINER BASKET

Pigment

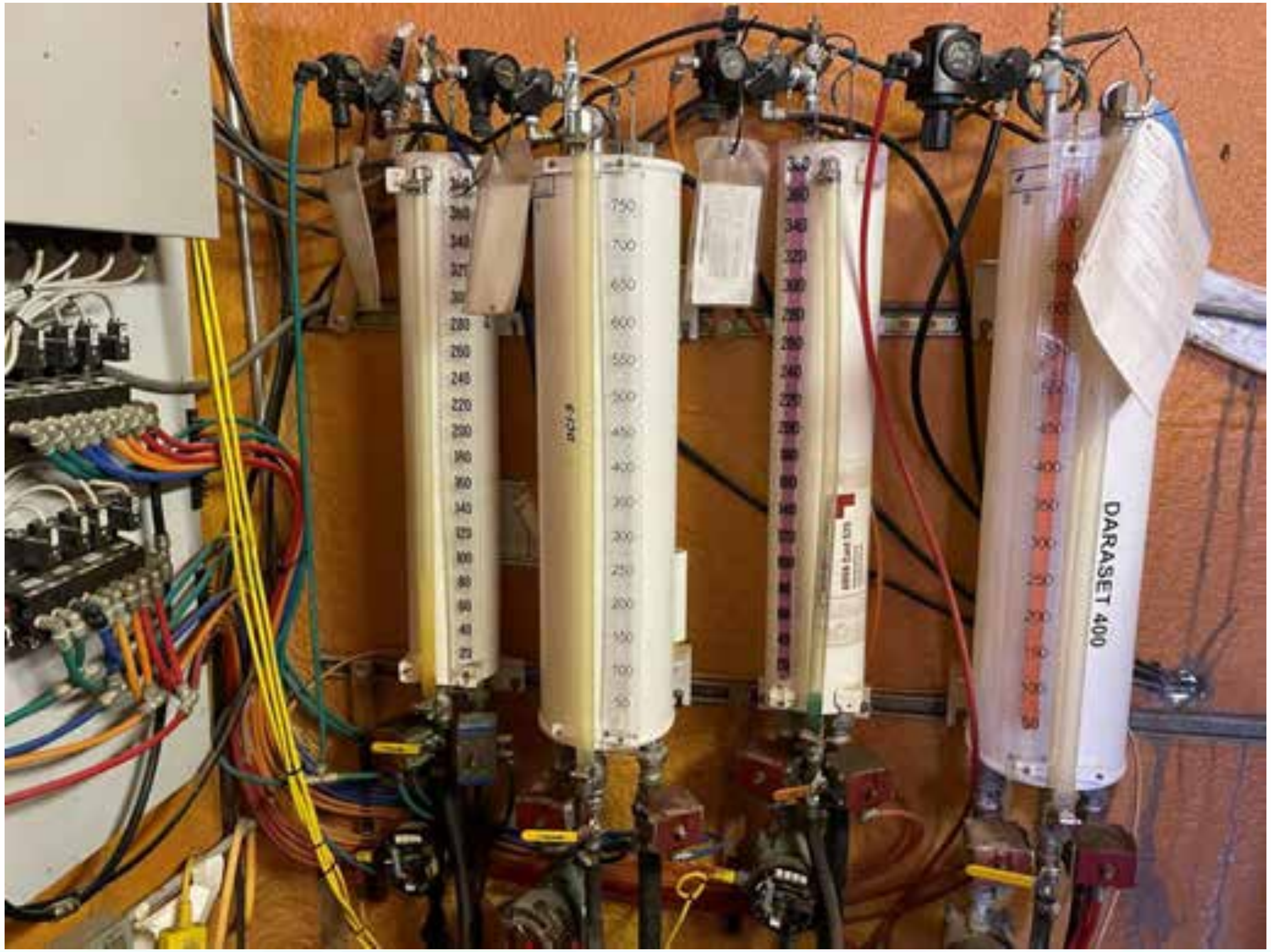
- Liquid

- Granular

Fibers

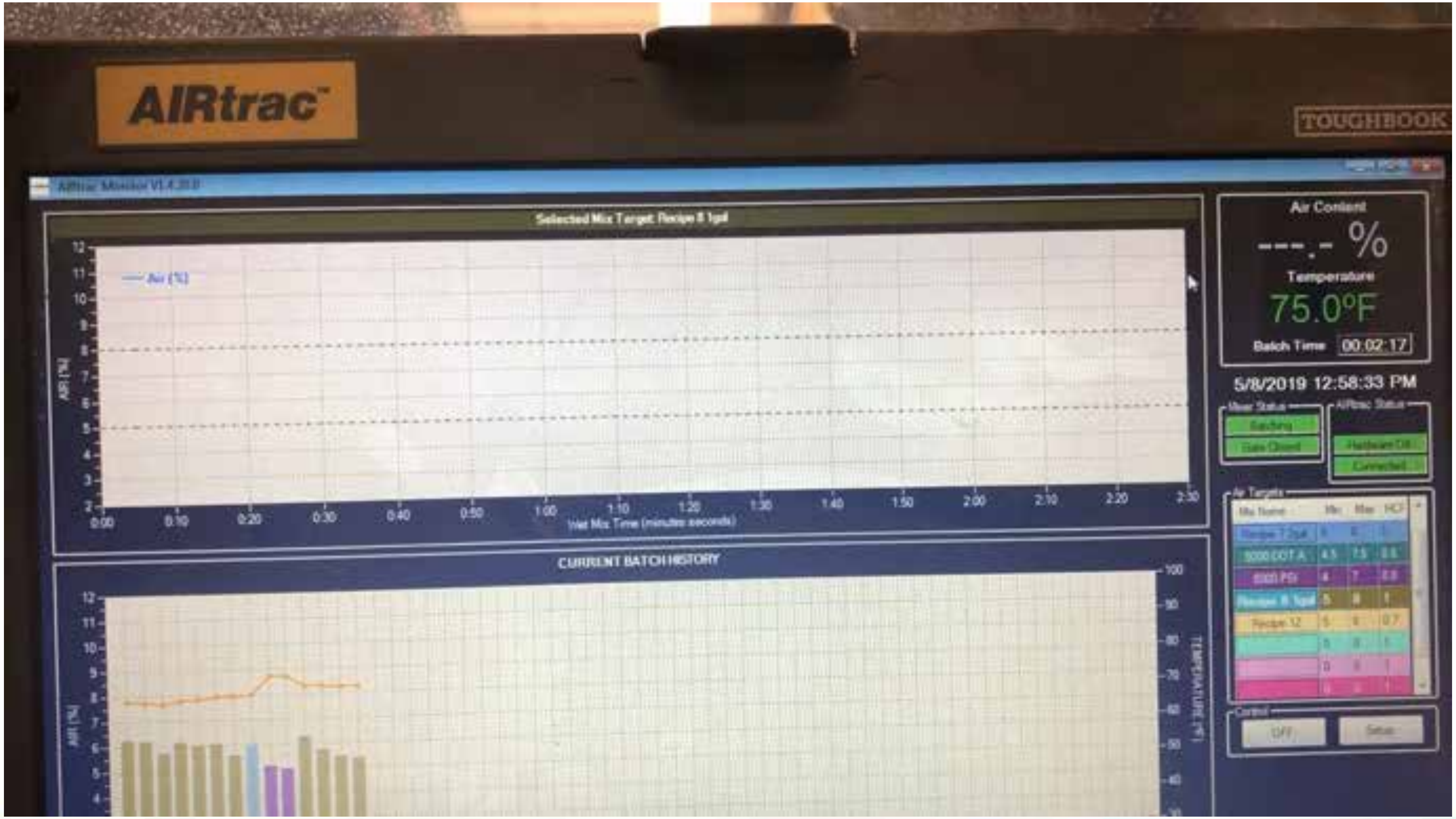
Fibers

Admixture



Admixtures

Mixers


AIRtrac
TOUGHBOOK
Selected Mix Target: Recipe 8 1gal
Air Content
---.- %
Temperature
75.0°F
Batch Time 00:02:17
5/8/2019 12:58:33 PM
Wet Mix Time (minutes:seconds)
CURRENT BATCH HISTORY
AIR (%)
TEMPERATURE (°F)

Mixers

Mixers

Mixers

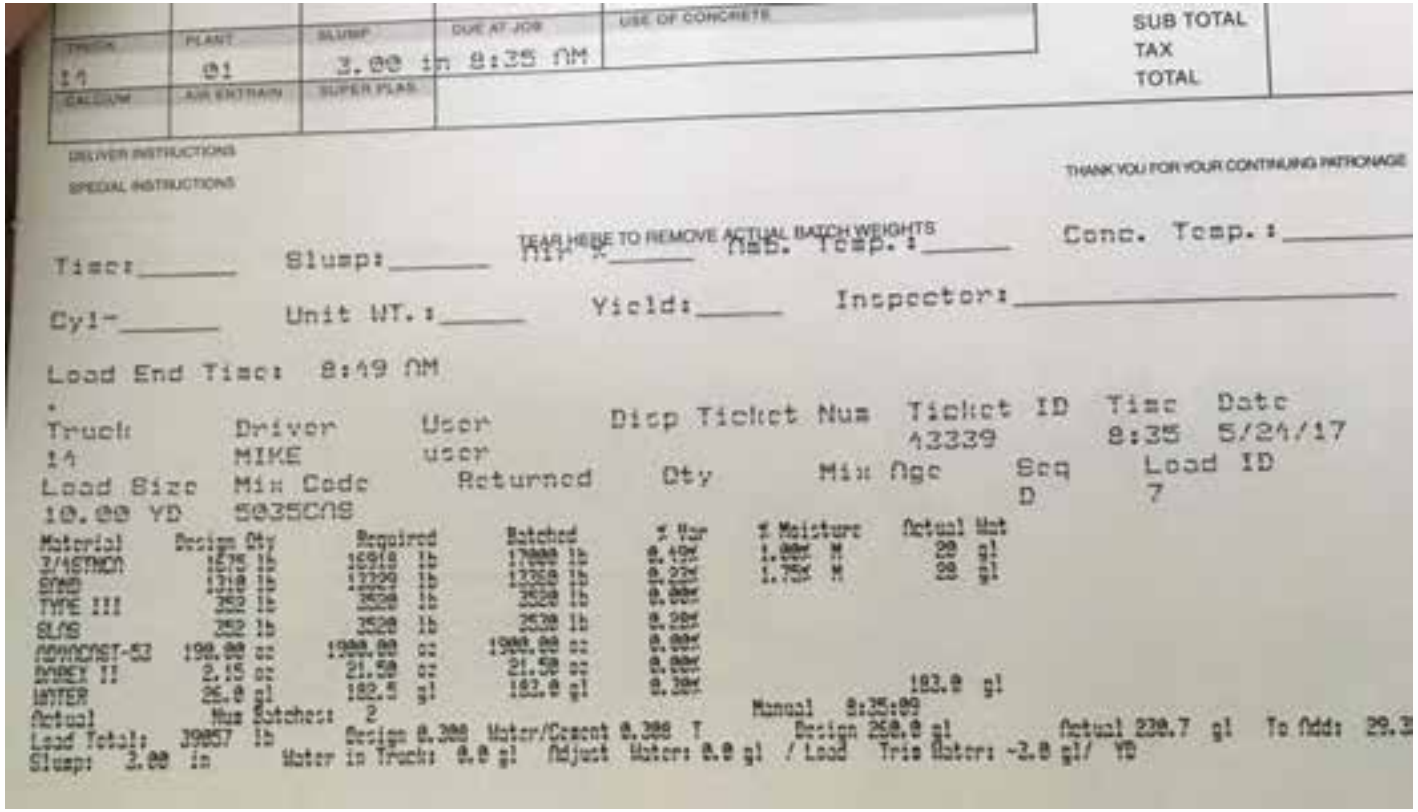
Sequencing

Aggregate
Fibre
Cement
Admix 1
Admix 2
Admix 3
Admix 4
Admix 5
Water
Hydromix
Consistens
Mixing time
Final mixing time

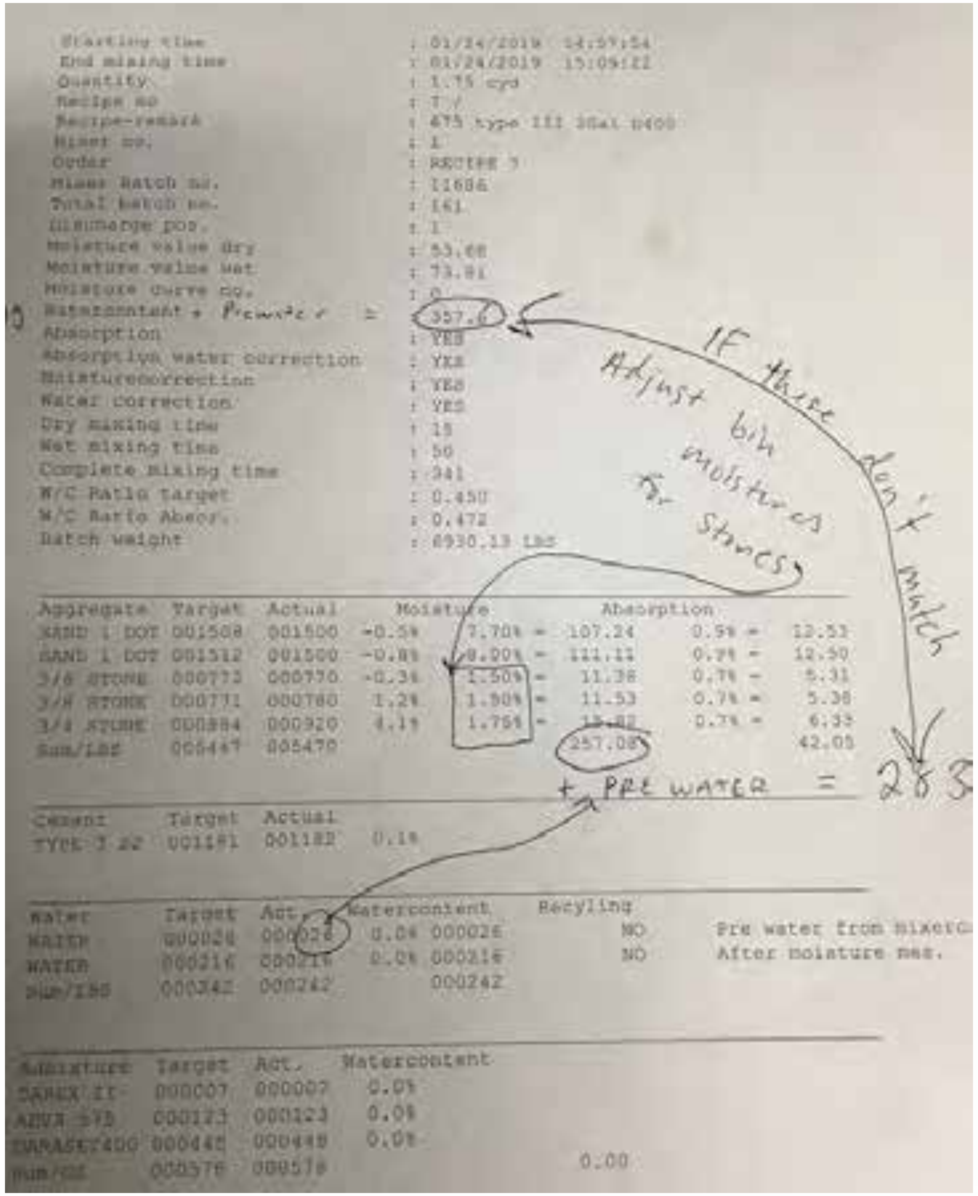
Cycle Time


Concrete Mix Quality & Production Data
View Details
Concrete Mix Quality
93.17%
4.78%
0.61%
75.65°F
Concrete Mix Production
6:38
2:43
5:00
4:12
9.05
454
-0.72%

Tickets

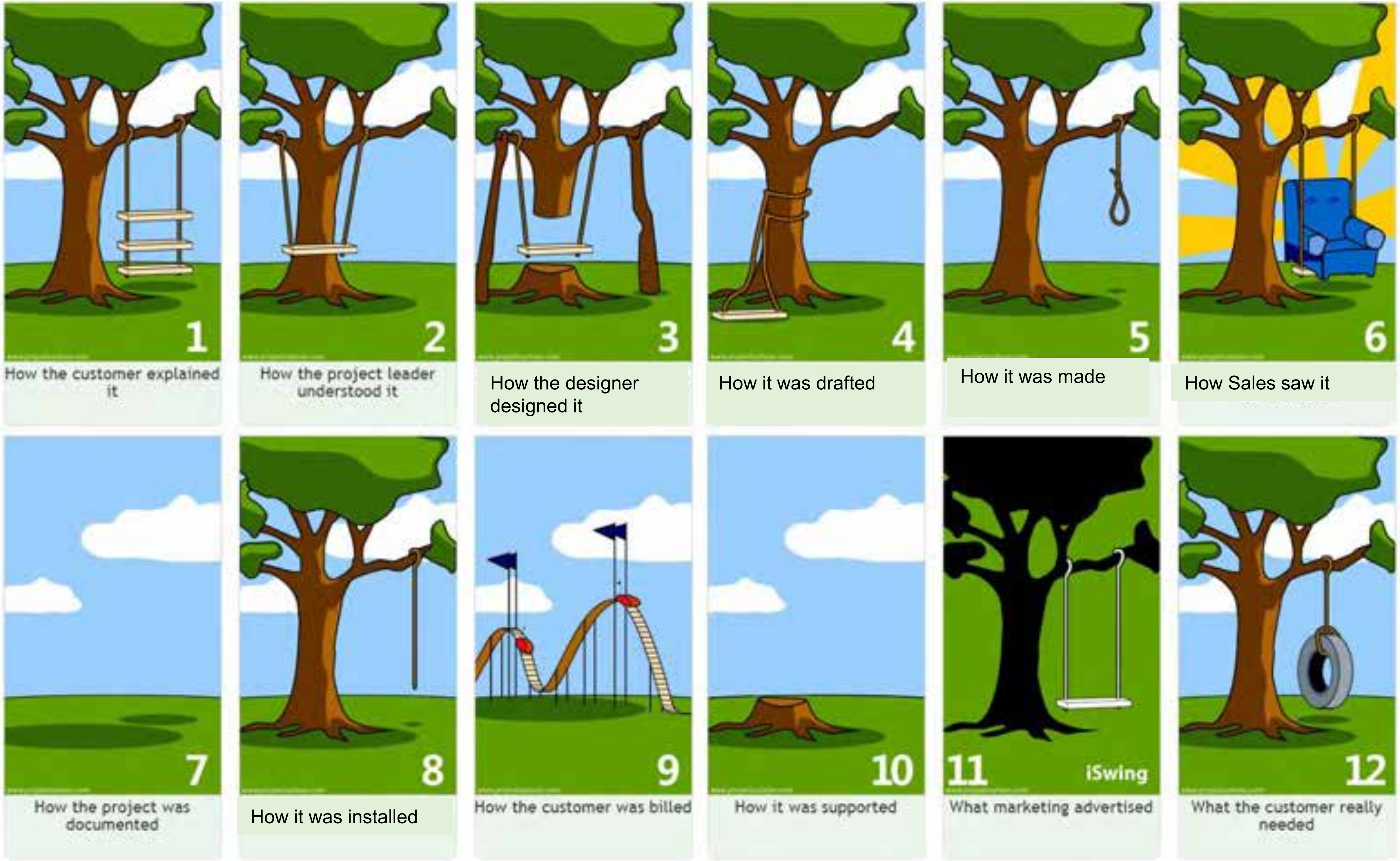


SUB TOTAL
TAX
TOTAL
THANK YOU FOR YOUR CONTINUING PATRONAGE
TEAR HERE TO REMOVE ACTUAL BATCH WEIGHTS
Time:
Slump:
Conc. Temp.:
Cyl-
Unit WT.:
Yield:
Inspector:
Load End Time: 8:49 AM
Truck 14
Driver MIKE
User user
Disp Ticket Num
Ticket ID 43339
Time 8:35
Date 5/24/17
Load Size 10.00 YD
Mix Code
Returned
Qty
Mix Age
Seq D
Load ID 7



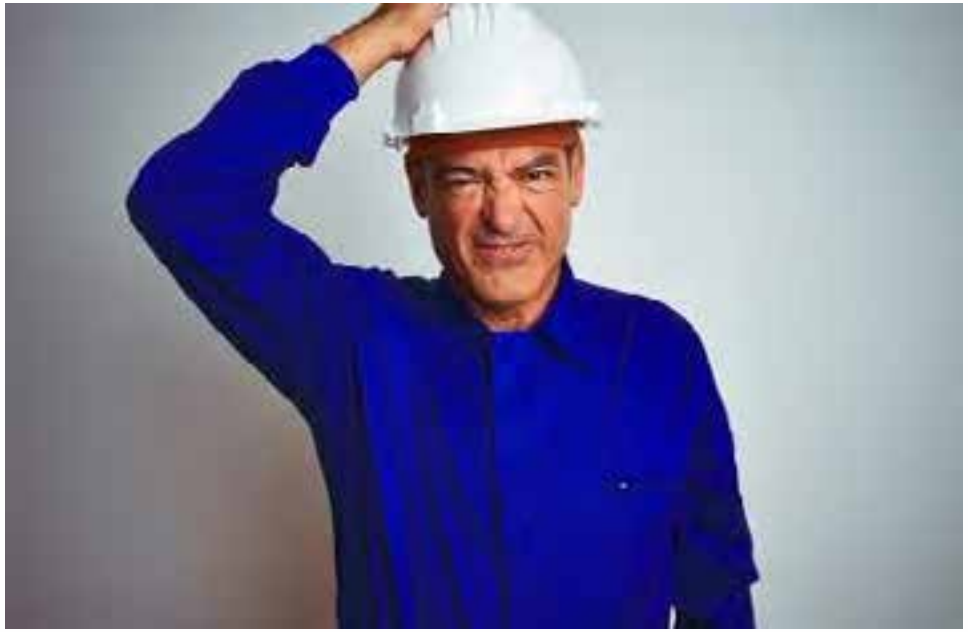
IF these don't match
Adjust bin moistures for stones
+ PRE WATER = 283
Aggregate Target Actual Moisture Absorption
Cement Target Actual
Water Target Act. Watercontent Recycling
Pre water from mixer
After moisture mea.

Transporting


1
How the customer explained it
2
How the project leader understood it
3
How the designer designed it
4
How it was drafted
5
How it was made
6
How Sales saw it
7
How the project was documented
8
How it was installed
9
How the customer was billed
10
How it was supported
11
iSwing
What marketing advertised
12
What the customer really needed

Transporting Concrete

You have just mixed perfect concrete , and now you need it to get delivered to your forms



Transporting Concrete

Batch Plant

Bucket

Pros:

- Lift height limit based on crane
- Controlled discharge
- Easy to position

Cons:

- 1-2 yds
- No blending or altering
- Higher segmentation potential

Tucker

Pros:

- Deliver uphill, higher reach
- Controlled discharge
- 4-6 yrds

Cons:

- Small loads
- No blending or altering
- Some segregation potential

RMX Truck

Pros:

- Blend multiple batches
- Make adjustments to mix
- 10 yds

Cons:

- Plastic properties can change
- Truck and driver dependent
- Maintenance often neglected

Some Suggestions

Bucket

- Concrete must meet spec before dumping
- Do not drive over bumps, rough roads
- Keep gate, seals, and controls clean and functioning well

Tucker

- Concrete must meet spec before dumping
- Develop SOPs for drivers
- Have inspection schedule and proactive maintenance plan

RMX Truck

- Develop SOPs for drivers
  - Rotation speed for transit (3-6 RPM)
  - If additions are made required rotations and speed
- Determine condition assessment for each truck, and adjust SOP accordingly
- Have inspection schedule and proactive maintenance plan

Casting and Consolidation

Concrete Placement

What are trying to accomplish?

Place the concrete in a way that it is:

- Uniform (does not segregate)
- Ensure that all reinforcement is completely encapsulated, and all cover requirements are met
- Provides a good finish and appearance in alignment with customer expectations

Placement Concrete - Guidelines

- Keep drop height minimized

Placing Concrete - Guidelines

- Keep drop height minimized
- Pour from one side of the form and let the concrete flow
- Place concrete on top of concrete
  - Create a flowing front

Placing Concrete - Guidelines

- Keep drop height minimized
- Pour from one side of the form and let the concrete flow
- Place concrete on top of concrete
  - Create a flowing front
- If raking is needed, do not rake over the top

Placing Concrete - Guidelines

Architectural

- Cast face mix in one placement – do not use leftover in next form

Tonight's Winning Lottery Numbers

2 30 8 26 45 33

Placing Concrete - Guidelines

Architectural

- Cast face mix in one placement – do not use leftover in next form
- Do not join two pours – pour one direction
- Do not walk on freshly placed concrete

Placing Concrete - 1

Placing Concrete - 2

Placing Concrete - 3

Placing Concrete - 4

What is Consolidation?

Process that evens the distribution of all ingredients in a mix, and removes unwanted air

Why Consolidate?

- **Freshly placed wet cast concrete can contain as much as 20% entrapped air**
- **Proper consolidation increases density by driving out entrapped air and helps ensure concrete uniformity around steel, hardware, etc.**
- **Results in:**
  - Optimum strength
  - Improved Durability
  - Improved finish and appearance
  - Watertightness
  - Encapsulated steel and helps ensure bond

Methods of Consolidation

- **Compaction**

Methods of Consolidation

- **Compaction**
- **Vibration**
  - Vibration – reduces the yield stress making the concrete fluid therefore allowing air to rise and particles to move closer together.
    - Internal Vibration – applied within the concrete
    - External Vibration – applied to the formwork or concrete surface

Frequency and Amplitude

Frequency

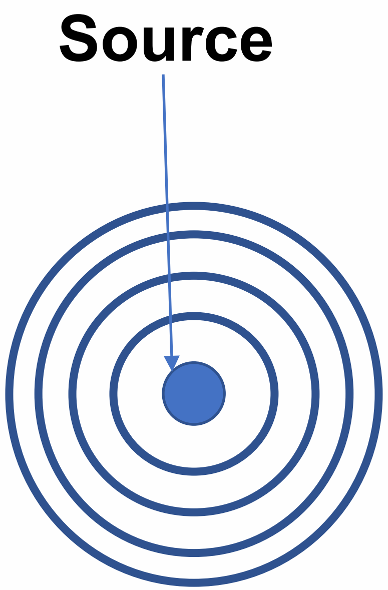
- Number of vibration cycles per minute
- Expressed as rpm or vpm
- Speed

Amplitude

- Maximum distance a point on the vibrator head moves from its position of rest
- Shake or Impact

Both are necessary for proper consolidation

Frequency and Amplitude



Frequency = number of waves per minutes

Note: frequency will be reduced about 20-25% when immersed in concrete

Amplitude = (magnitude of the wave – how far it influences

Amplitude & Frequency

Amplitude	Frequency
Effects Heavier Mass	Effects Lighter Mass
Moves the Aggregate	Moves Sand & Slurry around Aggregate
Determines Radius of Action	Governs Liquefication

Architectural Precast: Med to deep - exposures **Light - exposures**

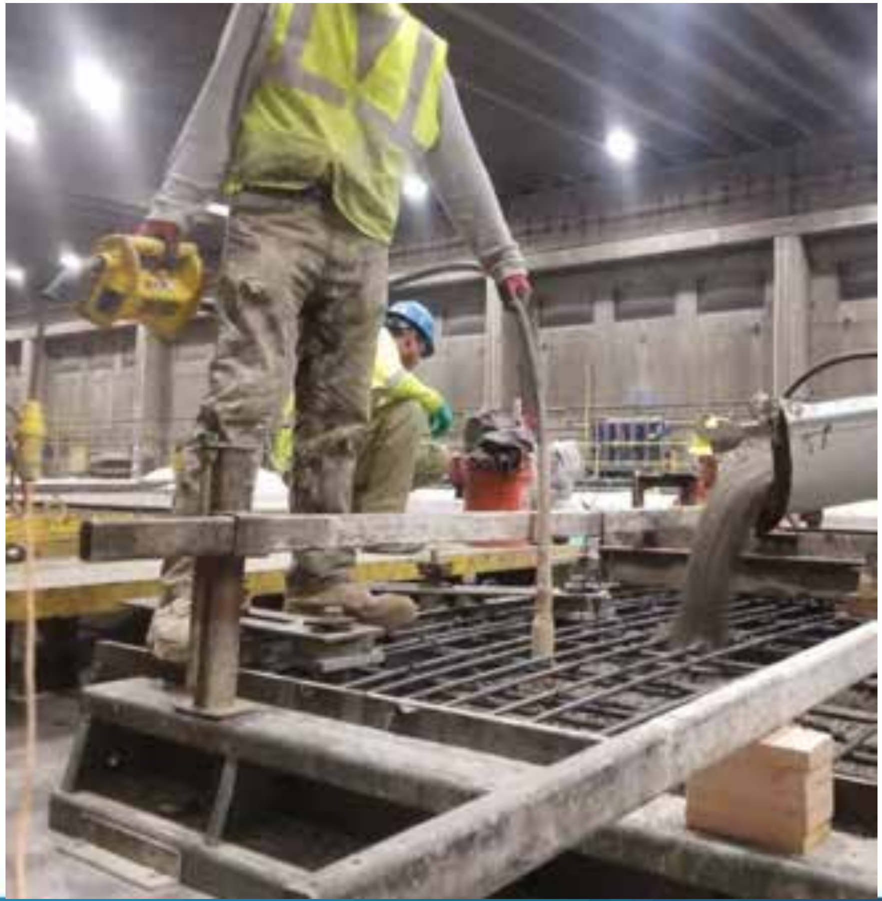
Frequency and Amplitude Guidelines

- Fine particles respond to high frequency vibration 12,000 being the optimum

VPM Range	Type	Particle size
3,000 – 6,000	External Vibrator	Small to large stone
6,000 – 9,000	High-Frequency External Vibrator	Coase sand to med. stone
9,000 – 12,000	Internal Vibrators	Fine sand to small stone

Internal Vibration

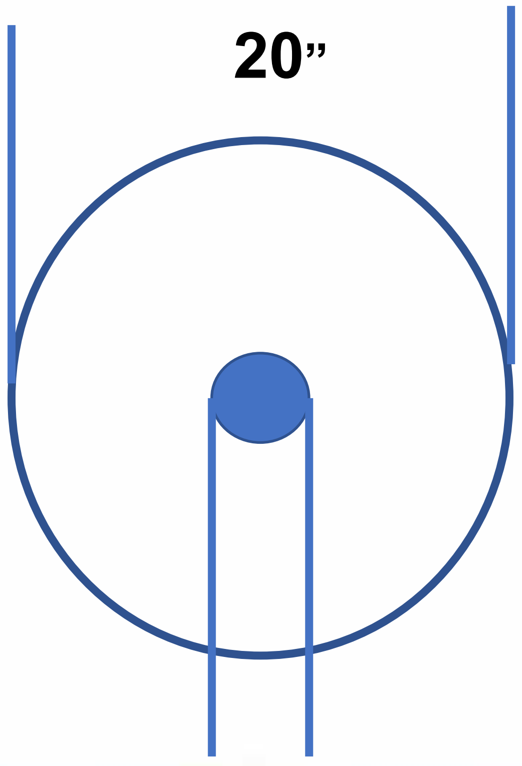
- Stingers, spuds
- Electric, pneumatic, or hydraulic



Area of Compaction

The general rule of thumb is the area of compaction is approximately 10 times the diameter of the head.

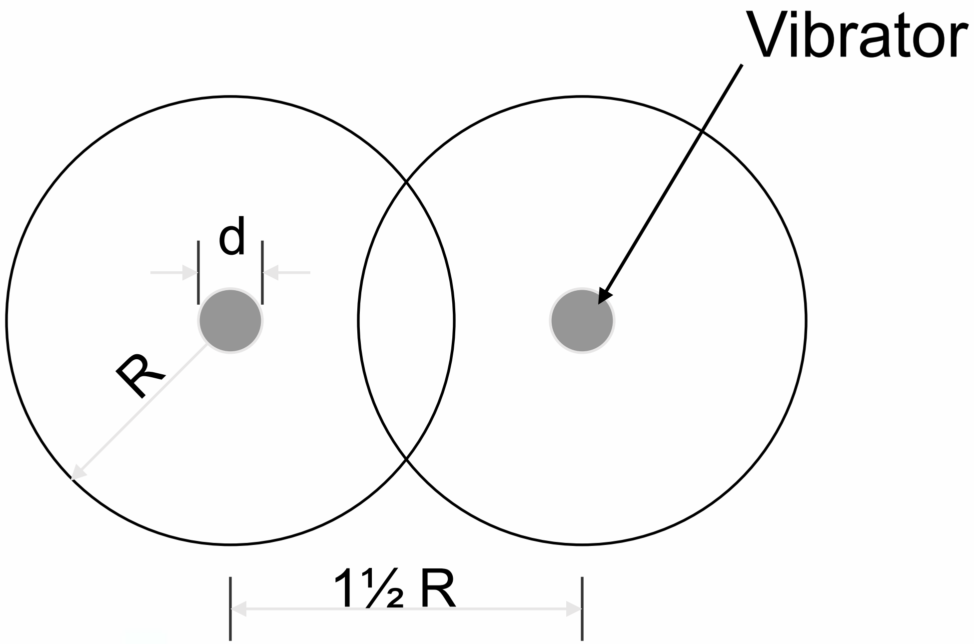
Example, a standard 2" head will have an effective area of compaction approximate 20" in diameter.



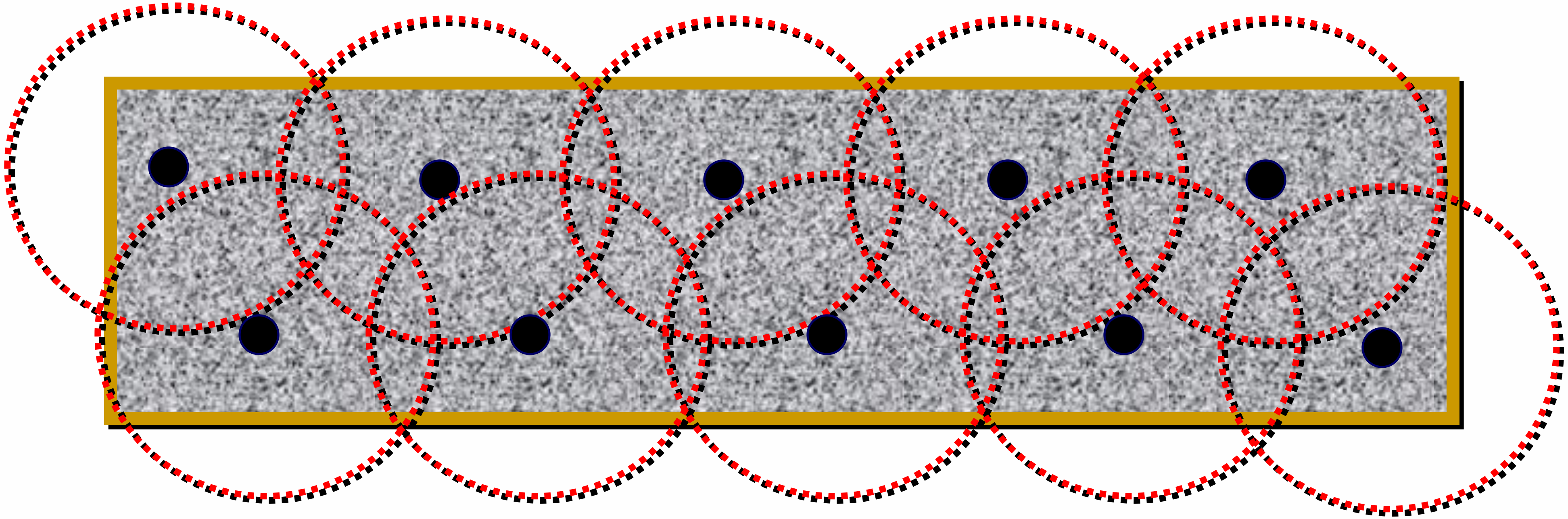
Internal Vibration - Radius of Action

Radius of Action – used to calculate insertion pattern

- 1 1/2 R = insertion spacing



Correct Insertion Method



Done properly there will be very few defects in the finish

Stinger – Best Practice

- Drop vertically under its own weight (≈1 sec./ft)
- Withdraw slightly slower (≈3 sec./ft)
- Place into each area only once, overlapping vibrating radius
- Each lift or layer of concrete should not exceed 20" to 24"
- Penetrate the last layer by a minimum of 6", bond the two layers together for 5 - 10 seconds
- Avoid touching the form or mold skin, and reinforcement with the vibrator
- Avoid running the head outside the mix
- Do NOT use vibrators to move a concrete mix laterally

Fishing?

External Vibration

- Form vibrators
- Vibrating screeds

External Vibration

External vibrators are often used when geometric or time constraints make the use of internal vibrators difficult or impossible:

- Complicated construction geometry (e.g. undercuts, canted or inclined surfaces, large box forms)
- Narrow or confined entry spaces
- Tight spacing between rebar preventing access by internal vibrators
- Time constraints due to labor

External Vibration

Proper location and sizing of external vibrators is important!

- Often over and under vibration can occur due to improper placement and design of the vibrators

- Precasters are better off to reduced the force and apply in more positions on the formwork/mold. This will result in a better product finish and lower noise levels

Vibration

Vibration

Vibrate when you need to, not just because:

• Conventional Concrete	Vibrated
• Flowable Concrete 18"- 24" slump flow	Vibrated
• SCC: >24"	Typically not vibrated

Quality Control Testing

Frequency

- Aggregate: sieve analysis
  - Fine – every 1,500 tons (1,350 metric tons)
  - Coarse – every 2,000 tons (1,800 metric tons)

- Aggregate: moisture content
  - With probes – Weekly
  - Without probes –
    - Conventional Slump = daily
    - Self-Consolidating = every 4 hours

Test Methods

- ASTM C136, “Standard Test Method of Sieve Analysis of Fine and Coarse Aggregates”
- ASTM C70, “Standard Test Method for Surface Moisture in Fine Aggregate”
- ASTM C566, “Standard Test Method for Total Evaporable Moisture Content of Aggregate by Drying”

Sampling

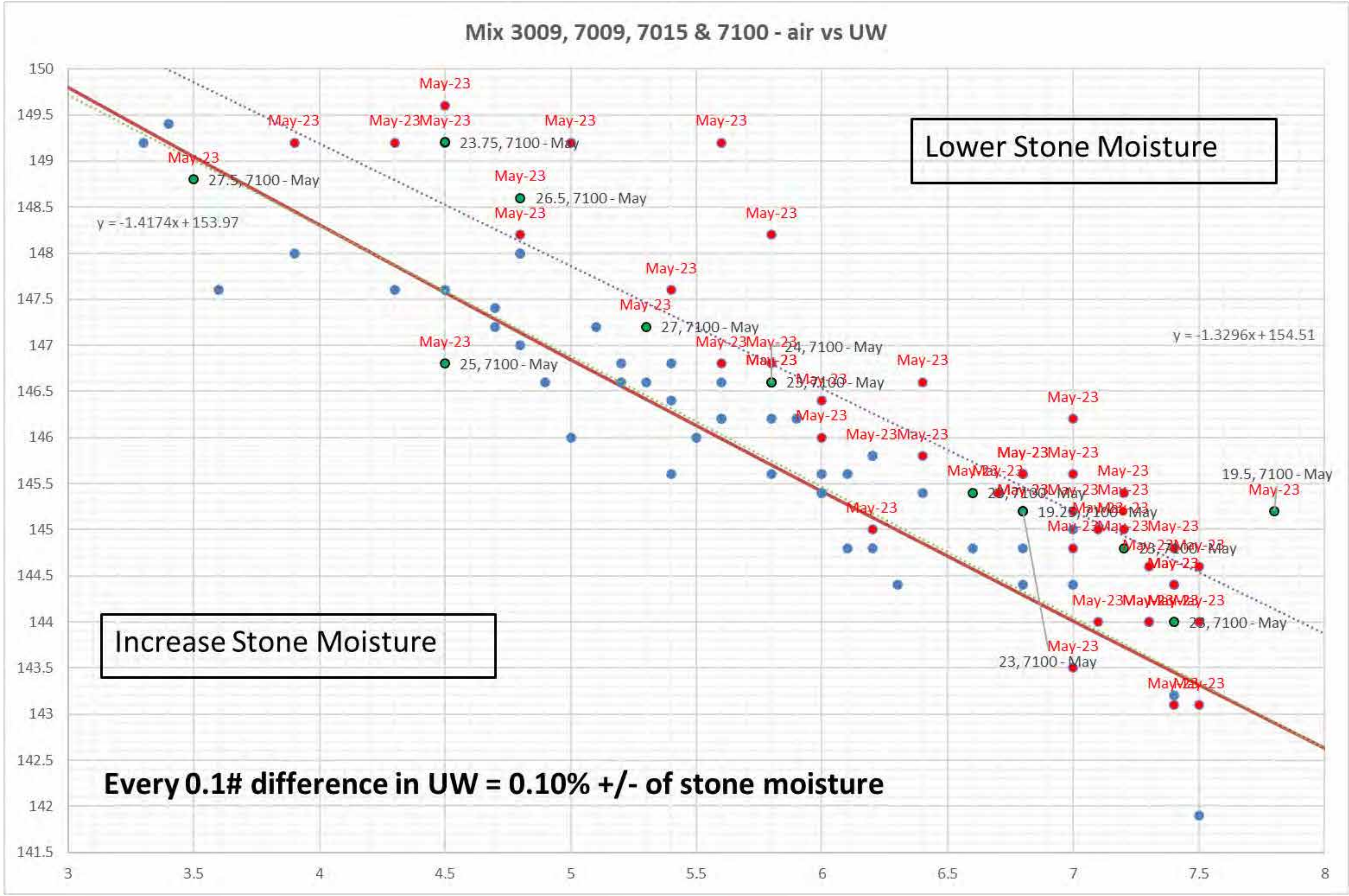
Frequency

- Slump: every 150 cubic yards (115 cubic meters); minimum once per production day. Dry-Cast concrete excluded.
- Spread / VSI: One of the first two batches each day
  - Whenever the mix design changes
  - Whenever the raw materials change
- Air Content:
  - Entrained = every 150 cubic yards (115 cubic meters); minimum once per production day. Dry-Cast concrete excluded.
  - Not Entrained = once per week or whenever test cylinders are made
  - Dry Cast concrete excluded

Test Methods

- Slump: ASTM C143, “Standard Test Method for Slump of Hydraulic-Cement Concrete”
- Spread / VSI: ASTM C1611 “Standard Test Method for Slump Flow of Self-Consolidating Concrete”
- Air Content: ASTM C231, “Standard Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method”
- Lightweight: ASTM C173, “Standard Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method”
- ASTM C1064, “Standard Test Method for Temperature of Freshly Mixed Portland Cement Concrete”

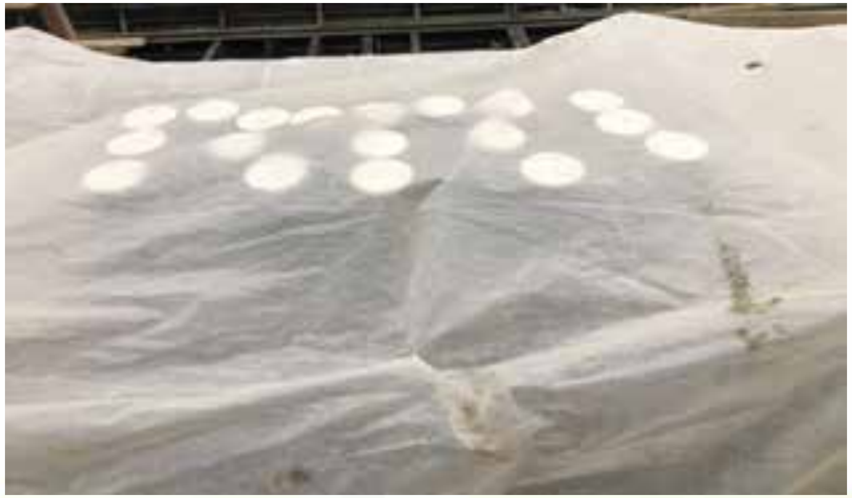
Unit Weight



Mix 3009, 7009, 7015 & 7100 - air vs UW
Lower Stone Moisture
Increase Stone Moisture
y = -1.4174x + 153.97
y = -1.3296x + 154.51
Every 0.1# difference in UW = 0.10% +/- of stone moisture
27.5, 7100 - May
23.75, 7100 - May
26.5, 7100 - May
27, 7100 - May
25, 7100 - May
24, 7100 - May
19.5, 7100 - May
23, 7100 - May
May-23
150
149.5
149
148.5
148
147.5
147
146.5
146
145.5
145
144.5
144
143.5
143
142.5
142
141.5
3
3.5
4
4.5
5
5.5
6
6.5
7
7.5
8

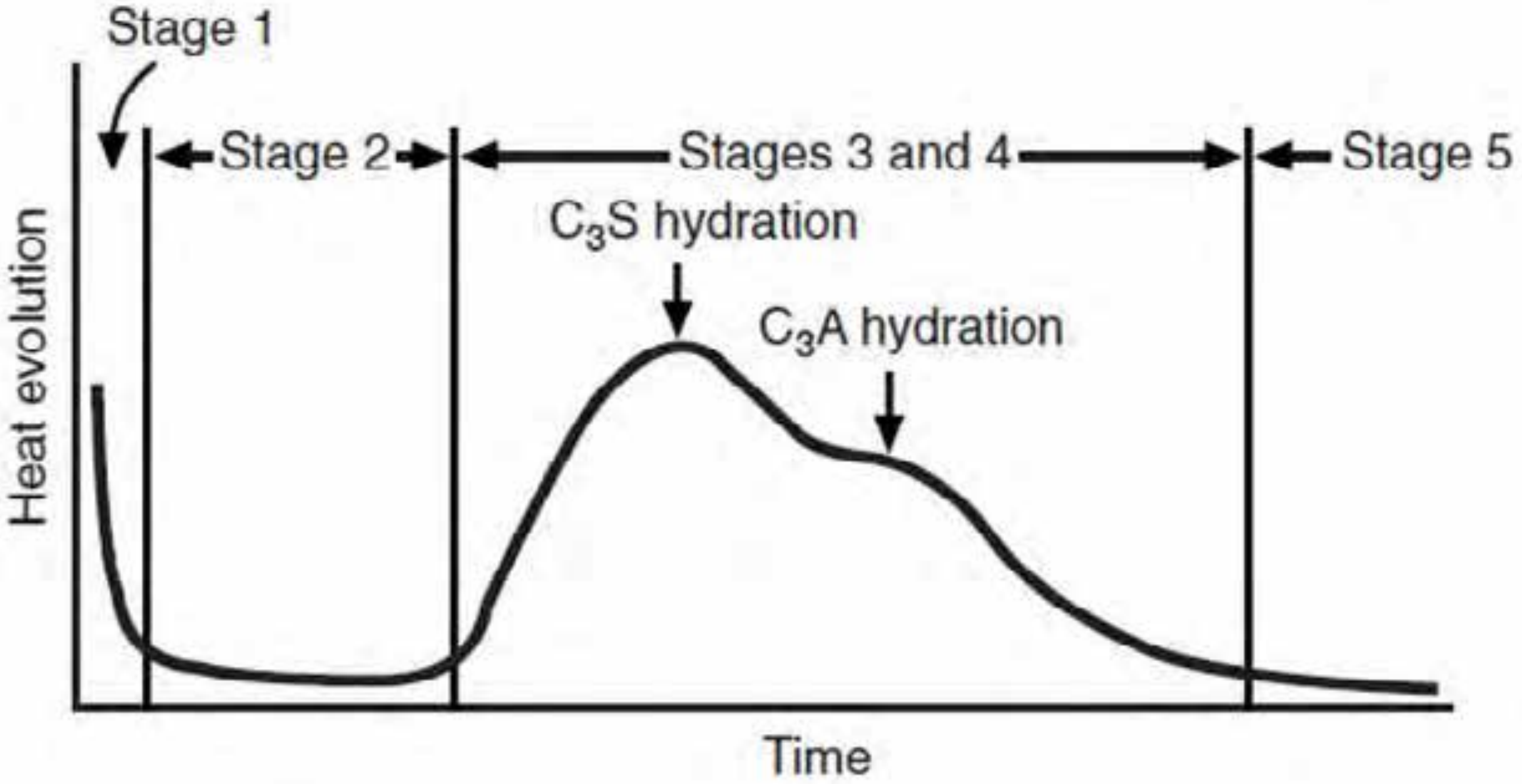
Cylinders

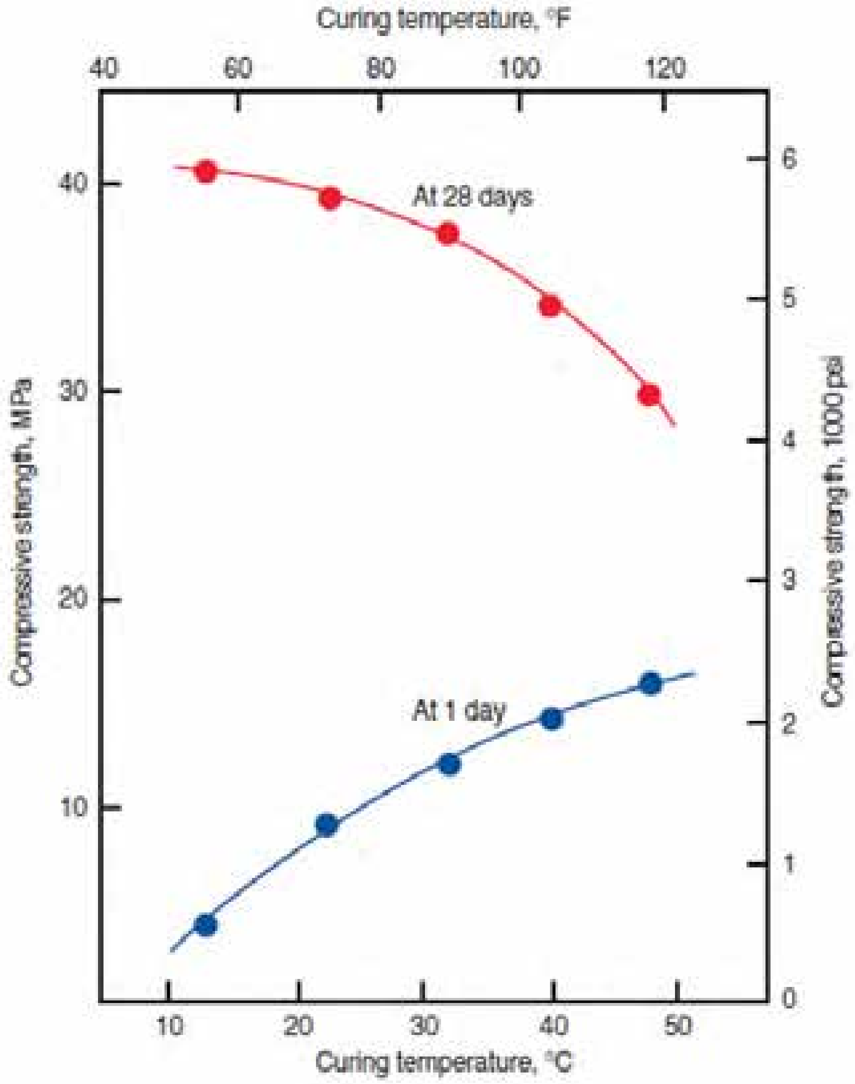
- (4) per 150 cubic yards (115 cubic meters); min once per week
- Conventional Slump, SCC, Dry-Cast fabrication process
- Specimens shall be cured in a manner consistent with the curing of the concrete products represented by the specimens



Curing

Stages


Stage 1
Stage 2
Stages 3 and 4
Stage 5
C_3S hydration
C_3A hydration
Heat evolution
Time

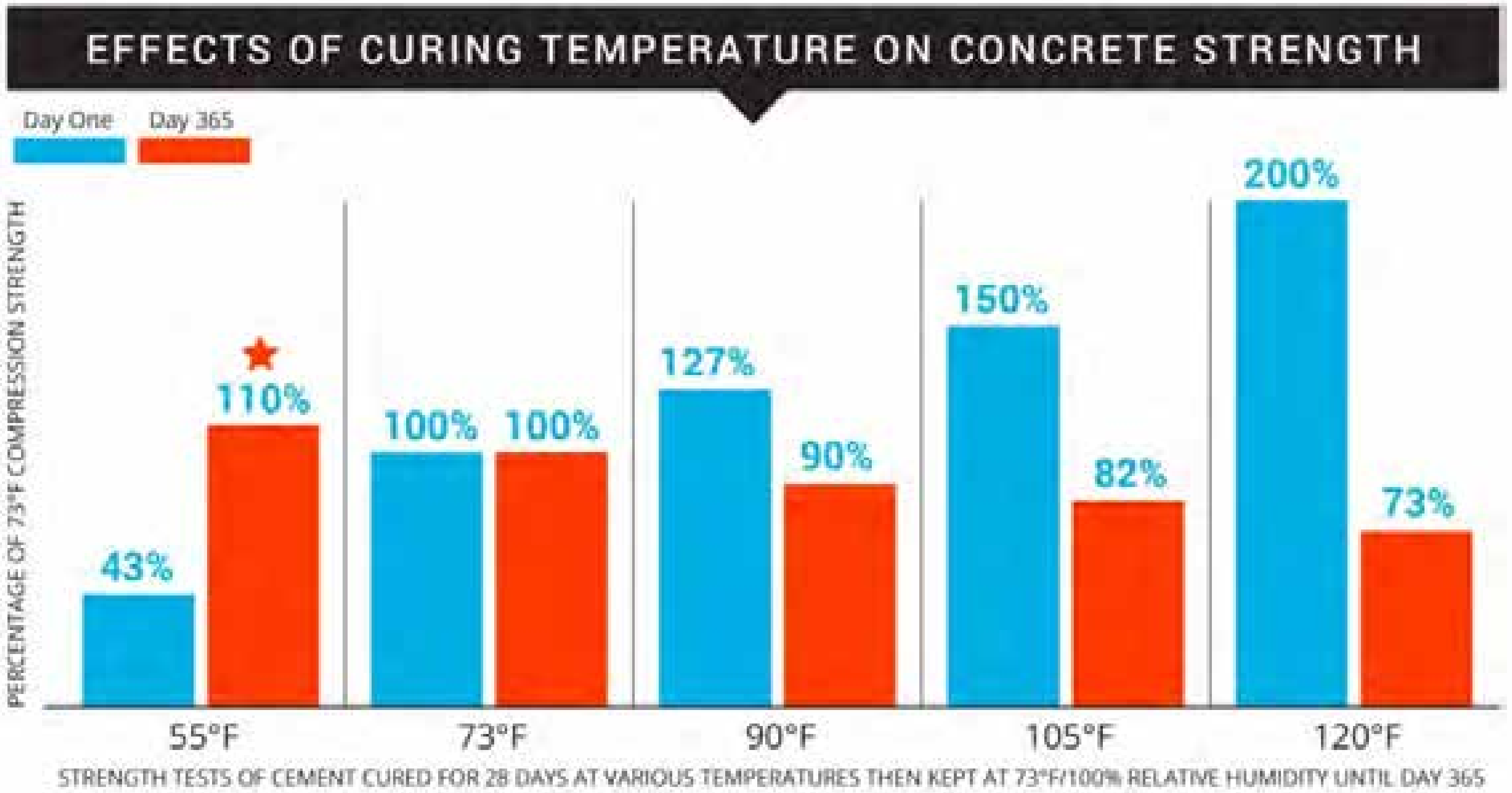

Curing temperature, °F
40
60
80
100
120
40
30
20
10
6
5
4
3
2
1
0
At 28 days
At 1 day
Compressive strength, MPa
Compressive strength, 1000 psi
10
20
30
40
50
Curing temperature, °C

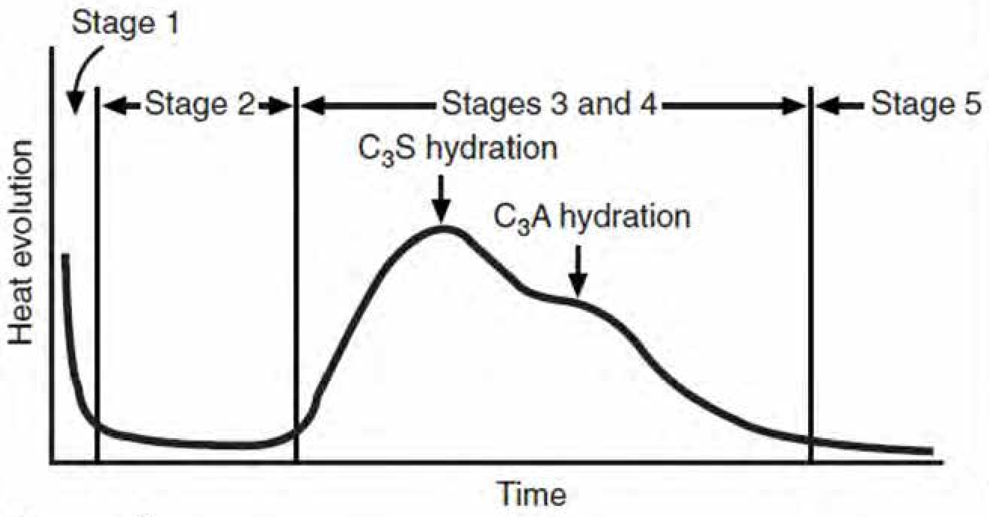
Retain Moisture

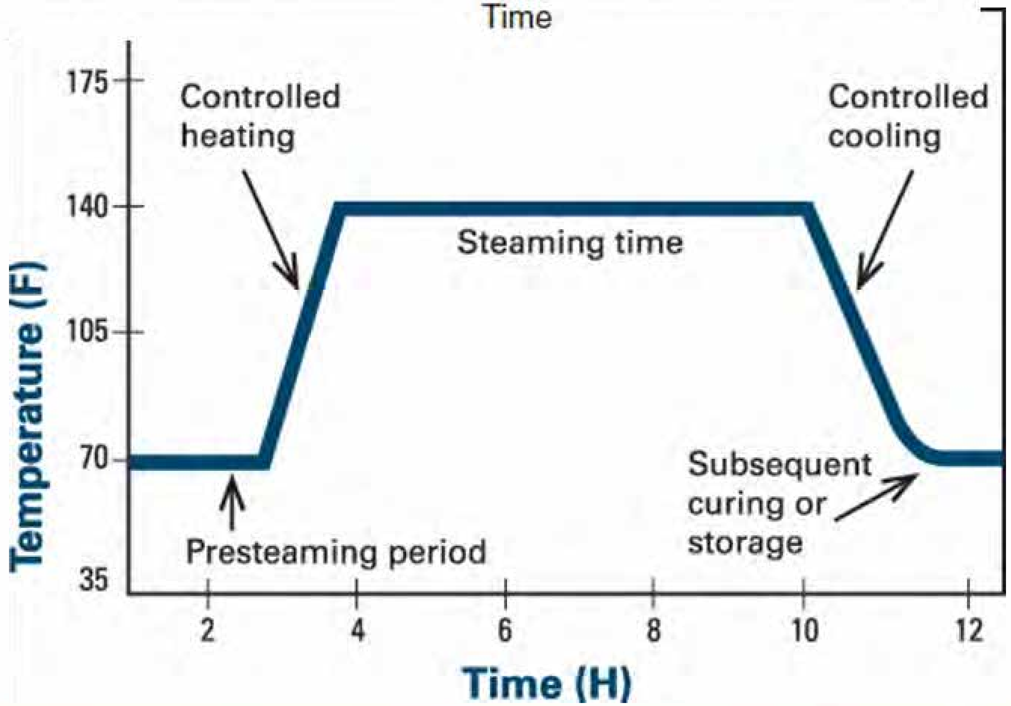
Retain Heat & Moisture

Retain Moisture, Add Heat

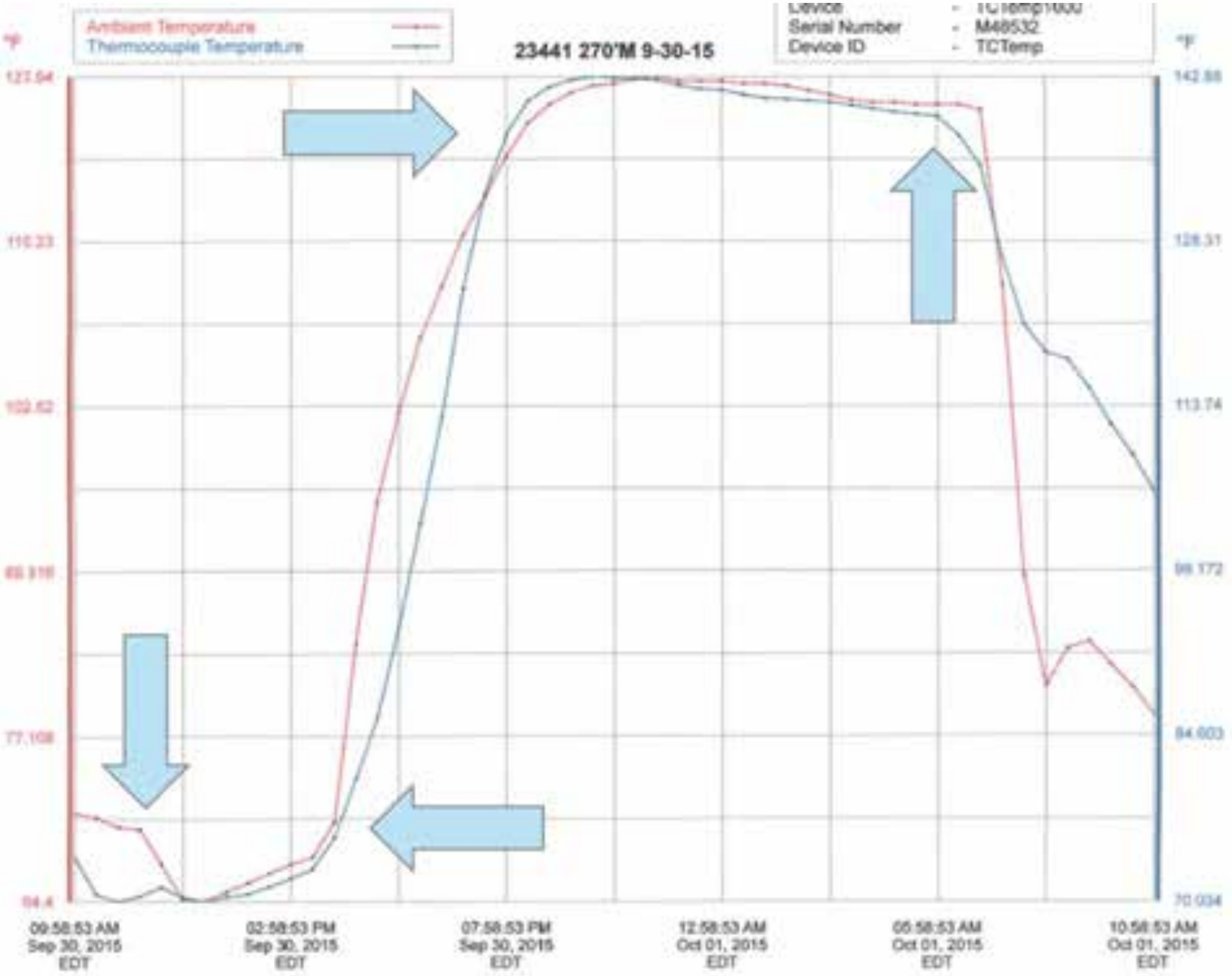
Accelerated Curing







Temperature Control



Representative Cylinders

Chipping & Handling

Geometry

Slip Formed

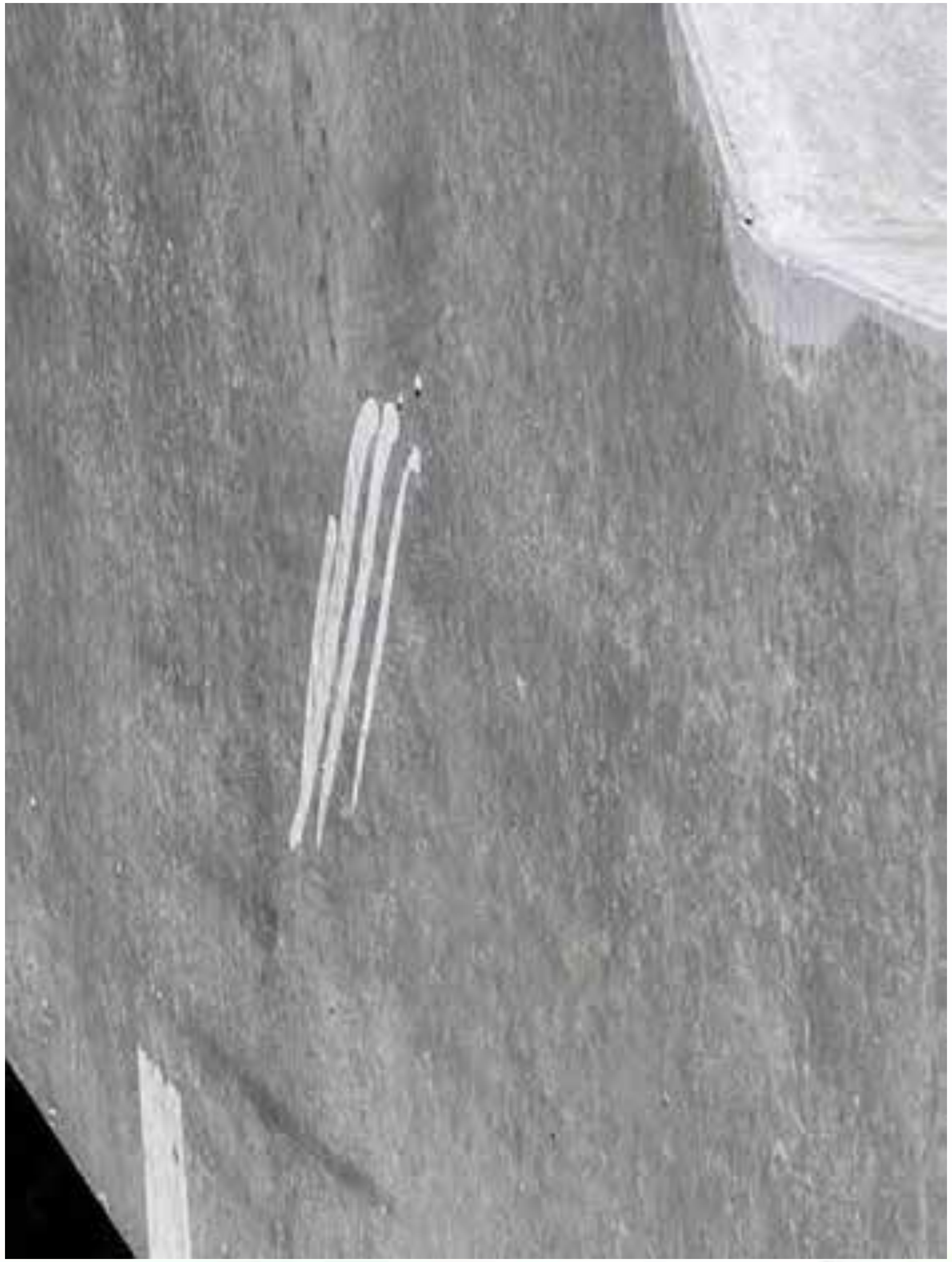
Rotating

Storage & Shipping

Storage

Storage

Storage

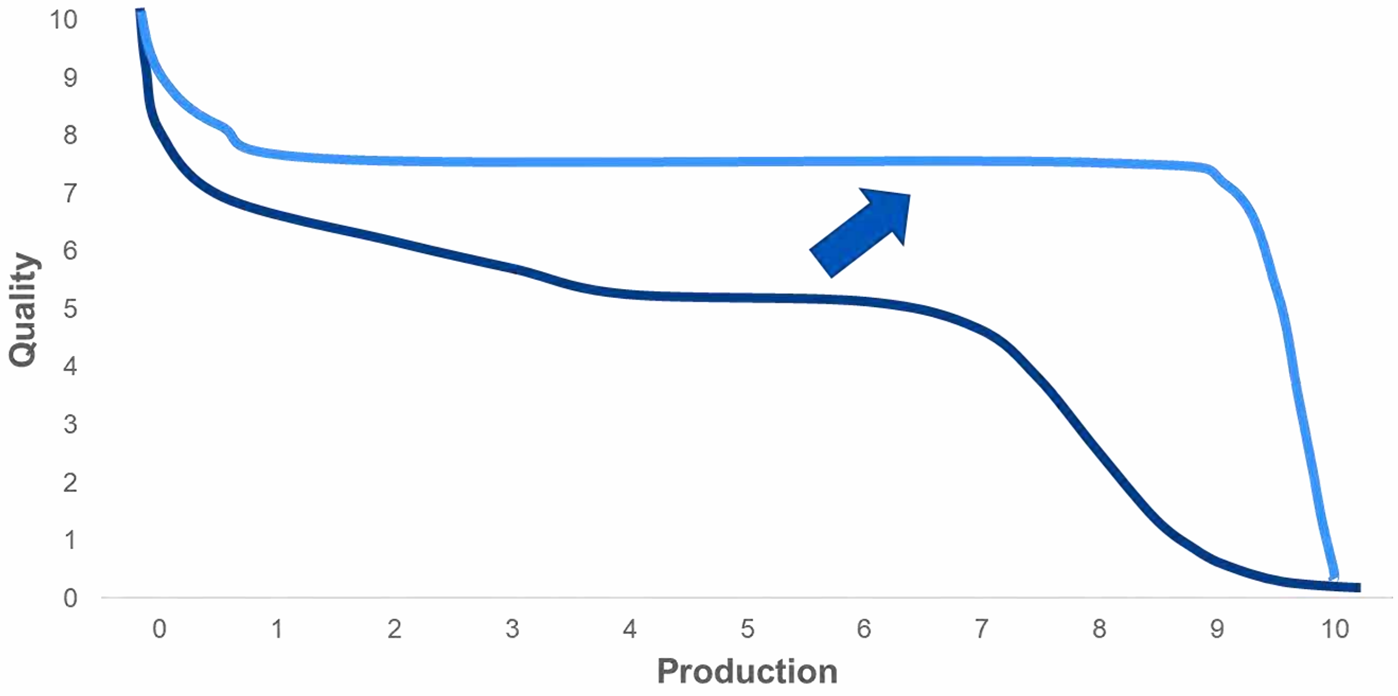


Shipping

Shipping

Optimization

“the *action* of making the most effective use of a situation or resource”



Thank you!
Questions

Excess Concrete

Excess Concrete

CP5 – Troubleshooting Precast Production

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