BRAUN INTERTEC

the science you build on

Trial Batching Fun in a Drum

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Director / Principal Engineer

“If I knew then what I know now,…”

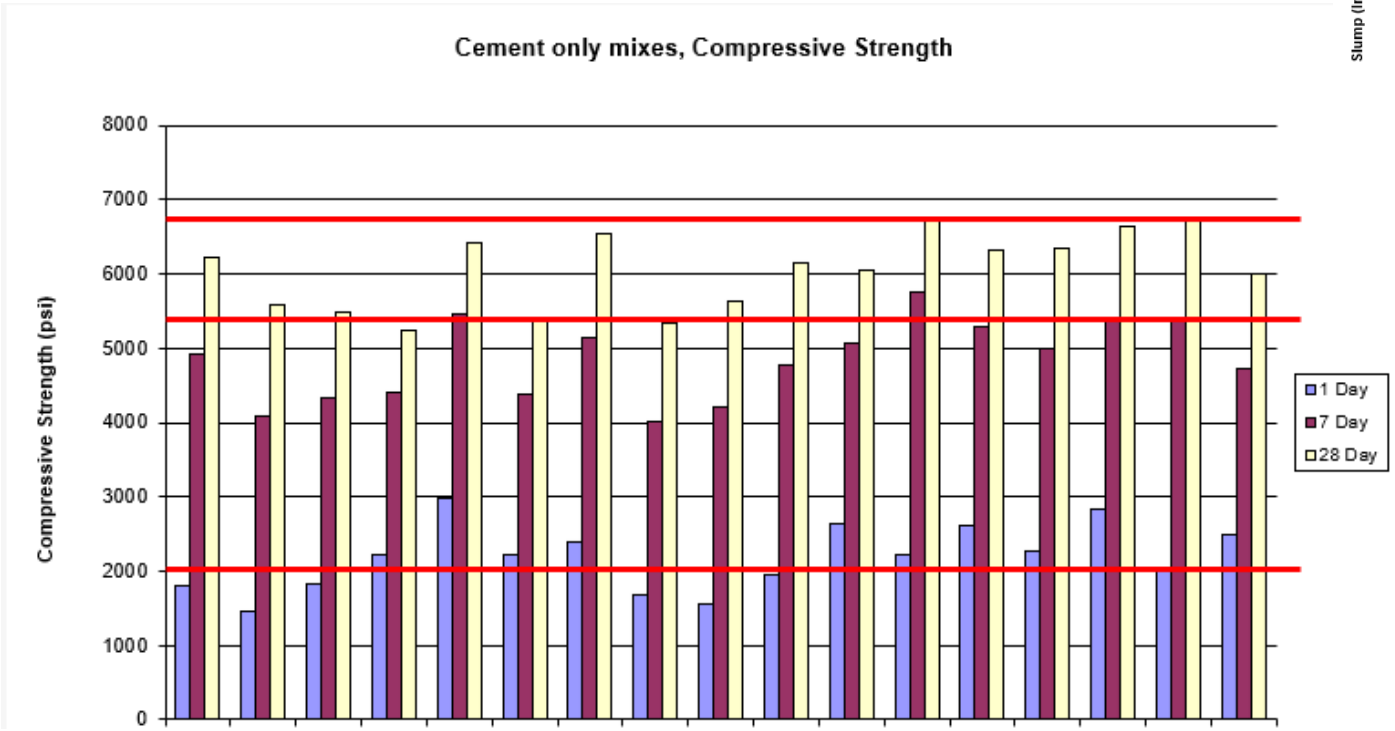
Lessons Learned from Trial Batching

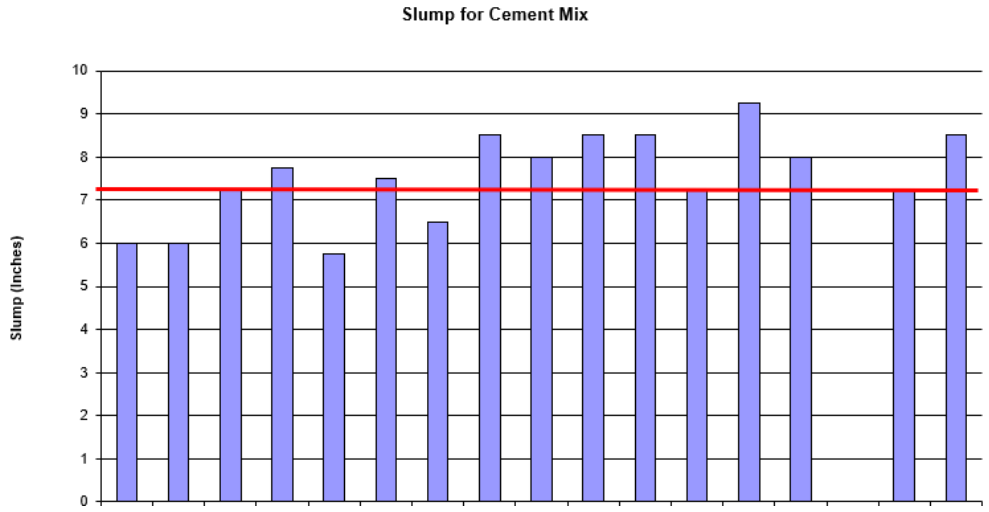
Why Trial Batching?

- Meet design requirement of a specification
- Verify a proposed mix design
- Evaluate Materials – New or old and any changes
- Reduce Risk of Failure
- Chase issues – develop a testing matrix

Where did I start

- Material Comparison in industry testing





What Now?


READY MIXED CONCRETE
"Here's what I want: Your concrete should pour like Niagara and have the strength of Gibraltar."

Trial Batching

- ACI – A batch of concrete prepared to establish acceptable proportions of the constituents.
  - Cementitious
  - Aggregates
  - Water
  - Admixture
  - Fibers
- Measuring
  - Slump
  - Air Content
  - Unit Weight
  - Temperature
  - Strength

Performance

- More complicated issues need to be evaluated
  - Workability
  - Finishability
  - Placability
  - Pumpability
  - Durability
  - Anti-washout (underwater concrete)
  - Box Test or V-Kelly
  - Pot life

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Steps in our Process

Step 1

- Understand the specification and performance requirements
- Review Materials

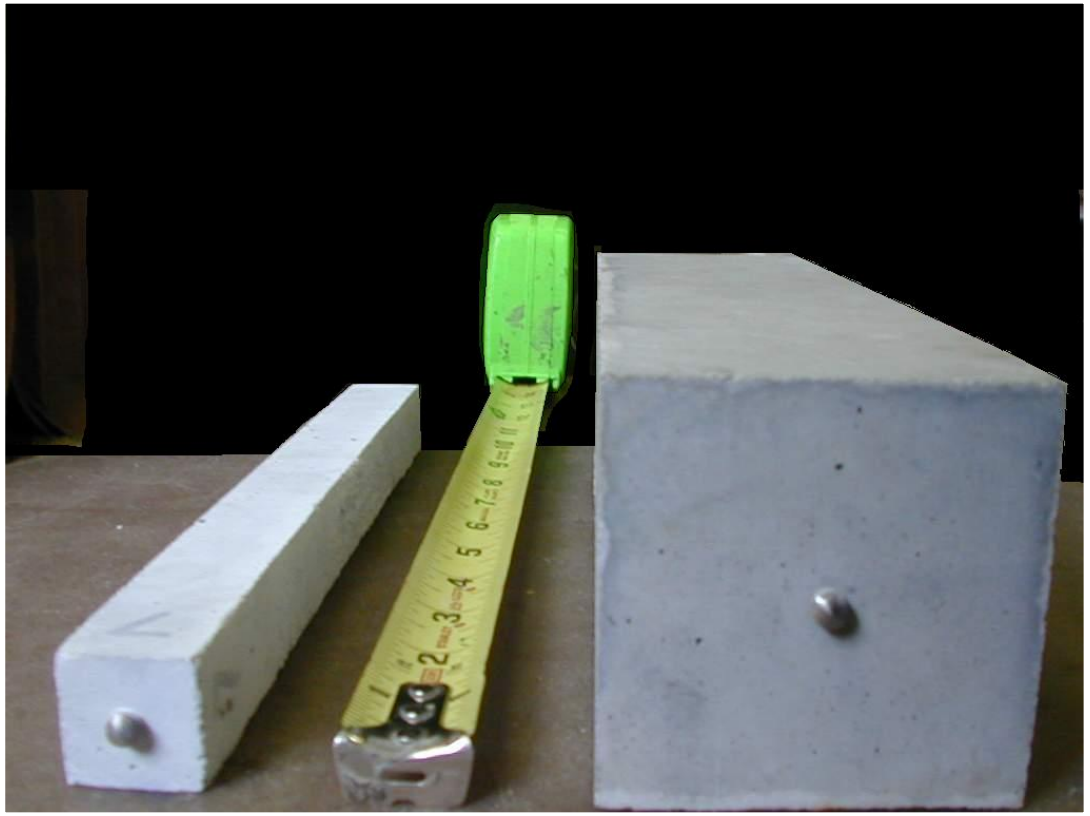
CaO = 24.94%

CHEMICAL ANALYSIS:	RESULTS:	ASTM C 618 Spec F/C
Silicon Dioxide, SiO_2, %	38.39	----
Aluminum Oxide, Al_2O_3, %	18.66	----
Iron Oxide, Fe_2O_3, %	5.23	----
Sum of SiO_2, Al_2O_3 & Fe_2O_3, %	62.28	50.0 Min./50.0 Min.
Calcium Oxide, CaO, %	24.94	18.0 Max/>18.0
Magnesium Oxide, MgO, %	4.27	----
Sodium Oxide, Na_2O, %	1.75	----
Potassium Oxide, K_2O, %	0.49	----
Sulfur Trioxide, SO_3, %	2.19	5.0 Max
Moisture Content, %	0.12	3.0 Max
Loss on Ignition, %	0.30	6.0 Max
Total Alkalis, % as Na_2O Equivalent	2.07	
Available Alkalis, % as Na_2O Equivalent	0.73	----
PHYSICAL ANALYSIS:	**RESULTS:**	**ASTM C 618 Spec F/C**
Amount Retained on No. 325 Sieve, %	17.5	34 Max
Strength Activity Index		
Portland Cement @ 7 days, % of Control	103	75 Min
Portland Cement @ 28 days, % of Control	107	75 Min
Water Requirement, % of Control	93	105 Max
Autoclave Expansion, %	+0.03	0.8 Max
Density	2.63	----

a. Fly ash. Fly ash shall meet the requirements of ASTM C618, with the exception of loss of ignition, where the maximum shall be less than 6%. Fly ash shall have a Calcium Oxide (CaO) content of less than 15% and a total alkali content less than 3% per ASTM C311. The Contractor shall furnish the previous three most recent, consecutive ASTM C618 reports for each source of fly ash proposed in the concrete mix, and shall furnish each additional report as they become available during the project. The reports can be used for acceptance or the material may be tested independently by the Resident Project Representative (RPR).

Step 2 – Find the critical path

- Test in sequence
- Typically, critical path is ASR Mitigation
  - Anti-Washout
  - Bleed rate
  - Set time

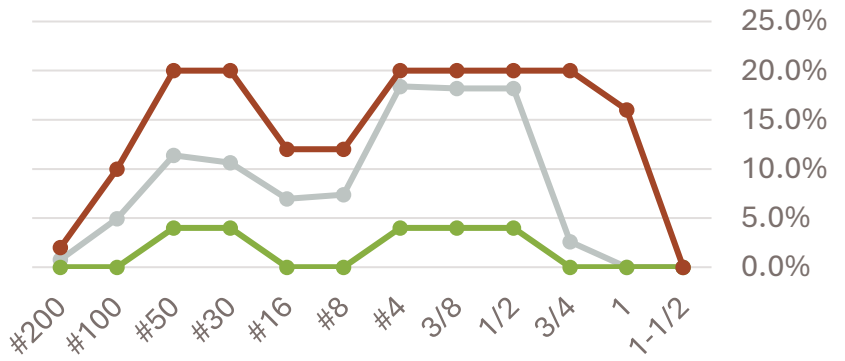


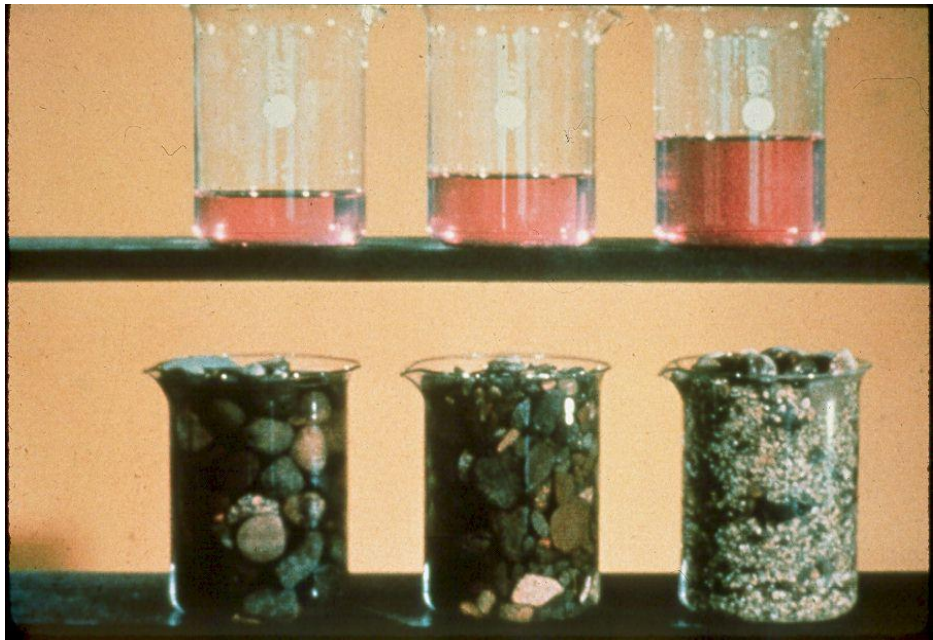
Step 3 - Sound/Dependable Concrete Practices

Table 19.3.1.1—Exposure categories and classes

Category	Class	Condition	
Freezing and thawing (F)	F0	Concrete not exposed to freezing-and-thawing cycles	
	F1	Concrete exposed to freezing-and-thawing cycles with limited exposure to water	
	F2	Concrete exposed to freezing-and-thawing cycles with frequent exposure to water	
	F3	Concrete exposed to freezing-and-thawing cycles with frequent exposure to water and exposure to deicing chemicals	
Sulfate (S)		Water-soluble sulfate (SO_4^{2-}) in soil, percent by mass[1]	Dissolved sulfate (SO_4^{2-}) in water, ppm[2]
	S0	$SO_4^{2-} < 0.10$	$SO_4^{2-} < 150$
	S1	$0.10 \le SO_4^{2-} < 0.20$	$150 \le SO_4^{2-} < 1500$ or seawater
	S2	$0.20 \le SO_4^{2-} \le 2.00$	$1500 \le SO_4^{2-} \le 10{,}000$
	S3	$SO_4^{2-} > 2.00$	$SO_4^{2-} > 10{,}000$
In contact with water (W)	W0	Concrete dry in service Concrete in contact with water and low permeability is not required	
	W1	Concrete in contact with water and low permeability is required	
Corrosion protection of reinforcement (C)	C0	Concrete dry or protected from moisture	
	C1	Concrete exposed to moisture but not to an external source of chlorides	
	C2	Concrete exposed to moisture and an external source of chlorides from deicing chemicals, salt, brackish water, seawater, or spray from these sources	

Tarantula Curve





Step 4 - Batching

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Trail Batching in the Field

- Less Controlled but closer to reality.
- Different mixing.
- Different accuracy

Trial Placement

Optimization Mixtures

- 7-day strength
  - 5010 psi
- 28-day strength
  - 7130 psi
- Some QA cylinders were reaching 9000 psi.

Cement	260	(lbs/yd3)
Fly Ash	104	(lbs/yd3)
Slag	156	(lbs/yd3)
No. 67 Natural Gravel	1444	(lbs/yd3)
No. 8 Natural Gravel	802	(lbs/yd3)
Sand	958	(lbs/yd3)
Water	234	(lbs/yd3)
Air Entraining Admixture	1.8	(oz/yd3)
Water Reducer Admixture	26.0	(oz/yd3)

Then we tried to pump it!

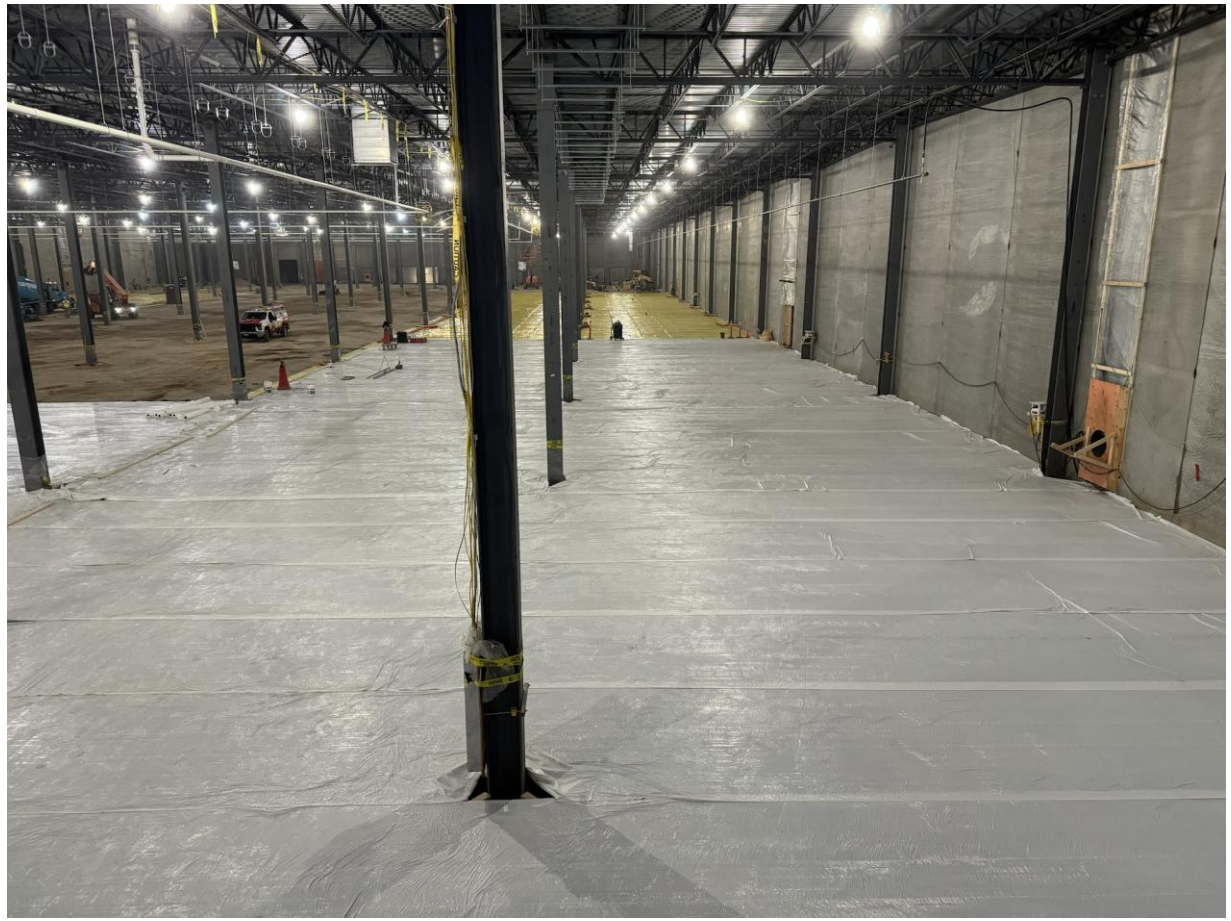
Graco Anoka Expansion

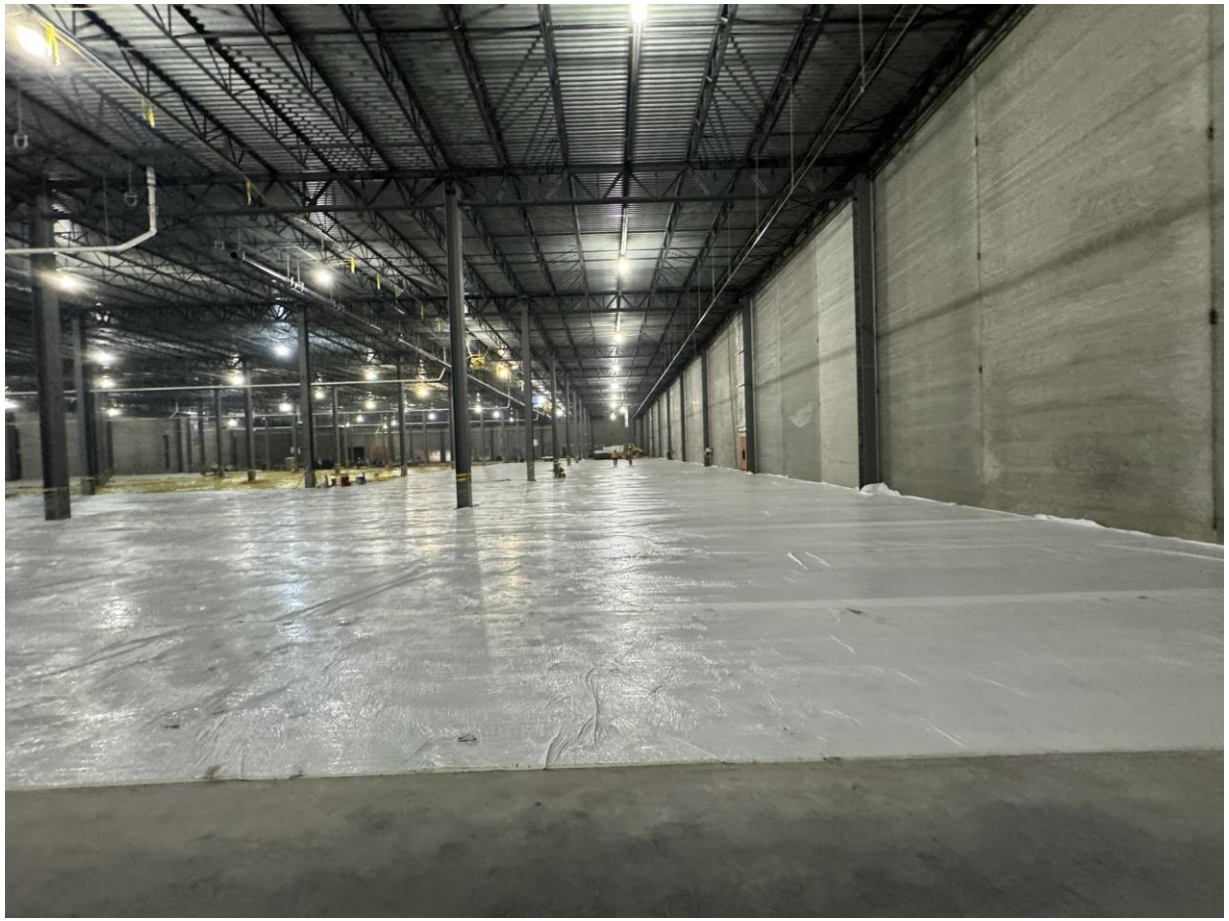
- 190,000 sq feet of warehouse slab addition
- Owner – Graco
- Contractor – Mortenson
- Engineer of Record – HGA
- Concrete Supplier – Cemstone
- Slab Design and Consulting – Braun Intertec

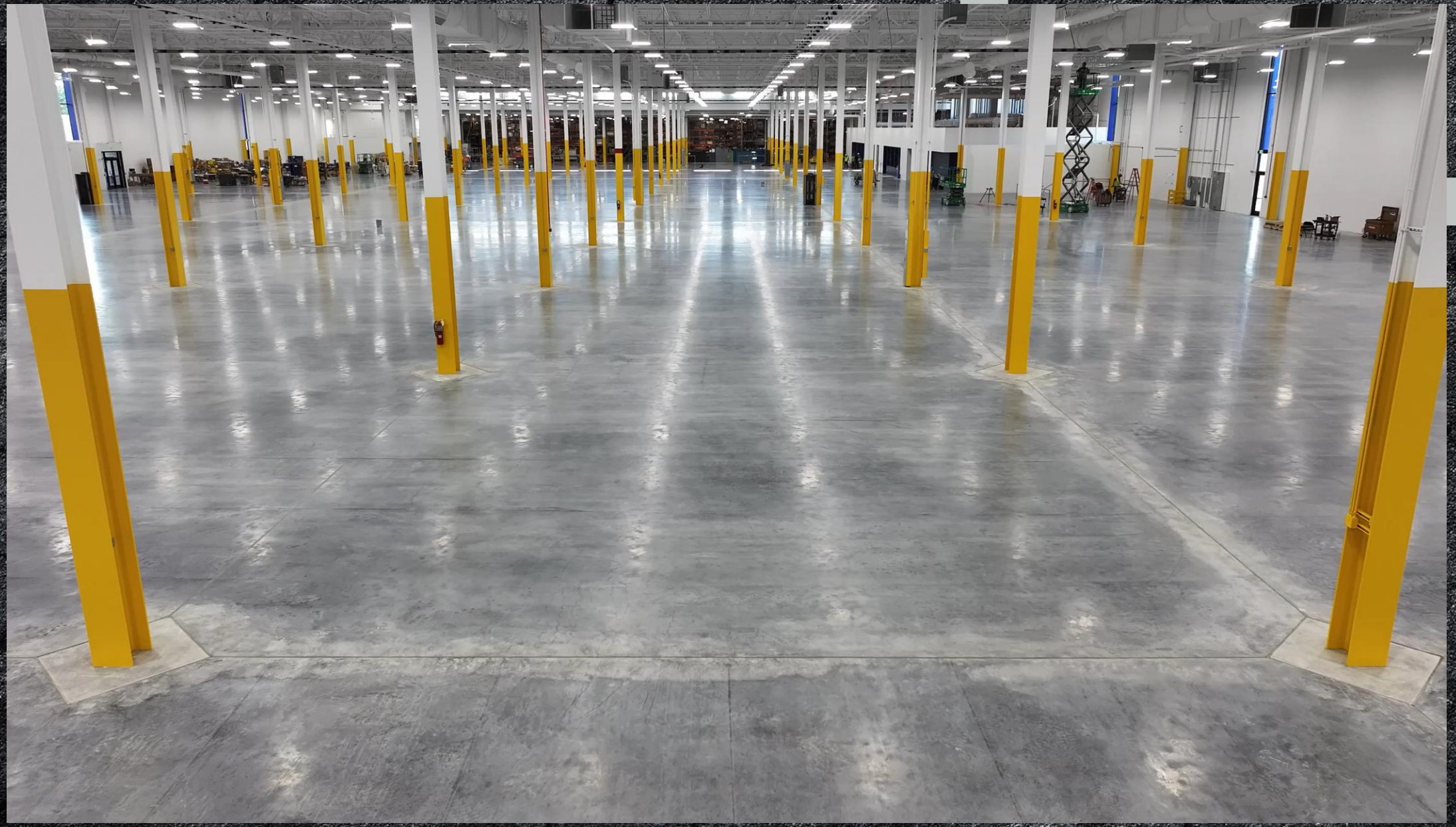
- The Story

Test Placements

Curing is Key



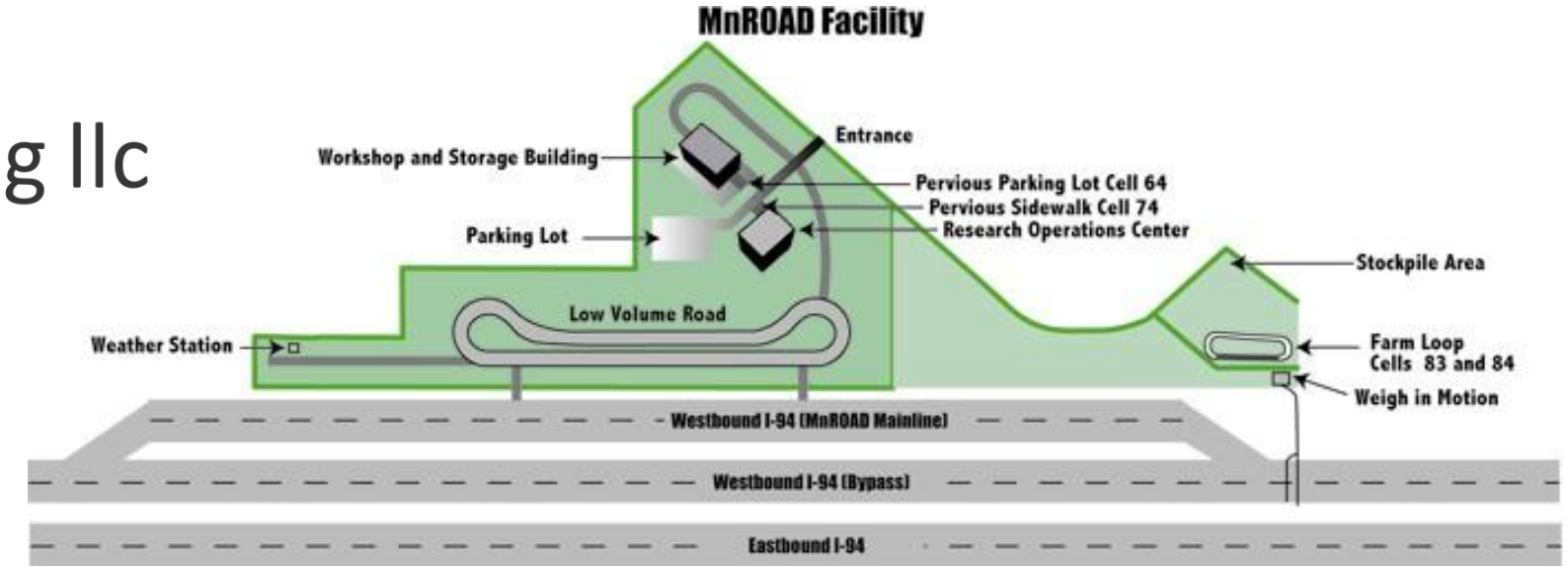




MnRoad Low Carbon Paving 2022 and 2024

- 3.5 mile of I-94 operated by **MnDOT**
- Partnership with the **National Road Research Alliance (NRRA)**
- 11 states, 50 industries, associations, and academia
- Designed to test new technologies in a real-world environment

sutter engineering llc



2022 Material Suppliers

- Ultra High Materials – zero portland cement
- Carbon Cure – additive
- Carbon Upcycling – Processing of ash
- Ash Grove – IP
- Urban Mining – Ground Glass
- Terra CO2 – Manufactured SCM
- Optimized Concrete Mixture
- Burgess Pigment – Metakaolin
- 3M – Natural Pozzolan
- Hess Pumice – Natural Pozzolan
- Continental Cement – 20% limestone

2024 Material Suppliers

- Ozinga – C1157 Cement
- C-Crete – C1157 – zero portland
- CEM Innovations – Microspheres
- Ashgrove – LC3
- Ternary Blend
- Optimized Concrete Mixture
- Amrize – Quaternary Mix

Braun Intertec's Part

- Prepare Concrete Mixtures for Paving
  - 5 to 8 percent air content
  - 500 psi flexural strength
  - Optimum workability to facilitate slipform placement
  - Maintains plastic state for at least 45 minutes

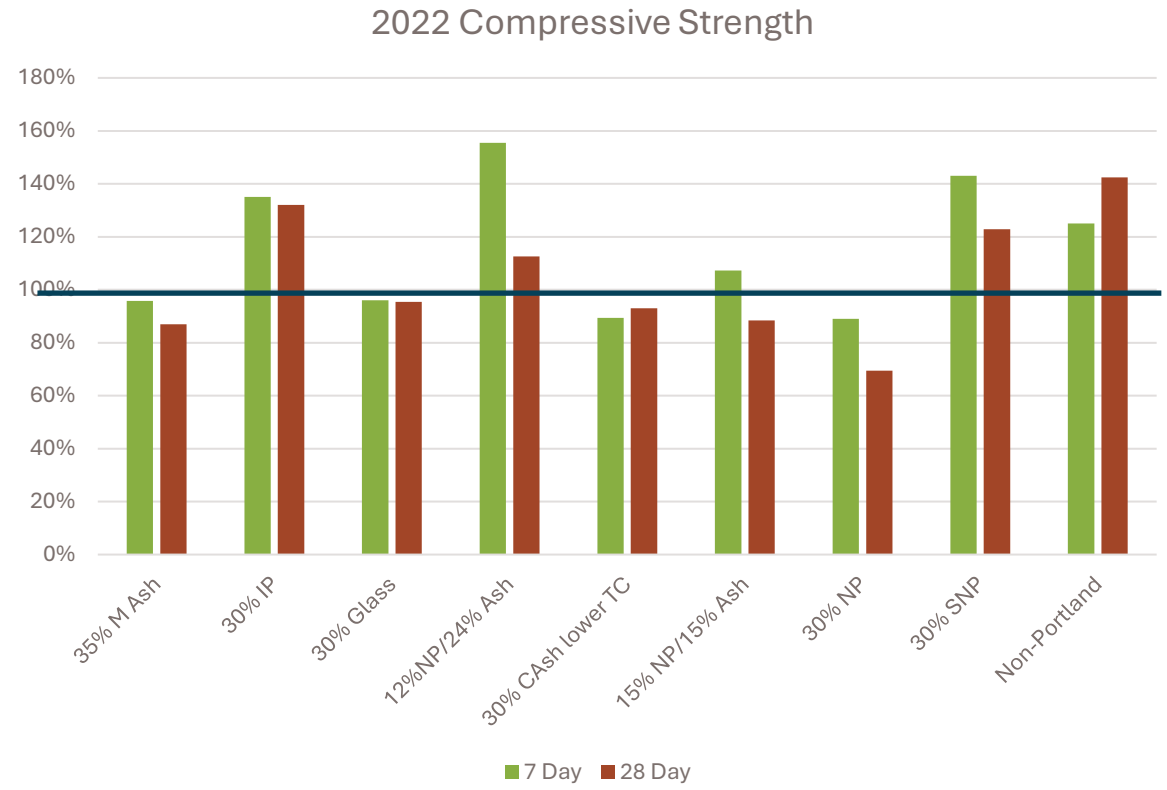
Control mixture

- Total Cementitious – 570 lb/yd^3
  - 30% Ash
- 0.40 w/c ratio
- Four aggregate mix for well grading mixture
- 28 day compressive strength 4,300 psi
- 28 day flexural strength 565 psi
- Time of set – 4 hours 25 min
- Slump 2.75
- Air content 6.0%

The Statistic

- 16 Different Mixtures Tested
- 2 mixtures with zero portland cement in the mix
- 1 mixture is 20 percent or less portland cement in the mix
- Lab Batched 7 yard of concrete

- We educated some very smart people.

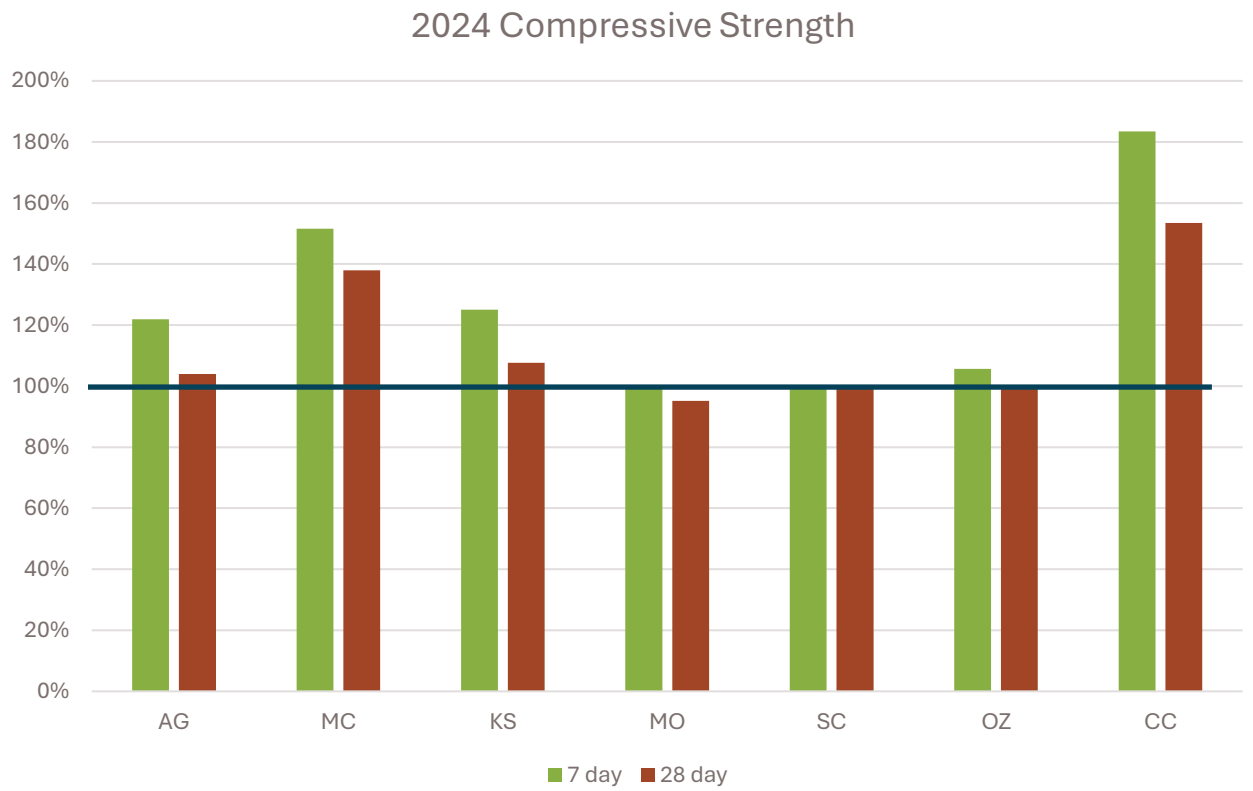


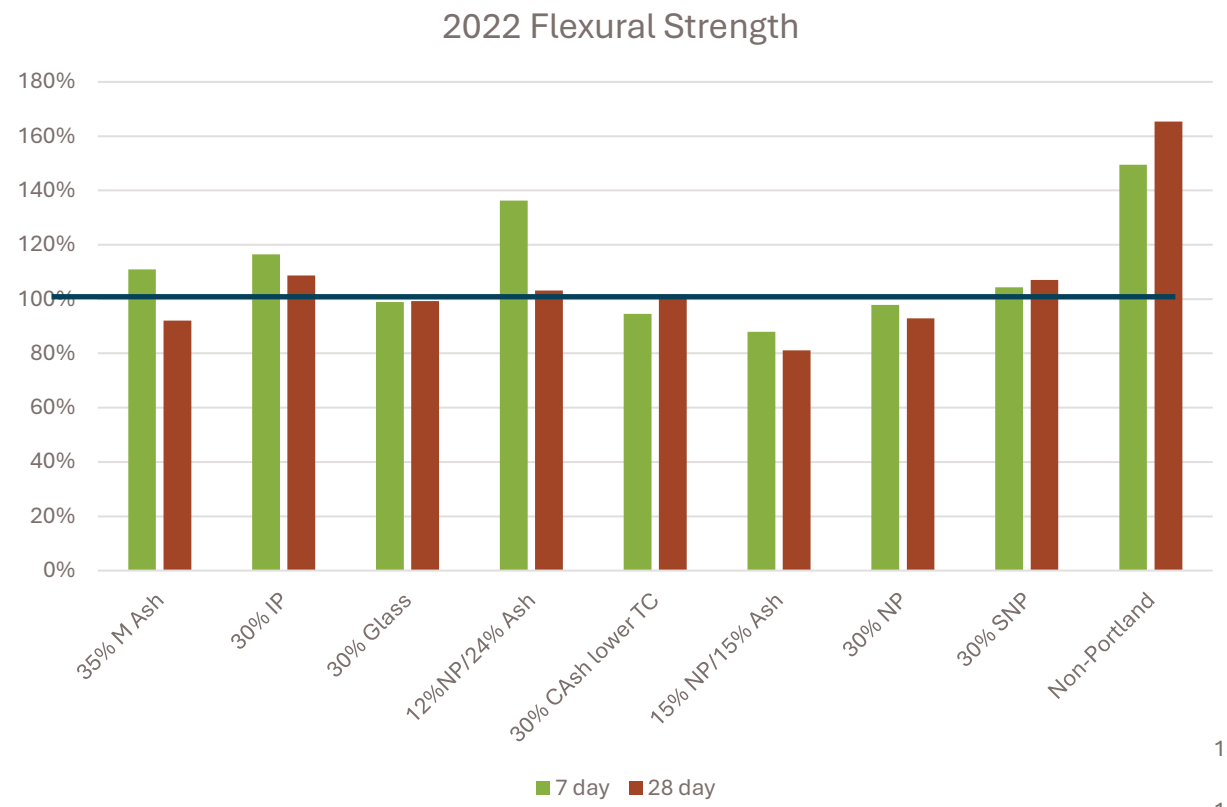
2022 Control

- 7-day = 3280 psi
- 28-day control = 4590 psi

2024 Control

- 7-day = 2830 psi
- 28-day control = 4300 psi



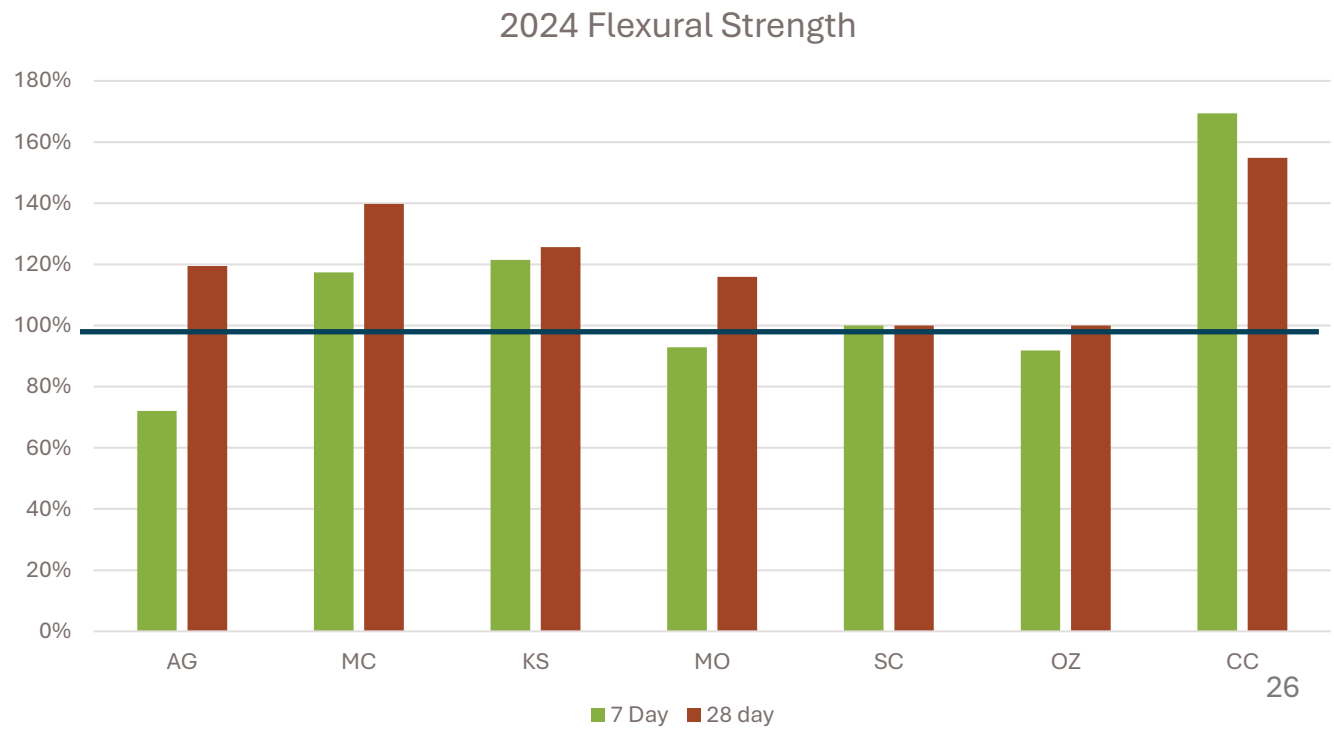


2022 Control

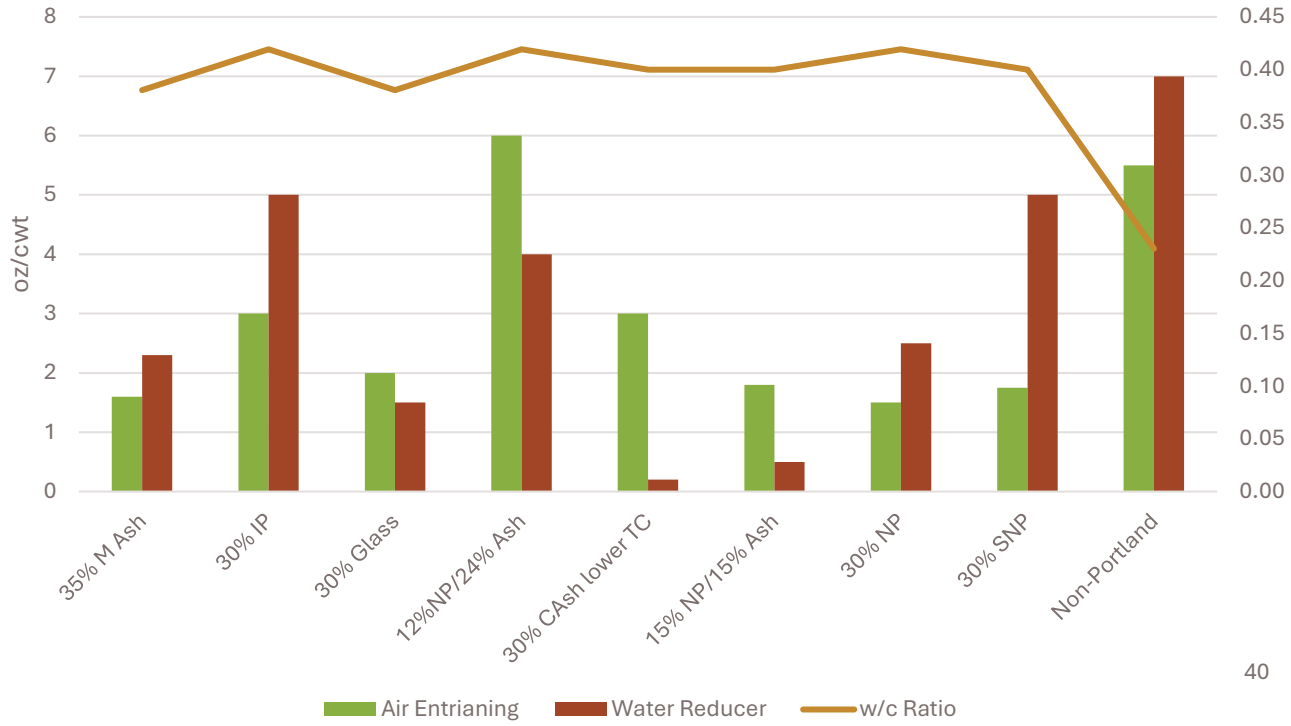
- 7-day = 455 psi
- 28-day control = 635 psi

2024 Control

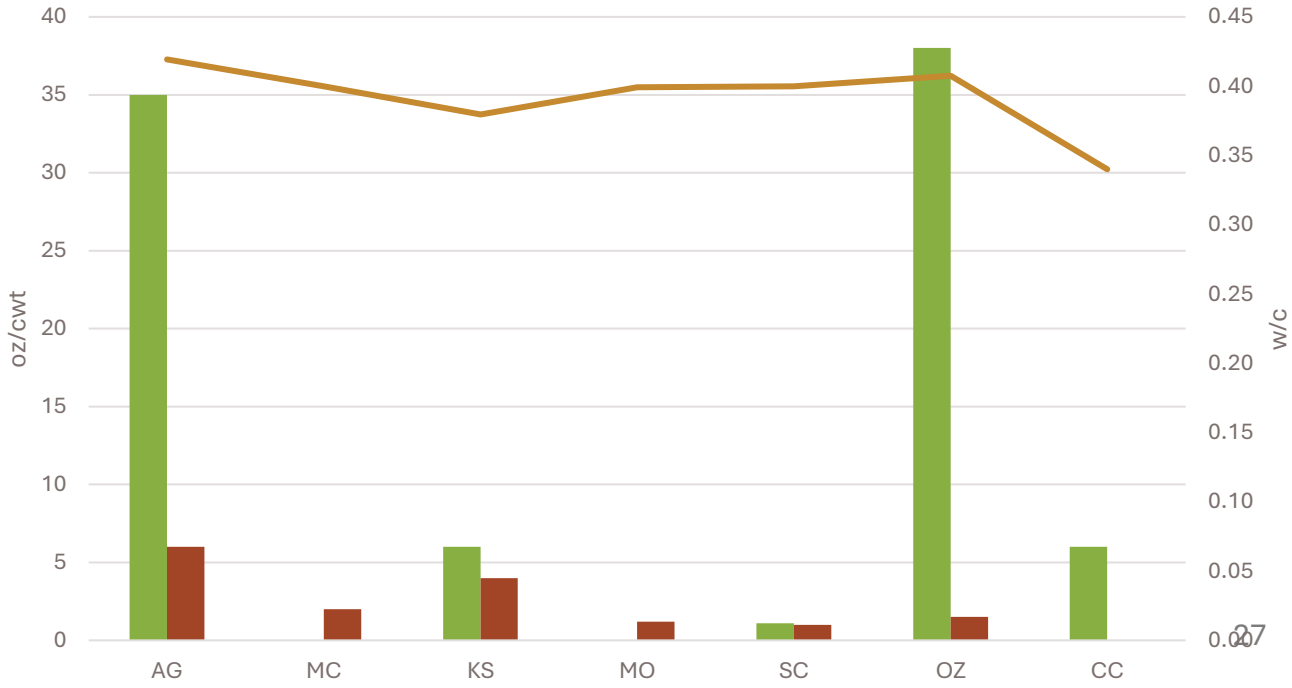
- 7-day = 490 psi
- 28-day control = 565 psi



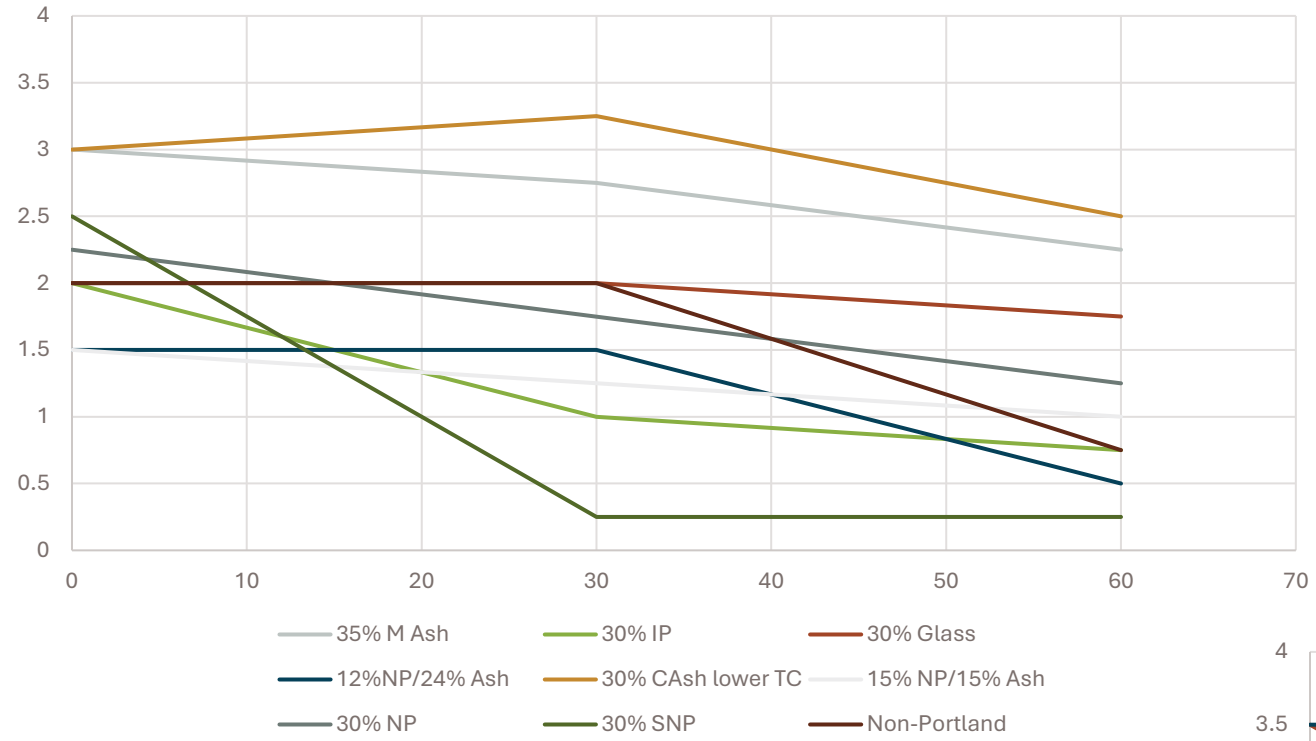
2022 Admixture Dosage



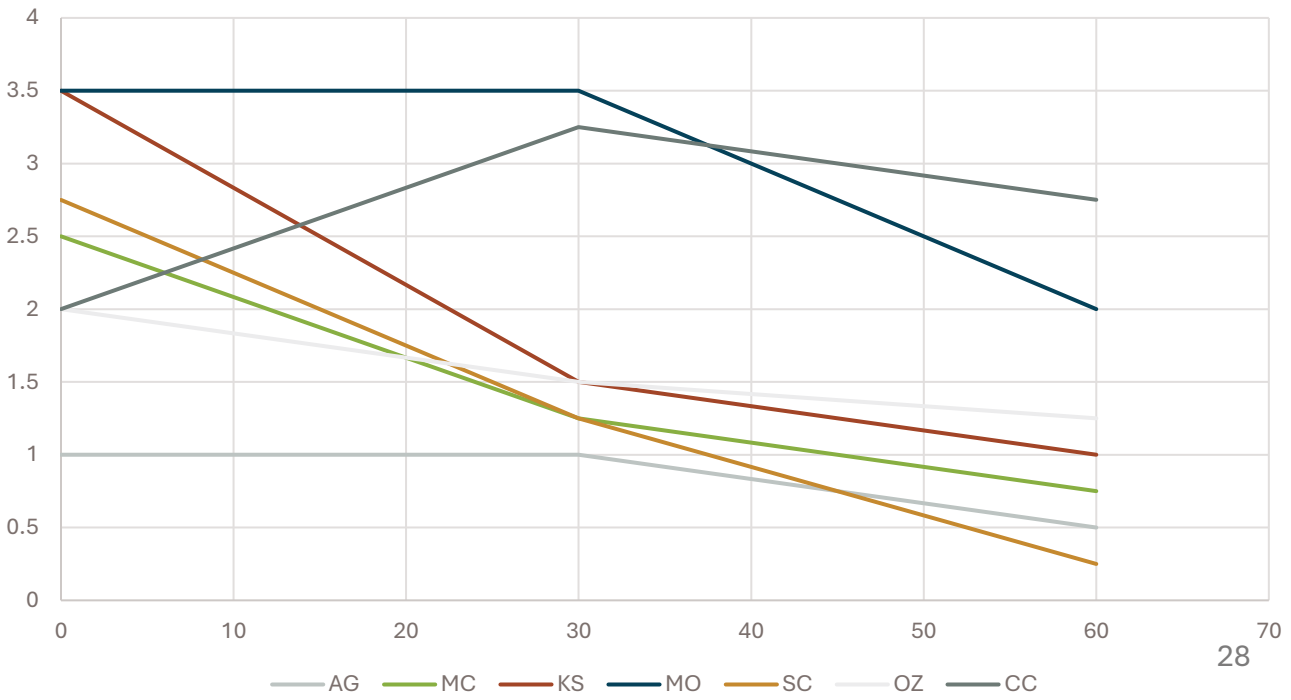
2024 Admixture Dosage Rates

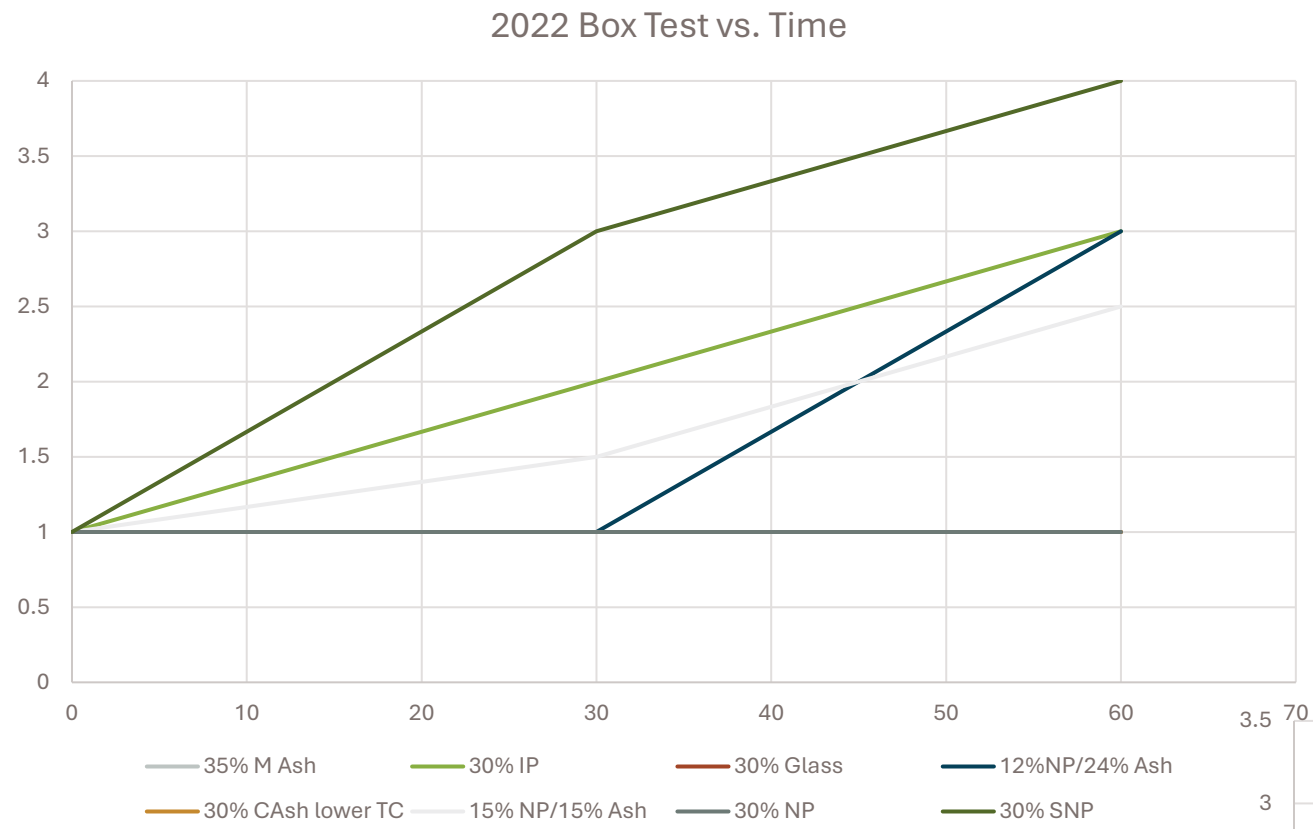


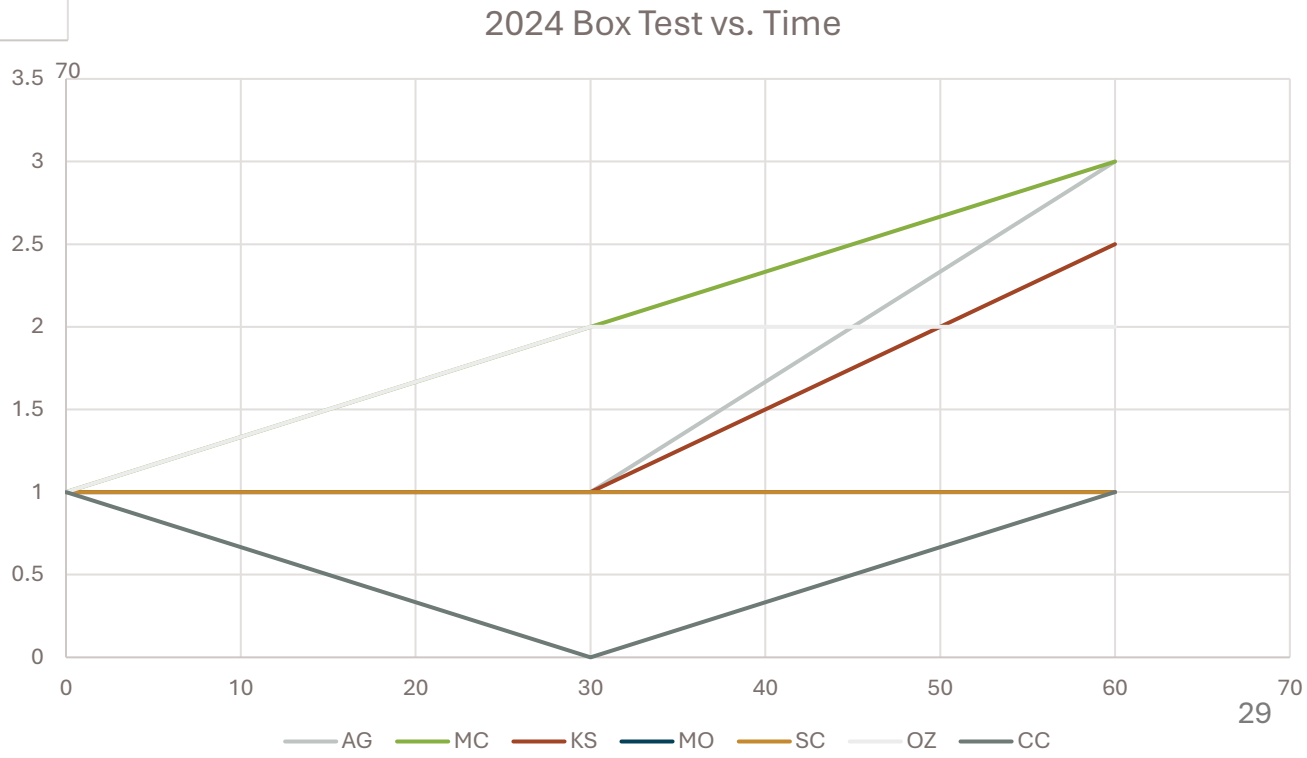
2022 Slump vs. Time



2024 Slump vs Time



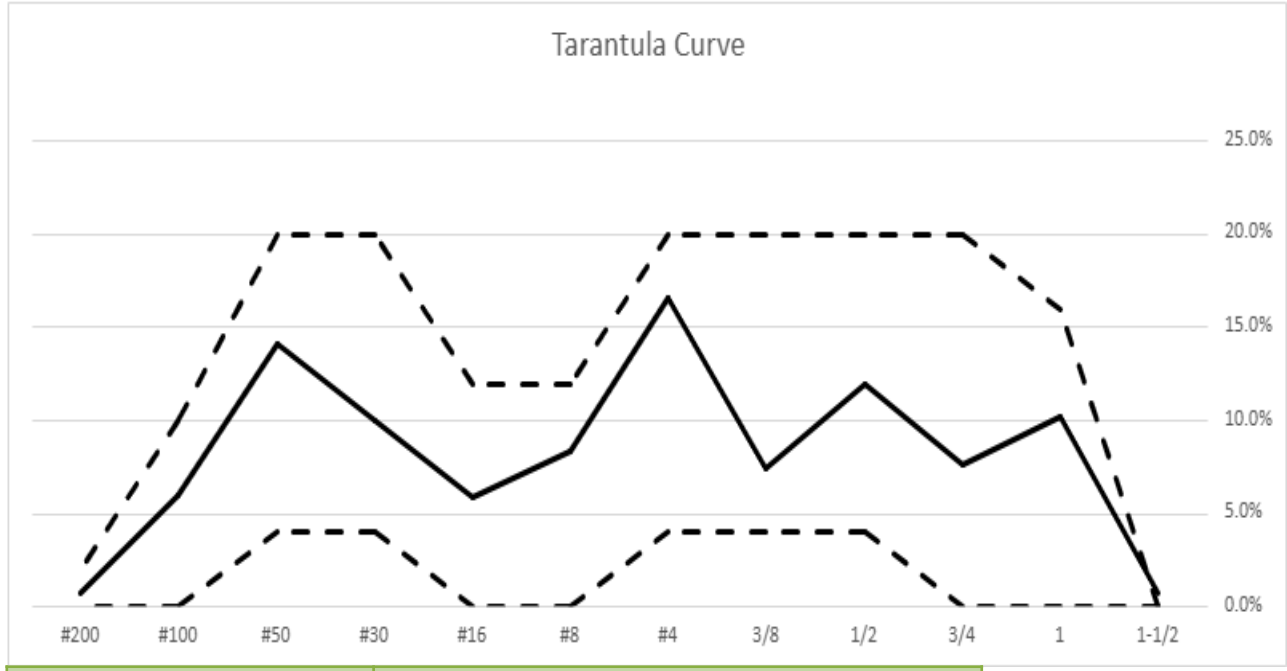

2022 Box Test vs. Time
4
3.5
3
2.5
2
1.5
1
0.5
0
0
10
20
30
40
50
60
35% M Ash
30% IP
30% Glass
12%NP/24% Ash
30% CAsh lower TC
15% NP/15% Ash
30% NP
30% SNP


2024 Box Test vs. Time
3.5
3
2.5
2
1.5
1
0.5
0
0
10
20
30
40
50
60
70
AG
MC
KS
MO
SC
OZ
CC


Labcrete
Realcrete
Researchcrete

Unconventional Paving – MnRoad 2022

- Mixture with Zero Portland Cement
- Great Aggregates and Gradation
- **660 lbs of binder per yard**
- 152 lbs of water per yard
- 0.23 w/binder ratio
- Total paste content was reasonable



Materials	Oven Dry Weights	
Binder	660	(lbs/yd³)
Sand	1655	(lbs/yd³)
3/4 in +	510	(lbs/yd³)
#67	690	(lbs/yd³)
3/8	250	(lbs/yd³)
Water	152	(lbs/yd³)
Air	1.0	(oz/cwt)
Water Reducer	4.5	(oz/cwt)

Step 1
Assemble the components. Hand scoop mixture into box until the concrete level is 9.5 in. (240 mm).

Step 2
From the top surface of the concrete, vibrate straight downward for 3 s.

Step 3
Now, vibrate straight upward for 3 s, then remove vibrator.

Step 4
After removing the clamps and forms, inspect the sides for surface voids and edge slumping.

Figure 3—Box Test Steps (Cook et al., 2015) (*Source: Oklahoma Transportation Center*)

But

- We can get the mix to do this with admixtures

Final Results

- Slump – 3 inches
- Air content – 4.5%
- Time of Set – 2 hours 42 mins
- Flexural Strength
  - 7 days – 680 psi
  - 14 days – 750 psi
  - 28 days – 1000 psi

Different Chemistry than Portland Cement

Alkali Activate Slag

- 700 lb/yd^3 of binder
- Slump – 2 inches
- Air content – 3.0%
- Time of Set – 2 hours 52 mins
- Flexural Strength
  - 7 days – 830 psi
  - 14 days – 835 psi
  - 28 days – 875 psi

Different Properties when Paving

Success Stories

All of these has some portion of Portland Cement in the mix

- Carbon Upcycling – Processing of ash
- Ash Grove – IP
- Urban Mining – Ground Glass
- Terra CO2 – Manufactured SCM
- Optimized Concrete Mixture
- Burgess Pigment – Metakaolin
- 3M – Natural Pozzolan
- Hess Pumice – Natural Pozzolan
- Continental Cement – 20% limestone
- Ozinga – C1157 Cement

- Ashgrove – LC3
- Ternary Blend
- Optimized Concrete Mixture
- Amrize – Quaternary Mix

Air Entraining Issue – Trial Batch or Not

- WWTP construction in Michigan
- Frist 3 trucks of the day are 5.8%, 6.0%, and 5.8% air content
- Fourth Truck is 2.8% air
- Next Two truck are 5.8% and 6.2%
- Seventh Truck is 2.5%

- What happen?

Summary

- Don’t start trail batching until you understand the performance expectations
  - Harden and Plastic
- Start with sound engineering practices in your design.
- Trial placement are critical
  - Placement Techniques
  - Finishing Techniques
  - Curing Techniques

Scary New Products

- The only thing constant in life is change
- Concrete for Paving currently needs Portland Cement
- New product will work in time but needs new chemistry

- Robustness of the mix will be critical

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