



TRC2403-AIR





This project started with the simple main goal of determining – Where should we sample concrete for air content



At the back of the truck



Or at the pump discharge



Currently its common knowledge that **concrete loses air** as it passes through a pump truck and therefor the pump discharge has been **the standard testing location**. – but where does that air go?



Tyler Ley, PE, PhD

Professor at Oklahoma State University for 13 y

Work experience with a contractor, DOT, and a consultant.

Research focus – Constructability, Durability, and Novel Test methods

YouTube Channel > 5M views and > 50K subscribers

CONCRETE FREAK!!!!



Why Do You Lose Air Volume When Pumping Air-Entrained Concrete???
and Why Does the Air Come Back?



Justin Becker, Nick Seader, Chad Staffileno
Tyler Ley, PE, PhD,

Dr. Tyler Ley from Oklahoma State conducted a **pooled fund study** making a compelling argument that the air doesn't go away, it goes into solution and **can't be measured by the conventional air meter**. And more importantly, the air comes back out of solution before the concrete hardens. If you want see the **science behind this phenomenon**, I invite you to check out Dr. Ley's Youtube channel.

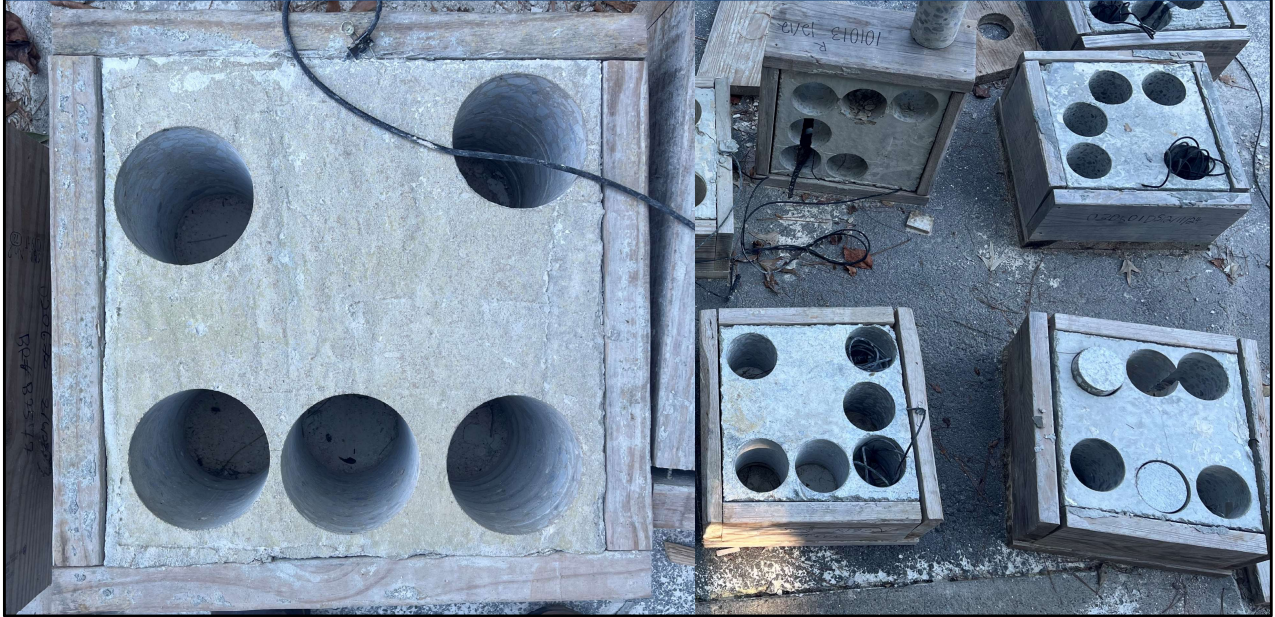


Our goal for this project was to duplicate **Dr. Ley's work** with some minor variation.



We visited **25** Bridge deck pours and took air content readings at the back of the truck and at the pump discharge for comparison. But how do we know **which reading most closely matches** our final product-the bridge deck.

Test Decks



We made concrete “test decks” for **every pour** and cut cores from each deck for **petrographic analysis**.

Petrographic Analysis



Samples from the test deck were sent to the university of Arkansas where an **image analysis system** is used to measure and calculate the volume of air in the samples. So, what did we find?

Preliminary Collection Point Results

- Only Five Petrographic analysis results received.
- Preliminarily the results show no significant difference between sample locations
- Total Samples sent



Job #	050342	090555	BR4707	100657	030501
Air Analysis (%)	4.71	5.31	6.33	3.36	6.80
truck air	5.3	4.9	5	3.7	6.2
Pump air	4.6	6.1	5.9	7.6	7.4
Air Closer to	Pump	Truck	Pump	Truck	Either
Difference in Air (Truck - Pump)	0.7	-1.2	-0.9	-3.9	-1.2

The first definitive conclusion is the University of Arkansas takes a **long time** to complete these test. We have only received **Air Analysis for five samples** thus far.

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We are awaiting more results, but so far, **the hardened air content** is better **represented by** the pump for two samples.

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Two that were closer to the truck

Preliminary Collection Point Results

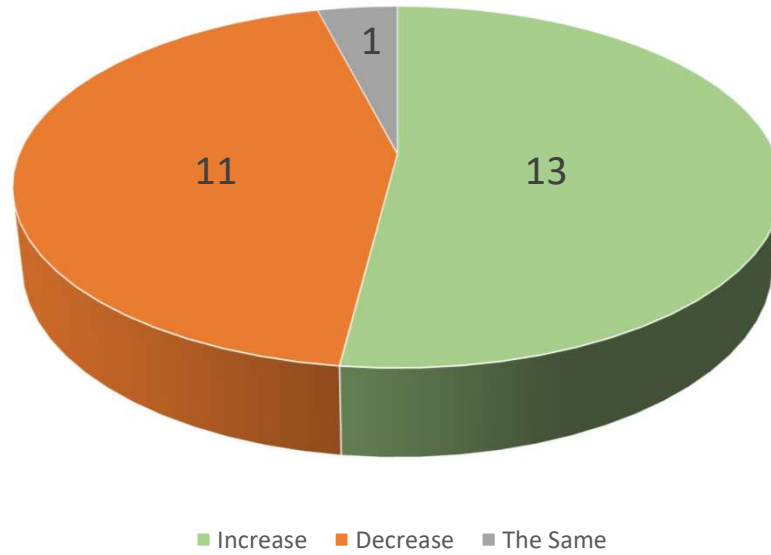
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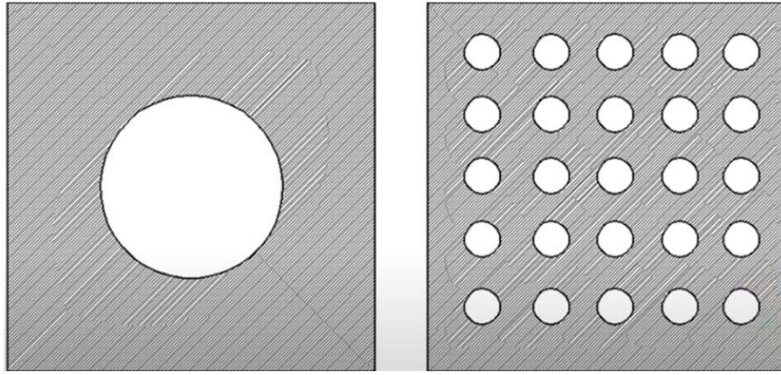
And one that is right in the middle.--- **Not the conclusive results** we hoped for, but as more samples come in, we are **confident a trend will show up**

Air Change After Pumping



One **interesting observation** is that air doesn't always go down during pumping. **The most common explanation** for air going **up** during pumping is that some pump systems are not sealed well and actually draw in air. It will be interesting to see how this plays out **when petrographic analysis is complete.**

Bubble Spacing

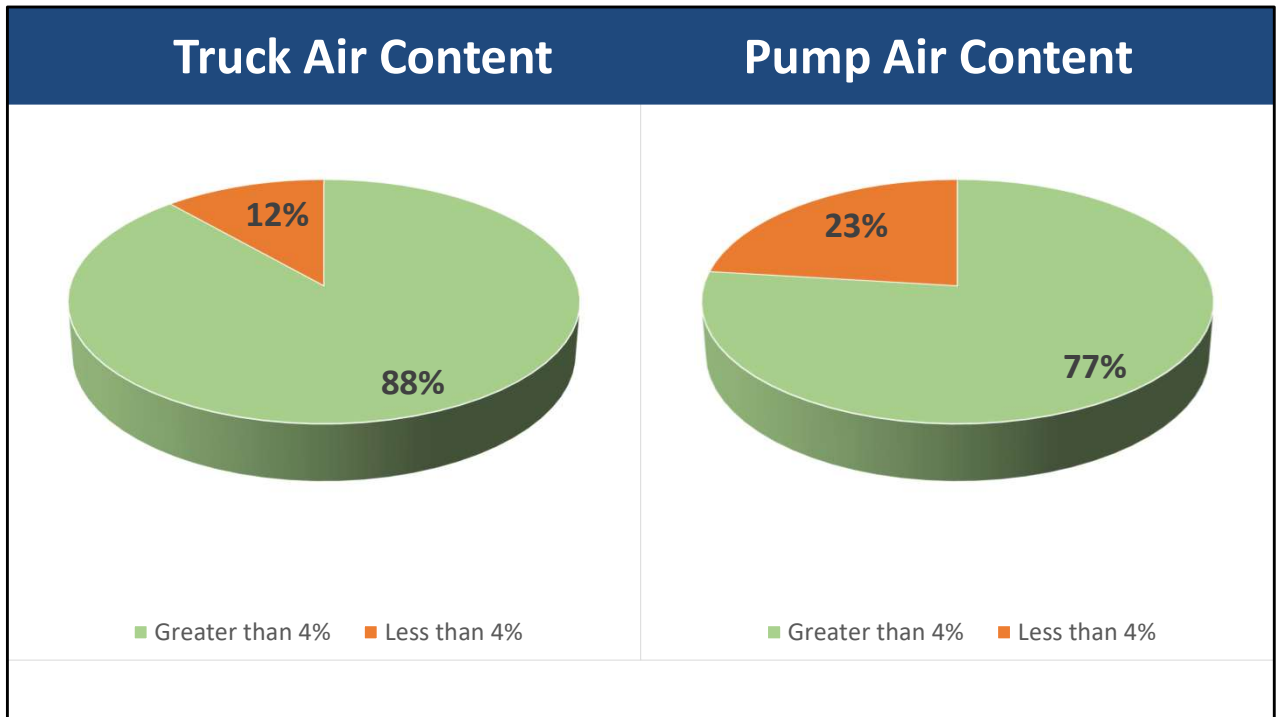


The second goal for the project was to learn the **quality of the Air matrix** in our concrete. If the white circles in these two illustration represent air, and they both have the same air content. We want the picture on the right with the small well distributed bubbles for the best **protection from freezing in our concrete.**

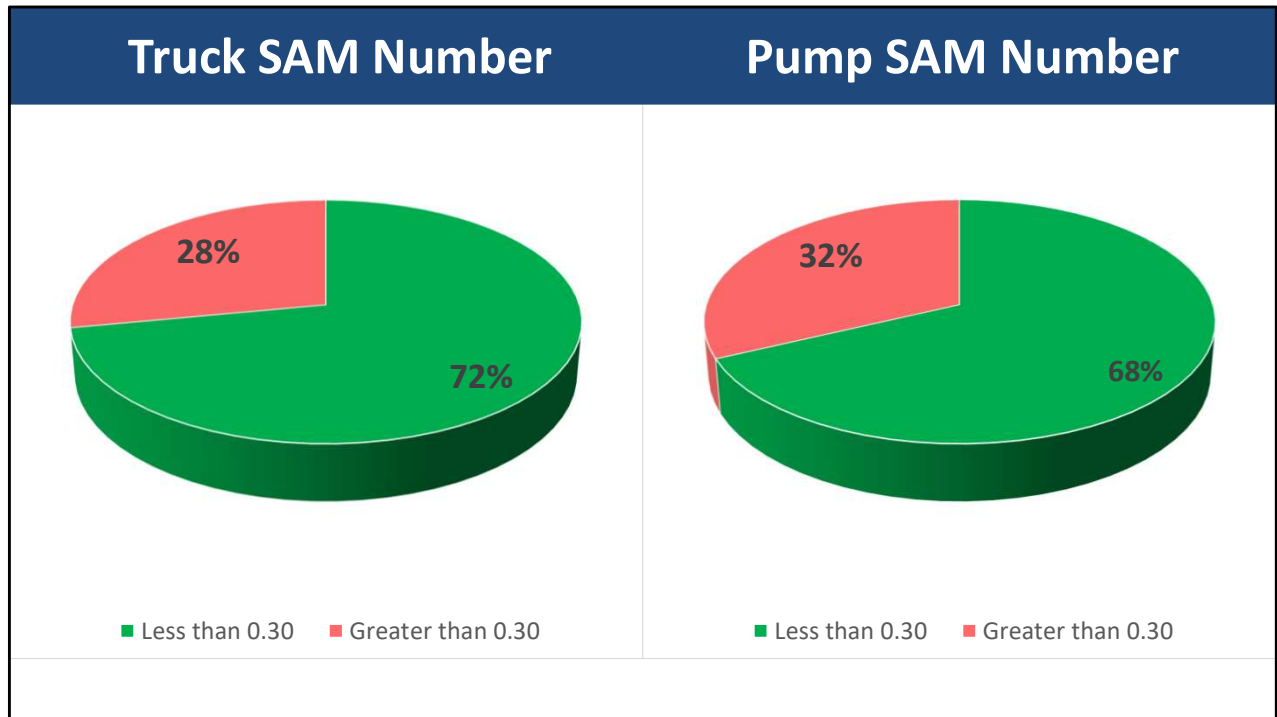
SAM (Super Air Meter)



We used the SAM or Super Air Meter to perform all our tests through the project. It is **similar to the conventional air meter** in which it gives the air content, but it also gives a **SAM number which is an indication bubble of spacing.**



AASHTO R101 Says we need an air volume > 4% **to give us protection from freezing.**
 The bridge deck pours we observed 88% from the truck were greater than 4% and 77% after going through the pump were greater than 4%...



AASHTO R101 also says a SAM number <0.30 in which 72% from the truck were in range and 68% from the pump.

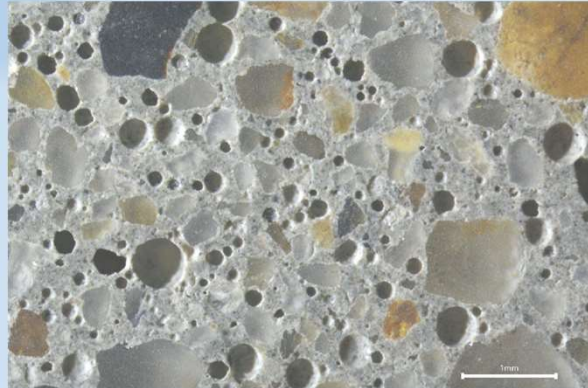
Most of the time we **get the required air content** but there is work to be done to **optimize our air matrix**.

(add reasoning) for self not presentation

Petrographic Analysis

Petrographic Analysis provides:

- Total Air Content (%)
- Spacing Factor (in.)
 - The Distance between air bubbles in hardened concrete
 - Ideally less than 0.008 in.
 - Freeze/Thaw Protection



We will get another piece of the **air durability puzzle** with our petrographic analysis. It will give us a **spacing factor** (distance between bubbles) along with the previously discussed air content of samples.

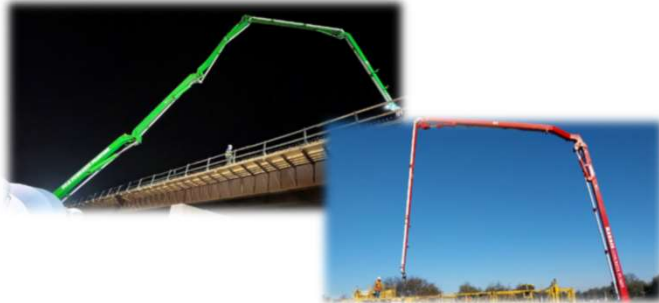
Now, Originally, Deciding where we should **sample for air testing** and the **quality of our air matrices** were the **two focus areas** for this project.

However, **my boss, Mr. Tinsley** likes to say that he is full of two things and **one of them are great ideas**. As his intern great ideas translates to more work.

Information Collected

Initial Collected Information:

- SAM Number
- Air Content from Pump and Truck
- Slump
- Mix Design Information
- Outside Temperature
- Free Fall Height
- Pump Angle photos
- Pump Diameter and Boom Length



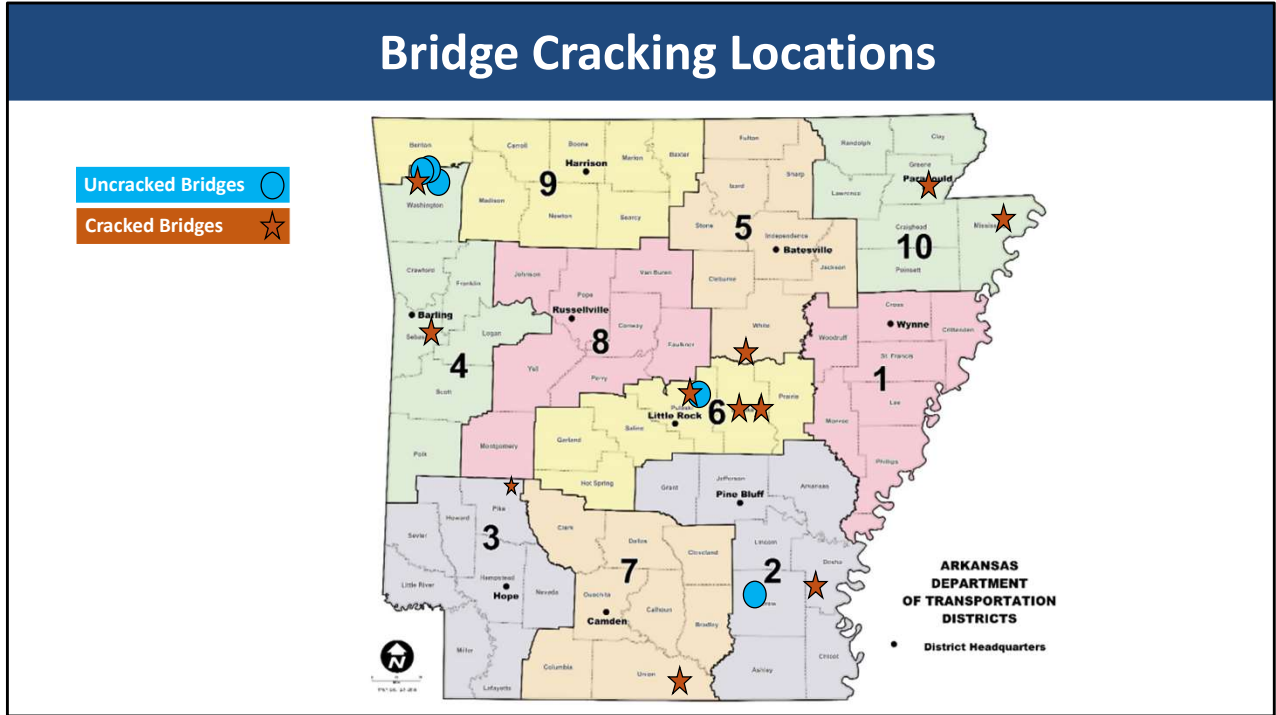
Final Collected Information:

- Evaporation Rate
- Time of Sample Collection and Testing
- Hose Diameter
- If the Pump Configuration was altered during Collection



A great idea Mr. Tinsley had early in the project was to collect as **many variables** as possible while we observed the bridge pours including (first set of bullets) Later on we started collecting.....

Bridge Cracking Locations



Since we collected so many variables, we decided to revisit each of the bridges we collected data at to see which had cracks and which ones did not.

Bridge Cracking Locations

CRACK INTENSITY RATINGS

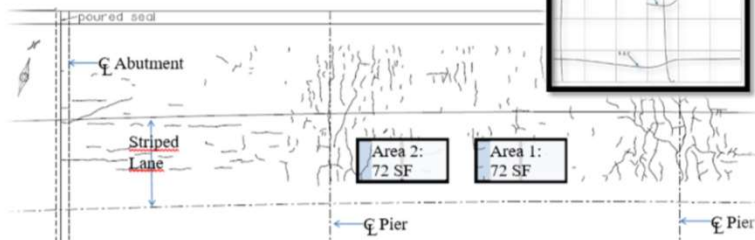
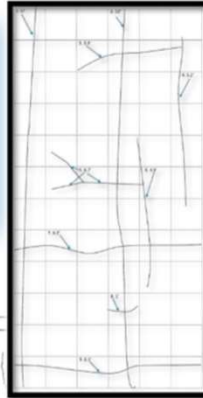


Figure 2: Illustration of crack mapping areas that will be used to characterize general cracking condition of the bridge deck surface

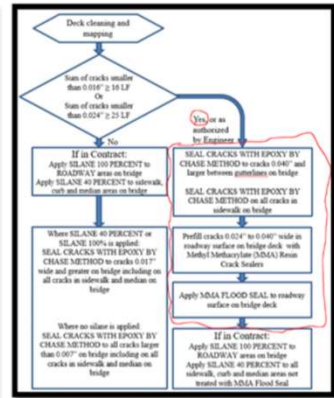


Bridge 27148
Prairie Center Drive

Area 1
Per Engineers Request
A1 (Black)

1. 12'
2. 12'
3. 3.3'
4. 5.2'
5. 6.7'
6. 4.9'
7. 6.2'
8. 1'
9. 6.1'

TOTAL: 57.4'



Meanwhile, the Research section is **supporting the project** by conducting Crack Intensity **Measurements**.

Cracking Measurements



The team from Research is using an **8'x 8' frame** and measuring the average crack **width** and **length**. They are comparing these field measurements to an image analysis software to compute crack length.

This will allow for a fast way to quantify the crack intensity.

Specification Options

CIR Range (ft/ft ²)	CIR Rating	Required Remediation
0.00 - 0.05	5	Bonus Payment to contractor, Additional bonus for low permeability & SAM below 0.3
0.06 - 0.20	4	Crack Sealing with approved Material
0.21 - 0.40	3	Crack Sealing and Upgraded Protective Surface Treatment
0.41 - 0.70	2	Healer / Sealer Treatment Required
0.71 - 1.00	1	Epoxy Overlay
> 1.00	0	

The goal for this extra work is to **develop a Specification** that incentivizes contractors to produce durable, crack free bridge decks and clearly define what action will be taken to remediate decks based on crack intensity. The District Engineers will soon receive a survey asking for locations where repairs were required during construction so we can start gathering performance data.

Core Resistivity

Job Number	Corrected (kΩcm)
061741	8
BR6210	9
100993	11
101124	11
020590	11



Job Number	Corrected (kΩcm)
012326	12
070471	12
012326	13
012326	13
101013	17
CA0604	19



- Cores were placed in a limewater bath, 3 g/L ratio of calcium hydroxide as per ASTM C511, for 4 days
- Cores were removed and marked
- Cores were rolled over a damp cloth
- Cores were tested by calibrated Resipod Proceq
- Values were corrected by 1.1 factor according to AASHTO T358-24

Someone –I'll let you guess who- had the **great idea** to borrow a surface resistivity meter from the Federal Highway Administration Mobile Concrete trailer. This test gives an **indication of the permeability and therefor durability** of concrete.

Core Resistivity

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**Low Resistivity,
Highly Permeable**

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The cores with a red corrected resistivity value are highly permeable.

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**Moderate Resistivity,
Moderately Permeable**

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the yellow are moderate.

None of the samples indicated high resistivity and therefore low permeability.

Once we **have all our testing** completed and **Research completes the cracking inspections**, ARDOT will be able to make **data-based decisions** on how to write the performance-durability specification.



Yes the great ideas continued when Mr. Tinsley discovered a new product

Maturity Meters

Conventional Maturity Meter

- Uses the principle that concrete strength is directly related to the hydration temperature
- Collects Internal Temperature
- Hydration Curve Needed
 - 15 Cylinders created with a specific Mix Design

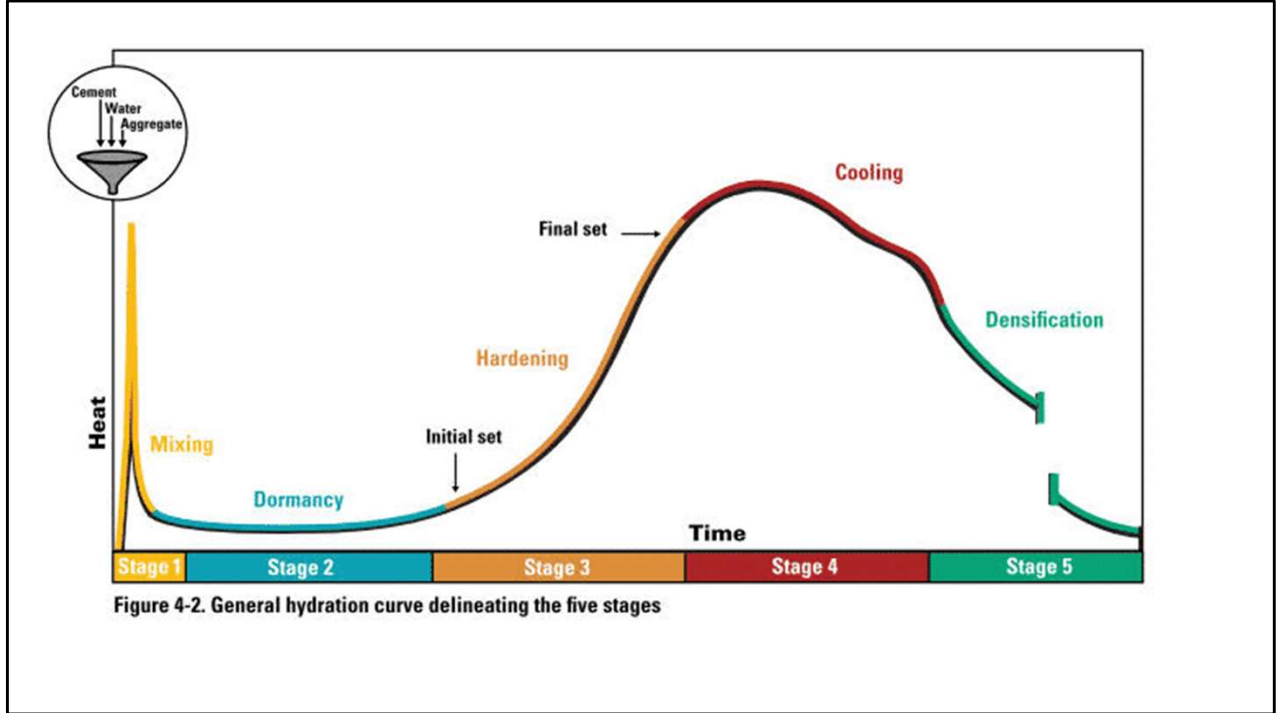


Stiffness Based Maturity Meter

- Collects Internal Temperature and Relates Stiffness to concrete strength
- No Hydration Curve
- Used on all Mix Designs



We had the opportunity to evaluate the newest concrete strength sensors on the market.



Conventional Maturity Meters which are widely accepted, correlate the strength of concrete to the area under the hydration time/temperature curve. They are widely used, but come with one drawback.



Calibration requires casting 15 cylinders and if the mix changes, the calibration must be repeated.

Stiffness Based Maturity Meters

Goal of Stiffness Maturity Meters:

- No Calibration needed
- Skips having perfectly representative concrete from calibration to mix design on site
- Constant data
- No destruction of concrete to gain strength data

 GIATEC



 wavelogix



The new “stiffness based” sensors do not require calibration. These sensors measure temperature, but they also perform strength predictions by sending a pulse into the concrete and reading the return to estimate stiffness which is a direct correlation to strength. We placed 18 of these sensors in our test decks and conducted one large scale experiment.

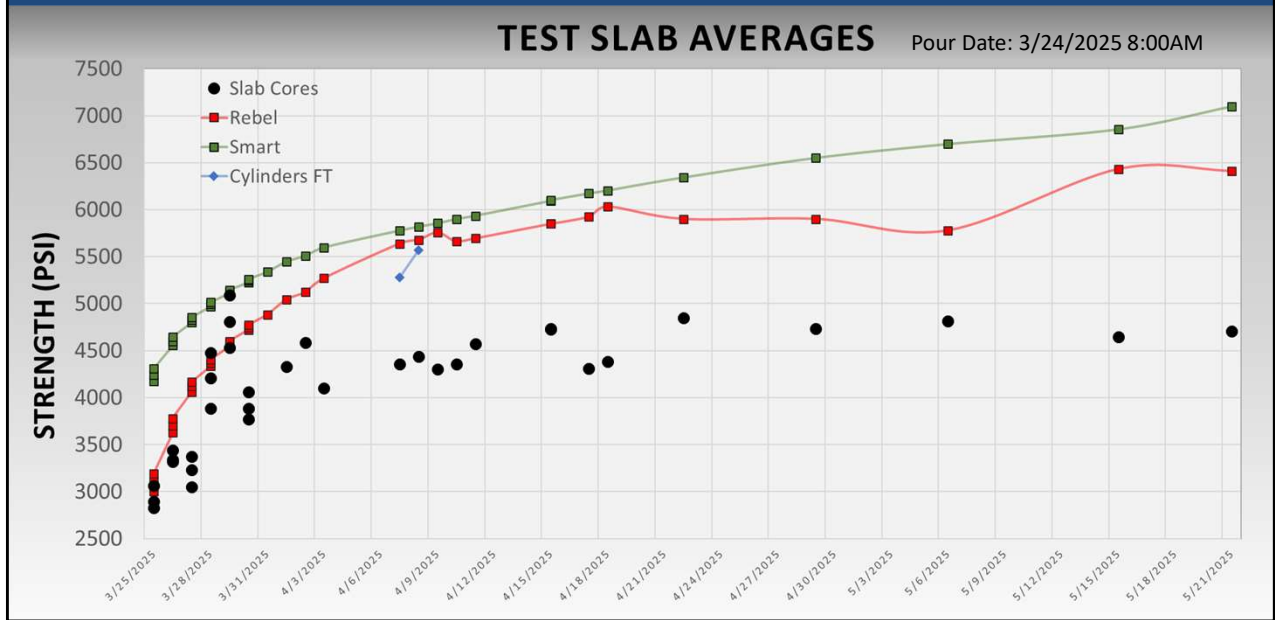
These sensors could be very useful for special applications such as removing formwork or opening pavement to traffic because they embedded in the actual structure as opposed to relying on cylinders to represent the structure

Test Slab



The test slab! This large-scale experiment involved constructing a 10' x 10' x 10" thick concrete pad. Four sensors of each type were embedded into the slab and a total of 72 cores were taken to correlate with the values predicted by the sensors.

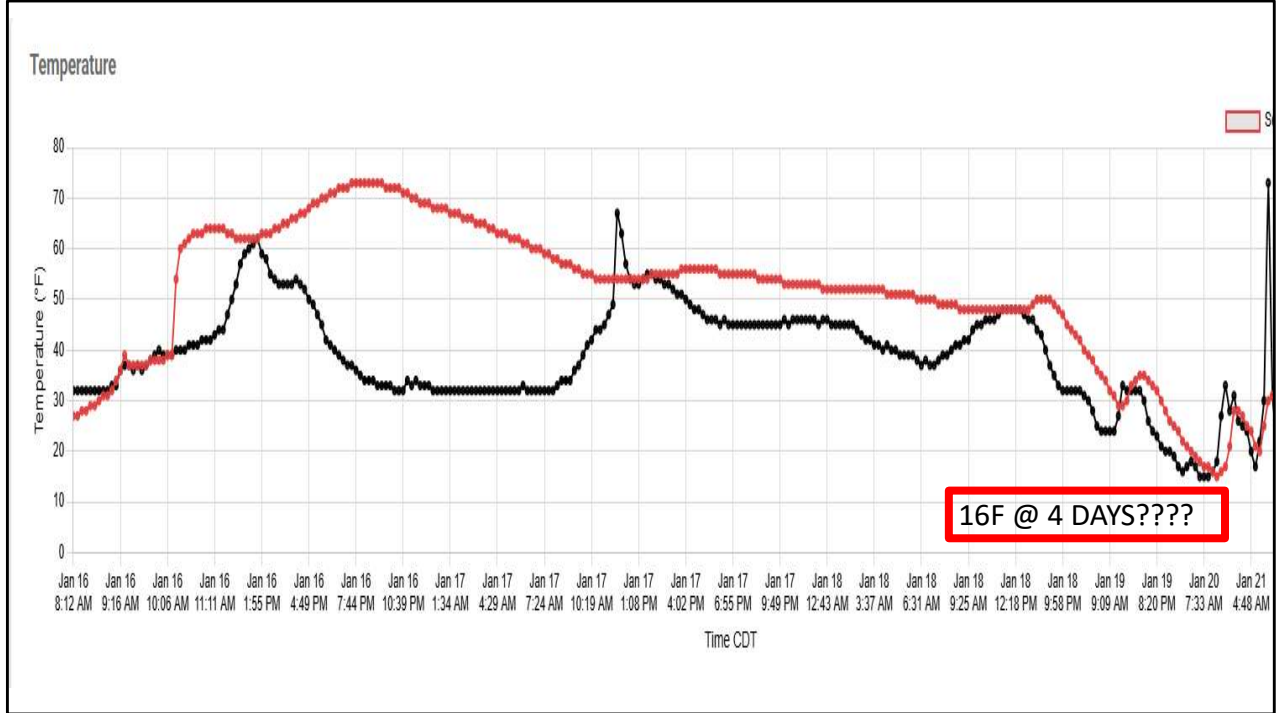
Test Slab Strength Graph



What did we learn? We think they have potential, but there is still a lot of work to do. The red line represents strength predictions for the wavelogix sensors, the green line represents the Smart Rock sensors strength predictions, and the black dots represent core strength at the same time from concrete placement.

To be fair, the Wavelogix sensor had only been on the market a couple of months when we received our first shipment, and our first shipment of Smart Rocks sensors came before they were commercially available.





We noticed that one of the bridge decks where we had placed a maturity meter was allowed to fall to 16F at only 4 days after placement. This left us wondering???

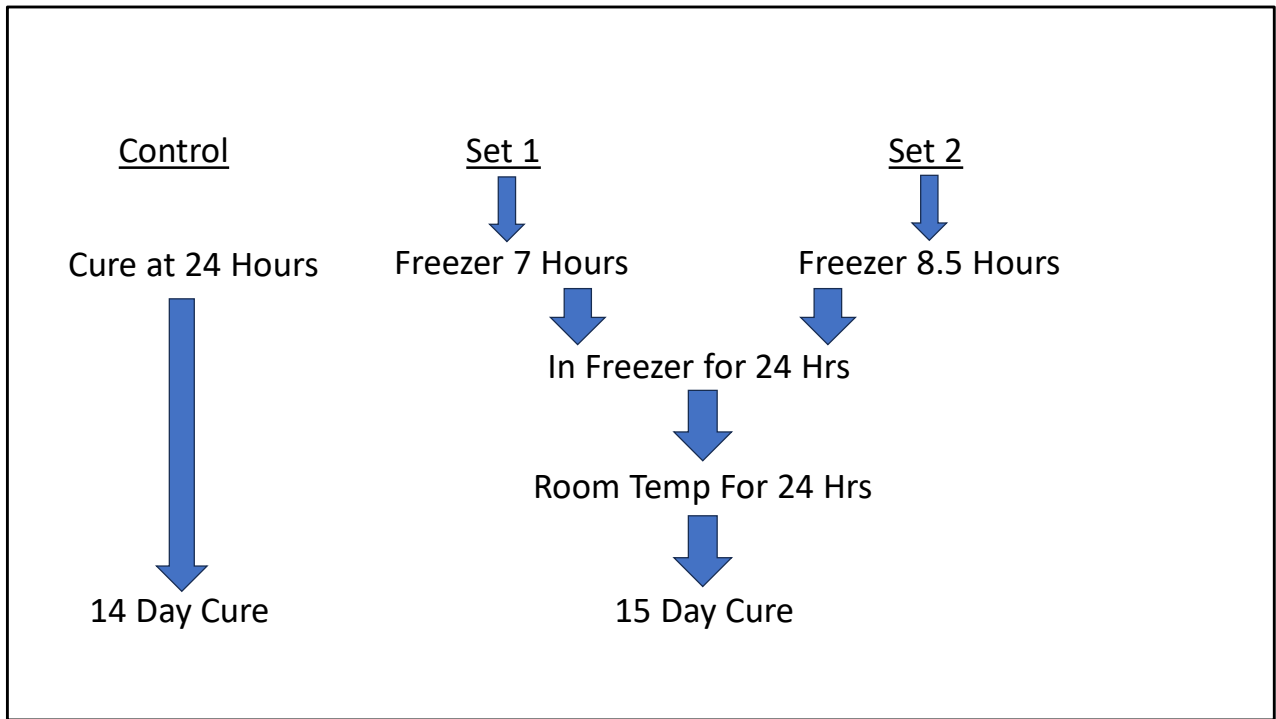




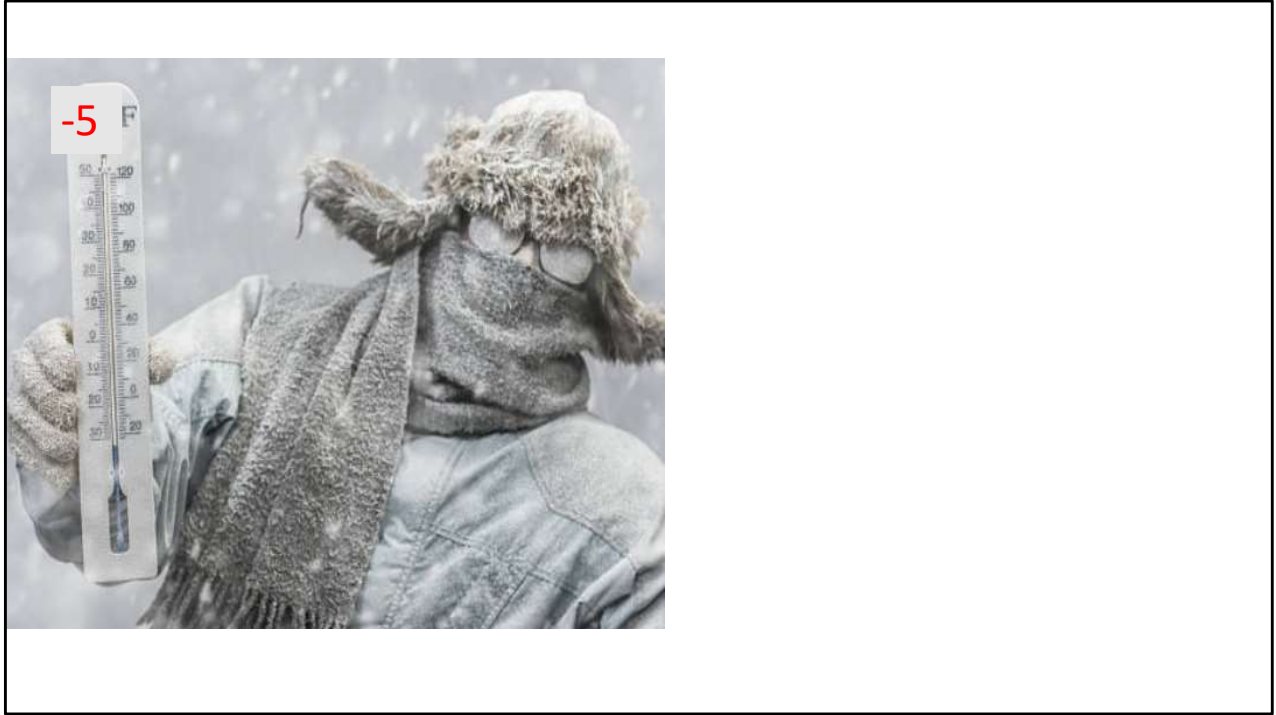
▶ “Once concrete has achieved a compressive strength of 500 psi (3.45 MPa), it is commonly considered to have enough strength to resist expansion and internal damage from a freeze thaw cycle”

After some research, we found that The American Concrete Institute says “read Slide”. When we showed this information to Mr. Tinsley he said





Prompting another great idea. We conducted an experiment where..... This follows what ACI



We put them in a freezer that was -5°F to make sure they were good and frozen



Control 5280 PSI



Control 5280 PSI
Set 1 5587 PSI
Set 2 5553 PSI

Set 1 and 2 broke higher than the control. Which is great! This follows what AIC has stated proving they have quality data.

(Cyclical freezing cycles – Top 1/4”)

Tyler Ley's Research Video



SCAN ME