PLACING, CONSOLIDATING AND PUMPING AIR ENTRAINED CONCRETE
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THANK YOU FOR BEING HERE!
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I will be happy to say in the room afterwards to respond to your questions and comments!

Description: There is a lot of confusion surrounding placing, pumping, and vibrating air entrained concrete. This seminar, presented by one of the industry’s leading experts, will dispel those myths and get to the facts to take advantage of effective placing methods. Understand all the factors such as the concrete mixture itself, types of admixtures, slump, combined aggregate grading, pumping rate and pressure, the rate of depressurization, angle of the boom, the length of free-fall, and the manner in which the concrete exits the line.

LEARNING OBJECTIVES
1. Know when changes in air content mean changes in freeze-thaw durability.
2. Plan pumping operations to minimize effects on air entrained concrete.
3. Speak-up in pre-pour conferences about how non-standard, point-of-placement test-methods change the test results.

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OUTLINE
- Pores are the problem
- Why we need air: Freeze-Thaw
- How to get the air
- How to keep the air we want
- Getting rid of air we don’t want
- Measuring what we got

PRE-NAP POINTS
- Loss of air DOES NOT always mean loss of freeze-thaw durability.
- Nobody knows the correct way to sample and test air content at the end of the pump line.
- Because there is no correct way to do it.
ASTM C231 Pressure
Air Meter
ASTM C173
Volume Air Meter

Concrete Composition
Air Entrained Concrete

Rich Mix
Air Entrained Concrete

Lean Mix
Air Entrained Concrete

AIR/PASTE Ratio
Air Entrained Concrete

Rich Mix

Lean Mix

Air-Entrained Concrete

Straight Pins
Air Entrained Concrete

• Concrete to which a detergent has been intentionally added for the purpose of stabilizing air bubbles formed during the concrete-mixing process.

Air Entraining Admixture

REASONS: FRESH CONCRETE

• Improved Workability
• Water Reduction
• Reduced Segregation
• Increased Cohesiveness
• Less Sand

REASONS: HARDENED CONCRETE

• General benefit of lower w/c
• Improved water-tightness
• Improved sulfate resistance

• Improved Freeze-Thaw resistance
• Improved Scaling Resistance
When Freeze-Thaw Damage is the problem, Air Entrainment is the solution. A Key Part ofAlong with mix-design, aggregates, placing, vibrating, finishing, and curing

When Freeze-Thaw Damage is NOT the problem, Air Entrainment is not necessarily a good idea...

DISADVANTAGES: HARDENED CONCRETE
- Strength Reduction
- Porous Paste
- Aggregate Interface
- Required Compensations
  - Lower water content
  - Admixtures
  - Higher cement content
  - Cost
  - Heat
  - Shrinkage

What's the downside?

Clustering of Air Bubbles

200-250 psi per 1% air

Strengthen and Air Content

613 lb of cement per cu yd

6 x 12-in. cylinders
DISADVANTAGES:
FRESH CONCRETE

- Stickiness
- Finishing Problems
- Bleeding, Plastic Cracking, Delaminations
- Variable Volume – Yield problems
- Interaction with other admixtures

"ASC
c
concrete contractors will hard-trowel air-entrained concrete if required by specification,..."

"...but only with the acknowledgment that the risk associated with delamination or blistering and the changes in hardened air void parameters are entirely the responsibility of the specifier."

ACI 302 - Construction of Floors
- Entrained air not recommended when smooth, dense, hard troweled finish required

ACI 301 - Specification
- Intentionally entrained air should not be incorporated in normalweight concrete slabs to be given a smooth, dense, hard troweled finish.
REASONS: HARDENED CONCRETE

- General benefit of lower w/c
- Improved water-tightness
- Improved sulfate resistance
- Improved Freeze-Thaw resistance
- Improved Scaling Resistance

HARDENED CONCRETE

- Control porosity by controlling water
- Control Finishing
- Wet Curing
- Temperature Control
- Frost-Resistant Aggregate
- Air-Entrained Paste

FROST AND SCALE RESISTANCE

- ✓ Control porosity by controlling water
- ✓ Control Finishing
- ✓ Wet Curing
- ✓ Temperature Control
- ✓ Frost-Resistant Aggregate
- □ Air-Entrained Paste

Air Voids Do Not Protect Aggregate
Frost Resistant Concrete Requires

• Durable, Frost Resistant Aggregate
• Air-Entrained Paste

Why does this happen?
And how do air bubbles prevent it?

Concrete is a Porous Material
Concrete is Porous

Penetration of Salts, Liquids, and Gases into the Concrete

Why does this happen? And how do air bubbles prevent it?
Air Void

SIZE (of the air bubbles) MATTERS

http://datagenetics.com/blog/december2013/index.html

The Protected Paste Shell
Air Void

0.010 INCHES OR THEREABOUTS

10 mil poly slab underlayment
WANTED:
- Large number of small voids
- Well distributed in paste
- Prefer bubbles around 5 mils
- < About 10 mils to nearest bubble
- Air vol about 18% of paste vol

Characteristics of AE Concrete
- 4-6% air bubbles by vol. of concrete
- 1 to 2 ft³ air bubbles / CY
- 10-15 billion air bubbles / CY
- 2 million in² air bubble surface area / CY
- 1500 SY of bubble surface area / CY
- Bubble Size Matters!
BUBBLE MANAGEMENT

<table>
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<tr>
<th>Obtaining Air</th>
<th>Retaining Air</th>
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<td>• Transport</td>
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<tr>
<td>• Thorough Mixing</td>
<td>• Placing</td>
</tr>
<tr>
<td>• Re-dosing AEA</td>
<td>• Consolidating</td>
</tr>
<tr>
<td>• Transport</td>
<td>• Finishing</td>
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</tbody>
</table>

AIR-ENTRAINING ADMIXTURES

The Fishing Bobber

Operates at the “Air-Water Interface”

Repelled by water (oils, fats, resins)

The Air-Entraining Admixture

Operates at the “Air-Water Interface”

Attracted to water (salts)
Air Bubbles vary in Size

From smaller than cement to larger than coarse aggregate

Air Bubble
Stabilized
By Air-Entraining Admixture
WHAT THE NAMES REALLY MEAN

“Entrapped”
- Coarse
- Rain drops
- Inefficient
- Less protection per unit volume
- More impact on strength

“Entrained”
- Fine
- Fog droplets
- Efficient
- More protection per unit volume
- Less impact on strength

TESTS OF FRESH CONCRETE ESTIMATE
TOTAL AIR VOLUME ONLY—THESE TESTS DO NOT PROVIDE INFORMATION ON BUBBLE SIZE!
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TESTS DO NOT PROVIDE INFORMATION
ON BUBBLE SIZE!

FACTORS AFFECTING THE AIR VOID SYSTEM
Mix Ingredients
Batching/Mixing/Transport
Construction Practices

ADMIXTURE INTERACTION WARNING
• Carbon-Bearing Materials
  • Portland Cement
  • Fly Ash
• Carbon can neutralize the AEA and reduce air content
• Carbon can neutralize the defoamer in HRWRA or Latex and increase air content

INFLUENCE OF WATER
• Temperature
• Hardness (calcium)
• Treated water
• Well water
• W/C
• Water Content

batching  mixing  transport
Placing

**FIRST LAW OF AIR ENTRAINMENT**

• There is almost always too much or too little air. Air volume meets specs only when no testing is performed.

**SECOND LAW OF AIR ENTRAINMENT**

• On those rare and happy occasions in which there is just about the right amount of air, further investigation will show that the bubbles are either too big or too small.

**THIRD LAW OF AIR ENTRAINMENT**

• Air Bubbles Obey the Laws of Physics.

**FOURTH LAW OF AIR ENTRAINMENT**

• The Laws of Physics are the responsibility of the contractor, and shall be submitted for approval.

**LAWS OF PHYSICS**

• Air and Water Don’t Mix
LAW OF PHYSICS

• Bubbles expand when heated

• Bubbles shrink when cooled

LAW OF PHYSICS

• Bubbles are fragile:

  Do not drop, shake, or vibrate!

• Little guys are tougher than big guys

Effects of Free Fall

Break air bubbles on impact

Inside or outside of line
Impact at Elbows
Impact at Placement

Effect of Pump Boom Configuration

Consolidation by Vibrator: Air Bubble Hunter-Killer

Effects of Finishing

Laws of Physics

- Bubbles compress when squeezed
- Bubbles expand when pressure released

Finishing

Removal of Air Bubbles Near Surface (Rapid depressurization?)
Pressure Increase

Pressure Decrease

Air voids before compression

Most air bubbles at atmospheric pressure

Compressed air voids

Smaller air bubbles - Lower air content

Higher compression

Smaller air bubbles - Lower air content

Controlled decompression

Larger air bubbles - Greater air content

Back to normal pressure

Larger air bubbles - back to normal
National Ready-Mixed Concrete Assn. & American Concrete Pumping Assn. Test Program-Baltimore

Free Fall

NRMCA TEST - 2A
Free Fall, Slow Discharge < 50 CY/hr

Air Content (%)

NRMCA TEST - 3A
Free Fall, Rapid Discharge < 100 CY/hr

Air Content (%)

NRMCA TEST - 3B
Free Fall, Faster Than 3A

Air Content (%)

NRMCA TEST - 4A
Free Fall, Slow Discharge

Air Content (%)

NRMCA TEST - 4B
Free Fall, Rapid Discharge

Air Content (%)
The "Loop"

PARTICIPANTS:
- Schwing America
- Cemstone / Wyatt
- American Engineering
- Concrete Microscopy, Inc.
- Minnesota DOT
- Cornell University

NRMCA TEST - 4C
4-Elbow Loop, Slow Discharge

Schwing Tests, White Bear, Minnesota

PARTICIPANTS:
Avg. Bubble Dia. (mils.)

Smaller is better

Spacing Factor (mils)

Lower (closer) is better

Spacing Factor (mils)

Lower (closer) is better

Spacing Factor (mils)

Lower (closer) is better

Spacing Factor (mils)

Lower (closer) is better

Spacing Factor (mils)

Lower (closer) is better

Durability Factor (%)

ASTM C666 Freeze-Thaw Testing

Durability Factor (%)

108 Chute 77 Chute 77 Kink 77 Free Fall 285 Conveyor
Air at the Chute (%)
Apparent Rate of Air-Loss Rate AT THE CHUTE:
2% / Hour

HOW MUCH AIR DO YOU NEED?

• How much paste do you have to protect?
• How severe is the exposure?
• How small are the bubbles?
• Who are you asking?

HOW MUCH AIR DO YOU NEED?

TABLE 4.1 — TOTAL AIR CONTENT FOR CONCRETE EXPOSED TO CYCLES OF FREEZING AND THAWING

<table>
<thead>
<tr>
<th>Water Content</th>
<th>Average Bubble Rad</th>
<th>Required Air Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.0% air</td>
<td>0.003 in.</td>
<td>0.005 in.</td>
</tr>
<tr>
<td>4.0% air</td>
<td>0.004 in.</td>
<td>0.006 in.</td>
</tr>
<tr>
<td>5.0% air</td>
<td>0.006 in.</td>
<td>0.008 in.</td>
</tr>
</tbody>
</table>

TABLE 4.2.1 — EXPOSURE CATEGORIES AND CLASSES

- Category: Severity
- Class: Exposure
- Condition: Freezing and thawing
- Fresh (pre-loss) or Hard (post-loss)

Legal responsibility of designer/specifier to include Exposure Category in contract documents.

HOW MUCH AIR DO YOU NEED?

- How much paste do you have to protect?
- How severe is the exposure?
- How small are the bubbles?
- Who are you asking?

- Fresh (pre-loss) or Hard (post-loss)?
**Concrete materials and methods of concrete construction**

The concrete will be considered to have a satisfactory air-void system when the average of all tests shows a spacing factor not exceeding 230 μm (0.009 inches), with no single test greater than 260 μm (0.010 inches), and air content greater than or equal to 3.0% in the hardened concrete.

For concrete with a water-to-cementing materials ratio of 0.36 or less, the average spacing factor shall not exceed 250 μm (0.010 inches), with no single value greater than 300 μm (0.0118 inches).

**C172-14 Standard Practice for Sampling Freshly Mixed Concrete**

**NO Standard Method Exists**
**POINT-OF-PLACEMENT SAMPLING COMPLICATIONS**

1. Before or after finishing?
2. Before or after consolidation?
3. Before or after placing?
4. Before or after concrete hits form?
5. “Clean catch?”
6. Composite sample?
7. Representative?
8. Safe?

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**A Story Problem:**

How long does it take to fill bucket if pumping rate is 60 CY/HR?

5 gal. x = 0.133680556 cubic foot / gal
0.66840276 cubic feet / (60x27.000)

= 0.000412594 hours

About a second and a half

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**If point-of-placement sampling is required:**

- It must be specified, not assumed
- It should be in addition to at-the-chute tests
- An unbiased sampling method must be developed and described by the specifier
- Point-of-placement acceptance criteria should be different from point-of-discharge acceptance criteria

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**IN-PLACE CRITERIA FOR AIR CONTENT NOT NECESSARILY SAME AS DELIVERY CRITERIA!**

*ACI 318 Chapter 5, Strength Evaluation*

5.6.5.4 — Concrete in an area represented by core tests shall be considered structurally adequate if the average of three cores is equal to at least 85 percent of $f'c$ and if no single core is less than 75 percent of $f'c$. 
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For concrete with a water-to-cementing materials ratio of 0.36 or less, the average spacing factor shall not exceed 250 μm (0.0010 inches).

CONCLUSIONS:

- Air is a moving target
- Air measurements approximate
- Multiple tests required
- Air loss expected with handling
- Air loss expected with vibration

CONCLUSIONS (CONT'D.):

- Loss of larger bubbles most likely
- Air Loss not equal to durability loss
- Expect different effects with different mixes
- Beware of non-standard sampling methods
- Specify hardened air on critical placements

SUGGESTIONS

- Minimum pressure increase
- Avoid rapid decrease in pressure.
- When possible and safe, do not slow pump rate to take samples.
- Take multiple samples at the chute for every sample taken at the hose.
- Consider different air criteria at end of hose (3 or 4%).

THANK YOU FOR BEING HERE!

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Questions?

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