Air void systems in pumped concrete

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Outline

• Introduction / Mechanisms
• Lab Testing
• Field Testing
• Recommendations
• Conclusions
Concrete Pumping

Concrete pumps are used to place over 60% of ready mix concrete.
When you pump air entrained concrete one of three things will happen:
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1. The air will go down
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1. The air will go down
2. The air will go up
When you pump air entrained concrete one of three things will happen:

1. The air will go down
2. The air will go up
3. The air will stay the same

- Ken Hover
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Most people are worried about this and so it is common to sample after the concrete pump.
What Do You Want in an Air-Void System?

- Volume of air provided is the same for both.
- Case B has a better air void distribution.
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- Volume of air provided is the same for both.
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Why does pumping impact air?
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Mechanisms

1. Pressure

2. Vacuum

3. Impact
Why does pumping impact air?

Mechanisms

1. Pressure

2. Vacuum

3. Impact
Methods

• Investigate the following before and after pumping:
  • Air volume
  • SAM Number (air void spacing) AASHTO TP 118
  • Spacing factor (petrographic analysis) ASTM C 457
  • Freeze-thaw performance ASTM C 666
Spacing Factor (inches) vs. Fresh Air %

- WROS .40
- WROS + PC1 .40
- ACI 201.2R

Not Recommended
Recommended

Ley et al., 2017
Durability Factor

Fresh Air %

WROS .40

WROS + PC1 .40

Recommended

Not Recommended

Ley et al., 2017
Durability Factor vs. SAM Number

Recommended

Not Recommended

WROS .40

WROS + PC1 .40

Ley et al., 2017
Discussion

The SAM Number tells you about the bubble size distribution in fresh concrete and the total air does not do this.
Over 227 lab mixtures from two different research groups
88% agreement

Ley et al., 2017
PennDOT 50 field mixtures

83% agreement
FHWA Mobile Concrete Lab 2014 and 2015 – 50 mixtures

75% agreement
ODOT – 53 mixtures

90% agreement
13 DOTs over 270 field mixtures
81% agreement
68 mixtures show a 88% agreement.
Discussion

The SAM Number correlates to performance in rapid freeze thaw testing.

A SAM Number of 0.20 correlates to a spacing factor of 0.008” for 497 concrete mixtures completed by 13 different DOTs and two research groups.

88% agreement in lab
81% agreement in the field
Mixture Design

• 0.45 w/cm
• 20% Class C ash
• 6.5 sacks (611 lbs)
• Limestone and natural sand
• 5” to 8” slump

Air contents from 4% to 8%
With and without water reducer/retarder
16 field mixtures
20 lab mixtures
Lab Pumping Information

• 4” diameter pipe
• 60’ of steel pipe
• 10’ Rubber hose
• pumping pressures from 55 to 110 psi
Recirculation Procedure

Testing Performed
1. Before Testing
2. After 1 cycle
3. Every 6 cycles after
There is an approximately 20% air loss after one circulation through the concrete pump.
Fresh Concrete

After one cycle

• Air content decreased
• SAM Number increased (air void system coarsened)

This means the air void system in the fresh concrete was changed due to pumping.
Where do the air voids change within the pump network?
Fresh Concrete

The air seems to change right after the pump and stay almost constant throughout the pipe network.
What about the hardened concrete?
Typically, when the SAM Number increases then so does the spacing factor.
Unpumped

After Pumping

Spacing Factor

SAM Number
Hardened Concrete

• The SAM Number and spacing factor do not show the same relationship before and after pumping.

• Satisfactory freeze thaw performance of pumped concrete was observed even though there were low air contents and high SAM Numbers after pumping.

• Spacing factor results indicate little change from pumping in the quality of the air void system in the hardened concrete.
Major finding

For the mixtures, equipment, and materials investigated, the measurements in the fresh concrete after pumping does not seem to be representative of the performance of the hardened concrete.
Does this hold for other equipment and mixtures?
Field Pumping Information

• 5” diameter pipe
• 120’ of steel pipe
• 10’ Rubber hose
• pumping pressures from 150 to 200 psi
• Used three different boom configurations
Pump configurations

- Flat
- Arch
- A-frame
Air Content

Before

After

Fresh Air A-Frame

SAM Number

Fresh A-Frame

A-frame shown others have similar performance
Field

- SAM After Pumping
- SAM Before Pumping
- Previous Work

- Durability Factor
- SAM Number
- Failure (D.F)

Field
Discussion

• The air content did not always decrease on the field samples but the SAM Number was still observed to change.
• We are seeing similar things in the lab and the field.
SAM over time

• In order to learn more we decided to do a pump mixture in the lab and then measure the change in the SAM Number over time.
The graph shows the SAM Number over time after pumping for two different mixes, labeled as Mix 1 and Mix 2. The X-axis represents the time after pumping, ranging from -20 to 140, while the Y-axis represents the SAM Number, ranging from 0 to 0.3.

- **SAM before pumping** is indicated by a blue line labeled as Mix 1, showing an initial high peak and then a steady decline over time.
- **SAM samples after pumping** is indicated by an orange line labeled as Mix 2, which also shows a peak initially but with a more sustained high value compared to Mix 1.

The graph highlights the differences in SAM response between the two mixes over the measured time period.
What might be happening???

• The pressures from pumping cause the small bubbles to **temporarily** dissolve

• Good performance in the petrographic analysis, freeze-thaw testing, and reducing SAM Number over time suggests that the **dissolved air comes back before the concrete hardens**.

• When the air comes back it seems to be well dispersed and provides a similar spacing factor to what went into the pump.
What does this mean?

• Air Content and SAM testing after pumping may not be representative of the hardened concrete.

• One should be hesitant to reject concrete for low air or high SAM Number after pumping.

• It appears that sampling the concrete prior to pumping is a good indicator to the air void system in the hardened concrete.
Conclusion

• The SAM was an invaluable tool to give insights into the performance of air before and after a concrete pump.

• Pumping was observed to modify the air content and SAM Number in both the lab and the field testing.

• Based on the hardened air void analysis, freeze thaw testing, and changing SAM Number over time, the air seems to return to the concrete with similar volume and spacing as was in the concrete before pumping.
Disclaimer

• Pumping and air is one of the black arts of concrete.

• These results were based on 16 lab and 18 field mixtures with a limited set of admixtures.

• However, the results are consistent and the recommendations are not based on a single measurement.
I need your help!!!

• I want to prove this is happening on a wide range of concrete.

• I need you to use the SAM to investigate concrete before pumping and make a hardened sample of concrete.

• I need you to then investigate the concrete with the SAM after pumping and take a hardened sample.
I need your help!!!

• Please run the SAM within 10 min of discharge from the pump.

• Please record as much information about the mixture, pump setup, and pump details as possible.
What should happen

• The hardened air void analysis before and after pumping should have similar values.

• The majority of the air content and SAM Numbers should be different before and after the pump.

• This will be very valuable data and can give us more insight into what is happening.
Questions?

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