Current Research on Air-Entrained Concrete

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Air-Entrained Concrete…
The Continuing Saga!!!

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Summary

• Introduction to air-entrained concrete
• Can air-entrained voids lose their ability to provide frost resistance in concrete?
• Can inadequate curing impact the void system in fresh concrete?
• Closing statements
Why Do We Add Air to Concrete?

- Air-entrained bubbles are the key to the freeze-thaw resistance of concrete.
- Smaller bubbles are more effective in providing freeze-thaw resistance than larger bubbles.
What Do You Want in an Air-Void System?
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- Volume of air provided is the same for both circumstances.
- Case B has a lower spacing factor and a higher specific surface.
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Current Measuring Techniques

PCA photo
ASTM C 231

PCA photo
ASTM C 173

ASTM C 138
Current Measuring Techniques

These only measure volume!!!
μCT Scanner
Void

0.42 w/c paste
48 mL/100 kg cm wood rosin AEA
What can we do with it?
Air bubbles in the material
Air bubbles and a 20 micron protected paste shell
Air bubbles and a 20 micron protected paste shell
Can air voids lose their ability to provide frost resistance?
Core from a JPCP

- All concrete images courtesy of Gerard Moulzoff
Core from a JPCP

Elevation

Plan
Core from a JPCP

failed joint

Elevation

Plan
Core from a JPCP

saw cut

deteriorated concrete

Elevation

Plan
Core from a JPCP

Elevation

Plan

saw cut

deteriorated concrete

A

A
Cut and lapped x-section
Cut and lapped x-section
Image 1 – light image taken near the top surface near the saw cut. Note the large number of air voids.
Cut and lapped x-section
Image 2 – light image taken at 60 mm from the surface near saw cut. Note the lack of small voids.
Image 1
Near surface at saw joint

Image 2
60 mm depth at saw joint
Cut and lapped x-section
Image 3 – light image taken at 90 mm from the surface near saw cut. Note the lack of small voids.
Cut and lapped x-section
Image 4 – light image taken at 90 mm from the surface away from the saw cut. The voids are back!
very few small air voids are present
Image 3b – light image taken at 90 mm from the surface near saw cut with higher resolution. A number of spherical white regions are shown.
Image 3c – polarized light image taken at >60 mm from the surface near saw cut with higher resolution. The voids appear to be full of ettringite and portlandite.
Observations

• A well distributed bubble system was observed:
  • Away from the joint in the bulk paste
  • At the joint near the surface

• A more coarse bubble system was observed:
  • At the joint in two different locations away from the surface
Observations

- Based on high magnification polarized light it appears that the small voids are being filled with ettringite and some portlandite.
- This was found along the joint near the failure and also at further depths in the concrete.
What could have happened?

• Since the sealant had failed the joint may have filled with water
• This water may have saturated the paste surrounding the joint
• Ettringite and portlanditite likely formed in the water filled space
• Whether these voids are filled with hydration products or water this is bad for frost durability (Weiss, 2011)
• Mortar samples from an air entrained concrete mixture were consolidated in a 5 mm (¼”) diameter straw
• One sample was stored in water for 50 days at 73°F
• The other sample was stored in water for one day and then in air for 49 days at 73°F
• Both samples were then investigated with the μCT scanner
1 day wet cure
50 day wet cure
1 day wet cure

50 day wet cure
Equal volumes were compared.
Observations

• Needle like hydration products are seen filling the voids in the 50 day water cure sample

• The sample that had been wet cured for 50 days had 60% less voids than the sample taken from the same mixture that had only been cured for 1 day
Observations

• This behavior is similar to what is hypothesized to happen in the field air-entrained concrete

• A number of others have observed ettringite in mature concrete
  • Iowa DOT
  • Folliard et al., 1998
  • Ley et al., 2009
  + Others…
Does inadequate curing impact the air-void system?
Does inadequate curing impact the air-void system?

- When rapid CSH formation occurs, water is consumed in the reaction and outside water may be needed.
- This can be seen in the field as the bleed water above the concrete is sucked back inside.
- This contributes to the disappearance of the bleed water and is the signal of setting.
An air-entrained 0.42 w/cm paste mixture was made and consolidated in a 5 mm (1/4”) straw. Some water was placed on top of the surface of the sample. Images were taken with the µCT scanner at 0.5, 2.5 and 4.5 hours after mixing. The sample was never moved from the machine.
• The water level dropped over time until there was no water present after 4.5 hours
If one looks closely, you can see the water level.
If one looks closely, you can see the water level.
0.5 hours  2.5 hours  4.5 hours

water level

no water
Notice the change in the void system!!

0.5 hours  
2.5 hours  
4.5 hours
Let's compare the void systems at these spots.
Equal volumes were used for all comparisons

4.5 hour near the surface!
Observations

• Between 2.5 and 4.5 hours there was a significant change in the water level and the air-void system near the top of the sample
What does this mean?

• If water is not available at the surface of the sample to satisfy the chemical suction of hydration then it appears that this could compromise the void system at the surface

• This could be a contributor to the surface scaling of concrete
The World of Air-Entrained Concrete...

• Providing a small and well distributed air-void system is crucial to frost durability
The World of Air-Entrained Concrete...

• Are we getting the needed air-void system when we first make the concrete?
• Are we keeping that air-void system through delivery and placement?
• Do we have it after setting?
• Do we have it after years of service?
The World of Air-Entrained Concrete…

- Are we getting the needed air-void system when we first make the concrete?
  - Current Mix Track Research - 2012
- Are we keeping that air-void system through delivery and placement?
- Do we have it after setting?
- Do we have it after years of service?
The World of Air-Entrained Concrete...

- Significant research is needed to better understand how to produce, maintain, and keep a quality air-void system in our concrete for years of service
- It is unclear where these needed resources will come from
Questions???

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