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Air, and Why it is Important in Concrete

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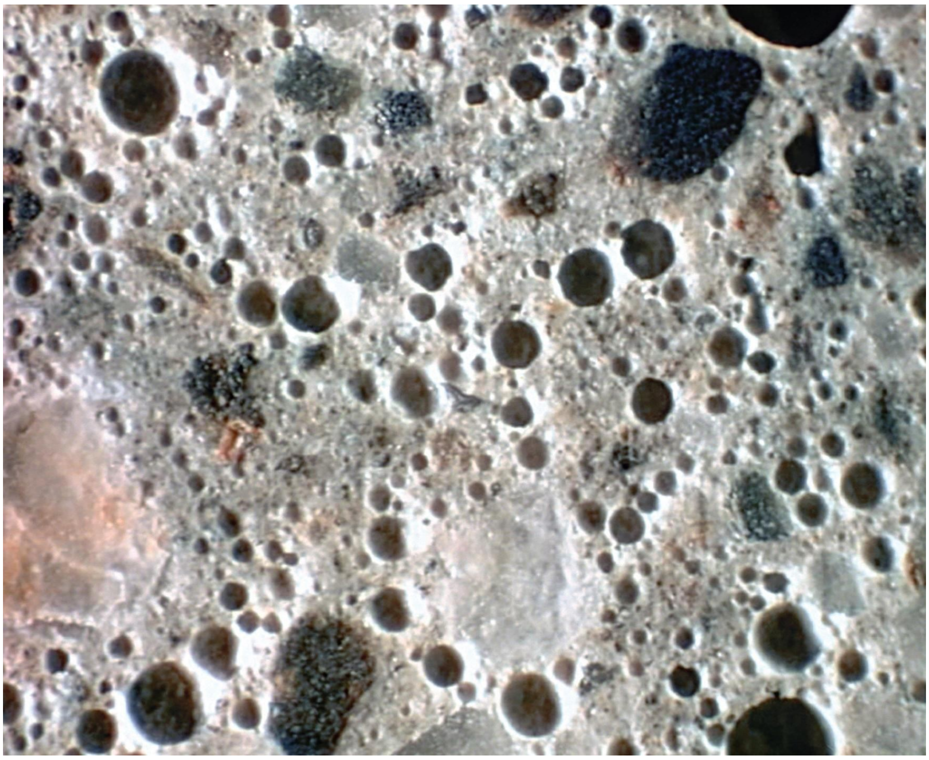
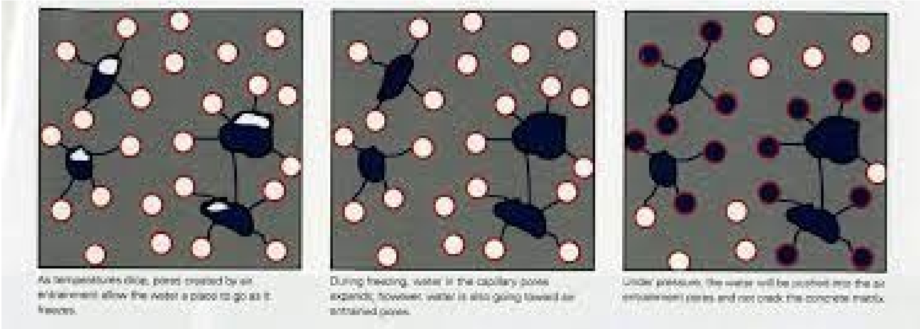


Why do we need Air in our Concrete?

Unless it was literally baked, moisture is almost always present in hardened exterior concrete elements. As we discussed In Technical Bulletin #9, this means C-S-H crystals are continuing to grow as they subsume the moisture present in the concrete. However, physics plays a pretty evil hand when the temperature falls below freezing. Water expands by 9% when it freezes, and in hardened concrete, we have a static system where things can't move out of the way to allow room for that water to expand. If the freezing water has nowhere to expand, it generates incredible stresses within the hardened concrete that can result in scaling (See Technical Bulletin #4).

To help prevent this, we entrain billions of air bubbles in the concrete mix that give the water somewhere to expand to when the water freezes. In essence, the voids are acting like billions of microscopic pressure relief valves in our concrete.



There are multiple factors that determine if the air present in a mix is suitable to prevent scaling, but three of the most important are below:
1. Air Content - Easily tested in plastic concrete with a pressure air meter, the total air content is the most comprehensive and testable measure of an air matrix system. For most aggregates, we want the air content to be ~5-7% of the total mix volume on exterior concrete. Non-air entrained mixes will often have 2-3% of what we call “entrapped” air, which are naturally forming, larger bubbles in the concrete mix. Entrapped air gives little to no freeze-thaw resistance.
2. Chord Length - This is the average size of individual bubbles. This is important as a mix could have 6% air, but it might be in one huge bubble. Obviously that void would not provide pressure relief for most of the concrete element. We target a bubble size of .0004-.004 inches in diameter.
3. Spacing Factor - In order to provide “coverage” for all of the paste where water might be present, the bubbles need to be very close together. We target an average spacing factor of .008 inches or less.

How Do We Get the Air into the Mix?

Some air is naturally present, but we *entrain* the bubbles for freeze-thaw resistance through the addition of an **Air Entraining Admixture**. These can be made from natural products like salts from wood oils or resins; or also from synthetic detergents. Essentially, they act like a soap detergent would by increasing the strength of the surface tension of water, allowing a bubble to hold it's shape when it otherwise would collapse. The mixing action in the ready mix truck or central mix plant creates the bubbles and the AEA stabilizes them. AEA's can come in a variety of types and strengths, but it is not uncommon for the dosage rate to be something like 2oz in an entire yard of concrete. Due of the potency of many of these admixtures, dosing accuracy is of the utmost importance.

What Factors Influence the Total Air Content?

Concrete is a very complex matrix, and unfortunately there are a great many factors that can affect total air content in a load of concrete. Anticipating these factors to produce concrete with the correct air volume is one of the great challenges of concrete production.

- **- AEA Dosage Rate**. In general, more AEA means a higher air content.
- **- Cement Content**. In general, more cement means more AEA needed to achieve the same air content.
- **- Cement Chemistry and Physical Properties**. Different cements will have different air demand, as alkalis in the cement and the fineness of cement will have a big impact on AEA needed. Also a

change in these characteristics can cause air changes in production.

- **- Fly Ash.** All fly ash has some level of unburnt carbon, known as LOI. This unburnt carbon will counteract the detergents in the AEA, making fly ash the first suspect whenever large, unexpected changes in air are found in concrete production. Some fly ashes have highly variable LOIs, making production of exterior concrete with these ashes very difficult.
- **- Other SCM's**. The use of slag, silica fume, or other SCM's can have slight impacts on air contents.
- **- Max Aggregate Size.** Larger aggregate sizes take up space in the mix design, thus limiting the amount of the concrete mix that is paste. Because of this, less air is needed as a function of the whole concrete mix.
- **- Sand-To-Total-Aggregate Ratio**. More sand in a mix will entrap more air, leading to a higher air content. Beware though, this air is not effective at protecting against freeze-thaw.
- **- Water/Slump.** In general, more water and a higher slump will allow for easier entrainment of air. However, at around a 9" slump, it is easy to “washout” the air in a mix, as the concrete matrix is not dense enough to stop the bubbles from rising to the surface and popping. A viscosity modifier is an effective way to “thicken the water” and combat this phenomenon at high slumps.
- **- Admixtures.** Some admixtures can raise or lower air contents in a mix. For example, lignin based water reducers often promote air build and help stabilize bubbles, but some polycarboxylate water reducers have a de-foaming package that reduces air contents.
- **- Integral Color**. Some integral colors like carbon-based blacks and greys will significantly reduce air contents.
- **- Temperature.** Air entrains best at about 50° concrete temperature. As the temperature goes up, AEA dosage will increase.
- **- Haul Time.** Concrete will naturally “burp” some of it's air on longer hauls in the truck. It's a good idea to mix the concrete thoroughly on site after a decent haul, to ensure proper air build.
- **- Placement Method.** Many ways we place and finish concrete can affect air contents. Pavers, pumps, conveyors, jitterbugs, and vibrating screeds can all knock some air out of the mix, reducing freeze-thaw durability.

How Does the Addition of Entrained Air Affect my Concrete?

Most importantly, as mentioned above, it provides freeze-thaw durability to the hardened concrete. Air also slightly increases slump and workability. It's not uncommon to see about a gallon/yard less water in an air entrained mix than an otherwise identical non-air-entrained mix. The addition of air does have a negative effect on strength, and as such air above 9% or so in place is not desirable. Air is also effective at reducing bleed water, leading to many finishers requesting a “half-air” mix to leverage the reduction of bleed into quicker finishing times. Fully air entrained concrete should never be used on interior floors that are being hard troweled, as this can cause delamination in the floor.

Other Cool Stuff About Air

Above, we discussed the three metrics that matter in freeze-thaw durability. Air content, chord length, and spacing factor. For a long time, we could only test the first of those on a jobsite. However, a new device, creatively called a “Super Air Meter” or SAM, has recently been introduced that can test for all three metrics in plastic concrete. Although the source of much debate, the SAMs appear to be relatively accurate. At this time they remain difficult to operate and much too slow to give results to be used on most concrete placements, but it is a neat tool for mix evaluation.

Another cool thing is the work of Oklahoma State professor Tyler Ley. Ley is working on the theory that while air content bubbles shrink or disappear under pressure in a pump, they can “rebound” and come back after some time. For anyone that has dealt with large air losses through a pump before, his work is very intriguing.

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