THE TROUBLE WITH BUBBLES

Why air content varies, and what you can do about it

By Ward R. Malisch

An adequate amount of entrained air is essential for durable exterior concrete in cold climates, but too much air can reduce strength without improving durability. That's why there are tight tolerances on air content. Because of this narrow range, control of air is on most producers' top-10 list of troubling technical problems.

The difficulty in controlling air

The amount of air that can be entrained by a given dosage of air-entraining admixture (AEA) varies with the properties and proportions of concrete-making materials (see box on page 562). The effect of some factors, such as sand, can be confusing because the effect varies with sand properties.

For instance, increasing the amount of fines (minus-100-mesh material) in the sand decreases air content, while increasing the amount of middle-size fractions (passing the No. 30 sieve but retained on the No. 50 sieve) increases the air content.

Voids within the sand hold the entrained air bubbles in the mix (Figure 1), preventing them from escaping or coalescing to form larger bubbles that are more likely to break. Sand with the right amount of middle-size fractions has the best void size for retaining bubbles. Coarse sand voids are too large, and fine sands reduce the bubble-forming abilities of the AEA.

Batching methods also affect air content. Adding the AEA after all other ingredients have been batched increases air content for a given dosage. Batching the AEA directly on dry cement decreases air content.

Entrained-air content may also vary with several factors related to mixing: amount of concrete being mixed, mixer condition, mixing time, and mixing speed (Figure 2, page 561). The effect of mixing time depends on mixer type. In stationary or paving mixers, air content increases with additional mixing time up to about 2 minutes. In most truck mixers, air content increases with mixing times up to about 15 minutes, then may decrease slowly due to slump loss. In some studies, air content constantly decreased with increased agitating time. Other studies show that air content plateaus up to about 90 minutes of agitation, then starts to decrease.

Hot concrete won't entrain as much air as cool concrete. The volume of entrained air can drop by 25% if concrete temperature increases from 70° F to 100° F. High air temperatures, hot concrete-making materials, or prolonged mixing increase concrete temperature and require higher dosages of AEA to maintain a specified air content.

Taking control of air content

Suggested dosage rate ranges for AEAs are given in fluid ounces per 100 pounds of cement used. Batch plant operators then vary the dosages to adjust for changing

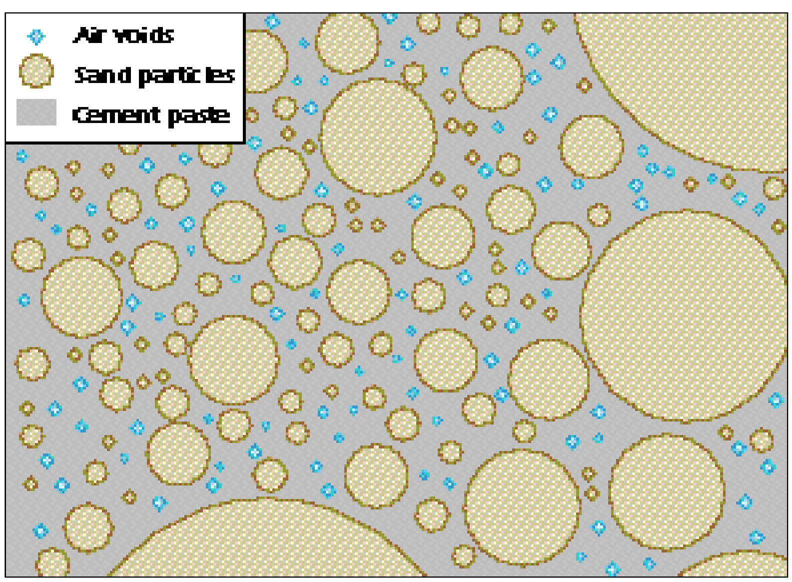
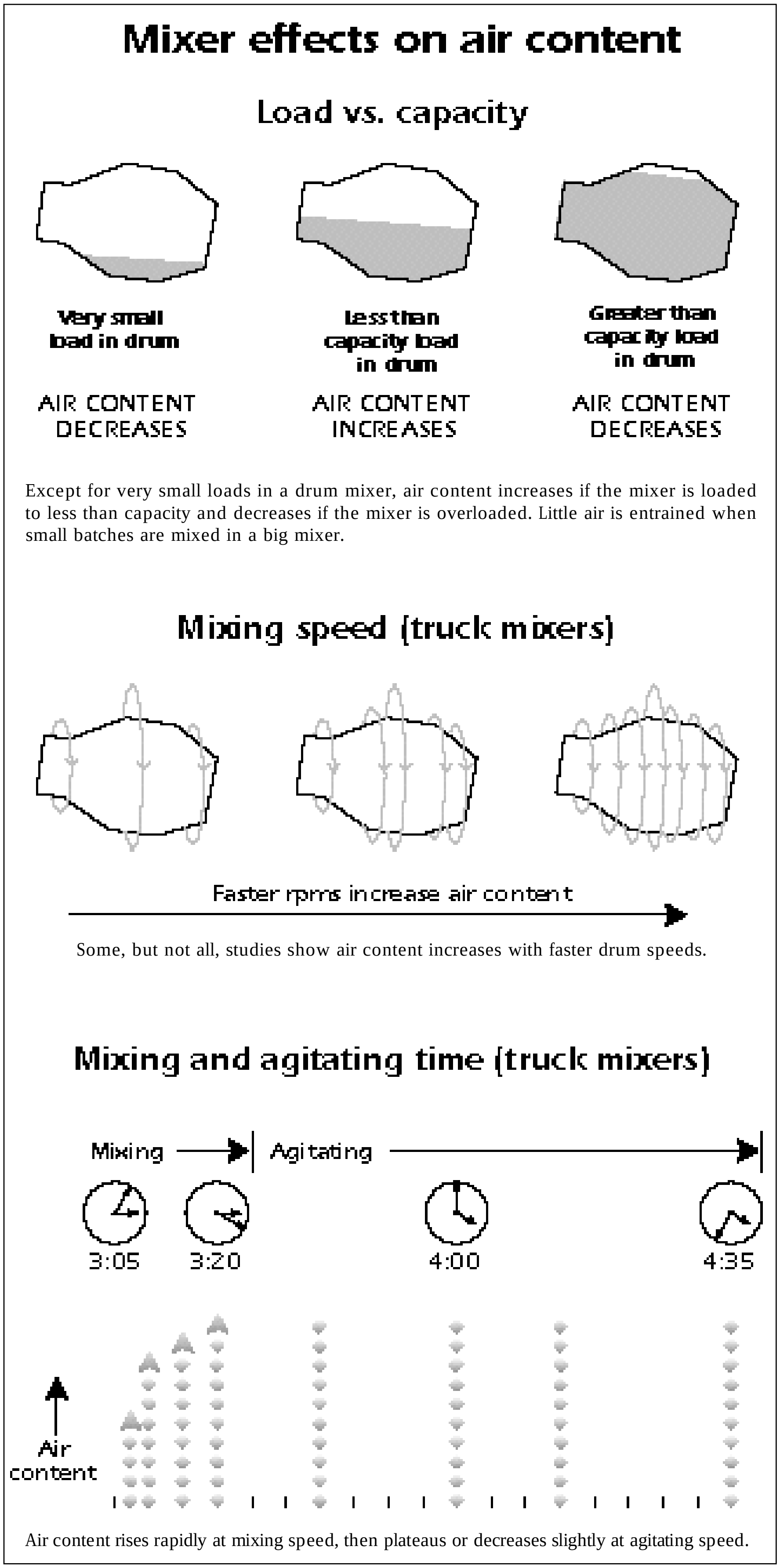


Figure 1. Voids in the sand hold entrained-air bubbles, preventing them from escaping or combining to form bigger, less stable bubbles. It's hard to produce high air contents in low-sand-content concretes.



Except for very small loads in a drum mixer, air content increases if the mixer is loaded to less than capacity and decreases if the mixer is overloaded. Little air is entrained when small batches are mixed in a big mixer.

Some, but not all, studies show air content increases with faster drum speeds.

Air content rises rapidly at mixing speed, then plateaus or decreases slightly at agitating speed.

Figure 2. Air content can vary with the amount of concrete being mixed, mixing speed, and mixing and agitating time.

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Big swings in air content can be caused by changes in concrete materials, proportions, batching sequence, or mixing methods.

conditions that affect air content. In mixes containing fly ash, for instance, the operator adds more AEA to maintain a constant air content.

It's not always possible to compensate for changing conditions by changing the amount of AEA used. Because the mortar carries all of the entrained air, there's an upper limit on achievable air content in concretes with low sand contents. Less sand means less mortar and less entrained air carrying capacity. Fortunately, when there's less mortar, less air is needed to protect the concrete from freeze-thaw damage.

But combine low-sand concrete with other conditions that decrease air content, and even the lower required air contents may not be achievable. When this happens, the batch plant operator may have to increase sand content, blend sands to change the grading, or use a different AEA.

Rapid air loss soon after mixing indicates an unstable air-void system. The use of high-alkali cement is one possible cause. Although increasing the cement alkali content also increases air content, the bubbles are more easily broken probably because the AEA films that surround the bubbles are thinner or more soluble than those in low-alkali concretes. In high-alkali concretes, air content may be within specification limits at the batch plant but not at the jobsite.

Clays found in some sand deposits disperse slowly in water. When they do disperse, entrained-air content decreases, so the air content at the point of delivery can be much lower than the value measured immediately after batching and mixing.

How to counter air-content swings

What's the best way to deal with erratic air contents? First, ensure that air content measurements are made correctly. When volumetric measurements are made, the meter must be agitated enough to ensure release of all entrained air. For pressure meters, the aggregate-correction factor must be applied uniformly by all inspectors. Apparent changes in air content can be caused by deviating from the standard methods for measuring air or by using out-of-calibration equipment.

If measurements are being made correctly, pinpoint the cause of air-content swings. Look for changes in sources of cement, fly ash, admixtures, and aggregates. A new shipment of cement may be ground finer, or fly ash from a new source may have a higher loss on ignition. Introducing a new admixture type, or the same type from a different manufacturer can change the air content. Changes in sand grading have a marked effect on air. And using rock from a different part of the quarry can change the air content by altering the amount of dust.

Next, check the production cycle for changes in sequencing or timing of admixture additions. Are the dispensers clean and functioning properly? When were they last calibrated?

Finally, when problem batches consistently come from the same truck, check for blade wear, concrete buildup, and uniformity in mixing time. If truck waiting times vary at the jobsite, look for problems in trucks that discharge late.

This approach for dealing with erratic air contents rules out some causes, thus narrowing the possibilities. The most likely identifiable causes will then suggest mix adjustments or other corrective measures to solve the problem. ✥

References

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Effect of materials on air content

Properties of concrete and concrete-making materials affect the amount of air entrained by a fixed dosage of air-entraining admixture (AEA). Effects of several factors are summarized below.

Fine aggregate

- Well-rounded particles entrain more air than angular particles.
- As fine fraction (minus-100-mesh) increases, air content decreases.
- As middle fractions (30- to 50-mesh) increase, air content increases.
- Clays found in some sand deposits disperse slowly in water. When they disperse, air content decreases.

Fly ash

- As fineness increases, air content decreases.
- As carbon content increases (higher loss on ignition), air content decreases.
- As fly ash content increases, air content decreases.

Oil and grease

- Poor lubricating practices at the cement plant, ready mix plant, or delivery truck may add these organic impurities to concrete. Depending on composition, they can increase or decrease air content.

Cement

- As fineness increases, air content decreases.
- As alkali content increases, air content increases.
- Type I-P cements entrain less air than cements that don't contain pozzolans.
- High-cement-content mixes entrain less air than lean mixes.

Coloring agents

- Adding carbon black decreases air content.

Chemical admixtures

- Adding a water reducer along with an AEA can increase the air content.
- Type C set-accelerating admixtures usually don't affect air content.
- Adding a pumping aid along with an AEA increases air content.

Coarse aggregate

- Dust on the aggregate decreases air content.
- Crushed-stone concrete entrains less air than gravel concrete.

Water

- Diluting AEA with hard water prior to batching decreases air content.
- Air content increases with increasing water content.