Air-Entraining Admixtures for Concrete

Observations from the FHWA Mobile Concrete Technology Center

Air-Entraining Admixtures and What They Do: Air-entraining admixtures facilitate the development of a system of microscopic air bubbles within concrete during mixing. They increase the freeze-thaw durability of concrete, increase resistance to scaling caused by deicing chemicals, and improve workability. Air entrainment will reduce concrete strength. As a general rule, a 1% increase in the concrete air content will decrease the 28-day compressive strength by about 3 to 5%.

Why Do I Need Air In Concrete? In cold weather climates, water within the concrete capillary pores will freeze and expand when the temperature drops below freezing. If the concrete is critically saturated (>91.7%), the expansion of ice (~9% in volume) exerts pressure within the hardened concrete and will cause cracking if the tensile strength of the concrete is exceeded. Entrained air voids spaced within the concrete provide a place for the freezing / expanding water to move into, which relieves the pressure and thereby prevents cracking.

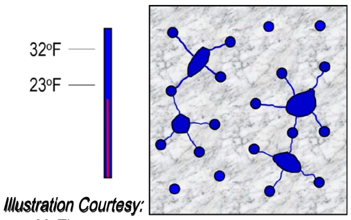

Illustration Courtesy: M. Thomas

Saturation > 91.7%

Entrained vs. Entrapped Air: The air content of concrete is made up of entrained and entrapped air voids. Entrained air refers to microscopic air bubbles intentionally incorporated into concrete during mixing, usually by use of a surface-active agent. These bubbles are spherical with diameters between 0.0004 and 0.04 in. (0.01 and 1 mm). By contrast, entrapped air voids are present in all concrete, irregular in shape, typically larger than 0.04 in. (1 mm), and less useful than entrained air voids. Due to smaller size and better distribution of the bubbles, entrained air provides a smaller distance that water needs to travel through the capillary pores and enter a microscopic void to expand and relieve the pressure.

How Do Air-Entraining Admixtures Work?

Air-entraining admixtures do not generate bubbles. They simply stabilize microscopic bubbles that are created during the mixing process by: 1) reducing the surface tension of the mixing water to promote the development of the microscopic bubbles; 2) stabilizing the bubbles by forming a sturdy shell that repels water, hinders their coalescence, and promotes attraction to cement and aggregate particles

Chemistry and Classification of Admixtures: Air-entraining admixtures are surface-active chemicals (surfactants) that consist of a water-repelling chain (non-polar hydrocarbon) with a water-attractive chain (anionic polar). The two major classifications of air-entraining admixtures are wood-derived acid salts (vinsol resins and wood rosins) and synthetic resins.

Wood-Derived Acid Salts

- ✓ Develop good bubble structures
- ✓ Used for more than 60 years
- ✓ Work well with low water-cementitious mixtures.
- ✓ Tend to lose air with time/haul distance
- ✓ Due to supply issues, wood rosins have replaced vinsol resins in most markets.

Synthetic Resins

- ✓ Can be detergents, fatty acids, gum resins, and tall oils
- ✓ Have been in the marketplace since the mid-1980's
- ✓ Can produce smaller bubbles that are spaced closer together relative to bubbles formed by vinsol resins and wood rosins; thus, offering greater durability under freeze/thaw conditions.
- ✓ Can lead to increased air contents with delayed additions of water.

Effect of Materials and Practices on Air Entrainment: Many factors, including those listed in the table below and others such as concrete temperatures influence the air content of concrete. This will require the air-entraining admixture dosage to be adjusted accordingly.

Material /Practice	Change	Effect
Cement	Increase in cement content	↓↑
	Increase in fineness	↓
	Increase in alkaline content	↑
Supplementary cementitious materials	Fly ash	↓↓
	Silica fume	↓↓
	Slag with increasing	↓
Aggregates	Increase in maximum size	↓
	Sand content	↑
Chemical Admixture	Water reducers	↑
	Retarders	↑
	Accelerators	↔
	High-range water reducers	↑
W/CM	Increase W/CM	↑
Production	Batching	↑↓
	Increase mixer capacity	↑
	Mixer speeds to 20 rpm	↑
	Longer mix time	↑
Transport and delivery	Transport	↓
	Long hauls	↓
	Retempering	↑
Placing and finishing	Belt conveyors	↓
	Pumping	↓↓
	Prolonged internal vibration	↓
	Excessive finishing	↓

How do Air-Entraining Admixtures improve concrete durability?:

- ✓ Increase resistance to damage from cyclic freezing and thawing
- ✓ Increase resistance to scaling from deicing salts
- ✓ Improve workability
- ✓ Reduce segregation and bleeding

For further information, refer to the following documents:

1. FHWA TechBrief: Chemical Admixtures for Concrete Paving Mixtures
2.ACI E4-12, Chemical Admixtures of Concrete
3. Integrated Materials and Construction Manual for Concrete Pavements

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