C - 11: Air-Entrainment: Benefits & Pitfalls

Air-entrainment provides important benefits to fresh and hardened concrete and is principally used to improve the resistance of concrete subjected to freeze-thaw cycles and/or deicing chemicals.

The advantages of using air-entrainment in concrete are numerous. Air-entrainment improves the workability of concrete, thus reducing the need for excess water and higher water/cement ratios. Air-entrainment also acts to decrease segregation, improve the sulfate resistance of concrete and can increase strength in lean mixes.

Air bubbles in concrete are often described as microscopic ball bearings, which make a more workable, "fatter" concrete, which reduces harshness in the mix. Air bubbles can make up for a lack of fines in the mix or a poor fine aggregate (sand) gradation. Air-entrainment also allows one to replace some sand with air bubbles at a reduced expense. An air-entrained mix holds together better than a non air-entrained mix, even at a relatively high slump. Bleeding and segregation are reduced, although reduced bleeding can have a downside, as discussed later.

The use of air-entrainment to improve freeze/thaw resistance of concrete is well- known. About 9% to 10% of the **mortar fraction** of the concrete should be entrained air, with proper air void spacing and properly sized air bubbles.

Air-entrainment in concrete also has its downside. The air content reduces the density of the concrete, which in turn reduces the compressive strength of the concrete except in lean mixes, i.e. low cement factor mixes.

The effect of air-entrainment on the strength of concrete is variable. In lean mixes, up to about a 3000 psi (20.7 MPa) compressive strength, increased strengths due to a lower water/cement ratio outweigh the reduced strength due to air-entrainment, until air reaches 5%. At higher strengths with higher cement contents, the reduced water/cement ratio does not make up for the lowered strength caused by the entrained air. In higher strength mixes each percent of entrained air above 3% can lead to a strength reduction of 4% to 5% of the 28 day strength. For example, a 5000 psi (34.5 MPa) mix can lose from 200 psi to 250 psi (1.4 MPa to 1.7 MPa) per % of entrained air above 3%.

Reduced bleeding may cause the surface of the concrete to appear ready to finish, while the concrete below the surface is still too plastic. This is prevalent in warm, low relative humidity, windy conditions. Machine finishing or troweling of air-entrained concrete may also lead to blistering. Air-entrained concrete is usually sticky, requiring metal floats rather than wood, and this sometimes leads to the undesirable need of fogging water on the surface just before troweling. As a general rule, air-entrained exterior flatwork should never be troweled and finishing operations should be kept to a minimum.

These are some of the benefits and pitfalls of using air-entrainment in concrete. Overall the benefits far outweigh the disadvantages when used in accordance with current standards.