



Manitoba Ready Mix Concrete Association

Technical Update

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What you should know about air entrainment

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Air entrained concrete has been available in Manitoba since the mid-1950's. Adding billions of microscopic air bubbles was found to greatly enhance concrete's durability in moist freeze/thaw environments while making it more impermeable to water, including sulphate-laden ground water. That's why we specify it for all exterior work in our climate and for any mix utilizing sulphate-resistant cement.

There's a slight loss of strength when air is added and usually a cost premium but this is more than compensated for by enhanced durability and impermeability.

Over the years, improved types of admixtures, such as petroleum distillates and fatty acids, have replaced the traditional Vinsol resin air entraining agents and become commonplace. These newer products are superior in performance, producing far smaller bubbles and more of them than the original products used for decades before.

Lab studies have shown that durability is assured only if the bubbles - the air voids - are very small and close together. The key factor, then, is the air-void spacing factor which can only be detected by microscopic examination of a polished slice of hardened concrete. A maximum spacing factor of 230 microns is mandated by CSA A23.1-04 4.3.3.3 for most mixes⁽¹⁾ with a even lower recommended target range of 170 microns. A related aspect is known as the specific surface; the higher that value the better since it indicates that there is a multitude of very small bubbles which together have a surface area greater than larger bubbles of the same gross volume.

There's a growing opinion that we should rethink how we both specify and monitor air contents, especially in critical exposures. Lower air contents are recommended for two reasons.

Firstly, microscopic testing repeatedly demonstrates that, because of the newer admixtures, we can readily develop the desirable close bubble spacing without the high percentage of air we commonly have specified in the past. In a recent article in ACI's Concrete International⁽²⁾, researchers point out that a 3.5% air content produced by modern admixtures that create these smaller, better bubbles can now readily provide the durability protection that the former admixtures provided at 6% and 7%.



Secondly, for field control, we rely on an air meter to determine the total volume of air in a sample since in the field we can't readily detect what's really important - the spacing of the bubbles. Of concern is the recognized fact that the pressure meters commonly used to monitor percent air in the field regularly low-ball the actual air content since many bubbles are now so minute that the pressure within the air meter cannot detect them all. The only solution to this problem - rarely addressed locally - is to use other techniques such as the slower but somewhat more accurate volumetric air meter or else regular checks of density to monitor true air contents. Higher air contents would also be reflected by lower densities.

All these factors suggest that we should prefer air contents on site to be in the low end of the permissible range stipulated in CSA A23.1-04 Table 4 provided that linear traverse air void spacings that had been performed on properly consolidated samples from test batches have confirmed in advance that these lower percentages in that mix will assure durability.

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There may be other concerns, too, when dealing with air entrained mixes which demonstrates it's not always a straight-forward decision. For example, pumping the mix down a vertical boom likely creates enough of a vacuum in the pipeline to reduce air contents 1% or more from that measured at the hopper. Pumping normal mixes horizontally, however, likely has no effect on the air content. Samples should regularly be taken at both the hopper and the discharge to confirm just what's happening.

Some other admixture, such as mid- and high-range water reducers – when field dosed – and some corrosion inhibitors can actually increase air contents significantly, especially when air contents are already in the high end of the permissible range. These phenomena are noted in the referenced ACI paper.

Pollutants such as organics (carbon) in the water or other mix ingredients can negatively affect the air void structure. Cement and flyash mill reports commonly report Loss on Ignition (LOI), a gauge of any excess carbon content that may influence air entraining. Check that LOI is less than 4% to avoid difficulties.

Temperature of the mix too, plays a role in the stability of the air void system, especially warm summer temperatures. We can readily demonstrate that colder water can retain more air in solution than warm water simply by running a glass of cold water from the tap and letting it sit on the desk. An hour or so later when the water has warmed to room temperature, we see hundreds of air bubbles have come out of solution and now cling to the sides of the glass. The same phenomenon occurs inside the drum of a ready mix truck if the concrete temperature rises unduly, prompting the need for higher dosages of air entraining agent in summer conditions than in cooler seasons.

Flatwork mixes that are air entrained show much less bleeding of excess mix water since the added air has replaced some of the mix water's volume in the batch. This is beneficial, since the cardinal rule of any finishing is *"do not perform any finishing procedure when bleed water is evident."*

But finishing air entrained mixes can be problematic. There are many applications where air entrainment is not recommended at all, such as any flatwork that will receive a hard trowelled surface. The intent of trowelling is to compact the surface to a depth of 1 mm or so. This destroys the air void system within that thin layer, leaving the surface very susceptible to scaling when subjected to freeze/thaw cycles.

The situation is aggravated if road salt dripping from a vehicle adds snow-melt water to the surface. Salt itself gives little damage to the concrete matrix but the water it creates can induce severe stresses at the surface as it freezes again. Countless floors in unheated garages are damaged every year after air entrained mixes have been hard trowelled instead of being given a light broom texture.

And if a dry shake hardener is specified on a floor, the instructions on the bag will specifically state the product is not to be applied to air entrained concrete. If it is floated and trowelled into place as instructed, not only may scaling be a risk, but localized delaminations known as blisters are very likely. Use non-air entrained mixes on all trowelled floors.

Even concrete for skating rinks and freezer floors should not be air entrained since these surfaces are commonly hard trowelled. This is noted under Table 2 of CSA A23.1-04. Durability is not an issue in these exposures since the number of annual freeze/thaw cycles experienced is so very small.

To summarize:

- DO:**
- use air entrainment air in all exterior moist freeze/thaw exposures.
 - always include air entrainment when specifying sulphate resistant mixes.
 - aim for air contents in the lower end of specified range.
 - air void analysis (linear traverse) should be performed on hardened samples of every mix prior to use.
 - expect a pressure air meter to read somewhat lower than actual air content.
 - consider alternate methods to confirm air content in the field.
 - check air contents at both ends of a pumping pipe line.
 - consider the possible influence of mid and high range water reducers and corrosion inhibitors on air content.

- DON'T:**
- hard trowel air entrained mixes.
 - use dry shake hardeners on air entrained floor mixes.

- References:**
- 1) CSA A23.1-04 , Concrete Materials and Methods of Concrete Construction; Canadian Standards Association, Mississauga, Ontario
 - 2) Jana, Erlin, Pistilli; A Closer Look at Air Entrainment; Concrete International, July 2005, pp 31-34.
 - 3) Design & Control of Concrete Mixtures, EB101.07T; Cement Association of Canada, Ottawa.

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