

The Real Truth About The Effects of Deicers

Low deicer concentrations actually cause the most scaling

BY WILLIAM F. PERENCHIO

For years, I have heard people say that deicers cause more damage to concrete during freeze-thaw cycles because they increase the number of freeze-thaw cycles the concrete goes through. Even some well-respected industry committees include this statement in their documents. Nevertheless, it isn't true.

During my first few years in the cement and concrete field, I worked with many well-known researchers at the Portland Cement Association (PCA) research and development laboratories. My supervisor at the time was George Verbeck, a brilliant physical chemist. Because my work included mixing and testing different types of concrete for resistance to deicer scaling, I asked George why the deicers caused increased scaling. The explanation he gave was extremely interesting and made a great deal of sense.

Study of Deicing Agents And Scaling

In the mid-1950s, George and his senior engineer, Paul Klieger, studied several different deicing agents and their effects on concrete scaling. Their paper was published in a Highway Research Board report (Bulletin No. 150) and reprinted by PCA (Research Department Bulletin RX083T). The results of their study show that it's not high concentrations of deicers that cause the heaviest scaling, but relatively

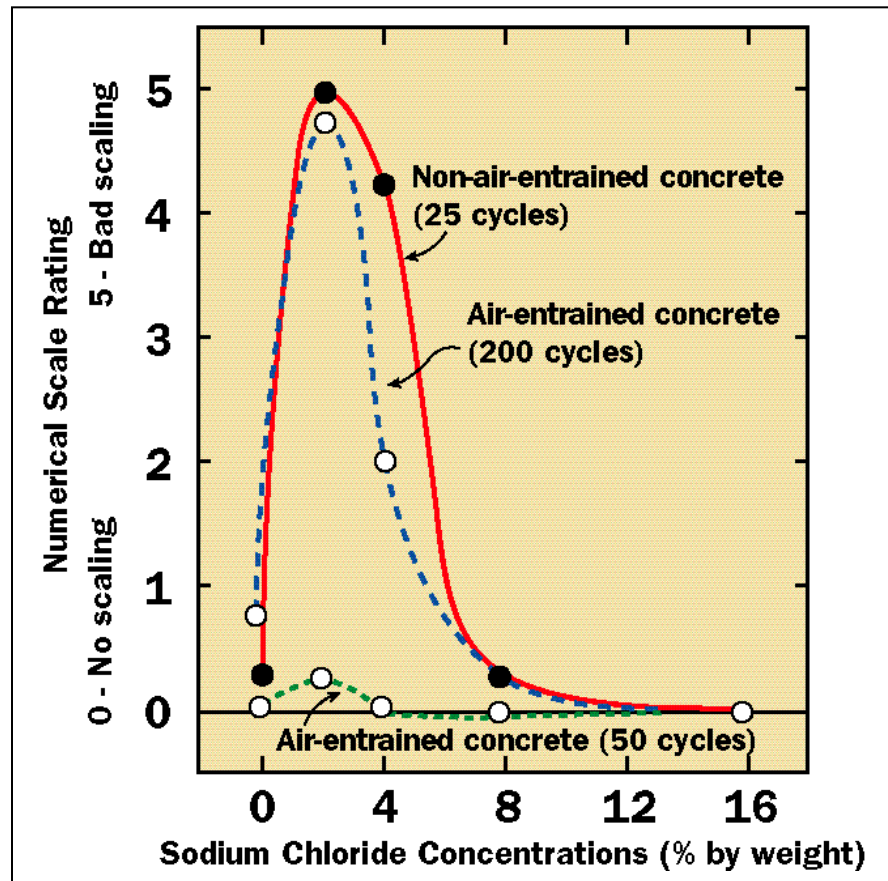


Figure 1. In both air-entrained and non-air-entrained concretes, there is a rapid rise in scaling as deicer concentrations reach 2%. As concentrations continue to rise, however, scaling decreases. The deicer solution (in this case, sodium chloride) remained on the surface of the concrete as it went through the freeze-thaw cycling, from 70° to -20°F and back again. The ascending part of the curve represents the increase in pressure caused by the hydraulic pressure that wet concrete is subject to during freezing.

low amounts—in the range of 2% to 4%. Their graphs of degree of scaling vs. deicer concentrations show low scaling at zero deicer, a rapid rise in scaling as deicer concentrations reach 2% to 4%, and then, depending on the deicer involved, a moderately slow to rapid drop-off in scaling as deicer concentrations

continue to rise. George explained this phenomenon to me by saying that two major destructive mechanisms are at work: hydraulic pressure and osmotic pressure. Unfortunately, his discussion was not included in the paper.

Figure 1 shows the results Verbeck and Klieger obtained for non-air-en-

trained concrete after 25 freeze-thaw cycles and for air-entrained concrete after 50 and 200 freeze-thaw cycles in the presence of a deicer (in this case, sodium chloride, which is sold in most stores for deicing sidewalks and driveways). All the other deicers—including calcium chloride, urea, and ethyl alcohol—produced similar curves, but none as sharply defined as this one. It's obvious from the graph that the worst scaling occurred at a deicer concentration of 2%.

Effects of Hydraulic Pressure

Hydraulic pressure develops because of the expansion (equal to 9%) that occurs when water turns into ice. The advancing ice front pushes water ahead of it. This expansion also explains why ice floats on water.

As anyone who has worked with concrete knows, water does not move quickly through concrete. Dry concrete will absorb water, much like a sponge. But once the concrete's capillaries are full or nearly so, it's very difficult to force more water into or through it. This resistance to flow is responsible for the pressure that builds when the internal water freezes: The water can't move away from the advancing ice front as fast as the ice is being formed.

In Figure 2 (top), the area marked A represents a source of freezable water in cement paste that is busy holding concrete together, and the area marked B represents an entrained air bubble. The two areas are connected by a capillary channel in the cement paste, marked C. As water starts to flow through the capillary from A, where the freezing is occurring, it encounters resistance due to the small diameter of the capillary. This resistance produces the hydraulic pressure. However, if the bubbles are close enough together, the pressure will not become high enough to cause any damage.

Effects of Osmotic Pressure

Osmotic pressure is a bit more

difficult to explain. Figure 2 (bottom) shows the same situation presented above, but now a deicer is present. As the ice front advances, the hydraulic pressure develops as before. But now a high salt concentration builds directly in front of the ice, because the ice consists of nearly all fresh water compared to the concrete, which has a lower overall concentration of water. This produces an osmotic force that tries to equalize the concentrations by moving water from the area of low deicer concentration on the right to the area of high deicer concentration in front of the ice.

Referring back to Figure 1, notice that as the concentration of deicer increases beyond that at the high point of the curve, both the hydraulic and osmotic forces are still acting, but the increasing deicer

concentration is reducing the amount of freezable water in the concrete. The freezing point of the resulting solution is also being reduced, so that both destructive mechanisms (hydraulic and osmotic pressure) are being starved for freezable water, without which they

TWO MAJOR DESTRUCTIVE MECHANISMS ARE AT WORK: HYDRAULIC PRESSURE AND OSMOTIC PRESSURE.

can't exert the pressure they were capable of at lower deicer concentrations. Nothing I have learned in the 35 years or so since George gave me this explanation has caused me to doubt its validity. 🏠

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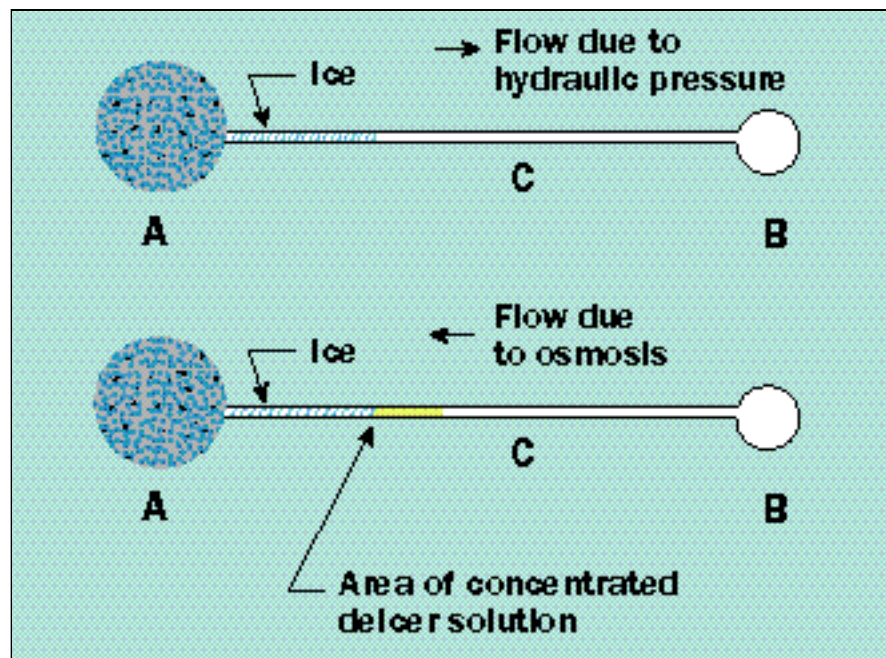


Figure 2. In both of these figures, A is a source of freezable water in cement paste connected by a capillary channel (C) to an entrained air bubble (B). When the water starts to freeze and turn to ice, hydraulic pressure can develop (top figure) because of the resistance that builds in the narrow capillary channel. When high deicer concentrations build directly in front of the ice (bottom figure), an osmotic force tries to equalize water concentrations by moving water from the area of low deicer concentration on the right to the area of high deicer concentration in front of the ice.