Magnesium Chloride As A Road Deicer: A Critical Review

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Problem Statement: During the winter of 2000-2001 it was observed that scaling of concrete surfaces increased approximately 10 times from that of the previous 9 winters in the Idaho Falls Regional Area . A review of concrete making materials from all producers, specifically, cement, sand, gravel, water, and admixtures, revealed that all materials came from the same sources as in previous years, so the logical conclusion is that none of these ingredients was the root cause of the very visible and costly problem. Scaling, as defined by the American Concrete Institute (ACI 302) and the National Ready Mix Concrete Association in their series of "Concrete In Practice," " is the local flaking or peeling of a finished surface of hardened concrete as a result of freezing and thawing."

A literature review of published scientific papers, principally from university researchers and experienced concrete consultants, reveals that chloride containing deicing materials such as calcium chloride, potassium chloride, and sodium chloride, can exacerbate a scaling problem as concrete goes through freeze-thaw cycles. This is particularly the case if the concrete is relatively new (less than 2 years old). Similar to water expanding in an ice tray, freezing water in saturated concrete exerts tremendous expansive force which consequently leads to the surface of the concrete scaling off if the concrete, especially the surface, is not adequately protected with entrained air. Entrained air provides spaces within the concrete mass for expanding water to move into, thereby reducing the potential stresses and associated deterioration. Deicing salts reduce the temperature at which water freezes and their use maintains a high level of saturation of concrete and significantly increases the number of freeze-thaw cycles witnessed by the surface. With typical salts like sodium, potassium or calcium chloride, the mechanism that causes surface scaling is purely physical in nature as described above and the chemical composition of the concrete surface is generally not modified. This is a well documented scientific phenomenon that is also discussed in numerous literature resources, many of which are published by the American Concrete Institute International and the Portland Cement Association.

What changed During the Winter of 2000-2001? : Our cities, counties, and state governments introduced a relatively new magnesium chloride based deicing material to the area . As the other deicing materials aforementioned have been utilized for years and were perceived to aggravate defects to concrete surfaces, this deicing chemical was believed by these governmental entities to be a non-damaging solution to public road safety and clean up issues. Bare pavement policy appears to be a favored term.

On what scientific documentation and research they based this decision upon is not clearly known. They have been asked on numerous occasions to allow industry personnel to examine this body of evidence, but to date have been unable to, or choose not to do so. The one piece of scientific information they have discussed with the concrete and cement industry, besides magnesium chloride sales literature, is a Strategic Highway Research Program Report entitled SHRP-H-332, "Handbook of Test Methods for Evaluating Chemical Deicers", published in 1992. They quote the data presented on page 215 of this report, which is designated as 8.14 "Example Test Results". Within this table it is shown that magnesium chloride is the equivalent of deionized water as to promoting concrete surface scaling. Experienced concrete technologists and research scientists would generally be suspect of this data as there is no other widely published technical reports to support or confirm its validity. In general, to establish the credibility of scientific data, the results must be reproducible by other investigators duplicating the test protocol. This has not happened. Indeed, the contrary is the case. At the end of this report a literature review list from a world wide search will reference a body of scientific literature and studies that indicate that salts containing magnesium are the most destructive deicing chemical commercially available. A phone conversation was held with Dr. David Darwin, a principal author of this referenced SHRP Report, and a Professor of Civil Engineering at the University of Kansas. He was asked specifically about the data presented on page 215. Professor Darwin, when questioned if he considered this data valid, and representative of what occurs when deicing chemicals are utilized,: responded that the results shown were "pure hogwash." As of this writing, calls to Cecil C. Chappelow of the Midwest Research Institute, have not been returned. Mr. Chappelow is also a principle co-author of the SHRP Report.

The ITD claims a twelve year history of the use of magnesium chloride. The industry has questioned where and when and in what environmental circumstances this 12 years of experience has been accrued. This has certainly not been, to the best of our knowledge, the case in eastern Idaho. From our own research we have determined that magnesium chloride does have a long history of use, on unimproved dirt or gravel type roads. Certainly, we are not being asked to make an assumption that if it works on dirt it will be fine for concrete. There is no disputing that this material keeps dust down when applied to unimproved dirt roads. Also, it is a superior road deicing chemical. Our investigation has revealed that in the winter of 1999-2000 there were some small test sections that utilized magnesium chloride, and it was allegedly evaluated by the City of Idaho Falls, Bonneville County, and the Idaho Transportation Department. We don't have any specifics or protocol as to how this evaluation was conducted. We don't even know if field testing was done on a concrete road. The governmental entities specified have not chosen to share this information with our industry, so therefore we can make no objective comments about the scientific validity of this experimentation. From the extensive damage to concrete surfaces observed this past winter, whatever was done, appears to be not adequate.

How Magnesium Chloride Damages Concrete: One must have a fundamental knowledge of concrete in its hardened state. Concrete, when setting from a plastic to hardened condition, goes through a number of chemical reactions. Basically, hardened concrete consists of two major chemical compounds; calcium-silicate-

hydrate and calcium hydroxide. Actually, the reaction products from cement hydration with water are very chemically complex, but for the purposes of this review, we will stick to the basics. When concrete is to be exposed to severe freezing, it is standard practice to entrain a system of microscopic air bubbles in concrete mixtures typically occupying a volume of 5-8%. The purpose of this air-void system is to provide space for the increased volume that water will occupy as it becomes ice. If one were to look at concrete under a microscope in the range of 3000X, this entrained air would look very much like a wasp nest. Magnesium chloride for deicing is effective in reducing the temperature at which water freezes. The problem begins as the magnesium chloride comes into contact with the now deiced concrete surface and remains contained in the melt water, and permeates into the concrete. While deicing salts containing sodium, potassium and calcium are chemically innocuous to concrete, this is not true of magnesium. The magnesium ions accumulate and react with the cementitious compound calcium- silicate-hydrate converting it to magnesium- silicate- hydrate (or a mineral called brucite)which is non-cementitious in nature. In other words, a fundamental major mineralogical product of solidified concrete has now been chemically altered (completely changed). Formation of magnesium-silicate-hydrate breaks down the “glue” that binds aggregates together and concrete surfaces begin to deteriorate. The net effect is we now have a chemical and physical attack that concrete is not designed to withstand, nor be subjected to.

Now that a fundamental understanding of what happens to concrete when magnesium chloride is used as a deicing material has been provided, it becomes a matter of a public decision. On the positive side, magnesium chloride does contribute to ease, convenience, and most importantly the safety of the motoring public. The bad news is that the consequent damage to concrete and its financial impact upon the community at large is significant. Private property owners particularly suffer damage and are looking for someone to blame. A couple of essential points. The magnesium chloride adheres to vehicle tires and to the vehicle itself and is therefore contaminating private property owners’ driveways and sidewalks and causing damage as previously outlined. Who is to pay for this? It is not realistic to expect building contractors and the ready mixed concrete industry to bear the financial burden of a problem caused by a governmental decision. If the government was willing to repair the private property damage then it is certainly fine with the concrete industry if they want to damage their own roads. Of course, one must remember that the roads will have a much reduced life cycle unless options for concrete mixtures are employed to resist the effects of magnesium chloride. It should be very clear at this point that private industry has no intention of paying for any damage that occurs in the winter season of 2001-2002 as a result of the use of inappropriate chemical substances. The last essential point of this review is that this material is extremely corrosive, causing damage to plant and vegetable life, and greatly accelerating the destruction of most metals, primarily automobiles and their accessories. The producers of the magnesium chloride claim to have integrated a corrosion inhibitor to attempt to negate some of the auto damage, but a joint study by the Colorado Transportation Department and a National Trucking Association (as a result of truckers complaints about corrosion to their vehicles and electronics) has not borne out that this “ corrosion inhibitor “ is effective.

List of Technical References

Handbook of Test Methods for Evaluating Chemical Deicers---SHRP-H-332

The Role Of Magnesium In Concrete Deterioration---Iowa DOT HR-355

The Economic Impact Of Magnesium Chloride Deicer On Concrete Bridge Decks: A Study For The Montana Department Of Transportation—Reid Crowther Consulting Inc., Seattle , WA. And Montana DOT, Bridge Bureau

Effects Of Various Deicing Chemicals On Pavement Concrete Deterioration---Mid-Continent Transportation Symposium Proceedings

Effects Of Salt Type On Concrete Scaling—American Concrete Institute, D. B. McDonald and W.F. Perenchio

Frost Action In Cement In The Presence Of Deicers—Cement and Concrete Research , Pergamon Press, Inc.—G. G. Litvan, National Research Council of Canada

Use Of Road Salt for Deicing—City Of Vancouver—R. Birch, Vancouver, B.C., Canada

ACI 201.2R Report “Guide To Durable Concrete “---Reported By Committee 201 of The American Concrete Institute, Farmington Hills, MI

Concerns Over Magnesium Chloride Prompt Study—Associated Press---Steven K. Paulson

Concrete Corrosion, Concrete Protection---Chemical Publishing Co., New York, New York---Imre Biczok

Experimental Work to Develop a Model for Cement Borehole Plug Degradation at the WIPP Site---Sandia National Laboratories, Albuquerque, NM.---Charles R. Bryan and Yifeng Wang

Modes of Experimental Concrete Deterioration--- Environmental & Engineering Geoscience—Association of Engineering Geologists and the Geographical Society of America

Cement and Concrete Chemist---H. F. W. Taylor 2nd Edition

Deteriorated Concrete from Liner of WIPP Waste Shaft---U.S. Army Corps of Engineers; L.D. Wakeley, T.S. Poole, J.P. Burkes

Individual and Combined Effects of Chloride, Sulfate, and Magnesium Ions on Hydrated Portland Cement Paste--- U.S. Army Corps of Engineers, Toy Poole, Lillian Wakely, Cameron Young

Salt Saturated Mass Concrete Under Chemical Attack---American Concrete Institute; L. Wakely, T.S. Poole, J.J. Ernzen, and B.D. Neeley

Durability of Concrete Materials in High-Magnesium Brine---U.S. Army Corps of Engineers; L. Wakely, T. Poole, P. Burke