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SUBJECT: Technical Memorandum #10
Corrosion Inhibitors in Concrete

Corrosion of embedded metals in concrete has caused the early failure of structures, or parts thereof, in environments where concrete is subjected to ingress of chlorides. One such environment is the reinforced concrete bridge decks to which deicing salts are applied to combat snow and ice conditions during winter storms. The primary methods used in Colorado to extend the life of concrete bridge decks include the use of increased cover, low-permeability concrete, epoxy-coated rebars, and sealers. Additionally, the Department will introduce the use of silica fume admixture to a concrete overlay in several Denver area projects. These overlays are being placed as a redundant future removable system such that should deck deterioration occur, it will be possible to place another protective system without interference to underpassing traffic because of the need for shoring.

A potential strategy to provide corrosion protection to the steel in reinforced concrete is the use of calcium nitrite as an inhibitor to the corrosion. The inhibitor is a liquid admixture and is distributed throughout the concrete protecting all the steel. The calcium nitrate serves to change the ferrous ions produced when reinforcing steel is placed in the alkaline concrete environment into a stable passive layer on the steel which blocks active corrosion.

The commercial use of calcium nitrite as a corrosion inhibitor for ingressed chlorides started in 1978 with bridge deck applications on an experimental basis by various State

Departments of Transportation in the United States. These older bridge decks in Illinois, New Hampshire, and Maine contain calcium nitrite protection for uncoated steel reinforcement. Several have recently been cored and show that the nitrite is still present in original quantities and corrosion measurements indicate complete passivity. The following table gives calcium nitrite levels and chloride levels in specimens taken from a deck in Illinois.

ILLINOIS BRIDGE DECK NITRITE AND CHLORIDE LEVELS AFTER 11 YEARS

POSITION	DEPTH (inches)	NITRITE (ppm)
1	1.75-2.25	2007
2	0.5-1	2387
3	0.1.5	1922
4	0.5-1	3095
5	0.5-1	2236
6	1.75-2.25	1997

Original Nitrite Content approximately equals 2100 ppm (4 gpy)

Steel is Still Passive

FHWA conducted research using calcium nitrate as a corrosion inhibitor during the early 1980's. In a letter from Douglas A. Bernard, Chief, Demonstration Projects Division, July 23, 1985, the following statement is made:

> "...Based on this research (report pages 17-18-FHWA/RD-83/012) initial indications are that under given conditions, the calcium nitrite can provide about the same level of corrosion protection that epoxy coating of reinforcing steel can."

This seems to me to suggest a promising potential for the use of calcium nitrite which unlike the physical bonding and placing of the epoxy coating on rebar is a chemical process which blocks the chemical reaction between the reinforcing steel and the chloride ions, thus preventing corrosion.

Included in that memorandum was a cell by FHWA to highway agencies to evaluate the inhibitor on an experimental basis. The following listing represents bridge demonstration projects regarding the use of the admixture in bridge decks through 1989.

California	-	Deck	-	1980
Illinois	-	Deck	-	1981
			(see references above)	
Indiana	-	Deck	-	1987
Virginia	-	Deck	-	1988
Kentucky	-	2 Decks	-	1986
Minnesota	-	Deck	-	1989
Texas	-	Deck	-	1986
Tennessee	-	Deck	-	1985
West Virginia	-	Deck	-	1988

Obviously, not all of the above experiments were in response of the FHWA, however, the listing does represent considerable use of information on results.

Calcium nitrite as a corrosion inhibitor is covered by ASTM C494, "Standard Specification for Chemical Admixtures for Concrete." As I read the specification, however, it is one which covers seven types of materials for use as chemical admixtures to be added to Portland cement concrete mixtures in general and for various peroses as follows:

Type A - Water-reducing admixtures,
Type B - Retarding admixtures,
Type C - Accelerating admixtures,
Type D - Water-reducing and retarding admixtures
Type E - Water-reducing and accelerating admixtures
Type F - Water-reducing, high range admixtures,
type G - water-reducing, high range, and retarding

Thus, the specifications not specific to calcium nitrite per se and the designer should specify a type. The purpose of the specification is more to insure that the inhibitor does not adversely affect the basic properties of the concrete.

The amount of active corrosion which the designer wishes to inhibit is the basis for the dosage of the admixture. ASTM Committee C -0.-384, Committee on Corrosion Inhibitors, is currently developing a specification which would include calcium nitrite. The following table is provided as guidance regarding appropriate dosage of calcium nitrite admixture to provide a corrosion-free performance.

Calcium Nitrite Dosage Rates vs Chloride Protection

Calcium Nitrite Gallons/c.y.	Chloride lbs./c.y.
2	6.0
2 1/2	8.0
3	9.9
3 1/2	11.5
4	13.0
4 1/2	14.1
5	15.0
5 1/2	15.6
6	16.0

The calcium nitrite inhibitor is normally added at a rate of 3 to 5 gallons per cubic yard. For marine environments, North Carolina recommends 5.4 gallons per cubic yard with the hardened concrete containing no less than 9.0 lb/cy Nitrate (NO_2). Michigan recommends 4.0 gallons pe cubic yard for all prestressed concrete beams to protect against deicing chemical attack.

This memorandum is prepared as informational guidance to designers contemplating the use of calcium nitrite as a corrosion inhibitor. My own view is that here appears to be sufficient evidence that the product "...can provide about the same level of corrosion protection that epoxy coating of reinforcing steel can...", bur without the danger of damage to the coating which a task force including bridge and materials personnel will be formed to evaluate potential use of the product within the Department.

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