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The Effects of DSS Corrosion Inhibitor on Physical Characteristics of Concrete

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16 **Abstract**

Corrosion of reinforcing steel in bridge decks and subsequent deterioration of the structure continues to challenge the materials engineering community. Hycrete DSS is a new product which has shown promising corrosion inhibiting behavior in testing by several northeastern states.

The physical effects of adding DSS corrosion inhibitor to a standard Kansas concrete mix were investigated in the summer of 2003 by the concrete research staff of the Kansas Department of Transportation. Four 1.70 cubic foot batches of concrete were produced: a control mix, a mix with air-entraining admixture, a mix with Hycrete DSS, and a mixture with Hycrete DSS and a de-foaming agent.

Conclusions

1. Hycrete DSS, used with a defoaming agent, reduces the permeability to one-tenth to one-third of plain air-entrained concrete as measured by the evapo-transpiration test.
2. The use of the de-foaming agent with the Hycrete DSS additive is highly recommended to control the amount of air in the mix. In this test, the de-foaming agent reduced the total air content by over 50%, into the normal air-content range for air-entrained concrete.
3. The addition of Hycrete DSS causes an approximately 10% strength reduction from expected valued for concrete with similar air contents.
4. The addition of Hycrete DSS had no appreciable effect on the slump of the concrete or the proportion of entrained air content to total air content.

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DISCLAIMER

The Effects of DSS Corrosion Inhibitor on Physical Characteristics of Concrete

Introduction

Corrosion of reinforcing steel in bridge decks and subsequent deterioration of the structure continues to challenge the materials engineering community. Hycrete DSS is a new product that has shown promising corrosion-inhibiting behavior in testing by several northeastern states (Civjan et al., 2003).

Hycrete DSS is an anticorrosion admixture adapted from the automotive industry, where it was used for preventing corrosion in engine cores. In concrete, Hycrete reacts with metallic cations to form an insoluble metallic salt. Molecules of this salt have a long-chain hydrocarbon on one end that repels water and a polar end that attaches to reinforcing steel, creating a water-repellant layer that is strongly attached to the steel.

Methods

The physical effects of adding DSS corrosion inhibitor to a standard Kansas concrete mix were investigated in the summer of 2003 by the concrete research staff of the Kansas Department of Transportation. Four 1.70 cubic foot batches of concrete were produced: a control mix, a mix with air-entraining admixture, a mix with Hycrete DSS, and a mixture with Hycrete DSS and a de-foaming agent. See Table 1 for batch weights and proportions.

Table 1. Mix designs for four batches of concrete tested.

	Batch Type			
Component	Control	AEA added	Hycrete DSS	de-foamed DSS
Cement, lbs	37.90	37.90	37.90	37.90
AEA, ml	0	8.94	0	0
Hycrete, lbs.	0	0	1.04	1.04
De-foaming agent, g	0	0	0	4.0
Water, lbs.	16.68	15.92	14.78	14.78
CA-6, lbs.	91.15	92.12	92.12	92.12
FA-A, lbs.	91.15	92.12	92.43	92.43
Design w/c	0.44	0.42	0.42	0.42

An air void analysis, total air content by volume and slump were performed on the fresh concrete. 16 4x8 in and 4 3x6 in cylinder samples were cast for testing according to the schedule shown in Table 2. All of the specimens were cured in a 100% humidity moist room until testing or 28 days after casting, whichever came first. After 28 days the specimens were kept in a 50% humidity environment, where they remained until testing.

Table 2. Sample description and testing schedule.

Hardened Concrete Tests			
age of sample	compressive strength	rapid chloride permeability	evapo-transpiration permeability
4 days	3-4×8 in		
7 days	3-4×8 in	1-4×8 in	1-3 ×6 in
28 days	3-4×8 in	1-4×8 in	1-3 ×6 in
56 days	3-4×8 in	1-4×8 in	1-3 ×6 in
90 days		1-4×8 in	1-3 ×6 in

Results

Slump varied little among the four test batches. Total air content behaved as predicted, ranging from 3.75% for the control mix to 13.75% for the Hycrete mix without de-foaming agent. Adding de-foaming agent to a Hycrete mixture reduced the total air content to 6.40%. See Table 3 for all results of fresh concrete tests.

Table 3. Results of testing of fresh concrete.

Results of Fresh Concrete Tests				
Batch Type	average spacing factor, mm	slump, in	total air content, %	entrained air content, %
Control	0.699	2.75	3.75	2.2
AEA added	0.140	2.75	8.75	6.2
Hycrete DSS	0.179	2.25	13.75	5.8
De-foamed DSS	0.213	2.50	6.40	4.5

Results of the tests on hardened concrete specimens are given as follows in Tables 4, 5, and 6.

Table 4. Average compressive strength test results from three samples

Results of Compressive Strength Tests, psi				
age of sample	Control	AEA added	Hycrete DSS	de-foamed DSS
4 days	3977	2490	2087	2837
7 days	4377	3330	2700	3377
28 days	6007	4547	3633	4287
56 days	7263	6007	4610	5027

Table 5. Average rapid chloride permeability test results from two samples.

Results of Rapid Chloride Permeability Tests, Coulombs				
age of sample	Control	AEA added	Hycrete DSS	de-foamed DSS
7 days	7645	6681	13648	5075
28 days	5769	4784	3983	3970
56 days	3679	2596	3148	2332
90 days	4053	1435	2948	1803

Table 6. Average evapo-transpiration test results from two samples.

Results of Evapo-transpiration Permeability Tests, ml/min x 100,000				
age of sample	Control	AEA added	Hycrete DSS	de-foamed DSS
7 days	65	130	30	15
28 days	45	25	25	8
56 days	45	50	35	35
90 days	80	95	77	30

Discussion

Although Hycrete DSS alone did not significantly reduce the permeability of the concrete as measured in the rapid chloride permeability test, the defoamed Hycrete mixture performed quite favorably in comparison to the control mix and the air-entrained mix. The permeability of the Hycrete-only mix was twice as high as the control mix at seven days, but had decreased to be slightly less than the permeability of the control mix at 28, 56 and 90 days. The increase in early-age rapid-chloride permeability may be related to the ionic nature of the Hycrete solution, which could make the concrete more electrically conductive but not necessarily more water-permeable. Results for all mixes at all ages greater than seven days varied amongst each other by 50% or less. See figure 1.

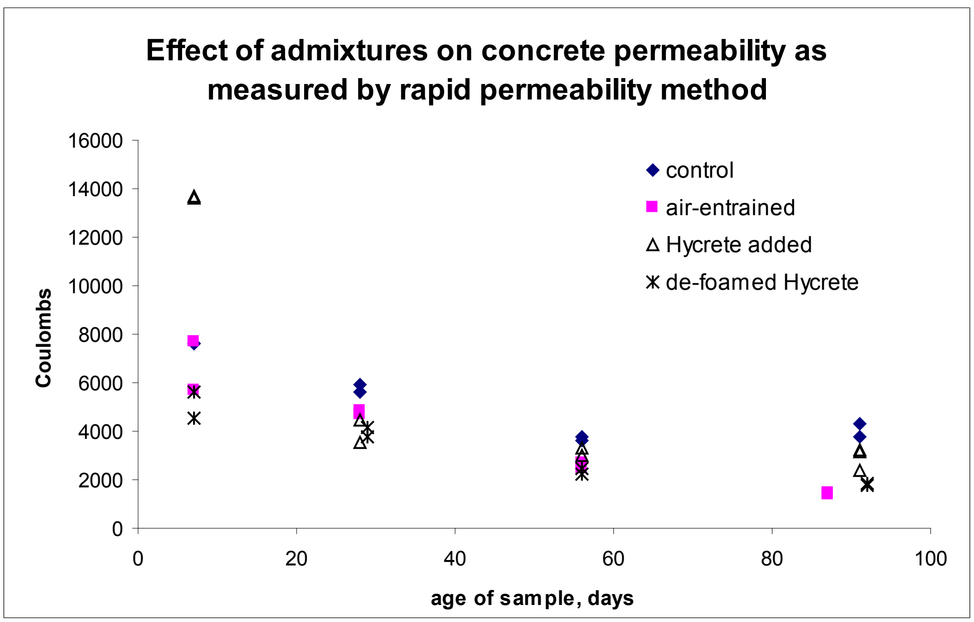

Figure 1. Comparison of permeability as measured by rapid method for four concrete mixes at 7, 28, 56 and 90 days after casting.

Resistance to capillary flow of water through the concretes was measured using the Kansas evapo-transpiration test, in which a desiccant on one side of a one-inch-thick sample draws water from the other side. The samples made with defoamed Hycrete had the lowest permeability at all ages when measured by the evapo-transpiration test. The mix with Hycrete alone performed almost as well as the defoamed Hycrete mix. Both had lower permeability at all ages than the standard air-entrained concrete. The permeabilities of the four types of concrete were quite similar and quite low at 56 days. The 90-day permeabilities for all mixes except the de-foamed Hycrete mix were actually higher than the 56-day permeabilities, suggesting the development of micro-cracking in the specimens. See figure 2.

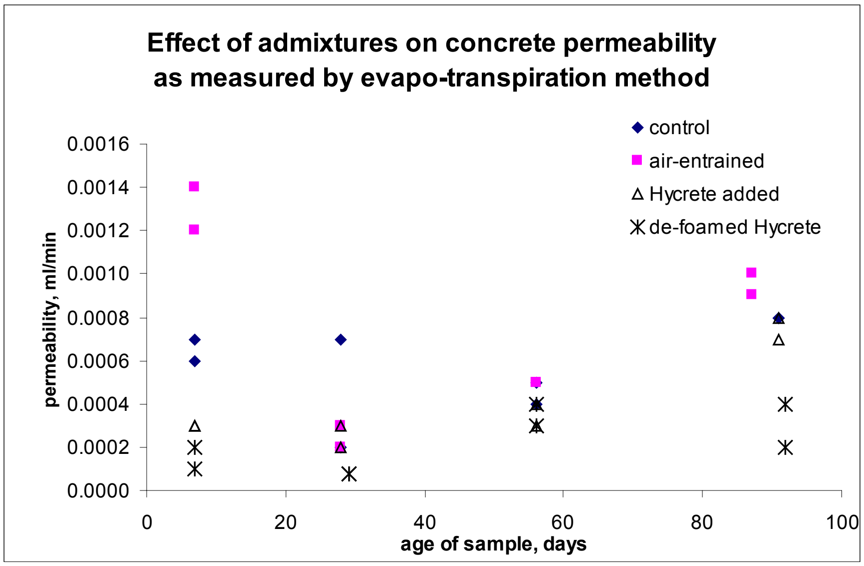

Figure 2. Comparison of permeability as measured by evapo-transpiration method for four concrete mixes at 7, 28, 56 and 90 days after casting.

The addition of Hycrete and Hycrete with the defoaming agent reduced the strength of the concrete. The control mix was the strongest, with an average 28-day strength of 6007 psi, followed by the air-entrained mix at 4547 psi. Although the defoamed Hycrete mixture had 26% less total air content (a reduction of 2.35% air) than the air-entrained concrete, its 28-day strength was lower at only 4287 psi. This strength reduction is approximately 10% higher than would be accounted for by differences in air content alone. Other researchers that have investigated the effect of Hycrete on physical properties of concrete have noticed similar effects on the strength (Civjan et al., 2003). See figures 3 and 4.

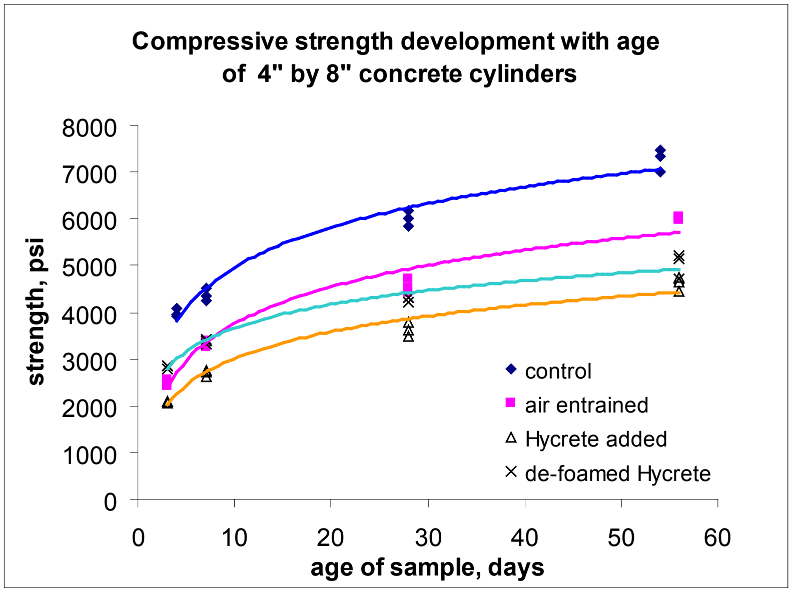

Figure 3. Change of compressive strength with time of concrete cylinder samples from four test mixes.

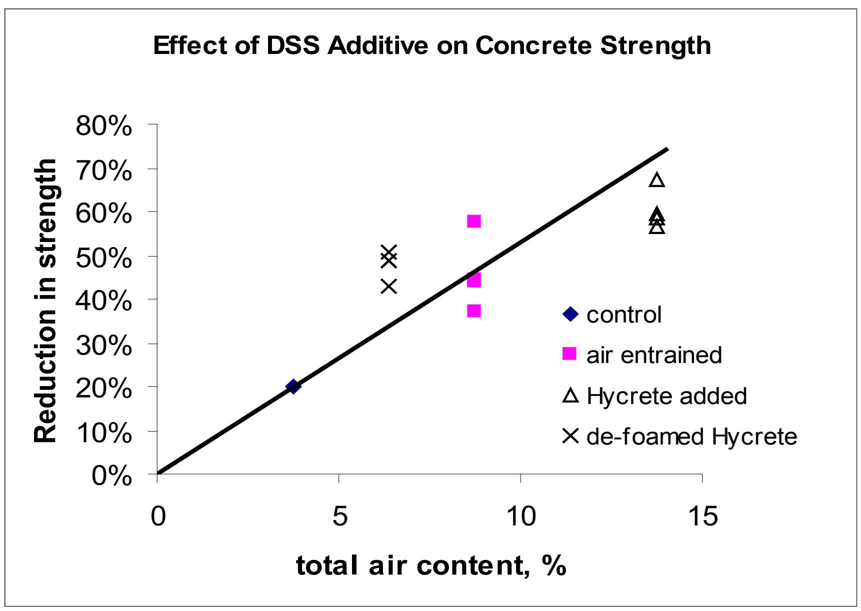

Figure 4. Comparison of expected and actual strength reduction due to sir content in concrete.

Conclusions

1. Hycrete DSS, used with a defoaming agent, reduces the permeability to one-tenth to one-third of plain air-entrained concrete as measured by the evapo-transpiration test.

2. The use of the de-foaming agent with the Hycrete DSS additive is highly recommended to control the amount of air in the mix. In this test, the de-foaming agent reduced the total air content by over 50%, into the normal air-content range for air-entrained concrete.

3. The addition of Hycrete DSS causes an approximately 10% strength reduction from expected valued for concrete with similar air contents.

4. The addition of Hycrete DSS had no appreciable effect on the slump of the concrete or the proportion of entrained air content to total air content.

Reference

Civjan, S.A., LaFave, J.M., Lovett, D.J., and Trybulski, J., Performance Evaluation and Economic Analysis of Combinations of Durability Enhancing Admixtures (Mineral and Chemical in Structural Concrete for the Northeast U.S.A., prepared for The New England Transpiration Consortium, February 2003, NETCR36, Project No. 97-2, 166 pp.

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