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DoD Corrosion Prevention and Control (CPC) Program

Hydrophobic Concrete Admixture Product Testing and Validation

Contractor's Supplemental Report for CPC Project F09-AR05A

Lawrence R. Wachowski, Paul G. Tourney,
Mathew A. Miltenberger, and Neal S. Berke

December 2017

Construction Engineering
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Hydrophobic Concrete Admixture Product Testing and Validation

Contractor's Supplemental Report for CPC Project F09-AR05A

Lawrence R. Wachowski, Paul G. Tourney, Mathew A. Miltenberger, and Neal S. Berke

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Final report

Prepared for Office of the Secretary of Defense (OUSD(AT&L))
3090 Defense Pentagon
Washington, DC 20301-3090

Under Military Interdepartmental Purchase Request (MIPR) DWAM90450; Contract W9132T-TCG-001, "Admixture Product Testing and Validation"

Monitored by Construction Engineering Research Laboratory
U.S. Army Engineer Research and Development Center
Champaign, IL 61822

Abstract

The Department of Defense spends many millions of dollars annually to repair or replace steel-reinforced structures that are seriously damaged by corrosion. Reinforced concrete is readily damaged by corrosion because the cement/aggregate matrix is porous, allowing corrosive chemicals (e.g., chlorides from marine salts or road-deicing salts) to deeply penetrate structures following wetting/drying cycles. Damage modes include loss of reinforcement steel mass through corrosion and fracturing due to corrosion-product buildup or freeze/thaw cycling. These stresses can destroy a concrete structure many years short of its intended service life.

This report documents one of several studies performed or supervised by the U.S. Army Engineer Research and Development Center to demonstrate or test the efficacy of a commercial hydrophobic concrete admixture in preventing the ingress of water and chlorides into reinforced concrete structures or specimens. Laboratory testing addressed chloride ingress threshold (destructive examination of specimens), absorption, and transport. This report includes an executive summary of the project and a detailed record of all testing program results.

Foreword

From FY09 to FY10 ERDC-CERL performed or supervised several studies on a hydrophobic concrete admixture to explore its characteristics, effects on concrete to which it was added, and ability to reduce moisture penetration as a way to mitigate the corrosion of reinforcement bars. Tourney Consulting Group (TCG) was subcontracted by Mandaree Enterprise Corporation (MEC), of Warner Robins, GA, to evaluate the ability of the Hycrete®* admixture product to minimize the ingress of water and chlorides into concrete and to inhibit corrosion of embedded reinforcing steel.

Absorption testing showed a reduction in absorption with Hycrete. Transport testing using the admixture showed no statistically significant reduction in the ion diffusion coefficient (IDC) but did show reductions in the moisture transport coefficient (MTC) at higher water/cement (w/c) ratios. The chloride levels for all but one control and all the Hycrete specimens were below the threshold value for corrosion initiation of the reinforcing bar. There was a decrease in chloride ions at the reinforcing bar for the Hycrete specimens compared to the controls, a 33% reduction for one gallon per cubic yard (gpy) of Hycrete and a 57% reduction for two gpy.

TCG reviewed testing and modeling results for a companion project conducted by SIMCO Technologies, Inc. (ERDC/CERL CR-17-5). SIMCO developed a new set of equations to use in its STADIUM (Software for Transport and Degradation In Unsaturated Materials) modeling software to account for water absorption properties of damproofing admixtures. TCG reviewed an example model for a cope wall with a 0.4 w/c concrete mix and 2 gal/yd^3 of Hycrete in a tidal exposure.

Results showed that Hycrete will significantly reduce chloride ingress and increase time to corrosion for a chloride threshold value of 0.2% (2000 ppm) by mass of concrete. Hycrete in this scenario will not provide a 75 year service life, but in combination with a corrosion protection system that increases the chloride threshold value may do so. However, typical chloride threshold values are considered to be at 0.05% (500 ppm). At this threshold there is a significant decrease in chloride ingress, however, even at the higher-than-normal chloride threshold value the Hycrete concrete would only extend time to corrosion to 37 years versus 12 years for the

control. Using a more conservative chloride threshold value would result in a much lower increase in time to corrosion versus the control.

Other ERDC-CERL research reports have been published about this material:

Michael K. McInerney, Steven C. Sweeney, Orange S. Marshall Jr., and Lawrence Clark. 2017. *Investigation of Hydrophobic Concrete Additive for Seawall Replacement at Pililaau Army Recreation Center, Hawaii: Final Report on Project F09-AR05A*. ERDC/CERL TR-17-10. Champaign, IL: ERDC-CERL. http://dx.doi.org/10.21079/11681/22550

Steven C. Sweeney. 2017. *Exposure Testing of Hycrete Concrete Additive in a Wastewater Treatment Environment: Final Report on Project F09-AR05B*. ERDC/CERL TR-17-11. Champaign, IL: ERDC-CERL. http://dx.doi.org/10.21079/11681/22583

Eric Samson and Tiewei Zhang. 2018. *Modeling the Effect of a Hydrophobic Concrete Admixture on Chloride Ingress: Contractor's Supplemental Report for Project F09-AR05A*. ERDC/CERL CR-17-5. Champaign, IL: ERDC-CERL.

Michael K. McInerney, P.E.

Program Coordinator, Corrosion Prevention and Control Program
ERDC-CERL
Champaign, Illinois

Preface

This study was performed for the U.S. Army Engineer Research and Development Center, Construction Engineering Research Laboratory (ERDC-CERL) by Tourney Consulting Group, Kalamazoo, MI, under Military Interdepartmental Purchase Request MIPRDWAM90450; Contract W9132T-TCG-001, "Admixture and Product Testing Validation." The contractor's final report has been accepted for publication by the Office of the Secretary of Defense (OSD). The project monitor and CPC Program Coordinator for OSD was Michael K. McInerney, CEERD-CFM.

The work was monitored by the Materials and Structures Branch of the Facilities Division (CEERD-CFM), U.S. Army Engineer Research and Development Center, Construction Engineering Research Laboratory (ERDC-CERL), Champaign, IL. At the time of publication, Vicki L. Van Blaricum was Chief, CEERD-CFM; Donald K. Hicks was Chief, CEERD-CF; and Kurt Kinnevan was the Technical Director for Adaptive and Resilient Installations, CEERD-CZT. The Interim Deputy Director of ERDC-CERL was Michelle J. Hanson, and the Interim Director was Dr. Kirankumar Topudurti.

The Commander of ERDC was COL Bryan S. Green, and the Director was Dr. David W. Pittman.

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Part 1: Executive Summary

Contractor's Summary of Research Objectives, Approach, and Results

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September 16, 2014

Larry Clark, Senior Program Manager
Mandaree Enterprise Corp.
812 Park Drive
Warner Robins, GA 31088

Re: Admixture Product Testing and Validation
Contract/Purchase Order No. W9132T-TCG-001, W9132T-06-D-0001

Larry:

This is the final report on the Admixture Product Testing and Validation , Contract/Purchase Order No. W9132T-TCG-001, W9132T-06-D-0001 conducted at TCG. The objective of this project is to validate the claims of Hycrete admixture as a corrosion inhibitor. The Hycrete admixture product has a similar protection mechanism as some hydrophobic admixtures but also claims corrosion inhibition at the steel reinforcing. The primary two protection mechanism claims are:

- Hycrete provides corrosion inhibition at the steel to increase the corrosion threshold level.
- Hycrete provides a hydrophobic concrete matrix to minimize the ingress of water and chlorides into the concrete.

At the end of the contract period the following was determined:

- Chloride threshold testing – not conclusive
    - One control specimen has shown signs of corrosion activity and has been autopsied after test cycle 69 (480 days)
    - No signs of corrosion activity for all other specimen after test cycle 72 (501 days)
    - Destructive examination indicates control specimens are in the range of commonly accepted chloride contents for corrosion initiation
- Absorption testing – complete and was reported previously (Appendix)
- Transport testing – complete and was reported previously (Appendix)
- STADIUM Modeling – Was completed in May 2013 by SIMCO Technologies, Inc.
    - IDC and MTC calculations were performed for three w/cm values on controls and concretes with 1 or 2 gallons per cubic yard of Hycrete
    - Water absorption was determined
    - A new module to model results was developed, but was not provided to TCG
    - One example was provided that will be summarized here

Work Scope

The following tests were performed as part of the project work scope:

1. Chloride Threshold Testing (proposed method in ASTM committee)**:** This test is conducted on 15 mortar cylinders per treatment containing two reinforcing steel bars. This test determines the chloride content at the reinforcing steel depth when corrosion begins. Multiple specimens provide a high level of statistical confidence. This is an 18 month or longer test program.

Test treatments:

- Control (plain mortar)
- 1 Gal/CY Hycrete
- 2 Gal/CY Hycrete

2. Absorption Testing:

- ASTM C642-97 Standard Test Method for Density, Absorption, and Voids in Hardened Concrete
- BS 1881-122:1983 Testing concrete. Method for determination of water absorption

3. Transport Testing of Concrete – Ionic migration and drying test are used to characterize the steady-state ion diffusion properties and the wetting / drying properties or moisture transport as inputs for STADIUM.

4. STADIUM Modeling / Simulations – Service life simulations were to be conducted using STADIUM for various USACOE applications assessing the differences/improvements offered by Hycrete once testing is complete. However, the model available does not account for water absorption and only one example was provided by SIMCO under W9132T-SIM-001 Task Order No. 0015, which is reviewed here.

Chloride Threshold Testing

Chloride threshold testing was conducted, but could not be completed, for 3 testing treatments as noted above including:

- a control group, 0.49 w/cm
- 1 gallon admixed Hycrete, 0.49 w/cm and
- 2 gallons of admixed Hycrete 0.49 w/cm

Macrocell current and half-cell potential measurements were performed to determine the time of corrosion initiation. Once corrosion initiation occurs, the corroding specimen is removed from the cyclic ponding environment and a destructive examination of the specimen is performed. Powder samples are obtained from the specimen at the reinforcing level during the examination. The chloride-ion content of the powder sample is determined for each test

specimen at the level of the steel. The chloride threshold is determined by subtracting the background chloride content from the chloride content obtained following corrosion initiation.

At the end of the contracted testing period, corrosion was not occurring so no conclusions can be stated as to the effect of Hycrete on the corrosion threshold. As reported in the interim report of March 18, 2011 the chloride levels for all but one corroding control and all the Hycrete specimens were below the threshold value of approximately 0.4% of chloride by mass of cement for corrosion initiation. There was a decrease in chloride ions at the reinforcing bar level for the Hycrete specimens due to the hydrophobic effect that lowers ingress of water and chloride. Analyzing the data from Table 2 of that report (eliminating the high control value that appeared to be an outlier and was on the one corroding specimen) showed a 33% reduction of chloride at the reinforcing bar level for 1 gpy of Hycrete and a 57% reduction in chloride for 2 gpy. However, the variation in chloride contents was high.

Absorption Testing

The absorption testing was performed in accordance to ASTM C642-97 Standard Test Method for Density, Absorption, and Voids in Hardened Concrete and BS 1881-122:1983 Testing concrete - Method for determination of water absorption. After 117 days of curing, there was about a 10% to 30% reduction in porosity at 0.35 and 0.5 w/c but at 0.65 there were not any appreciable differences. At 28 days of curing the 0.5 w/c specimens had slightly more permeable voids than those cured for 117 days, but the control and Hycrete specimens were similar.

The BS 1881-122 test was performed on the 0.5 w/c concrete mixes. The previously reported results are in Table 1. The percentage decreases are included and show a significant reduction in absorption, especially at 30 minutes. At 48 hours the percent reduction in absorption is less indicating that long times submerged in water will lessen the benefits of this technology, which will be addressed in more detail, later in this final report.

Table 1 – Synopsis of BS 1881 Absorption Data for Control and Hycrete Concretes at 0.5 w/c

Soak Time	Control		Hycrete (1gpy)		Hycrete (2gpy)	
hours	%Absorption	%Reduction vs. Control	%Absorption	%Reduction vs. Control	%Absorption	%Reduction vs. Control
0.5	2.61	0	0.98	62	0.58	78
48	5.58	0	4.75	16	2.99	46

Transport Testing

Transport testing is used to characterize the steady-state ion diffusion properties and the wetting / drying properties or moisture transport as inputs for STADIUM®. The test methods used are specific to STADIUM and were developed by SIMCO. The transport properties were in the interim report, but are represented in Table 2.

Table 2 – Transport Properties Determined for Use in STADIUM®

Property	w/c								
	0.35			0.5			0.65		
	Control	Hycrete (1 gpy)	Hycrete (2 gpy)	Control	Hycrete (1 gpy)	Hycrete (2 gpy)	Control	Hycrete (1 gpy)	Hycrete (2 gpy)
Ion Diffusion Coefficent (IDC) (10^{-11} m^2/s)	10	9.4	9.1	15	14	13	20	18	18
Moisture Transfer Coeff. (MTC), (10^{-22} m^2)	1.1	1.2	2	28	23	17	64	50	46

The results in Table 2 indicate that there is not a large difference in the IDC values with the addition of Hycrete given the normal distribution of IDC values for a given concrete tested from the same batch or different batches. The MTC values are lowered in the higher w/c concretes, but not in the concrete at 0.35 w/c.

STADIUM® Modeling

STADIUM modeling for time to corrosion requires inputs obtained from chloride threshold testing. Since corrosion did not initiate in the allotted time for corrosion testing, just the effects of Hycrete on chloride ingress can be estimated.

Since the IDC values in Table 2 are essentially the same with or without Hycrete, in submerged conditions Hycrete would not be expected to offer a benefit in chloride ingress reduction.

MTC values with Hycrete are lower than the controls at w/c of 0.5 and 0.65, so there would be an expected reduction in chloride ingress in wetting and drying conditions where the concrete is not water saturated, at the higher w/c's.

The standard STADIUM testing for MTC is a drying test conducted at 50% RH at 72 °F. This test doesn't capture the lower absorption rate of water back into the concrete. This is important for

Hycrete and similar dampproofing additives as they will make the concrete hydrophobic upon drying.

A contract W9132T-SIM-001 Task Order No. 0015—Modeling the Effect of Dampproofing Admixtures on Chloride Ingress was awarded to SIMCO Technologies to develop a module and test methods to address the special properties of a dampproofing admixture.

SIMCO determined the IDC, MTC, porosity, and water absorption properties of Controls and mixes with 1 gpy and 2 gpy of Hycrete. Two sets of mixes were at a w/c of 0.4, and 0.55 with just Portland cement, and another set was at 0.45 w/cm with a 20% fly ash cement replacement. Complete details are given in W9132T-SIN-001 Modeling the Effect of Damproofing Admixtures on Chloride Ingress.

SIMCO found that at 0.4 w/c there was a reduction in the IDC for the Hycrete versus the control mixes, in contrast with results they had at 0.55 w/c and 0.45 w/cm with fly ash showing equivalent IDC values. TCG didn't find an improvement in IDC at 0.35, 0.5, or 0.65 w/c. It appears that the results at 0.4 w/c contradict the bulk of the data. One possible explanation is that the SIMCO control at 0.4 w/c had 8.0% air which could possibility increase IDC due to coalescence of air voids near aggregate interfaces. The 0.4 w/c Hycrete mixes had air contents that were 5.6% (1 gpy Hycrete) and 5.4%(2 gpy Hycrete), so they would have a lower probability of having coalesced air voids at the aggregate interfaces.

SIMCO developed a methodology and a substitute equation to use in the STADIUM modeling program. However, they did not include this in the commercial program, so TCG could not conduct STADIUM modeling for Hycrete.

The SIMCO report, dated May 2013, has an example for a cope wall, with 60 mm of concrete cover over the reinforcing bars, in a tidal zone, at 0.4 w/c and 2 gpy of Hycrete. They estimated the chloride threshold at 0.2% by mass of concrete which is considerably higher than 0.05-0.1% range typically used.

Figure 1 copied from SIMCO's report shows the estimated chloride levels as a function of time for the cope wall. A chloride threshold value of 0.2% (2000 ppm) by mass of concrete was selected by SIMCO, though typical chloride threshold values are considered to be at 0.05% (500 ppm) of concrete. There is a significant decrease in chloride ingress, however, even at the higher than normal chloride threshold value the Hycrete concrete would only extend time to corrosion to 37 years versus 12 years for the control. Using a more conservative chloride threshold value would result in a much lower increase in time to corrosion versus the control.

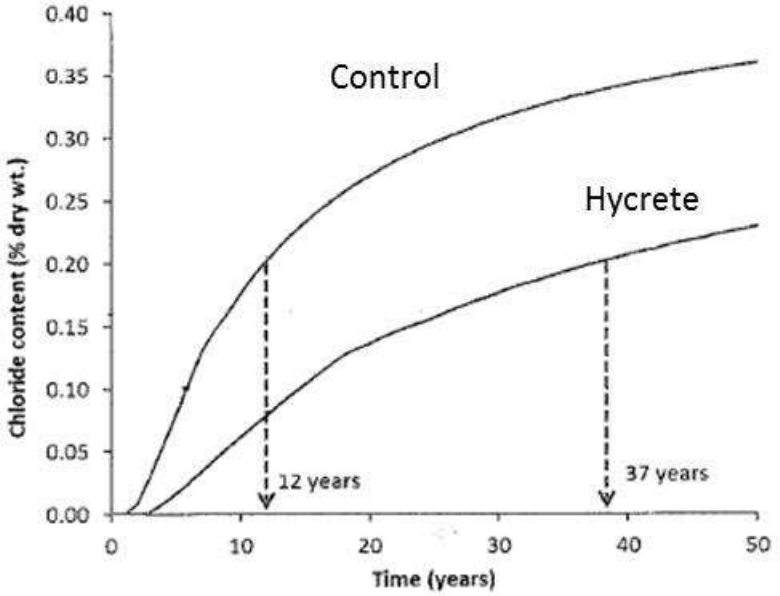


Figure 1 – STADIUM prediction of chloride content vs. time for a cope wall in the tidal zone, w/c=0.4 with 60 mm of concrete cover over the reinforcement.

Other curves presented indicate that 75 mm of cover would be close to 50 years at the high chloride threshold level. Nevertheless, there is an improvement with Hycrete that is significant and if used with another corrosion protection system that raises the chloride threshold values, this would perhaps lead to a significant improvement in time to corrosion.

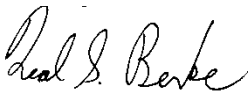
SIMCO didn't mention the temperature used in the simulation, but in a colder environment, time to reach the chloride threshold would be increased, and times decreased for a warmer environment.

Summary

- Absorption testing – completed and shows a reduction in absorption with Hycrete
- Transport testing – completed, shows no statistically significant reduction in IDC with Hycrete, but reductions in MTC with Hycrete at higher w/c concretes tested.
- Chloride threshold testing – inconclusive for test duration
    - Only one control specimen out of 15 failed
    - No signs of corrosion activity for all other specimens
    - Destructive examination indicates control specimen are below or at the range of commonly accepted chloride contents for corrosion initiation
- STADIUM Modeling – Required modification to the program to account for water absorption properties of dampproofing admixtures
    - SIMCO developed new set of equations to use

- Hycrete will reduce chloride ingress in the tidal zone and other exposures where the concrete goes through wetting and drying cycles
- Hycrete will not reduce chloride ingress in concrete that is always water saturated.
- SIMCO did not provide a module to STADIUM so that TCG could model several scenarios
- TCG reviewed example from SIMCO for a cope wall at 0.4 w/c in a tidal exposure
    - Hycrete will significantly reduce chloride ingress and increase time to corrosion if threshold for chloride is not changed
    - Hycrete for this scenario will not provide a 75 year service life, but in combination with a corrosion protection system that increases the chloride threshold value could do so.

Tourney Consulting Group, LLC



Neal S. Berke, PhD

Vice President, Research

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Part 2: Appendix

Unabridged Report on Experimental Procedures, Data, and Results

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March 18, 2011

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Re: Hycrete Admixture Product Testing and Validation

Larry:

This interim report provides an update on the Hycrete admixture product testing being conducted at TCG. The objective of this project is to validate the claims of Hycrete admixture as a corrosion inhibitor. The Hycrete admixture product has a similar protection mechanism as some hydrophobic admixtures but also claims corrosion inhibition at the steel reinforcing. The primary two protection mechanism claims are:

- Hycrete provides corrosion inhibition at the steel to increase the corrosion threshold level.
- Hycrete provides a hydrophobic concrete matrix to minimize the ingress of water and chlorides into the concrete.

The current project status indicates:

- Chloride threshold testing – in progress
  - One control specimen has shown signs of corrosion activity and has been autopsied after test cycle 69 (480 days)
  - No signs of corrosion activity for all other specimen after test cycle 72 (501 days)
  - Destructive examination indicates control specimen are in the range of commonly accepted chloride contents for corrosion initiation
- Absorption testing – complete
- Transport testing – complete
- STADIUM Modeling – Start date to be determined by chloride threshold results

Work Scope

The following tests were performed as part of the project work scope:

1. Chloride Threshold Testing (proposed method in ASTM committee)**:** This test is conducted on 15 mortar cylinders per treatment containing two reinforcing steel bars. This test determines the chloride content at the reinforcing steel depth when corrosion begins. Multiple specimens provide a high level of statistical confidence. This is an 18 month or longer test program.

Test treatments:

- Control (plain mortar)
- 1 Gal/CY Hycrete
- 2 Gal/CY Hycrete

2. Absorption Testing:

- ASTM C642-97 Standard Test Method for Density, Absorption, and Voids in Hardened Concrete
- BS 1881-122:1983 Testing concrete. Method for determination of water absorption

3. Transport Testing of Concrete – Ionic migration and drying test are used to characterize the steady-state ion diffusion properties and the wetting / drying properties or moisture transport as inputs for STADIUM.

4. STADIUM Modeling / Simulations - Simulations will be conducted using STADIUM for various USACOE applications using Hycrete once testing is complete.

Chloride Threshold Testing

Chloride threshold testing is underway for 3 testing treatments as noted above including:

- a control group, 0.49 w/cm
- 1 gallon admixed Hycrete, 0.49 w/cm and
- 2 gallons of admixed Hycrete 0.49 w/cm

Macrocell current and half cell potential measurements are performed to determine the time of corrosion initiation. Once corrosion initiation occurs, the corroding specimen is removed from the cyclic ponding environment and a destructive examination of the specimen is performed. Powder samples are obtained from the specimen at the reinforcing level during the examination. The chloride-ion content of the powder sample is determined for each test specimen at the level of the steel. The chloride threshold is determined by subtracting the background chloride content from the chloride content obtained following corrosion initiation. The proposed ASTM test method is provided in the Annex.

Figure 1 – Photograph of chloride threshold experimental setup

Macro Cell Current

The macrocell current is measured between the top and bottom reinforcing steel on regular intervals. The top and bottom reinforcing steel are electrically connected through a 100 Ω resistor or shunt inside a junction box. Each junction box holds connections for 15 specimens. Switches open and close the circuit for each specimen to the main connections of the junction box. The voltage drop across the resistor is measured and the current is calculated using Ohm's law.

$$V = IR \quad \text{(Ohm's Law)}$$

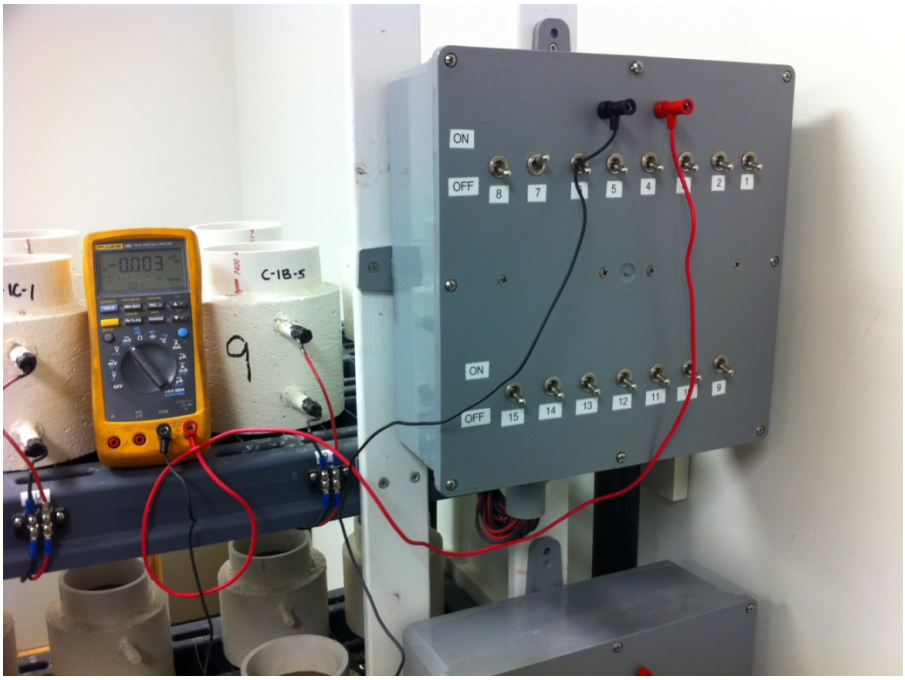


Figure 2 – Photograph of macro cell current measurement

The results obtained from macro cell current measurements are provided in Figure 3. The results are an average of 15 specimens per treatment at the start of the experiment. One specimen per treatment was dissected for chloride analysis on 6/4/10 (cycle 32), 10/6/10 (cycle 49), 3/18/11 (cycle 72) so the results are an average of 15 minus the number of samples autopsied thereafter. After 69 ponding cycles, measurements indicated signs of corrosion activity on one control specimen. A macrocell current measurement greater than 0.1 $\mu A/cm^2$ of reinforcing steel or 1.0 μA is assumed to be adequate sign of corrosion initiation. Individual specimen results are provided in the Annex.

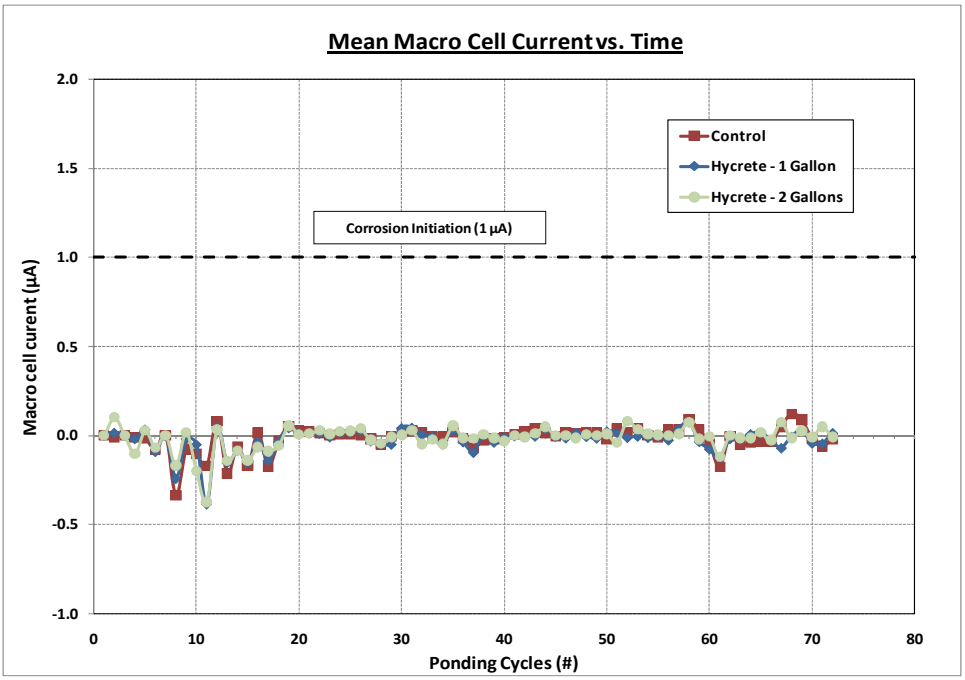


Figure 3 - Average macro cell current as a function of test cycle

Half Cell Potential

The method prescribed in ASTM C 876 – "Half-Cell Potentials of Uncoated Reinforcing Steel in Concrete" is used to measure specimen with active corrosion. Corrosion potential measurements describe the probability for active reinforcing steel corrosion in concrete using a copper/copper-sulfate ($Cu/CuSO_4$) reference electrode and a hand-held multimeter. In this procedure, the common lead from the multimeter is connected to the reference electrode, and the test lead is connected to the reinforcing steel. The measurement is taken with the reference electrode against a wet sponge and the surface of moist concrete and recording the voltage difference between the reinforcing steel and the reference electrode.

Table 1 contains the potential evaluation criteria normalized to standard conditions 25 degrees centigrade, (77 degrees F or CSE_{77}) so all measurements must be corrected for temperature. ASTM C876 recommends standardization at 72 degrees F, however NACE standards use 77 degrees F. The temperature correction factor for copper sulfate electrodes is 0.5 degrees for each degree F, resulting in a negligible 2.5 mV difference between the two reference temperatures. All potential measurements reported in this document are standardized to CSE_{77}.

Table 1 - Standard evaluation criteria for determining severity of corrosion activity

Reading (CSE_{77})	Corrosion Condition
> -200 mV	Low (< 10% probability of corrosion)
-200 to -350 mV	Uncertain (50 % probability of corrosion)
< -350 mV	High (> 90% probability of corrosion)

Half cell potential measurements were performed on each of the slabs using a standard copper sulfate reference electrode. The temperature of the slabs was measured to apply a correction

factor to measured values, as explained above. Half cell potential measurements were obtained on each specimen (15 per group). Figure 5 shows the average value as a function of test cycle for each group of specimen. Individual results are provided in the Annex. Half cell potential measurements show no signs of corrosion activity and indicate all specimens are passive.

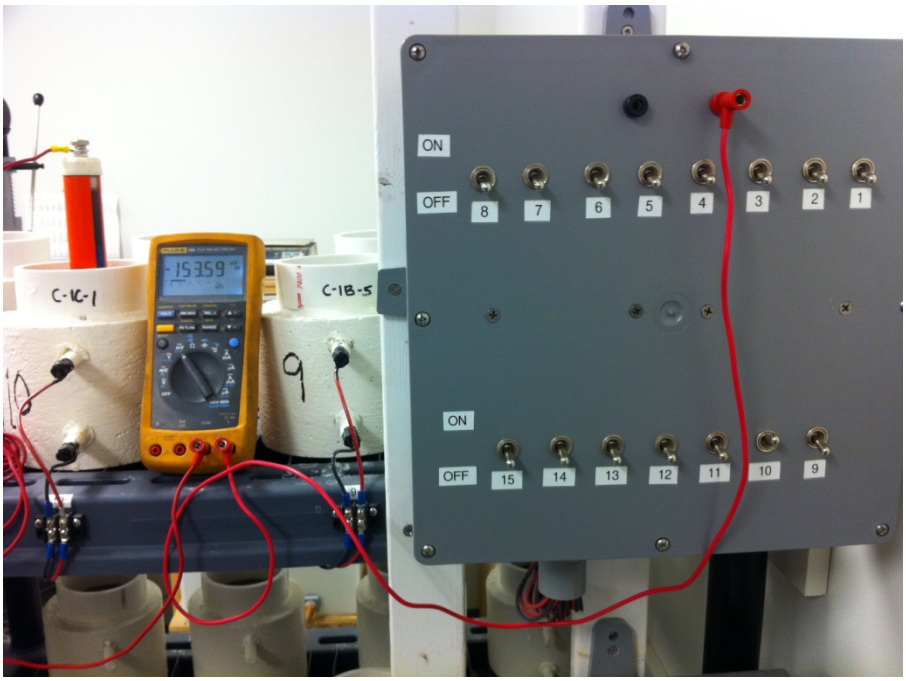


Figure 4 – Photograph of half cell potential measurement

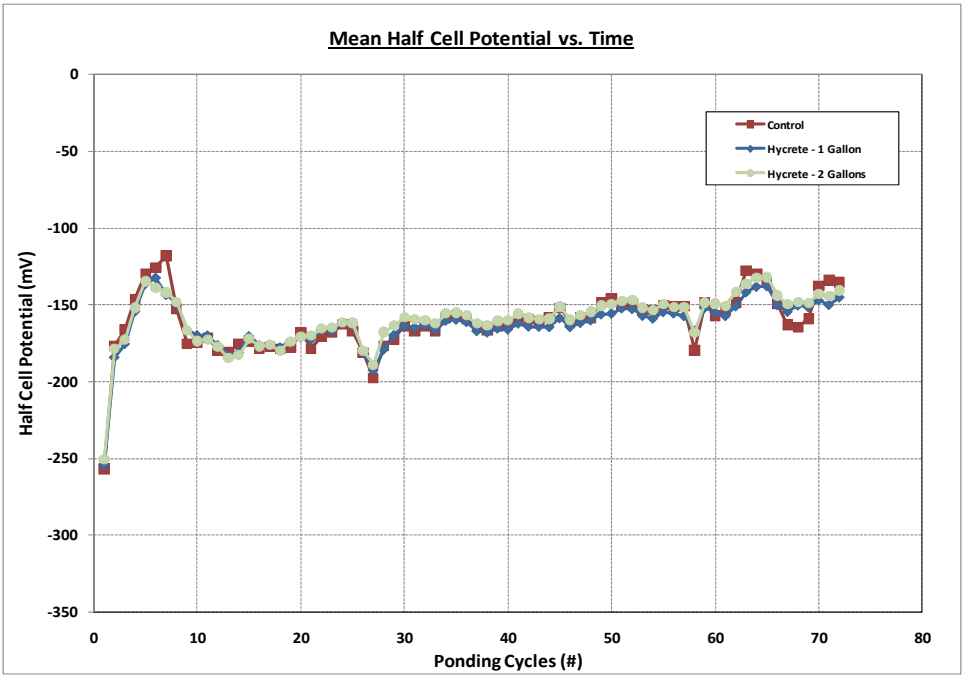


Figure 5 – Average half cell potentials as a function of test cycle

Destructive Examinations (Autopsy)

Forensic examinations or autopsies were performed on one mortar cylinder per treatment after 32, 49, and 72 cycles. Typically this type of destructive examination will only occur following two weeks of measurements indicating corrosion initiation. The electrochemical measurements did not indicate corrosion for any specimen, so one specimen from each treatment group was autopsied during cycle 32, or June 9th, 2010. When corrosion initiation was still not evident a second autopsy was performed during cycle 49, or October 7, 2010. A third autopsy was performed after cycle 72, or March 18, 2011.

The net chloride content after adjusting for background chlorides is provided in Table 2. The specimens autopsied after cycle 72 is below the commonly accepted corrosion threshold value of 0.5% weight of cement at the level of the rebar. By comparison, the mixture with 1 gallon of Hycrete is similar to the control and the mixture with 2 gallons of Hycrete is less than 1/2 the chloride content of the controls.

After 69 cycles, one control specimen indicated signs of corrosion activity. An autopsy was performed and the acid soluble chloride content was determined for mortar at the level of the rebar. The results show the chloride content at the level of rebar after adjusting for background chlorides is 1815 ppm, or 0.77% by weight of cement. This specimen is possibly an outlier as the chloride content was much higher than expected. A plot of chloride content as a function of cycle for the specimens is provided in Figure 6. The # of cycles predicted for each mixture to reach the chloride threshold of 0.5% cement weight is provided. The control sample and 1 gallon Hycrete mixtures were predicted to reach the threshold at 103 cycles, while the mixture with 2 gallons Hycrete was predicted to reach the threshold at 187 cycles.

Table 2 – Chloride content of specimens at time of destructive examination

ASTM C1152 Acid-Soluble Chloride Content, % Cement Weight				
Test Cycle (Specimen #)	**Location**	**Control**	**Hycrete – 1 Gallon**	**Hycrete – 2 Gallons**
32 (15, 30, 45)	Surface	2.10	1.47	1.47
	Rebar Level	0.11	0.04	0.06
49 (14, 29, 44)	Surface	1.94	1.40	1.27
	Rebar Level	0.15	0.03	0.05
72 (12, 28, 43)	Surface	2.62	1.75	1.81
	Rebar Level	0.32	0.32	0.14
69 (13*)	Rebar Level	0.77	-	-

*Specimen autopsied following measurements indicating corrosion initiation

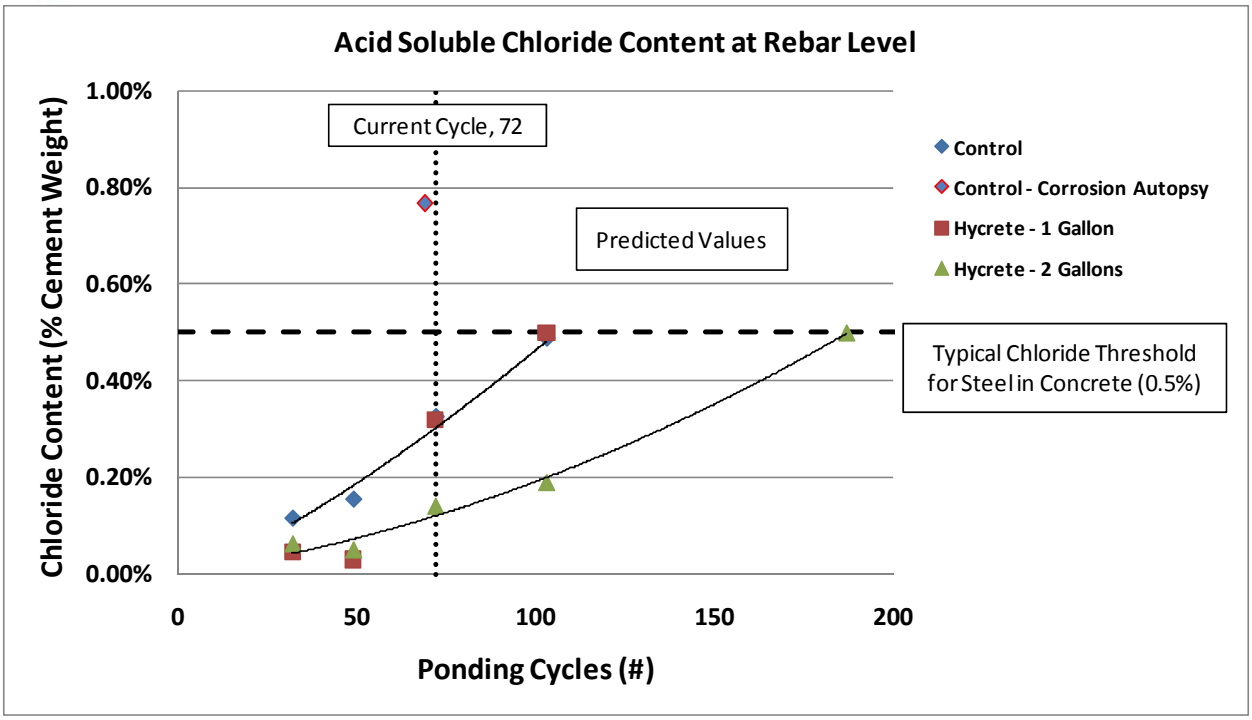


Figure 6 - Chloride content at time of destructive examination

Absorption Testing

The absorption testing was performed in accordance to ASTM C642-97 Standard Test Method for Density, Absorption, and Voids in Hardened Concrete and BS 1881-122:1983 Testing concrete - Method for determination of water absorption. Please see the following sheet for a summary of the data. The full data set can be found in the Annex.

Tourney Consulting Group LLC
3401 Midlink Drive
Kalamazoo, MI 49048

Phone 269.384.9980
Fax 269.384.9981
www.tourneyconsulting.com

Concrete Mixture Data - Absorption & Transport Property Testing

Client : Mandaree Enterprises

TCG # 09106

Report Date: 2/16/10

	.35 W/C Series			.50 W/C Series			.65 W/C Series		
	Control	Hycrete 1 gal	Hycrete 2 gal	Control	Hycrete 1 gal	Hycrete 2 gal	Control	Hycrete 1 gal	Hycrete 2 gal
	.35 W/C	.35 W/C	.35 W/C	.50 W/C	.50 W/C	.50 W/C	.65 W/C	.65 W/C	.65 W/C
Mix ID	35-C	35-1	35-2	50-C	50-1	50-2	65-C	65-1	65-2
Mix Date:	10/8/09	10/8/09	10/8/09	10/2/09	10/2/09	9/30/09	10/2/09	10/2/09	9/30/09
ASTM C642 (117 days)									
Absorption % after 48 hr soak	4.61	3.84	2.88	5.62	4.79	4.21	5.78	5.20	4.85
Absorption % after 48 hr soak & 5hr Boil	4.66	4.12	3.25	5.58	4.06	4.78	5.87	5.95	5.96
ASTM C642 (28 days) (avg. 2 samples 28 days)									
Absorption % after 48 hr soak				6.05	5.60	3.88			
Absorption % after 48 hr soak & 5hr Boil				6.36	6.69	5.37			
BS 1881 (avg. 2 samples 28 days)									
Absorption % after 30 minute soak				2.61	0.98	0.58			
Absorption % after 48 hr soak				5.58	4.75	2.99			

ASTM C-1585 Rate of Absorption of Water by Hydraulic - Cement Concretes

Initial absorption {mm/(sec)$^{1/2}$}	2.62E-03	1.09E-03	7.89E-04
Secondary absorption {mm/(sec)$^{1/2}$}	1.19E-03	5.63E-04	8.42E-04

Transport Testing

Transport testing is used to characterize the steady-state ion diffusion properties and the wetting / drying properties or moisture transport as inputs for STADIUM. Please see the following sheet for a summary of the data. Please see the Annex for raw data.

Tourney Consulting Group LLC
3401 Midlink Drive
Kalamazoo, MI 49048

Phone 269.384.9980
Fax 269.384.9981
www.tourneyconsulting.com

Concrete Mixture Data - Absorption & Transport Property Testing

Client : Mandaree Enterprises

TCG # 09106

Report Date: 2/16/10

	.35 W/C Series			.50 W/C Series			.65 W/C Series		
	Control	Hycrete 1 gal	Hycrete 2 gal	Control	Hycrete 1 gal	Hycrete 2 gal	Control	Hycrete 1 gal	Hycrete 2 gal
	.35 W/C	.35 W/C	.35 W/C	.50 W/C	.50 W/C	.50 W/C	.65 W/C	.65 W/C	.65 W/C
Mix ID	35-C	35-1	35-2	50-C	50-1	50-2	65-C	65-1	65-2
Mix Date:	10/8/09	10/8/09	10/8/09	10/2/09	10/2/09	9/30/09	10/2/09	10/2/09	9/30/09
Ion Diffusion Coeff. (IDC), $(10)^{-11}$ m^2/s	10.0	9.4	9.1	14.6	13.8	12.9	19.5	18.3	18.3
ASTM C642 Porosity, Voids %	10.75*	9.59	7.46	12.47*	9.43	10.91	13.26*	13.62	13.44
Moisture Trans. Coeff. (MTC), $(10)^{-22}$ m^2	1.10	1.22	2.05	27.97	22.66	17.24	63.65	50.11	46.25
Isothem B m^3/m^3	-83.03	-79.23	-85.15	-123.7	-107.4	-110.0	-27.9	-25.1	-22.6
Isothem C	0.104	0.104	0.104	0.130	0.130	0.130	1.458	1.458	1.458

Notes for Transport Properties

* Porosity of the Control Mixture was used to calculate the MTC.

STADIUM Modeling

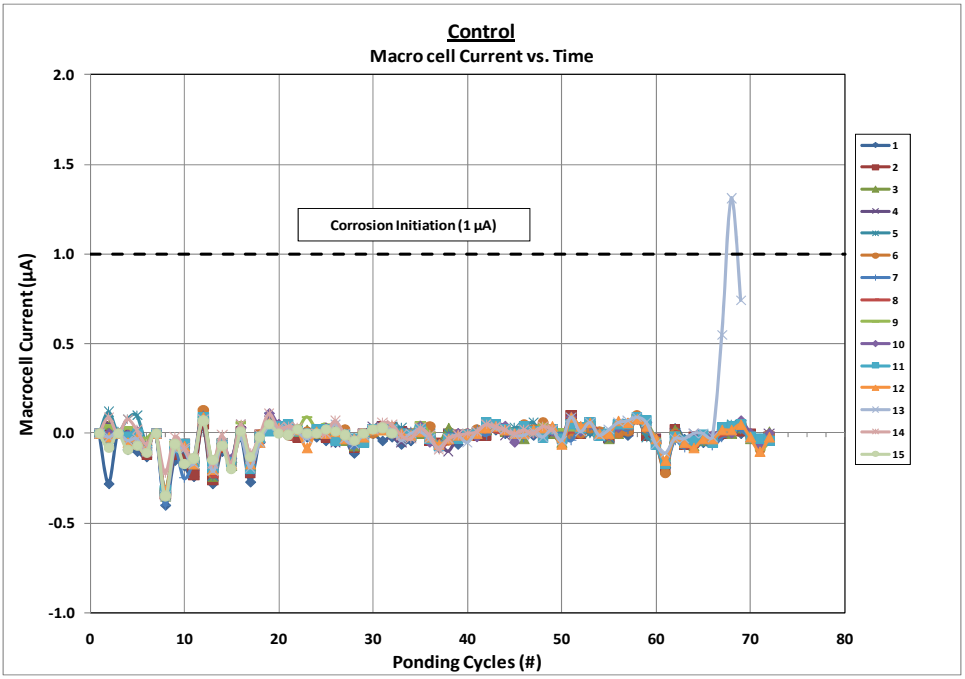
STADIUM modeling requires inputs obtained from chloride threshold testing which is currently in progress. Modeling will begin immediately following.

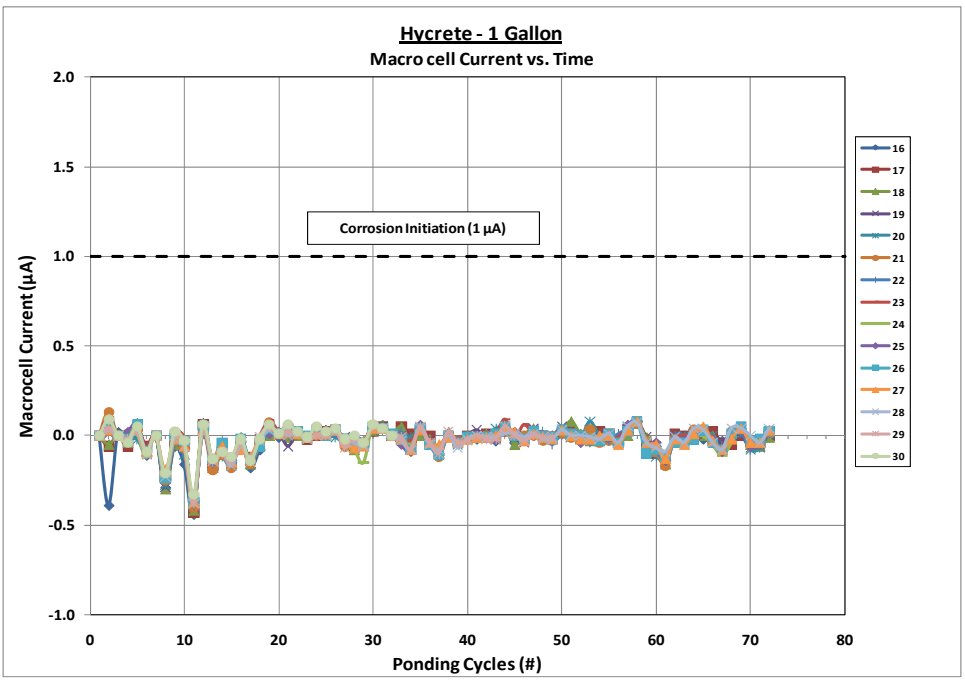
Summary

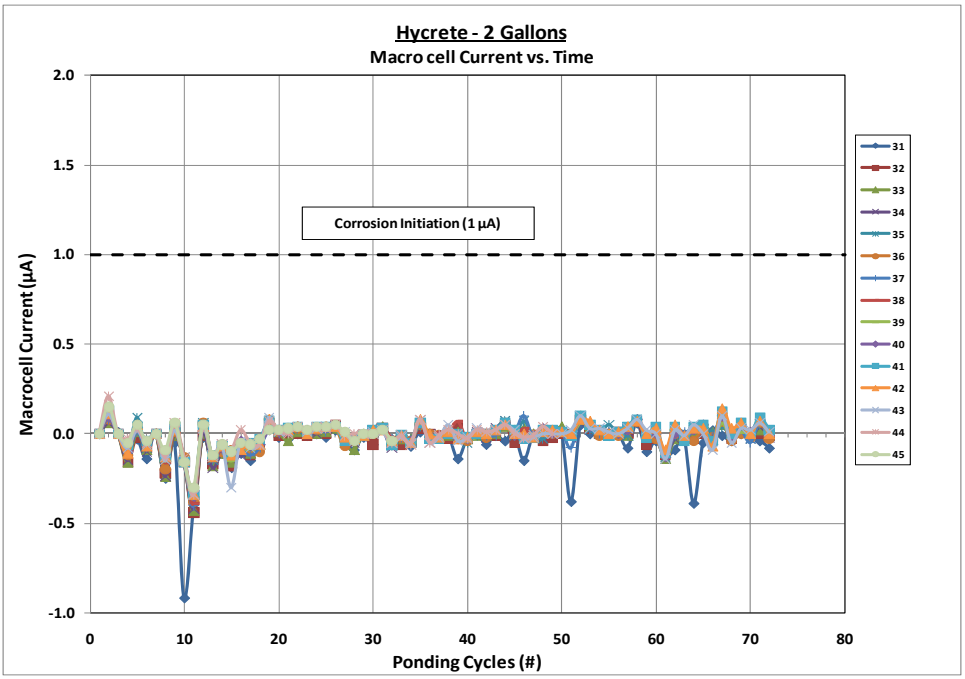
- Chloride threshold testing – in progress
    - One control specimen has shown signs of corrosion activity and has been autopsied after test cycle 69 (480 days)
    - No signs of corrosion activity for all other specimen at test cycle 72 (501 days)
    - Destructive examination indicates control specimen are below the range of commonly accepted chloride contents for corrosion initiation
- Absorption testing – complete
- Transport testing – complete
- STADIUM Modeling – Start date to be determined by chloride threshold results

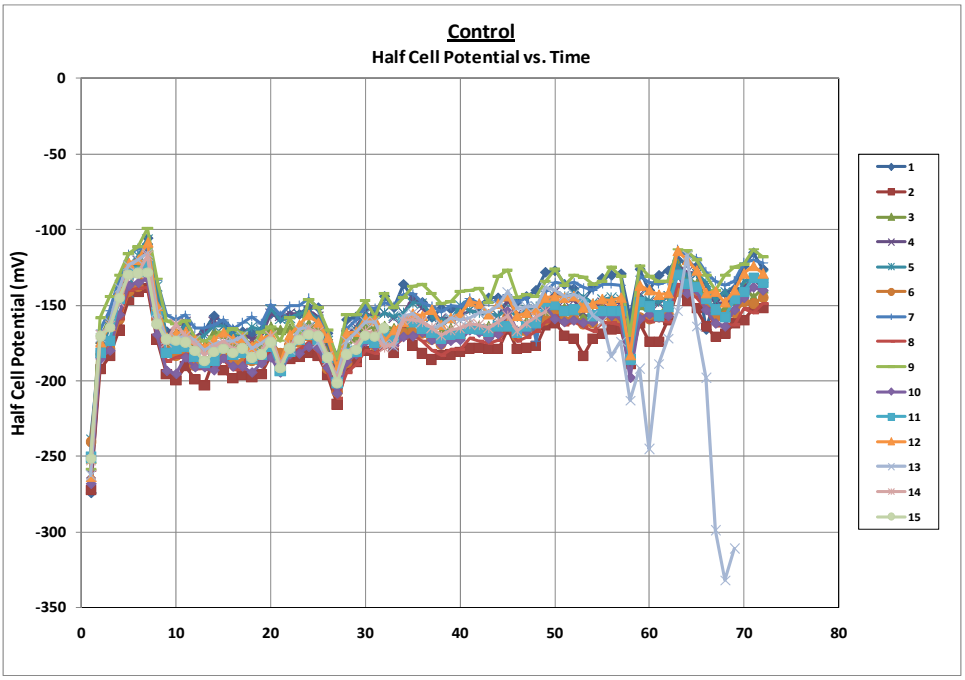
ANNEX [NX]

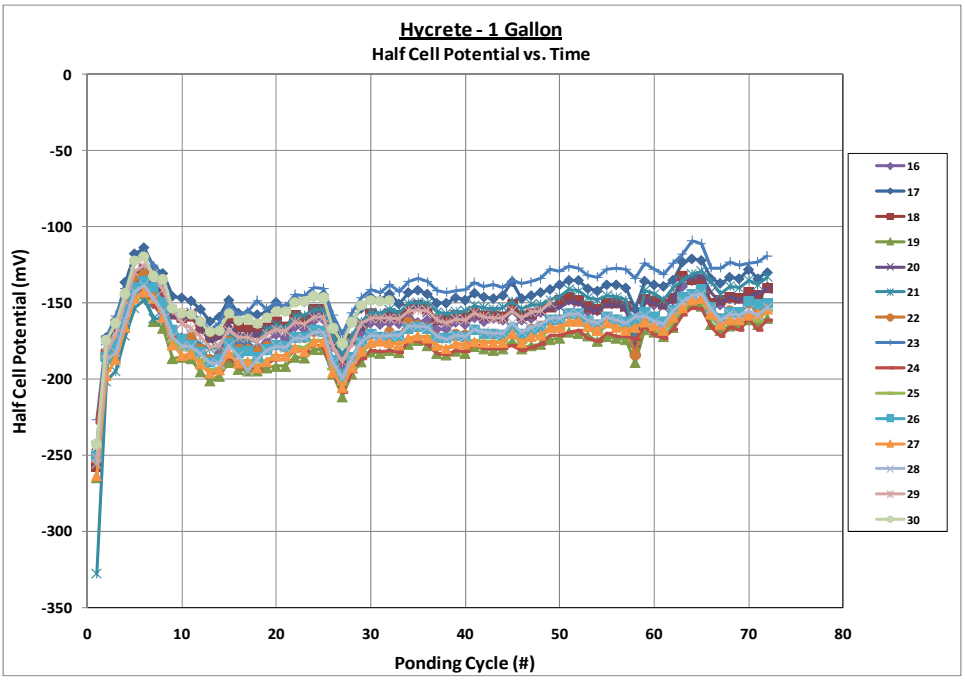
Chloride Threshold Testing

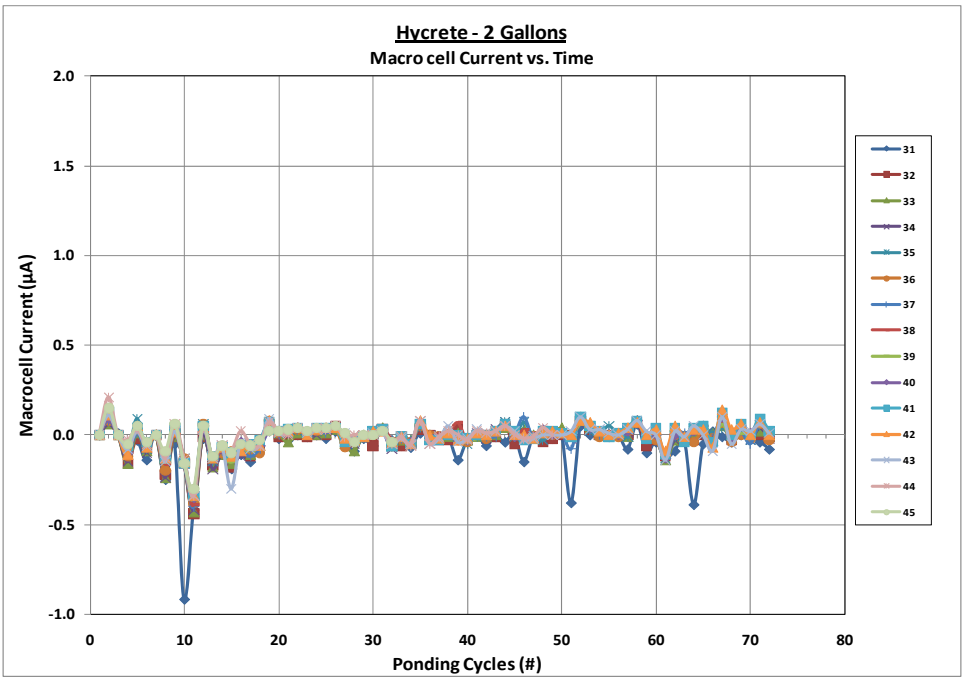





Hycrete - 2 Gallons
Macro cell Current vs. Time
Corrosion Initiation (1 µA)
Macrocell Current (µA)
Ponding Cycles (#)
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
0
10
20
30
40
50
60
70
80
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45


Control
Half Cell Potential vs. Time
Half Cell Potential (mV)
0
-50
-100
-150
-200
-250
-300
-350
0
10
20
30
40
50
60
70
80
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15


Hycrete - 1 Gallon
Half Cell Potential vs. Time
Half Cell Potential (mV)
0
-50
-100
-150
-200
-250
-300
-350
0
10
20
30
40
50
60
70
80
Ponding Cycle (#)
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30


Hycrete - 2 Gallons
Macro cell Current vs. Time
Macrocell Current (µA)
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
0
10
20
30
40
50
60
70
80
Ponding Cycles (#)
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45

Tourney Consulting Group LLC
3401 Midlink Drive
Kalamazoo, MI 49048

Phone 269.384.9980
Fax 269.384.9981
www.tourneyconsulting.com

Concrete Mixture Data - Mixes Containing Hycrete 1000X Admixture

Client : Mandaree Enterprises

TCG # 09106

Report Date: 2/16/10

	.35 W/C Series			.50 W/C Series			.65 W/C Series		
	Control	Hycrete 1 gal	Hycrete 2 gal	Control	Hycrete 1 gal	Hycrete 2 gal	Control	Hycrete 1 gal	Hycrete 2 gal
	.35 W/C	.35 W/C	.35 W/C	.50 W/C	.50 W/C	.50 W/C	.65 W/C	.65 W/C	.65 W/C
Mix ID	**35-C**	**35-1**	**35-2**	**50-C**	**50-1**	**50-2**	**65-C**	**65-1**	**65-2**
Mix Date:	**10/8/09**	**10/8/09**	**10/8/09**	**10/2/09**	**10/2/09**	**9/30/09**	**10/2/09**	**10/2/09**	**9/30/09**
Cement Lafarge Type II lb/yd^3	658	658	658	564	564	564	470	470	470
Consumer C33 Concrete Sand	1252	1271	1295	1194	1215	1252	1212	1231	1270
Stoneco Ottawa lake#57 Stone	1800	1800	1800	1800	1800	1800	1800	1800	1800
Total Water lb/yd^3	230	222	214	282	274	265	305	298	288
Liquid From Admix lbs/yd^3	0	8	17	0	8	17	0	8	17
Designed Air Content %	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00
Water/Cement Ratio (Includes adı	**0.35**	**0.35**	**0.35**	**0.50**	**0.50**	**0.50**	**0.65**	**0.65**	**0.65**
Hycrete 1000 X gal/yd^3	0	1	2	0	1	2	0	1	2
BASF MB-AE-90 AEA oz/Cwt	0.75	0	0	0.8	0	0	0	0	0
BASF Glenium 3030NS Super P (	6.8	7.6	8.5	0	0	0	0	0	0
Pressure Air Content, %	5.90	6.60	6.30	6.60	6.70	5.80	6.70	6.20	6.50
Unit Weight lb/ft^3	147.5	146.5	147.1	143.7	142.7	145.7	142.3	143.3	143.3
Design Weight, lb/ft^3	145.9	146.4	146.9	142.2	142.7	143.7	140.3	140.7	141.8
Yield, ft^3	26.71	27.03	27.07	26.71	27.05	26.74	26.61	26.56	26.73
Slump, in.	5.00	3.75	3.75	6.50	7.25	4.50	7.75	5.00	9.00
ASTM C39									
7 Day Compressive Strength (Avg 2 cyl.) psi	7130	6755	6750	3425	3955	3735	2150	2240	1955
28 Day Compressive Strength (Avg 2 cyl.) psi	8775	8055	7765	4315	4685	4815	2685	2610	2880

August 25, 2010

Glenn Schaefer
Vice President
TCG Tourney Consulting Group
5200 East Cork Street
Kalamazoo MI 49048
USA

Subject: STADIUM® Input parameters determination Report **(O/Ref: SIMCO10017)**

Dear Mr. Schaefer:

SIMCO Technologies inc. (SIMCO) was hired to evaluate the ionic diffusion coefficient (IDC) and moisture transport coefficient (MTC) for different concrete mixtures that were prepared and tested in your laboratory. The properties were evaluated for one maturity. Thus a total of 9 ionic diffusion coefficients and 9 moisture diffusion coefficients were determined.

For this project, a series of test results was sent, via email, to our office in Québec City on July 30th, 2010. The analysis was done on these results.

Documents received

The following information has been received to perform the analysis:

- Migration test data
- Drying test data
- Compilation of mixture proportion, compressive strength test data, and porosity test data

Ionic Diffusion Coefficient

Results of the migration tests performed on 9 mixtures were analyzed with STADIUM®-IDC to calculate the ionic diffusion coefficients of concrete. For the analysis, only the first series of each mixture were used after a careful comparison of each series results. All results are presented in Table 1.

The measured diffusion coefficients vary from 10.0 x 10^{-11} m^2/s to 19.5 x 10^{-11} m^2/s depending on the quality of the concrete. A high diffusion coefficient means that contaminants such as chlorides will diffuse faster through the concrete.

SIMCO
Technologies inc.

Moisture Transport Coefficient

Results of the drying tests performed on 9 mixtures were analyzed with STADIUM®-MTC. The analysis has been made with the porosity of the reference mixture. This decision has been made because the concrete's porosity of a similar mixture (i.e., similar water/binder) is not influenced by using a damproofing admixture. For every series, a thickness of 14 mm has been used for the thin specimens. Usually, the thin specimens shall have a thickness of no more than 10 mm.

All results are presented in Table 1. In the Table, the isotherm's parameters B and C are provided with the concrete permeability. The measured permeability varies from 1.10 x 10^{-22} m^2 to 63.65 x 10^{-22} m^2.

Table 1 – Ionic diffusion coefficients (IDC) and moisture transport coefficients (MTC)

Parameter	W/C = 0.35			W/C = 0.5			W/C = 0.65		
	Ref.	1 gal.	2 gal.	Ref.	1 gal.	2 gal.	Ref.	1 gal.	2 gal.
IDC ($x10^{-11}$ m^2/s)	10.0	9.4	9.1	14.6	13.8	12.9	19.5	18.3	18.3
Porosity (%)	10.75	10.75	10.75	12.47	12.47	12.47	13.26	13.26	13.26
Permeability (x 10^{-22} m^2)	1.10	1.22	2.05	27.97	22.66	17.24	63.65	50.11	46.25
Isotherm B (m^3/m^3)	-83.026	-79.233	-85.153	-123.703	-107.362	-109.986	-27.934	-25.083	-22.613
Isotherm C	0.104	0.104	0.104	0.130	0.130	0.130	1.458	1.458	1.458

We hope that this document meets your expectations. Please contact us for any additional information you may require.

Sincerely yours,

SIMCO TECHNOLOGIES INC.

Vincent Lapointe, Eng. M.Sc.
Project Manager

203-1400, boul. du Parc-Technologique, Quebec City QC Canada G1P 4R7
Phone : 418-656-1003 Fax : 418-656-6083

TCG TOURNEY CONSULTING GROUP

Migration Test

Project Number : Hycrete / USACE - 09106
Maturity (days) :
Identification : Series 1 - 0.35 W/C 2 Gallon Hycrete

Date/Hour	t	Specimen #1			Specimen #2			Vm
	(hrs)	I (mA)	Ve (V)	Vc (V)	I (mA)	Ve (V)	Vc (V)	
1/8/2010 8:00	0.00	35.13	21.95	20.24				
1/10/2010 8:00	48.00	24.08	20.99	21.08				
1/10/2010 14:30	54.50	24.45	21.98	20.80				
1/11/2010 13:45	77.75	24.45	21.70	20.70				
1/12/2010 10:25	98.42	23.62	21.59	21.30				
1/13/2010 16:15	128.25	23.38	21.80	21.35				
1/14/2010 8:20	144.33	23.04	21.90	21.22				
1/15/2010 16:20	176.33	24.42	21.79	21.33				
1/17/2010 14:30	222.50	25.13	21.81	21.22				
1/18/2010 13:55	245.92	26.43	21.75	21.03				
1/19/2010 13:55	269.92	27.77	22.63	22.03				
1/20/2010 13:55	293.92							
1/21/2010 11:50	315.83	30.16	22.61	21.51				
1/22/2010 8:00	336.00	31.78	22.71	21.96				
		Average :	21.9	21.2				

Specimens Specifications

	Specimen #1	Specimen #2
H1 (mm)	51.206	
H2 (mm)	51.384	
H3 (mm)	51.156	
D1 (mm)	101.295	
D2 (mm)	103.200	
Mass SSD (g)	1007.29	
Average Tickness (mm)	51.25	#DIV/0!
Average Diameter (mm)	102.25	#DIV/0!

Rings Specifications

	Specimen #1	Specimen #2
D1 upstream (mm)	93.14	
D2 upstream (mm)	93.14	
D1 downstream (mm)	93.14	
D2 downstream (mm)	93.14	
Average Diameter upstream (mm)	93.14	#DIV/0!
Average Diameter downstream (mm)	93.14	#DIV/0!

TCG TOURNEY CONSULTING GROUP

Migration Test

Project Number : Hycrete / USACE - 09106
Maturity (days) :
Identification : Series 1 - 0.35 W/C Reference

Date/Hour	t	Specimen #1			Specimen #2			Vm
	(hrs)	I (mA)	Ve (V)	Vc (V)	I (mA)	Ve (V)	Vc (V)	
1/8/2010 8:00	0.00	36.69	21.98	20.16				
1/10/2010 8:00	48.00	24.49	22.00	20.26				
1/10/2010 14:30	54.50	24.76	21.85	20.50				
1/11/2010 13:45	77.75	24.18	21.00	20.37				
1/12/2010 10:25	98.42	18.58	17.40	16.17				
1/13/2010 16:15	128.25	21.77	20.62	20.17				
1/14/2010 8:20	144.33	21.13	20.70	19.73				
1/15/2010 16:20	176.33	21.54	22.99	22.16				
1/17/2010 14:30	222.50	22.94	23.02	22.06				
1/18/2010 13:55	245.92	23.61	22.34	21.73				
1/19/2010 13:55	269.92	23.19	22.63	21.43				
1/20/2010 13:55	293.92							
1/21/2010 11:50	315.83	24.37	22.08	21.20				
1/22/2010 8:00	336.00	25.27	22.18	21.23				
		Average :	21.6	20.6				

Specimens Specifications	Specimen #1	Specimen #2
H1 (mm)	51.816	
H2 (mm)	51.156	
H3 (mm)	51.003	
D1 (mm)	101.371	
D2 (mm)	102.921	
Mass SSD (g)	1007.75	
Average Tickness (mm)	51.32	#DIV/0!
Average Diameter (mm)	102.15	#DIV/0!

Rings Specifications	Specimen #1	Specimen #2
D1 upstream (mm)	93.14	
D2 upstream (mm)	93.14	
D1 downstream (mm)	93.14	
D2 downstream (mm)	93.14	
Average Diameter upstream (mm)	93.14	#DIV/0!
Average Diameter downstream (mm)	93.14	#DIV/0!

TCG TOURNEY CONSULTING GROUP

Migration Test

Project Number : Hycrete / USACE - 09106
Maturity (days) :
Identification : Series 1 - 0.50 W/C 1 Gallon Hycrete

Date/Hour	t	Specimen #1			Specimen #2			Vm
	(hrs)	I (mA)	Ve (V)	Vc (V)	I (mA)	Ve (V)	Vc (V)	
1/8/2010 8:00	0.00	47.64	22.15	20.89				
1/10/2010 8:00	48.00	32.85	22.50	21.50				
1/10/2010 14:30	54.50	33.44	22.67	21.43				
1/11/2010 13:45	77.75	34.18	21.90	21.50				
1/12/2010 10:25	98.42	33.55	22.28	20.98				
1/13/2010 16:15	128.25	38.19	22.30	21.66				
1/14/2010 8:20	144.33	39.50	22.14	21.23				
1/15/2010 16:20	176.33	45.18	21.80	21.26				
1/17/2010 14:30	222.50	50.15	22.01	21.16				
1/18/2010 13:55	245.92	53.14	21.41	20.95				
1/19/2010 13:55	269.92	53.78	21.46	21.00				
1/20/2010 13:55	293.92							
1/21/2010 11:50	315.83	56.87	21.63	20.36				
1/22/2010 8:00	336.00	59.38	21.60	20.96				
		Average :	22.0	21.1				

Specimens Specifications	Specimen #1	Specimen #2
H1 (mm)	52.070	
H2 (mm)	50.851	
H3 (mm)	50.952	
D1 (mm)	102.260	
D2 (mm)	101.981	
Mass SSD (g)	979.88	
Average Tickness (mm)	51.29	#DIV/0!
Average Diameter (mm)	102.12	#DIV/0!

Rings Specifications	Specimen #1	Specimen #2
D1 upstream (mm)	93.14	
D2 upstream (mm)	93.14	
D1 downstream (mm)	93.14	
D2 downstream (mm)	93.14	
Average Diameter upstream (mm)	93.14	#DIV/0!
Average Diameter downstream (mm)	93.14	#DIV/0!

TCG TOURNEY CONSULTING GROUP

Migration Test

Project Number : Hycrete / USACE - 09106
Maturity (days) :
Identification : Series 1 - 0.50 WC 2 Gallon Hycrete

Date/Hour	t	Specimen #1			Specimen #2			Vm
	(hrs)	I (mA)	Ve (V)	Vc (V)	I (mA)	Ve (V)	Vc (V)	
1/8/2010 8:00	0.00	52.27	22.43	20.50				
1/10/2010 8:00	48.00	35.55	22.20	21.50				
1/10/2010 14:30	54.50	36.53	21.53	20.27				
1/11/2010 13:45	77.75	37.12	21.60	20.20				
1/12/2010 10:25	98.42	37.67	21.40	20.78				
1/13/2010 16:15	128.25	38.90	21.39	20.80				
1/14/2010 8:20	144.33	40.74	20.81	21.53				
1/15/2010 16:20	176.33	45.47	21.45	20.66				
1/17/2010 14:30	222.50	48.71	20.93	20.64				
1/18/2010 13:55	245.92	51.33	21.06	20.47				
1/19/2010 13:55	269.92	51.69	20.98	20.59				
1/20/2010 13:55	293.92							
1/21/2010 11:50	315.83	54.16	20.95	19.81				
1/22/2010 8:00	336.00	56.24	20.82	20.46				
		Average :	21.4	20.6				

Specimens Specifications	Specimen #1	Specimen #2
H1 (mm)	50.952	
H2 (mm)	51.257	
H3 (mm)	51.384	
D1 (mm)	102.159	
D2 (mm)	101.854	
Mass SSD (g)	1000.31	
Average Tickness (mm)	51.20	#DIV/0!
Average Diameter (mm)	102.01	#DIV/0!

Rings Specifications	Specimen #1	Specimen #2
D1 upstream (mm)	93.14	
D2 upstream (mm)	93.14	
D1 downstream (mm)	93.14	
D2 downstream (mm)	93.14	
Average Diameter upstream (mm)	93.14	#DIV/0!
Average Diameter downstream (mm)	93.14	#DIV/0!

TCG TOURNEY CONSULTING GROUP

Migration Test

Project Number : Hycrete / USACE - 09106
Maturity (days) :
Identification : Series 1 - 0.50 W/C Reference

Date/Hour	t	Specimen #1			Specimen #2			Vm
	(hrs)	I (mA)	Ve (V)	Vc (V)	I (mA)	Ve (V)	Vc (V)	
1/8/2010 8:00	0.00	56.24	22.19	20.90				
1/10/2010 8:00	48.00	35.87	22.05	21.22				
1/10/2010 14:30	54.50	26.52	21.14	19.92				
1/11/2010 13:45	77.75	36.95	21.00	20.16				
1/12/2010 10:25	98.42	37.54	20.92	20.59				
1/13/2010 16:15	128.25	40.23	20.93	20.52				
1/14/2010 8:20	144.33	41.48	20.82	20.50				
1/15/2010 16:20	176.33	46.78	20.90	20.50				
1/17/2010 14:30	222.50	51.75	21.47	20.47				
1/18/2010 13:55	245.92	55.38	20.67	20.25				
1/19/2010 13:55	269.92	56.31	20.81	20.35				
1/20/2010 13:55	293.92							
1/21/2010 11:50	315.83	60.47	20.72	19.57				
1/22/2010 8:00	336.00	63.41	20.72	20.31				
		Average :	21.1	20.4				

Specimens Specifications	Specimen #1	Specimen #2
H1 (mm)	51.714	
H2 (mm)	51.867	
H3 (mm)	51.079	
D1 (mm)	101.371	
D2 (mm)	102.946	
Mass SSD (g)	986.72	
Average Tickness (mm)	51.55	#DIV/0!
Average Diameter (mm)	102.16	#DIV/0!

Rings Specifications	Specimen #1	Specimen #2
D1 upstream (mm)	93.14	
D2 upstream (mm)	93.14	
D1 downstream (mm)	93.14	
D2 downstream (mm)	93.14	
Average Diameter upstream (mm)	93.14	#DIV/0!
Average Diameter downstream (mm)	93.14	#DIV/0!

TCG TOURNEY CONSULTING GROUP

Migration Test

Project Number : Hycrete / USACE - 09106
Maturity (days) :
Identification : Series 1 - 0.65 WC 1-Gallon Hycrete

Date/Hour	t	Specimen #1			Specimen #2			Vm
	(hrs)	I (mA)	Ve (V)	Vc (V)	I (mA)	Ve (V)	Vc (V)	
1/8/2010 8:00	0.00	56.51	21.65	20.60				
1/10/2010 8:00	48.00	46.04	21.60	21.60				
1/10/2010 14:30	54.50	47.16	20.63	20.54				
1/11/2010 13:45	77.75	50.70	21.07	20.09				
1/12/2010 10:25	98.42	48.76	19.16	19.03				
1/13/2010 16:15	128.25	46.41	16.23	16.10				
1/14/2010 8:20	144.33	63.91	21.22	21.11				
1/15/2010 16:20	176.33	73.00	21.04	20.88				
1/17/2010 14:30	222.50	78.55	20.68	20.52				
1/18/2010 13:55	245.92	82.63	20.78	20.63				
1/19/2010 13:55	269.92	82.45	20.99	20.72				
1/20/2010 13:55	293.92	0.00						
1/21/2010 11:50	315.83	85.49	20.20	19.98				
		Average :	20.4	20.2				

Specimens Specifications	Specimen #1	Specimen #2
H1 (mm)	50.698	
H2 (mm)	51.156	
H3 (mm)	51.308	
D1 (mm)	102.743	
D2 (mm)	101.829	
Mass SSD (g)	989.13	
Average Tickness (mm)	51.05	#DIV/0!
Average Diameter (mm)	102.29	#DIV/0!

Rings Specifications	Specimen #1	Specimen #2
D1 upstream (mm)	93.14	
D2 upstream (mm)	93.14	
D1 downstream (mm)	93.14	
D2 downstream (mm)	93.14	
Average Diameter upstream (mm)	93.14	#DIV/0!
Average Diameter downstream (mm)	93.14	#DIV/0!

TCG TOURNEY CONSULTING GROUP

Migration Test

Project Number : Hycrete / USACE - 09106
Maturity (days) :
Identification : Series 1 - 0.65 WC 1-Gallon Hycrete

Date/Hour	t	Specimen #1			Specimen #2			Vm
	(hrs)	I (mA)	Ve (V)	Vc (V)	I (mA)	Ve (V)	Vc (V)	
1/8/2010 8:00	0.00	54.52	22.55	20.70				
1/10/2010 8:00	48.00	44.88	22.60	21.50				
1/10/2010 14:30	54.50	45.89	21.92	20.48				
1/11/2010 13:45	77.75	50.40	22.03	20.64				
1/12/2010 10:25	98.42	54.41	21.88	20.79				
1/13/2010 16:15	128.25	62.05	21.72	20.70				
1/14/2010 8:20	144.33	64.91	21.69	20.56				
1/15/2010 16:20	176.33	74.59	21.54	20.57				
1/17/2010 14:30	222.50	82.57	21.86	20.73				
1/18/2010 13:55	245.92	85.95	21.42	20.37				
1/19/2010 13:55	269.92	88.36	22.13	20.93				
1/20/2010 13:55	293.92							
1/21/2010 11:50	315.83	93.48	22.23	20.59				
		Average :	22.0	20.7				

Specimens Specifications	Specimen #1	Specimen #2
H1 (mm)	50.825	
H2 (mm)	50.800	
H3 (mm)	51.664	
D1 (mm)	101.930	
D2 (mm)	102.819	
Mass SSD (g)	986.75	
Average Tickness (mm)	51.10	#DIV/0!
Average Diameter (mm)	102.37	#DIV/0!

Rings Specifications	Specimen #1	Specimen #2
D1 upstream (mm)	93.14	
D2 upstream (mm)	93.14	
D1 downstream (mm)	93.14	
D2 downstream (mm)	93.14	
Average Diameter upstream (mm)	93.14	#DIV/0!
Average Diameter downstream (mm)	93.14	#DIV/0!

TCG TOURNEY CONSULTING GROUP

Migration Test

Project Number : Hycrete / USACE - 09106
Maturity (days) :
Identification : Series 1 - 0.65 WCReference

Date/Hour	t	Specimen #1			Specimen #2			Vm
	(hrs)	I (mA)	Ve (V)	Vc (V)	I (mA)	Ve (V)	Vc (V)	
1/8/2010 8:00	0.00	63.18	22.64	20.70				
1/10/2010 8:00	48.00	49.05	22.40	21.70				
1/10/2010 14:30	54.50	50.36	21.95	20.67				
1/11/2010 13:45	77.75	55.83	21.90	21.06				
1/12/2010 10:25	98.42	60.90	22.30	21.35				
1/13/2010 16:15	128.25	69.64	22.17	21.23				
1/14/2010 8:20	144.33	73.20	21.95	21.21				
1/15/2010 16:20	176.33	83.04	21.92	21.13				
1/17/2010 14:30	222.50	87.85	21.97	20.93				
1/18/2010 13:55	245.92	90.87	21.40	20.74				
1/19/2010 13:55	269.92	89.62	21.76	20.86				
1/20/2010 13:55	293.92							
1/21/2010 11:50	315.83	90.56	21.76	20.15				
		Average :	22.0	21.0				

Specimens Specifications

	Specimen #1	Specimen #2
H1 (mm)	51.130	
H2 (mm)	51.435	
H3 (mm)	51.283	
D1 (mm)	103.251	
D2 (mm)	100.914	
Mass SSD (g)	982.79	
Average Tickness (mm)	51.28	#DIV/0!
Average Diameter (mm)	102.08	#DIV/0!

Rings Specifications

	Specimen #1	Specimen #2
D1 upstream (mm)	93.14	
D2 upstream (mm)	93.14	
D1 downstream (mm)	93.14	
D2 downstream (mm)	93.14	
Average Diameter upstream (mm)	93.14	#DIV/0!
Average Diameter downstream (mm)	93.14	#DIV/0!

TCG TOURNEY CONSULTING GROUP

Migration Test

Project Number : Hycrete / USACE - 09106
Maturity (days) :
Identification : Series 2 - 0.35 WC 1-Gallon Hycrete

Date/Hour	t (hrs)	Specimen #1 I (mA)	Specimen #1 Ve (V)	Specimen #1 Vc (V)	Specimen #2 I (mA)	Specimen #2 Ve (V)	Specimen #2 Vc (V)	Vm
1/25/2010 15:00	0.00	36.33	21.65	20.14				
1/26/2010 14:00	23.00	27.26	21.49	21.12				
1/27/2010 14:10	47.17	25.39	21.38	20.96				
1/28/2010 16:50	73.83	24.59	21.30	20.98				
2/1/2010 8:30	161.50	22.24	21.21	20.84				
2/2/2010 16:30	193.50	22.89	21.14	20.81				
2/3/2010 10:30	211.50	23.22	21.27	20.86				
2/4/2010 8:30	233.50	23.56	21.30	20.73				
2/5/2010 15:50	264.83	24.60	21.29	20.93				
2/6/2010 11:20	284.33	26.03	21.22	20.85				
2/7/2010 14:30	311.50	26.44	21.12	20.76				
2/8/2010 9:00	330.00	27.16	21.29	20.77				
		Average :	21.3	20.8				

Specimens Specifications

	Specimen #1	Specimen #2
H1 (mm)	51.435	
H2 (mm)	51.054	
H3 (mm)	51.206	
D1 (mm)	101.498	
D2 (mm)	102.311	
Mass SSD (g)	997.27	
Average Tickness (mm)	51.23	#DIV/0!
Average Diameter (mm)	101.90	#DIV/0!

Rings Specifications

	Specimen #1	Specimen #2
D1 upstream (mm)	93.14	
D2 upstream (mm)	93.14	
D1 downstream (mm)	93.14	
D2 downstream (mm)	93.14	
Average Diameter upstream (mm)	93.14	#DIV/0!
Average Diameter downstream (mm)	93.14	#DIV/0!

TOURNEY CONSULTING GROUP

Migration Test

Project Number : Hycrete / USACE - 09106
Maturity (days) :
Identification : Series 2 - 0.35 WC 2-Gallon Hycrete

Date/Hour	t (hrs)	Specimen #1 I (mA)	Specimen #1 Ve (V)	Specimen #1 Vc (V)	Specimen #2 I (mA)	Specimen #2 Ve (V)	Specimen #2 Vc (V)	Vm
1/25/2010 15:00	0.00	31.33	21.40	20.52				
1/26/2010 14:00	23.00	23.57	21.29	20.94				
1/27/2010 14:10	47.17	22.19	21.10	20.77				
1/28/2010 16:50	73.83	21.48	21.24	20.87				
2/1/2010 8:30	161.50	20.21	21.26	20.80				
2/2/2010 16:30	193.50	20.25	21.26	20.71				
2/3/2010 10:30	211.50	20.47	21.21	20.78				
2/4/2010 8:30	233.50	20.49	21.18	20.70				
2/5/2010 15:50	264.83	21.06	21.27	20.86				
2/6/2010 11:20	284.33	22.05	21.18	20.75				
2/7/2010 14:30	311.50	22.12	21.06	20.66				
2/8/2010 9:00	330.00	22.58	21.13	20.60				
		Average :	21.2	20.7				

Specimens Specifications

	Specimen #1	Specimen #2
H1 (mm)	51.765	
H2 (mm)	51.435	
H3 (mm)	51.460	
D1 (mm)	102.946	
D2 (mm)	102.387	
Mass SSD (g)	1005.71	
Average Tickness (mm)	51.55	#DIV/0!
Average Diameter (mm)	102.67	#DIV/0!

Rings Specifications

	Specimen #1	Specimen #2
D1 upstream (mm)	93.14	
D2 upstream (mm)	93.14	
D1 downstream (mm)	93.14	
D2 downstream (mm)	93.14	
Average Diameter upstream (mm)	93.14	#DIV/0!
Average Diameter downstream (mm)	93.14	#DIV/0!

TCG TOURNEY CONSULTING GROUP

Migration Test

Project Number : Hycrete / USACE - 09106
Maturity (days) :
Identification : Series 2 - 0.35 WC Reference

Date/Hour	t (hrs)	Specimen #1 I (mA)	Specimen #1 Ve (V)	Specimen #1 Vc (V)	Specimen #2 I (mA)	Specimen #2 Ve (V)	Specimen #2 Vc (V)	Vm
1/25/2010 15:00	0.00	24.55	21.59	20.09				
1/26/2010 14:00	23.00	18.93	21.43	20.96				
1/27/2010 14:10	47.17	17.67	21.24	20.89				
1/28/2010 16:50	73.83	17.23	21.24	20.89				
2/1/2010 8:30	161.50	15.66	21.19	20.75				
2/2/2010 16:30	193.50	15.62	21.19	20.53				
2/3/2010 10:30	211.50	15.63	21.15	20.71				
2/4/2010 8:30	233.50	15.68	21.36	20.62				
2/5/2010 15:50	264.83	16.11	21.22	20.87				
2/6/2010 11:20	284.33	16.85	21.12	20.81				
2/7/2010 14:30	311.50	16.81	21.12	20.72				
2/8/2010 9:00	330.00	17.10	21.27	20.61				
		Average :	21.3	20.7				

Specimens Specifications

	Specimen #1	Specimen #2
H1 (mm)	51.460	
H2 (mm)	51.054	
H3 (mm)	51.105	
D1 (mm)	102.235	
D2 (mm)	102.870	
Mass SSD (g)	1013.56	
Average Tickness (mm)	51.21	#DIV/0!
Average Diameter (mm)	102.55	#DIV/0!

Rings Specifications

	Specimen #1	Specimen #2
D1 upstream (mm)	93.14	
D2 upstream (mm)	93.14	
D1 downstream (mm)	93.14	
D2 downstream (mm)	93.14	
Average Diameter upstream (mm)	93.14	#DIV/0!
Average Diameter downstream (mm)	93.14	#DIV/0!

TOURNEY CONSULTING GROUP

Migration Test

Project Number : Hycrete / USACE - 09106
Maturity (days) :
Identification : Series 2 - 0.50 WC 1-Gallon Hycrete

Date/Hour	t (hrs)	Specimen #1 I (mA)	Specimen #1 Ve (V)	Specimen #1 Vc (V)	Specimen #2 I (mA)	Specimen #2 Ve (V)	Specimen #2 Vc (V)	Vm
1/25/2010 15:00	0.00	43.62	20.70	20.18				
1/26/2010 14:00	23.00	36.96	20.93	20.50				
1/27/2010 14:10	47.17	34.58	20.89	20.44				
1/28/2010 16:50	73.83	34.93	20.69	20.43				
2/1/2010 8:30	161.50	41.87	20.60	20.15				
2/2/2010 16:30	193.50	45.58	20.54	19.96				
2/3/2010 10:30	211.50	47.62	20.57	20.09				
2/4/2010 8:30	233.50	49.71	20.65	20.01				
2/5/2010 15:50	264.83	53.82	20.43	20.03				
2/6/2010 11:20	284.33	57.60	20.39	19.97				
2/7/2010 14:30	311.50	58.94	20.20	19.78				
2/8/2010 9:00	330.00	60.16	20.36	19.85				
		Average :	20.6	20.1				

Specimens Specifications

	Specimen #1	Specimen #2
H1 (mm)	50.978	
H2 (mm)	50.749	
H3 (mm)	51.156	
D1 (mm)	100.711	
D2 (mm)	102.819	
Mass SSD (g)	983.01	
Average Tickness (mm)	50.96	#DIV/0!
Average Diameter (mm)	101.77	#DIV/0!

Rings Specifications

	Specimen #1	Specimen #2
D1 upstream (mm)	93.14	
D2 upstream (mm)	93.14	
D1 downstream (mm)	93.14	
D2 downstream (mm)	93.14	
Average Diameter upstream (mm)	93.14	#DIV/0!
Average Diameter downstream (mm)	93.14	#DIV/0!

TCG TOURNEY CONSULTING GROUP

Migration Test

Project Number : Hycrete / USACE - 09106
Maturity (days) :
Identification : Series 2 - 0.50 WC 2-Gallon Hycrete

Date/Hour	t (hrs)	Specimen #1 I (mA)	Specimen #1 Ve (V)	Specimen #1 Vc (V)	Specimen #2 I (mA)	Specimen #2 Ve (V)	Specimen #2 Vc (V)	Vm
1/25/2010 15:00	0.00	36.75	20.92	20.30				
1/26/2010 14:00	23.00	32.19	20.74	20.49				
1/27/2010 14:10	47.17	30.27	21.05	20.47				
1/28/2010 16:50	73.83	30.41	21.08	20.57				
2/1/2010 8:30	161.50	36.86	20.55	20.26				
2/2/2010 16:30	193.50	40.32	20.43	19.60				
2/3/2010 10:30	211.50	41.98	20.50	20.06				
2/4/2010 8:30	233.50	44.03	20.58	19.99				
2/5/2010 15:50	264.83	47.54	20.80	20.12				
2/6/2010 11:20	284.33	51.23	20.32	19.96				
2/7/2010 14:30	311.50	53.08	20.14	19.87				
2/8/2010 9:00	330.00	54.58	20.35	19.91				
		Average :	20.6	20.1				

Specimens Specifications

	Specimen #1	Specimen #2
H1 (mm)	51.359	
H2 (mm)	51.232	
H3 (mm)	50.851	
D1 (mm)	102.286	
D2 (mm)	102.286	
Mass SSD (g)	994.74	
Average Tickness (mm)	51.15	#DIV/0!
Average Diameter (mm)	102.29	#DIV/0!

Rings Specifications

	Specimen #1	Specimen #2
D1 upstream (mm)	93.14	
D2 upstream (mm)	93.14	
D1 downstream (mm)	93.14	
D2 downstream (mm)	93.14	
Average Diameter upstream (mm)	93.14	#DIV/0!
Average Diameter downstream (mm)	93.14	#DIV/0!

TOURNEY CONSULTING GROUP

Migration Test

Project Number : Hycrete / USACE - 09106
Maturity (days) :
Identification : Series 2 - 0.50 WC Reference

Date/Hour	t (hrs)	Specimen #1 I (mA)	Specimen #1 Ve (V)	Specimen #1 Vc (V)	Specimen #2 I (mA)	Specimen #2 Ve (V)	Specimen #2 Vc (V)	Vm
1/25/2010 15:00	0.00	38.24	20.99	21.27				
1/26/2010 14:00	23.00	41.83	20.84	20.48				
1/27/2010 14:10	47.17	38.82	20.69	20.30				
1/28/2010 16:50	73.83	39.65	20.65	20.34				
2/1/2010 8:30	161.50	50.26	20.36	19.95				
2/2/2010 16:30	193.50	56.10	20.27	19.84				
2/3/2010 10:30	211.50	59.21	20.34	19.91				
2/4/2010 8:30	233.50	62.18	19.82	19.28				
2/5/2010 15:50	264.83	66.60	20.50	19.63				
2/6/2010 11:20	284.33	70.87	19.98	19.62				
2/7/2010 14:30	311.50	72.28	19.94	19.44				
2/8/2010 9:00	330.00	73.86	20.04	19.49				
		Average :	20.4	20.0				

Specimens Specifications

	Specimen #1	Specimen #2
H1 (mm)	51.054	
H2 (mm)	51.308	
H3 (mm)	51.384	
D1 (mm)	103.327	
D2 (mm)	100.965	
Mass SSD (g)	977.67	
Average Tickness (mm)	51.25	#DIV/0!
Average Diameter (mm)	102.15	#DIV/0!

Rings Specifications

	Specimen #1	Specimen #2
D1 upstream (mm)	93.14	
D2 upstream (mm)	93.14	
D1 downstream (mm)	93.14	
D2 downstream (mm)	93.14	
Average Diameter upstream (mm)	93.14	#DIV/0!
Average Diameter downstream (mm)	93.14	#DIV/0!

TCG TOURNEY CONSULTING GROUP

Migration Test

Project Number : Hycrete / USACE - 09106
Maturity (days) :
Identification : Series 2 - 0.65 WC 1-Gallon Hycrete

Date/Hour	t (hrs)	Specimen #1 I (mA)	Specimen #1 Ve (V)	Specimen #1 Vc (V)	Specimen #2 I (mA)	Specimen #2 Ve (V)	Specimen #2 Vc (V)	Vm
1/25/2010 15:00	0.00	50.01	20.41	20.32				
1/26/2010 14:00	23.00	47.83	20.25	20.15				
1/27/2010 14:10	47.17	48.45	20.24	20.14				
1/28/2010 16:50	73.83	53.10	20.17	20.07				
2/1/2010 8:30	161.50	71.71	20.05	19.90				
2/2/2010 16:30	193.50	78.35	19.84	19.71				
2/3/2010 10:30	211.50	81.13	19.88	19.70				
2/4/2010 8:30	233.50	84.07	19.82	19.65				
2/5/2010 15:50	264.83	88.84	19.79	19.64				
2/6/2010 11:20	284.33	94.02	19.73	19.53				
2/7/2010 14:30	311.50	95.45	19.59	19.39				
2/8/2010 9:00	330.00	96.83	19.61	19.37				
		Average :	19.9	19.8				

Specimens Specifications

	Specimen #1	Specimen #2
H1 (mm)	51.257	
H2 (mm)	51.156	
H3 (mm)	51.384	
D1 (mm)	101.041	
D2 (mm)	102.743	
Mass SSD (g)	988.28	
Average Tickness (mm)	51.27	#DIV/0!
Average Diameter (mm)	101.89	#DIV/0!

Rings Specifications

	Specimen #1	Specimen #2
D1 upstream (mm)	93.14	
D2 upstream (mm)	93.14	
D1 downstream (mm)	93.14	
D2 downstream (mm)	93.14	
Average Diameter upstream (mm)	93.14	#DIV/0!
Average Diameter downstream (mm)	93.14	#DIV/0!

Migration Test

Project Number : Hycrete / USACE - 09106
Maturity (days) :
Identification : Series 2 - 0.65 WC 2-Gallon Hycrete

Date/Hour	t (hrs)	Specimen #1 I (mA)	Specimen #1 Ve (V)	Specimen #1 Vc (V)	Specimen #2 I (mA)	Specimen #2 Ve (V)	Specimen #2 Vc (V)	Vm
1/25/2010 15:00	0.00	45.29	21.21	20.04				
1/26/2010 14:00	23.00	40.79	21.39	20.53				
1/27/2010 14:10	47.17	40.30	21.39	20.46				
1/28/2010 16:50	73.83	44.34	21.32	20.40				
2/1/2010 8:30	161.50	61.08	21.13	20.11				
2/2/2010 16:30	193.50	67.31	20.98	19.75				
2/3/2010 10:30	211.50	70.29	21.03	19.97				
2/4/2010 8:30	233.50	73.28	20.99	19.84				
2/5/2010 15:50	264.83	78.03	20.89	19.82				
2/6/2010 11:20	284.33	82.54	20.72	19.82				
2/7/2010 14:30	311.50	83.60	20.29	19.73				
2/8/2010 9:00	330.00	85.04	20.89	19.66				
		Average :	21.0	20.0				

Specimens Specifications	Specimen #1	Specimen #2
H1 (mm)	50.546	
H2 (mm)	51.003	
H3 (mm)	50.952	
D1 (mm)	101.981	
D2 (mm)	102.108	
Mass SSD (g)	981.87	
Average Tickness (mm)	50.83	#DIV/0!
Average Diameter (mm)	102.04	#DIV/0!

Rings Specifications	Specimen #1	Specimen #2
D1 upstream (mm)	93.14	
D2 upstream (mm)	93.14	
D1 downstream (mm)	93.14	
D2 downstream (mm)	93.14	
Average Diameter upstream (mm)	93.14	#DIV/0!
Average Diameter downstream (mm)	93.14	#DIV/0!

TCG TOURNEY CONSULTING GROUP

Migration Test

Project Number : Hycrete / USACE - 09106
Maturity (days) :
Identification : Series 2 - 0.65 WC Reference

Date/Hour	t (hrs)	Specimen #1 I (mA)	Specimen #1 Ve (V)	Specimen #1 Vc (V)	Specimen #2 I (mA)	Specimen #2 Ve (V)	Specimen #2 Vc (V)	Vm
1/25/2010 15:00	0.00	50.47	21.06	20.28				
1/26/2010 14:00	23.00	44.98	20.10	20.43				
1/27/2010 14:10	47.17	44.60	20.85	20.33				
1/28/2010 16:50	73.83	48.61	20.71	20.22				
2/1/2010 8:30	161.50	67.18	20.37	19.77				
2/2/2010 16:30	193.50	73.20	20.02	19.47				
2/3/2010 10:30	211.50	76.02	20.12	19.60				
2/4/2010 8:30	233.50	78.53	20.04	19.52				
2/5/2010 15:50	264.83	83.47	19.74	19.51				
2/6/2010 11:20	284.33	88.65	19.91	19.43				
2/7/2010 14:30	311.50	89.38	19.75	19.32				
2/8/2010 9:00	330.00	90.30	19.77	19.35				
		Average :	20.2	19.8				

Specimens Specifications

	Specimen #1	Specimen #2
H1 (mm)	51.333	
H2 (mm)	51.613	
H3 (mm)	51.714	
D1 (mm)	101.981	
D2 (mm)	101.041	
Mass SSD (g)	992.86	
Average Tickness (mm)	51.55	#DIV/0!
Average Diameter (mm)	101.51	#DIV/0!

Rings Specifications

	Specimen #1	Specimen #2
D1 upstream (mm)	93.14	
D2 upstream (mm)	93.14	
D1 downstream (mm)	93.14	
D2 downstream (mm)	93.14	
Average Diameter upstream (mm)	93.14	#DIV/0!
Average Diameter downstream (mm)	93.14	#DIV/0!

TCG TOURNEY CONSULTING GROUP

Migration Test

Project Number : Hycrete / USACE - 09106
Maturity (days) :
Identification : Series 3 - 0.35 WC 1-Gallon Hycrete

Date/Hour	t (hrs)	Specimen #1 I (mA)	Specimen #1 Ve (V)	Specimen #1 Vc (V)	Specimen #2 I (mA)	Specimen #2 Ve (V)	Specimen #2 Vc (V)	Vm
2/9/2010 11:40	0.00	81.14	21.10	20.71				
2/10/2010 9:10	21.50	60.24	21.41	20.79				
2/11/2010 7:00	43.33	59.76	21.23	20.71				
2/12/2010 7:40	68.00	57.32	21.19	20.69				
2/13/2010 11:45	96.08	53.84	21.26	20.76				
2/14/2010 12:30	120.83	54.68	21.35	20.70				
2/15/2010 6:50	139.17	52.78	21.10	20.63				
2/16/2010 7:20	163.67	53.30	21.31	20.60				
2/17/2010 14:30	194.83	53.92	21.15	20.63				
2/18/2010 8:45	213.08	55.62	21.41	20.72				
2/19/2010 8:25	236.75	54.65	21.29	20.63				
2/20/2010 18:15	270.58	56.30	21.09	20.48				
2/21/2010 14:30	290.83	57.57	21.35	20.65				
		Average :	21.2	20.7				

Specimens Specifications

	Specimen #1	Specimen #2
H1 (mm)	51.410	
H2 (mm)	51.384	
H3 (mm)	51.384	
D1 (mm)	101.295	
D2 (mm)	100.940	
Mass SSD (g)	1011.69	
Average Tickness (mm)	51.39	#DIV/0!
Average Diameter (mm)	101.12	#DIV/0!

Rings Specifications

	Specimen #1	Specimen #2
D1 upstream (mm)	93.14	
D2 upstream (mm)	93.14	
D1 downstream (mm)	93.14	
D2 downstream (mm)	93.14	
Average Diameter upstream (mm)	93.14	#DIV/0!
Average Diameter downstream (mm)	93.14	#DIV/0!

TCG TOURNEY CONSULTING GROUP

Migration Test

Project Number : Hycrete / USACE - 09106
Maturity (days) :
Identification : Series 3 - 0.35 WC 2-Gallon Hycrete

Date/Hour	t	Specimen #1			Specimen #2			Vm
	(hrs)	I (mA)	Ve (V)	Vc (V)	I (mA)	Ve (V)	Vc (V)	
2/9/2010 11:40	0.00	79.74	21.23	20.80				
2/10/2010 9:10	21.50	54.60	21.17	20.89				
2/11/2010 7:00	43.33	54.66	21.30	20.84				
2/12/2010 7:40	68.00	53.74	21.32	20.81				
2/13/2010 11:45	96.08	51.49	21.26	20.78				
2/14/2010 12:30	120.83	52.60	21.34	20.73				
2/15/2010 6:50	139.17	50.83	21.49	20.88				
2/16/2010 7:20	163.67	50.71	21.21	20.58				
2/17/2010 14:30	194.83	50.46	21.14	20.61				
2/18/2010 8:45	213.08	51.54	21.25	20.64				
2/19/2010 8:25	236.75	49.97	21.27	20.64				
2/20/2010 18:15	270.58	50.40	21.32	20.66				
2/21/2010 14:30	290.83	51.06	21.33	20.64				
		Average :	21.3	20.7				

Specimens Specifications

	Specimen #1	Specimen #2
H1 (mm)	51.359	
H2 (mm)	51.359	
H3 (mm)	51.664	
D1 (mm)	102.794	
D2 (mm)	101.549	
Mass SSD (g)	1018.74	
Average Tickness (mm)	51.46	#DIV/0!
Average Diameter (mm)	102.17	#DIV/0!

Rings Specifications

	Specimen #1	Specimen #2
D1 upstream (mm)	93.14	
D2 upstream (mm)	93.14	
D1 downstream (mm)	93.14	
D2 downstream (mm)	93.14	
Average Diameter upstream (mm)	93.14	#DIV/0!
Average Diameter downstream (mm)	93.14	#DIV/0!

TCG TOURNEY CONSULTING GROUP

Migration Test

Project Number : Hycrete / USACE - 09106
Maturity (days) :
Identification : Series 3 - 0.35 WC Reference

Date/Hour	t (hrs)	Specimen #1 I (mA)	Specimen #1 Ve (V)	Specimen #1 Vc (V)	Specimen #2 I (mA)	Specimen #2 Ve (V)	Specimen #2 Vc (V)	Vm
2/9/2010 11:40	0.00	79.50	21.14	20.58				
2/10/2010 9:10	21.50	67.31	21.24	20.65				
2/11/2010 7:00	43.33	67.86	21.26	20.58				
2/12/2010 7:40	68.00	65.64	21.44	20.61				
2/13/2010 11:45	96.08	63.69	21.41	20.61				
2/14/2010 12:30	120.83	67.11	21.32	20.38				
2/15/2010 6:50	139.17	66.28	21.32	20.33				
2/16/2010 7:20	163.67	69.33	21.24	20.26				
2/17/2010 14:30	194.83	72.28	21.08	20.31				
2/18/2010 8:45	213.08	75.11	21.21	20.24				
2/19/2010 8:25	236.75	74.11	21.30	20.28				
2/20/2010 18:15	270.58	76.08	21.24	20.11				
2/21/2010 14:30	290.83	77.08	21.38	20.08				
		Average :	21.3	20.4				

Specimens Specifications

	Specimen #1	Specimen #2
H1 (mm)	51.105	
H2 (mm)	51.156	
H3 (mm)	51.206	
D1 (mm)	102.489	
D2 (mm)	101.422	
Mass SSD (g)	1012.44	
Average Tickness (mm)	51.16	#DIV/0!
Average Diameter (mm)	101.96	#DIV/0!

Rings Specifications

	Specimen #1	Specimen #2
D1 upstream (mm)	93.14	
D2 upstream (mm)	93.14	
D1 downstream (mm)	93.14	
D2 downstream (mm)	93.14	
Average Diameter upstream (mm)	93.14	#DIV/0!
Average Diameter downstream (mm)	93.14	#DIV/0!

Migration Test

Project Number : Hycrete / USACE - 09106
Maturity (days) :
Identification : Series 3 - 0.50 WC 1-Gallon Hycrete

Date/Hour	t	Specimen #1			Specimen #2			Vm
	(hrs)	I (mA)	Ve (V)	Vc (V)	I (mA)	Ve (V)	Vc (V)	
2/9/2010 11:40	0.00	102.72	21.29	20.78				
2/10/2010 9:10	21.50	95.61	21.12	20.70				
2/11/2010 7:00	43.33	92.89	21.15	20.69				
2/12/2010 7:40	68.00	92.42	21.26	20.62				
2/13/2010 11:45	96.08	95.97	21.16	20.52				
2/14/2010 12:30	120.83	105.94	21.14	20.51				
2/15/2010 6:50	139.17	108.86	21.15	20.61				
2/16/2010 7:20	163.67	116.31	21.29	20.52				
2/17/2010 14:30	194.83	126.08	21.13	20.43				
2/18/2010 8:45	213.08	132.31	21.02	20.31				
2/19/2010 8:25	236.75	134.69	21.03	20.26				
2/20/2010 18:15	270.58	140.61	20.93	20.04				
2/21/2010 14:30	290.83	143.44	21.08	20.33				
		Average :	21.1	20.5				

Specimens Specifications	Specimen #1	Specimen #2
H1 (mm)	51.257	
H2 (mm)	51.054	
H3 (mm)	51.206	
D1 (mm)	102.616	
D2 (mm)	102.946	
Mass SSD (g)	993.01	
Average Tickness (mm)	51.17	#DIV/0!
Average Diameter (mm)	102.78	#DIV/0!

Rings Specifications	Specimen #1	Specimen #2
D1 upstream (mm)	93.14	
D2 upstream (mm)	93.14	
D1 downstream (mm)	93.14	
D2 downstream (mm)	93.14	
Average Diameter upstream (mm)	93.14	#DIV/0!
Average Diameter downstream (mm)	93.14	#DIV/0!

TCG TOURNEY CONSULTING GROUP

Migration Test

Project Number : Hycrete / USACE - 09106
Maturity (days) :
Identification : Series 3 - 0.50 WC 2-Gallon Hycrete

Date/Hour	t (hrs)	Specimen #1 I (mA)	Specimen #1 Ve (V)	Specimen #1 Vc (V)	Specimen #2 I (mA)	Specimen #2 Ve (V)	Specimen #2 Vc (V)	Vm
2/9/2010 11:40	0.00	102.97	21.21	20.52				
2/10/2010 9:10	21.50	82.68	21.17	20.54				
2/11/2010 7:00	43.33	81.08	21.27	20.54				
2/12/2010 7:40	68.00	78.42	21.17	20.52				
2/13/2010 11:45	96.08	74.66	20.99	20.31				
2/14/2010 12:30	120.83	80.03	21.12	20.27				
2/15/2010 6:50	139.17	81.18	21.09	20.28				
2/16/2010 7:20	163.67	86.16	20.45	19.22				
2/17/2010 14:30	194.83	89.08	20.36	19.43				
2/18/2010 8:45	213.08	93.18	20.52	19.47				
2/19/2010 8:25	236.75	94.32	20.31	19.06				
2/20/2010 18:15	270.58	95.97	20.19	18.78				
2/21/2010 14:30	290.83	99.45	20.31	18.74				
		Average :	20.8	19.8				

Specimens Specifications

	Specimen #1	Specimen #2
H1 (mm)	51.054	
H2 (mm)	50.673	
H3 (mm)	51.054	
D1 (mm)	102.108	
D2 (mm)	102.006	
Mass SSD (g)	987.81	
Average Tickness (mm)	50.93	#DIV/0!
Average Diameter (mm)	102.06	#DIV/0!

Rings Specifications

	Specimen #1	Specimen #2
D1 upstream (mm)	93.14	
D2 upstream (mm)	93.14	
D1 downstream (mm)	93.14	
D2 downstream (mm)	93.14	
Average Diameter upstream (mm)	93.14	#DIV/0!
Average Diameter downstream (mm)	93.14	#DIV/0!

TCG TOURNEY CONSULTING GROUP

Migration Test

Project Number : Hycrete / USACE - 09106
Maturity (days) :
Identification : Series 3 - 0.50 WC Reference

Date/Hour	t (hrs)	Specimen #1 I (mA)	Specimen #1 Ve (V)	Specimen #1 Vc (V)	Specimen #2 I (mA)	Specimen #2 Ve (V)	Specimen #2 Vc (V)	Vm
2/9/2010 11:40	0.00	118.89	21.13	20.80				
2/10/2010 9:10	21.50	111.14	21.07	20.77				
2/11/2010 7:00	43.33	107.00	21.04	20.70				
2/12/2010 7:40	68.00	107.91	21.07	20.49				
2/13/2010 11:45	96.08	114.03	20.68	20.36				
2/14/2010 12:30	120.83	129.31	20.78	20.43				
2/15/2010 6:50	139.17	135.91	20.79	20.35				
2/16/2010 7:20	163.67	151.49	20.88	20.30				
2/17/2010 14:30	194.83	169.74	20.66	20.08				
2/18/2010 8:45	213.08	182.94	20.31	19.93				
2/19/2010 8:25	236.75	189.49	20.53	19.95				
2/20/2010 18:15	270.58	201.86	20.37	19.89				
2/21/2010 14:30	290.83	208.63	20.46	19.89				
		Average :	20.8	20.3				

Specimens Specifications

	Specimen #1	Specimen #2
H1 (mm)	50.851	
H2 (mm)	51.410	
H3 (mm)	51.079	
D1 (mm)	101.524	
D2 (mm)	101.829	
Mass SSD (g)	982.48	
Average Tickness (mm)	51.11	#DIV/0!
Average Diameter (mm)	101.68	#DIV/0!

Rings Specifications

	Specimen #1	Specimen #2
D1 upstream (mm)	93.14	
D2 upstream (mm)	93.14	
D1 downstream (mm)	93.14	
D2 downstream (mm)	93.14	
Average Diameter upstream (mm)	93.14	#DIV/0!
Average Diameter downstream (mm)	93.14	#DIV/0!

TCG TOURNEY CONSULTING GROUP

Migration Test

Project Number : Hycrete / USACE - 09106
Maturity (days) :
Identification : Series 3 - 0.65 WC 1-Gallon Hycrete

Date/Hour	t (hrs)	Specimen #1 I (mA)	Specimen #1 Ve (V)	Specimen #1 Vc (V)	Specimen #2 I (mA)	Specimen #2 Ve (V)	Specimen #2 Vc (V)	Vm
2/9/2010 11:40	0.00	109.19	21.12	20.75				
2/10/2010 9:10	21.50	116.59	21.07	20.69				
2/11/2010 7:00	43.33	118.49	21.08	20.65				
2/12/2010 7:40	68.00	130.19	20.84	20.56				
2/13/2010 11:45	96.08	149.68	21.05	20.55				
2/14/2010 12:30	120.83	176.57	21.05	20.47				
2/15/2010 6:50	139.17	187.57	20.91	20.46				
2/16/2010 7:20	163.67	209.35	20.99	20.41				
2/17/2010 14:30	194.83	235.97	20.70	20.19				
2/18/2010 8:45	213.08	250.92	20.87	20.24				
2/19/2010 8:25	236.75	258.65	20.55	19.86				
2/20/2010 18:15	270.58	271.62	20.64	19.92				
2/21/2010 14:30	290.83	278.54	20.66	19.80				
		Average :	20.9	20.4				

Specimens Specifications

	Specimen #1	Specimen #2
H1 (mm)	51.435	
H2 (mm)	51.181	
H3 (mm)	51.435	
D1 (mm)	102.845	
D2 (mm)	101.778	
Mass SSD (g)	999.59	
Average Tickness (mm)	51.35	#DIV/0!
Average Diameter (mm)	102.31	#DIV/0!

Rings Specifications

	Specimen #1	Specimen #2
D1 upstream (mm)	93.14	
D2 upstream (mm)	93.14	
D1 downstream (mm)	93.14	
D2 downstream (mm)	93.14	
Average Diameter upstream (mm)	93.14	#DIV/0!
Average Diameter downstream (mm)	93.14	#DIV/0!

TCG TOURNEY CONSULTING GROUP LLC

Migration Test

Project Number : Hycrete / USACE - 09106
Maturity (days) :
Identification : Series 3 - 0.65 WC 2-Gallon Hycrete

Date/Hour	t	Specimen #1			Specimen #2			Vm
	(hrs)	I (mA)	Ve (V)	Vc (V)	I (mA)	Ve (V)	Vc (V)	
2/9/2010 11:40	0.00	102.17	20.66	20.50				
2/10/2010 9:10	21.50	103.69	20.60	20.47				
2/11/2010 7:00	43.33	106.89	20.53	20.40				
2/12/2010 7:40	68.00	114.29	20.45	20.33				
2/13/2010 11:45	96.08	127.51	20.62	20.31				
2/14/2010 12:30	120.83	146.00	20.54	20.20				
2/15/2010 6:50	139.17	152.51	20.28	20.10				
2/16/2010 7:20	163.67	166.46	20.18	20.01				
2/17/2010 14:30	194.83	178.71	20.19	19.54				
2/18/2010 8:45	213.08	186.03	19.98	19.45				
2/19/2010 8:25	236.75	187.31	19.84	19.23				
2/20/2010 18:15	270.58	196.83	19.78	19.04				
2/21/2010 14:30	290.83	198.43	19.86	19.09				
		Average :	20.3	19.9				

Specimens Specifications

	Specimen #1	Specimen #2
H1 (mm)	51.029	
H2 (mm)	51.460	
H3 (mm)	51.079	
D1 (mm)	102.159	
D2 (mm)	102.133	
Mass SSD (g)	1002.16	
Average Tickness (mm)	51.19	#DIV/0!
Average Diameter (mm)	102.15	#DIV/0!

Rings Specifications

	Specimen #1	Specimen #2
D1 upstream (mm)	93.14	
D2 upstream (mm)	93.14	
D1 downstream (mm)	93.14	
D2 downstream (mm)	93.14	
Average Diameter upstream (mm)	93.14	#DIV/0!
Average Diameter downstream (mm)	93.14	#DIV/0!

TCG TOURNEY CONSULTING GROUP

Migration Test

Project Number : Hycrete / USACE - 09106
Maturity (days) :
Identification : Series 3 - 0.65 WC Reference

Date/Hour	t (hrs)	Specimen #1 I (mA)	Specimen #1 Ve (V)	Specimen #1 Vc (V)	Specimen #2 I (mA)	Specimen #2 Ve (V)	Specimen #2 Vc (V)	Vm
2/9/2010 11:40	0.00	117.28	20.84	20.46				
2/10/2010 9:10	21.50	111.75	20.82	20.37				
2/11/2010 7:00	43.33	115.86	20.95	20.32				
2/12/2010 7:40	68.00	126.47	20.61	20.24				
2/13/2010 11:45	96.08	142.42	21.05	20.08				
2/14/2010 12:30	120.83	163.39	20.73	19.86				
2/15/2010 6:50	139.17	172.75	20.66	19.83				
2/16/2010 7:20	163.67	188.67	20.66	19.55				
2/17/2010 14:30	194.83	200.22	20.64	18.81				
2/18/2010 8:45	213.08	204.44	19.79	18.16				
2/19/2010 8:25	236.75	198.33	20.10	17.42				
2/20/2010 18:15	270.58	198.14	19.86	17.02				
2/21/2010 14:30	290.83	192.69	19.79	17.02				
		Average :	20.5	19.2				

Specimens Specifications

	Specimen #1	Specimen #2
H1 (mm)	51.638	
H2 (mm)	51.435	
H3 (mm)	51.054	
D1 (mm)	101.498	
D2 (mm)	102.743	
Mass SSD (g)	985.40	
Average Tickness (mm)	51.38	#DIV/0!
Average Diameter (mm)	102.12	#DIV/0!

Rings Specifications

	Specimen #1	Specimen #2
D1 upstream (mm)	93.14	
D2 upstream (mm)	93.14	
D1 downstream (mm)	93.14	
D2 downstream (mm)	93.14	
Average Diameter upstream (mm)	93.14	#DIV/0!
Average Diameter downstream (mm)	93.14	#DIV/0!

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Contractor's Supplemental Report for CPC Project F09-AR05A

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14. ABSTRACT

The Department of Defense spends many millions of dollars annually to repair or replace steel-reinforced structures that are seriously damaged by corrosion. Reinforced concrete is readily damaged by corrosion because the cement/aggregate matrix is porous, allowing corrosive chemicals (e.g., chlorides from marine salts or road-deicing salts) to deeply penetrate structures following wetting/drying cycles. Damage modes include loss of reinforcement steel mass through corrosion and fracturing due to corrosion-product buildup or freeze/thaw cycling. These stresses can destroy a concrete structure many years short of its intended service life.

This report documents one of several studies performed or supervised by the U.S. Army Engineer Research and Development Center to demonstrate or test the efficacy of a commercial hydrophobic concrete admixture in preventing the ingress of water and chlorides into reinforced concrete structures or specimens. Laboratory testing addressed chloride ingress threshold (destructive examination of specimens), absorption, and transport. This report includes an executive summary of the project and a detailed record of all testing program results.

15. SUBJECT TERMS
Concrete–Mixing; Concrete–Additives–Evaluation; Reinforced concrete–Corrosion; Corrosion and anti-corrosives; Waterproofing; Concrete–Effect of salt on; STADIUM reactive transport model; Hycrete

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