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Evaluation of Masterlife CI 222+ as Corrosion Inhibiting Admixture for Concrete

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Background:

Sample of MasterLife CI 222+, manufactured by BASF, was provided by Cortec Middle East for evaluation to determine if it behaves as a corrosion inhibitor.

Sample Received:

MasterLife CI 222+ from Cortec Middle East

Method:

1. ASTM G180 Standard Test Method for Corrosion Inhibiting Admixtures for Steel in Concrete by Polarization Resistance in Cementitious Slurries
2. Immersion Testing, CC-029

Materials:

- Lab grade methanol
- Lab grade calcium hydroxide
- Lab grade sodium chloride
- Carbon dioxide free air
- Deionized water
- Ten C1215 plugs for G180
- MCI-2005 (B# 06545)
- Hydrochloric Acid

Procedure:

1. ASTM G180 Standard Test Method
    - 0.5M sodium chloride concentration used
    - MasterLife CI 222+ was tested at its recommended dose rate of 5 L/m^3 (as per MasterLife CI 222+ data sheet). MCI-2005 was tested at its recommended dose rate of 0.6 L/m^3.
2. Immersion Testing
    - Test Solution: 3% NaCl, 0.42% $Ca(OH)_2$, comparative inhibitor concentrations
    - Temperature: 40 ± 2 °C
    - Exposure Time: 312 hours
    - Metal: 1008 Steel

ASTM G180 Results and Discussion:

ASTM G180 is a standardized test method used to qualify given admixtures for their ability to inhibit corrosion on steel reinforcement in concrete structures. The test is performed by mimicking the chemistry present in concrete, and consequently the chemistry steel reinforcement is exposed to.

First, mortar mixes are prepared and the liquid component is extracted. Then calcium hydroxide is added and CO_2-free air is purged through the solution for several days while stirring. A steel sample is exposed to the solution during this time, allowing it to form passivating layers or any other protection offered by the admixture. On the second day, sodium chloride is added to bring the solution to a 0.5 M concentration, and the stirring is stopped to encourage crevice corrosion. On the third day, electrochemical testing is performed by varying the potential applied to the metal sample and measuring the resulting current.

The results of the G180 standard test method are primarily interpreted from the experimentally derived polarization resistance (Rp). To qualify as a corrosion inhibitor in this test method, the average $\log_{10}(1/Rp)$ value must be 1.0 or less than that of the control. The Icorr and corrosion rate are largely just interpretations of the Rp.

	Control Run 1	Control Run 2	Control Avg.
Rp (kΩ)	3.565	2.776	3.1705
Avg. $\log_{10}(1/Rp)$	-0.498		
Icorr (mA/cm^2)	1.624	2.086	1.855
Corrosion rate (mpy)	0.814	1.046	0.93

	MCI-2005 Run 1	MCI-2005 Run 2	MCI-2005 Run 3	MCI-2005 Run 4	MCI-2005 Avg.
Rp (kΩ)	19.14	55.99	61.47	30.06	41.665
Avg. $\log_{10}(1/Rp)$	-1.574				
Icorr (mA/cm^2)	0.302	0.103	0.094	0.193	0.173
Corrosion rate (mpy)	0.136	0.056	0.043	0.087	0.0805

	MasterLife CI 222+ Run 1	MasterLife CI 222+ Run 2	MasterLife CI 222+ Avg.
Rp (kΩ)	1.568	1.197	1.3825
Avg. $\log_{10}(1/Rp)$	-0.137		
Icorr (mA/cm^2)	3.693	4.836	4.2645
Corrosion rate (mpy)	1.688	2.209	1.9485

Table 1: Results from ASTM-G180 Standard Test Method. The control values were taken from previous data.

When evaluated with the ASTM G180 test method for polarization resistance (Rp) in cementitious slurries at the recommended dosage, MasterLife CI 222+ results are well below those required to classify it as a corrosion inhibitor. Results for MCI-2005 exceeded the reuired criteria confirming its classification as a corrosion inhibitor.

Per ASTM C1582: *If Test Method G180 is used, the average polarization resistance, Rp, of the test specimens with the corrosion inhibitor shall be at least 8 times greater than that of the control specimens.* The average polarization resistance for MCI-2005 is 41.67 kΩ compared to 1.383 kΩ for MasterLlife CI 222+. While MCI-2005 exceeds that requirement, MasterLife CI 222+ fails to show any improvement.

At the standard recommended dosage in ASTM G180, MasterLife CI 222+ yielded corrosion rates of 1.949 mpy compared to 0.081 mpy for MCI-2005 and 0.930 mpy for the control.

Immersion Testing Results and Discussion:

Immersion testing is a well-accepted method of corrosion testing and yields reproducible results with little effort. In essence, a test solution is made with the properties to be evaluated and pre-weighed metal panels are placed into the solution. These solutions are left to sit for two weeks at 40 ± 2 °C before collecting the metal panels and cleaning off the corrosion. Cleaning is performed with a concentrated hydrochloric acid solution since abrasive methods of oxide removal remove too much mass and in an inconsistent manner. Once clean, the panels are reweighed with an analytical balance to accurately determine the mass lost due to corrosion. Cleaning is also performed on a blank panel to determine the mass lost through the cleaning process.

The mass loss from cleaning, determined from the blank panel, is added to the final mass of each panel to adjust for the cleaning process. This corrected mass loss is used to determine the rate of corrosion of each sample (equation 1). Furthermore, the average corrosion rate of the experimental samples can be compared with the average corrosion rate of the control samples to determine the amount of inhibition offered (equation 2).

$$Corrosion\ Rate\ (mpy) = \frac{3.449 * 10^6 * W}{A * T * D}$$

Equation 1: Corrosion rate calculation formula. W is the mass loss in g to the nearest 1 mg, A is the area in cm^2 to the nearest 0.01 cm^2, T is the time of exposure to the nearest 0.1 h, and D is the density of the metal in g/cm^3.

$$1 - \left(\frac{Experimental\ Corrosion\ Rate}{Control\ Corrosion\ Rate}\right) * 100\%$$

Equation 2: Inhibition equation

Sample	Product	Initial Mass (g)	End Mass (g)	Δ mass (g)	Corrosion Rate (mpy)	Avg Corrosion Rate (mpy)	Std. Dev.	Inhibition (%)
1	Controls	32.1972	32.1616	0.0356	1.9426	1.8635	0.0791	NA
2		32.1076	32.0749	0.0327	1.7844			
3	MCI-2005 0.40%	32.3483	32.3464	0.0019	0.1037	0.1110	0.0493	94.05
4		32.2382	32.2372	0.001	0.0546			
5		32.0157	32.0125	0.0032	0.1746			
6	MasterLife CI 222+ 3.50%	32.1169	32.1025	0.0144	0.7858	0.7931	0.0068	57.44
7		32.197	32.1825	0.0145	0.7912			
8		32.2777	32.263	0.0147	0.8022			

Table 2: The results of the immersion testing.

The immersion testing performed for this report was done to simulate the conditions experienced in ASTM G180. To this end, a solution of 0.42% calcium hydroxide, 3.0% sodium chloride, and varying concentrations of inhibitor were mixed into deionized water. These conditions are conducive to the formation of pitting corrosion.

Conclusion:

At the recommended dosage of 5.0 L/m^3, MasterLife CI 222+ did not perform as an effective corrosion inhibitor in both ASTM G180 and Immersion Testing.

Per ASTM C1582: *If Test Method G180 is used, the average polarization resistance, Rp, of the test specimens with the corrosion inhibitor shall be at least 8 times greater than that of the control specimens.* The average polarization resistance for MCI-2005 is 41.67 kΩ compared to 1.383 kΩ for MasterLife CI 222+. While MCI-2005 exceeds that requirement, MasterLife CI 222+ fails to show any improvement.

At the standard recommended dosage in ASTM G180, MasterLife CI 222+ yielded corrosion rates of 1.949 mpy compared to 0.081 mpy for MCI-2005 and 0.930 mpy for the control.

In immersion testing, MasterLife CI yielded 57% reduction in corrosion rates at its recommended dosage of 5.0 L/m^3 compared to a 94% corrosion rate reduction achieved by MCI-2005 at its recommended dosage of 0.6 L/m^3.