AMERICAN ENGINEERING TESTING, INC.

CONSULTANTS
• GEOTECHNICAL
• MATERIALS
• ENVIRONMENTAL

REPORT OF CONCRETE CORROSION INHIBITOR TESTING

PROJECT:

MCI 2005 NS

REPORTED TO:

CORTEC CORPORATION
4119 WHITE BEAR PARKWAY
ST. PAUL MN 55110

ATTN: JESSI JACKSON MEYER

AET JOB NO: 05-01171

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INTRODUCTION

This report presents the results of our testing of Cortec's MCI 2005NS, and competing products. We understand the admixture was developed to provide corrosion protection to steel embedded in concrete. We understand Illinois DOT is considering using MCI 2005NS. Ms. Jessi Jackson Meyer of Cortec Corporation requested we evaluate the material's effectiveness. The scope of our work consists of batching concrete; testing plastic concrete for properties; casting, curing and testing cylinders and beams for strength; and casting beams containing steel and testing for corrosion.

CONCLUSIONS

Base on the results of our work and experience, it is our opinion the following conclusions are appropriate:

1. The cracked beams in the control and concretes with corrosion inhibitors showed corrosion currents greater than 10 μA by the second cycle.

2. MCI 2005NS reduced the corrosion current about 81 % and the total corrosion about 80% at the end of 20 cycles.

3. DCI at 4 gpy reduced corrosion current about 3 % and total corrosion about 25 % at the end of 20 cycles.

4. Rheocrete 222+ reduced corrosion currents about 12% and total corrosion about 39% at the end of 20 cycles.

5. The average corrosion currents over the test were control -58.5 μA, Rheocrete 222 + 44.5 μA, DCI 41.0 M, and MCI 2005NS 11.4 μA.

6. The average corroded area on the top bar was DCI 1.0 in^2, Rheocrete 222+ 0.8 in^2, control 0.5 in^2, and MCI 2005NS 0.3 in^2.

550 Cleveland Avenue North • St. Paul, MN 55114 • 651-659-9001 • Fax 651-659-1379
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6. The average corroded area on the top bar was DCI 1.0 in^2, Rheocrete 222+ 0.8 in^2, control 0.5 in^2, and MCI 2005NS 0.3 in^2.

TESTING METHODS AND RESULTS

Between January 7 and 15, 2003, four test batches of concrete were made at our laboratory. The batches were 1¾ cubic feet and proportioned to the following mix designs:

	Mix 1	Mix 2	Mix 3	Mix 4
Portland Cement, Type I, pcy	600	600	600	600
3/4" Glacial Gravel, pcy	1225	1225	1225	1225
3/8" Glacial Gravel, pcy	410	410	410	410
Sand, pcy	1370	1370	1370	1370
MCI 2005 NS, pints/yd (liquid)	-	1.5	-	-
DCI, gal/yd	-	-	4	-
Rheocrete, gal/yd	-	-	-	1
Neutralized Vinsol Resin, ocy	6.0	3.0	3.0	3.0
Water, pcy	238	238	238	238
Water/Cement Ratio	0.40	0.40	0.40	0.40

The plastic concrete was tested for slump, and air content, immediately after discharge into a wheelbarrow. Specimens were cast, cured and tested for compressive strength and flexural strength. The following data was obtained:

	Control Mix #1	MCI 2005 NS Mix #2	DCI 4 gcy Mix #3	Rheocrete 222 Mix #4
Slump, in	6	6	6	6
Air, %	10.5	6.1	5.8	7.8
Compressive Strength, psi				
1 day	1620	2670	2640	1750
	1540	2570	2590	1950
28 days	5530	6990	7350	5650
	5200	6900	7190	5230

	Control Mix #1	MCI 2005 NS Mix #2	DCI 4 gcy Mix #3	Rheocrete 222 Mix #4
Flexural Strength, psi				
1 day	370	510	610	340
	420	540	490	400
28 days	710	810	770	720
	740	700	680	780

Four beams were cast from each concrete batch for corrosion testing. Three 18" long #3 bars were sandblasted to near white metal. The ends were coated with epoxy leaving a 15-inch section of bar exposed to the concrete. The bars were cleaned with acetone and set in a triangular array with one bar 1" from the concrete beam top surface. The concrete was moist cured 7 days, then air dried 14 days. The beams were cut 0.75" deep across the width at mid-length. The beams were loaded in flexure using center point loading with the notched surface in tension. Load was applied until a crack developed just beyond the single top bar. A plexiglass container was sealed onto the beam's top surface and allows ponding of saline solution over the middle 4". Epoxy was applied to the concrete beam sides and unponded top surface. The top bar was connected to the bottom bars with a shielded copper wire and a 10 ohm resistor.

A 6% solution of sodium chloride was poured into the plexiglass container. A weekly test schedule was initiated consisting of 96-hour salt water ponding, testing half cell potential of bars, testing macrocell corrosion top bar to bottom bars, vacuum removal, fresh water rinse, vacuum removal, and 72 hours air drying. The test data is contained in Tables 1-4.

At the end of 20 cycles the bars were removed from the concrete. The corroded metal was measured and the area estimated. The corrosion data is contained in Table 5.

REMARKS

The corroded bars will be retained for 30 days. We will discard the bars unless we receive other instructions.

Report Prepared by:
American Engineering Testing, Inc.

Daniel M. Vruno, P.E.
Sr. Concrete Engineer
Phone: 651-659-1334
Fax: 651-647-2744
dvruno@amengtest.com

American Engineering Testing, Inc.

Richard D. Stehly, P.E.
MN Reg. No. 12856
Phone: 651-659-1333
Fax: 651-647-2744
rstehly@amengtest.com

TABLE #1 - CONTROL

	CORROSION POTENTIAL (Mv)			CORROSION CURRENT (μA)				TOTAL CORROSION, COULOMBS
Test Cycle	BEAM A Top/Left/Right	BEAM B Top/Left/Right	BEAM C Top/Left/Right	BEAM A	BEAM B	BEAM C	AVERAGE	
1	486/485/485	366/366/366	476/475/475	11.0	3.8	6.9	7.2	2
2	OL/OL/OL	346/346/346	OL/OL/OL	83.0	26.0	65.6	58.2	22
3	488/487/487	380/380/380	474/473/477	72.0	0.0	32.0	34.7	50
4	482/480/480	377/377/377	482/481/482	88.0	34.6	142.8	88.5	87
5	495/493/493	381/381/381	476/475/475	94.5	32.9	56.6	61.3	132
6	489/488/489	377/377/377	472/471/476	93.2	31.0	55.4	59.9	169
7	484/483/483	385/384/384	467/466/465	103.2	39.2	63.2	68.5	208
8	490/489/489	375/375/375	469/468/469	102.7	34.5	62.0	66.4	249
9	491/490/490	368/368/368	480/480/482	102.6	33.1	64.3	66.7	289
10	490/489/489	367/367/367	482/482/472	95.0	32.1	54.4	60.5	327
11	489/481/485	368/368/368	480/473/470	93.3	28.2	59.6	60.4	364
12	479/478/478	369/369/369	468/467/467	92.4	17.6	64.4	58.1	400
13	478/477/477	375/382/376	473/473/473	88.6	21.6	63.7	58.0	435
14	476/475/475	398/397/397	482/482/482	84.2	26.2	62.4	57.6	470
15	473/470/471	389/389/389	468/467/473	84.2	26.2	70.2	60.2	506
16	471/470/471	390/390/390	465/470/471	86.3	28.1	63.5	59.3	542
17	468/467/467	392/392/392	469/468/474	89.0	31.3	68.4	62.9	579
18	466/466/463	390/390/389	466/467/470	85.2	32.4	64.9	60.8	616
19	465/465/465	392/390/390	465/465/470	87.0	34.0	62.4	61.1	653
20	463/462/462	390/389/389	461/461/465	82.5	35.7	58.9	59.0	689

TABLE #2 - MCI 2005 NS

	CORROSION POTENTIAL (FA)			CORROSION CURRENT (FA)				TOTAL CORROSION, COULOMBS
Test Cycle	BEAM B Top/Left/Right	BEAM C Top/Left/Right	BEAM D Top/Left/Right	BEAM B	BEAM C	BEAM D	AVERAGE	
1	442/440/430	288/288/288	442/425/435	5.1	34.5	1.5	13.7	4
2	358/358/358	262/262/261	OL/OL/OL	7.0	10.4	19.8	12.4	12
3	469/426/463	298/298/298	450/450/450	0.0	8.5	2.4	3.6	17
4	514/463/463	332/330/330	433/427/429	45.9	45.0	27.3	39.4	30
5	439/439/439	389/383/389	451/451/451	13.1	26.8	6.9	15.6	47
6	436/436/436	394/393/392	444/444/444	0.6	7.4	3.4	3.8	53
7	432/433/433	404/399/397	428/426/426	53.0	7.3	2.3	20.9	60
8	442/442/444	409/395/394	436/437/437	0.6	50.1	9.9	20.2	72
9	433/453/461	392/388/388	426/426/426	0.5	3.7	5.3	3.2	79
10	478/469/474	415/385/383	436/435/435	0.2	56.0	13.5	23.2	
11	463/450/446	423/384/380	432/430/430	0.2	5.3	12.8	6.1	96
12	450/449/449	432/382/379	430/425/425	0.2	4.9	9.3	4.8	99
13	450/449/447	426/392/384	429/426/426	1.0	5.1	7.0	4.4	102
14	449/449/444	413/397/396	427/426/426	3.2	5.3	6.3	4.9	105
15	455/405/452	410/402/399	419/423/422	6.4	5.1	6.7	6.1	108
16	448/448/448	387/387/387	423/424/424	5.1	6.3	5.2	5.5	112
17	441/441/441	368/368/368	421/422/422	0.7	7.9	3.9	4.2	115
18	449/447/447	382/382/382	420/419/419	1.2	15.6	11.8	9.5	119
19	443/430/440	390/379/383	423/422/423	1.3	17.2	12.6	10.4	125
20	444/414/439	403/400/399	424/424/423	2.5	25.0	17.8	15.1	133

TABLE #3 - DCI

	CORROSION POTENTIAL (Mv)				CORROSION CURRENT (µA)					TOTAL CORROSION, COULOMBS
Test Cycle	BEAM A Top/Left/Right	BEAM B Top/Left/Right	BEAM C Top/Left/Right	BEAM D Top/Left/Right	BEAM A	BEAM B	BEAM C	BEAM D	AVERAGE	
1	328/326/326	412/411/411	331/333/333	428/427/427	17.6	6.3	5.2	7.6	9.2	3
2	340/339/339	269/269/269	212/212/212	OL/OL/OL	26.5	9.0	9.4	74.4	29.8	15
3	361/358/357	420/419/419	373/376/377	421/420/420	76.2	48.0	42.3	0.0	41.6	37
4	382/381/381	422/422/422	366/364/361	412/411/411	74.7	75.0	46.9	47.9	61.1	68
5	377/379/379	422/421/421	351/352/353	418/417/417	48.3	38.8	35.6	48.7	42.9	99
6	374/373/373	406/404/404	347/347/347	428/427/427	47.9	83.3	35.2	59.0	56.4	129
7	366/367/367	416/412/411	323/324/325	432/430/430	35.1	55.8	23.2	62.5	44.2	159
8	383/382/382	424/424/424	310/312/313	436/435/435	55.6	50.0	25.3	51.0	45.5	186
9	395/394/394	413/406/405	345/349/349	414/414/414	74.4	49.3	36.7	46.0	51.6	215
10	394/393/393	417/411/417	338/340/341	407/407/407	67.0	41.4	36.7	38.2	45.8	244
11	364/356/390	415/411/415	332/333/340	403/405/405	75.3	46.2	37.3	24.6	45.9	272
12	349/348/348	411/411/411	327/328/324	402/402/402	78.8	45.0	37.8	19.8	45.4	300
13	352/350/350	415/416/416	333/336/352	409/409/409	62.4	38.3	40.2	22.6	40.9	326
14	361/359/359	420/424/424	358/360/360	416/416/416	42.4	35.1	48.2	29.4	38.8	350
15	365/361/360	423/422/422	353/353/354	413/413/413	48.0	40.2	50.0	30.6	42.2	374
16	371/370/370	420/419/419	342/342/342	390/390/390	56.5	38.7	46.4	25.6	41.8	399
17	386/386/386	421/420/420	329/330/321	381/381/381	69.5	37.9	40.4	10.0	39.5	424
18	382/380/380	426/424/424	343/340/337	386/386/386	70.1	38.0	44.3	5.6	39.5	448
19	384/383/385	428/427/430	356/363/343	392/391/394	70.3	42.6	48.6	0.9	40.6	472
20	380/379/380	435/435/435	364/367/365	401/401/401	71.8	45.4	55.2	-	57.5	502

TABLE #4 - RHEOCRETE 222+

	CORROSION POTENTIAL (FA)			**CORROSION CURRENT (FA)**				**TOTAL CORROSION, COULOMBS**
Test Cycle	BEAM A Top/Left/Right	BEAM B Top/Left/Right	BEAM C Top/Left/Right	BEAM A	BEAM B	BEAM C	AVERAGE	
1	437/436/436	412/412/411	390/390/390	8.5	5.0	5.5	6.3	2
2	OL/OL/OL	402/401/401	357/357/357	-	32.9	28.9	30.9	13
3	483/185/185	420/415/414	373/373/373	134.0	21.0	29.0	61.3	41
4	489/176/176	441/441/441	395/394/394	86.0	40.7	42.9	56.5	77
5	434/433/433	448/447/447	402/401/401	54.3	33.9	43.9	44.0	107
6	438/437/437	444/444/444	403/402/402	58.6	29.9	44.6	44.4	134
7	441/441/441	450/450/450	404/404/404	56.5	30.0	47.2	44.6	161
8	446/445/445	454/453/453	403/402/402	33.8	29.0	46.8	36.5	186
9	443/442/442	444/444/444	406/405/405	50.0	21.2	50.0	40.4	209
10	454/454/454	448/447/447	409/408/408	55.4	27.0	49.4	43.9	234
11	450/450/450	447/447/447	400/400/402	59.2	23.0	50.2	44.1	261
12	449/448/448	446/446/446	399/396/398	60.1	23.7	51.4	45.1	288
13	447/445/445	450/450/450	400/400/400	63.2	19.9	53.2	45.4	315
14	443/442/442	456/456/456	403/402/402	64.0	14.6	55.5	44.7	342
15	441/444/445	449/448/448	392/390/392	62.0	14.3	50.2	42.2	268
16	442/442/442	447/446/446	398/396/396	65.5	33.2	51.8	50.2	296
17	444/443/443	441/440/440	400/400/400	69.3	35.9	55.9	53.7	327
18	444/444/442	442/442/442	401/401/401	66.7	36.0	55.4	52.7	359
19	443/443/442	443/441/442	403/403/403	65.7	36.3	54.7	52.2	391
20	442/441/441	444/443/443	405/404/404	64.7	37.8	52.7	51.7	422

TABLE #5 - BAR CORROSION AT END OF TEST

CONTROL

Beam A Top Bar

- 25% of area on top of bar for a length of 1" from crack, 3/16" diameter pit about 0.05" deep
- 10% of area on bottom of bar for a length of 1" from crack
  corroded area 0.4 in^2

Beam B Top Bar

- 20% of area on top of bar for a length of 1/2" from crack
- None on bottom of bar
  corroded area 0.1 in^2

Beam C Top Bar

- 100% of area on top of bar for a length of 3/4" from crack
- 10% of area on bottom of bar for a length of 3/4" from crack
- 1/8" diameter pit on side about 0.06" deep
  corroded area 1.0 in^2

MCI 2005NS

Beam B Top Bar

- Top of bar, 3 small areas near crack, 1/2" x 1/4", 3/8" x 3/8", 1/8" x 1/4"
- Bottom of bar none
  corroded area 0.3 in^2

Beam C Top Bar

- Top of bar, 1 small area near crack, 1/8" diameter
- Bottom of bar, 10% of area for a length of 3/4" from crack
  corroded area 0.1 in^2

Beam D Top Bar

- Top of bar, 1 pit 1/8" diameter about 0.03" deep, 1 area 1/4" x 1/4" both near crack
- Bottom of bar, 40% of area within 5/8" of crack
  corroded area 0.4 in^2

DCI

Beam A Top Bar

- Top of bar, along longitudinal rib 4" x 1/8", 10% of area within 1/2" of crack
- Bottom of bar, along longitudinal rib 3" x 3/16", 40% of area within 5/8" of crack
  corroded area 1.4 in^2

Beam B Top Bar

- Top of bar, along longitudinal rib 4-1/2" x 1/8", 50% of area within 5/8" of crack
- Bottom of bar, 10% of area within 5/8" of crack
  corroded area 1.0 in^2

Beam C Top Bar

- Top of bar, along longitudinal rib 1" x 1/16", 1 small area 1/4" x 1/8"
- Bottom of bar, 40% of area within 1" of crack
  corroded area 0.6 in^2

Beam D Top Bar

- Top of bar, 6 small pits less than 1/16" diameter, 1 area 1/2" x 3/8" near crack
- Bottom of bar, 80% of area within 5/8" of crack, 2nd area 1" x 1/8"
  corroded area 1.0 in^2

RHEOCRETE 222+

Beam A Top Bar

- Top of bar, 25% of area 2" in length near crack, 15% of area within 2-1/2" in length near beam end
- Bottom of bar, 30% of area over 7" length from near crack to beam end
  numerous pits of 0.02" diameter
  corroded area 1.8 in^2

Beam B Top Bar

- Top of bar, 1/2" x 1/4" area near crack
- Bottom of bar, 40% of area within 1" of crack
  corroded area 0.6 in^2

Beam C Top Bar

- Top of bar, 40% of area within 3/8" of crack
- Bottom of bar, 20% of area within 3/8" of crack, 1 pit 3/16" diameter
  corroded area 0.3 in^2

Beam D Top Bar

- Top of bar, 20% of area within 1-1/4" of crack
- Bottom of bar, 15% of area within 1" of crack
  corroded area 0.5 in^2