AMERICAN ENGINEERING TESTING, INC.

CONSULTANTS
- GEOTECHNICAL
- MATERIALS
- ENVIRONMENTAL

REPORT OF CONCRETE CORROSION INHIBITOR TESTING

PROJECT:

MCI 2005

REPORTED TO:

CORTEC CORPORATION
4119 WHITE BEAR PARKWAY
ST. PAUL MN 55110

ATTN: BORIS MIKSIC

AET JOB NO: 05-00021

DATE: JANUARY 23, 2003

INTRODUCTION

This report presents the results of our testing of Cortec's MCI 2005. We understand the admixture was developed to provide corrosion protection to steel embedded in concrete. Mr. Boris Miksic 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 for compressive 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. Cortec's MCI 2005 provides valuable corrosion protection for steel embedded in concrete. The product delayed the onset of corrosion. When corrosion developed, the product reduced the corrosion current and extent of corrosion.

2. Cortec's MCI 2005 generally doubled the time to the onset of corrosion. The control concrete developed corrosion in the 9th test cycle. MCI 2005 developed corrosion in the 17th test cycle.

3. Cortec's MCI 2005 reduced the corrosion current more than 4 fold once corrosion began. The control concrete corrosion current generally increased over the 47 cycles observed with an average corrosion current of 120 μA. MCI 2005 average corrosion current was 29 μA over the 6½ year testing period.

4. Cortec's MCI 2005 reduced the total corrosion experienced during the test 4 fold. The average total current passed by the control concrete was 13,053 coulombs at the end of cycle 55. MCI 2005 passed only 2735 coulombs after 55 cycles.

5. Cortec's MCI 2005 extended the time to cracking of concrete from rebar corrosion at least two times. The control concrete cracked at cycle 15. The MCI 2005 beams cracked at cycles 34, 49, and 58.

6. The surface corrosion was much less for the MCI 2005 concrete even though the exposure time was 50% longer. The control bars contained corrosion on 75 to 100% of the top surface of the bar with pits 0.062" deep. The MCI 2005 concrete bars contained corrosion on only 25 to 35% of the top surface and pits ranged from 0.010" to 0.050".

TESTING METHODS AND RESULTS

On July 17, 1996, and the subsequent dates, test batches of concrete were made at our laboratory. The batches were 2¼ cubic feet proportioned to the following mix designs:

	MCI 2005	Control
Portland Cement, Type I, pcy	600	600
3/4" Glacial Gravel, pcy	1800	1800
Sand, pcy	1130	1130
MCI 2005, pints/yd (liquid)	1.0	-
Neutralized Vinsol Resin, ocy	3.9	3.9
Water, pcy	300	300
Water/Cement Ratio	0.5	0.5

The plastic concrete was tested for slump, air content, temperature, and unit weight immediately after discharge into a wheelbarrow. The following data was obtained:

	MCI 2005	**Control**
Slump, in	3¼	3¾
Air, %	6.3	5.7
Temp, °F	80	75
Unit Wt., lb/ft^3	143.6	144.0
Set Time		
Initial hr:min	4:55	4:15
Final hr:min	5:50	5:43

	MCI 2005	Control
Compressive Strength, psi		
7 days	4340	3820
28 days	5530	5520
	5200	5590
Average	5370	5560

Three concrete beams were cast from each concrete batch for corrosion testing per ASTM:G109. The beams were 4.5" x 6" x 11". Three steel reinforcing bars were set in the form in a triangular pattern prior to casting. The bars were taped tightly with electroplater's tape to prevent rusting during curing. At one day the beams were stripped and moist cured for 27 days. Upon removal from the moist room, the concrete surface was wire brushed. The four vertical sides were sealed with a concrete epoxy sealer. A plastic dam was positioned on top of the beam. Silicon caulk was used to seal the dam to the beam. A 3% NaCl solution was poured into the dam for two weeks. After two weeks of ponding, samples were dried for two weeks. This cycle was repeated with the corrosion potential and current measured during the middle of the ponding interval. Corrosion is considered to occur when the macrocell current is at least 10 μA.

Periodically the beams were examined for cracks. Fractures parallel to the top bar did develop and the crack width was measured. At the end of the test the top bar was broken from the concrete and examined for corrosion. The maximum depth of metal loss was measured. The data is contained in Tables 1-4.

Report Prepared by:

Tim Suess
Concrete Engineer

Richard D. Stehly, P.E.
MN Reg. No. 12856

ASTM:G109 TEST DATA
TABLE #1 - MCI 2005

Date Cast: 7/17/96

			Corrosion Potential, (Mv)			Corrosion Current, (μA)				Total Corrosion (Coulombs)
Test Cycle	Reading Date	Concrete Age, Days	Beam A Top/Left/Right	Beam B Top/Left/Right	Beam C Top/Left/Right	Beam A	Beam B	Beam C	Average	Average
1	8/30/96	44	183/183/183	179/179/179	196/196/196	0.1	0.1	0.2	0.1	0
2	9/27/96	72	137/137/137	136/136/136	140/140/140	0	0	0	0	0
3	10/25/96	100	104/104/104	122/122/122	129/129/129	0	0	0	0	0
4	11/22/96	128	135/135/155	136/136/136	141/141/141	0.5	0.5	0.5	0.5	0
5	12/20/96	156	118/117/117	117/117/117	121/121/121	0	0	0	0	0
6	1/17/97	184	109/109/109	111/111/111	113/113/113	0	0	0	0	0
7	2/14/97	212	110/110/110	112/112/112	113/113/113	0	0	0	0	0
8	3/14/97	240	100/100/100	105/104/104	106/106/105	0	0	0	0	0
9	4/11/97	268	97/97/97	96/96/96	94/94/96	0	0	0	0	0
10	5/9/97	296	99/99/99	197/197/197	100/100/100	0	0	0	0	0
11	6/6/97	324	90/90/90	205/205/205	90/90/90	0	3	0	1	1
12	7/7/97	352	92/92/92	264/264/264	85/85/85	0	10.8	0	3.6	5
13	8/8/97	384	91/88/88	331/328/328	84/84/84	1.4	28.4	0	9.9	14
14	9/5/97	412	91/88/88	331/328/328	84/89/84	0	8	0	2.7	29
15	10/10/97	447	98/97/95	271/259/258	74/75/75	1.3	6.4	0	2.6	37

			Corrosion Potential, (Mv)			Corrosion Current, (μA)				Total Corrosion (Coulombs)
Test Cycle	Reading Date	Concrete Age, Days	Beam A Top/Left/Right	Beam B Top/Left/Right	Beam C Top/Left/Right	Beam A	Beam B	Beam C	Average	Average
16	11/10/97	478	97/95/95	269/264/264	69/65/69	0.2	10	0	3.4	41
17	12/8/97	506	321/321/318	267/254/261	61/61/64	28.1	16.3	0	14.8	59
18	1/5/98	533	327/233/232	240/238/238	270/270/270	0.7	6.1	0	2.3	80
19	2/2/98	562	331/331/299	226/227/226	107/107/107	38.5	7.3	13.6	19.8	107
20	3/2/98	590	322/304/304	274/274/273	317/316/312	14.9	4.7	12.5	10.7	144
21	3/30/98	618	303/298/289	250/248/249	326/293/299	7.6	11.3	14.2	11.0	170
22	4/27/98	646	269/236/233	290/287/286	294/276/275	8.3	16.3	8.6	11.1	197
23	5/26/98	675	278/226/256	248/239/248	258/257/235	7.2	11.5	20.8	13.2	227
24	6/22/98	702	237/237/237	280/279/279	253/245/251	2.4	3.3	0.8	2.2	245
25	7/20/98	730	237/124/130	303/302/303	264/238/238	27.6	10.0	17.2	18.3	270
26	8/17/90	758	253/252/255	355/310/349	278/141/107	1.9	18.3	7.0	9.1	303
27	9/14/98	786	287/284/284	OL/OL/OL	271/269/270	7.6	30.6	5.4	14.5	332
28	10/16/98	818	272/248/271	OL/OL/OL	288/236/236	13.7	21.0	0.1	11.6	368
29	11/13/98	846	289/288/288	OL/OL/OL	295/243/235	18.7	70.6	17.0	35.4	425
30	12/14/98	877	318/316/317	OL/260/254	OL/201/202	10.3	3.3	61.2	24.9	506
31	1/11/99	905	250/250/250	OL/OL/OL	OL/OL/OL	3.9	42.7	26.0	24.2	565
32	2/8/99	933	OL/OL/OL	OL/OL/OL	OL/OL/OL	37.2	45.6	16.2	33.0	634
33	3/8/99	961	321/321/321	OL/OL/OL	OL/OL/OL	10.7	29.3	13.9	18.0	696

			Corrosion Potential, (Mv)			Corrosion Current, (μA)				Total Corrosion (Coulombs)
Test Cycle	Reading Date	Concrete Age, Days	Beam A Top/Left/Right	Beam B Top/Left/Right	Beam C Top/Left/Right	Beam A	Beam B	Beam C	Average	Average
34	4/6/99	990	361/359/358	OL/251/227	OL/OL/OL	31.4	78.4	3.7	37.8	766
35	5/4/99	1018	OL/OL/OL	OL/OL/OL	OL/OL/OL	15.1	51.0	3.0	23.0	840
36	6/1/99	1046	OL/OL/OL	OL/OL/OL	OL/OL/OL	24.2	0.1	0.3	8.2	878
37	6/28/99	1074	OL/OL/OL	OL/OL/OL	OL/OL/OL	31.8	25.9	21.6	26.4	920
38	7/26/99	1102	OL/OL/OL	OL/OL/OL	OL/OL/OL	34.0	47.0	34.6	38.5	999
39	8/23/99	1130	OL/OL/OL	OL/OL/OL	OL/OL/OL	67.5	25.2	30.1	40.9	1095
40	9/20/99	1158	OL/OL/OL	OL/OL/OL	OL/OL/OL	48.0	50.4	23.6	40.7	1194
41	10/18/99	1186	OL/OL/OL	OL/OL/334	OL/OL/OL	41.8	65.4	20.2	42.5	1295
42	11/15/99	1214	OL/OL/OL	OL/OL/OL	OL/OL/OL	49.4	61.6	32.7	47.9	1404
43	12/15/99	1244	OL/OL/OL	OL/OL/OL	OL/140/140	93.4	107.6	90.5	97.2	1592
44	1/10/00	1270	OL/OL/OL	OL/OL/OL	OL/OL/OL	56.0	53.2	16.8	42.0	1748
45	2/9/00	1300	OL/OL/OL	OL/OL/OL	OL/126/126	72.6	40.1	75.8	62.8	1867
46	3/6/00	1326	OL/377/OL	OL/OL/OL	OL/398/OL	73.4	64.3	23.3	53.7	1998
47	4/3/00	1354	OL/190/190	OL/OL/OL	OL/400/400	109.2	25.7	17.4	50.8	2124
48	5/1/00	1382	OL/157/156	OL/201/201	394/OL/394	20.0	11.1	19.5	16.9	2206
49	6/2/00	1414	OL/OL/OL	OL/OL/OL	390/389/OL	41.0	40.4	17.1	32.8	2275
50	6/26/00	1438	OL/OL/OL	OL/OL/OL	403/401/401	50.4	36.5	19.0	35.3	2346
51	7/24/00	1466	OL/OL/OL	OL/OL/215	OL/OL/OL	48.6	47.0	30.0	41.9	2439
52	8/21/00	1494	OL/OL/OL	OL/OL/OL	OL/OL/OL	52.4	35.6	10.7	32.9	2529

			Corrosion Potential, (Mv)			Corrosion Current, (μA)				Total Corrosion (Coulombs)
Test Cycle	Reading Date	Concrete Age, Days	Beam A Top/Left/Right	Beam B Top/Left/Right	Beam C Top/Left/Right	Beam A	Beam B	Beam C	Average	Average
53	9/18/00	1522	OL/OL/371	OL/OL/315	OL/OL/OL	29.2	26.8	12.6	22.9	2597
54	10/19/00	1553	OL/OL/OL	OL/150/212	OL/OL/OL	12.9	27.2	32.1	24.1	2660
55	11/20/00	1585	OL/OL/OL	OL/OL/OL	OL/OL/OL	26.9	27.5	36.0	30.1	2735
56	12/18/00	1613	OL/OL/OL	OL/OL/OL	OL/OL/OL	27.8	27.0	23.0	25.9	2803
57	1/15/00	1641	OL/OL/OL	OL/OL/OL	OL/OL/OL	35.0	50.3	76.0	53.8	2899
58	2/5/01	1662	OL/264/271	OL/OL/OL	OL/284/285	46.7	28.3	66.2	47.1	2991
59	3/6/01	1691	OL/OL/146	OL/135/137	OL/OL/OL	32.6	40.6	39.6	37.6	3097
60	4/2/01	1718	OL/OL/OL	OL/OL/OL	OL/OL/OL	18.2	82.3	88.7	63.1	3214
61	5/2/01	1748	OL/155/155	OL/OL/OL	OL/OL/OL	37.9	41.0	60.5	46.5	3356
62	5/28/01	1774	OL/OL/OL	OL/148/148	OL/117/120	37.7	71.0	22.0	43.6	3455
63	6/25/01	1802	OL/OL/OL	OL/OL/OL	OL/OL/OL	45.0	73.5	28.6	49.0	3567
64	7/23/01	1830	OL/OL/OL	OL/OL/OL	OL/OL/OL	50.5	76.2	35.9	54.2	3692
65	8/27/01	1865	OL/OL/OL	OL/OL/OL	OL/OL/OL	94.0	84.0	52.0	76.7	3890
66	9/24/01	1893	OL/OL/OL	OL/263/OL	OL/OL/OL	42.0	58.0	49.0	49.7	4043
67	10/16/01	1915	OL/331/330	OL/OL/122	OL/OL/OL	13.9	0.0	16.5	10.1	4100
68	11/19/01	1949	OL/125/123	OL/363/129	OL/233/291	71.0	50.0	93.0	71.3	4120
69	12/12/01	1972	OL/OL/OL	OL/121/121	OL/99/363	22.0	14.4	13.4	16.6	4207
70	1/17/02	2008	OL/OL/OL	OL/109/311	OL/OL/OL	18.4	14.5	11.0	14.6	4256
71	2/14/02	2036	OL/OL/OL	OL/OL/OL	OL/334/339	37.0	87.0	64.0	62.7	4350

			Corrosion Potential, (Mv)			Corrosion Current, (μA)				Total Corrosion (Coulombs)
Test Cycle	**Reading Date**	**Concrete Age, Days**	**Beam A Top/Left/Right**	**Beam B Top/Left/Right**	**Beam C Top/Left/Right**	**Beam A**	**Beam B**	**Beam C**	**Average**	**Average**
72	3/15/02	2065	OL/OL/OL	OL/OL/OL	OL/OL/OL	3.6	1.1	0.0	1.6	4429
73	4/10/02	2091	OL/OL/OL	OL/OL/OL	OL/OL/OL	36.0	116.0	3.5	51.8	4488
74	5/13/02	2124	277/277/304	OL/264/306	391/383/396	26.0	15.3	10.2	17.2	4586
75	6/4/02	2146	OL/139/125	OL/OL/OL	OL/OL/OL	18.0	17.5	82.0	39.2	4640
76	7/1/02	2173	OL/OL/OL	OL/OL/OL	OL/OL/OL	19.5	16.0	60.0	31.8	4723
77	7/29/02	2201	OL/136/140	OL/OL/OL	OL/OL/OL	40.0	19.5	105.0	54.8	4828
78	8/26/02	2229	OL/OL/386	OL/OL/OL	OL/OL/OL	5.8	20.6	119.2	48.5	4953
79	10/4/02	2268	OL/OL/OL	OL/OL/OL	OL/OL/360	46.1	30.1	119.0	65.0	5144
80	11/11/02	2306	OL/OL/OL	OL/OL/OL	OL/OL/395	45.3	26.7	104.0	58.7	5307
81	11/25/02	2320	OL/OL/OL	OL/OL/OL	OL/OL/OL	22.2	24.3	144.0	63.5	5381
82	12/20/02	2345	OL/OL/OL	OL/OL/OL	OL/OL/OL	30.2	18.2	129.0	59.1	5512

All test values are negative.

ASTM:G109 TEST DATA
TABLE #2 - CONTROL CONCRETE

Date Cast: 7/24/96

			Corrosion Potential, (mV)			Corrosion Current, (μA)				Total Corrosion (Coulombs)
Test Cycle	Reading Date	Concrete Age, Days	Beam A Top/Left/Right	Beam B Top/Left/Right	Beam C Top/Left/Right	Beam A	Beam B	Beam C	Average	Average
1	8/30/96	37	200/201/201	174/174/174	160/161/161	0.5	0.3	0.1	0.3	0
2	9/27/96	65	133/134/134	119/119/119	121/121/121	0	0	0.1	0	0
3	10/25/96	93	116/116/115	104/104/104	104/104/104	0	0	0	0	0
4	11/22/96	121	132/132/132	121/121/121	123/123/123	0.5	0.5	0.5	0.5	0
5	12/20/96	149	194/194/194	104/104/104	108/108/108	0	0	0	0	0
6	1/17/97	177	106/106/106	96/96/96	97/97/97	0	0	0	0	0
7	2/14/97	205	107/107/107	98/98/98	98/98/98	0	0	0	0	0
8	3/14/97	233	209/209/209	203/203/203	232/232/232	0	0	0	0	0
9	4/11/97	261	348/344/344	243/242/241	317/315/314	43	14	31	30	36
10	5/9/97	289	378/373/373	269/267/267	346/341/341	48	23	37	36	115
11	6/6/97	317	OL/OL/OL	309/309/309	391/391/391	58	56	56	57	227
12	7/7/97	345	-	285/274/272	403/401/401	-	53	51	52	326
13	8/8/97	377	-	310/308/243	OL/333/OL	-	52	53	52	452
14	9/5/97	405	-	316/309/309	OL/OL/OL	-	54	56	55	582
15	10/10/97	440	-	328/325/325	OL/OL/OL	-	19	54	37	682
16	11/10/97	471	-	350/350/350	OL/OL/OL	-	31	79	55	752

			Corrosion Potential, (mV)			Corrosion Current, (μA)				Total Corrosion (Coulombs)
Test Cycle	**Reading Date**	**Concrete Age, Days**	**Beam A Top/Left/Right**	**Beam B Top/Left/Right**	**Beam C Top/Left/Right**	**Beam A**	**Beam B**	**Beam C**	**Average**	**Average**
17	12/8/97	499	-	367/364/364	OL/OL/OL	-	29	80	55	850
18	1/5/98	527	-	400/396/396	OL/OL/OL	-	34	101	68	996
19	2/2/98	555	-	OL/OL/OL	OL/OL/OL	-	34	93	64	1155
20	3/2/98	583	-	OL/OL/OL	OL/OL/OL	-	46	91	69	1315
21	3/30/98	611	-	OL/OL/OL	OL/OL/OL	-	32	89	61	1471
22	4/27/98	639	-	OL/OL/OL	OL/OL/OL	-	69	96	83	1651
23	5/26/98	668	-	OL/OL/OL	OL/OL/OL	-	45	111	78	1850
24	6/22/98	695	-	OL/OL/OL	OL/OL/OL	-	114	114	114	2082
25	7/20/98	723	-	OL/OL/OL	OL/OL/OL	-	111	61	86	2324
26	8/17/98	751	-	OL/OL/OL	OL/OL/OL	-	123	84	103	2553
27	9/14/98	779	-	OL/OL/OL	OL/OL/OL	-	154	103	129	2834
28	10/16/98	811	-	OL/OL/OL	OL/OL/OL	-	103	122	113	3169
29	11/13/98	839	-	OL/OL/OL	OL/OL/OL	-	148	124	136	3470
30	12/14/98	870	-	OL/OL/OL	OL/OL/OL	-	169	126	148	3850
31	1/11/99	898	-	OL/OL/OL	OL/OL/OL	-	119	159	139	4197
32	2/8/99	926	-	OL/OL/OL	OL/OL/OL	-	205	138	172	4573
33	3/8/99	954	-	OL/OL/OL	OL/OL/OL	-	212	132	172	4989
34	4/6/99	983	-	OL/OL/OL	OL/OL/OL	-	186	121	153	5396

			Corrosion Potential, (mV)			Corrosion Current, (μA)				Total Corrosion (Coulombs)
Test Cycle	Reading Date	Concrete Age, Days	Beam A Top/Left/Right	Beam B Top/Left/Right	Beam C Top/Left/Right	Beam A	Beam B	Beam C	Average	Average
35	5/4/99	1011	-	OL/OL/OL	OL/OL/OL	-	200	150	175	5793
36	6/1/99	1039	-	OL/OL/OL	OL/OL/OL	-	313	119	216	6266
37	6/28/99	1067	-	OL/OL/OL	OL/OL/OL	-	357	140	214	6786
38	7/26/99	1095	-	OL/OL/OL	OL/OL/OL	-	197	103	150	7226
39	8/23/99	1123	-	OL/OL/OL	OL/OL/OL	-	172	135	154	7594
40	9/20/99	1151	-	OL/OL/OL	OL/OL/OL	-	186	155	171	7988
41	10/18/99	1179	-	OL/OL/OL	OL/OL/OL	-	195	163	179	8411
42	11/15/99	1207	-	OL/OL/OL	OL/OL/OL	-	164	93	129	8784
43	12/15/99	1237	-	OL/OL/OL	OL/OL/OL	-	226	189	208	9221
44	1/10/00	1263	-	OL/OL/OL	OL/OL/OL	-	279	236	258	9744
45	2/9/00	1293	-	OL/OL/OL	OL/OL/OL	-	219	191	205	10,344
46	3/6/00	1319	-	-	OL/OL/OL	-	-	110	110	10,698
47	4/3/00	1347	-	-	OL/OL/OL	-	-	102	102	10,954
48	5/1/00	1375	-	-	OL/OL/OL	-	-	129.1	129.1	11,234
49	6/2/00	1407	-	-	OL/OL/OL	-	-	60.2	60.2	11,496
50	6/26/00	1431	-	-	OL/OL/OL	-	-	46.0	46.0	11,606
51	7/24/00	1459	-	-	OL/OL/OL	-	-	91.8	91.8	11,773
52	8/21/00	1487	-	-	OL/OL/OL	-	-	142.0	142.0	12,056
53	9/18/00	1515	-	-	OL/OL/OL	-	-	136.7	136.7	12,393

			Corrosion Potential, (mV)			Corrosion Current, (μA)				Total Corrosion (Coulombs)
Test Cycle	**Reading Date**	**Concrete Age, Days**	**Beam A Top/Left/Right**	**Beam B Top/Left/Right**	**Beam C Top/Left/Right**	**Beam A**	**Beam B**	**Beam C**	**Average**	**Average**
54	10/19/00	1546	-	-	OL/OL/OL	-	-	129.0	129.0	12,749
55	11/20/00	1588	-	-	OL/OL/OL	-	-	90.0	90.0	13,053
56	Test Stopped									

OL - Outside limit of test equipment
All test values are negative

CRACK WIDTH DATA
TABLE #3

	MCI 2005			Control		
Cycle	Beam A	Beam B	Beam C	Beam A	Beam B	Beam C
15	-	-	-	Test Stopped	-	0.001
16	-	-	-		-	0.005
18	-	-	-		-	0.010
20	-	-	-		0.001	-
21	-	-	-		0.005	0.015
29	-	-	-		0.010	0.020
34	-	0.003	-		0.015	0.025
45	-	0.004	-		0.020	0.025
49	0.004	0.004	-		Test Stopped	0.025
55	-	-	-			0.060
58	0.004	0.004	0.002			Test Stopped
65	0.004	0.007	0.006			
78	0.005	0.020	0.010			
82	0.005	0.025	0.010			

SURFACE CORROSION COMPARISON
TABLE #4

MCI 2005

Sample	Corrosion	Cycle
Beam A Bottom	No Corrosion	82
Beam A Top	25% of surface, pits to 0.010"	82
Beam B Bottom	No Corrosion	82
Beam B Top	35% of surface, pits to 0.040"	82
Beam C Bottom	No Corrosion	82
Beam C Top	30% of surface, pits to 0.050"	82

Control

Beam B Bottom	No significant corrosion	45
Beam B Top	75% of surface, pits to 0.062" (13% of diameter)	45
Beam C Bottom	Slight corrosion to 0.020" depth	55
Beam C Top	100% of surface, 60% severe with 0.091" metal loss (20% of diameter)	55