AMERICAN ENGINEERING TESTING, INC.

CONSULTANTS
· GEOTECHNICAL
· MATERIALS
· ENVIRONMENTAL

REPORT OF CONCRETE CORROSION INHIBITOR TESTING

PROJECT:

MCI 2006

REPORTED TO:

CORTEC CORPORATION
4119 WHITE BEAR PARKWAY
ST. PAUL MN 55110

ATTN: BORIS MIKSIC

AET JOB NO: 05-00021

DATE: JANUARY 22, 2003

INTRODUCTION

This report presents the results of our testing of Cortec's MCI 2006. 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 2006 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 2006 tripled the time to the onset of corrosion. The control concrete developed corrosion in the 9th test cycle. MCI 2006 developed corrosion in the 28th test cycle.

3. Cortec's MCI 2006 reduced the corrosion current more than 12 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 2006 average corrosion current was 10 μA over the 6½ year testing period.

4. Cortec's MCI 2006 reduced the total corrosion experienced during the test 16 fold. The average total current passed by the control concrete was 13,053 coulombs at the end of cycle 55. MCI 2006 passed only 793 coulombs after 55 cycles.

5. Cortec's MCI 2006 extended the time to cracking of concrete from rebar corrosion at more than four times. The control concrete cracked at cycle 15. One beam containing MCI 2006 did not crack during the test. The other two cracked at cycle 58 and 65.

6. The surface corrosion was much less for the MCI 2006 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 2006 concrete contained no corrosion on one bar. Surface corrosion on the other bars ranged from 15 to 30% with pits of 0.040 and 0.060".

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 2006	Control
Portland Cement, Type I, pcy	600	600
3/4" Glacial Gravel, pcy	1800	1800
Sand, pcy	1130	1130
MCI 2006, pcy (powder)	0.5	-
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 2006	Control
Slump, in	3¼	3¾
Air, %	5.8	5.7
Temp, °F	78	75
Unit Wt., lb/ft^3	144.5	144.0
Set Time		
Initial hr:min	4:25	4:15
Final hr:min	5:20	5:43
Compressive Strength, psi		
7 days	3710	3820
28 days	5960	5520
	5850	5590
Average	5900	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:

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ASTM:G109 TEST DATA
TABLE #1 - MCI 2006

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	217/216/216	185/185/185	184/184/184	1.0	0.7	0.1	0.6	0
2	9/27/96	72	145/145/145	134/134/134	120/122/122	0.2	0.0	0.0	0.1	0
3	10/25/96	100	119/119/119	113/113/114	112/113/113	0	0	0.1	0	0
4	11/22/96	128	135/135/155	122/122/122	134/134/134	0.5	0.5	0.5	0.5	0
5	12/20/96	156	115/115/115	113/113/113	118/118/118	0	0	0	0	0
6	1/17/97	184	109/109/109	103/103/103	108/108/108	0	0	0	0	0
7	2/14/97	212	109/109/109	103/103/103	108/108/108	0	0	0	0	0
8	3/14/97	240	101/101/101	99/99/99	102/101/101	0	0	0	0	0
9	4/11/97	268	88/88/88	84/84/84	101/101/101	0	0	0	0	0
10	5/9/97	296	92/92/92	94/94/94	105/105/105	0	0	0	0	0
11	6/6/97	324	81/81/81	80/80/80	98/98/98	0	0	0	0	0
12	7/7/97	352	87/87/87	80/80/80	99/99/99	0	0	0	0	0
13	8/8/97	384	88/88/88	76/76/76	203/202/95	0	.4	.4	.3	0
14	9/5/97	412	88/88/88	76/76/76	95/94/94	0	0	0	0	0
15	10/10/97	447	87/87/88	275/274/275	99/98/98	0	15.5	0	5.2	8

			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	84/83/83	278/285/275	97/97/97	0	14.5	0	4.8	21
17	12/8/97	506	81/81/81	257/257/257	94/94/94	7.1	6.4	0	4.5	32
18	1/5/98	533	74/76/76	220/221/221	94/94/92	0.2	4.7	0	1.6	39
19	2/2/98	562	250/220/215	199/199/199	91/91/91	9.0	1.6	0.9	3.8	46
20	3/2/98	590	273/272/274	203/197/195	93/94/93	43.3	2.5	0.3	15.4	69
21	3/30/98	618	281/287/286	193/193/193	91/91/91	12.9	1.8	0	4.9	94
22	4/27/98	646	286/242/265	211/211/210	93/94/93	17.8	3.0	0.2	7.0	108
23	5/26/98	675	249/93/93	169/172/170	91/91/91	44.7	2.5	0	15.7	136
24	6/22/98	702	203/142/147	157/157/157	94/93/93	26.6	0.7	0	9.1	166
25	7/20/98	730	201/201/199	241/141/141	92/85/89	9.5	20.3	0	10.0	189
26	8/17/98	758	172/172/171	191/190/190	177/178/170	1.8	1.7	0	1.2	203
27	9/14/98	786	173/171/176	196/193/193	220/167/223	3.6	3.3	23.7	10.2	217
28	10/16/98	818	228/92/92	220/220/220	253/249/247	37.8	4.3	10.8	17.6	255
29	11/13/98	846	258/258/258	243/242/243	273/92/92	66.0	4.5	0	23.5	305
30	12/14/98	877	293/293/234	266/233/231	266/99/99	7.9	6.3	0	4.7	343
31	1/11/99	905	251/232/229	251/250/250	225/94/94	2.7	4.2	0	2.3	351
32	2/8/99	933	247/246/246	261/261/261	261/94/94	4.5	5.4	0	3.3	358
33	3/8/99	961	240/237/232	243/243/242	225/89/89	3.5	3.0	0	2.2	365

			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	247/239/233	229/227/226	293/165/160	4.2	3.3	0	3.8	373
35	5/4/99	1018	234/235/235	220/221/221	246/101/101	3.5	3.8	0	3.7	382
36	6/1/99	1046	234/236/231	212/124/212	193/85/85	3.7	3.8	0	3.8	391
37	6/28/99	1074	247/247/238	274/261/259	184/83/83	13.5	5.9	0.1	6.5	403
38	7/26/99	1102	263/108/107	270/188/107	177/79/79	33.4	5.3	0.0	12.9	426
39	8/23/99	1130	259/259/273	362/280/301	191/96/96	5.5	6.2	1.0	4.2	447
40	9/20/99	1158	292/95/93	295/295/293	136/51/49	36.2	6.9	0.0	14.4	490
41	10/18/99	1186	295/275/294	305/301/301	133/54/49	6.2	21.8	0.4	9.5	519
42	11/15/99	1214	285/285/278	325/324/324	109/53/46	3.9	6.6	0.0	3.5	535
43	12/15/99	1244	277/276/251	OL/OL/OL	192/52/49	11.5	12.2	0.0	7.9	550
44	1/10/00	1270	262/236/310	OL/OL/OL	221/221/221	15.0	13.3	10.5	12.9	573
45	2/9/00	1300	268/268/268	OL/OL/OL	243/243/221	4.4	16.1	4.8	8.4	601
46	3/6/00	1326	280/248/246	OL/OL/OL	234/234/214	11.9	20.0	6.1	12.7	625
47	4/3/00	1354	OL/296/291	OL/OL/OL	259/86/96	4.1	6.0	8.2	6.1	648
48	5/1/00	1382	294/115/114	OL/OL/OL	224/217/221	1.5	28.0	11.6	13.7	672
49	6/2/00	1414	OL/283/277	OL/OL/OL	201/194/212	11.9	18.6	2.3	11.1	703
50	6/26/00	1438	278/117/109	OL/OL/OL	198/198/197	4.2	12.0	3.0	6.4	721
51	7/24/00	1466	273/273/273	OL/OL/OL	187/187/187	2.8	0.0	0.6	1.1	730
52	8/21/00	1494	279/279/279	OL/147/147	192/90/115	2.4	4.1	1.4	2.6	734

			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/304/304	OL/OL/OL	214/214/107	4.6	20.2	5.4	10.1	749
54	10/19/00	1553	334/OL/323	OL/OL/369	191/176/123	3.4	17.1	2.3	7.6	773
55	11/20/00	1585	390/390/390	OL/119/119	234/75/168	8.0	12.6	0.2	6.9	793
56	12/18/00	1613	OL/OL/489	OL/127/127	206/76/102	5.0	18.4	0.0	7.8	811
57	1/15/01	1641	OL/OL/OL	OL/340/334	173/164/86	11.0	40.0	3.3	18.1	842
58	2/5/01	1662	OL/OL/OL	OL/OL/OL	166/157/83	10.9	12.5	2.5	8.6	866
59	3/6/01	1691	OL/OL/OL	OL/OL/OL	181/181/74	13.6	20.6	7.1	13.8	900
60	4/2/01	1718	OL/OL/OL	OL/122/122	228/70/137	17.1	22.6	0.0	13.2	931
61	5/2/01	1748	OL/OL/OL	OL/378/375	222/64/62	9.8	5.1	0.0	5.0	955
62	5/28/01	1774	OL/160/147	OL/124/124	227/58/51	35.0	17.7	6.7	19.8	982
63	6/25/01	1802	OL/152/145	OL/110/111	230/151/151	25.4	10.5	6.0	14.0	1023
64	7/23/01	1830	OL/OL/OL	OL/109/117	230/225/225	16.4	8.1	5.2	9.9	1052
65	8/27/01	1865	OL/OL/OL	OL/109/118	231/231/231	10.3	5.9	3.6	6.6	1077
66	9/24/01	1893	OO/175/OL	356/OL/OL	181/181/157	14.7	3.1	1.7	6.5	1093
67	10/16/01	1915	OL/137/137	OL/OL/OL	189/190/170	0.0	3.0	1.6	1.5	1101
68	11/19/01	1949	OL/172/172	OL/OL/OL	166/164/163	4.5	4.4	0.2	3.0	1108
69	12/12/01	1972	OL/165/173	OL/336/OL	145/145/145	8.2	27.8	21.0	19.0	1130
70	1/17/02	2008	OL/148/189	OL/374/OL	160/160/155	1.8	48.0	2.1	17.3	1186
71	2/14/02	2036	OL/149/149	OL/OL/OL	150/151/86	23.2	40.0	0.0	21.1	1237

			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/134/135	OL/OL/130	178/177/175	0.0	0.0	1.9	0.6	1264
73	4/10/02	2091	OL/341/341	OL/337/355	147/147/147	4.1	6.2	1.5	3.9	1269
74	5/13/02	2124	OL/OL/OL	261/261/261	105/106/106	31.2	3.0	1.1	11.8	1291
75	6/4/02	2146	OL/OL/OL	OL/OL/310	143/132/130	34.3	9.0	1.7	15.0	1316
76	7/1/02	2173	OL/OL/OL	OL/220/180	220/170/160	50.3	90.2	4.0	48.2	1390
77	7/29/02	2201	OL/OL/OL	OL/OL/OL	190/197/197	25.0	11.6	1.3	12.6	1464
78	8/26/02	2229	OL/OL/OL	OL/OL/OL	190/190/184	1.3	140.2	1.5	47.7	1537
79	10/4/02	2268	OL/377/386	OL/OL/OL	180/181/165	24.3	0.3	0.1	8.2	1629
80	11/11/02	2306	OL/OL/OL	OL/OL/OL	180/179/179	22.1	17.1	0.1	13.1	1664
81	11/25/02	2320	OL/382/382	OL/OL/OL	214/214/214	27.1	6.8	3.0	12.3	1679
82	12/20/02	2345	OL/348/402	OL/129/133	222/219/219	16.6	10.1	1.3	9.3	1702

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 2006			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					0.015	0.025
45					0.020	0.025
49					Test Stopped	0.025
55						0.060
58	-	0.002	-			Test Stopped
65	0.003	0.005	-			
78	0.005	0.008	-			
82	0.010	0.008	-			

SURFACE CORROSION COMPARISON
TABLE #4

MCI 2006

Sample	Corrosion	Cycle
Beam A Bottom	No Corrosion	82
Beam A Top	15% of surface, pit to 0.040"	82
Beam B Bottom	No Corrosion	82
Beam B Top	30% of surface, pit to 0.060"	82
Beam C Bottom	No Corrosion	82
Beam C Top	No corrosion, no pits	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