



May 3, 2013

Mr. Steve Gillen
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**Evaluation of B-Quality Aggregates for Freeze-Thaw Durability
CTLGroup Project No. 057153**

Dear Mr. Gillen:

As requested, CTLGroup performed freeze-thaw (F-T), compressive strength, and organic testing on 5 samples of B-quality aggregate, submitted on December 19, 2012. The aggregate samples were used to fabricate concrete mixtures in the laboratory. As part of the effort to increase the sustainability of the IL Tollway I-90 expansion project, this work was initiated to investigate the possibility of incorporating B-Quality aggregate (B-quality crushed stone, gravel, and FRAP) into the lower lift portion of the Black Rock pavement without sacrificing durability.

Testing preparations commenced upon receipt of the samples in accordance with AASHTO T 161, AASHTO T 22, and ASTM C40. Concrete mixtures were proportioned as shown in Table 1 and fabricated in the CTLGroup lab on February 20 and 22, 2013, after receiving aggregate property test results from STATE. Samples were stored in saturated limewater prior to F-T testing. The results are attached.

Results indicate that the concrete mixtures tested, consisting of 5 different types of B-quality aggregate, are resistant to F-T damage, with the exception of Bluff City Bartlett 016CA07, which did not pass F-T testing. From the visual appearance of the prism samples after undergoing F-T tests, the failure appears to be caused by the aggregate, which generated a crack in the prism about one-quarter to one-third of the length from the end, as shown in Figure 1. This type of behavior results in a failed test result due to the inability to collect further measurements. The hardened cement paste in each sample appeared to be of good quality and did not exhibit scaling. FRAP aggregate samples were tested for organic impurities, and the results are shown in Table 2. No significant issues were detected with FRAP aggregates in the concretes tested. FRAP samples exhibited slightly lower strength (as expected) and no issues were observed with air entrainment.

As always, we appreciate the opportunity to continue working with you on this project. Let us know if we can be of any further assistance.

Sincerely,

A handwritten signature in black ink, appearing to read "Matthew D'Ambrosia".

Matthew D'Ambrosia, PhD, PE (Illinois)
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Attachment(s): ASTM C666 Freeze-thaw test reports (5 pages)

Table 1. Concrete Mixture Proportions

ASTM C192 Mixture Summary						
		Mix ID: Bluff City	Vulcan	Allied	Arrow	K-Five
		Source: 016CA07 Bartlett	042CM11 McCook	017CM1204 Huntley	017CM1204 Mt Prospect	017CM1204 Lemont
Date Fabricated:		2/20/2013	2/20/2013	2/22/2013	2/22/2013	2/22/2013
Material		lb/yd ³ (SSD)				
Cement	<i>St. Marys, Charlevoix Type I/II</i>	370	370	370	370	370
Fly Ash	<i>MRT, Labadie, MO Class C</i>	85	85	85	85	85
Slag	<i>Lafarge NewCem Gr. 100</i>	115	115	115	115	115
Coarse Aggregate	<i>Source Indicated in Mix ID above</i>	1880	1916	647	637	640
Coarse Aggregate	<i>020CM11, Meyer, Algonquin</i>	0	0	1240	1240	1240
Fine Aggregate	<i>027FM02, Meyer, Algonquin</i>	1190	1190	1190	1190	1190
Water	<i>Potable</i>	238	238	228	228	228
Total Cementitious Content		570	570	570	570	570
w/cm		0.42	0.42	0.40	0.40	0.40
Paste Content Volume (including air), %		31.9%	31.9%	31.4%	31.4%	31.4%
		fl. oz./cwt (100 lbs of cementitious material)				
Air Entraining Agent	<i>Daravair 1400</i>	1.41	1.02	1.02	1.02	1.02
Water Reducer	<i>WRDA-82</i>	4.00	4.00	4.00	4.00	4.00
Target Fresh Properties						
Target Slump		2 - 4 inches				
Design Air Content		5 - 8%				
Measured Fresh Properties						
Slump, in.	ASTM C143	0.75	2.25	1.5	2.5	2.25
Air Content, %	ASTM C231	6.5%	8.0%	7.0%	8.5%	8.0%
Temperature, °F	ASTM C1064	72.8	71.2	72.3	73.7	73.8
Fresh Density, lb/ft³	ASTM C138	145.0	143.6	144.3	141.3	142.8
Age, days		Measured Compressive Strength, psi. - ASTM C39				
7		4,417	4,337	3,773	3,253	3,510
14		5,413	5,503	4,647	4,083	4,487
28		6,213	6,277	4,937	4,337	4,980
Test	Test Method	Test Result				
Total Air, %	ASTM C457	7.18%	9.18%	5.85%	8.29%	6.95%
Spacing Factor, in.	ASTM C457	0.0044	0.0028	0.0037	0.0033	0.0037
Specific Surface, 1/in.	ASTM C457	947.6	1029.1	1079.2	1085.3	1023.6



Figure 1. Concrete prism F-T specimens after cracking failure
 (Bluff City Bartlett Coarse Aggregate)

Table 2. Results of Organic Impurity Testing of FRAP Aggregate

REPORT of ANALYSIS			
ASTM C40, Organic Impurities in Fine Aggregates for Concrete			
Client Sample Identification	K-5 Frap	Arrow Frap	PCI Frap (Allied)
CTLGroup Sample Identification	3293901	3293902	3293903
Sample Source	0	0	0
Sample Reduction Method	017CM1204 Lemont	017CM1204 Mt Prospect	017CM1204 Huntley
Procedure	Glass Color Standard	Glass Color Standard	Glass Color Standard
Results - initial (Organic Plate No.)	1	1	1
Results - after 3 days (Organic Plate N)	2	2	2

Interpretation:
 Per ASTM C40, the fine aggregates under test is not considered to possibly contain injurious organic impurities.

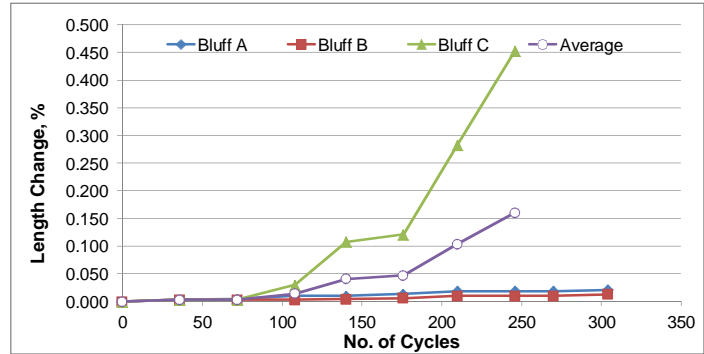
After three days of immersion, samples were re-evaluated for color. This is not part of the standard method, but was used to determine if the asphalt binder content in solution was changing with time. Some change was detected.

ASTM C666, Standard Test Method for Resistance of Concrete to Rapid Freezing and Thawing Procedure A, Freezing and Thawing in Water

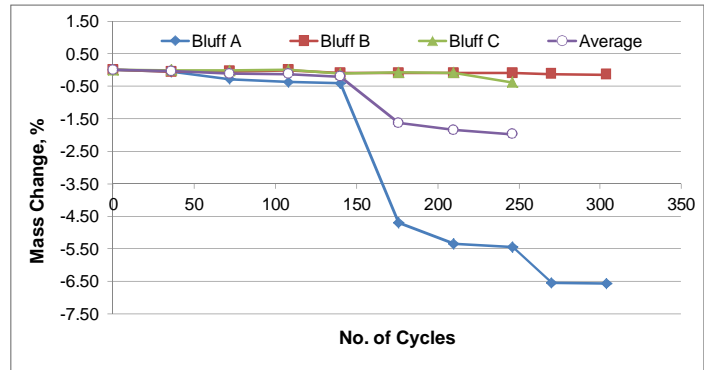
Summary of Test Results

Average length change at 246 cycles, %: **0.161**
 Average mass change at 246 cycles, %: **-1.97**
 Average RDM at 246 cycles, %: **64**

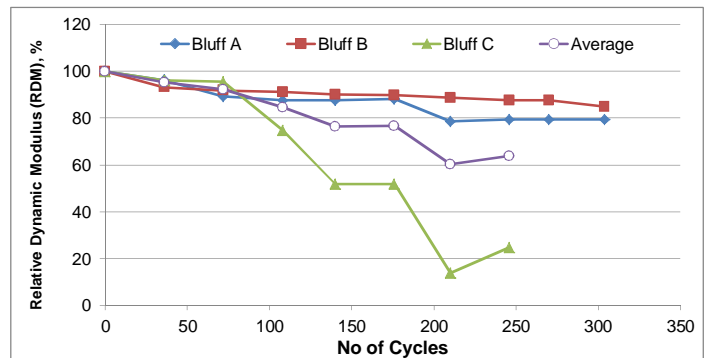
Freeze-Thaw Cycles	Length Change, %			
	Bluff A	Bluff B	Bluff C	Average
0	0.000	0.000	0.000	0.000
36	0.003	0.003	0.003	0.003
72	0.004	0.003	0.003	0.003
108	0.010	0.003	0.030	0.014
140	0.010	0.004	0.108	0.041
176	0.014	0.006	0.121	0.047
210	0.019	0.010	0.283	0.104
246	0.019	0.010	0.453	0.161
270	0.019	0.010	See note 5	
304	0.021	0.013		



Freeze-Thaw Cycles	Mass Change, %			
	Bluff A	Bluff B	Bluff C	Average
Initial Mass	3972.8 g	3952.7 g	3959 g	--
0	0.00	0.00	0.00	0.00
36	-0.05	-0.05	-0.01	-0.03
72	-0.28	-0.05	-0.01	-0.11
108	-0.37	-0.01	0.00	-0.12
140	-0.40	-0.10	-0.11	-0.20
176	-4.69	-0.10	-0.08	-1.63
210	-5.34	-0.10	-0.09	-1.84
246	-5.44	-0.10	-0.38	-1.97
270	-6.54	-0.12	See note 5	
304	-6.56	-0.14		



Freeze-Thaw Cycles	Relative Dynamic Modulus, %			
	Bluff A	Bluff B	Bluff C	Average
0	100	100	100	100
36	96	93	96	95
72	89	92	96	92
108	88	91	75	85
140	88	90	52	76
176	88	90	52	77
210	79	89	14	60
246	79	88	25	64
270	79	88	See note 5	
304	79	85		



Notes:

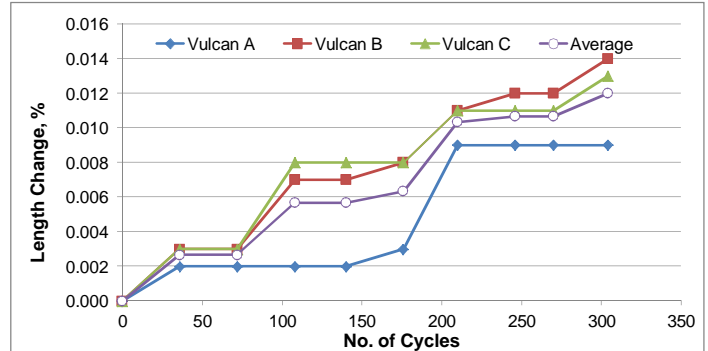
1. Test specimens fabricated at CTLGroup on February 20, 2013.
2. Test specimens measure approximately 3x3x11-in. at 0 cycles.
3. A negative mass change indicates mass loss; a positive mass change indicates a mass gain.
4. The relative dynamic modulus was determined by the transverse frequency method of ASTM C215, Section 9.
5. Specimen Bluff A broke in half after 246 cycles and could no longer be tested.
6. This report may not be reproduced except in its entirety.

ASTM C666, Standard Test Method for Resistance of Concrete to Rapid Freezing and Thawing Procedure A, Freezing and Thawing in Water

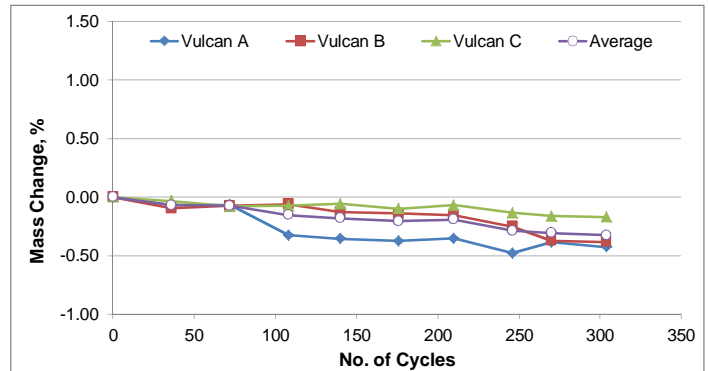
Summary of Test Results

Average length change at 304 cycles, %: **0.012**
 Average mass change at 304 cycles, %: **-0.33**
 Average RDM at 304 cycles, %: **87**

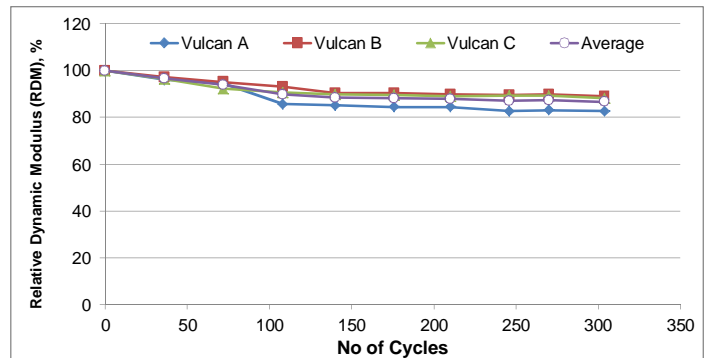
Freeze-Thaw Cycles	Length Change, %			
	Vulcan A	Vulcan B	Vulcan C	Average
0	0.000	0.000	0.000	0.000
36	0.002	0.003	0.003	0.003
72	0.002	0.003	0.003	0.003
108	0.002	0.007	0.008	0.006
140	0.002	0.007	0.008	0.006
176	0.003	0.008	0.008	0.006
210	0.009	0.011	0.011	0.010
246	0.009	0.012	0.011	0.011
270	0.009	0.012	0.011	0.011
304	0.009	0.014	0.013	0.012



Freeze-Thaw Cycles	Mass Change, %			
	Vulcan A	Vulcan B	Vulcan C	Average
Initial Mass	3994.7 g	3981.2 g	3947.2 g	--
0	0.00	0.00	0.00	0.00
36	-0.07	-0.10	-0.03	-0.07
72	-0.07	-0.08	-0.08	-0.07
108	-0.33	-0.06	-0.07	-0.15
140	-0.36	-0.13	-0.06	-0.18
176	-0.37	-0.14	-0.10	-0.20
210	-0.35	-0.15	-0.07	-0.19
246	-0.48	-0.25	-0.13	-0.29
270	-0.39	-0.37	-0.16	-0.31
304	-0.43	-0.38	-0.17	-0.33



Freeze-Thaw Cycles	Relative Dynamic Modulus, %			
	Vulcan A	Vulcan B	Vulcan C	Average
0	100	100	100	100
36	96	97	96	97
72	94	95	92	94
108	86	93	91	90
140	85	90	90	88
176	84	90	90	88
210	84	90	89	88
246	83	89	89	87
270	83	90	89	87
304	83	89	88	87



Notes:

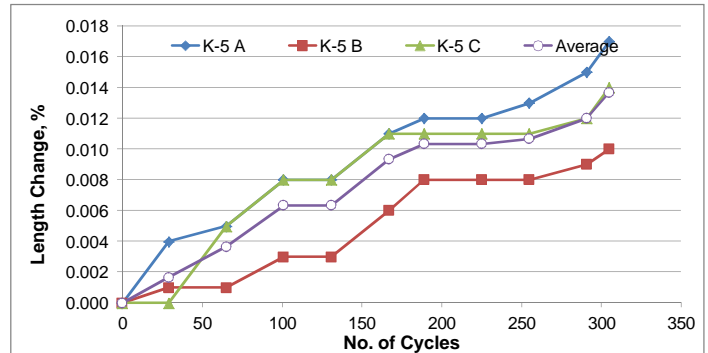
1. Test specimens fabricated at CTLGroup on February 20, 2013.
2. Test specimens measure approximately 3x3x11-in. at 0 cycles.
3. A negative mass change indicates mass loss; a positive mass change indicates a mass gain.
4. The relative dynamic modulus was determined by the transverse frequency method of ASTM C215, Section 9.
5. This report may not be reproduced except in its entirety.

ASTM C666, Standard Test Method for Resistance of Concrete to Rapid Freezing and Thawing Procedure A, Freezing and Thawing in Water

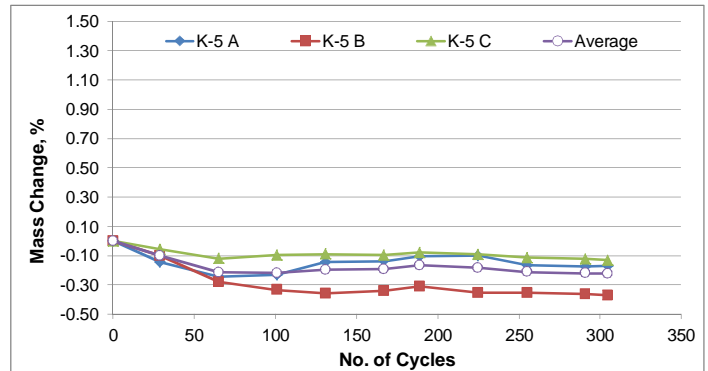
Summary of Test Results

Average length change at 305 cycles, %: **0.014**
 Average mass change at 305 cycles, %: **-0.22**
 Average RDM at 305 cycles, %: **88**

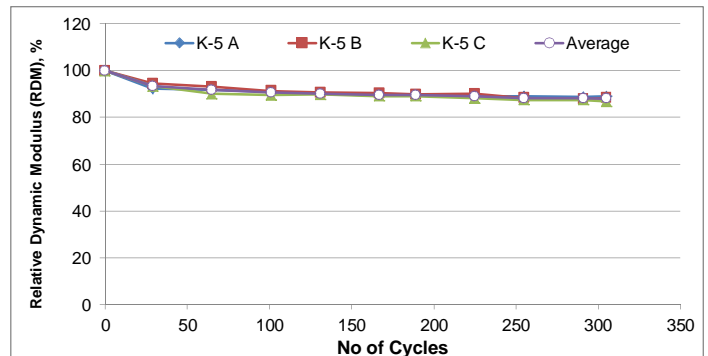
Freeze-Thaw Cycles	Length Change, %			
	K-5 A	K-5 B	K-5 C	Average
0	0.000	0.000	0.000	0.000
29	0.004	0.001	0.000	0.002
65	0.005	0.001	0.005	0.004
101	0.008	0.003	0.008	0.006
131	0.008	0.003	0.008	0.006
167	0.011	0.006	0.011	0.009
189	0.012	0.008	0.011	0.010
225	0.012	0.008	0.011	0.010
255	0.013	0.008	0.011	0.011
291	0.015	0.009	0.012	0.012
305	0.017	0.010	0.014	0.014



Freeze-Thaw Cycles	Mass Change, %			
	K-5 A	K-5 B	K-5 C	Average
Initial Mass	3882.5 g	3954.6 g	3931.1 g	--
0	0.00	0.00	0.00	0.00
29	-0.14	-0.10	-0.06	-0.10
65	-0.24	-0.28	-0.12	-0.21
101	-0.23	-0.33	-0.09	-0.22
131	-0.14	-0.36	-0.09	-0.20
167	-0.14	-0.34	-0.10	-0.19
189	-0.11	-0.31	-0.08	-0.16
225	-0.10	-0.35	-0.09	-0.18
255	-0.16	-0.35	-0.11	-0.21
291	-0.18	-0.36	-0.12	-0.22
305	-0.17	-0.37	-0.13	-0.22



Freeze-Thaw Cycles	Relative Dynamic Modulus, %			
	K-5 A	K-5 B	K-5 C	Average
0	100	100	100	100
29	92	94	93	93
65	92	93	90	92
101	91	91	90	91
131	90	91	90	90
167	89	90	89	90
189	90	90	89	89
225	89	90	88	89
255	89	88	88	88
291	89	88	88	88
305	89	88	87	88



Notes:

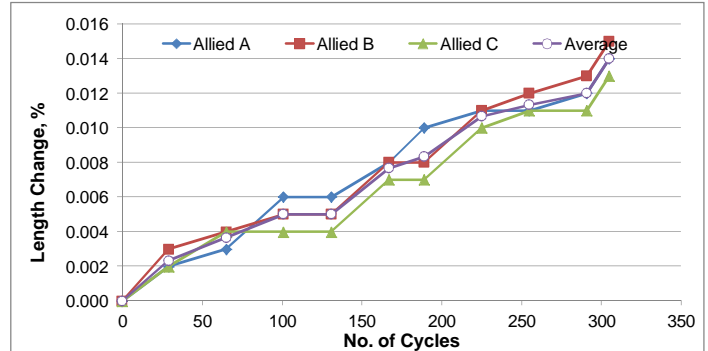
1. Test specimens fabricated at CTLGroup on February 22, 2013.
2. Test specimens measure approximately 3x3x11-in. at 0 cycles.
3. A negative mass change indicates mass loss; a positive mass change indicates a mass gain.
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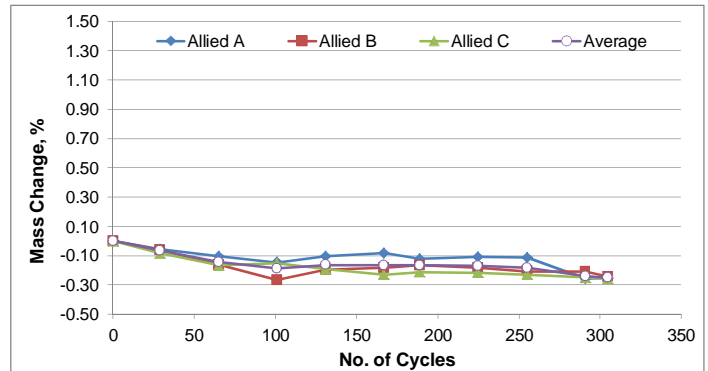
Summary of Test Results

Average length change at 305 cycles, %: **0.014**
 Average mass change at 305 cycles, %: **-0.25**
 Average RDM at 305 cycles, %: **88**

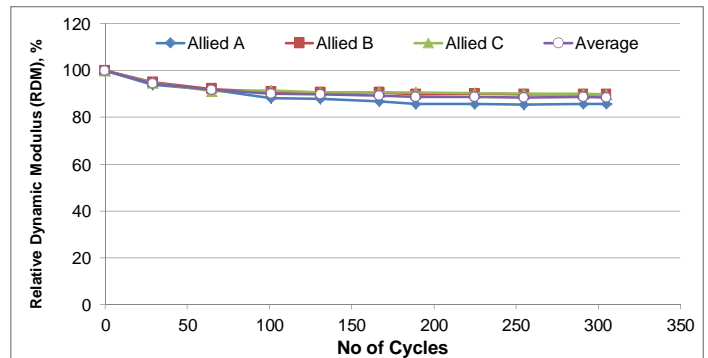
Freeze-Thaw Cycles	Length Change, %			
	Allied A	Allied B	Allied C	Average
0	0.000	0.000	0.000	0.000
29	0.002	0.003	0.002	0.002
65	0.003	0.004	0.004	0.004
101	0.006	0.005	0.004	0.005
131	0.006	0.005	0.004	0.005
167	0.008	0.008	0.007	0.008
189	0.010	0.008	0.007	0.008
225	0.011	0.011	0.010	0.011
255	0.011	0.012	0.011	0.011
291	0.012	0.013	0.011	0.012
305	0.014	0.015	0.013	0.014



Freeze-Thaw Cycles	Mass Change, %			
	Allied A	Allied B	Allied C	Average
Initial Mass	3976.1 g	3957.3 g	3986.2 g	--
0	0.00	0.00	0.00	0.00
29	-0.06	-0.06	-0.08	-0.07
65	-0.11	-0.16	-0.17	-0.14
101	-0.15	-0.27	-0.15	-0.19
131	-0.10	-0.19	-0.19	-0.16
167	-0.08	-0.18	-0.23	-0.16
189	-0.12	-0.16	-0.21	-0.17
225	-0.11	-0.18	-0.22	-0.17
255	-0.11	-0.21	-0.23	-0.18
291	-0.26	-0.21	-0.25	-0.24
305	-0.25	-0.25	-0.26	-0.25



Freeze-Thaw Cycles	Relative Dynamic Modulus, %			
	Allied A	Allied B	Allied C	Average
0	100	100	100	100
29	94	95	95	95
65	92	92	91	92
101	88	91	91	90
131	88	91	91	90
167	87	91	91	89
189	86	90	91	89
225	86	90	90	89
255	85	90	90	89
291	86	90	90	89
305	86	90	90	88



Notes:

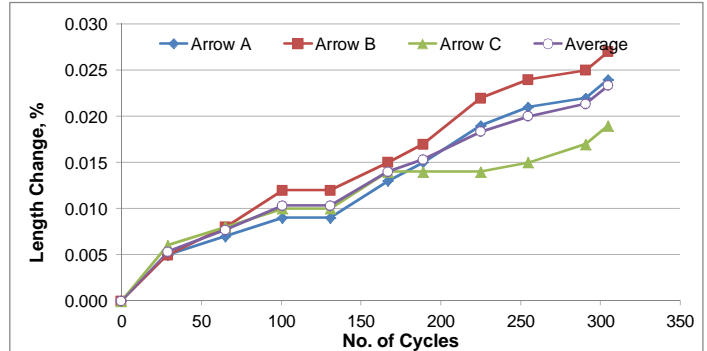
1. Test specimens fabricated at CTLGroup on February 22, 2013.
2. Test specimens measure approximately 3x3x11-in. at 0 cycles.
3. A negative mass change indicates mass loss; a positive mass change indicates a mass gain.
4. The relative dynamic modulus was determined by the transverse frequency method of ASTM C215, Section 9.
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ASTM C666, Standard Test Method for Resistance of Concrete to Rapid Freezing and Thawing Procedure A, Freezing and Thawing in Water

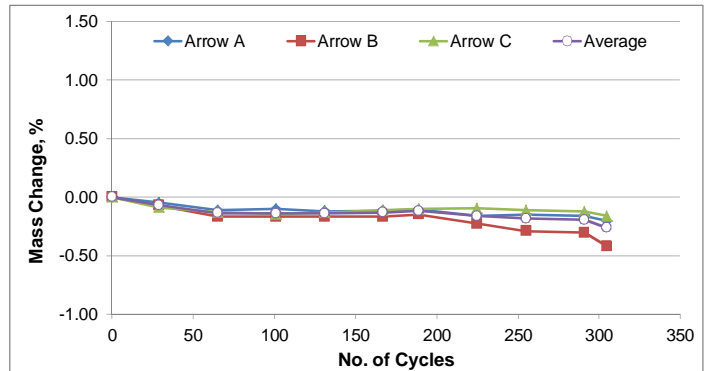
Summary of Test Results

Average length change at 305 cycles, %: **0.023**
 Average mass change at 305 cycles, %: **-0.26**
 Average RDM at 305 cycles, %: **85**

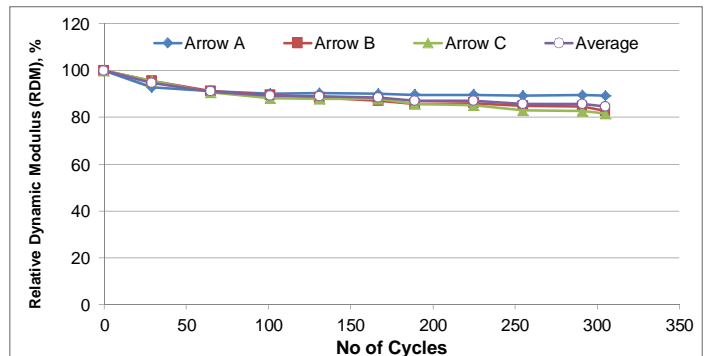
Freeze-Thaw Cycles	Length Change, %			
	Arrow A	Arrow B	Arrow C	Average
0	0.000	0.000	0.000	0.000
29	0.005	0.005	0.006	0.005
65	0.007	0.008	0.008	0.008
101	0.009	0.012	0.010	0.010
131	0.009	0.012	0.010	0.010
167	0.013	0.015	0.014	0.014
189	0.015	0.017	0.014	0.015
225	0.019	0.022	0.014	0.018
255	0.021	0.024	0.015	0.020
291	0.022	0.025	0.017	0.021
305	0.024	0.027	0.019	0.023



Freeze-Thaw Cycles	Mass Change, %			
	Arrow A	Arrow B	Arrow C	Average
Initial Mass	3931.5 g	3946.7 g	3893.3 g	--
0	0.00	0.00	0.00	0.00
29	-0.05	-0.07	-0.09	-0.07
65	-0.11	-0.17	-0.13	-0.14
101	-0.10	-0.17	-0.14	-0.14
131	-0.12	-0.16	-0.13	-0.14
167	-0.11	-0.17	-0.11	-0.13
189	-0.10	-0.15	-0.10	-0.12
225	-0.16	-0.23	-0.10	-0.16
255	-0.15	-0.29	-0.11	-0.18
291	-0.16	-0.30	-0.12	-0.20
305	-0.21	-0.42	-0.16	-0.26



Freeze-Thaw Cycles	Relative Dynamic Modulus, %			
	Arrow A	Arrow B	Arrow C	Average
0	100	100	100	100
29	93	96	96	95
65	91	91	91	91
101	90	90	88	89
131	90	89	88	89
167	90	87	88	88
189	90	86	86	87
225	90	86	85	87
255	89	85	83	86
291	89	85	83	86
305	89	83	82	85



Notes:

1. Test specimens fabricated at CTLGroup on February 22, 2013.
2. Test specimens measure approximately 3x3x11-in. at 0 cycles.
3. A negative mass change indicates mass loss; a positive mass change indicates a mass gain.
4. The relative dynamic modulus was determined by the transverse frequency method of ASTM C215, Section 9.
5. This report may not be reproduced except in its entirety.