Department of Civil Engineering

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Effects of Different Accelerated and Moist Curing Periods on Chloride Penetration Resistance of Precast Concrete Elements

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For the Canadian Precast Concrete Institute (CPCI)

February 25, 2015

1. Background

The National Research Council of Canada (NRCC) recently completed a research program [1] for the CPCI demonstrating that precast concrete subject to accelerated curing does not need to have an additional 7-day moist curing period as required since 2009 in CSA A23.1 for exposure classes C-XL and C-1. Traditionally, the precast concrete standard, CSA A23.4, has simply referenced the curing regimes given in A23.1, but this has become problematic for precasters since the 2009 A23.1 change, that was targeting cast-in-place concrete.

However, concerns were raised by the Ministry of Transportation Ontario (MTO) that the NRCC research data did not adequately demonstrate that the outer 10 mm or so of concrete cover would not have reduced resistance to chloride penetration by de-icing salts, for example from salt splash or wind driven spray. There are currently no test methods in CSA A23.2 that address this concern with surface absorption of chlorides.

However, in the work by Titherington (1998), the surface absorption of water of high-performance concretes given accelerated temperature curing was up to 40% less than when the same concrete mixtures were moist cured for 7 days at ambient temperature.

This test program was designed to address MTO's concerns by evaluating the effects of additional moist curing, subsequent to accelerated, high-temperature curing, on the ingress of chloride solutions.

2. Test Program

2.1 Casting and Curing Concrete Test Specimens

Five precast concrete slabs (275mm x 375mm x 100mm in size) and 26 100mm x 200mm cylinders were cast on June 10, 2014 at Strescon's plant in Bedford Nova Scotia using a 60 MPa C-XL concrete mixture where:

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a) one slab was moist cured to 7 days without accelerated curing then stored in air until 56 days.

b) three slabs were steam/accelerated cured and then demolded at 16 h and subjected to 3 different post-steam curing regimes: 0, 3, and 7 days moist curing then stored in air at ambient temperature to 20 days then were wrapped in plastic and shipped to University of Toronto. Slabs were cored for tests at 56 days of age as follows:

i) one slab was exposed to air at ambient conditions, then once transferred to University of Toronto it was exposed to air at 23 ^{o}C and 50% rh until 56 days.

ii) one slab was covered in wet burlap and sealed in plastic for 3d, then exposed to air at ambient conditions, then once transferred to University of Toronto it was exposed to air at 23 ^{o}C and 50% rh until 56 days.

iii) one slab was covered in wet burlap and sealed in plastic for 7d, then exposed to air at ambient conditions, then once transferred to University of Toronto it was exposed to air at 23 ^{o}C and 50% rh until 56 days.

In addition, 26- 100x200mm cylinders were cast. Four were used by Strescon to measure “release strength” at 16 h while 22 cylinders were shipped to University of Toronto for strength, resistivity and ASTM C1202 (coulomb) testing: 11 with and 11 without being exposed to the accelerated curing regime and moist cured until 7 days of age.

c) one slab was steam/accelerated cured for 16 h and then placed in a refrigerator and the concrete held at a temperature of between 2 to 4^{o}C until 7 days of age as shown in Figure 3, then stored in air at ambient conditions, then once transferred to University of Toronto it was exposed to air at 23 ^{o}C and 50% rh until 56 days. This was to simulate precast elements being immediately transferred to outdoor storage in cold weather after the accelerated curing regime.

The concrete was cast at 21^{o}C, given a pre-set period of approximately 7 hours, then heated using live steam with the accelerated curing cycle achieved a maximum concrete temperature of between 62^{o}C (thermocouples embedded in one slab) with temperature of the concrete above 50^{o}C for approximately 11.5h. The thermocouple temperature logs are shown in Figure 1 for the accelerated curing cycle. The “release strength”, measured at 16 hours, for the accelerated cured concrete cylinders was 48.6 MPa and for the ambient temperature cured cylinders was 28.3 MPa. Ambient temperature in the factory where the slabs were stored over the 7-day period ranged from 14 to 22^{o}C with the average around 19-20^{o}C as shown in Figure 2.

The casting and curing were conducted under supervision of Philip Jack and John Fraser of Strescon and was witnessed by Gordon Leaman of Stantec. He was there to corroborate that the sampling and testing was in conformance with standard procedures and that the batched materials were within tolerance for the mix design as submitted by Strescon. His report is included as an Appendix.

The concrete slabs and cylinders were then wrapped in plastic and shipped to the University of Toronto at an age of 20 days. After arrival at the university, slabs were stored in air in the laboratory until coring, and cylinders were moist cured until testing.

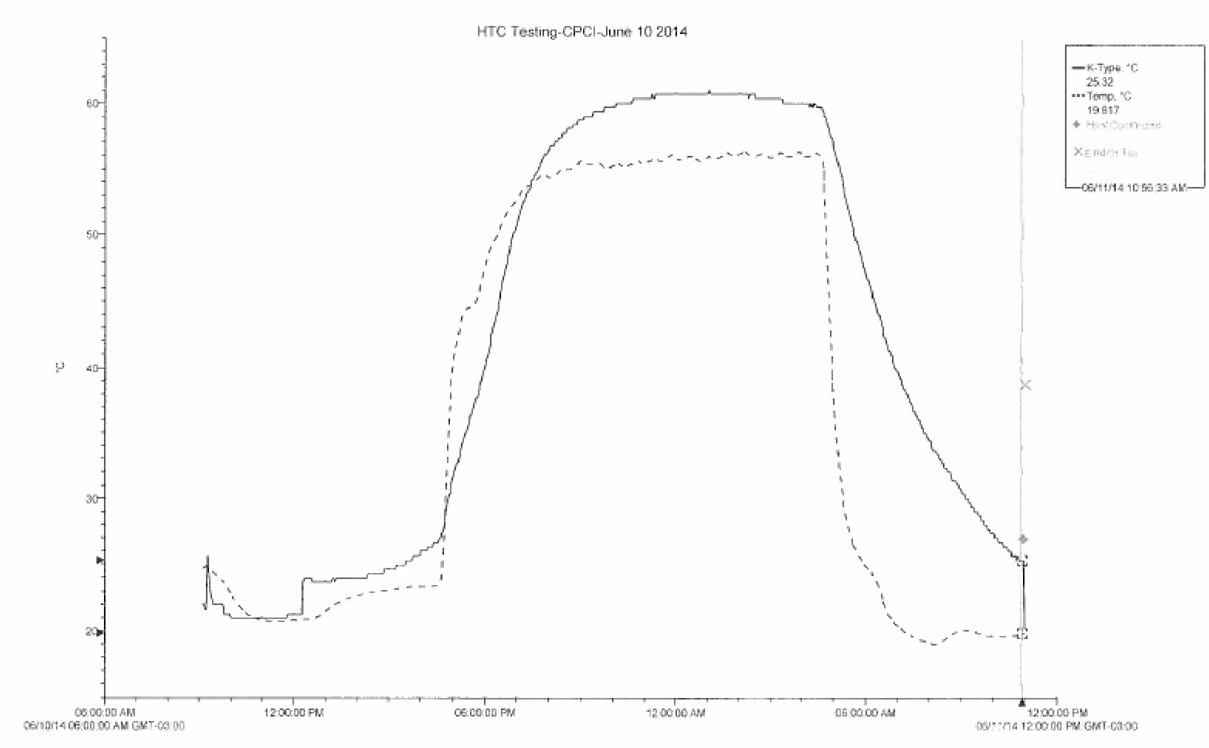

Figure 1. Concrete slab temperature during the accelerated curing cycle (Solid line) The dashed line is curing chamber temperature.

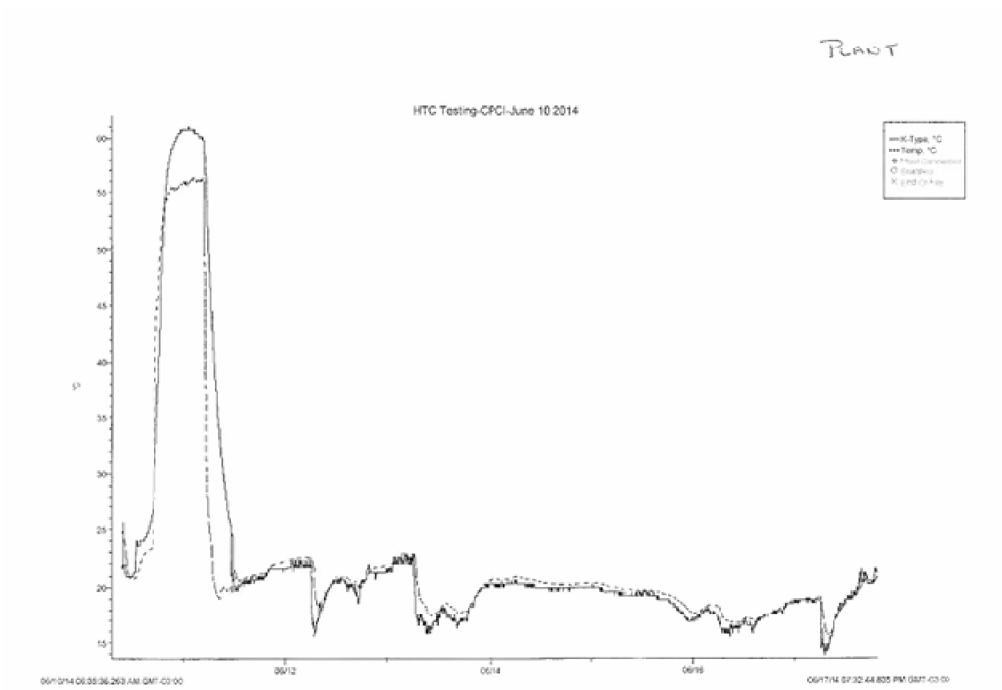

Figure 2. Concrete slab temperature (solid line) during the accelerated curing cycle followed by the ambient temperature in the factory afterwards

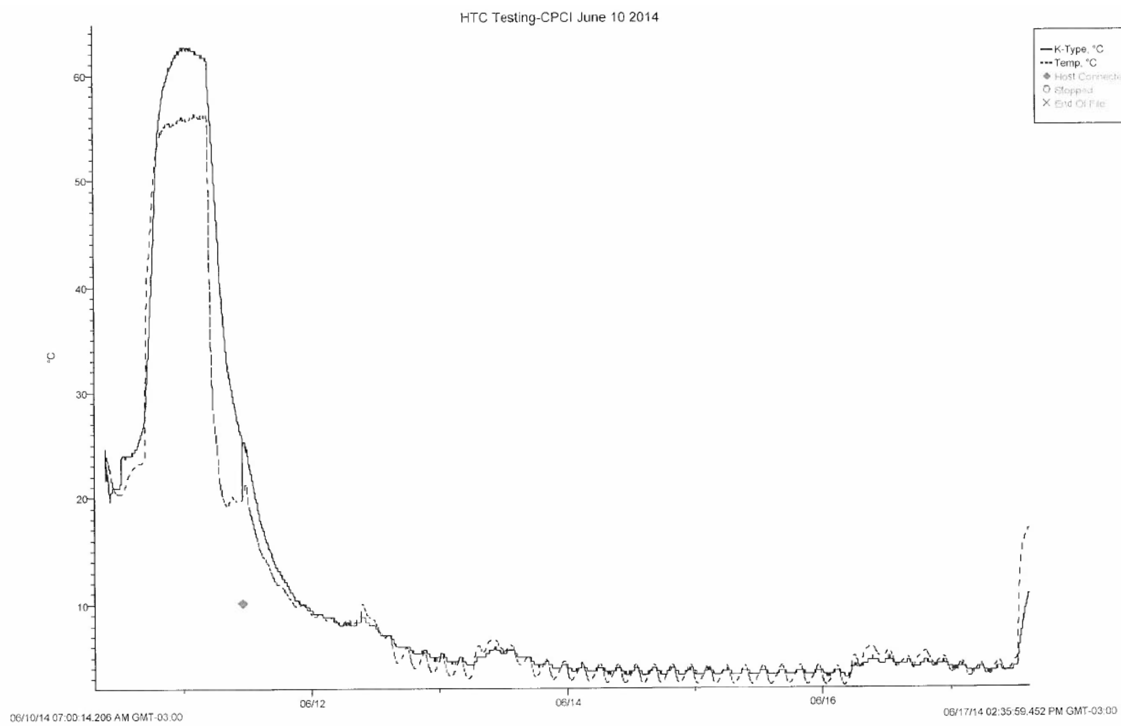

Figure 3. Concrete slab temperature (solid line) during the accelerated curing cycle followed by the cold temperature exposure in a refrigerator until 7 days of age

2.2 Testing Performed at University of Toronto

Concrete slabs and cylinders were wrapped and shipped from Strescon to the University of Toronto at an age of 20 days.

2.1.1 Cylinder Tests

a) Strength

Three 100x200 mm moist cured and accelerated cured cylinders were tested at 28, 56, and 120 days of age. After the accelerated curing regime, cylinders were demolded and kept in the moist curing room at Strescon. They were then wrapped in plastic and placed back in a moist room on arrival. Results are shown in Table 1. All strengths exceeded the CSA C-XL 50 MPa requirement by 28 days. The strengths moist cured cylinders stored at 23°C were higher than the ones exposed to the accelerated curing at all ages by 5.3 to 7.8 MPa.

Table 1. Cylinder strengths

Age	Strength (MPa) Accelerated Curing	Strength (MPa) Moist Curing
28 days	62.0	69.8
56 days	66.1	73.9
120 days	69.3	74.5

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b) ASTM C1202 and Bulk Resistivity

These tests were performed on concrete cylinders cured the same as those used for the cylinder strength tests. The tests were performed on two 50 mm thick slices from the centre portion of the cylinders. The average results shown in Table 2 are the average of two tests. All of the ASTM C1202 values are well below the 91-day, 1000 coulomb limit specified for CSA C-XL in CSA A23.1-14, as well as the 28-day limit specified by MTO for high-performance concrete. The cylinders that received the accelerated curing have lower (better) values than for the ones stored at ambient temperature prior to demolding and moist curing. Bulk resistivity results for the cylinders that received the accelerated curing have significantly higher (better) values than for the ones stored at ambient temperature both at 28 and 56 days of age. The results from the 2 different resistivity test devices (Merlin by Germann Instruments and Rcon by Giatec) are essentially the same: all within 3.4% of each other.

Table 2. ASTM C1202 and bulk resistivity results on cylinders

Age (days)	ASTM C1202 (Coulombs)		Bulk Resistivity (kohm-cm)			
	Accelerated Cured	Moist Room Cured	Accelerated Cured		Moist Room Cured	
			Merlin	Rcon	Merlin	Rcon
28	340	465	54.1	52.4	35.5	34.9
56	315	375	61.4	59.8	50.2	48.5

2.2.2 Slab Core Tests

At an age of 56 days, the following tests were performed on different segments cut from the centre of each of the slabs:

a) ASTM C1202

56-day core test results shown in Table 3 are the average of two tests on 50 mm thick slices of 100 mm diameter cores from both the top, cast face and bottom, formed face of each slab. The slab that received accelerated curing with no additional moist curing had exactly the same coulomb values as the accelerated cured concrete that was given an additional 7

Table 3. ASTM C1202 results on 56 day old cores taken from slabs

Curing Regime	ASTM C1202 (coulombs)
16 h accel. cure; then stored in air	285
16 h accel. cure; moist cured to 72 h; then stored in air	310
16 h accel. cure; moist cured to 168 h; then stored in air	285
7 d moist cured at 23^{o}C	325
16 h accel. cure; then stored to 7 d at cold temp.; then in air at 23^{o}C	290

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days of moist curing. The cold temperature exposure after accelerated curing had no detrimental effect on coulomb values. All five values are statistically identical.

b) ASTM C1585 Rate of Absorption

ASTM C1585 rate of absorption tests were conducted on the formed face, and surfaces 10 and 20mm from the formed face. Instead of using water for this test, a 2.8M NaCl solution was used. The purpose was to determine whether the differences in curing regimes affected the surface absorption relative to absorption of the interior of each concrete slab, and also to see if the depth of near surface chloride penetration was affected. The test specimens were exposed to salt water absorption for a total of 8 days and the depth of chloride penetration was determined on split surfaces using silver nitrate spray using the same method as in the NT492 test.

Three 100 mm diameter x 50 mm thick discs were cut from cores with the test face at the formed surface, 10 mm below the formed surface, and 20 mm below the formed surface, as shown in Figure 4. Similar to ASTM C1585, discs were conditioned by oven drying for 3 days at 50°C followed by four more days inside a sealed container at 50°C prior to test (this last part, allows residual moisture to be redistributed throughout the thickness of the concrete test sample). This conditioning regime was previously found to provide a reasonably uniform residual moisture content of about 1% (relative to more severe drying at 110°C) and a near-surface relative humidity of 50 to 60% (DeSouza et al. 1997). An example of a rate of absorption plot showing initial and secondary rates of absorption is shown in Figure 5.

The values given in Table 4 show the rate of absorption results and the average depth of chloride penetration after the 8-day test. The initial rate of absorption is of most interest in terms of relating to chloride ingress from salt splash, with lower initial rates of absorption being better. In all cases, the rate of the absorption of the formed surface (0 mm) is higher than further in (10 and 20 mm). This is likely in large part due to the formed surface having a paste layer, while the 10 and 20 mm depth tests were on saw cut surfaces. The results in all cases are very similar and, from Table 5, it can be seen that the initial rates of absorption at the surface relative to 20-mm inside the slab are no worse for the high-temperature cured slab with no additional moist curing than for the slabs that received additional moist curing. The depth of chloride penetration after absorption from the formed surfaces was only 0.3 to 1.7 mm deeper than from surfaces at 10 or 20 mm depth. Six days of additional moist curing after the accelerated curing regime did not reduce the depth of chloride penetration relative to the accelerated cured slab with no additional moist curing.

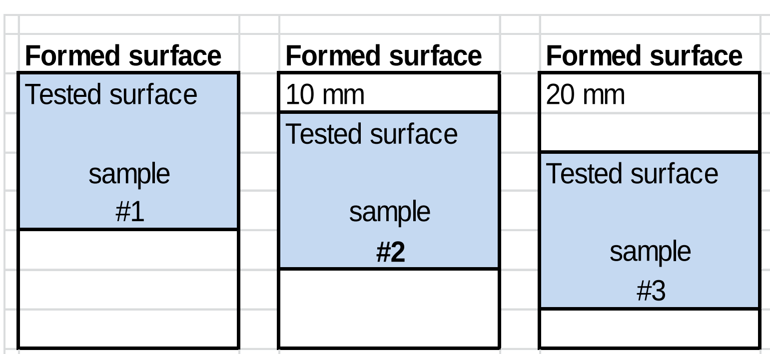

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Figure 4. Schematic showing the location of the tested surface of the rate of absorption tests on 100 mm diameter cores in the 100 mm thick slabs

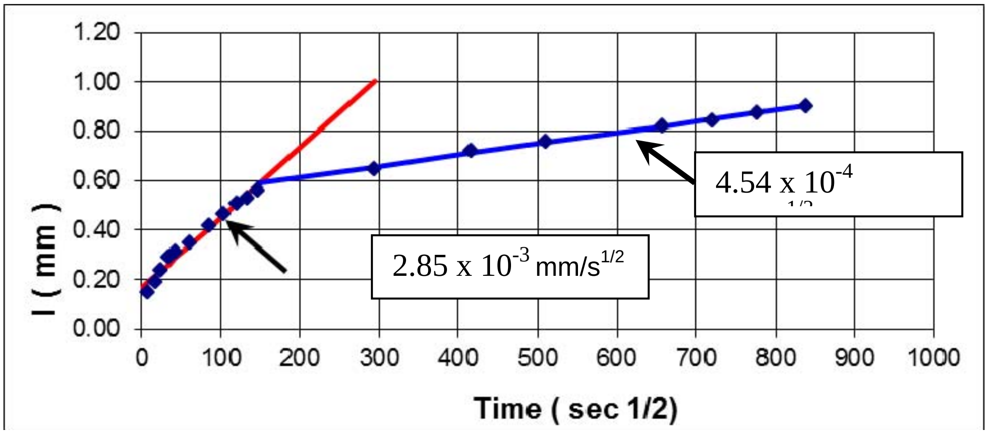

Figure 5. Example of 56-day rate of absorption plot for accelerated-cured concrete (formed surface with no additional moist curing)

Table 4. Initial and secondary rates of absorption and resulting depth of chloride ingress on cores taken from slabs

Curing Regime	Depth from formed surface (mm)	Initial rate of absorption (10^{-3} mm/s$^{1/2}$)	Secondary rate of absorption (10^{-4} mm/s$^{1/2}$)	Depth of Chloride Penetration (mm)
16 h accel. cure; then stored in air	0	2.85	4.54	6.3
	10	2.18	4.4	6.1
	20	2.56	6.93	5.8
16 h accel. cure; moist cured to 72 h; then stored in air	0	2.19	4.05	7.9
	10	1.98	3.48	6.4
	20	1.9	4.06	6.9
16 h accel. cure; moist cured to 168 h; then stored in air	0	2.48	5.94	7.2
	10	1.82	5.18	6.2
	20	1.89	4.53	5.5
7 d moist cured at 23^{o}C	0	2.78	6.03	5.8
	10	2.12	4.36	4.9
	20	1.93	4.33	5.1
16 h accel. cure; then stored to 7 d at cold temp.; then in air at 23^{o}C	0	2.55	4.87	5.7
	10	2.01	4.67	5.7
	20	2.08	5.37	5.1

Table 5. Ratio of Initial Rate of absorption values at the Formed surface to 20 mm below

Curing Regime	Ratio of Initial Absorption between the Formed Surface and 20 mm Inside
16 h accel. cure; then stored in air	1.11
16 h accel. cure; moist cured to 72 h; then stored in air	1.15
16 h accel. cure; moist cured to 168 h; then stored in air	1.32
7 d moist cured at 23^{o}C	1.44
16 h accel. cure; then stored to 7 d at cold temp.; then in air at 23^{o}C	1.22

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c) Modified Chloride Migration Tests

The Nordtest NT492 (AASHTO TP64) rapid migration test was conducted on a slice of each concrete slab with the face exposed to sodium chloride in the test being the one perpendicular to the cured face, as shown in Figure 6. This approach was used by Hooton et al (2002) and by Ha (2003) to demonstrate the impact of curing on the chloride resistance and service life of concrete.

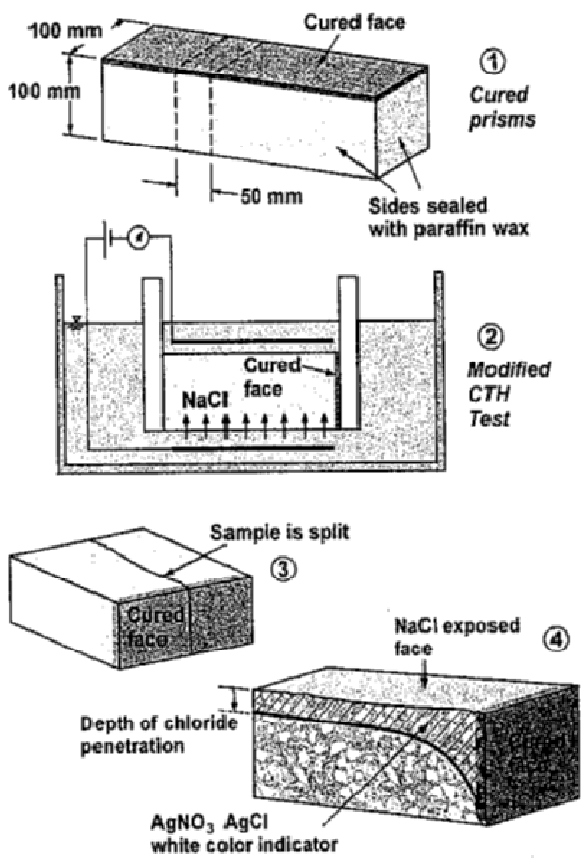

Figure 6. Schematic of Nordtest NT 492 modified as in Hooton et al (2002).

Four 100 x 100 x 50 mm thick slices were cut from the slabs and the slices were vacuum saturated as per ASTM C1202. The face perpendicular to the finished and formed faces was exposed to the Nordtest NT Build 492 test at 56 days of age (as shown in Figure 4). Since the concrete was a high-performance concrete, the test was run at the maximum voltage of 60V DC and time of 48 h. After the test, the slices were split open and the split faces were sprayed with 0.1N silver nitrate solution to visually show the depth of chloride penetration (chloride-penetrated portions turn white due to precipitation of silver chloride). Example photographs are shown in Figure 7. The depth of chloride penetration was then measured with a ruler every 2 mm from the top and bottom of each slab for each of the 8 split faces, and then at 10 mm intervals in between. As noted in Figure 7, there is some variability in the depth of chloride penetration near coarse aggregates, but these variations get averaged out in the 8 measurements taken at each depth location. The average depths of chloride penetration are shown in Figure 8 for each of the five curing regimes. This data is also provided in Table 6 along with the average depth of chloride penetration and the calculated non-steady state chloride migration coefficients (as per NT492) for each curing regime, for positions from 10 to 90 mm (ie. not including the outer 10 mm from the cast of formed faces).

Without considering the curing-affected, outer 10 mm curing affected zone of the slabs, as shown in Table 6, the calculated 56-day chloride migration coefficients for all of the accelerated cured slabs were statistically identical. The concrete that was moist cured for 7 days at ambient temperature had a lower chloride migration coefficient than any of the slabs that had received accelerated curing. This was not unexpected and is reasonably consistent with the results of Titherington and Hooton (2004).

Figure 7. Example photographs of split surfaces of concrete slices sprayed with silver nitrate for accelerated-cured concrete (left) and accelerated-cured plus moist curing to 7 days (right). C = cast face and F = formed face of slab.

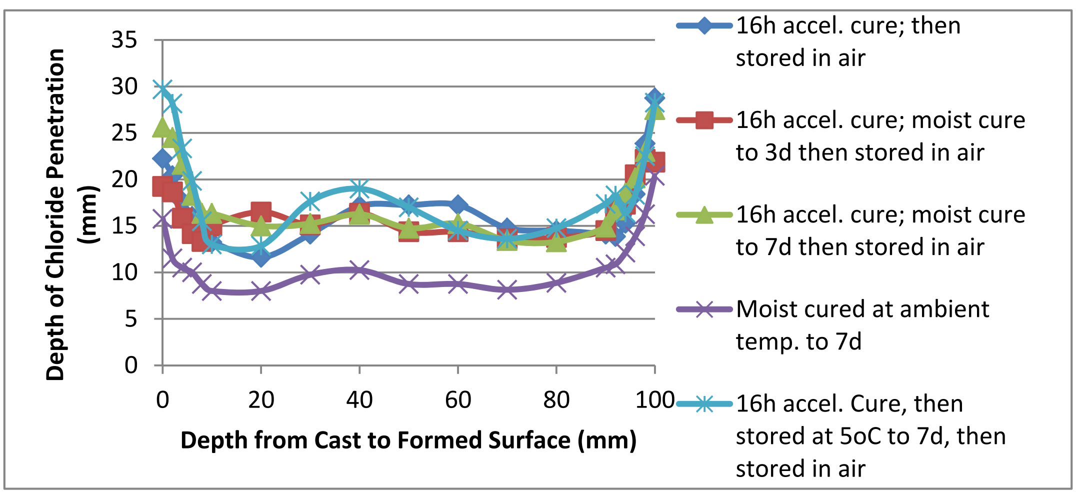

Figure 8. Average depths of chloride penetration from the cast face (left) to the bottom formed face (right) for each curing regime

Values of chloride diffusion (D_{nssm}) obtained from the NT492 non-steady state chloride migration test were calculated at each depth with the equation provided in the NT492 test method using data in Table 6; the diffusion coefficients are shown in Table 7 and Figure 9.

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Table 6. Average chloride penetration depths from the cast face (0 mm) to the formed face (100 mm) of the slabs for each curing regime. Also, average depths of chloride penetration and chloride migration coefficients are shown without the outer 10 mm included for comparison to near-surface values.

	Average Chloride Penetration Depth (mm)				
Depth from Cast Face (mm)	16h accel. cure; then stored in air	16h accel. cure; moist cure to 3d then stored in air	16h accel. cure; moist cure to 7d then stored in air	Moist cured at ambient temp. to 7d	16h accel. Cure, then stored at 5°C to 7d, then stored in air
0	22.3	19.3	25.6	15.8	29.7
2	20.4	18.7	24.5	11.5	28.2
4	17.6	15.8	21.6	10.5	23.3
6	16.0	14.2	18.3	10.0	19.8
8	13.6	13.3	16.3	8.8	15.5
10	13.3	15.0	16.3	8.0	13.0
20	11.6	16.5	15.0	8.0	12.9
30	14.1	15.1	15.3	9.8	17.6
40	17.1	16.4	16.3	10.3	19.0
50	17.3	14.4	14.8	8.8	17.0
60	17.3	14.4	15.3	8.8	14.5
70	14.8	13.6	13.4	8.1	13.6
80	14.5	13.8	13.3	8.9	14.8
90	14.1	14.5	14.9	10.5	17.4
92	13.9	16.8	16.7	10.9	18.3
94	15.3	17.3	18.5	12.1	16.4
96	18.4	21	20.2	13.9	18.3
98	23.9	22.2	23.0	16.3	22.5
100	28.8	21.9	27.5	20.4	28.3
Average chloride penetration from 10 to 90 mm position (mm)	14.9	14.8	14.9	9.0	15.5
Average Chloride Migration Coefficient (10^{-12} m^2/s)	1.7	1.7	1.7	1.0	1.8

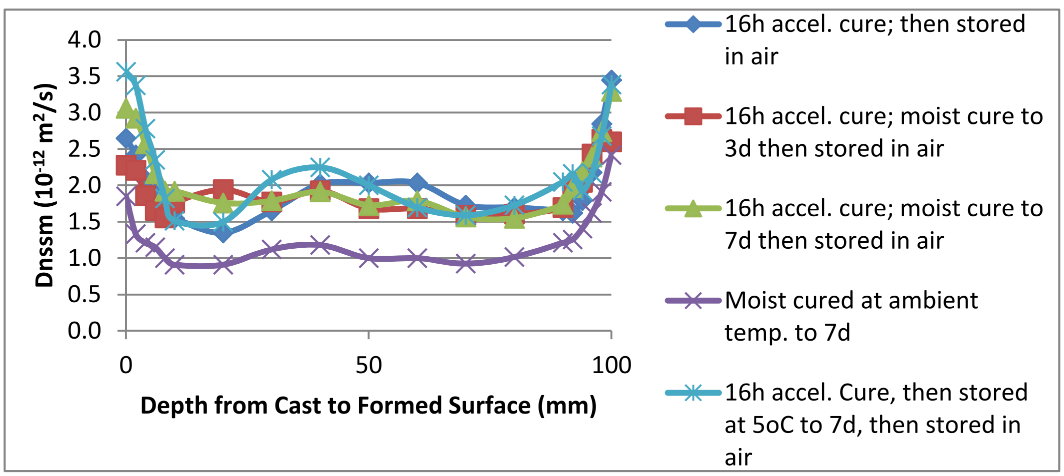

Figure 9. Average NT492 chloride migration coefficients vs slab depths for different curing regimes

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Table 7. Average NT492 chloride migration coefficients vs slab depths for different curing regimes

Depth from Cast Face (mm)	Average Dnnsm 10^{-12} m^2/s				
	16h accel. cure; then stored in air	16h accel. cure; moist cure to 3d then stored in air	16h accel. cure; moist cure to 7d then stored in air	Moist cured at ambient temp. to 7d	16h accel. Cure, then stored at 5°C to 7d, then stored in air
0	2.6	2.3	3.1	1.8	3.6
2	2.4	2.2	2.9	1.3	3.4
4	2.1	1.9	2.6	1.2	2.8
6	1.9	1.7	2.2	1.1	2.3
8	1.6	1.6	1.9	1.0	1.8
10	1.5	1.8	1.9	0.9	1.5
20	1.3	1.9	1.8	0.9	1.5
30	1.7	1.8	1.8	1.1	2.1
40	2.0	1.9	1.9	1.2	2.2
50	2.0	1.7	1.7	1.0	2.0
60	2.0	1.7	1.8	1.0	1.7
70	1.7	1.6	1.6	0.9	1.6
80	1.7	1.6	1.5	1.0	1.7
90	1.7	1.7	1.7	1.2	2.0
92	1.6	2.0	2.0	1.3	2.2
94	1.8	2.0	2.2	1.4	1.9
96	2.2	2.4	2.4	1.6	2.2
98	2.8	2.6	2.7	1.9	2.7
100	3.4	2.6	3.3	2.4	3.4

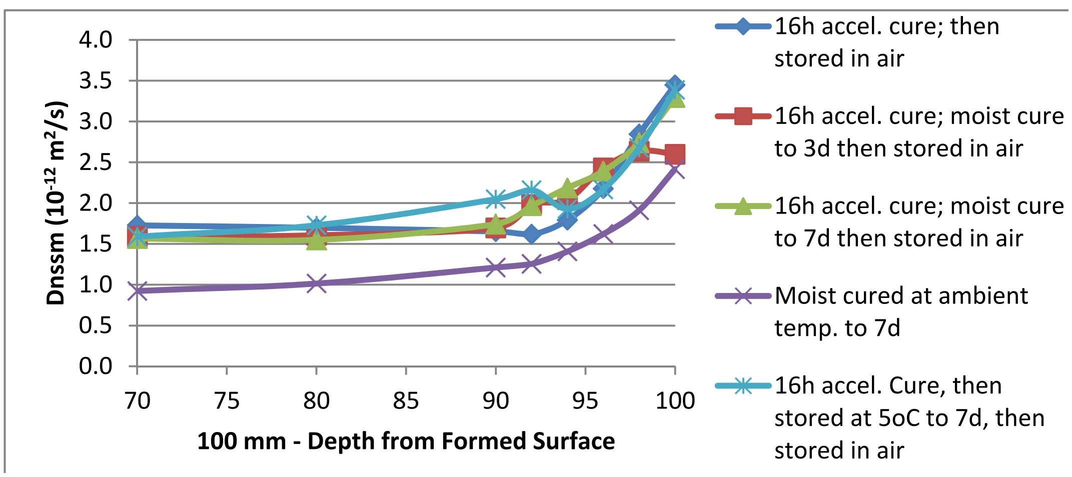

Figure 9. Average NT492 chloride migration coefficients near the formed surfaces of slabs for different curing regimes

This shows that chloride diffusion coefficients in the top and bottom outer 10 mm depths of concretes that were accelerated cured with 0 or 2 days of additional moist curing were at least as good as that of the accelerated cured concrete that was then moist cured to 7 days of age. The accelerated cured concrete that was then stored at $5^{o}C$ in air only had higher diffusion (migration) coefficients in the 2 mm depth from the cast surface and less than 2 mm for the formed surface. Again, the concrete that was moist cured at ambient temperature had the lowest diffusion values. An enlargement of part of Figure 8 between 30 and 0 mm from the formed surfaces of the slabs is shown in Figure 9. For precast bridge girders, the formed surfaces will be the ones exposed to salt spray.

3. Conclusions and Recommendations

3.1. Additional moist curing was not required for accelerated-cured concrete prior to the changes made in the 2009 edition of CSA A23.1. The data show that there is no negative impact of omitting additional moist curing for CSA C-XL concrete that has undergone a 16 hour accelerated curing regime. Neither the 56-day rates of surface absorption, chloride penetration resulting from absorption, nor depth-dependant chloride diffusion coefficients were adversely affected. Therefore, it appears that similar precast, accelerated-cured CSA C-XL concretes do not require any additional moist curing to provide high chloride resistance in order to have the expected long service life.

3.2. The impact of placing one concrete slab immediately after accelerated curing at one-day of age to low-temperature (2-$4^{o}C$) storage (simulating cold outdoor temperatures) had no impact on initial rates of surface absorption and did not have any bigger impact the depth-dependent chloride diffusion tests on the outer few mm below the cast and formed surfaces.

3.3. Relative to any of the specimens that were accelerated cured, seven-days of ambient temperature moist curing resulted in a better (lower) average chloride diffusion and better (higher) cylinder strengths. However, for the same relative comparison, seven days of ambient temperature most curing had no net positive effect on either the rapid chloride permeability when measured in accordance to ASTM C1012, or the initial rate of absorption, when measured in accordance with ASTM C1585, or chloride penetration after 8 days of absorption. Finally, for the same comparison, the bulk resistivity of the ambient temperature moist cured specimens showed significantly lower results than the accelerated cured specimens, but for this test "lower" is a "worse" condition

3.4. The ASTM C1585 initial rate of absorption test should be considered as a standard test for evaluation of near surface properties of precast concrete, for a specific plant and specific mix. In such a test, cores could be taken from a formed surface of a precast element (or from a similarly cured test slab) and the initial rate of absorption (sorptivity) of the outer surface (using ASTM C1585 procedures) compared to that of a saw cut, 20 mm deep inner surface of companion cores. Test and acceptance criteria would have to be developed, but the ratio of the one-face formed surface sorptivity to that at 20-mm depth should be as low as possible and be no worse than that of concretes given 7 days most curing at ambient temperatures. As an alternative, it would also be possible to develop a shorter test method measuring rate of absorption of a NaCl solution and stopping the test after 2 to 3 hours, then splitting and spraying with silver nitrate to also measure the depth of chloride penetration due to absorption.

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Stantec Consulting Ltd.
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June 18, 2014
File: 121616822

Attention: Mr. Robert Burak, P.Eng., President
Canadian Precast/Prestressed Concrete Institute
#100 - 196 Bronson Avenue
Ottawa, ON K1R 6H4

Dear Mr. Burak,

Reference: Witnessing Specimen Casting for CPCI Research, Strescon Limited, Bedford, NS

At your request, Stantec observed the casting of numerous test specimens at the Strescon Limited facility on June 10, 2014. We offer the following comments.

The concrete mixture was Strecon's typical high performance concrete utilized for Nova Scotia Department of Transportation and Infrastructure Renewal projects.

After batching, the concrete batch was sampled for plastic property tests. The results of the tests are summarized in the work sheet prepared by Strescon Limited in Appendix A. The work sheet also summarizes the concrete mixture proportions for the batch. Once the plastic properties of the concrete were determined and the concrete accepted for use, the required specimens were cast. Five 275 x 375 x 100 mm thick slabs and 26 - 100 x 200 mm cylindrical test specimens were cast from the trial batch.

The cylindrical specimens were cast in accordance with CSA Test Method A23.2-3C-09, Making and Curing Concrete Compression and Flexural Test Specimens, and the slab specimens were generally cast in accordance with ASTM C672-12, Standard Test Method for Scaling Resistance of Concrete Surfaces Exposed to Deicing Chemicals. The slab specimens were consolidated by rodding the concrete mixture in one lift. The concrete surface was rodded with 80 strokes distributed over the entire surface. In addition to rodding the slab specimens, the moulds were also jigged by dropping each long end of the mould from a height of 40 to 50 mm onto the concrete floor. The jigging procedure was believed to be beneficial to eliminate bug holes on the formed surface.

One half of the cylindrical specimens were stored in moist curing at standard laboratory conditions while the remainder of the specimens and four of the five slabs were steamed cured in a purpose-made tent enclosure. The remaining slab was cured at ambient conditions in the production facility.

Appendix B presents the temperature record for the steam curing cycle of the test specimens while Appendix C presents a photograph log of the casting and storage of the test specimens.

Reference: Witnessing Specimen Casting for CPCI Research, Strescon Limited, Bedford, NS

We trust this is all the information that you require at this time. If you have any questions, please contact us at your convenience.

Regards,

STANTEC CONSULTING LTD.

Gordon H Leaman

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Principal
Phone: (902) 468-0414
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enclosure

cc: Mr. John Fraser, P.Eng., Strescon Limited

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Appendix A
Trial Batch Summary and Plastic Concrete Properties

Technician: C Muscat	june 10 2014	Test Time: 12:30	Job No. HTC-CPCI

Design Information

Strength:	8760 psi	60 mpa	Mix No: 046014TINS		Mod No: 26079
Batch size:	2 yd^3	0 m^3	Unit weight (WD)	142.46 lbs/ft^3	
Max slump:	230mm	5.0-8.0	W/C	0.35	

Water to Cement Ratio =	0.320	Column 2 = Column 1 ÷ Batch Size
Design Yield (YD) = T/WD =	27.3903	Column 2 = Column 2 ÷ 1.00 + Free Water %
Current Yield (Y) = T/W =	26.5082	Column 3 = Column 2 - Column 4
Correction Factor (F) = 35.3145/(YD) or 27.0/(YD) =	0.9858	Column 5 = Column 4 x (F)
Mathematical Check =	27.0000	= 27.0 for yd^3 or 35.3145 for m^3

DCI Free Water = Imp oz X 0.960750 US oz/Imp oz X 0.0078125 US gal/US oz X 7 lbs water replacement/US gal

Design Proportions — Mix Proportions

	Design Weights	(1) Computer Weights Required	(1) Computer Weights Batched	(2) Weights /yd3	(3) Free Water	(4) S. S. D. Weights	(5) Corrected Weights
Water lbs	220	339	384	192.00	62.72	254.72	251.09
Cement lbs	789	1,578	1,590	795.00	-	795.00	783.67
Silica Fume lbs				-	-	-	-
Fly Ash lbs				-	-	-	-
Stone 3/4 x 1/2 lbs				-	-	-	-
Stone 1/2 x #4 lbs	1,673	3,376	3,380	1,690.00	16.40	1,673.60	1,649.75
Stone 3/8 x #4 lbs				-	-	-	-
Sand, Coarse lbs	1,203	2,477	2,450	1,225.00	46.32	1,178.68	1,161.88
Sand, Fine lbs				-	-	-	-
	oz/100 lbs				-	T= 3,902.00	K= 3,846.40
Micro Air	1.75 oz/100 lbs	27.62	27.00				
Delvo	2.00 oz/100 lbs	31.56	32.00				
7500	14.00 oz/100 lbs	220.92	220.00				

	Unit of Measure	(1st)	(2nd)	(3rd)	(4th)	Average	
Concrete Sample Time		12:30					
Slump		140.00				140.00	
Air Content %		6.2 %				6.2 %	
Concrete Temp.		24.2°					
Air Temp		18.0°					
Weight Concrete + Tare	LBS	46.250					lbs or kg
Weight Tare	LBS	9.450					lbs or kg
Weight Concrete	lbs	36.800		-	-		
Volume of Bucket	ft^3	0.25		0.25	0.25		
Unit Weight lbs/ft^3 (W)		147.20		-	-	147.20	

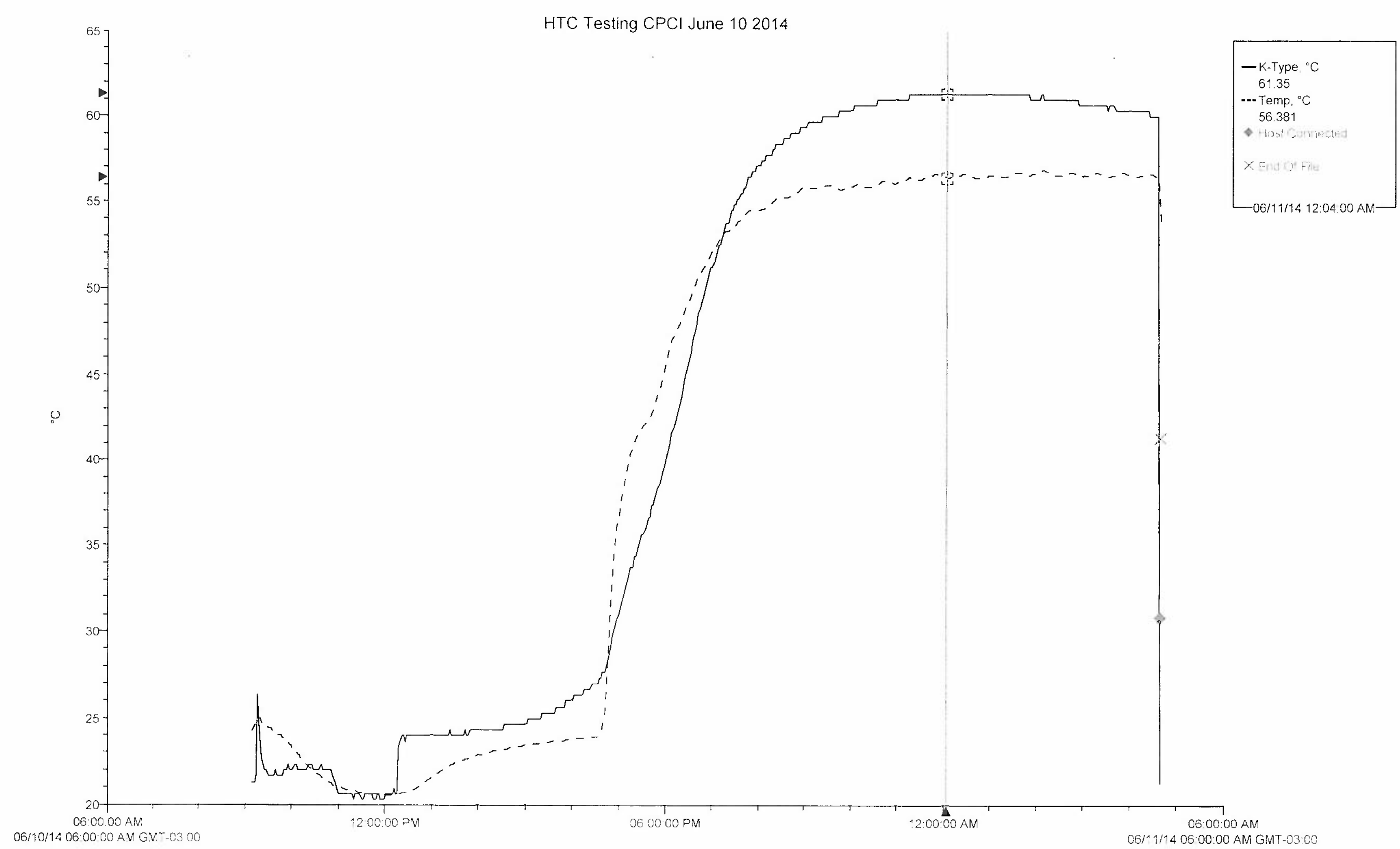
Aggregate Moisture Content

Sample Time: 12:30

	Unit of Measure	Stone 3/4 x 1/2	Stone	Stone 3/8 x #4	Sand Coarse	Sand Fine
Aggregate Wet + Tare	grams	-	2924.3		2028.4	
Aggregate Dry + Tare	grams		2877.5		1951.5	
Tare Weight	grams		249.9		255.5	
Weight of Water	grams	-	47	-	76.9	-
Weight of Dry Aggregate	grams	-	2627.6	-	1696.0	-
Total Free Water %		0.00%	1.78%	0.00%	4.53%	0.00%
Absorption %			0.80%		0.60%	
Free Water %		0.00%	0.98%	0.00%	3.93%	0.00%
Probe Reading			1.10		1.08	

Notes: HTC-CPCI Test - Approved for 2014, CXL, NSTIR Mix

Appendix B
Temperature Regime for Steam Curing Cycle



HTC Testing CPCI June 10 2014
°C
65
60
55
50
45
40
35
30
25
20
06:00:00 AM
06/10/14 06:00:00 AM GMT-03:00
12:00:00 PM
06:00:00 PM
12:00:00 AM
06:00:00 AM
06/11/14 06:00:00 AM GMT-03:00
K-Type, °C
61.35
Temp, °C
56.381
Host Connected
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06/11/14 12:04:00 AM

Appendix C
Photograph Log for
Casting Test Specimens

Photo 1 – Form plywood moulds prepared to cast slab test specimens

Photo 2 – Concrete consolidated in slab mould. Cylindrical test specimens for steam curing being prepared in background.

Photo 3 – Slab moulds jigged by dropping one end from a height of 40 to 50 mm onto concrete floor

Photo 4 – Final screeding of test slab surfaces using minimal passes of mag trowel.

Photo 5 – Cylindrical and slab test specimens placed in steam curing enclosure. One test slab monitored for temperature during curing.

Photo 6 – Steam curing enclosure covered and ready for curing.

Photo 7 – Test slab covered with polyethylene sheeting for ambient curing condition.

Photo 8 – Consolidating cylindrical test specimens for moist curing at standard laboratory conditions.

Photo 9 – Typical formed surface condition for test slab upon demoulding the following day.