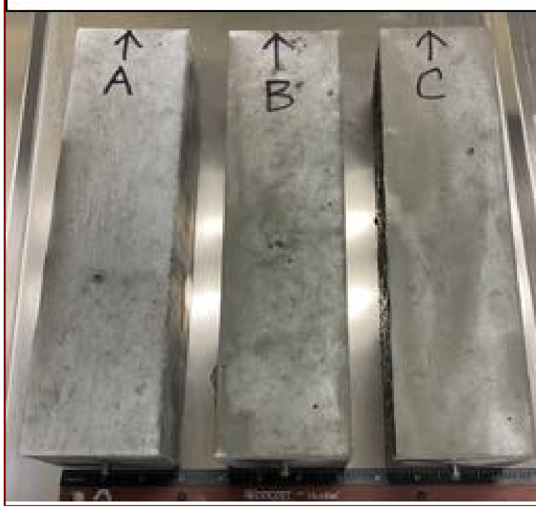
CONSTRUCTION MATERIALS CONSULTANTS, INC.

Laboratory Testing of Concrete Prisms For Length-Change Measurements (ASTM C 157) and Concrete Cylinders For Chloride Content (ASTM C 1218), Rapid Chloride Permeability (ASTM C 1202), and Air-Void Parameters (ASTM C 457)

Concrete Prisms For ASTM C 157



Concrete Cylinders For ASTM C 457, C 1202, and C 1218

May 26, 2020
CMC 0420118

TABLE OF CONTENTS

INTRODUCTION

Provided for laboratory testing are representative prisms and cylinders of a concrete mixture shown in Figures 1 and 2. Four 4″ × 8″ laboratory-cured concrete cylinders (Figure 3) were provided for rapid chloride permeability tests (ASTM C 1202) of two cylinders, one containing a calcium nitrate corrosion inhibitor and the other without the inhibitor; a third cylinder for air-void analysis (ASTM C 457); and the forth one for water-soluble chloride content (ASTM C 1218). Three concrete prisms (Figure 4) were provided for length change measurements (ASTM C 157).

Mix Design of Concrete

BRAYMANPRECAST

REVISION DATE:	4/24/2020	CONCRETE SOURCE:	BRAYMAN PRECAST
PRODUCT TYPE:	PRECAST STAIRS	MIXING & DELIVERY:	CENTRAL MIXED
CUSTOMER NAME:	HCG	MIX NAME:	STD GREY / SILICA
PROJECT NAME:	NEWARK AIRPORT (CONRAC)	MIX DESIGN ID:	Mixer 1 = ID #35 Mixer 2 = ID #36

MIX DESIGN

REQUIREMENTS - SPEC. SECTIONS:	034100 & 033010	CONCRETE PROPERTIES BY DESIGN: TRIAL BATCHING			
COMPRESSIVE STRENGTH (28 Day)	6000 psi	COMPRESSIVE STRENGTH (28 Day)	6000 psi	UNIT WT.	141.1 pcf
CORROSION INHIBITOR @	3 gal / yd^3	STANDARD DEVIATION	NA psi	INITIAL SLUMP (in)	2
MAXIMUM WATER/CEMENT RATIO	0.40	MAXIMUM WATER/CEMENT RATIO	0.38	FINAL SLUMP (in)	6.5 ± 2.5"
AIR CONTENT (%)	6.5 +/-1.5%	AIR CONTENT (%)	6.5 +/-1.5%		

MATERIALS		NAME	SUPPLIER	SPECIFICATION		LBS. / YD^3	FT^3
CEMENT	SSD S.G = 3.15	TYPE I/II GREY LA	CEMEX; LOUISVILLE	ASTM C-150		700	3.56
CEMENT II	SSD S.G = 2.2	MASTERLIFE SF 100	BASF	ASTM C-1240	6.7%	50	0.36
COARSE AGGREGATE	SSD S.G = 2.69	# 67 LIMESTONE	ALLEGHENY MINERAL	ASTM C-33	63.4%	1750	10.41
FINE AGGREGATE	SSD S.G = 2.62	TYPE A CONCRETE SAND	H & H MATERIALS	ASTM C-33	36.6%	1010	6.18
WATER		SAXONBURG AREA AUTHORITY		U.S. GALLONS = 30.1		250.6	4.02
WATER CONTRIBUTED FROM ADMIXTURES TYPE S AND C / yd^3				U.S. GALLONS = 4.1		34.4	24.53
TOTAL WATER				U.S. GALLONS = 34.2		285.0	

ADMIXTURES	NAME	TYPE	SUPPLIER		SPECIFICATION	OZ. / CWT	OZ. / YD^3	FT^3
AIR ENTRAINING AGENT (Adjust)	MASTERAIR VR 10		BASF		ASTM C-260	2	15	1.76
WATER RETARDING AGENT (Use & adjust as needed)	MASTERSET R 100	B & D	BASF		ASTM C-494	1	8	0.01
HIGH RANGE WATER REDUCING AGENT (Adjust)	MASTERGLENIUM 3400	A & F	BASF		ASTM C-494	8	60	0.07
SHRINKAGE REDUCING ADMIXTURE	MASTERLIFE-SRA 035	S	BASF	1.5 gal	ASTM C-494		192	0.20
CORROSION INHIBITOR	MASTERLIFE CI 30	C	BASF		ASTM C-494		384	0.51
					TOTAL ADMIX LBS.		50	2.55
					YIELD TOTALS		3811	27.00

All noted admixtures may be adjusted without notice to the customer during normal batching operations to accommodate for pouring conditions; without affecting the proportioning or integrity of the mix design.

PREPARED AND RESPECTFULLY SUBMITTED BY:

Rick Balazs

RICK BALAZS
DIRECTOR OF PROJECT DEVELOPMENT

Figure 1: The reported concrete mix that was used for preparation of concrete prisms and cylinders.

From this concrete mix:

a. Three 3 in. sq. cross section prisms were prepared for ASTM C 157;

b. One each 4″ × 8″ cylinder was cured for 28 days in standard water bath curing for ASTM C 457 and C 1218; and finally,

c. Two cylinders one with a corrosion inhibitor and another without were prepared by standard curing for 7 days followed by 21 days of curing at 100 degrees F for ASTM C 1202 test.

Mix Design of Concrete

DATE: 4/23/2020

BRAYMAN PRECAST
STD GREY / SILICA Mixer 1 = ID #35 Mixer 2 = ID #36
BATCH DATA

BASE DESIGN PROPORTIONS FOR 1 CUBIC YARD TEST SIZE 1 CY

DESIGN % AIR =	6.5	DESIGN SLUMP =	6.5
W/C RATIO =	0.38	% STONE I =	100%
% CEMENT I =	100%	% SAND I =	100%

MATERIAL		SUPPLIER		SSD SG	WEIGHT	FT^3
CEMENT I	TYPE I/II GREY LA	CEMEX	LOUISVILLE	3.15	700 lbs	3.56
CEMENT II	MASTERLIFE SF 100	BASF	CLEVELAND	2.20	50 lbs	0.36
CEMENT III						
STONE I	# 67 LIMESTONE	ALLEGHENY	SLIPPERY ROCK	2.69	1750 lbs	10.41
STONE II						
SAND I	TYPE A CONCRETE SAND	H&H MINERAL	STONEBORO	2.62	1010 lbs	6.18
SAND II						
WATER		LOCAL	*Adjusted for all admixes*		251 lbs	4.02

FREE MOISTURES	
STONE I	1.10%
STONE II	
SAND I	4.40%
SAND II	

MATERIAL	TYPE	NAME	SUPPLIER	OZ/CWT	WEIGHT	FT^3
ADMIX I	AE	MASTERAIR VR 10	BASF	2	15 oz	1.76
ADMIX II	RETARDER	MASTERSET R 100	BASF	1	8 oz	0.01
ADMIX III	HRWR	MASTERGLENIUM 3400	BASF	8	60 oz	0.08
ADMIX IV	SHRINKAGE	MASTERLIFE-SRA 035	BASF	25.60	192 oz	0.20
ADMIX V						
ADMIX VI	CORROSION INHIBITOR	CNI	BASF	51.20	384 oz	0.51
				YIELD	3810 lbs	27.08
					140.6771	

TEST #:	Yards	W/C	Ttl Cementitious
2	1.000	0.38	750

MATERIAL		SUPPLIER	BATCH WEIGHT	MOIST ADJ	ACTUAL		
CEMENT I	TYPE I/II GREY LA	CEMEX	700.0 lbs				
CEMENT II	MASTERLIFE SF 100	BASF	50.0 lbs				
CEMENT III							
STONE I	# 67 LIMESTONE	ALLEGHENY	1750.0 lbs	1769.3 lbs			
STONE II				lbs			
SAND I	TYPE A CONCRETE SAND	H&H MINERAL	1009.7 lbs	1054.2 lbs			
SAND II			0.0 lbs	0.0 lbs			
WATER		LOCAL	250.6 lbs	186.9 lbs	186.9	22.4	gal
ADMIX I	MASTERAIR VR 10	BASF	15.0 oz	444 ml	64		
ADMIX II	MASTERSET R 100	BASF	7.5 oz	222 ml	8		
ADMIX III	MASTERGLENIUM 3400	BASF	60.0 oz	1776 ml	40		
ADMIX IV	MASTERLIFE-SRA 035	BASF	192.0 oz	5683 ml	192		
ADMIX V				ml			
ADMIX VI	CNI	BASF	384.0 oz	11366 ml	384		
			3810.2	*3810.2 lbs*			

PLASTIC TESTS		TEMPERATURE	
TIME:	11:35:00 AM	MIN	
A. TEMP:	66	MAX	
C. TEMP:	71		
AIR %:	6.1		
SLUMP:	8		
Unit Wt.:	143.6		
# CYL:	13		

ASTM C 157

Demold	Test
10:35:00 AM	12:05:00 PM

CYLINDER BREAKS			
DAY/HRS	DATE		
1	4/24		
7	4/30		
14	5/7		
28	5/21		

Figure 2: The reported concrete mix that was used for preparation of concrete prisms and cylinders.

SAMPLES

CYLINDERS FOR AIR-VOID ANALYSIS (ASTM C 457), CHLORIDE CONTENT (ASTM C 1218), AND CHLORIDE PERMEABILITY (ASTM C 1202)

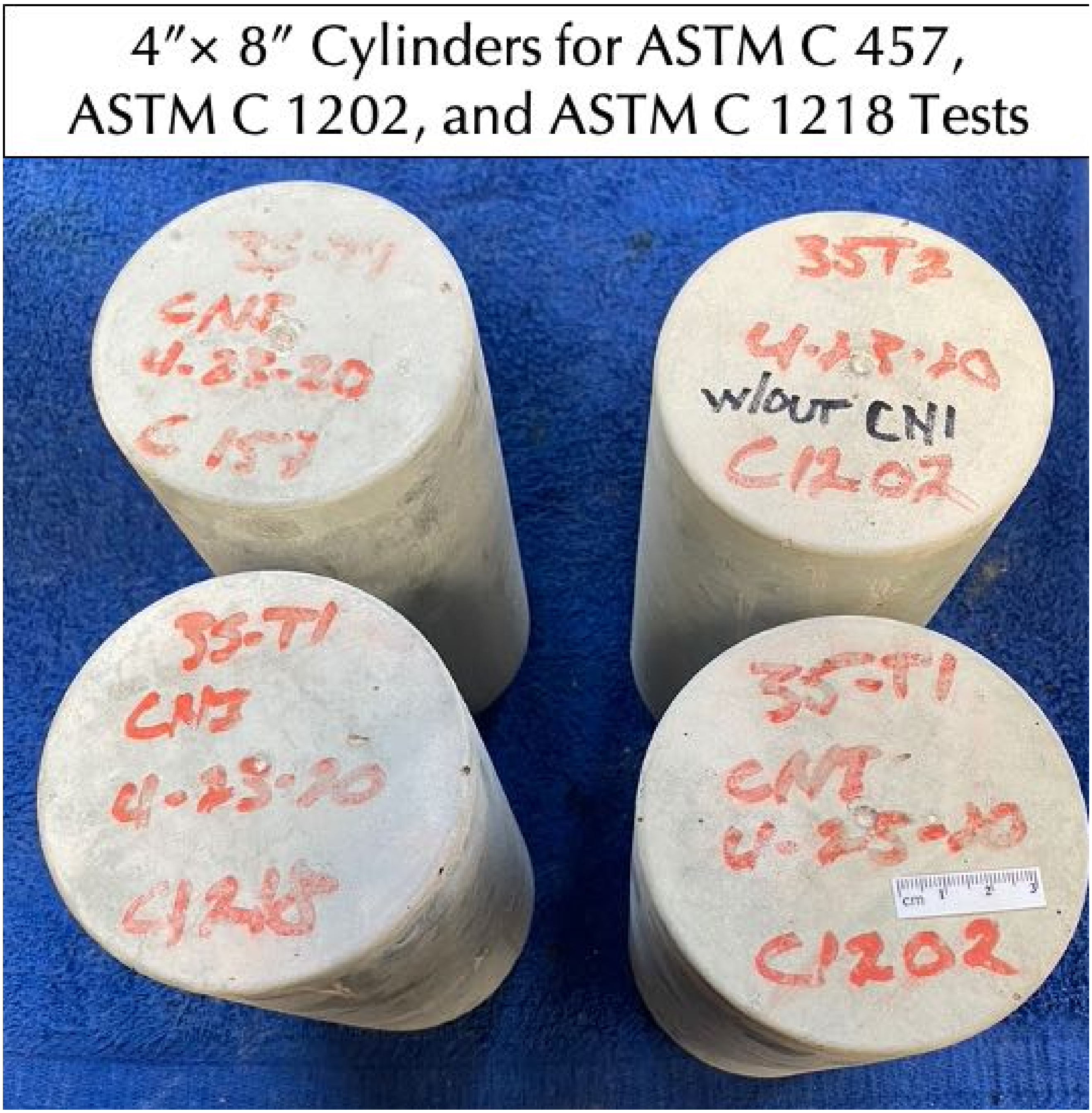


Figure 3: Four 4″ × 8″ laboratory-cured concrete cylinders were provided for rapid chloride permeability tests (ASTM C 1202) of two cylinders, one containing a calcium nitrate corrosion inhibitor and the other without the inhibitor, a third cylinder for air-void analysis (ASTM C 457), and the forth one for water-soluble chloride content (ASTM C 1218). The top surfaces of the cylinders are finished. The bottom and cylindrical side surfaces are formed.

PRISMS FOR LENGTH CHANGE MEASUREMENTS (ASTM C 157)

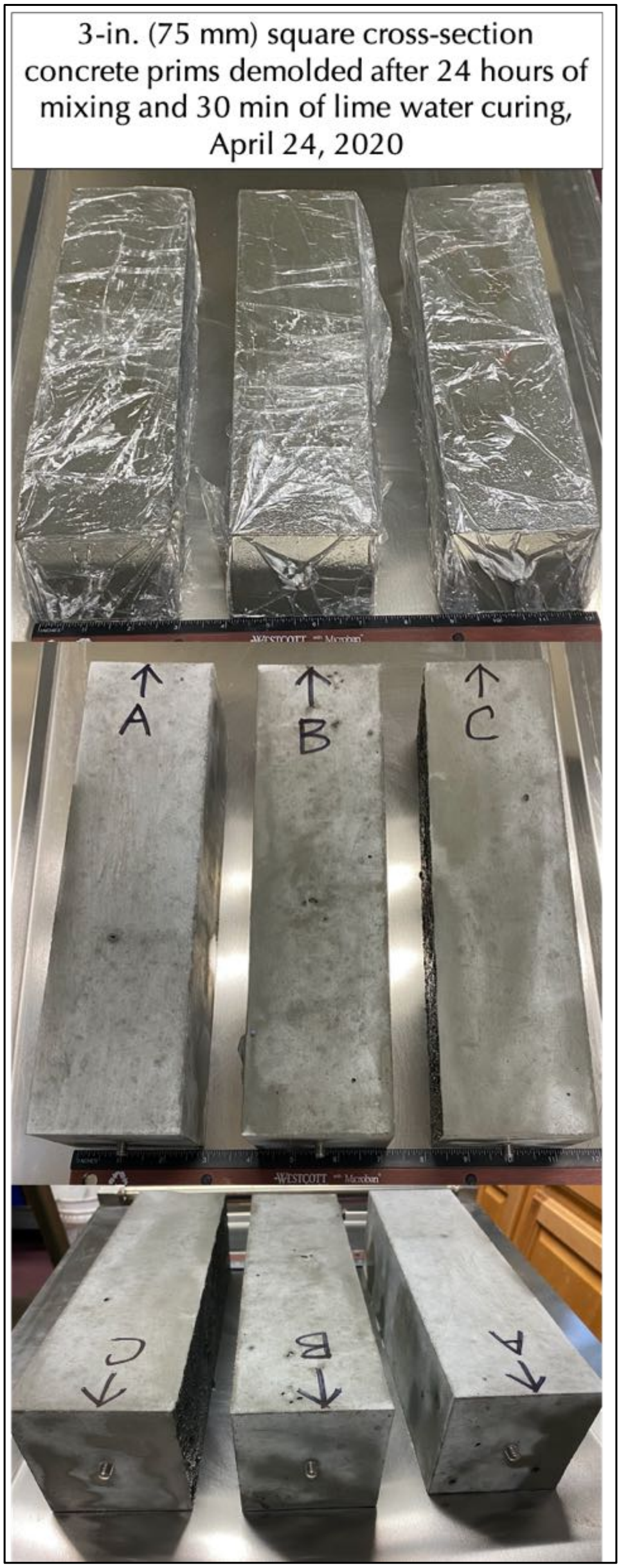


Figure 4: Three concrete prisms were provided for length change measurements (ASTM C 157). The top left photo shows how the prisms were provided after de-molding where each was wrapped in plastic and received in moist condition.

The prisms were reportedly prepared by following Sections 10.1 and 10.2 of ASTM C 157 with respect to initial curing of prisms for 23.5±0.5 hr., removal of prisms from molds, and initial comparator readings at 24±0.5 hr.

However, subsequent wet curing period described in Section 10.3 of ASTM C 157 were eliminated for all three prims. Instead of wet curing, prims were stored in ambient laboratory air. Section 11.1.2 of ASTM C 157 was immediately followed after initial comparator reading for air storage (dry) method for 28 days. Comparator readings were taken at 4, 7, 14, 21, and 28 days after initial comparator reading.

METHODOLOGIES

WATER-SOLUBLE CHLORIDE CONTENT (ASTM C 1218)

Representative section of concrete of approximately 10 to 20 grams of weight was obtained from the concrete cylinder selected for water-soluble chloride content (ASTM C 1218) by saw-cutting with a water-cooled diamond saw from the mid-depth location of the cylinder. The sectioned concrete slice was pulverized (Figure 5) to finer than US No. 50 sieve. Approximately 10 grams of pulverized concrete was thoroughly digested in 100 ml deionized water first in near-boiling temperature for 15 minutes with a magnetic stirrer, followed by further room-temperature digestion for 24 hours. The digested sample solution was then filtered under vacuum, first through two 2.5-micron filter papers, followed by another filtration through two 0.2-micron filter papers to collect the filtrate. The filtrate thus obtained was diluted to a final volume of 200 ml in a volumetric flask. The filtrate thus prepared was used for potentiometric titration with a silver nitrate titrant *a la* ASTM C 1218 by using a Metrohm titrator shown below.

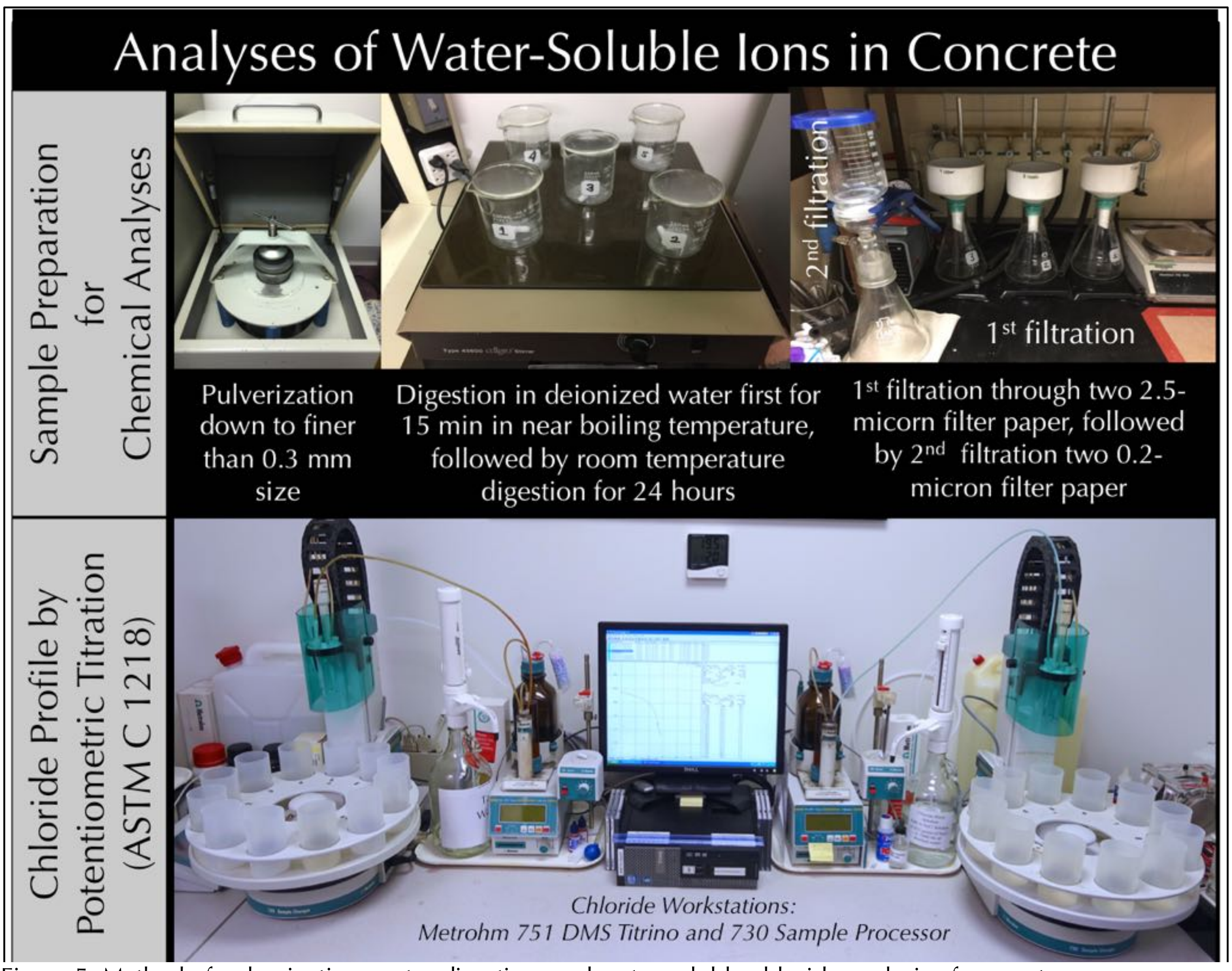


Figure 5: Method of pulverization, water-digestion, and water-soluble chloride analysis of concrete.

RAPID CHLORIDE PERMEABILITY (ASTM C 1202)

Resistance to chloride penetration testing of two concrete cylinders were done by following the methods and procedures of ASTM C 1202: "Standard Test Method for Electrical Indication of Concrete's Ability to Resist Chloride Ion Penetration."

The following step-by-step methods show the conditioning and procedures for rapid chloride permeability test:

Conditioning:

a. De-Aerated Boiled, Sealed, and Air-Cooled water - Vigorously boil a liter (2-gallon) or more of tap water in a large sealable container to remove air. Remove container from heat, cap tightly, and allow water to cool to room temperature.

b. Sample Sectioning & Air-Drying - Cores and cylinders must be 100mm (4-in.) diameter. Cut the core or cylinder to 2-inch length and grind the sectioned ends down to 1 $^{7}/_{8}$ in. length (50mm) by light lapping on a coarse metal-bonded lapping plate. Allow the core or cylinder samples (prepared to 1 $^{7}/_{8}$ in. thickness by sectioning and lapping) to surface dry in air for at least 1 hour.

c. Sample Coating (for Cores only) - Prepare approximately $^{1}/_{2}$ oz. (10 grams) of rapid-setting coating or epoxy and brush as a thin layer onto the side (i.e. cylindrical) surface of specimen. Place the sample on a suitable support while coating to ensure complete coating of sides. Turn sample upside down after 5 minutes to reduce dripping and ensure epoxy is evenly distributed along surface. Make sure NO epoxy is applied to sectioned ends. Grind off any epoxy that gets on sectioned ends. Allow coating to cure according to manufacturer's instruction. The coating should be allowed to cure until it is no longer sticky to the touch. Fill any apparent holes in the coating and allow additional curing time, as necessary. For cylinders it is not necessary to coat the cylindrical surface.

d. Repair of Spalled Cylinders and Cores - Beuler Vardur Powder and Hardener Ratio-Approximately 2:1, 2 parts powder to 1 part liquid (should be the consistency of cake batter). Use clear packing tape to build up around the top/bottom of sample where spalling has occurred. Apply patch only in spalled area. Let it dry for 10 minutes. Grind down excess patch close to original surface.

e. 3-hr Vacuuming - Place above-prepared samples in the large chloride permeability vacuum desiccator that has an upper lid with the vacuum-line upper stopcock valve, and, the sealable lower container (with an O-ring) with the water-entry stopcock valve. Place samples vertically i.e. on their end sides exposed to maximize vacuuming and water penetration. Place the upper lid on desiccator. Connect vacuum line to the stopcock at the upper lid of the bowl and open valve. Close the opposite stopcock valve at the lower half of the desiccator. Seal the desiccator, turn on the vacuum pump, and pressure should decrease to less than 50 mm Hg (6650 Pa) within a few minutes. Maintain the vacuum for three (3) hours.

f. 1-hr Water Immersion of Samples in Vacuum - Attach hose to the lower water-entry stopcock and place the other end of hose deep into the container with the boiled, de-aerated water. After three (3) hours in vacuum, with vacuum pump still running, open water stopcock valve at the bottom half of the desiccator and drain sufficient water into the desiccator to cover the sample completely (do not allow air to enter desiccator through this stopcock). Allow the de-aerated water to flow slowly into the desiccator by opening the water-entry stopcock only slightly. Don't let water splash, no air should enter the desiccator. Close the lower water-entry stopcock value when the samples are completely covered. Run the vacuum pump for another one (1) hour.

g. <u>18-hr Immersion</u> - Close the upper vacuum-line stopcock and turn off the pump. (Change pump oil if a water trap is not being used). We use a water trap in between the vacuum pump and the desiccator, as shown. Open the vacuum-line stopcock to allow air to re-enter the desiccator. Soak the samples under water for 18 ± 2 hrs.

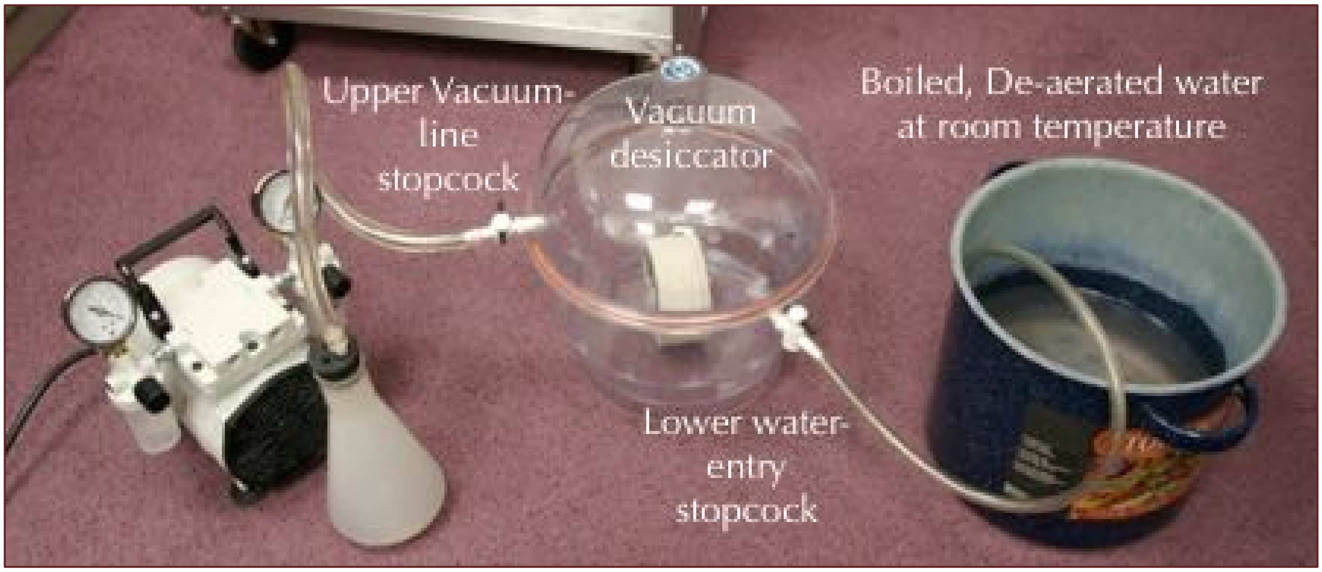


Figure 6: CMC laboratory setup for conditioning of concrete cylinder before rapid chloride permeability test.

h. After soaking for 18 ± 2 hours remove specimen from water, blot off excess water, and transfer to a sealed container that will maintain the specimen in 95% or higher relative humidity unless the specimen is reading for mounting with rubber gaskets for the permeability cells.

Procedures:

i. <u>Proove iT by Germann Instruments</u> – Rapid chloride permeability test was done by using the instrument Proove iT manufactured by Germann Instruments. Figure 7 shows the instrument set up of sample cells as prepared and conditioned for the permeability test:

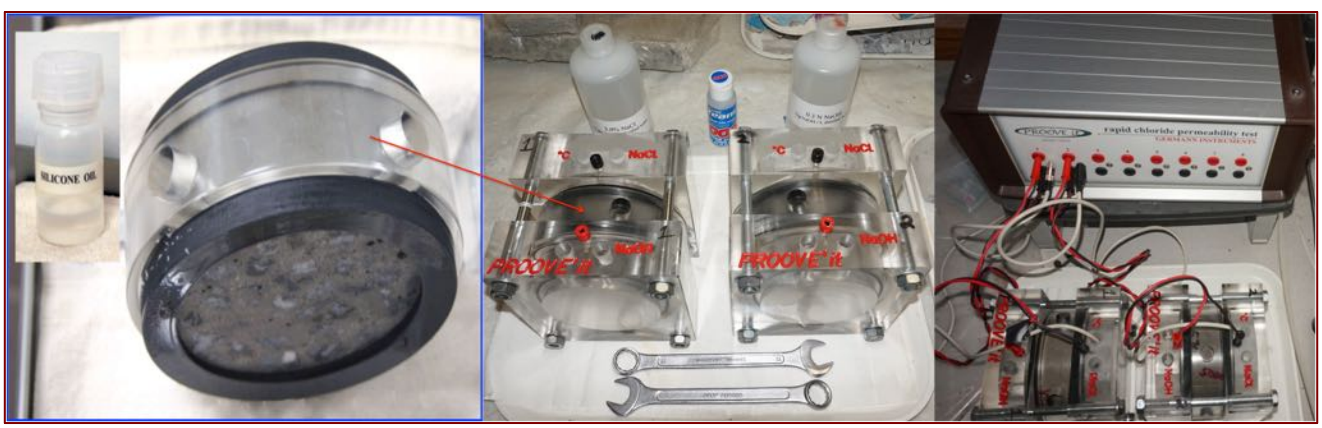


Figure 7: CMC laboratory set-up for conducting rapid chloride permeability test of concrete cylinders.

j. The concrete cylinders ($1^{7}/_{8}$ in. thick, 4-in. diameter) are placed inside a spacer and sealed on both ends by rubber gaskets (thoroughly lubricated by silicone oil, shown at the left photo in Figure 7). The spacer with the concrete was then placed in between the NaCl and NaOH reservoirs (shown in the middle photo) and alternatively tightened the bolts.

k. After checking for leaks in the permeability cells thus prepared (by filling the reservoirs with distilled water and checking for leaks), the NaCl and NaOH reservoirs are respectively filled with 3% NaCl (i.e. 30-gm. NaCl in 1-litre distilled water) and 0.3N NaOH (i.e. 12-gm. NaOH in 1-litre distilled water).

l. The leak-proof cells, thus prepared, are then connected to the Proove iT tester (shown at the back of right photo) by connecting appropriate black (for NaCl) and red (for NaOH) cables for each cell to the numbered connectors in the Proove iT, as well as connecting the temperature gage and placing the probe in the C hole in the NaCl reservoir of the cell (shown in the front of right photo).

m. The Proove iT Tester was then turned on, along with the Proove iT software in the PC. The instrument recognized the cells/samples with green light.

n. Appropriate parameters for the runs were then inserted in the Proove iT program software set-up by selecting voltage – 60V, testing time – 6-hour for each sample/channel, specimen diameter – 100 mm for each sample/channel, and maximum temperature – 90ºC. Runs for each channel/sample was then started and ran for 6 hours.

o. At the end of the run, reports were prepared for each sample with the CMC project number and sample identifications.

AIR-VOID ANALYSIS (ASTM C 457)

The cylinder for air-void analysis was tested and examined by using the ASTM Standard Practice of air-void analysis by following the modified point count method, as mentioned in ASTM C 457 “Standard Test Method for Microscopical Determination of Parameters of the Air-Void System in Hardened Concrete,” where the steps followed during air-void analysis are given below. Details of sample preparation for air-void analysis are given in Jana 2007.

a. The Velmex point-count device used in the analysis (see Figure 8) is comprised of a platform connected to E-W and N-S lead screws and designed in such a way that a lapped concrete sample placed on the stage can be moved smoothly and uniformly through equal distances by turning of the screws. It was ensured that the total possible translation of the stage was at least 100 mm (4.0 in.) in each direction. Lead screws were fitted with notched wheels and stopping devices, such that with each rotation of the screws the operator can detect a click when a stop position was reached. It was ensured that the intervals between the stops correspond to a translation of the stage a distance of 0.025 to 0.64 to 5.0 mm (0.025 to 0.200 in.). The magnitude of the average translation of the stage between stops was determined to the nearest 0.03 mm (0.001 in.). A total of six digital counters were used for calculating aggregates, paste, entrained and entrapped voids, and total voids intercepted during the traverse.

b. A high-resolution Olympus SZH stereomicroscope attached to a high-resolution digital microscope camera was used to capture live image of the lapped concrete surface on the PC screen.

c. A lapped section of concrete was place on the stage of the point-count device. Using the spirit level, the prepared surface was leveled with the leveling device so that the surface may be traversed and microscopically examined with a minimum of refocusing. Lamp was adjusted so the beam evenly illuminated the field of view of the microscope and was incident upon the surface at a low angle, so the air voids were demarked by a shadow. Superimposed in the computer screen was the index point of the cross hairs to pinpoint the area to be counted. A magnification not less than 50X was used and wasn’t changed during the course of the analysis. For a rectangular lapped section, the index was placed near an upper corner (for a circular section, it is usually placed near the top) and at one end of the initial traverse. The stopping device was positioned at a stop or click position at the beginning of the traverse. The initial stops for each traverse line were not included in the total number of stops or in the number of stops for any component. Zeroed all counters. By operation of the E-W lead screw, caused movement of the stage and specimen while simultaneously scrutinizing the surface. At each click stop, except not at the beginning of any traverse line, paused and examined the field of view, and recorded on the appropriate counter the material or phase on which the index point was superimposed. Normally used one counter for air voids, one for paste, and one for all other phases (or a totaling counter). Other components (fine and coarse aggregate, for example—if they are lithologically distinguishable) of the concrete was determined with the use of additional counters. Continued in this way along the line until a last stop is reached just within the prepared area, but close to its edge. When the end of the line is reached, turned off the totaling counter. Reversed the E-W lead screw and proceeded back along the same line, recording on another counter each air void intersected, whether or not a stop has occurred within the air void. Terminated the void counting just before the initial stop. Took extreme care to determine whether a section of an air void was intersected by the movement of the index when the line of traverse is nearly tangent to the void section. The results can be affected significantly by consistent error in this respect. If the periphery of an air void was crumbled or rounded, estimated the position of the true periphery in the plane of the surface by extrapolation of the surface contour of the air void. If the examination was being made to determine only the air content of the concrete, the number of air voids intersected by the line of traverse need not be determined. By means of the N-S lead screw, shifted the concrete specimen at right angles to the direction of traverse an appropriate distance. Spaced the segments of the traverse so as to cover the whole prepared surface and achieved at least the minimum length of traverse and the minimum number of points specified in C 457. Proceeded along the new line of traverse as before, and so on, for all segments of the total traverse and for all sections prepared from a sample of concrete so as to comply with the requirements of this test method.

d. Minimum length of traverse and minimum number of points for the modified point count method are: (a) 2540 mm (100 in.) and 1500 points for $1^{1}/_{2}$-in. nominal size aggregate, (b) 2413 mm (95 in.) and 1425 points for 1-in. nominal size aggregate, (c) 2286 mm (90 in.) and 1350 points for $^{3}/_{4}$-in. nominal size aggregate, (d) 2032 mm (80 in.) and 1200 points for $^{1}/_{2}$-in. nominal size aggregate, and (e) 1905 mm (75 in.) and 1125 points for $^{3}/_{8}$-in. nominal size aggregate.

e. Air-void parameters were calculated by using the equations provided in C 457.

f. The cylinder was sectioned vertically through depth to examine through-depth variation of air content.

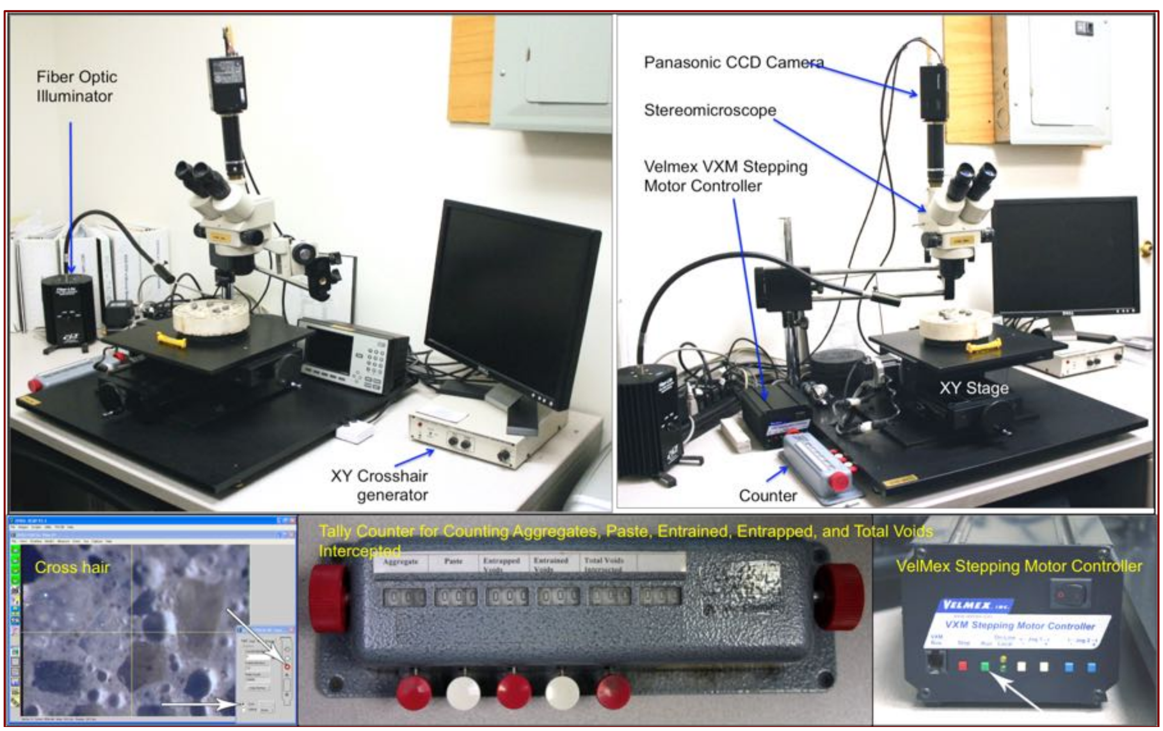


Figure 8: Set-up in the CMC laboratory for air-void analysis in hardened concrete by the modified point count method of ASTM C 457.

LENGTH CHANGE MEASUREMENTS (ASTM C 157)

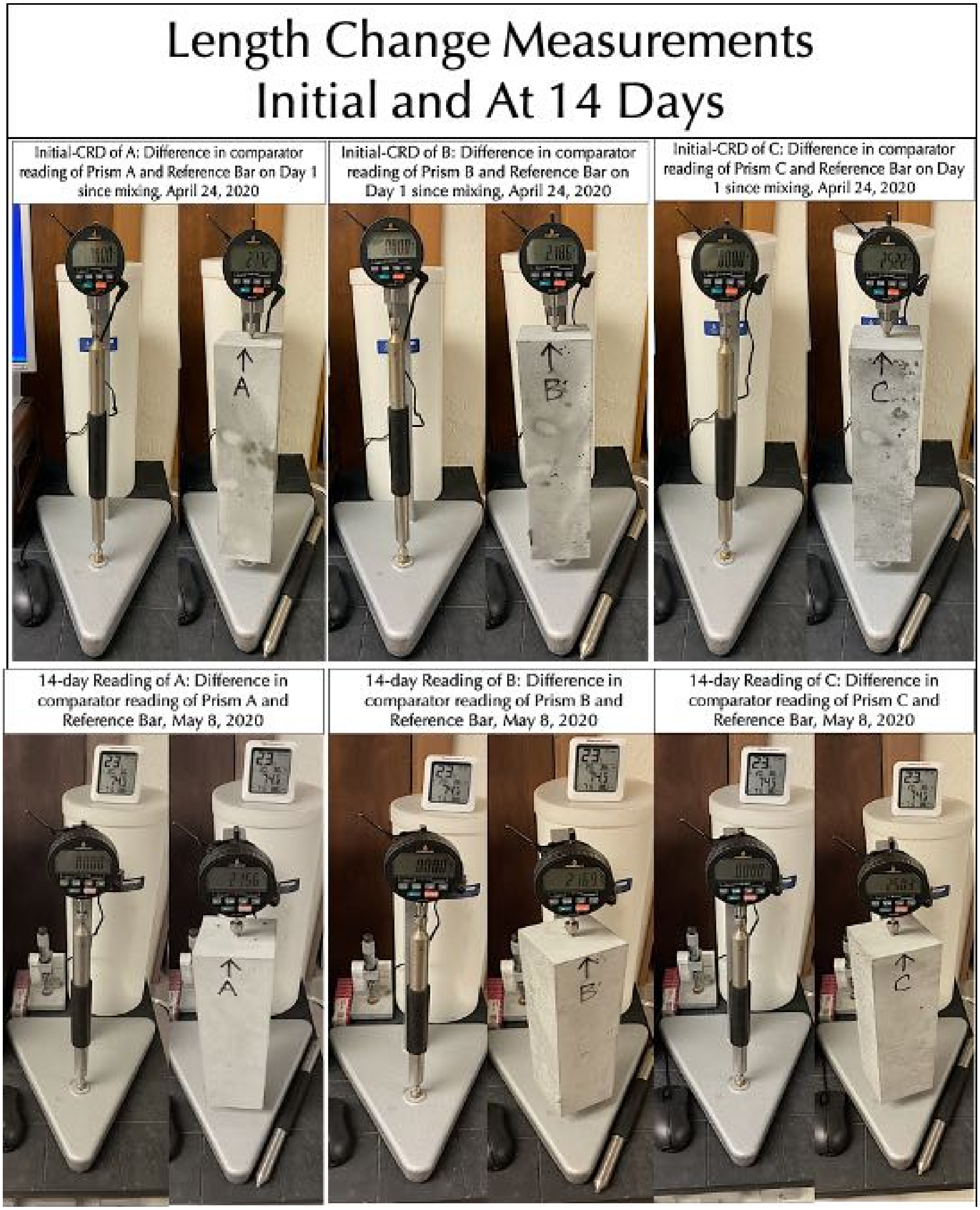


Figure 9: Shown are the photos of measurements of three concrete prisms taken from Humboldt's digital length comparator at the initial reading (without wet curing) and another reading after 14 days of curing of prisms in laboratory air. Each measurement was preceded by a measurement of the reference bar as shown for each prism.

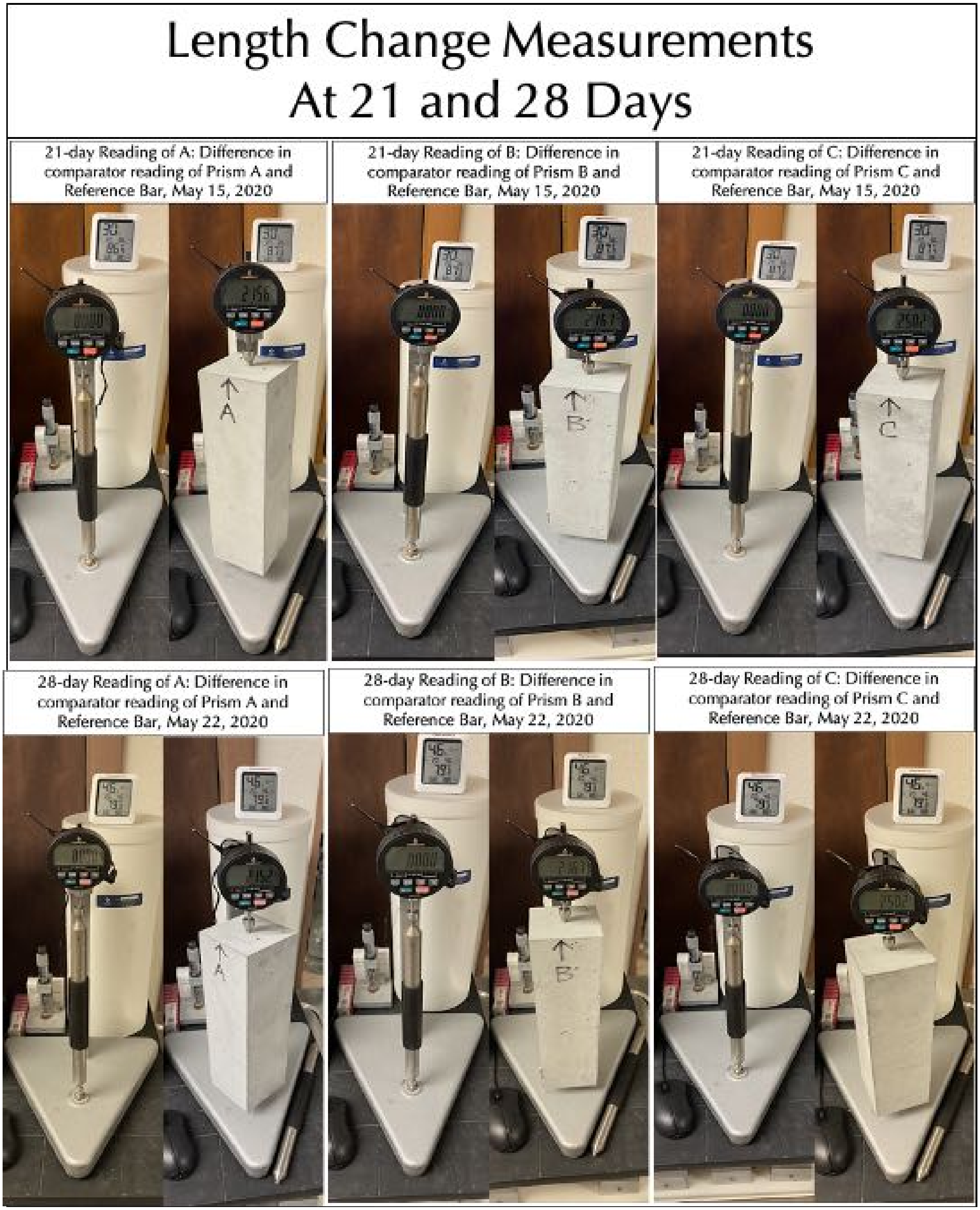
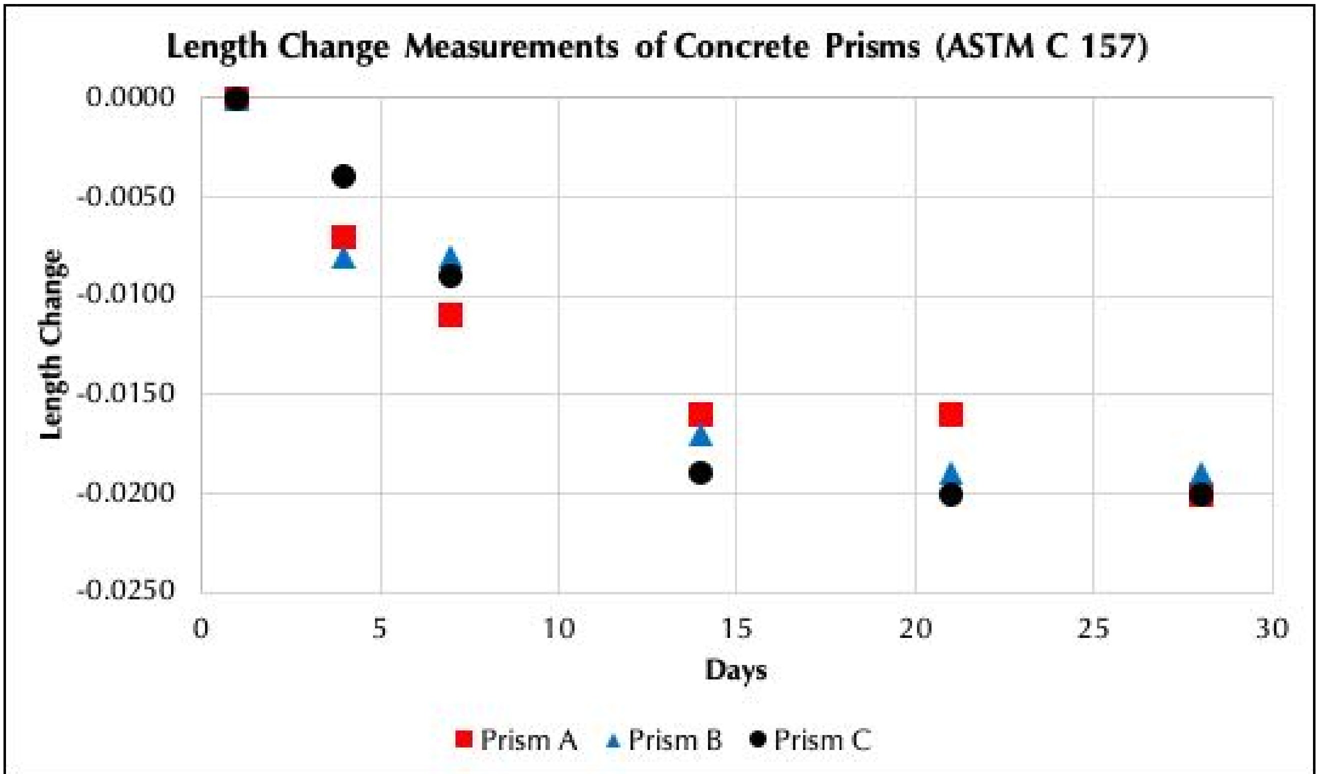


Figure 10: Shown are the photos of measurements of three concrete prisms taken from Humboldt's digital length comparator after 21 and 28 days of curing of prisms in laboratory air. Temperature and relative humidity of ambient laboratory air are also shown for each measurements.

RESULTS

LENGTH CHANGE MEASUREMENTS (ASTM C 157)



Day	Date	Prism ID	Length	ΔL	Date	Prism ID	Length	ΔL	Date	Prism ID	Length	ΔL
1	24-Apr	A	0.2172	0.0000	24-Apr	B	0.2186	0.0000	24-Apr	C	0.2522	0.0000
4	28-Apr	A	0.2165	-0.0070	24-Apr	B	0.2178	-0.0080	24-Apr	C	0.2518	-0.0040
7	1-May	A	0.2161	-0.0110	1-May	B	0.2178	-0.0080	1-May	C	0.2513	-0.0090
14	8-May	A	0.2156	-0.0160	8-May	B	0.2169	-0.0170	8-May	C	0.2503	-0.0190
21	15-May	A	0.2156	-0.0160	15-May	B	0.2167	-0.0190	15-May	C	0.2502	-0.0200
28	22-May	A	0.2152	-0.0200	22-May	B	0.2167	-0.0190	22-May	C	0.2502	-0.0200

Length Change (ΔL)= 100*[(CRD-Initial CRD)/Gage Length 10 in.]

Figure 11: Plot of length change measurements of three concrete prims for 28 days since mixing showing a maximum 0.02 percent shrinkage, which is half of the reported absolute drying shrinkage limit of 0.04 percent for Category II-V applications and less than 0.03 percent limit for Category I and structural slab applications. The wet curing period described in ASTM C 157 was eliminated for all three prims, which were all subjected to air storage for 28 days after removal from molds. Comparator readings were taken at 4, 7, 14, 21, and 28 days as requested after initial comparator reading.

AIR VOID ANALYSIS (ASTM C 457)

Figure 12 shows lapped cross section of concrete cylinder selected for air-void analysis. Figures 13 and 14 show air-void systems of concrete and distribution of entrained and entrapped air voids in the concrete as seen through a stereo-zoom microscope. As seen in these 12 micrographs, the concrete contains many coarser sizes (approaching 1 mm diameter) entrained air voids.

Air occurs as: (i) numerous very fine (less than 100 micron) to fine (100 micron to 1 mm) discrete, spherical and near-spherical voids having sizes of up to 1 mm, and (ii) a few coarse, near-spherical and irregularly shaped voids of sizes coarser than 1 mm. The former voids are characteristic of entrained air, and the latter ones are entrapped air.

Based on detailed air-void analysis, concrete in the cylinder is determined to be air-entrained having a clear evidence of addition of an air-entraining agent. The following Table provides the determined air-void parameters of concrete in the cylinder:

Air-void System and Parameters	CYLINDER 35T1 4-23-20
Air-Void System	Air-Entrained
Total Air Content, %, Determined	4.91
Entrained Air Content, %, Determined	4.50
Paste Content, %, Determined	24.02
Paste-Air Ratio	4.89
Specific Surface, $in.^2/in.^3$	390
Air-Void Spacing Factor, in.	0.0149

Table 1: Properties and parameters of air-void system of concrete in the cylinder. Entrained air-voids are defined as discrete, spherical or near-spherical voids of sizes 1 mm or less. Common industry (e.g., ACI, ASTM) requirements for a concrete containing $^1/_2$ in. nominal maximum size coarse aggregate and exposed to a moist outdoor environment of cyclic freezing and thawing are an air content of $7.5\pm1^1/_2$ percent, a minimum air-void specific surface of 600 $in.^2/in.^3$, and a maximum void-spacing factor of 0.008 in.

Based on the measurements of air-void parameters, the concrete is determined to be air-entrained, however, with a coarse air-void system where the air-void specific surface is less than the common industry-recommended minimum value of 600 $in.^2/in.^3$ and void-spacing factor is greater than the common recommended maximum of 0.0080 inch. The total air content is within the reported design air content range of $6^1/_2 \pm1^1/_2$ percent.

Lapped Cross Section of Cylinder For Air-Void Analysis ASTM C 457

Figure 12: Lapped cross section of a cylinder that was selected for air-void analysis.

The cylinder was sectioned with a water-cooled diamond sectioning saw and then ground with successively finer-sized diamond abrasives mounted on metal or resin-bonded lapping discs mounted on a cast iron lapping plate.

Concrete in the cylinder shows crushed stone coarse aggregates having nominal maximum sizes of 1 in. (25 mm).

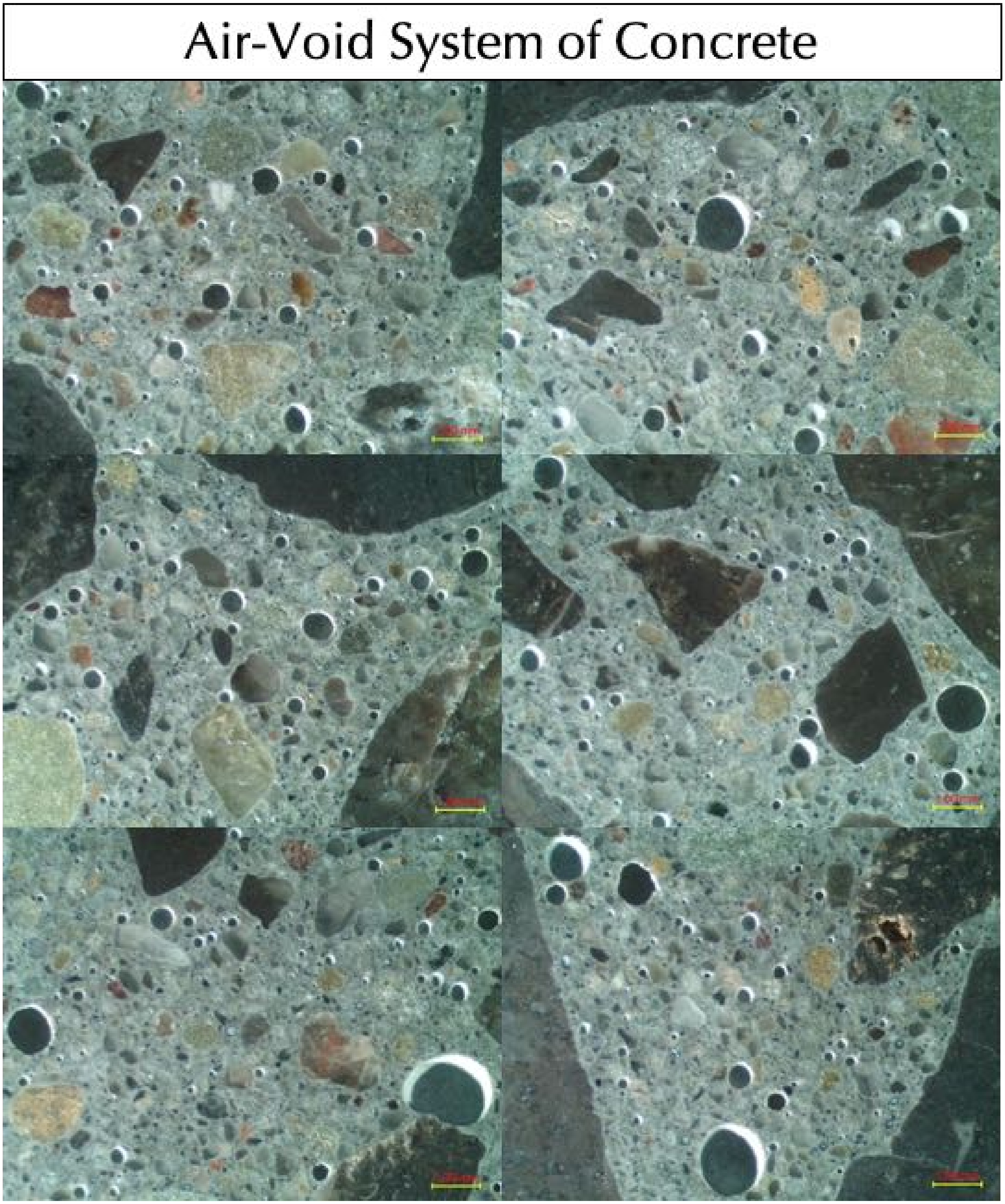


Figure 13: Micrographs of lapped cross section of the cylinder used for air-void analysis showing many spherical and near-spherical, < 1 mm size entrained air voids. Scale bars are of 1 mm.

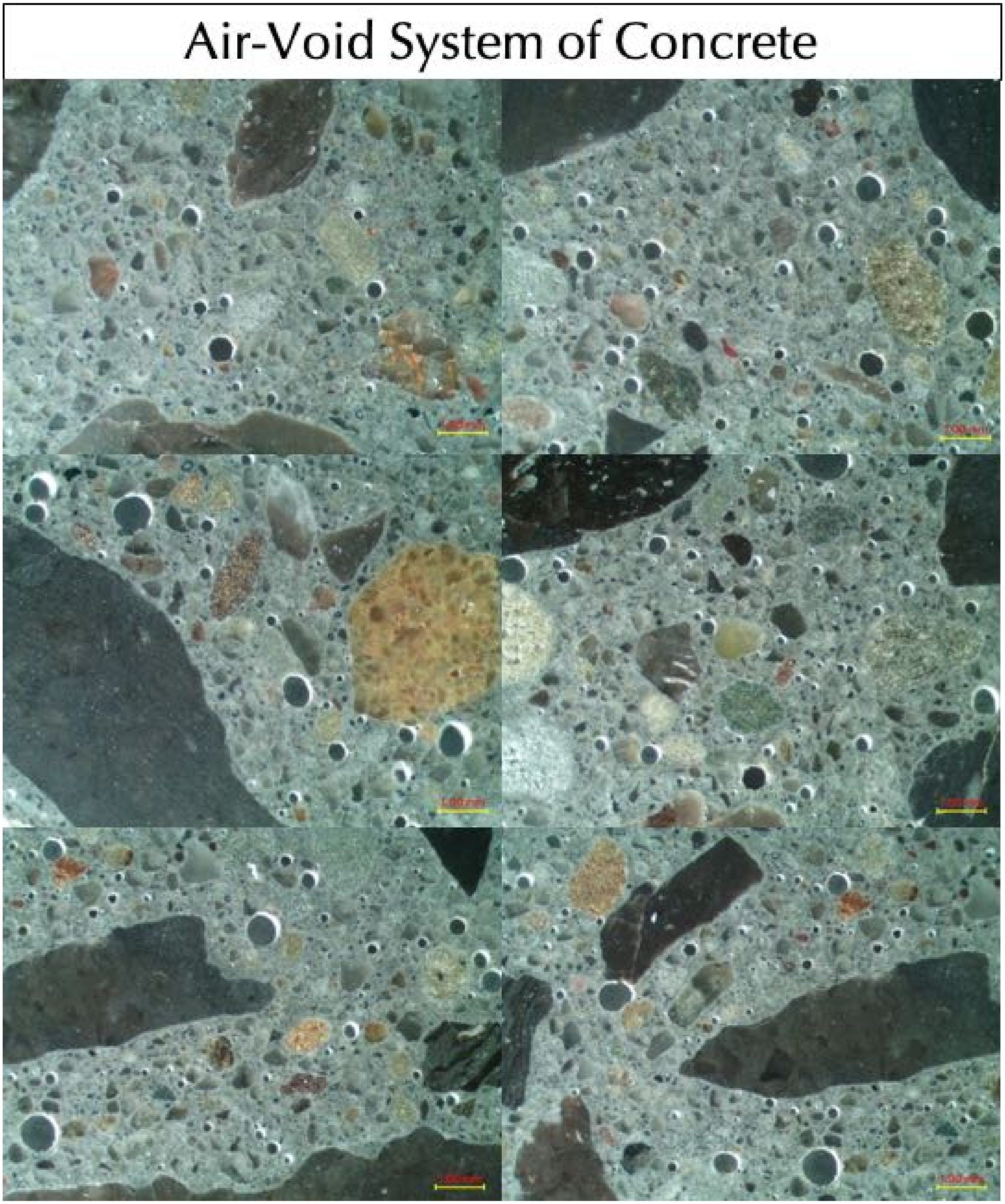


Figure 14: Micrographs of lapped cross section of the cylinder used for air-void analysis showing many spherical and near-spherical, < 1 mm size entrained air voids. Scale bars are of 1 mm.

WATER-SOLUBLE CHLORIDE CONTENT (ASTM C 1218)

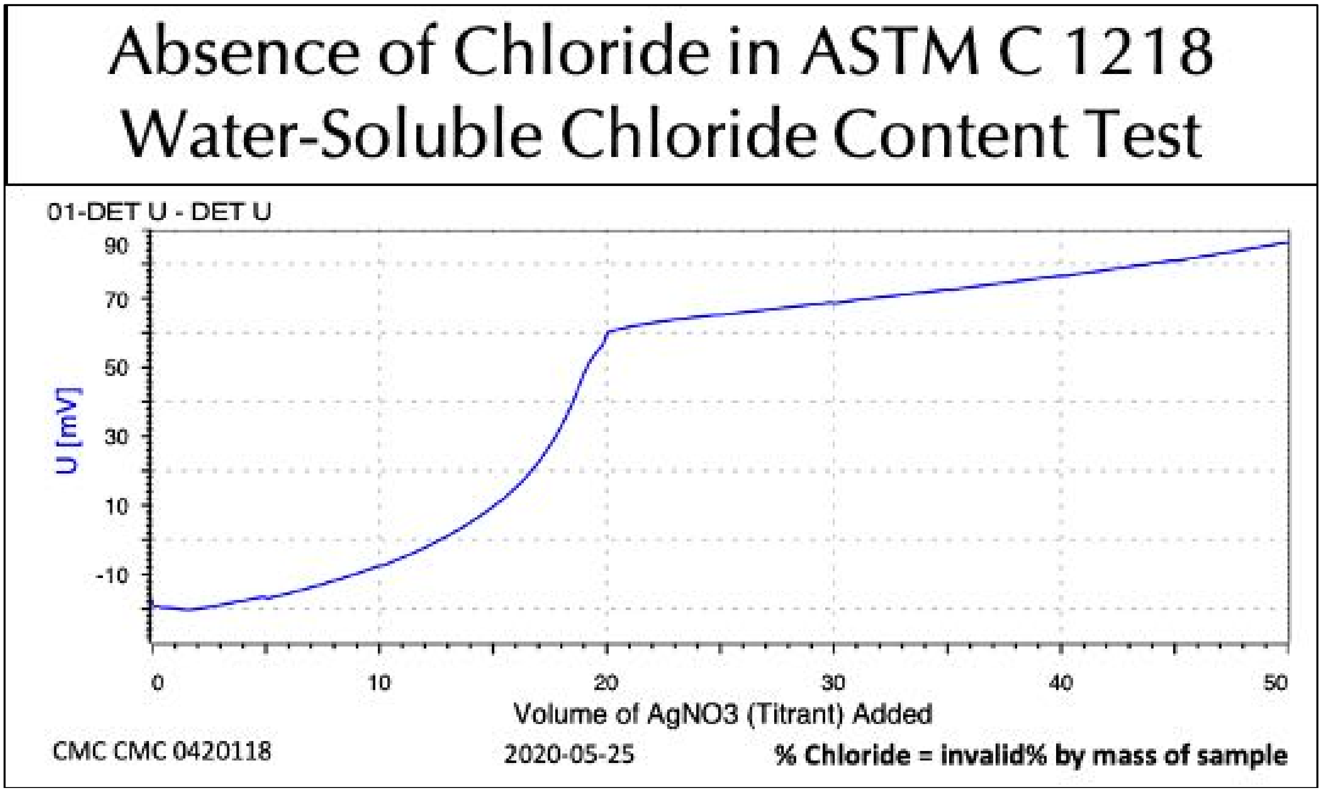


Figure 15: Potentiometric titration of filtrate from the water-digested concrete with silver nitrate titrant showing lack of measurable chloride in the filtrate. No equivalence point of titration was found due to the lack of chloride in the filtrate.

Absence of chloride in potentiometric titration is consistent with the lack of addition of any chloride-containing set-accelerating admixture in the concrete.

RAPID CHLORIDE PERMEABILITY TESTS (ASTM C 1202)

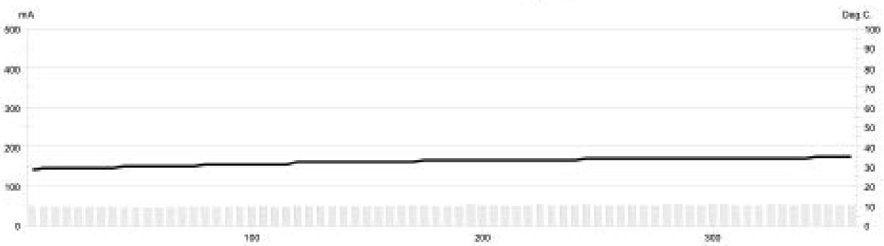
Cylinder 35T1 with CNI: ASTM C 1202

PROOVE it

ASTM C 1202-97

Test report

Voltage Used:	60
Testing time:	06:00 hour
Charge passed:	1028
Adjusted Charge passed:	928
Permeability class:	Very Low
Instrument number:	053204
Channel number:	1
Report date:	5/25/2020
Testing by:	DJ
Reference:	CMC 0520118
Sample diameter:	100
Comment:	Cylinder 35T1 With CNI



Time	°C	mA	Time	°C	mA	Time	°C	mA	Time	°C	mA
00:05	28	44.6	01:35	31	44.8	03:05	33	47.2	04:35	34	48.1
00:10	29	45.3	01:40	31	45.5	03:10	33	47.5	04:40	34	51.4
00:15	29	45.5	01:45	31	46.1	03:15	33	50.5	04:45	34	50.6
00:20	29	45.4	01:50	31	45.6	03:20	33	49.7	04:50	34	49.8
00:25	29	45.3	01:55	31	45.1	03:25	33	49.0	04:55	34	49.1
00:30	29	45.0	02:00	32	46.6	03:30	33	48.2	05:00	34	51.8
00:35	29	44.7	02:05	32	46.7	03:35	33	47.4	05:05	34	50.9
00:40	29	44.1	02:10	32	46.2	03:40	33	48.8	05:10	34	50.0
00:45	30	43.7	02:15	32	45.8	03:45	33	50.3	05:15	34	49.1
00:50	30	43.0	02:20	32	47.0	03:50	33	49.6	05:20	34	49.9
00:55	30	42.5	02:25	32	47.9	03:55	33	48.9	05:25	34	51.6
01:00	30	42.7	02:30	32	47.3	04:00	33	48.0	05:30	34	50.8
01:05	30	44.2	02:35	32	46.6	04:05	34	50.8	05:35	34	49.9
01:10	30	44.5	02:40	32	46.2	04:10	34	50.1	05:40	34	50.8
01:15	30	44.1	02:45	32	48.6	04:15	34	49.3	05:45	35	51.9
01:20	31	43.7	02:50	32	49.3	04:20	34	48.6	05:50	35	50.9
01:25	31	45.2	02:55	33	48.6	04:25	34	48.2	05:55	35	49.9
01:30	31	45.3	03:00	33	47.9	04:30	34	48.1	06:00	35	49.2

Cylinder with CNI:
Permeability Class: Very Low
Adjusted Charge Passed: 928 Coulombs

Figure 16: Rapid-chloride permeability tests of a cylinder containing calcium nitrate corrosion inhibitor, which showed very low permeability of less than 1000 coulombs of passed charged, which is in conformance to the reported maximum accelerated coulomb count of <1000 at 28 days for Category III and IV concrete (7 days standard curing, 21 days at 100 degrees F).

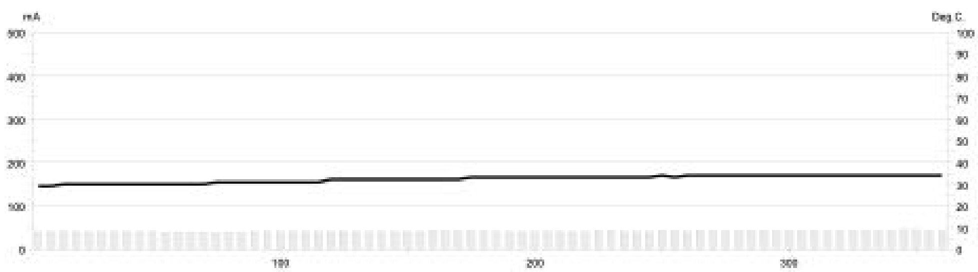
Cylinder 35T2 without CNI: ASTM C 1202

PROOVE it

ASTM C 1202-97

Test report

Voltage Used:	60
Testing time:	06:00 hour
Charge passed:	883
Adjusted Charge passed:	797
Permeability class:	Very Low
Instrument number:	053204
Channel number:	2
Report date:	5/25/2020
Testing by:	DJ
Reference:	CMC 0520118
Sample diameter:	100
Comment:	Cylinder 35T1 Without CNI



Time	°C	mA	Time	°C	mA	Time	°C	mA	Time	°C	mA
00:05	29	39.4	01:35	31	39.9	03:05	33	40.8	04:35	34	41.7
00:10	29	40.2	01:40	31	39.9	03:10	33	40.3	04:40	34	42.4
00:15	30	40.6	01:45	31	39.9	03:15	33	40.2	04:45	34	42.1
00:20	30	40.8	01:50	31	39.9	03:20	33	40.7	04:50	34	42.5
00:25	30	40.9	01:55	31	39.9	03:25	33	40.6	04:55	34	41.9
00:30	30	40.9	02:00	32	39.8	03:30	33	40.5	05:00	34	42.3
00:35	30	40.7	02:05	32	40.2	03:35	33	40.4	05:05	34	42.1
00:40	30	40.4	02:10	32	40.3	03:40	33	40.5	05:10	34	41.8
00:45	30	40.1	02:15	32	40.3	03:45	33	41.3	05:15	34	42.5
00:50	30	39.6	02:20	32	40.3	03:50	33	41.4	05:20	34	42.0
00:55	30	39.0	02:25	32	40.4	03:55	33	40.9	05:25	34	41.5
01:00	30	38.6	02:30	32	40.5	04:00	33	40.9	05:30	34	42.2
01:05	30	38.2	02:35	32	40.6	04:05	33	40.8	05:35	34	41.9
01:10	30	37.9	02:40	32	41.6	04:10	34	41.4	05:40	34	42.6
01:15	31	38.4	02:45	32	41.6	04:15	33	41.3	05:45	34	44.0
01:20	31	38.9	02:50	32	41.5	04:20	34	41.1	05:50	34	43.9
01:25	31	38.9	02:55	33	41.5	04:25	34	41.9	05:55	34	43.4
01:30	31	39.7	03:00	33	41.4	04:30	34	41.4	06:00	34	42.5

Cylinder without CNI:
Permeability Class: Very Low
Adjusted Charge Passed: 797 Coulombs

Figure 17: Rapid-chloride permeability tests of a cylinder without the calcium nitrate corrosion inhibitor, which showed very low permeability of less than 1000 coulombs of passed charged, which is in conformance to the reported maximum accelerated coulomb count of <1000 at 28 days for Category III and IV concrete (7 days standard curing, 21 days at 100 degrees F).

**Portions of Cylinders 35T1 and 35T2
With and without CNI, respectively
After ASTM C 1202 Test**

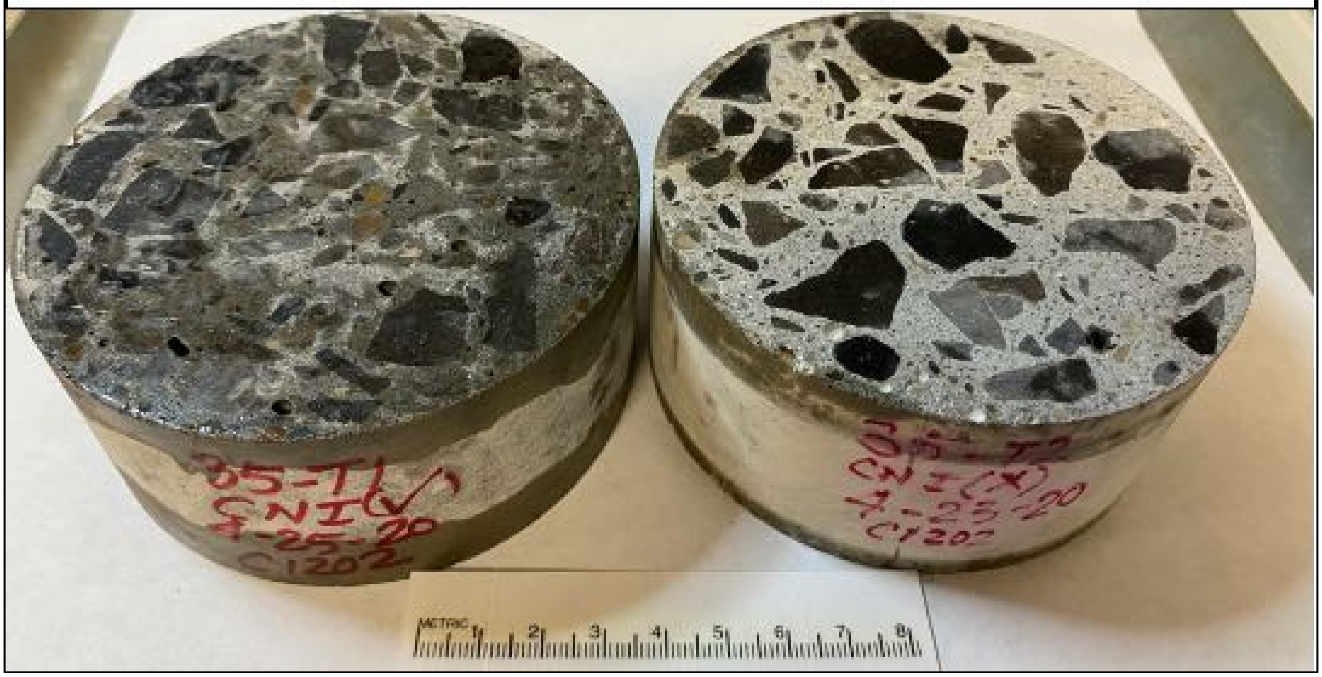


Figure 18: Portions of two concrete cylinders after the rapid chloride permeability tests.

Cylinders	Adjusted Charge Passed (Coulomb)	Permeability Class
With CNI	928	Very Low
Without CNI	797	Very Low

Table 2: Results of rapid chloride permeability tests of portions of two concrete cylinders. Results for both cylinders are in conformance to the reported maximum accelerated coulomb count of <1000 at 28 days for Category III and IV concrete (7 days standard curing, 21 days at 100 degrees F).

CONCLUSION

AIR ENTRAINMENT

Hardened air content of concrete is 4.9 percent of which 4.5 percent is found to be entrained air. Air content is within the design limit of $6^1/_2 \pm 1^1/_2$ percent. However, the concrete has a coarse air-void system where the air-void specific surface is less than the common industry-recommended minimum value of 600 in.^{2}/in.^{3} and void-spacing factor is greater than the common recommended maximum of 0.0080 inch.

CHLORIDE CONTENT

The concrete lacks any detectable chloride in potentiometric titration, which is consistent with the reported lack of addition of any chloride-containing set accelerating admixture.

CHLORIDE PERMEABILITY

Rapid chloride permeability test of two concrete cylinders with and without a calcium nitrate corrosion inhibitor showed very low permeability with passed adjusted coulomb values of 928 and 797, respectively.

LENGTH CHANGE

Length change measurements of three concrete prims during 28 days of laboratory air storage since mixing showed a maximum 0.02 percent shrinkage, which is half of the reported absolute drying shrinkage limit of 0.04 percent for Category II-V applications and less than 0.03 percent limit for Category I and structural slab applications.

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END OF REPORT[1]

[1] The CMC logo is made using a lapped polished section of a 1930's concrete from an underground tunnel in the U.S. Capitol.