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BURNS COOLEY DENNIS, INC.

GEOTECHNICAL AND MATERIALS ENGINEERING CONSULTANTS

MDOT State Study 281—Permeability Reduction of Restrained Concrete in a Chloride-Rich Environment – Phase I

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16. Abstract

The Mississippi Department of Transportation (MDOT) is currently requiring that permeability reducing admixtures be included in concrete mixtures used for bridge deck overlays through Special Provision No. 907-804-1 in an effort to improve the long-term performance of bridges. These admixtures are also included in section 713.02.4 of the 2017 edition of "Mississippi Standard Specifications for Road and Bridge Construction" where these materials are referenced as "waterproofing admixtures." Hydrostatic permeability reducing admixtures (PRAHs) typically contain hydrophilic crystalline materials that react with water and byproducts of hydration to form non-water soluble deposits that reportedly seal pores, capillary tracts, and hairline cracks in hardened concrete. This makes hardened concrete less permeable and more resistant to ingress of chloride ions that corrode reinforcing steel and create costly repairs. This study evaluates two hydrostatic permeability reducing admixtures for their effectiveness in reducing permeability and sealing hairline cracks in hardened concrete. Three concrete mixtures were evaluated including one with no permeability reducing admixture (control mixture) and two mixtures each using a hydrostatic permeability reducing admixture. Hardened concrete properties used in this evaluation included; compressive strength, rapid chloride permeability, surface resistivity, cracking tendency, and chloride ion content. While all data developed for this study did not ascertain the benefit of the current practice of requiring permeability reducing admixtures in portland cement concrete for bridge deck overlays, one product did reduced chloride ion intrusion through hairline cracks when compared to the control mixture.

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List of Abbreviations

AASHTO – American Association of State Highway and Transportation Officials

ACI – American Concrete Institute

MDOT – Mississippi Department of Transportation

OPC – Ordinary Portland Cement

PCC – Portland Cement Concrete

PRAs – Permeability Reducing Admixtures

PRAHs – Hydrostatic Permeability Reducing Admixtures

PRANs – Non-Hydrostatic Permeability Reducing Admixtures

Executive Summary

The Mississippi Department of Transportation is using portland cement concrete (PCC) bridge deck overlays to rehabilitate the surface of otherwise structurally sound bridges that only need bridge deck maintenance. This process of rehabilitating consists of removing the top 1 inch of PCC deck surface and other unsound concrete with the use of hydrodemolition and replacing the removed PCC with a minimum 2-inch thick overlay of new concrete. This concrete not only provides structural support for the deck, it also serves to protect the reinforcing steel from corrosion caused by chloride ions that penetrate into the concrete. Admixtures capable of reducing permeability of concrete in non-cracked areas and/or sealing hairline cracks should enhance the overlay and increase serviceability of the deck. These admixtures are called permeability reducing admixtures (PRAs).

MDOT desired independent data to evaluate the performance of PRAs in concrete exposed to similar conditions as bridge deck overlays. In order to accomplish this, testing was performed on specimens conditioned in a restrained system exposed to a chloride-rich environment. This study used a combination of AASHTO test methods and conditioning of test specimens to simulate field conditions of bridge deck overlays and to evaluate the effectiveness of two hydrostatic permeability reducing admixtures (PRAHs) in reducing chloride ion penetration in concrete.

Results developed using the testing protocol of this study did not definitively show that PRAHs reduce permeability and chloride ion intrusion in PCC. Typical test methods developed for determining permeability of concrete such as rapid chloride permeability and surface resistivity did not definitively show that PRAHs aid in reducing concrete's permeability. Chloride ion content testing showed that one PRAH reduced chloride ion ingress at cracks and the other PRAH increased chloride ion ingress at cracks when compared to the control mixture. Additionally, mixtures containing PRAHs increased concrete's affinity for water indicated by an increase the chloride ion content near the surface of non-ponded areas when compared to the control mixture. MDOT should consider that PRAHs integrally mixed in concrete may be counterproductive in bridge deck overlays if these materials increase concrete's affinity for water. Increasing affinity for water could increase ingress of waterborne chloride ions and other deleterious substances into the concrete.

Introduction/Background

The Mississippi Department of Transportation (MDOT) is using portland cement concrete (PCC) bridge deck overlays to rehabilitate the surface of otherwise structurally sound bridges that only need bridge deck maintenance. This process of rehabilitating a bridge deck consists of removing the top 1 inch of PCC deck surface and other unsound concrete with the use of hydrodemolition and replacing the removed PCC with a minimum 2-inch thick overlay of new concrete. Hydrodemolition is a process that uses a high pressure water jet stream in the range of 15,000 psi to 20,000 psi (Wenzlick 2002) to remove concrete. High early strength concrete (2,500 psi in 24 hours) is used to construct this overlay so the bridge can be quickly opened for traffic. High quality concrete is needed for this overlay not only for structural integrity, but to protect the reinforcing steel from ingress of chloride ions introduced to bridge decks by exposure to seawater or deicing salts. In order to ensure these new overlays have a decreased susceptibility to accelerated deterioration, MDOT now requires the inclusion of permeability-reducing admixtures (PRAs) in the PCC to reduce its permeability which makes the concrete more resistant to chloride ion intrusion. Details of this requirement for bridge deck overlays are presented in Special Provision No. 907-804-1 “Bridge Deck Overlays.”

MDOT concrete specifications for bridge structures provide for concrete with good durability because of its requirements for low water cementitious ratio (0.45 or less), its use of supplementary cementitious materials, and proper curing. However, no concrete is absolutely waterproof. Concrete is a porous material and water carrying chloride ions can penetrate concrete through pores and microcracks (ACI 212.3R 2016). Water carrying chloride ions can enter concrete through two mechanisms including; capillary absorption under non-hydrostatic conditions (often referred to a wicking) and the direct ingress of water under pressure (Kosmatka and Wilson 2016). Absorption occurs when water encounters a dry concrete surface and the water is drawn into the pore structure through capillary suction (Stanish, et al.). Chloride ions can also enter concrete through a process called diffusion (Stanish, et al.). When concrete is saturated and at least one surface is exposed to chloride solution, then diffusion will occur as the solutions seek to attain equilibrium causing the chloride ions from high concentrations to move to low concentrations (Hong 1998).

Permeability reducing admixtures (PRAs) reportedly reduce permeability of concrete by plugging pores and capillaries throughout the entire mass of concrete. This makes concrete less permeable to water and chemicals that corrode reinforcing steel and create costly repairs. PRAs can be divided into two types; 1) Permeability Reducing Admixture – Non-Hydrostatic (PRAN) and 2) Permeability Reducing Admixture – Hydrostatic (PRAH) (Kosmatka and Wilson 2016). Only hydrostatic permeability reducing admixtures were used in this study and these products usually consist of hydrophilic crystal materials. This study utilized two different manufacturers of PRAHs crystalline products. These admixtures react with water and cement hydration byproducts to formulate crystalline structures that seal pores, capillary tracts, and microcracks in hardened concrete. Crystalline materials consist of proprietary active chemicals provided in a carrier of cement and sand (ACI 212.3R 2016). The hydrophilic nature of these materials causes an increase in calcium silicate hydrate (C-S-H) (ACI 212.3R 2016), a primary product of hydrated cement. These crystalline deposits become integrally bound with the hydrated cement paste. These crystalline deposits develop throughout concrete and become a permanent part of the concrete mass. Crystalline materials are hydrophilic meaning they have a strong affinity for water.

As a part of ensuring the safety of the traveling public, MDOT uses deicing materials to keep bridges open to and safe for traffic during times of wintery weather. These deicing materials provide a source of chloride ions that can penetrate into the PCC bridge decks and accelerate the deterioration of the deck reinforcing steel. In order to ensure these new overlays have a decreased susceptibility to accelerated deterioration, MDOT requires the inclusion of PRAs in the PCC which act to reduce its permeability. Reducing the permeability of the PCC is assumed to reduce the rate of sorption and diffusion of chloride ions into the concrete with the intended result of slowing the onset of deterioration in the reinforcing steel.

Bridge structures create a restrained system for concrete shrinkage and many Mississippi bridges are exposed to chloride ions when salt is broadcast on the decks in winter months. Limited data are available to document PRA's performance under these conditions in a bridge deck. This laboratory study uses testing equipment and chloride ion exposure to simulate these field conditions. Data compiled from this study will be used to evaluate the testing protocol for effectiveness in determining the beneficial uses of permeability reducing admixtures in bridge deck overlays and bridge decks.

The objective of this study was to develop a test procedure that MDOT can use to ascertain the benefit of the current practice of requiring PRAs in PCC in a chloride-rich environment. This study is Phase I of a potential two-phase study that will evaluate the beneficial use of other PRAs and cementitious materials in bridge deck overlays and bridge decks. However, the focus of Phase I was to use a combination of AASHTO test methods and conditioning of test specimens to simulate field conditions of bridge deck overlays and to use this testing protocol the test the effectiveness of two commercially available PRAs in reducing chloride ion penetration in concrete.

This objective was achieved by developing and carrying out a laboratory test plan that evaluated the performance of two commercially available admixtures which claim to reduce the permeability of PCC. The experimental plan included provision of test results from PCC mixtures with no PRA; i.e., control samples, to demonstrate the benefit of using the admixture(s) to reduce chloride-ion intrusion.

Three concrete mixtures were tested for fresh and hardened properties including: 1) compressive strength; 2) rapid chloride permeability; 3) surface resistivity; 4) cracking tendency; and 5) chloride ion content. These tests were performed in general accordance with the relevant AASHTO standards, but modified as needed to closer simulate field conditions of bridge deck overlays.

Literature Search

A literature search was performed of test methods available to determine chloride ion content of PCC and available test methods used to measure the rate of chloride ion transport in hardened PCC.

The following list of AASHTO and ASTM testing standards were developed to measure, directly or indirectly, the penetrability of chloride ions into concrete.

1. Salt ponding methods
    a. AASHTO T 259 “Standard Method of Test for Resistance of Concrete to Chloride Ion Penetration”
    b. ASTM C1543 “Standard Test Method for Determining the Penetration of Chloride Ion into Concrete by Ponding”
2. Chloride ion determination
    a. AASHTO T 260 “Standard Method of Test for Sampling and Testing for Chloride Ion in Concrete and Concrete Raw Materials”
    b. ASTM C 1152 “Standard Test Method for Acid-Soluble Chloride in Mortar and Concrete”
    c. ASTM C 1218 “Standard Test Method for Water-Soluble Chloride in Mortar and Concrete”
3. Electrical methods
    a. AASHTO T 277“Standard Method of Test for Electrical Indication of Concrete’s Ability to Resist Chloride Ion Penetration”
    b. ASTM C1202 “Standard Test Method for Electrical Indication of Concrete’s Ability to Resist Chloride Ion Penetration”
4. Resistivity methods
    a. AASHTO T 358 “Standard Method of Test for Surface Resistivity Indication of Concrete’s Ability to Resist Chloride Ion Penetration”
    b. ASTM C1760 “Standard Test Method for Bulk Electrical Conductivity of Hardened Concrete”
5. Fundamental properties of concrete
    a. ASTM C1556 “Standard Test Method for Determining the Apparent Chloride Diffusion Coefficient of Cementitious Mixtures by Bulk Diffusion”
    b. ASTM C1585 “Standard Test Method for Measurement of Rate of Absorption of Water by Hydraulic-Cement Concretes”

The following test methods referenced above have been used in evaluating one or both of the PRAs used in this study to show their effectiveness in reducing the ingress of chloride ions; ASTM C1585, ASTM C1202, and either AASHTO T 260, ASTM C 1152, or ASTM C 1218.

Methodology/Research Approach

Objective

The object was to provide data for MDOT engineers to determine if ordinary portland cement (OPC) with certain permeability-reducing admixtures beneficially reduces the permeability of portland cement concrete (PCC) used for constructing bridge deck overlays in a restrained system for a chloride-rich environment.

Approach

This study is Phase I of a potential two-phase study that will evaluate the beneficial use of other PRAs and cementitious materials in bridge deck overlays and bridge decks. However, the focus of Phase I was to use a combination of AASHTO test methods and conditioning of test specimens to simulate field conditions of bridge deck overlays and to use this testing protocol the test the effectiveness of two commercially available PRAs in reducing chloride ion penetration in concrete.

This objective was achieved by developing and carrying out a laboratory test plan to evaluate the performance of two commercially available admixtures which claim to reduce the permeability of PCC. The experimental plan included provision to test a PCC mixture with no PRA; i.e., control sample, and two mixtures that included a PRA to demonstrate the benefit of using the admixture to reduce chloride-ion intrusion. Experimental mixtures are presented in Table 1. These three mixtures were tested for fresh properties and hardened properties including: 1) compressive strength; 2) rapid chloride permeability; 3) surface resistivity; 4) cracking tendency; and 5) chloride ion content. A summary of tests performed and number of replicate specimens is presented in Table 2. These tests were performed in general accordance with the relevant AASHTO standards, but modified as needed to closer simulate field conditions of bridge deck overlays. Testing was performed on hardened concrete to determine mechanical properties. The test methods used to determine these properties are listed below:

- AASHTO T 22 "Standard Test method for Compressive Strength of Cylindrical Concrete Specimens" – Compressive Strength Test
- AASHTO T 227 "Standard Method of Test for Electrical Indication of Concrete's Ability to Resist Chloride Ion Penetration" –Rapid Chloride Permeability Test
- AASHTO T 259 "Standard Method of Test for Resistance of Concrete to Chloride Ion Penetration" – Salt Ponding Test
- AASHTO T 260 "Standard Method of Test for Sampling and Testing for Chloride Ion in Concrete and Concrete Raw Materials" – Chloride Ion Content Test
- AASHTO T 334 "Standard Method of Testing for Estimating the Cracking Tendency of Concrete" – Restrained Shrinkage Ring Test

- AASHTO T 358 "Standard Method of Test for Surface Resistivity Indication of Concrete's Ability to Resist Chloride Ion Penetration" – Surface Resistivity Test

Results from rapid chloride permeability, surface resistivity, and chloride ion content of mixtures containing PRAs (mixes 2 and 3) were compared to the control mixture without PRAs (mix 1) and used to evaluate the effectiveness of the PRAs.

Table 1. Experimental Mixtures

Mixture Number	Description	Permeability Reducing Admixture
1	Overlay, OPC – 24 hour	None - Control
2	Overlay, OPC – 24 hour	Admixture A (PRAH-1)
3	Overlay, OPC – 24 hour	Admixture B (PRAH-2)

Table 2. Tests Performed on Each Mixture

Test	Replicates	Standard	Specimen Size	Notes
Slump	1 per mix	AASHTO T 119	NA	Fresh Property
Unit Weight	1 per mix	AASHTO T 121	NA	Fresh Property
Air	1 per mix	AASHTO T 152	NA	Fresh Property
Temperature	1 per mix	AASHTO T 309	NA	Fresh Property
Compressive Strength	3	AASHTO T 22	4 x 8	1, 3, 7, 14, 28, 56 days
Cracking Tendency	2	AASHTO T 334	18 ¾ in. outer diameter x 12 ¾ in. inner diameter	Continuous monitoring until cracking occurs. Specimens were monitored for at least two weeks after the specimen cracked.
Surface Resistivity	3	AASHTO T 358	4 x 8	28 and 56 days
Chloride Ion Profile	6 – Not exposed to external chloride ions. 18 – Exposed to external chloride ions. **Sampling depth:** 0.0625 to 0.5 in. 0.5 in. to 1.0 in. 1.0 in. to 1.5 in.	AASHTO T 259 AASHTO T 260	±6 x ±6 x ±3	The ring specimens were used to determine the chloride ion profile.

Materials

This section provides details of the materials used for the laboratory mixtures. All materials were selected from MDOT's approved products list and were also approved by MDOT Technical Advisory Committee members.

Portland Cement

Ordinary Portland Cement (OPC) is hydraulic cement and is the primary cementing material in portland cement concrete (PCC). Portland cement meeting requirements of AASHTO M 85, "Standard Specification for Portland Cement," is hydraulic cement made to conform to specific chemical and physical property limits according to these specifications. Portland cement meeting requirements of both Type I and Type II was used in this study as the primary cementing material. Only one source of portland cement was used. Hydraulic cements react with water to produce calcium silicate hydrate (C-S-H) and other cementing compounds that cause concrete to set and gain strength. A byproduct of this reaction is calcium hydroxide which remains suspended in the concrete matrix and may be available to react with pozzolans such as Class C fly ash, Class F fly ash, or slag cement to create more cementing compounds. Chemical and physical properties of the portland cement used in this study were provided by the supplier and are presented in Table 3.

Supplementary Cementitious Materials (SCMs)

Supplementary Cementitious Materials (SCMs) are included in concrete mixtures as part of the overall cementitious system. SCMs are often used in concrete produced in Mississippi, particularly Class C fly ash and Class F fly ash. SCMs are often added to concrete in order to improve plastic and hardened properties. Class C fly ash was the only SCM used in this study. SCMs have both hydraulic and pozzolanic value in concrete. Pozzolans are materials that have little cementing value by themselves, but will react with calcium hydroxide to provide additional cementing compounds within portland cement concrete.

Fly Ash

Fly ash is finely divided residue of burned ground coal, captured from the flue gases of a coal combustion device, usually at a coal-burning electric power plant. The combustion byproduct is usually harvested with electrostatic precipitators, conveyed to storage and shipping, and is commonly used as a cementitious component of concrete without further processing. Class C fly ash and Class F fly ash conform to the provisions of AASHTO M 295 "Standard Specification for Coal Fly Ash and Calcined Natural Pozzolan for Use in Concrete." Both classes of fly ash are predominately pozzolanic. MDOT bridge deck overly specifications require a minimum of 15 percent fly ash to be used to replace portland cement. Mixtures for this study were proportioned with one source of Class C fly ash. Chemical and physical properties of the Class C fly ash used were provided by the supplier and are presented in Table 4.

Table 3. Portland Cement Properties

Chemical Properties	**Results**
Silicon Dioxide (SiO_2), %	20.4
Aluminum Oxide (Al_2O_3), %	4.8
Ferric Oxide (Fe_2O3), %	3.4
Calcium Oxide (CaO), %	66.3
Magnesium Oxide (MgO), %	1.0
Sulfur Trioxide (SO_3), %	3.1
Loss of Ignition (LOI), %	2.4
Insoluble Residue, %	0.45
Carbon Dioxide (CO_2), %	1.8
$CaCO_3$ in limestone, %	90
Tricalcium Silicate (C_3S), %	62
Dicalcium Silicate (C_2S), %	10
Tricalcium Aluminate (C_3A), %	7
Tetracalcium Aluminoferrite (C_4AF), %	10
$C_3S + 4.75C_3A$,%	96
Alkalies (Na_2O equivalent), %	0.26
Physical Properties	**Results**
Air Content, %	7
Blaine Fineness, m^2/kg	405
Autoclave Expansion, %	0.02
Compressive Strength, 3 day (psi)	3,890
Compressive Strength, 7 day (psi)	5,030
Time of setting (Vicat) Initial Set, minutes	111
Mortar Bar Expansion C1038, %	0.013

Table 4. Class C Fly Ash Properties

Chemical Properties	**Results**
Silicon Dioxide (SiO_2), %	38.68
Aluminum Oxide (Al_2O_3), %	20.56
Iron Oxide (Fe_2O_3), %	6.66
Sum of Constituents, %	65.90
Sulfur Trioxide (SO_3), %	1.51
Calcium Oxide (CaO), %	22.30
Magnesium Oxide (MgO), %	4.42
Sodium Oxide (Na_2O), %	1.39
Potassium Oxide (K_2O), %	0.62
Sodium Oxide Equivalent (Na2o+0.658K2O)	1.80
Moisture Content, %	0.07
Loss on Ignition, %	0.52
Physical Properties	**Results**
Fineness, % retained on No. 325	18.00
Strength Activity Index 7 day, % of control	99
Strength Activity Index 28 day, % of control	115
Water Requirement, % control	95
Autoclave Soundness	0.01
Density	2.61

Aggregates

No. 8 gravel and natural sand were utilized in the mixtures. These aggregates were sampled from the same source. A single sieve analysis was conducted on each aggregate. Two tests were performed on separate samples of each aggregate to determine gravities and absorption. Average properties of aggregates are presented in Tables 5 and 6.

Table 5. Coarse Aggregate Properties: No. 8 Gravel

Sieve Size	Individual % Retained	Total % Passing	MDOT Specifications
¾ in.	0.0	100	100
½ in.	1.2	99	95-100
3/8 in.	3.2	96	75-100
No. 4	69.4	26	5-30
No. 8	24.9	1	0-10
No. 16	0.7	1	0-5
No. 30	0.1	1	
No. 50	0.2	0	
No. 100	0.1	0	
% Finer Than No. 200	0.3		
FM	5.75		
Average Bulk Gravity (DRY)	2.482		
Average Bulk Gravity (SSD)	2.538		
Average Absorption, %	2.26		
Average Unit Weight, pcf	98		
Average Void Content, %	37		

Table 6. Fine Aggregate Properties

Sieve Size	Individual % Retained	Total % Passing	MDOT Specifications
½ in.	0.0	100	100
3/8 in.	0.0	100	97-100
No. 4	4.9	100	92-100
No. 8	7.2	95	75-100
No. 16	8.2	87	45-90
No. 30	16.0	70	25-70
No. 50	49.6	12	3-35
No. 100	10.3	1	0-10
% Finer Than No. 200	1.8		
FM	2.55		
Average Bulk Gravity (DRY)	2.639		
Average Bulk Gravity (SSD)	2.643		
Average Absorption (%)	0.13		

Chemical Admixtures

All mixtures included one Type A water reducing admixture and one Type F water reducing admixture meeting requirements of AASHTO M 194 “Standard Specifications for Chemical Admixtures for Concrete.” All mixtures included an air-entraining admixture meeting the requirements of AASHTO M 154 "Standard Specifications for Air-Entrained Admixture." See Table 7 for products and dosage rates for each mixture. The manufacture's statement on the use of calcium chloride is as follows: "The admixture does not contain calcium chloride or chloride containing compounds as a functional ingredient. Chloride ions may be present in trace amounts contributed from the process water used in manufacturing."

Table 7. Admixture Dosage Rates

Admixture	Dosage Rate (oz. per 100 lbs. cementitious)	Dosage Rate (oz. per cubic yard)
Air Entraining	0.71	4.15
Water Reducer Type A	4.00	23.52
Water Reducer Type F	16.63	97.76

Concrete Mixtures

Three mixtures were utilized to develop data for this study. Compressive strength, rapid chloride permeability, surface resistivity, cracking tendency, and chloride ion content are properties that were tested. Mixtures were proportioned in 3.00 cubic feet batches to produce enough material to fabricate test specimens. The specimen sizes and number of replicates are presented in Table 8.

Table 8. Number of Replicates and Size of Test Specimens

Test	Replicates	Standard	Specimen Size (in.)	Specimen Age (days)
Compressive Strength	3	AASHTO T 22	4 x 8	1,3,7,14,28,56
Rapid Chloride Permeability	2	AASHTO T 227	4 x 2±0.125-in. thick	28,56
Surface Resistivity	3	AASHTO T 358	4 x 8	28,56
Cracking Tendency	2	AASHTO T 334	18 ¾ in. outer diameter x 12 ¾ in. inner diameter	NA

Mixture proportions were based on criteria established in Special Provision No. 907-804-1 and by the MDOT Technical Advisory Committee along with the author of this report. These criteria are summarized in Table 9 and the mixture proportions are present in Table 10. Mixture proportions were based on a nominal air content of 4.5 percent. Details of the mixtures are a presented in Appendix A "Mixture Proportions."

Table 9. Bridge Overlay Mixtures

Minimum Cementitious Content	564 lbs/cy
Minimum Fly Ash Replacement Required	15%
Coarse Aggregate Size	#7, #8, or #78
Coarse Aggregate Type	see Subsection 907-804.02.2.1
Synthetic Structural Fibers[1]	see Subsection 907-804.02.2.2
Total Air Content	3 - 6%
Maximum Slump	6 inches
Required Compressive Strength	2,500 psi in 24 hours

Note 1: Synthetic structural fibers were not included in mixtures tested in the study.

Table 10. Summary of Mixture Proportions

Material	Mix 1 (Control)	Mix 2	Mix 3
Ordinary Portland Cement (pcy)	500	500	500
Class C Fly Ash (pcy)	88	88	88
Total Cementitious (pcy)	588	588	588
Water (pcy)	245	245	245
Water (gallons/cy)	29.4	29.4	29.4
w/cm ratio	0.417	0.417	0.417
Coarse Aggregates SSD (pcy)	1700	1700	1700
Fine Aggregate SSD (pcy)	1326	1326	1326
Air (oz/cy)	4.15	4.15	4.15
Type A Water Reducer (oz/cy)	23.52	23.52	23.52
Type F Water Reducer (oz/cy)	97.76	97.79	97.79
PRA (pcy)	None	5.88 (PRAH-1)	11.76 (PRAH-2)

Laboratory Testing

Aggregate Testing

Aggregate testing was performed to determine if samples met MDOT requirements and to determine aggregate properties needed for concrete mixture proportioning. These tests include; 1) AASHTO T 85 "Specific Gravity and Absorption of Coarse Aggregate," 2) AASHTO T 84 "Specific Gravity and Absorption of Fine Aggregate," 3) AASHTO T 27 "Sieve Analysis of Fine and Coarse Aggregates," and 4) AASHTO T 19 "Bulk Density (Unit Weight) and Voids in Aggregate" for the coarse aggregate. Details of aggregate testing are presented in Appendix B "Aggregate Properties."

Mixing

Mixing was conducted in 3.00 cubic feet batches using a revolving drum mixer in accordance with AASHTO R 39 "Standard Practice for Making and Curing Concrete Test Specimens in the Laboratory."

Fresh Concrete Properties

Each batch was tested for unit weight, yield, slump, air content (pressure method), and temperature. All testing was performed by certified ACI Grade 1 Field-Testing Technicians in accordance with the following standards:

- **Density and Yield** – AASHTO T 121 "Standard Test Method for Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete" (Figure 1)
- **Slump** – AASHTO T 119 "Standard Test Method for Slump of Hydraulic-Cement Concrete" (Figure 2)
- **Air Content (Pressure Meter)** – AASHTO T 152 "Standard Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method" (Figure 3)
- **Making and Curing Cylinders** – AASHTO R 39 "Standard Practice for Making and Curing Concrete Test Specimens in the Laboratory" (Figure 4)
- **Temperature** – AASHTO T 309 "Standard Test Method for Temperature of Freshly Mixed Hydraulic-Cement Concrete"

Figure 1. Density and Yield

Figure 2. Slump

Figure 3. Pressure Meter

Figure 4. Making Cylinders

Hardened Concrete Properties

Compressive Strength

Compressive strength specimens were cast immediately following testing of plastic properties. Technicians made 4 in. x 8 in. strength specimens and used rodding as the method of consolidation. Upon completion of consolidation, strike-off, and finishing of the top surface, strength specimens were moved to a temperature controlled moisture room for curing until time of testing. These specimens were tested in accordance with AASHTO T 22 "Standard Test method for Compressive Strength of Cylindrical Concrete Specimens." Eighteen specimens were tested for each mixture as follows: 3 specimens at 1-day, 3 at 3-days, 3 at 7-days, 3 at 14-days, 3 at 28-days, and 3 at 56-days. Unbonded capping was utilized in accordance with ASTM C 1231 "Standard Practice for Use of Unbonded Caps in Determination of Compressive Strength of Hardened Concrete Cylinders." Specimens for test ages 28-days and 56-days were first tested for surface resistivity in accordance AASHTO T 358 "Standard Method of Test for Surface Resistivity Indication of Concrete's Ability to Resist Chloride Ion Penetration" before testing for compressive strength. Details of compressive strength testing are presented in Appendix C "Compressive Strength."

Rapid Chloride Ion Permeability

Resistance to chloride ion penetrability was determined according to AASHTO T 277 "Standard Test Method for Electrical Indication of Concrete's Ability to Resist Chloride Ion Penetration." Specimens were cast utilizing 4 x 8 inch cylinder molds. Two specimens were cast for each mixture and the average coulomb reading of the two specimens was reported. Details of rapid chloride permeability testing are presented in Appendix D "Rapid Chloride Ion and Surface Resistivity."

Specimens were cast and compacted utilizing rodding according to AASHTO 39. Specimens were immediately placed into a moist curing room for a 24 hour initial curing period. After initial curing, specimens were labeled with identifying information using a permanent marker. Specimens were placed back into the moisture room and moist cured until the time of testing. Specimens were removed from the moisture room and the top 2.0 ± 1/8 in. was cut for testing. The unused portion of the sample was immediately returned to the moisture room for future penetrability testing. Once cleaned, the samples were towel dried and placed in front of a fan to remove excess surface moisture. Once dry, the samples received a coating of quick setting epoxy on the perimeter of the specimens. Specimens were placed in a vacuum desiccator in a vacuum greater than 50 mm Hg. Once vacuum was achieved, they were left under vacuum for 3 hours and then water was introduced to the desiccators while maintaining the vacuum. The specimens remained under water and vacuum for one additional hour. The specimens remained under water for 18 ± 2 hours.

The specimens were removed from the desiccators and excess water was removed. Specimens were then placed in testing cells utilizing rubber gaskets and secured with bolts to prevent leaking. Testing cells had solutions of 3.0% sodium chloride (NaCl) in one cell and 0.3 normality (N) sodium hydroxide (NaOH) in an adjacent cell. A positive lead was attached to the cell containing the 0.3 N NaOH solution and a negative terminal attached to the cell with 3.0% NaCl. Ample solution was added to completely cover the entire ends of the specimens (Figure 5). An apparatus with a power supply and digital readout (Figure 6) was used to apply a constant 60 ± 0.1 volt DC current to the specimens and record coulombs. Once testing began the apparatus automatically took readings at 30 minute intervals and calculated the coulomb values. The coulomb value was adjusted for specimen diameter according to AASHTO T 277. This testing was conducted on two specimens cut from two cylinders and the average adjusted coulomb value was calculated and reported.

Table 11 is an excerpt from AASHTO T 277 that provides a correlation between charge passed (coulombs) and penetrability rating for the concrete ranging from negligible to high.

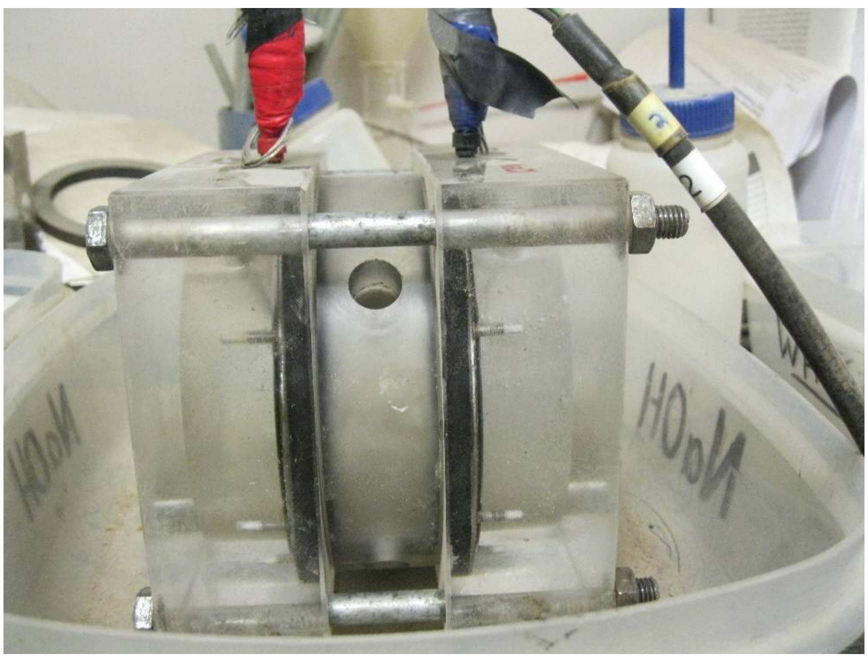

Figure 5: Penetrability Specimen in Test Cell

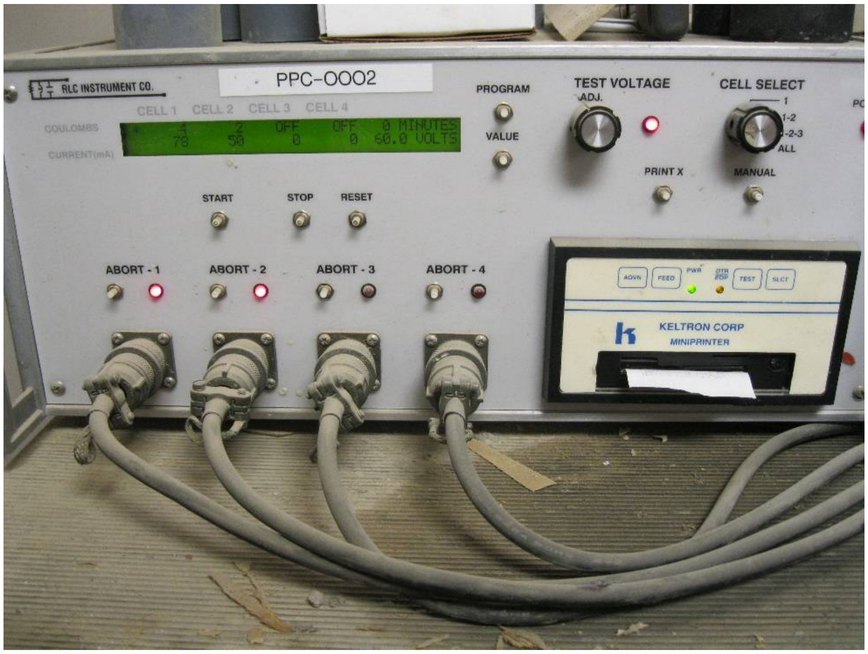

Figure 6: Chloride Ion Penetrability Apparatus

Table 11: Chloride Ion Penetrability based on Charge Passed

Charge Passed (coulombs)	Chloride Ion Penetrability
>4,000	High
2,000 – 4,000	Moderate
1,000 – 2,000	Low
100 – 1,000	Very Low
<100	Negligible

Surface Resistivity

This test method consist of measuring the electrical resistivity of water-saturated 4 by 8 in. concrete specimens by using a 4-pin Wenner probe array. See Figure 7 for a photograph of the probe used. Surface resistivity of concrete expressed in kilohms-centimeters (kΩ-cm) was determined at specimen ages of 28 and 56 days. Details of surface resistivity testing are presented in Appendix D “Rapid Chloride Ion and Surface Resistivity.”

The specimens were taken from the moist storage room and placed in a container of water to ensure that the surface was fully saturated. The specimens were then placed in a specimen holder for testing. The prongs of the apparatus were push down into a container of water to saturate the sponges on the prongs. The probe was then placed on the specimen, prongs push against the test specimen, and readings taken directly from the apparatus. Readings were taken at 0°, 90°, 180°, and 270°. A second set of readings were taken and the two results were averaged to determine the surface resistivity of the specimen. This procedure was repeated on two companion specimens and an average of the three was determined and reported as the surface resistivity for the test age. A table indicating kilohms-centimeters and chloride ion penetrability is presented in AASHTO T 358. This table provides ratings of penetrability ranging from negligible to high based on kilohms-centimeters readings. Relevant portions of this table are presented in Table 12.

Figure 7. Four-Point Wenner Apparatus

Table 12. Chloride Ion Penetration

Chloride Ion Penetrability	4 by 8 inch. Cylinder (kΩ-cm)
High	<12
Moderate	12-21
Low	21-37
Very Low	37-254
Negligible	>254

Cracking Tendency

Cracking tendency was determined in general accordance with AASHTO T 334 "Standard Method of Test for Estimating the Cracking Tendency of Concrete." This test method was used to evaluate volume change properties of the mixtures and to induce shrinkage cracks within the concrete ring specimens for the permeability reducing admixtures to seal. Two ring specimens were cast for each mixture. A 12-3/4 in. diameter x 6 in. high steel pipe was used for the inner form and a 1/8 in. thick metal form was used for the outer form. See Figure 8 for a photograph of steel forms used for cracking tendency testing.

Samples were fabricated in accordance with AASHTO T 334. Specimens were then immediately moved to the curing room. This curing room had a temperature and humidity controlled environment of 50% ± 4% relative humidity and 73 ± 3 ° F (Figure 9). Curing of the specimens follow this requirement of AASHTO T 334 except specimens were moist cured for 14 days in lieu for the first 24 hours. This was accomplished with the use of wet burlap covered with polyethylene sheeting. The burlap was periodically checked and tap water was added as needed with a spray bottle to keep the burlap wet (Figure 10). This method of curing was implemented in our testing protocol to simulate wet curing of a bridge deck. After the 14 day moist curing period, the wet burlap and polyethylene sheeting were removed and the specimens were exposed to drying conditions for a period of 56 days. Strain was monitored during this 70 day period.

Four strain gages were installed at equidistance on the inside surface of the inner steel ring. These gages were wired for a ¼ bridge circuit. Strain measurement using a ¼ bridge circuit involves wiring a strain gage as one leg of a full-bridge circuit, applying a voltage across the bridge, and measuring the voltage across the two intermediate bridge nodes via a pair of instruNet Vin+ and Vin- input terminals. The excitation voltage for the bridge was supplied by instruNet. See Figures 11 and 12 for a schematic of the strain gage wiring and attachment.

The data acquisition system consists of OMEGA's Inet-555 Starter system with three INET strain gage wiring boxes and two INET-420 voltage input modules (Figure 13). This system allowed for monitoring and recording twenty-five strain gages. The twenty-five gages included four for each ring specimen and two specimens per mixture. One strain gage was used to monitor a steel ring to have the ability to adjust final readings for influence of temperature on stain in the steel rings. Omega's BCM-1 was used to complete the Wheatstone Bridge circuit. This system was then connected to a laptop computer with Windows 10 operating system for data processing and recording. This system monitored and recorded strain at 1 minute intervals.

Figure 8. Molding of Cracking Tendency Specimens

Figure 9. Cracking Tendency Specimens in Curing and Test Room

Figure 10. Wet Curing of Cracking Tendency Specimens

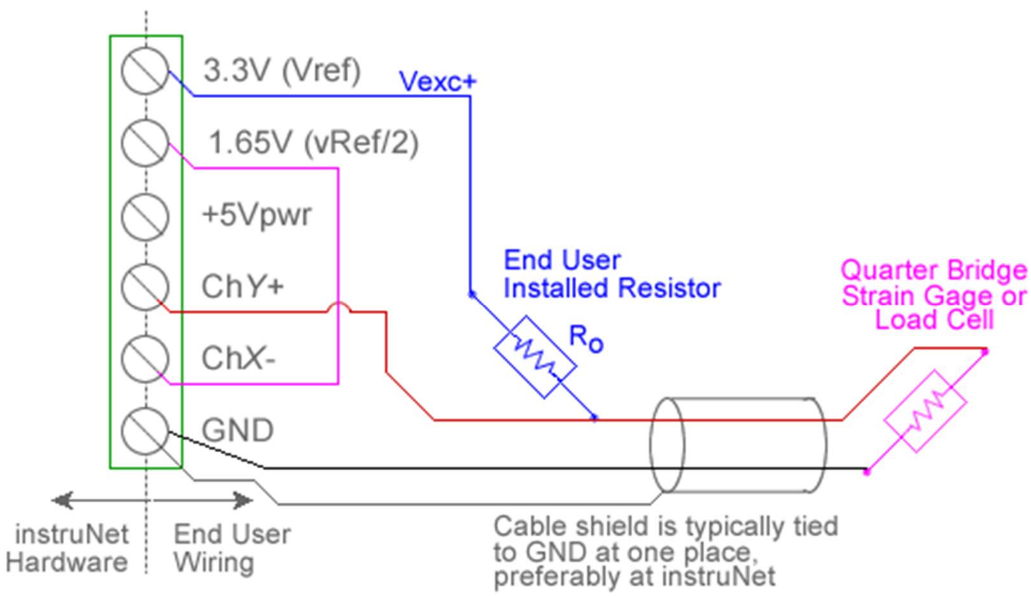

Figure 11. Schematic of Strain Gage (From Omega's Website)

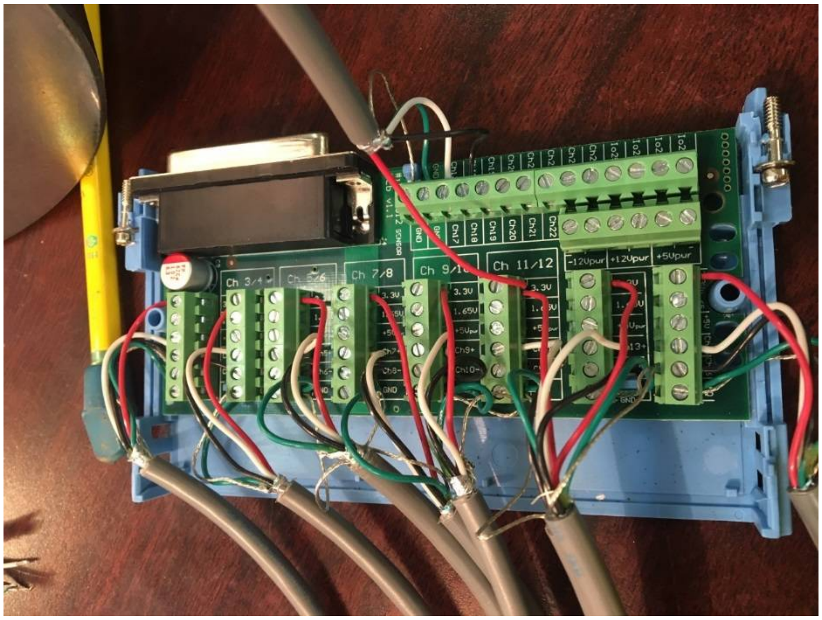

Figure 12. Strain Gage Attachment

Figure 13. Data Acquisition System

All ring specimens cracked during the 56-day drying period. These cracks extended vertically through the depth of the concrete rings. Crack widths were measured after the drying period with the use of a crack width comparator. Five measurements were taken along the vertical face of the ring. These measurements are presented in Table 13. A photograph of the shrinkage crack in mix 3, ring B is shown in Figure 14.

Table 13. Measurements of Crack Widths (mm)

Mix No.	**1**		**2**		**3**	
Ring	E	F	C	D	A	B
Width 1	0.1	0.1	0.1	0.1	0.1	0.1
Width 2	0.1	0.1	0.1	0.1	0.1	0.1
Width 3	0.1	0.1	0.1	0	0.2	0.1
Width 4	0.1	0.1	0.1	0	0.2	0.1
Width 5	0.1	0.1	0.1	0	0.1	0.1

Figure 14. Drying Shrinkage Crack – Mix 3, Ring B

In order to create favorable conditions for the PRAs to react and seal cracks, a 28-day period of wetting and drying cycles was added to our testing protocol. This water curing period after drying was implemented to provide water for the reaction needed. The water simulates rain events on bridge decks. Wetting / drying cycles were also implemented to better simulate in service conditions of bridge decks. The 28-day wetting / drying period was followed by 28 days of drying before exposing the specimens to a chloride-rich environment. The ring specimens were stored in laboratory conditions for the wetting and drying cycles then placed in a temperature and humidity controlled room with 50% ± 4% relative humidity and 73 ± 3 ° F for

28 days of drying. A summary of conditioning of cracking tendency specimens is presented in Table 14.

Table 14. Wetting and Drying Conditioning of the Cracking Tendency Specimens

Beginning Date	Ending Date	Total Time (Days)	Task
4/24/2019	4/25/2019	1	Distilled Water Ponding
4/25/2019	4/29/2019	4	Drying
4/29/2019	4/30/2019	1	Distilled Water Ponding
4/30/2019	5/1/2019	1	Drying
5/2/2019	5/3/2019	1	Distilled Water Ponding
5/3/2019	5/6/2019	3	Drying
5/6/2019	5/7/2019	1	Distilled Water Ponding
5/7/2019	5/9/2019	2	Drying
5/9/2019	5/10/2019	1	Distilled Water Ponding
5/10/2019	5/13/2019	3	Drying
5/13/2019	5/14/2019	1	Distilled Water Ponding
5/14/2019	5/16/2019	2	Drying
5/16/2019	5/17/2019	1	Distilled Water Ponding
5/17/2019	5/20/2019	3	Drying
5/20/2019	5/21/2019	1	Distilled Water Ponding
5/22/2019	5/23/2019	1	Drying
5/23/2019	5/24/2019	1	Distilled Water Ponding
5/24/2019	6/21/2019	28	Drying Before Chloride Ponding
6/21/2019	9/19/2019	90	Chloride Ion Ponding

Chloride Ion Content

In order to create a chloride rich environment, chloride ions were introduced to the specimens. This was accomplished by ponding chloride-rich water on the surface of the bottom half of the specimens. The top half of the specimens (non-ponded) did not have chloride-rich water introduced to the surface. Ponding procedures of AASHTO T 259 "Standard Method of Test for Resistance of Concrete to Chloride Ion Penetration" were modified for use with the concrete ring specimens. This procedure included ponding the bottom 3 in. of the specimen in a 3 percent sodium chloride solution to a depth of approximately ¾ in. A copolymer polypropylene riser from Tuf-Tite was used to create the outer ring for ponding chloride-rich water. Concentric circles were counter bored in the ultra-high molecular weight bases and silicon sealant was used to create a watertight seal. See Figure 15 for a photograph of the ponding apparatus. The ring specimens were stored in the temperature and humidity room with 50% ± 4% relative humidity and 73 ± 3 ° F for 90 days of chloride-rich water ponding.

Figure 15. Apparatus for Ponding with Chloride-Rich Water

A grinder was used to remove all salt crystal buildup before drilling into the specimens to collect samples to determine chloride ion content. This was done so that samples could be collected without fear of contamination from the salt on the surface. A photograph of the prepared surface is shown in Figure 16. These samples were collected in general accordance with AASHTO T 259 using a rotary hammer to collect samples with a mass of at least 10 grams at the following depths:

- 0.0625 in. to 0.5 in.
- 0.5 in. to 1.0 in.
- 1.0 in. to 1.5 in.

Photographs of drilling and collecting samples are shown in Figures 17 and 18.

Figure 16. Surface Preparation of a Drying Shrinkage Crack (Mix 2, Ring C)

Figure 17. Use of Rotary Hammer to Collect Samples for Chloride Ion Analysis

Figure 18. Collecting Powered Samples for Chloride Ion Analysis

Chloride ion content for three (3) concrete mixtures with two (2) rings each was performed in accordance with AASHTO Test Method T 260 “Standard Method of Test for Sampling and Testing for Chloride Ion in Concrete and Concrete Raw Materials.” The water-soluble chloride ion content by Potentiometric Titration Method (Procedure A) was used. The specimens tested were designated as follows:

- Mix 1 (the control)- Ring E and F
- Mix 2- Ring C and D
- Mix 3- Ring A and B

Each specimen was tested under the following four conditions (See Figure 19):

- Non-ponded Non-cracked
- Ponded Non-cracked
- Ponded Crack Upper
- Ponded Crack Lower

The initial step was to determine the mass of the pulverized concrete to the nearest milligram of an approximate 3-g sample representative of the material to be tested. The following procedure was then utilized:

- Transfer the sample quantitatively to a beaker and add 60 to 70 mL distilled H_20.
- Cover the beaker with a watch glass and bring to a boil on a hot plate-magnetic stirrer using a small magnet. (Figure 20)
- Boil for 5 minutes, then let stand for 24 hours in an HCl flume-free atmosphere.
- Filter the clear supernatant liquid in the beaker through double filter paper into a 25-mL beaker; take care to quantitatively transfer any adhering drops on the watch glass, and use a stirring rod to aid transfer. (Figure 21)
- Add sufficient hot distilled H_20 to cover any residue left in the original beaker, stir 1 minute on a magnetic stirrer, and filter into the 250-mL beaker with a swirling action. Wash the beaker and the stirring rod once into the filter with hot distilled H_2O.
- Wash the filter paper once with hot distilled H_2O. Lift the filter paper carefully from the funnel and wash the outside surface of the paper with hot distilled H_2O. Set aside the paper and wash the interior of the beaker.
- Add concentrated HNO_3 dropwise with continuous stirring until a permanent pink to red color is obtained. Make up the volume to 125 to 150 mL with distilled H_2O.

To determine the Cl^- content of the solution, Method 1: Potentiometric Titration was used. The procedure included in the following:

- Fill the Cl^- electrode with the solution recommended by the manufacturer, plug it into the millivoltmeter and determine the approximate equivalence point by immersing the electrode in a beaker of distilled H_2O. Note the approximate millivoltmeter reading.
- Take the cooled sample in the mass determination procedure listed above and carefully add 4.00 mL of 0.1000 normality NaCL, swirling constantly.
- Remove the beaker of distilled H_2O from the electrode, wipe the electrode with absorbent paper, and immerse the electrode in the same solution.
- Place the entire beaker-electrode assembly on a magnetic stirrer and begin gentle stirring.
- Using a calibrated burette, add gradually and record the amount of standard 0.01 normality $AgNO_3$ solution necessary to bring the millivoltmeter reading to -40 mV of the equivalence point determined in distilled H_2O. (Figure 22)

- Add standard 0.01 normality $AgNo_3$ solution in 0.10 mL increments recording the millivoltmeter reading after each addition.

The end point of the titration was determined by plotting the volume of $AgNO_3$ solution added versus the millivoltmeter readings. The end point corresponded to the point of inflection of the resultant smooth curve. The exact point of inflection was determined by the use of regression equations to determine where the slope was zero. Details of regression equations and chloride ion determination are presented in Appendix E "Chloride Ion Content."

The percent Cl^- ion was determined by the following equation:

$$Cl^-, \% = (3.453(V_1N_1 - V_2N_2))/W$$

Where:

V_1= end point, mL of $AgNO_3$;

N_1= normality, $AgNO_3$;

W= mass of original concrete sample, g;

V_2= volume of NaCl solution added, mL; and

N_2= normality of NaCl solution.

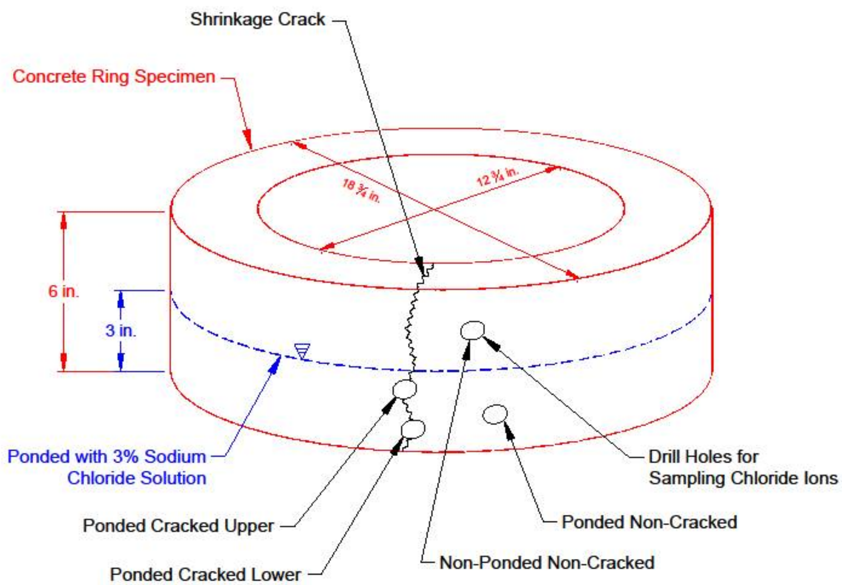

Figure 19. Chloride Ion Sampling Diagram

Figure 20. Boiling of the Chloride Ion Sample

Figure 21. Filtering the Chloride Ion Sample

Figure 22. Titrating and Millivolt Reading of the Chloride Ion Sample

The results from testing chloride ion content in accordance with AASHTO Standard T260 Procedure A provide chloride content in units of percent chloride ion by mass. Threshold limits presented in ACI 318-11 "Building Code Requirements for Structural Concrete" and ACI 222R-19 "Guide to Protection of Reinforcing Steel in Concrete against Corrosion" are provided in either percent chloride ion by weight of portland cement (ACI 318 2011) or percent chloride ion by weight of cementitious materials (ACI 222 2019). These threshold limits are summarized in Table 15 in reference to acceptable levels of chloride ions in concrete to protect reinforcing steel. When testing chloride ion content by water soluble methods, the threshold is generally taken as 0.15 percent by weight of cement (Holland 1998). For a mixture containing 588 pounds of cementitious as used in this study, this threshold can be expressed as 0.9 pounds of chloride ion per cubic yard of concrete.

Table 15. Allowable Admixed Chloride Limits for New Construction

Type of Reinforced Concrete Member	ACI 318-11	ACI 222R-19	
	Maximum water-soluble chloride ion (Cl-) content in concrete, percent by weight of portland cement	Maximum acid-soluble chloride ion (Cl-) content in concrete, percent by weight of cementitious materials	Maximum water-soluble chloride ion (Cl-) content in concrete, percent by weight of cementitious materials
Concrete dry and protected from moisture	1.00	0.30	0.25
Concrete exposed to moisture but not to external sources of chlorides	0.30	0.20	0.15
Concrete exposed to moisture and an external source of chlorides	0.15	NA	NA

Results of Laboratory Testing

Fresh Concrete Properties

Plastic properties of each individual batch are presented in Table 16. The slump ranged from 5 ½ inches to 6 ¾ inches. The air content as determined by the pressure meter ranged from 5.8 percent to 6.8 percent. The temperature of the fresh concrete ranged from 75° F to 78° F. The density of the fresh concrete ranged from 140.1 pcf to 141.2 pcf.

Table 16. Plastic Properties Individual Batches

Mix No.	Batch Size (ft^3)	Density (pcf)	Slump (in.)	% Air Pressure Method	Temp (°F)
1	3.00	140.1	6.00	6.5	78
2	3.00	141.2	5.50	5.8	75
3	3.00	140.8	6.75	5.8	75

Hardened Concrete Properties

Compressive Strength

Results from compressive strength testing are presented in this section. Details of compressive strength testing are presented in Appendix C. Individual test results shown are calculated as the nearest 1 psi. The average of the individual specimens was then calculated and rounded to the nearest 10 psi for the compressive strength at a given test age. Standard deviation of each set of compressive strength specimens was also calculated and reported. Compressive strength results for all mixtures are presented in Table 17. The compressive strength requirement for bridge deck overlays is 2,500 psi in 24 hours. Additionally, the MDOT Technical Advisory Committee members specified a maximum 24 hour compressive strength of 3,000 psi for the control mixture (Mix 1). The control mixture exceeded this maximum by 50 psi. The committee approved this 50 psi strength above the maximum. Mix 3 had a 24 hour strength of 2,060 psi which did not meet the minimum 24 hour strength requirement for bridge deck overlays. The range of compressive strengths for each test age are as follows:

1-day - 2,060 psi (Mix 3) to 3,240 psi (Mix 2)

3-day - 5,090 psi (Mix 1) to 5,300 psi (Mix 2)

7-day - 6,330 psi (Mix 1) to 6,600 psi (Mix 2)

14-day - 7,210 psi (Mix 1) to 7,490 psi (Mix 2)

28-day - 7,710 psi (Mix 1) to 8,270 psi (Mix 2)

56-day - 8,630 psi (Mix 1) to 9,140 psi (Mix 2)

Table 17: Compressive Strengths, psi

Mix No.	Specimen	1-Day	3-Day	7-Day	14-Day	28-Day	56-Day
1	A	2,946	4,957	6,392	7,051	7,647	8,916
	B	3,008	5,152	6,236	7,494	7,717	8,454
	C	3,196	5,173	6,347	7,083	7,772	8,509
	Average	3,050	5,090	6,330	7,210	7,710	8,630
	STDEV	130	119	80	247	63	252
2	A	3,239	5,223	6,670	7,511	8,346	9,393
	B	3,242	5,361	6,711	7,574	8,316	9,184
	C	3,239	5,312	6,405	7,386	8,149	8,836
	Average	3,240	5,300	6,600	7,490	8,270	9,140
	STDEV	2	70	166	96	106	281
3	A	1,964	5,004	6,226	7,105	7,946	8,689
	B	2,055	5,155	6,201	7,467	8,195	8,673
	C	2,153	5,142	6,626	7,177	8,175	9,041
	Average	2,060	5,100	6,350	7,250	8,110	8,800
	STDEV	95	84	239	191	138	208

Rapid Chloride Ion Permeability

A summary of chloride ion permeability data is presented in Table 18. The penetrability of all mixtures at 28 days is characterized as moderate. The penetrability of all mixtures at 56 days is characterized as low.

Table 18: Rapid Chloride Ion Permeability (Coulombs)

Mix No.	Specimen	28-Day	56-Day
1	A	2,044	1,469
	B	2,713[1]	1,355
	Average	2,378	1,412
	STDEV	473	81
	Penetrability	Moderate	Low
2	A	1,950	1,331
	B	2,185[1]	1,307
	Average	2,068	1,319
	STDEV	166	17
	Penetrability	Moderate	Low
3	A	2,061	1,387
	B	2,403[1]	1,410
	Average	2,232	1,399
	STDEV	242	16
	Penetrability	Moderate	Low

Note 1: Test performed at a specimen age of 30 days.

Surface Resistivity

A summary of surface resistivity testing is presented in Table 19. The penetrability of all mixtures at 28 days is moderate. The penetrability of all mixtures at 56 days is low.

Table 19. Surface Resistivity Test Results (kΩ-cm)

Mix No.	Specimen	28-Day	56-Day
1	A	17.6	23.3
	B	17.0	22.7
	C	17.5	23.1
	Average	17	23
	Penetrability	Moderate	Low
2	A	17.4	24.1
	B	17.3	24.0
	C	17.6	24.1
	Average	17	24
	Penetrability	Moderate	Low
3	A	15.3	22.9
	B	14.9	22.9
	C	15.2	21.9
	Average	15	23
	Penetrability	Moderate	Low

Cracking Tendency

The restrained ring shrinkage specimens were equipment with strain gages that monitored strain to determine the age when specimens cracked. Additionally, each specimen was visually inspected Monday through Friday for cracks. Figures 23 through 28 present graphs of microstrain verses drying days for each of the ring specimens. Figure 29 presents a similar graph of one steel ring exposed to the same temperature and humidity, but without strain imposed by concrete. Table 20 presents a summary of the number of drying days before cracking for both visual and strain gage monitoring. These data are based on evaluation of individual stain gage readings and reporting the first one on each ring that indicated a rapid reduction in strain (cracking).

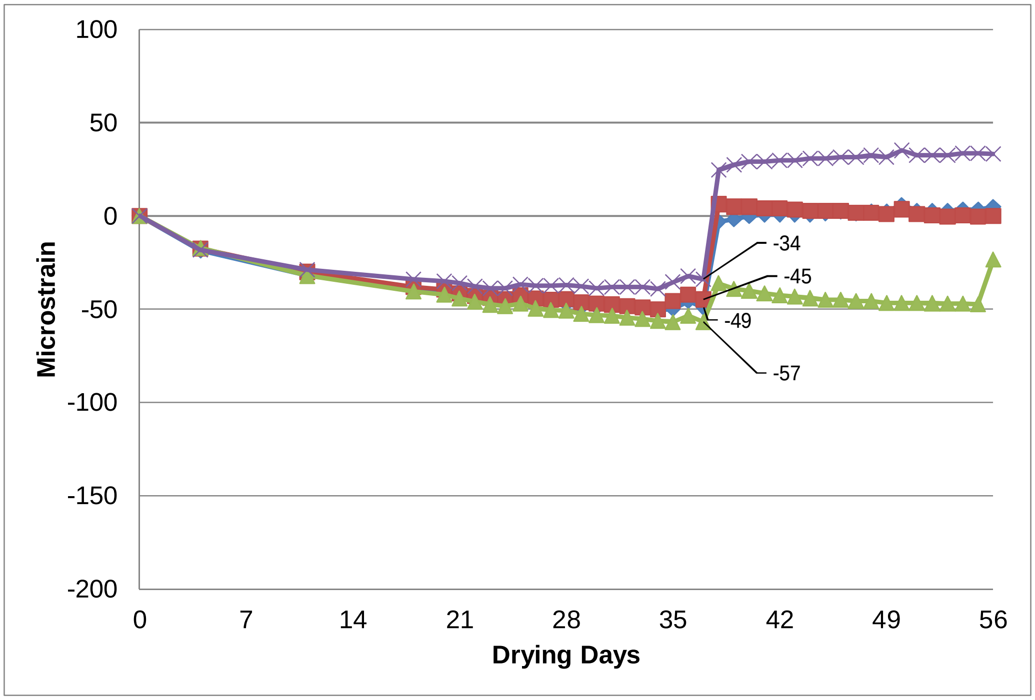

Figure 23. Microstrain VS. Drying Days – Mix 1, Ring E

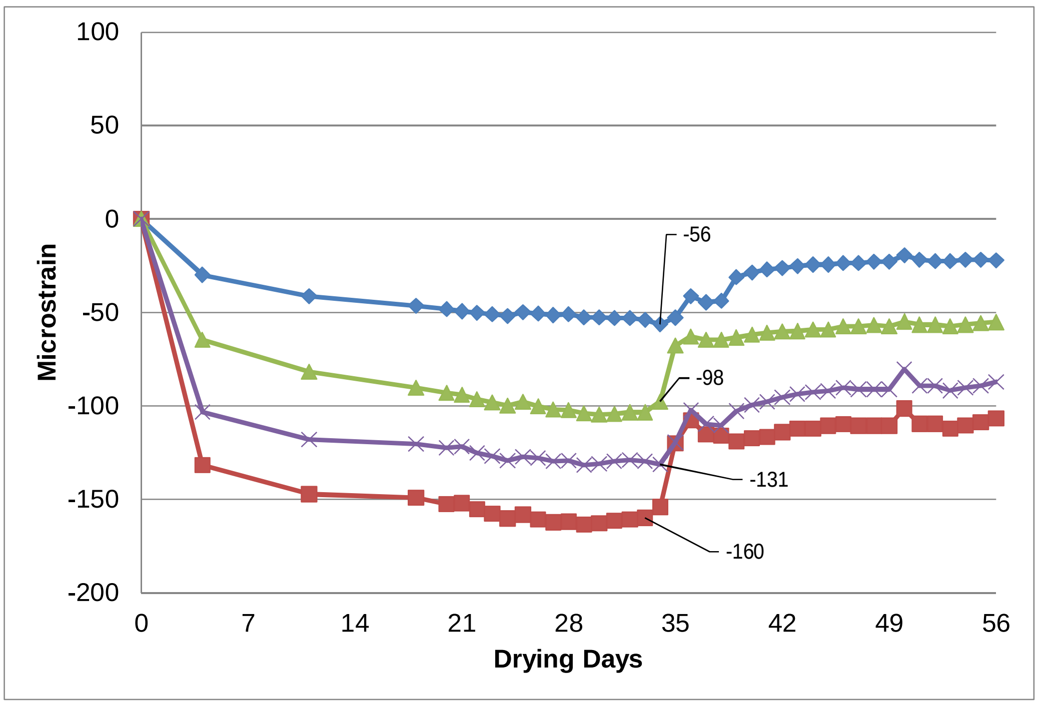

Figure 24. Microstrain VS. Drying Days - Mix 1, Ring F

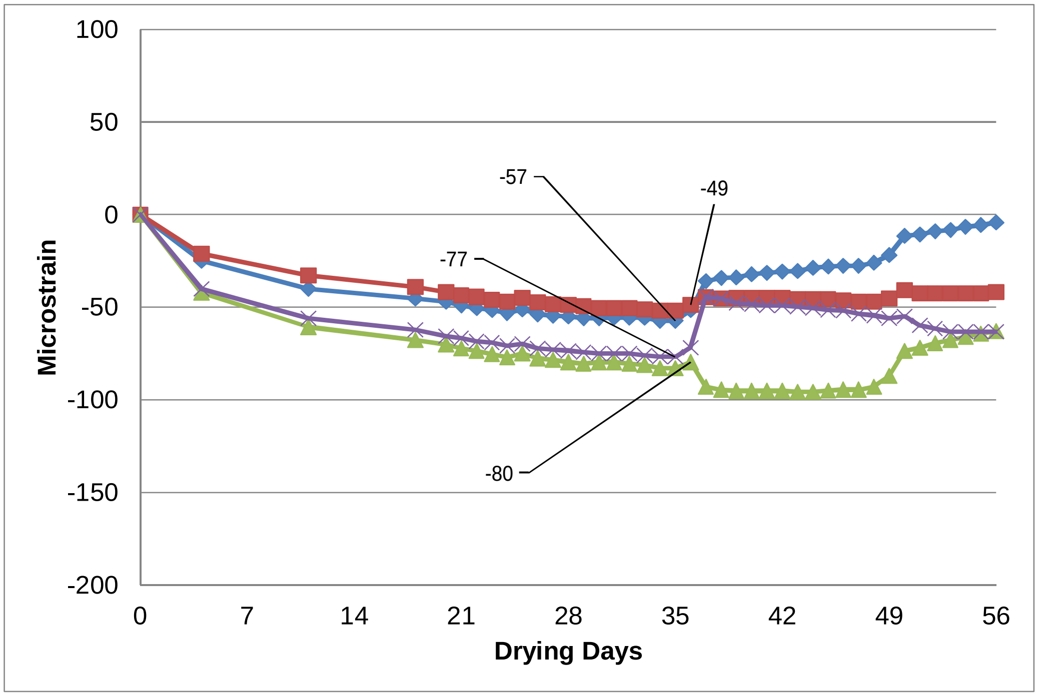

Figure 25. Microstrain VS. Drying Age - Mix 2, Ring C

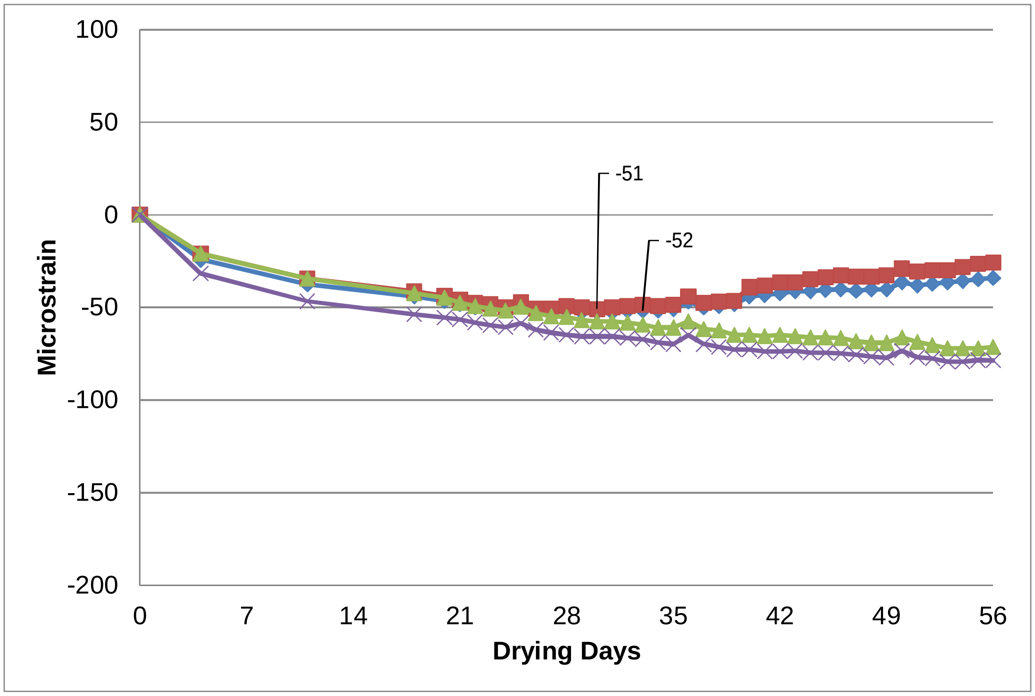

Figure 26. Microstrain VS. Drying Days - Mix 2, Ring D

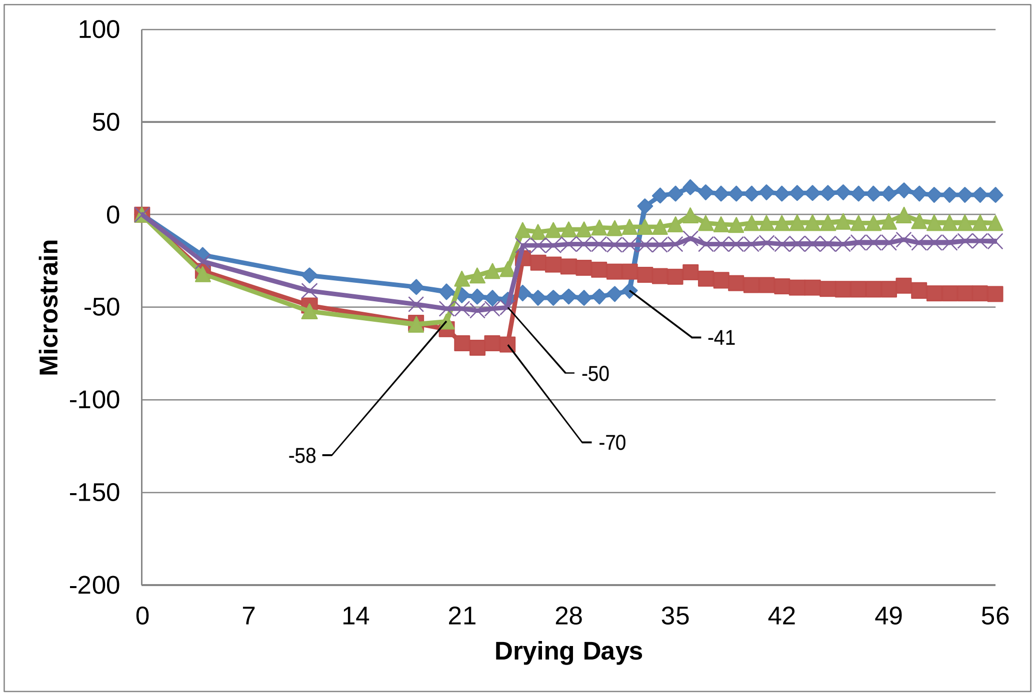

Figure 27. Microstrain VS. Drying Days - Mix 3, Ring A

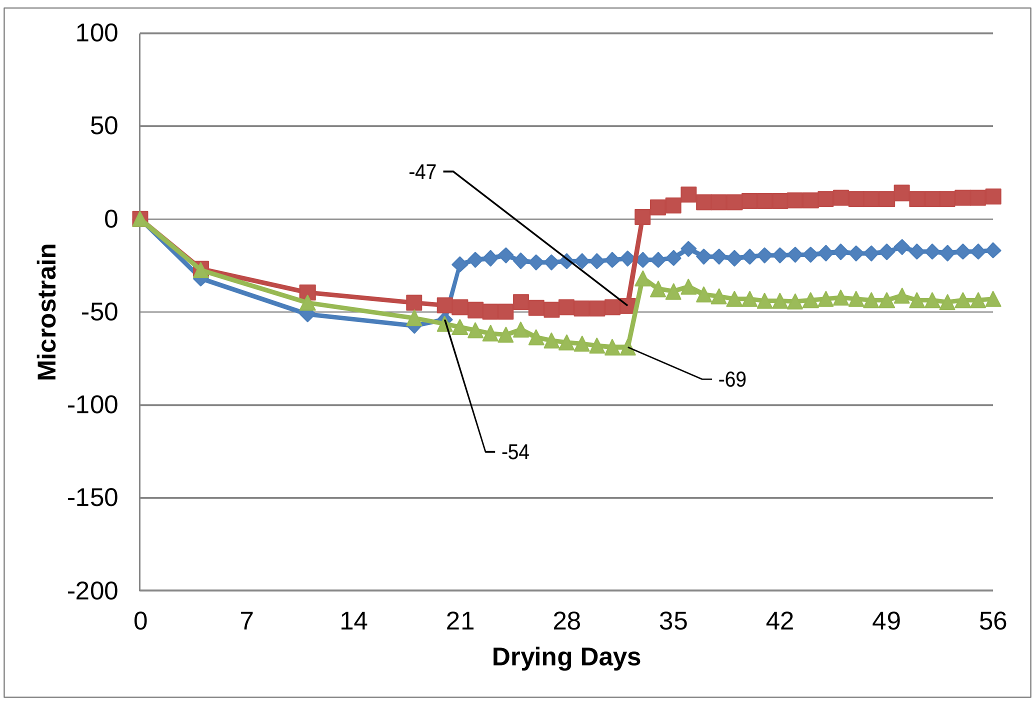

Figure 28. Microstrain VS. Drying Age - Mix 3, Ring B

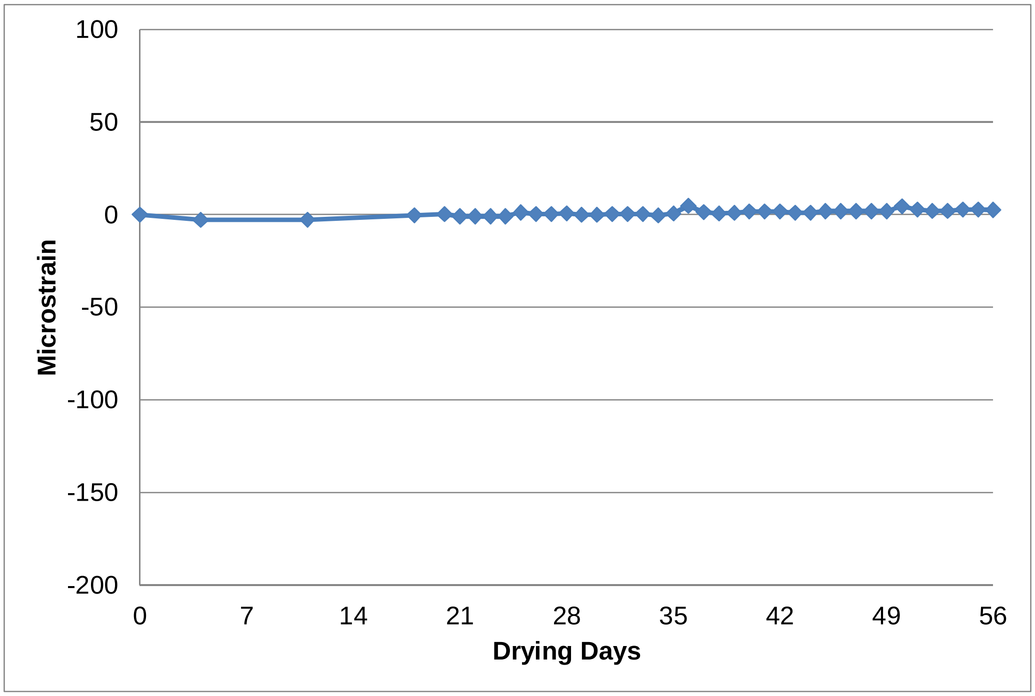

Figure 29 . Microstrain VS. Drying Age - Unstressed Steel Ring

Table 20. Time-To-Cracking (Days of Drying) and Corresponding Microstrain

Mix No.	Ring	Time –To-Cracking Based on Visual Inspection (Days of Drying)	Time –To-Cracking Based on Strain Gages (Days of Drying)	Microstrain at Time of Cracking
1	E	39	34.3	-49
	F	39	34.0	-56
2	C	39	35.0	-57
	D	48	30.0	-51
3	A	25	19.7	-58
	B	33	20.0	-54

Chloride Ion Content

Chloride ion content was determined in accordance AASHTO Standard T 260 Procedure A. Results are presented in Table 21 for percent chloride ion by mass of concrete. These data were used to convert percent by mass to pounds of chloride ion per cubic yard of concrete in saturated surface dry conditions and percent chloride ion by weight of cementitious materials. Chloride ion contents (percent be mass) are presented in Figures 30 through 35 for each ring specimen.

Table 21. Chloride Ion Content

Test Rep ID	Mix	Ring	Ponded	Crack	Mid-Depth of Testing Zone	% Chloride Ion by Mass of Concrete	Lbs. CL^- /yd^3 SSD	% CL- By Weight of Cementitious
1	Mix 1	RING E	Non-Ponded	Non-Crack	0.25	0.0065	0.25	0.04
2	Mix 1	RING E	Non-Ponded	Non-Crack	0.75	0.0028	0.11	0.02
3	Mix 1	RING E	Non-Ponded	Non-Crack	1.25	0.0047	0.18	0.03
4	Mix 1	RING E	PONDED	Non-Crack	0.25	0.2025	7.81	1.33
5	Mix 1	RING E	PONDED	Non-Crack	0.75	0.0064	0.25	0.04
6	Mix 1	RING E	PONDED	Non-Crack	1.25	0.0080	0.31	0.05
7	Mix 1	RING E	PONDED	Crack Upper	0.25	0.2338	9.02	1.53
8	Mix 1	RING E	PONDED	Crack Upper	0.75	0.0363	1.40	0.24
9	Mix 1	RING E	PONDED	Crack Upper	1.25	0.0222	0.86	0.15
10	Mix 1	RING E	PONDED	Crack Lower	0.25	0.2774	10.70	1.82
11	Mix 1	RING E	PONDED	Crack Lower	0.75	0.0465	1.79	0.31
12	Mix 1	RING E	PONDED	Crack Lower	1.25	0.0446	1.72	0.29
13	Mix 1	RING F	Non-Ponded	Non-Crack	0.25	0.0559	2.16	0.37
14	Mix 1	RING F	Non-Ponded	Non-Crack	0.75	0.0035	0.14	0.02
15	Mix 1	RING F	Non-Ponded	Non-Crack	1.25	0.0026	0.10	0.02
16	Mix 1	RING F	PONDED	Non-Crack	0.25	0.1490	5.75	0.98
17	Mix 1	RING F	PONDED	Non-Crack	0.75	0.0020	0.08	0.01
18	Mix 1	RING F	PONDED	Non-Crack	1.25	0.0030	0.12	0.02
19	Mix 1	RING F	PONDED	Crack Upper	0.25	0.2097	8.09	1.38
20	Mix 1	RING F	PONDED	Crack Upper	0.75	0.0692	2.67	0.45
21	Mix 1	RING F	PONDED	Crack Upper	1.25	0.0380	1.47	0.25
22	Mix 1	RING F	PONDED	Crack Lower	0.25	0.2209	8.52	1.45
23	Mix 1	RING F	PONDED	Crack Lower	0.75	0.0476	1.84	0.31
24	Mix 1	RING F	PONDED	Crack Lower	1.25	0.0205	0.79	0.13
25	Mix 2	RING C	Non-Ponded	Non-Crack	0.25	0.2581	9.96	1.69
26	Mix 2	RING C	Non-Ponded	Non-Crack	0.75	0.0064	0.25	0.04
27	Mix 2	RING C	Non-Ponded	Non-Crack	1.25	0.0028	0.11	0.02
28	Mix 2	RING C	PONDED	Non-Crack	0.25	0.2090	8.07	1.37
29	Mix 2	RING C	PONDED	Non-Crack	0.75	0.0044	0.17	0.03
30	Mix 2	RING C	PONDED	Non-Crack	1.25	0.0140	0.54	0.09
31	Mix 2	RING C	PONDED	Crack Upper	0.25	0.2223	8.58	1.46
32	Mix 2	RING C	PONDED	Crack Upper	0.75	0.0682	2.63	0.45
33	Mix 2	RING C	PONDED	Crack Upper	1.25	0.0046	0.18	0.03
34	Mix 2	RING C	PONDED	Crack Lower	0.25	0.2629	10.15	1.73
35	Mix 2	RING C	PONDED	Crack Lower	0.75	0.0866	3.34	0.57
36	Mix 2	RING C	PONDED	Crack Lower	1.25	0.0393	1.52	0.26
37	Mix 2	RING D	Non-Ponded	Non-Crack	0.25	0.0805	3.11	0.53
38	Mix 2	RING D	Non-Ponded	Non-Crack	0.75	0.0000	0.00	0.00
39	Mix 2	RING D	Non-Ponded	Non-Crack	1.25	0.0024	0.09	0.02

Test Rep ID	Mix	Ring	Ponded	Crack	Mid-Depth of Testing Zone	% Chloride Ion by Mass of Concrete	Lbs. CL⁻ /yd³ SSD	% CL- By Weight of Cementitious
40	Mix 2	RING D	PONDED	Non-Crack	0.25	0.1816	7.01	1.19
41	Mix 2	RING D	PONDED	Non-Crack	0.75	0.0045	0.17	0.03
42	Mix 2	RING D	PONDED	Non-Crack	1.25	0.0048	0.19	0.03
43	Mix 2	RING D	PONDED	Crack Upper	0.25	0.2533	9.77	1.66
44	Mix 2	RING D	PONDED	Crack Upper	0.75	0.0045	0.17	0.03
45	Mix 2	RING D	PONDED	Crack Upper	1.25	0.0022	0.08	0.01
46	Mix 2	RING D	PONDED	Crack Lower	0.25	0.2422	9.35	1.59
47	Mix 2	RING D	PONDED	Crack Lower	0.75	0.0124	0.48	0.08
48	Mix 2	RING D	PONDED	Crack Lower	1.25	0.0162	0.63	0.11
49	Mix 3	RING A	Non-Ponded	Non-Crack	0.25	0.2233	8.62	1.47
50	Mix 3	RING A	Non-Ponded	Non-Crack	0.75	0.0048	0.19	0.03
51	Mix 3	RING A	Non-Ponded	Non-Crack	1.25	0.0021	0.08	0.01
52	Mix 3	RING A	PONDED	Non-Crack	0.25	0.2048	7.90	1.34
53	Mix 3	RING A	PONDED	Non-Crack	0.75	0.0119	0.46	0.08
54	Mix 3	RING A	PONDED	Non-Crack	1.25	0.0045	0.17	0.03
55	Mix 3	RING A	PONDED	Crack Upper	0.25	0.3119	12.04	2.05
56	Mix 3	RING A	PONDED	Crack Upper	0.75	0.1057	4.08	0.69
57	Mix 3	RING A	PONDED	Crack Upper	1.25	0.0963	3.72	0.63
58	Mix 3	RING A	PONDED	Crack Lower	0.25	0.3114	12.02	2.04
59	Mix 3	RING A	PONDED	Crack Lower	0.75	0.1241	4.79	0.81
60	Mix 3	RING A	PONDED	Crack Lower	1.25	0.1082	4.18	0.71
61	Mix 3	RING B	Non-Ponded	Non-Crack	0.25	0.1518	5.86	1.00
62	Mix 3	RING B	Non-Ponded	Non-Crack	0.75	0.0035	0.14	0.02
63	Mix 3	RING B	Non-Ponded	Non-Crack	1.25	0.0048	0.19	0.03
64	Mix 3	RING B	PONDED	Non-Crack	0.25	0.1578	6.09	1.04
65	Mix 3	RING B	PONDED	Non-Crack	0.75	0.0097	0.37	0.06
66	Mix 3	RING B	PONDED	Non-Crack	1.25	0.0044	0.17	0.03
67	Mix 3	RING B	PONDED	Crack Upper	0.25	0.2243	8.66	1.47
68	Mix 3	RING B	PONDED	Crack Upper	0.75	0.0736	2.84	0.48
69	Mix 3	RING B	PONDED	Crack Upper	1.25	0.0720	2.78	0.47
70	Mix 3	RING B	PONDED	Crack Lower	0.25	0.2846	10.98	1.87
71	Mix 3	RING B	PONDED	Crack Lower	0.75	0.0906	3.50	0.59
72	Mix 3	RING B	PONDED	Crack Lower	1.25	0.0557	2.15	0.37

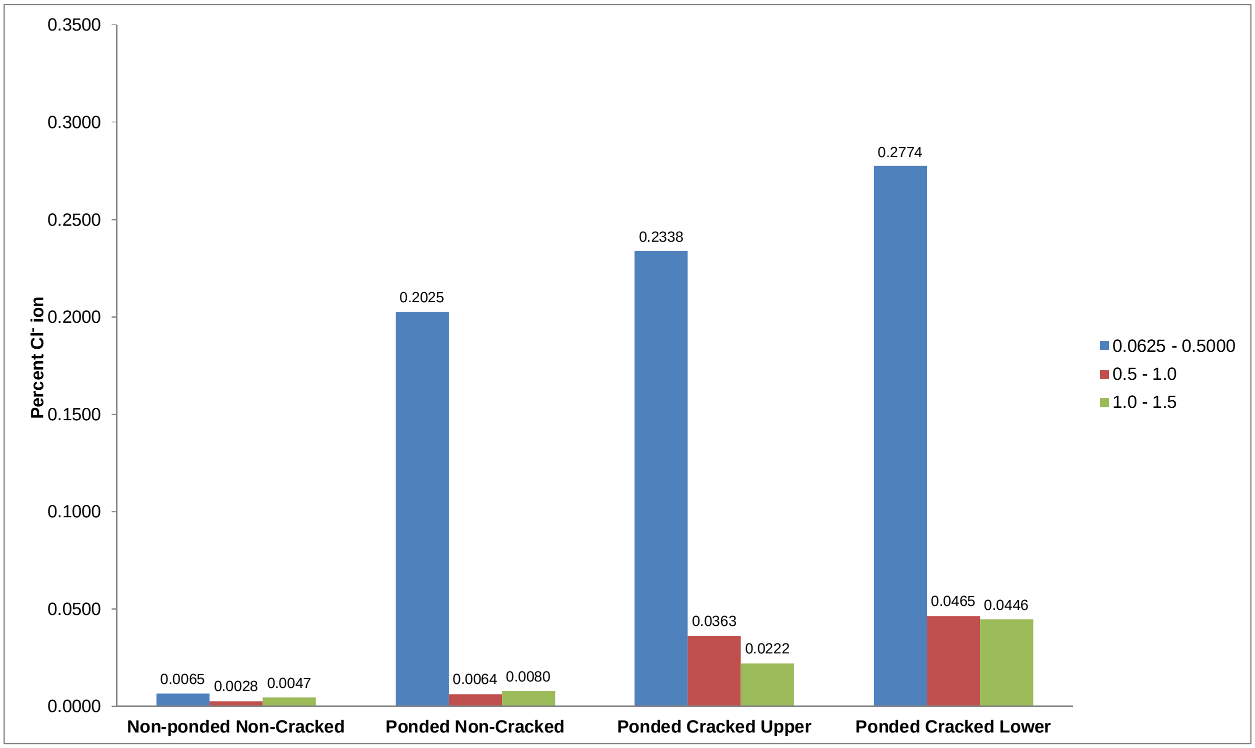

Figure 30. Percent Chloride Ion Content – Mix 1, Ring E

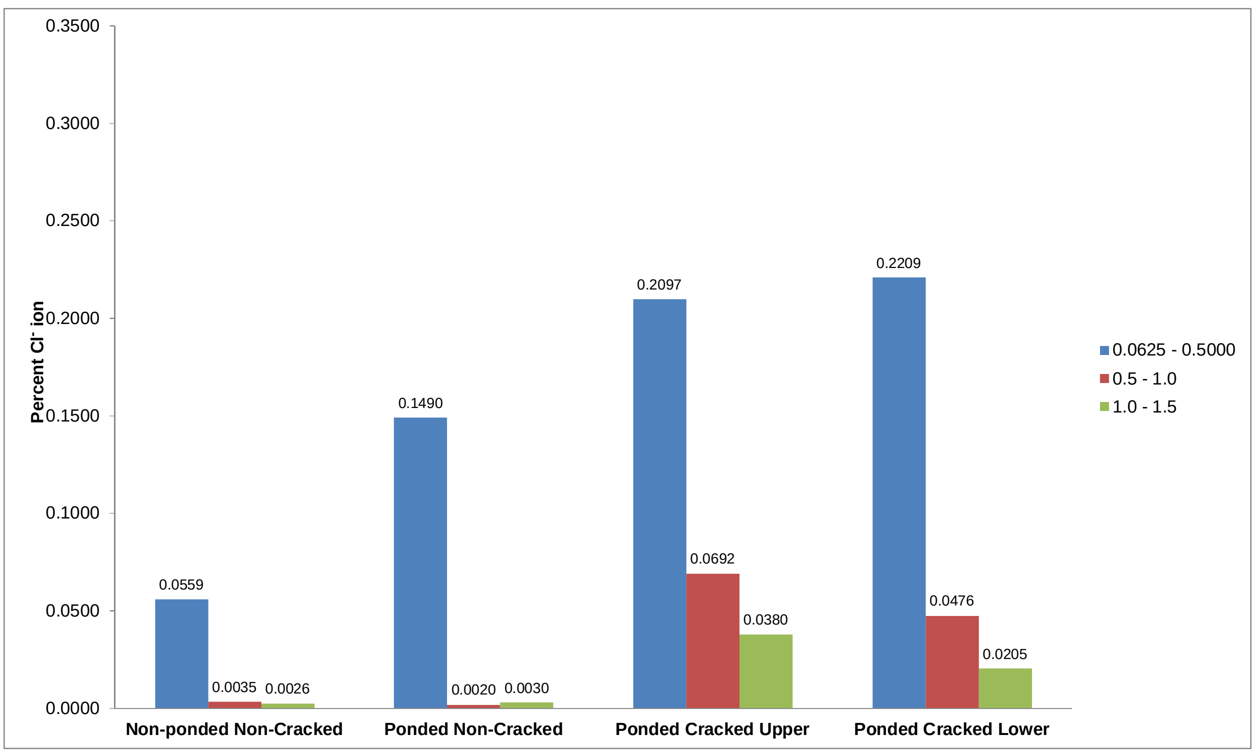

Figure 31. Percent Chloride Ion Content - Mix 1, Ring F

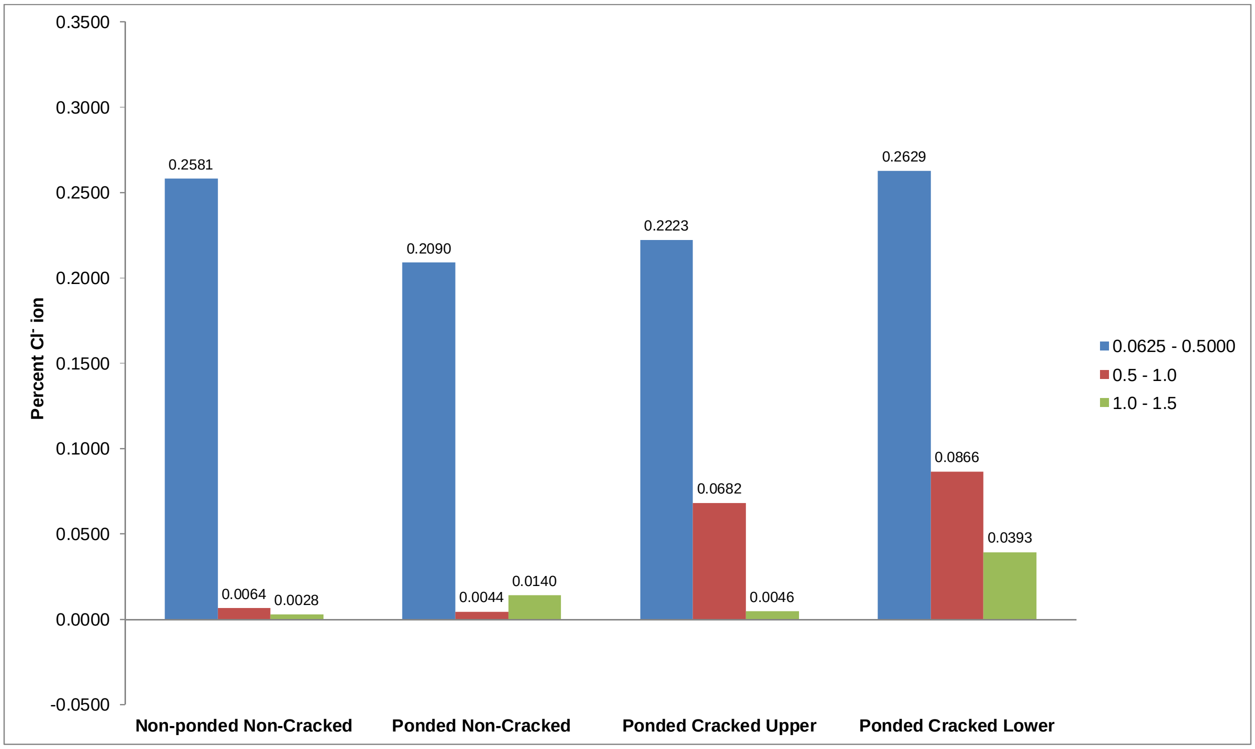

Figure 32. Percent Chloride Ion Content - Mix 2, Ring C

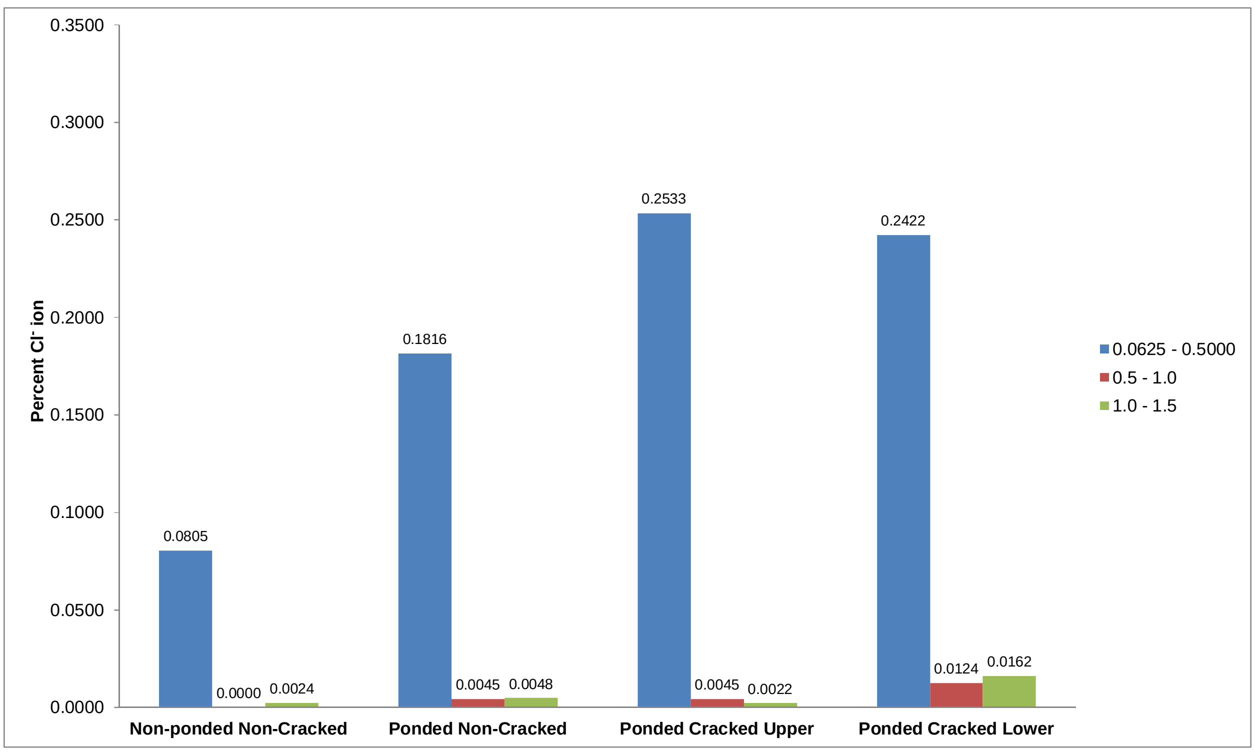

Figure 33. Percent Chloride Ion Content - Mix 2, Ring D

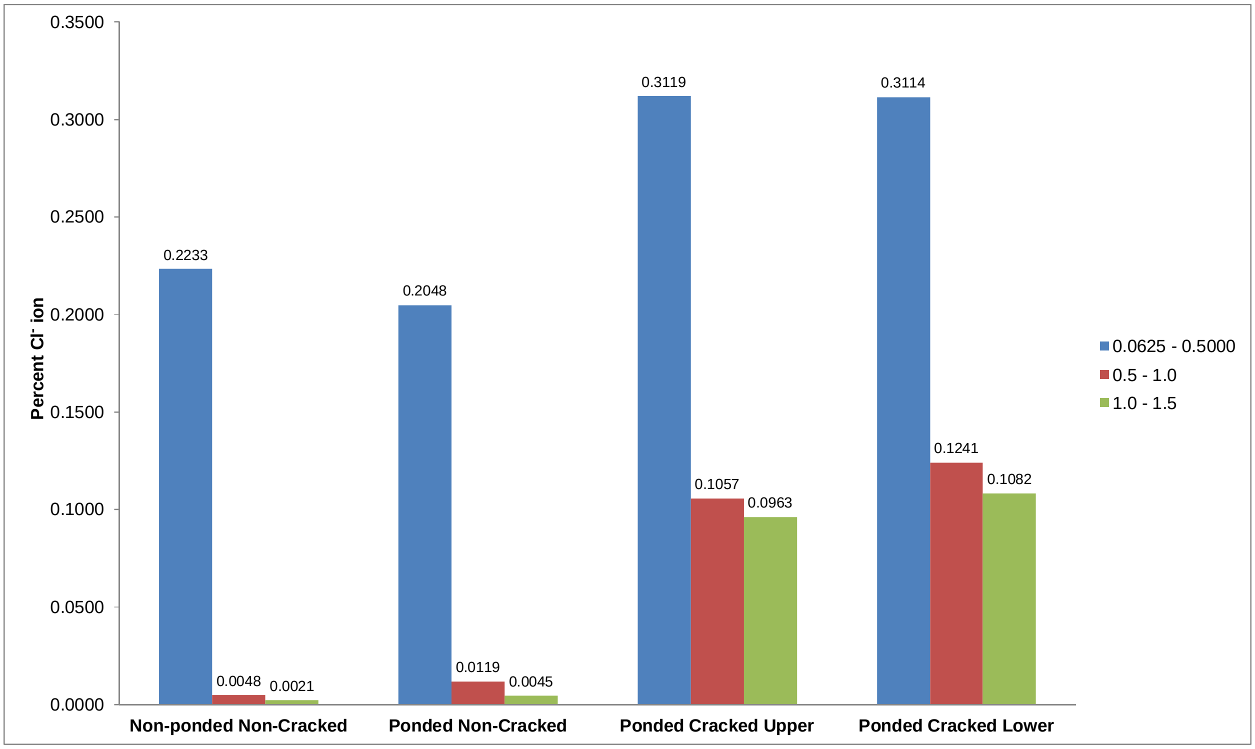

Figure 34. Percent Chloride Ion Content - Mix 3, Ring A

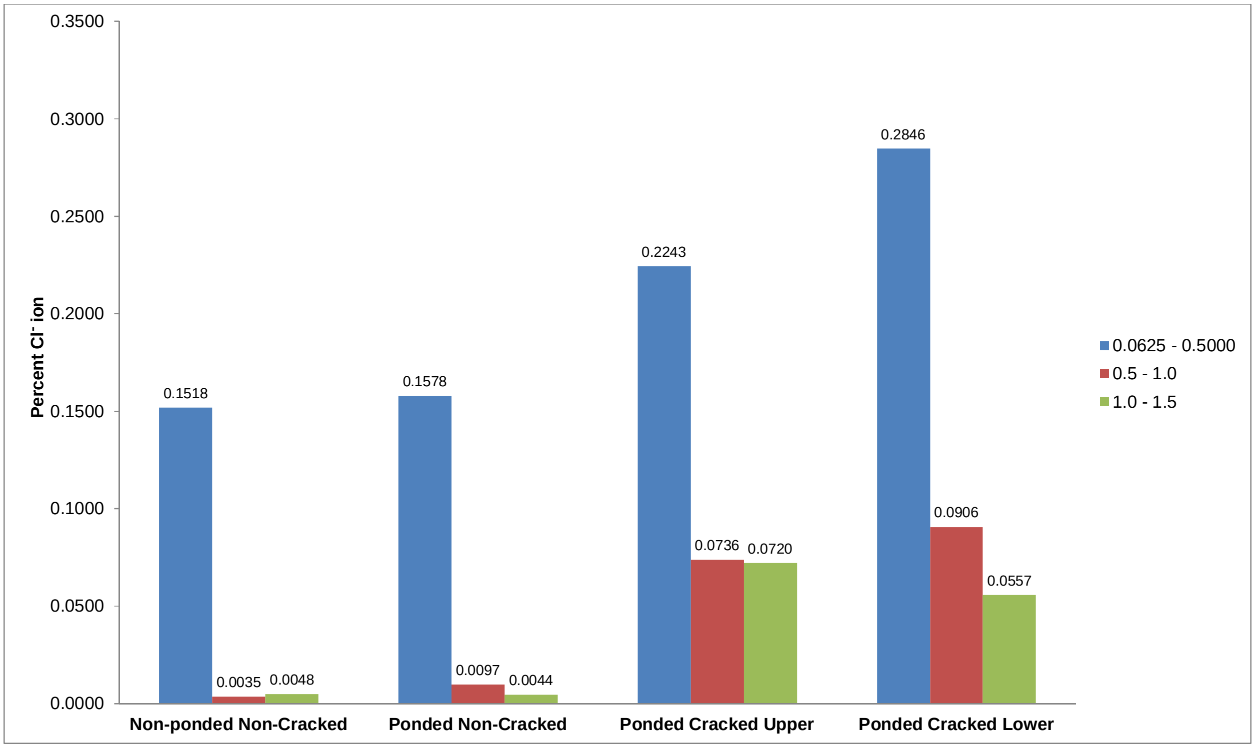

Figure 35. Percent Chloride Ion Content - Mix 3, Ring B

Research Findings and Applications

Three concrete mixtures were tested for fresh and hardened properties including: 1) compressive strength; 2) rapid chloride permeability; 3) surface resistivity; 4) cracking tendency; and 5) chloride ion content. Findings of this study are provided in this section.

Compressive Strength

A graph showing compressive strength versus age is presented in Figure 36. These data show that mixtures containing a permeability reducing admixture had higher 28-day compressive strengths (average approximately 6 percent) and higher 56-days compressive strengths (average approximately 4 percent) than the control mix. Mix 3 (utilizing PRAH-2) had an approximate 32 percent lower 1-day compressive strength than the control mixture. This lower 1-day strength is concerning because it indicates that permeability reducing admixtures can slow the setting time of concrete. This is important for bridge deck overlays because of the high early strength requirement of 2,500 psi in 24 hours. The slow setting time would to be compensated by use of additional portland cement, less fly ash, a non-calcium accelerator or a combination of these to provide similar strengths as Mix 1 and Mix 2. These additional materials will increase the cost of mixtures proportioned with permeability reducing admixture PRAH-2.

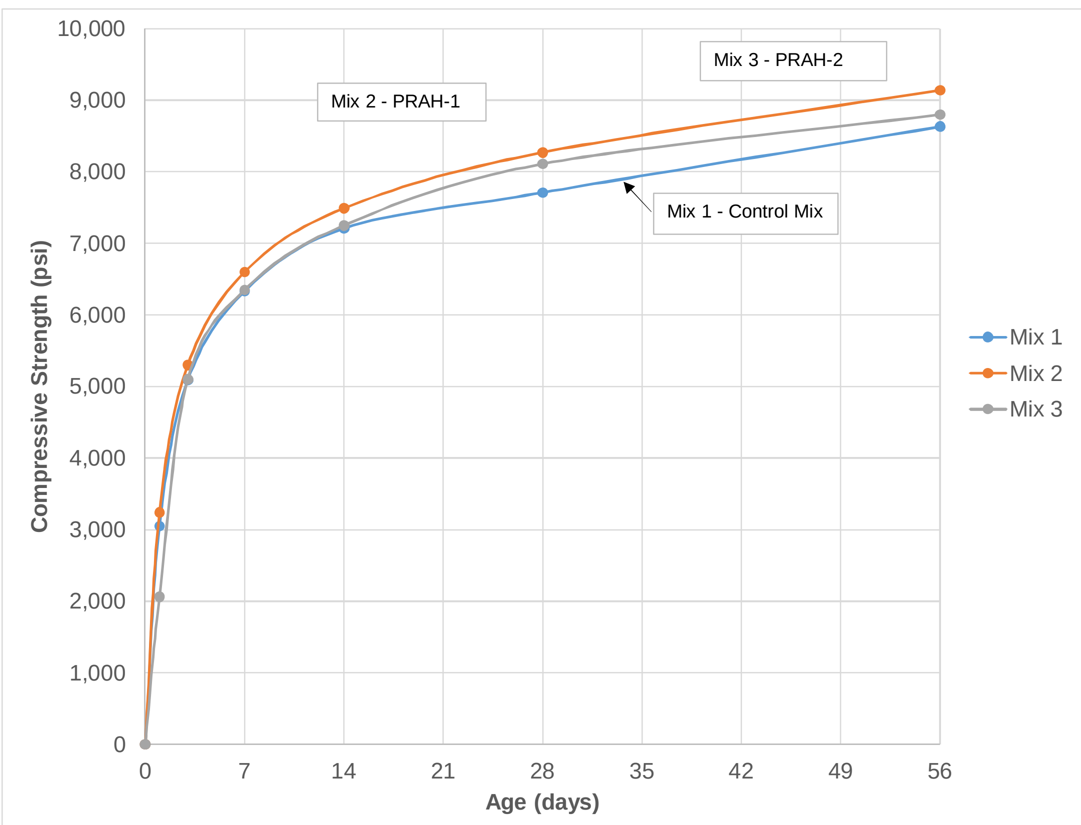

Figure 36. Compressive Strength VS. Age - All Mixtures

Rapid Chloride Permeability

A graph showing coulombs passed versus mixture number is presented in Figure 37. These data show that mixtures containing a permeability reducing admixture had a lower coulomb reading than to control mixture for 28-day and 56-day test results. When using these results and the qualitative relationship between the results and the chloride ion penetrability of the concrete in accordance with AASHTO T-277, mixtures containing a permeability reducing admixture performed similar to the control mixture. All mixtures produced moderate chloride ion penetrability when tested at 28 days and low chloride penetrability when tested at 56 days. Therefore, the use of permeability reducing admires did not change the chloride ion penetrability with respect to high, moderate, low, very low, and negligible categories established in AASHTO T277.

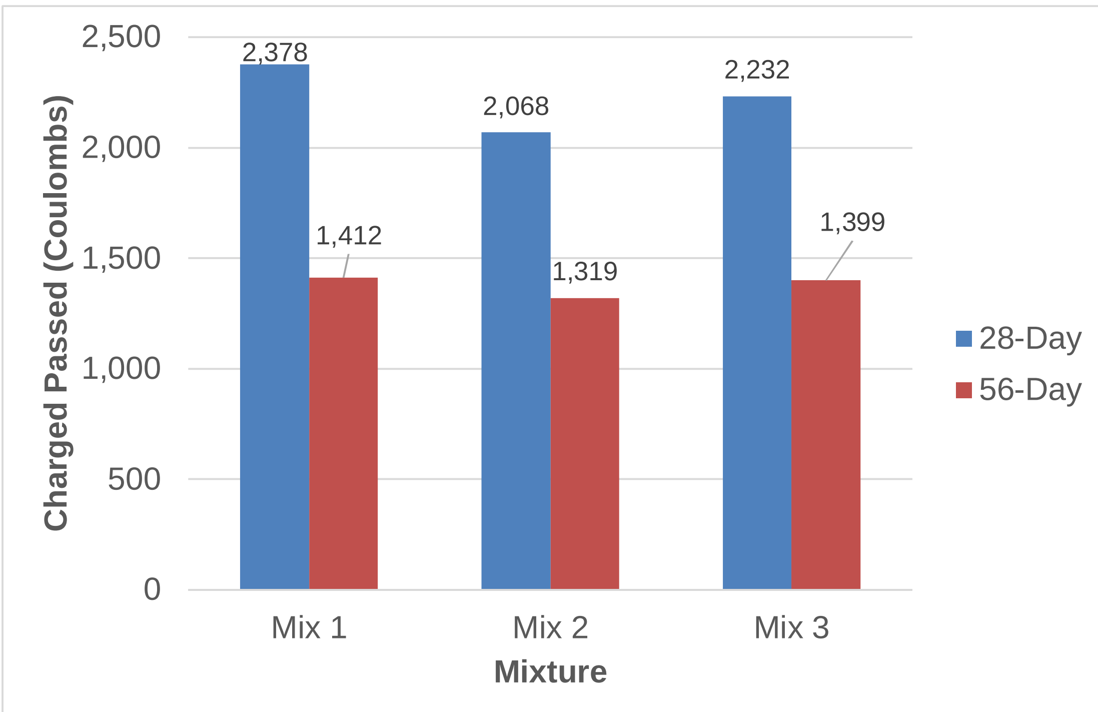

Figure 37. Charge Passed (Coulombs) VS. Mixture

Surface Resistivity

A graph showing surface resistivity versus mixture number is presented in Figure 38. These data show that mixtures containing a permeability reducing admixtures had similar readings as the control mixture for 28-day and 56-day test results. When using these results and the qualitative relationship between the results and the chloride ion penetrability of the concrete in accordance with AASHTO T 358, mixtures containing a permeability reducing admixture performed similar to the control mixture. All mixtures produced moderate chloride ion penetration when tested at 28 days and low chloride ion penetration when tested at 56 days. Therefore, the use of permeability reducing admixtures did not change the chloride ion penetration with respect to high, moderate, low, very low, and negligible categories established in AASHTO T 358.

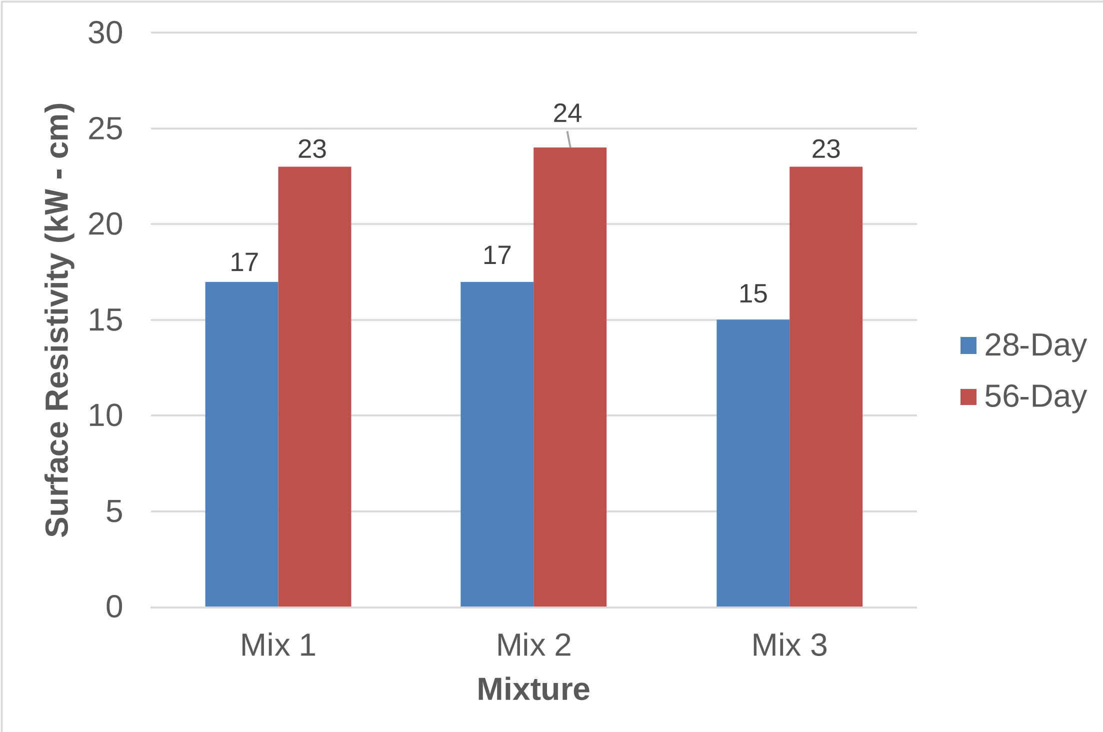

Figure 38. Resistivity (kΩ –cm) VS. Mixture

Cracking Tendency

A graph showing number of days until cracking is presented in Figure 39. These days are based on the first of the four strain gages in each ring that showed a steady decrease in strain. The control mixture cracked after 34 days (specimen age of 48 days) of exposure to drying conditions. Data for Mix 3 showed that this mixture cracked before the control mixture cracked. This indicates that the permeability reducing admixture used in Mix 3 increased the rate of strain associated with length changed attributed to drying shrinkage. One of the ring specimens made with Mix 2 cracked at 35 days (1 day after the control mix cracked) of drying and one cracked at 30 days of drying (4 days before the control mix cracked). Strain associated with cracking ranged from 49 microstains (Mix 1) to 58 microstrains (Mix 3).

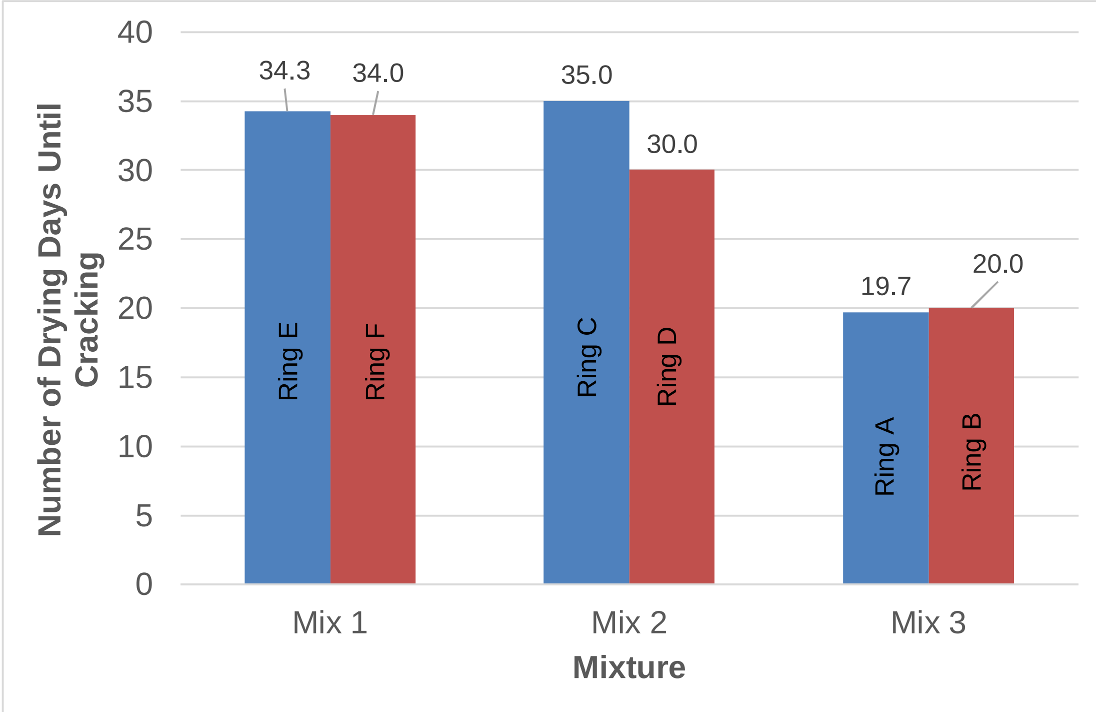

Figure 39. Number of Drying Days Until Cracking

Chloride Ion Profile

The chloride ion content (percent mass of concrete) results were averaged based on sample depth and location within the specimens. This produced average chloride ion content values at non-ponded, non-cracked; ponded, non-cracked; and ponded, cracked areas. These average data were converted to pounds of chloride ion per cubic yard of concrete and plotted based on mixture number and sample depth. These plots are presented in Figures 40, 41, and 42. The ACI 318 and ACI 222R threshold limit of 0.9 pounds of chloride ions per cubic yard of concrete is also shown in these figures for reference.

Results from testing non-ponded, non-cracked areas are presented in Figure 40. Data show that more chloride ions were present at depth ranging from 0.0625 in. to 0.50 in. in mixtures that utilized permeability reducing admixtures than in the control mixture. There was over five times more chloride ion content in these mixtures when compared to the control mixture. This increase in chloride ion content in non-ponded areas is influenced by several factors including capillary absorption. However, these data show permeability reducing admixtures likely increased concrete's affinity for water and pulled more water carrying chloride ions into the top section (non-ponded) section of the ring specimens. The chloride ion concentration decreased with depth into the ring specimens. Chloride ion content was approximately the same for all mixtures at depths ranging from 0.5 in. to 1.5 in. for non-ponded, non-cracked areas which can also be seen in Figure 40.

Results from testing ponded, non-cracked areas are presented in Figure 41. Mixes utilizing permeability admixtures contained more chloride ions at 0.0625 in. to 0.5 in. than the control mixture. All mixtures contained similar chloride ion contents within a depth ranging from 0.5 in. to 1.5 in. at ponded, non-cracked areas.

Results from testing ponded, cracked areas are presented in Figures 42 through 44. Mixes utilizing permeability reducing admixtures contained more chloride ions at 0.0625 in. to 0.5 in. than the control mixture. Mix 2 (containing PRAH-1) had a lower chloride ion content than the control mixture at depths of 0.50 in. to 1.5 in. indicating that the crack may have been partially or completely sealed by the permeability reducing admixture. Mix 3 (PRAH-2) had a higher concentration of chloride ions than the control mix indicating that the crack was not sealed by the permeability reducing admixture.

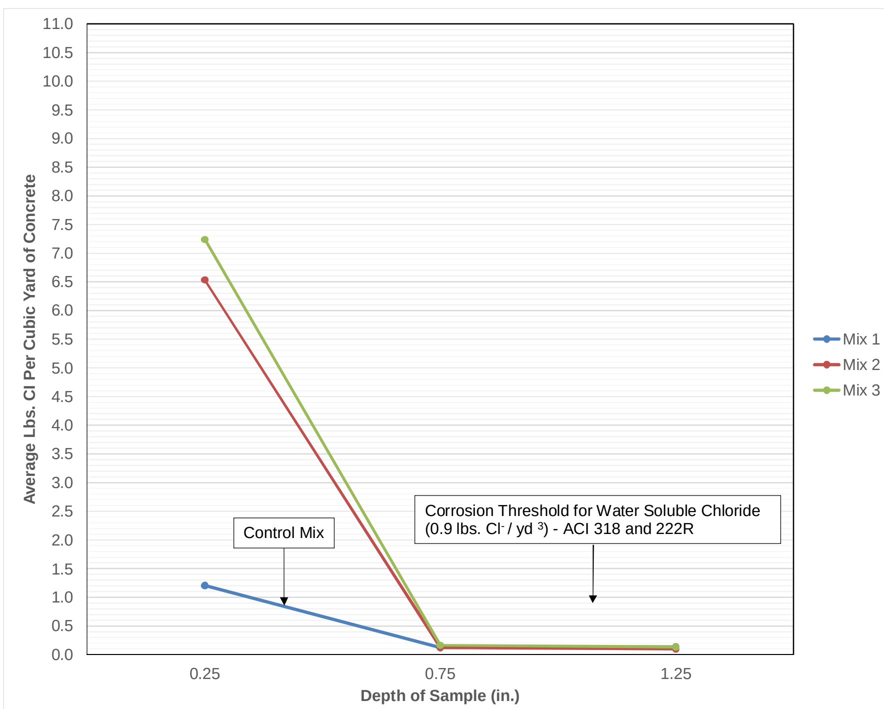

Figure 40. Non-Ponded, Non-Crack

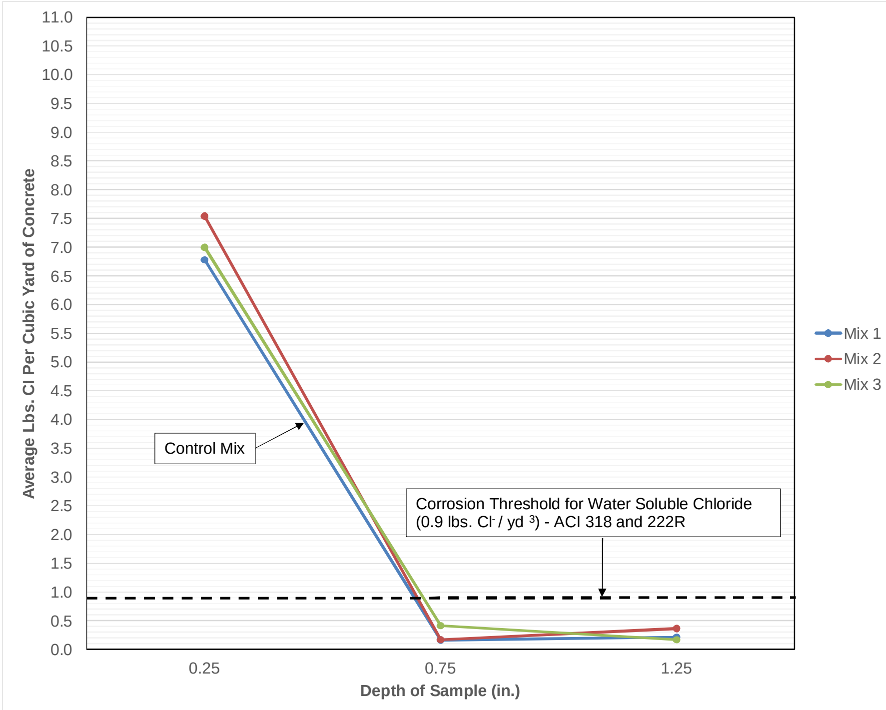

Figure 41. Ponded, Non-Crack

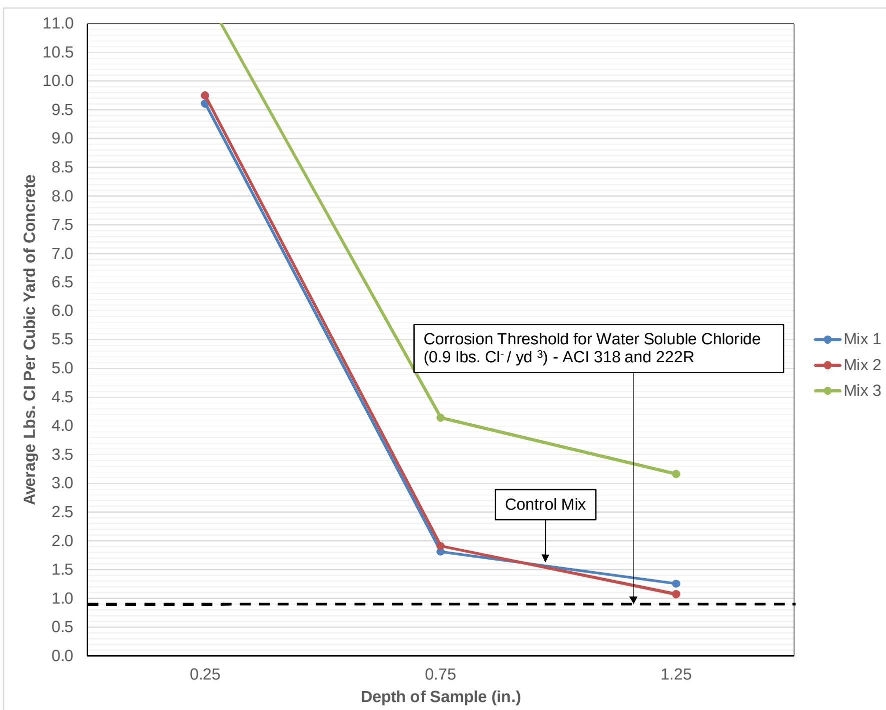

Figure 42. Ponded, Cracked Lower

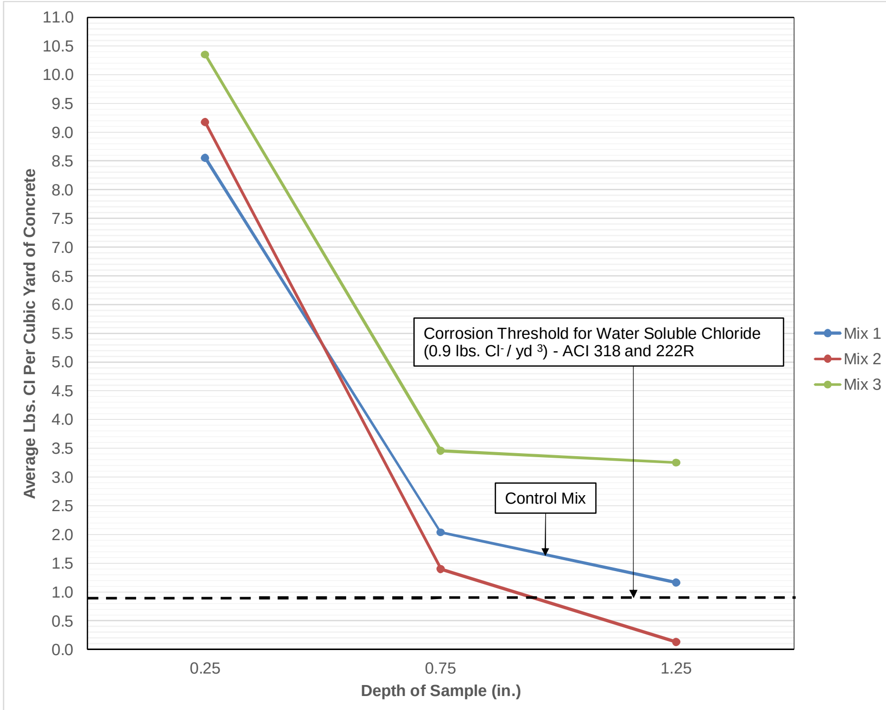

Figure 43. Ponded, Cracked Upper

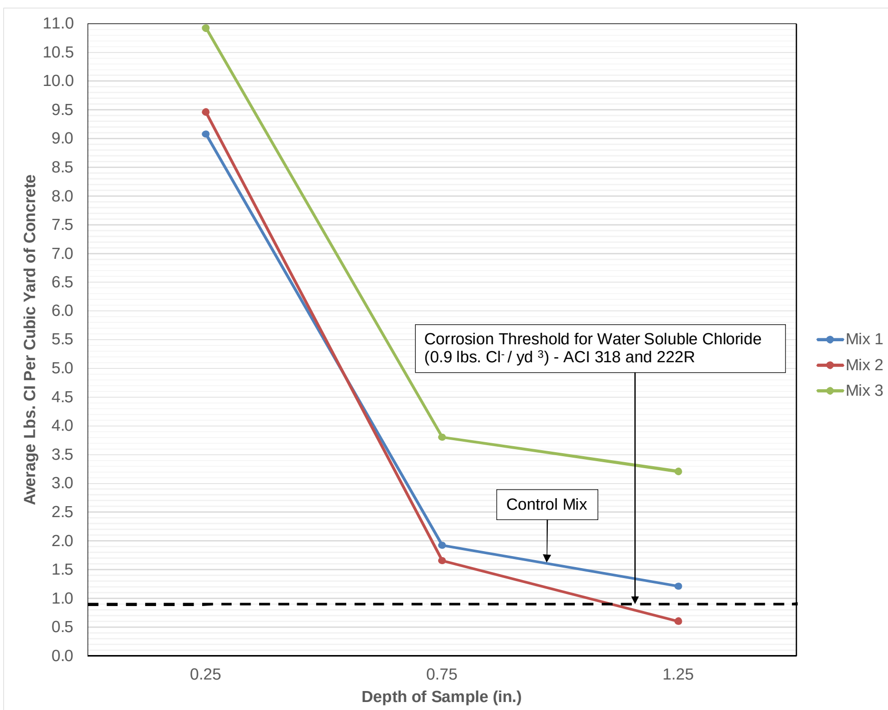

Figure 44. Ponded, Cracked Lower and Upper Averaged

Conclusions

Conclusions are based on limited data that included one control mixture (Mix 1) without permeability reducing admixtures and two mixtures (Mix 2 and Mix 3) that included hydrostatic permeability reducing admixtures. These conclusions may not apply to concrete mixtures containing non-hydrostatic permeability reducing admixtures or different materials or mixtures proportions than those utilized in this study.

The testing protocol utilized in this study did not produce results definitively showing that hydrostatic permeability reducing admixtures reduce permeability and chloride ion intrusion in portland cement concrete. Typical test methods developed for determining permeability of concrete such as rapid chloride permeability and surface resistivity did not definitively show that hydrostatic permeability reducing admixtures aid in reducing concrete's permeability.

The two hydrostatic permeability reducing admixtures utilized in this study did not provide similar results with respect to crack sealing. Mix 2 utilizing PRAH-1 showed reduced chloride ion ingress at cracked sections when compared to the control mixture. Mix 3 utilizing PRAH-2 showed an increase in chloride ion ingress at cracked sections when compared to the control.

The hydrostatic permeability reducing admixtures utilized in this study appear to have increased the concrete mixture's affinity for water. This conclusion is shown in Figure 40 where chloride ion content near the surface of specimens ranged from five to six times higher in mixtures containing hydrostatic permeability reducing admixtures than in the control mixture. Increasing affinity for water could increase ingress of waterborne chloride ions and other deleterious substances into the concrete.

Implementation Plan/Recommendations

We recommend that MDOT consider that the use of hydrostatic permeability reducing admixtures could be counterproductive in bridge deck overlays if these materials increase the concrete mixture's affinity for water.

We recommend that MDOT perform similar testing on non-hydrostatic permeability admixtures that are mostly hydrophobic in nature to determine their ability to reduce permeability of concrete without increasing affinity for water.

We recommend that MDOT develop acceptable ranges of surface resistivity values for critical structures such as bridges. Data developed in this study show that rapid chloride permeability tests and surface resistivity tests provide similar results. Therefore, surface resistivity can provide MDOT with a quick test to check durability of concrete mixtures.

References

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4. K.D. Stanish, R.D. Hooton, and M.D.A. Thomas. “Testing the Chloride Penetration Resistance of Concrete: A Literature Review.” Department of Civil Engineering, University of Toronto. Toronto, Ontario, Canada.
5. Katherine Hong. “Cyclic Wetting and Drying and its Effects on Chloride Ingress in Concrete.” Department of Civil Engineering, University of Toronto. Toronto, Ontario, Canada. 1998.
6. Mississippi Department of Transportation Special Provision No. 907-804-1 “Bridge Deck Overlays”
7. Mississippi Department of Transportation. 804 Specifications “Concrete Bridges and Structures.”
8. ACI Committee 318, “Building Code Requirements for Structural Concrete.” (ACI 318-11).” American Concrete Institute, Farmington Hills, MI.
9. ACI Committee 222, “Guide to Protection of Reinforcing Report on Chemical Admixtures for Concrete. (ACI 212.3R-16).” American Concrete Institute, Farmington Hills, MI.
10. Terry Holland. “Chloride Limits in the ACI 318 Building Code Requirements.” The Aberdeen Group. Publication No. J980869. 1998.

Appendix A – Mixture Proportions

Final Report

Customer:	MDOT	Project:	BCD 180143	Lab #:	BCD
MIX NUMBER	Mix 1	Notes:	MDOT Bridge Deck Overlay	Set #:	Mix 1
Date:	2/7/2019	Mix Code:	f'c: 2,500 to 3,000 psi; Size(c.f.): 3	Factor:	0.11

MIX DESIGN INFO

Material	Vol. (c.f.)	SSD mix 1 cu. yd. Wt. (lbs.)	SSD mix lab batch Wt. (lbs.)	Adjusted lab batch Wt. (lbs.)	Actual lab batch Wt. (lbs.)	Material Source	SSD Specific Gravity	Agg. absorp-tion	Agg. FM
Cement 1:	2.54	500.00	**55.56**	**55.56**	55.56	Holcim - Theodore, AL Type II	3.15		
Cement 2:	0.00	0.00	**0.00**	**0.00**					
Fly Ash:	0.54	88.00	**9.78**	**9.78**	9.78	Boral Resources - Plant Miller Class C	2.61		
GGBFS:	0.00	0.00	**0.00**	**0.00**					
Sand 1:	8.04	1326.04	**147.34**	**156.96**	156.96	Concrete Sand - Hammett Kuhn Mine MDOT 3-26-4	2.643	0.13%	2.55
Coarse Aggregate 1:	10.73	1700.00	**188.89**	**188.78**	188.78	No 8 - Hammett Kuhn Mine MDOT 3-26-4	2.538	2.26%	5.75
Coarse Aggregate 2:	0.00	0.00	**0.00**	**0.00**			1.000	1.00%	1.00
Coarse Aggregate 3:	0.00	0.00	**0.00**	**0.00**			1.000	1.00%	1.00
Coarse Aggregate 4:	0.00	0.00	**0.00**	**0.00**			1.000	1.00%	1.00
Air: **4.50%**	1.22	0.00	**0.00**	**0.00**					
Water:	3.93	245.00	**27.22**	**17.71**	17.71		1.00		
"+-Air: **0.50%**									
Total:	27.00	3859.04	428.78	428.78					
UW w/o Air:		149.66	149.66	149.66					

ADMIX INFORMATION

Type	oz /cwt	oz /cy	ml /cy	batch ml	actual	Brand / Name
Air	0.71	4.15	122.6	13.6	13.6	GCP - DARAVAIR 1000
Type A	4.00	23.52	695.6	77.3	77.3	GCP - ZYLA 610
Type F	16.63	97.76	2891.0	321.2	321.2	GCP - ADVA 140M
	oz /cwt	**lbs /cy**	**lbs/batch**	**g/batch**		
Waterproofing	0.0	0.0	0.00	0.00		None

Aggregate Moistures

	Free H_2O Content	Batch free H_2O (lbs.)
Sand:	6.54%	9.62
CA 1	-0.06%	-0.11
CA 2	0.00%	0.00
CA 3	0.00%	0.00
CA 4	0.00%	0.00

Water Added/Withheld

+/- h2o	Added	W/held

PLASTIC TEST RESULTS				OTHER INFO	
Batch Time	**12:11 PM**	% Air	**6.50**	Des. w/c	0.417
Sample Time	**12:19 PM**	Unit Weight (pcf)	**140.1**	Act. w/c	0.417
Slump, in.	**6.00**	Yield	**3.06**	Des.Un.Wt.	142.93
Mix Temp.	**78.0**	Initial set, min.	**NA**	Fine/Coarse	0.78
Air Temp.	**78.0**	Relative Yield	**1.020**	Bag Factor	6.26

Comments / Notes / Observations

Fresh Property Ranges in Lab

Slump 5 1/4 to 6 3/4 in. (6 in. Max.)

Air: 5 1/2 to 6 1/2% (4.5% Nominal)

Admixture Ranges:

Zyla 610: 2 to 10 oz./100 lbs.

Adva 140M: 2 to 25 oz/100 lbs.

Strength Test Results

Date	AGE	psi	Avg. psi
2/8/2019	1	2,946	3,050
		3,008	
		3,196	
2/10/2019	3	4,957	5,090
		5,152	
		5,173	
2/14/2019	7	6,392	6,330
		6,236	
		6,347	
2/21/2019	14	7,051	7,210
		7,494	
		7,083	
3/7/2019	28	7,647	7,710
		7,717	
		7,772	
4/4/2019	56	8,916	8,630
		8,454	
		8,509	

Technician who conducted tests:	MR,SB,RV

Customer:	**MDOT**	Project:	**BCD 180143**	Lab #:	**BCD**
MIX NUMBER	**Mix 2**	Notes:	**MDOT Bridge Deck Overlay**	Set #:	Mix 2
Date:	**2/7/2019**	Mix Code:	f'c: 2,500 to 3,000 psi; Size(c.f.): 3	Factor:	**0.11**

MIX DESIGN INFO

Material	Vol. (c.f.)	SSD mix 1 cu. yd. Wt. (lbs.)	SSD mix lab batch Wt. (lbs.)	Adjusted lab batch Wt. (lbs.)	Actual lab batch Wt. (lbs.)	Material Source	SSD Specific Gravity	Agg. absorp-tion	Agg. FM
Cement 1:	2.54	500.00	**55.56**	**55.56**	55.56	Holcim - Theodore, AL Type II	3.15		
Cement 2:	0.00	0.00	**0.00**	**0.00**					
Fly Ash:	0.54	88.00	**9.78**	**9.78**	9.78	Boral Resources - Plant Miller Class C	2.61		
GGBFS:	0.00	0.00	**0.00**	**0.00**					
Sand 1:	8.04	1326.04	**147.34**	**156.96**	156.96	Concrete Sand - Hammett Kuhn Mine MDOT 3-26-4	2.643	0.13%	2.55
Coarse Aggregate 1:	10.73	1700.00	**188.89**	**188.78**	188.78	No 8 - Hammett Kuhn Mine MDOT 3-26-4	2.538	2.26%	5.75
Coarse Aggregate 2:	0.00	0.00	**0.00**	**0.00**			1.000	1.00%	1.00
Coarse Aggregate 3:	0.00	0.00	**0.00**	**0.00**			1.000	1.00%	1.00
Coarse Aggregate 4:	0.00	0.00	**0.00**	**0.00**			1.000	1.00%	1.00
Air: **4.50%**	1.22	0.00	**0.00**	**0.00**					
Water:	3.93	245.00	**27.22**	**17.71**	17.71		1.00		
"+-Air: **0.50%**									
Total:	27.00	3859.04	428.78	428.78					
UW w/o Air:		149.66	149.66	149.66					

ADMIX INFORMATION

Type	oz /cwt	oz /cy	ml /cy	batch ml	actual	Brand / Name
Air	0.71	4.15	122.6	13.6	13.6	GCP - DARAVAIR 1000
Type A	4.00	23.52	695.6	77.3	77.3	GCP - ZYLA 610
Type F	16.63	97.76	2891.0	321.2	321.2	GCP - ADVA 140M
	oz /cwt	**lbs /cy**	**lbs/batch**	**g/batch**		
Waterproofing	16.0	5.88	0.65	296.35	0.65	PRAH-1

Aggregate Moistures

	Free H_2O Content	Batch free H_2O (lbs.)
Sand:	6.54%	9.62
CA 1	-0.06%	-0.11
CA 2	0.00%	0.00
CA 3	0.00%	0.00
CA 4	0.00%	0.00

Water Added/Withheld

+/- h2o	Added	W/held

PLASTIC TEST RESULTS

Batch Time	**1:31 PM**	% Air	**5.80**
Sample Time	**1:37 PM**	Unit Weight (pcf)	**141.2**
Slump, in.	**5.50**	Yield	**3.04**
Mix Temp.	**75.0**	Initial set, min.	**NA**
Air Temp.	**77.0**	Relative Yield	**1.012**

OTHER INFO

Des. w/c	0.417
Act. w/c	0.417
Des.Un.Wt.	142.93
Fine/Coarse	0.78
Bag Factor	6.26

Comments / Notes / Observations

Fresh Property Ranges in Lab

Slump 5 1/4 to 6 3/4 in. (6 in. Max.)

Air: 5 1/2 to 6 1/2% (4.5% Nominal)

Admixture Ranges:

Zyla 610: 2 to 10 oz./100 lbs.

Adva 140M: 2 to 25 oz/100 lbs.

Strength Test Results

Date	AGE	psi	Avg. psi
2/8/2019	1	3,239	3,240
		3,242	
		3,239	
2/10/2019	3	5,223	5,300
		5,361	
		5,312	
2/14/2019	7	6,670	6,600
		6,711	
		6,405	
2/21/2019	14	7,511	7,490
		7,574	
		7,386	
3/7/2019	28	8,346	8,270
		8,316	
		8,149	
4/4/2019	56	9,393	9,140
		9,184	
		8,836	

Technician who conducted tests:	**MR,SB,RV**

Customer:	**MDOT**		Project:	**BCD 180143**				Lab #:	**BCD**
MIX NUMBER	**Mix 3**		Notes:	**MDOT Bridge Deck Overlay**				Set #:	Mix 3
Date:	**2/7/2019**		Mix Code:	f'c:	2,500 to 3,000 psi	Size(c.f.):	3	Factor:	**0.11**

MIX DESIGN INFO

Material	Vol. (c.f.)	SSD mix 1 cu. yd. Wt. (lbs.)	SSD mix lab batch Wt. (lbs.)	Adjusted lab batch Wt. (lbs.)	Actual lab batch Wt. (lbs.)	Material Source	SSD Specific Gravity	Agg. absorp-tion	Agg. FM
Cement 1:	2.54	500.00	**55.56**	**55.56**	55.56	Holcim - Theodore, AL Type II	3.15		
Cement 2:	0.00	0.00	**0.00**	**0.00**					
Fly Ash:	0.54	88.00	**9.78**	**9.78**	9.78	Boral Resources - Plant Miller Class C	2.61		
GGBFS:	0.00	0.00	**0.00**	**0.00**					
Sand 1:	8.04	1326.04	**147.34**	**156.96**	156.96	Concrete Sand - Hammett Kuhn Mine MDOT 3-26-4	2.643	0.13%	2.55
Coarse Aggregate 1:	10.73	1700.00	**188.89**	**188.78**	188.78	No 8 - Hammett Kuhn Mine MDOT 3-26-4	2.538	2.26%	5.75
Coarse Aggregate 2:	0.00	0.00	**0.00**	**0.00**			1.000	1.00%	1.00
Coarse Aggregate 3:	0.00	0.00	**0.00**	**0.00**			1.000	1.00%	1.00
Coarse Aggregate 4:	0.00	0.00	**0.00**	**0.00**			1.000	1.00%	1.00
Air: **4.50%**	1.22	0.00	**0.00**	**0.00**					
Water:	3.93	245.00	**27.22**	**17.71**	17.71		1.00		
"+-Air: **0.50%**									
Total:	27.00	3859.04	428.78	428.78					
UW w/o Air:		149.66	149.66	149.66					

ADMIX INFORMATION

Type	oz /cwt	oz /cy	ml /cy	batch ml	actual	Brand / Name
Air	0.71	4.15	122.6	13.6	13.6	GCP - DARAVAIR 1000
Type A	4.00	23.52	695.6	77.3	77.3	GCP - ZYLA 610
Type F	16.63	97.76	2891.0	321.2	321.2	GCP - ADVA 140M
	oz /cwt	**lbs /cy**	**lbs/batch**	**g/batch**		
Waterproofing	32.0	11.76	1.31	592.69	1.31	PRAH-2

Aggregate Moistures

	Free H_2O Content	Batch free H_2O (lbs.)
Sand:	6.54%	9.62
CA 1	-0.06%	-0.11
CA 2	0.00%	0.00
CA 3	0.00%	0.00
CA 4	0.00%	0.00

Water Added/Withheld

+/- h2o	Added	W/held

PLASTIC TEST RESULTS

Batch Time	**2:34 PM**	% Air	**5.80**
Sample Time	**2:42 PM**	Unit Weight (pcf)	**140.8**
Slump, in.	**6.75**	Yield	**3.04**
Mix Temp.	**75.0**	Initial set, min.	**NA**
Air Temp.	**78.0**	Relative Yield	**1.015**

OTHER INFO

Des. w/c	0.417
Act. w/c	0.417
Des.Un.Wt.	142.93
Fine/Coarse	0.78
Bag Factor	6.26

Comments / Notes / Observations

Fresh Property Ranges in Lab

Slump 5 1/4 to 6 3/4 in. (6 in. Max.)

Air: 5 1/2 to 6 1/2% (4.5% Nominal)

Admixture Ranges:

Zyla 610: 2 to 10 oz./100 lbs.

Adva 140M: 2 to 25 oz/100 lbs.

Strength Test Results

Date	AGE	psi	Avg. psi
2/8/2019	1	1,964	2,060
		2,055	
		2,153	
2/10/2019	3	5,004	5,100
		5,155	
		5,142	
2/14/2019	7	6,226	6,350
		6,201	
		6,626	
2/21/2019	14	7,105	7,250
		7,467	
		7,177	
3/7/2019	28	7,946	8,110
		8,195	
		8,175	
4/4/2019	56	8,689	8,800
		8,673	
		9,041	

Technician who conducted tests:	MR,SB,RV

Appendix B – Aggregate Properties

Final Report

BURNS COOLEY DENNIS, INC.

CONSTRUCTION MATERIALS AND ENGINEERING TESTING SERVICES

278 Commerce Park Drive
Ridgeland, Mississippi 39157

Phone : (601) 856-2332
Fax: (601) 856-3552

To: Mississippi Department of Transportation
Post Office Box 1850
Jackson, Mississippi 39215

Report Date: 1/15/2019

BCD Project No.: 180143

Attn: Cynthia Smith

Project: SPR-2017(018)/107-461-101000 Phase I

SOURCE AND SAMPLING INFORMATION

Aggregate Source: Hammett Gravel Company Kuhn Pit 3-26-4

Aggregate Size: Fine

Sampling Location: Stockpile

Natural Sand

Sampled By: S. Bivings

Gradation ID No: 2

Sample Date: 1/11/2019

Tested By: J. Seay

BCD Lab No: Sample 2

Date Tested: 1/15/2019

AGGREGATE GRADATION INFORMATION

Initial Dry Weight (g): 421.7 Sieve Sizes: Fine 12 in. dia.

Sieve Size	Cumulative Weight Retained (g)	Individual Weight Retained (g)	Individual % Retained	Total % Retained	Total % Passing	Specification	
						Min.	Max.
1 1/2"	0.0	0.0	0.0	0.0	100	100	100
1 1/4"	0.0	0.0	0.0	0.0	100	100	100
1"	0.0	0.0	0.0	0.0	100	100	100
3/4"	0.0	0.0	0.0	0.0	100	100	100
1/2"	0.0	0.0	0.0	0.0	100	100	100
3/8"	0.0	0.0	0.0	0.0	100	97	100
No. 4	20.6	20.6	4.9	4.9	95	92	100
No. 8	50.8	30.2	7.2	12.0	88	75	100
No. 16	85.2	34.4	8.2	20.2	80	45	90
No. 30	152.5	67.3	16.0	36.2	64	25	70
No. 50	361.6	209.1	49.6	85.7	14	3	35
No. 100	405.0	43.4	10.3	96.0	4	0	10
No. 200	412.5	7.5	1.8	97.8	2.2		
Pan	412.8	0.3	0.1				

FM: 2.55

Note:
Gradation meets MDOT requirements.

REPORTED BY: Kevin Williams
CMET Manager

REVIEWED BY: Robert Varner
Engineer

BURNS COOLEY DENNIS, INC.
CONSTRUCTION MATERIALS AND ENGINEERING TESTING SERVICES
278 Commerce Park Drive
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To: Mississippi Department of Transportation
Post Office Box 1850
Jackson, Mississippi 39215

Report Date: 1/15/2019

BCD Project No.: 180143

Attn: Cynthia Smith

Project: SPR-2017(018)/107-461-101000 Phase I

SOURCE AND SAMPLING INFORMATION

Aggregate Source:	Hammett Gravel Company Kuhn Pit 3-26-4	Aggregate Size:	Fine
Sampling Location:	Stockpile		Natural Sand
Sampled By:	S. Bivings	Gradation ID No:	2
Sampled Date:	1/11/2019	Tested By:	J. Seay
BCD Lab No:	Sample 2	Date Tested:	1/15/2019

MATERIALS FINER THAN NO. 200 SIEVE IN MINERAL AGGREGATES BY WASHING (AASHTO T11)

B =	original dry mass of sample (g)	421.7
C =	dry mass of sample after washing (g)	413.1
A =	Percent of materials finer than a No. 200 sieve by washing (%)	2.0

REPORTED BY: Kevin Williams
CMET Manager

REVIEWED BY: Robert Varner
Engineer

Final Report

BURNS COOLEY DENNIS, INC.
CONSTRUCTION MATERIALS AND ENGINEERING TESTING SERVICES

278 COMMERCE PARK DRIVE
RIDGELAND, MISSISSIPPI 39157

Phone: (601) 856-2332
Fax: (601) 856-3552

To: Mississippi Department of Transportation
Post Office Box 1850
Jackson, Mississippi 39215

Report Date: 1/16/2019

BCD Project No.: 180143

Attn: Cynthia Smith

Project: SPR-2017-(018)/10-461-101000 Phase I

SOURCE AND SAMPLING INFORMATION

Aggregate Source:	Hammett Gravel Kuhn Pit 3-26-4	Aggregate Size:	Fine
Sampling Location:	Stockpile		Fine
Sampled By:	S. Bivings		
Date Received:	1/11/2019	Tested By:	J. Seay
BCD Lab No:	1	Date Tested:	1/15/2019

SPECIFIC GRAVITY AND ABSORPTION OF FINE AGGREGATE (AASHTO T84)

A = mass of oven-dry test sample in air (0.1 g)	**500.0**
B = mass of pycnometer filled with water (0.1 g)	**672.8**
S = mass of saturated-surface-dry specimen (0.1 g)	**500.5**
C = mass of pycnometer with SSD specimen and water to calibration mark (0.1 g)	**983.2**
Bulk Specific Gravity (Dry) **Bulk sp gr = A / (B+S-C)**	**2.630**
Bulk Specific Gravity (Saturated-Surface-Dry) **Bulk sp gr (saturated-surface-dry) = S / (B+S-C)**	**2.633**
Absorption, percent **= [(S-A) / A] X 100**	**0.10**

REPORTED BY: Kevin Williams, CMT Manager — Robert Varner, Engineer

Final Report

BURNS COOLEY DENNIS, INC.
CONSTRUCTION MATERIALS AND ENGINEERING TESTING SERVICES

278 COMMERCE PARK DRIVE
RIDGELAND, MISSISSIPPI 39157

Phone: (601) 856-2332
Fax: (601) 856-3552

To: Mississippi Department of Transportation
Post Office Box 1850
Jackson, Mississippi 39215

Attn: Cynthia Smith

Report Date: 1/16/2019

BCD Project No.: 180143

Project: SPR-2017-(018)/10-461-101000 Phase I

SOURCE AND SAMPLING INFORMATION

Aggregate Source: Hammett Gravel Kuhn Pit 3-26-4

Aggregate Size: Fine

Sampling Location: Stockpile

Fine

Sampled By: S. Bivings

Date Received: 1/11/2019

Tested By: J. Seay

BCD Lab No: 2

Date Tested: 1/15/2019

SPECIFIC GRAVITY AND ABSORPTION OF FINE AGGREGATE (AASHTO T84)

A = mass of oven-dry test sample in air (0.1 g)	**500.1**
B = mass of pycnometer filled with water (0.1 g)	**644.8**
S = mass of saturated-surface-dry specimen (0.1 g)	**500.9**
C = mass of pycnometer with SSD specimen and water to calibration mark (0.1 g)	**956.8**
Bulk Specific Gravity (Dry) **Bulk sp gr = A / (B+S-C)**	**2.647**
Bulk Specific Gravity (Saturated-Surface-Dry) **Bulk sp gr (saturated-surface-dry) = S / (B+S-C)**	**2.652**
Absorption, percent **= [(S-A) / A] X 100**	**0.16**

REPORTED BY: Kevin Williams, CMT Manager

Robert Varner, Engineer

Final Report

BURNS COOLEY DENNIS, INC.

CONSTRUCTION MATERIALS AND ENGINEERING TESTING SERVICES

278 Commerce Park Drive
Ridgeland, Mississippi 39157

Phone : (601) 856-2332
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To: Mississippi Department of Transportation
Post Office Box 1850
Jackson, Mississippi 39215

Report Date: 1/15/2019

BCD Project No.: 180143

Attn: Cynthia Smith

Project: SPR-2017(018)/107-461-101000 Phase I

SOURCE AND SAMPLING INFORMATION

Aggregate Source:	Hammett Gravel Company Kuhn Pit 3-26-4	Aggregate Size:	No 8
Sampling Location:	Stockpile		Natural Coarse Gravel
Sampled By:	S. Bivings	Gradation ID No:	1
Sample Date:	1/11/2019	Tested By:	J. Seay
BCD Lab No:	Sample 1	Date Tested:	1/15/2019

AGGREGATE GRADATION INFORMATION

Initial Dry Weight (g): 2692.0 Sieve Sizes: Coarse 16 x 24

Sieve Size	Cumulative Weight Retained (g)	Individual Weight Retained (g)	Individual % Retained	Total % Retained	Total % Passing	Specification	
						Min.	Max.
1 1/2"	0.0	0.0	0.0	0.0	100	100	100
1 1/4"	0.0	0.0	0.0	0.0	100	100	100
1"	0.0	0.0	0.0	0.0	100	100	100
3/4"	0.0	0.0	0.0	0.0	100	100	100
1/2"	31.8	31.8	1.2	1.2	99	95	100
3/8"	117.3	85.5	3.2	4.4	96	75	100
No. 4	1985.0	1867.7	69.4	73.7	26	5	30
No. 8	2655.4	670.4	24.9	98.6	1	0	10
No. 16	2673.6	18.2	0.7	99.3	1	0	5
No. 30	2677.2	3.6	0.1	99.5	1		
No. 50	2681.7	4.5	0.2	99.6	0		
No. 100	2684.6	2.9	0.1	99.7	0		
No. 200	2685.0	0.4	0.0	99.7	0.3		
Pan	2685.1	0.5	0.0				

FM: 5.75

Note:
Gradation meets MDOT requirements.

REPORTED BY: Kevin Williams
CMET Manager

REVIEWED BY: Robert Varner
Engineer

BURNS COOLEY DENNIS, INC.
CONSTRUCTION MATERIALS AND ENGINEERING TESTING SERVICES
278 Commerce Park Drive
Ridgeland, Mississippi 39157
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To: Mississippi Department of Transportation
Post Office Box 1850
Jackson, Mississippi 39215

Report Date: 1/15/2019

BCD Project No.: 180143

Attn: Cynthia Smith

Project: SPR-2017(018)/107-461-101000 Phase I

SOURCE AND SAMPLING INFORMATION

Aggregate Source:	Hammett Gravel Company Kuhn Pit 3-26-4	Aggregate Size:	No 8
Sampling Location:	Stockpile		Natural Coarse Gravel
Sampled By:	S. Bivings	Gradation ID No:	1
Sampled Date:	1/11/2019	Tested By:	J. Seay
BCD Lab No:	Sample 1	Date Tested:	1/15/2019

MATERIALS FINER THAN NO. 200 SIEVE IN MINERAL AGGREGATES BY WASHING (AASHTO T11)

B =	original dry mass of sample (g)	2692.0
C =	dry mass of sample after washing (g)	2685.1
A =	Percent of materials finer than a No. 200 sieve by washing (%)	0.3

REPORTED BY: Robert Varner
CMET Manager

REVIEWED BY: Kevin Williams
Engineer

Final Report

BURNS COOLEY DENNIS, INC.
CONSTRUCTION MATERIALS AND ENGINEERING TESTING SERVICES

278 COMMERCE PARK DRIVE
RIDGELAND, MISSISSIPPI 39157

Phone: (601) 856-2332
Fax: (601) 856-3552

To: Mississippi Department of Transportation
Post Office Box 1850
Jackson, Mississippi 39215

Report Date: 1/16/2019

BCD Project No.: 180143

Attn: Cynthia Smith

Project: SPR-2017-(018)/10-461-101000 Phase I

SOURCE AND SAMPLING INFORMATION

Aggregate Source: Hammett Gravel Kuhn Pit 3-26-4

Aggregate Size: #8

Sampling Location: Stockpile

Coarse

Sampled By: S. Bivings

Date Received: 1/11/2019

Tested By: J. Seay

BCD Lab No: 1

Date Tested: 1/15/2019

SPECIFIC GRAVITY AND ABSORPTION OF COARSE AGGREGATE (AASHTO T85)

A = mass of oven-dry test sample in air (0.1 g)	**2004.8**
B = mass of saturated-surface-dry sample in air (0.1 g)	**2049.4**
C = mass of saturated test sample in water (0.1 g)	**1242.3**
Bulk Specific Gravity (Dry) **Bulk sp gr = A / (B-C)**	**2.484**
Bulk Specific Gravity (Saturated-Surface-Dry) **Bulk sp gr (saturated-surface-dry) = B / (B-C)**	**2.539**
Absorption, percent **= [(B-A) / A] X 100**	**2.23**

REPORTED BY: Kevin Williams, CMT Manager

Robert Varner, Engineer

Final Report

BURNS COOLEY DENNIS, INC.
CONSTRUCTION MATERIALS AND ENGINEERING TESTING SERVICES

278 COMMERCE PARK DRIVE
RIDGELAND, MISSISSIPPI 39157

Phone: (601) 856-2332
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To: Mississippi Department of Transportation
Post Office Box 1850
Jackson, Mississippi 39215

Attn: Cynthia Smith

Report Date: 1/16/2019

BCD Project No.: 180143

Project: SPR-2017-(018)/10-461-101000 Phase I

SOURCE AND SAMPLING INFORMATION

Aggregate Source: Hammett Gravel Kuhn Pit 3-26-4

Aggregate Size: #8

Coarse

Sampling Location: Stockpile

Sampled By: S. Bivings

Date Received: 1/11/2019

Tested By: J. Seay

BCD Lab No: 2

Date Tested: 1/15/2019

SPECIFIC GRAVITY AND ABSORPTION OF COARSE AGGREGATE (AASHTO T85)

A = mass of oven-dry test sample in air (0.1 g)	**2271.8**
B = mass of saturated-surface-dry sample in air (0.1 g)	**2323.5**
C = mass of saturated test sample in water (0.1 g)	**1407.3**
Bulk Specific Gravity (Dry) **Bulk sp gr = A / (B-C)**	**2.480**
Bulk Specific Gravity (Saturated-Surface-Dry) **Bulk sp gr (saturated-surface-dry) = B / (B-C)**	**2.536**
Absorption, percent **= [(B-A) / A] X 100**	**2.28**

REPORTED BY: Kevin Williams, CMT Manager

Robert Varner, Engineer

BURNS COOLEY DENNIS, INC.
CONSTRUCTION MATERIALS AND ENGINEERING TESTING SERVICES

278 COMMERCE PARK DRIVE
RIDGELAND, MISSISSIPPI 39157

Phone: (601) 856-2332
Fax: (601) 856-3552

To: Mississippi Department of Transportation
Post Office Box 1850
Jackson, Mississippi 39215
Attn: Cynthia Smith
Project: SPR-2017(018)/10-461-101000 Phase I

Report Date: 1/16/2019
BCD Project No.: 180143

BULK DENSITY ("UNIT WEIGHT") AND VOIDS IN AGGREGATE (AASHTO T19 / ASTM C29)

Aggregate Source: Hammett Gravel Company Kuhn Pit 3-26-4
Aggregate Size: No. 8
Sample Location: Stockpile
Sampled By: S. Bivings
Tested By: J. Seay
Date Received: 1/11/2019
Date Tested: 1/16/2019
BCD Lab No: Sample 1

Unit Weight (lb/ft^3)		
Sample Number:	1	2
Calibrated volume of measure, V, ft^3	0.103	0.103
Tare weight of measure, T, lb	5.94	5.94
Mass of aggregate plus measure, G, lb	16.02	16.04
Unit weight of aggregate, M, lb/ft^3 M=(G-T)/V	98	98
Void Content (%)		
Average unit weight, M_{avg}, lb/ft^3	98	
Bulk Specific Gravity (Dry Basis), S	2.482	
Density of Water, W (62.3 lb/ft^3)	62.3	
Void Content, % = 100[(S*W)-M]/(S*W)	37	

REPORTED BY: Jimmy Seay
REVIEWED BY: Robert Varner

Appendix C – Compressive Strength

Final Report

BURNS COOLEY DENNIS, INC.
CONSTRUCTION MATERIALS AND ENGINEERING TESTING SERVICES

Ridgeland Lab
278 COMMERCE PARK DRIVE
RIDGELAND, MISSISSIPPI 39157

Phone: (601) 856-2332
Fax: (601) 856-3552

CONCRETE CYLINDER COMPRESSIVE STRENGTH REPORT

To: Mississippi Department of Transportation
Post Office Box 1850
Jackson, Mississippi 39215

Report Date: December 26, 2019

BCD Project No.: 180143

Attn: Cynthia Smith
Project: SPR-2017(018)/107-461-101000 Phase I

Set Number: 52635

FIELD TEST CONDITIONS AND RESULTS				
Date Sampled:	2/7/2019	Field Test(s):	Specimens	Additional Tests
Supplier:	BCD Lab	Time Sampled:	12:19 PM	
Mix Number:	Mix 1	Ticket Number:	NA	
Specified Strength (psi) in 24 Hours:	2,500	Water Added (gal):	0	
Specimen Type:	4-in. Diam. Cylinder	Air Content (%):	6.5	
Concrete Quantity, (ft^3):	3	Concrete Temp. (°F)	78	
Initial Curing Temperatures, (°F):		Slump (in.)	6	
Minimum:	NA	Unit Weight (pcf):	140.1	
Maximum:	NA	Technician:	RV/CB/SB	
Control Mix				

Sample Number	Test Date	Age Days	Dim 1 (in.)	Dim 2 (in.)	Area ($in.^2$)	Max Load (lbs)	Strength (psi)	% of Specified Strength	Type Fracture	Comments
7	2/8/2019	1	4.01	4.01	12.63	37,202	2,946	118	5	
8	2/8/2019	1	4.01	4.01	12.63	37,985	3,008	120	5	
9	2/8/2019	1	4.00	4.01	12.60	40,259	3,196	128	5	
10	2/10/2019	3	4.01	4.00	12.60	62,448	4,957	198	5	
11	2/10/2019	3	4.00	4.01	12.60	64,909	5,152	206	5	
12	2/10/2019	3	4.01	4.01	12.63	65,331	5,173	207	5	
13	2/14/2019	7	3.99	4.01	12.57	80,326	6,392	256	5	
14	2/14/2019	7	3.99	4.01	12.57	78,367	6,236	249	2	
15	2/14/2019	7	4.01	4.00	12.60	79,962	6,347	254	5	
16	2/21/2019	14	4.01	4.00	12.60	88,832	7,051	282	1	
17	2/21/2019	14	3.99	4.01	12.57	94,172	7,494	300	3	
18	2/21/2019	14	4.01	4.01	12.63	89,451	7,083	283	5	
19	3/7/2019	28	4.02	4.01	12.66	96,823	7,647	306	2	
20	3/7/2019	28	4.01	4.00	12.60	97,213	7,717	309	5	
21	3/7/2019	28	4.00	4.00	12.57	97,661	7,772	311	5	
22	4/4/2019	56	3.97	4.01	12.50	111,481	8,916	357	1	
23	4/4/2019	56	4.01	4.00	12.60	106,508	8,454	338	1	
24	4/4/2019	56	4.00	4.00	12.57	106,923	8,509	340	2	

Remarks: Tests conducted as required by the following AASHTO Standards: AASHTO R39, T23, T22, T119, T121, T152, T309. Cylinder specimens were capped in accordance with ASTM 1231.

Comments: We appreciate the opportunity to be of service. If you should have any questions concerning this report, please do not hesitate to call us.

REPORTED BY: Scott Bivings
Concrete Materials Manager

REVIEWED BY: Robert Varner
Engineer

Final Report

BURNS COOLEY DENNIS, INC.
CONSTRUCTION MATERIALS AND ENGINEERING TESTING SERVICES

Ridgeland Lab
278 COMMERCE PARK DRIVE
RIDGELAND, MISSISSIPPI 39157

Phone: (601) 856-2332
Fax: (601) 856-3552

CONCRETE CYLINDER COMPRESSIVE STRENGTH REPORT

To: Mississippi Department of Transportation
Post Office Box 1850
Jackson, Mississippi 39215

Report Date: December 26, 2019

BCD Project No.: 180143

Attn: Cynthia Smith
Project: SPR-2017(018)/107-461-101000 Phase I

Set Number: 52636

FIELD TEST CONDITIONS AND RESULTS				
Date Sampled:	2/7/2019	Field Test(s):	Specimens	Additional Tests
Supplier:	BCD Lab	Time Sampled:	1:37 PM	
Mix Number:	Mix 2	Ticket Number:	NA	
Specified Strength (psi) in 24 Hours:	2,500	Water Added (gal):	0	
Specimen Type:	4-in. Diam. Cylinder	Air Content (%):	5.8	
Concrete Quantity, (ft^3):	3	Concrete Temp. (°F)	75	
Initial Curing Temperatures, (°F):		Slump (in.)	5.5	
Minimum:	NA	Unit Weight (pcf):	141.2	
Maximum:	NA	Technician:	RV/CB/SB	

Mix with CWA1

COMPRESSION TESTS RESULTS

Sample Number	Test Date	Age Days	Dim 1 (in.)	Dim 2 (in.)	Area ($in.^2$)	Max Load (lbs)	Strength (psi)	% of Specified Strength	Type Fracture	Comments
25	2/8/2019	1	3.98	4.03	12.60	40,812	3,239	130	5	
26	2/8/2019	1	4.00	4.01	12.60	40,838	3,242	130	5	
27	2/8/2019	1	3.98	4.04	12.63	40,902	3,239	130	5	
28	2/10/2019	3	4.01	4.00	12.60	65,799	5,223	209	5	
29	2/10/2019	3	4.01	4.00	12.60	67,532	5,361	214	5	
30	2/10/2019	3	4.01	4.00	12.60	66,914	5,312	212	5	
31	2/14/2019	7	4.01	4.00	12.60	84,025	6,670	267	5	
32	2/14/2019	7	4.01	4.00	12.60	84,549	6,711	268	3	
33	2/14/2019	7	4.00	4.01	12.60	80,693	6,405	256	2	
34	2/21/2019	14	4.01	3.99	12.57	94,388	7,511	300	1	
35	2/21/2019	14	3.99	4.02	12.60	95,410	7,574	303	1	
36	2/21/2019	14	4.01	4.01	12.63	93,275	7,386	295	3	
37	3/7/2019	28	4.00	4.00	12.57	104,876	8,346	334	3	
38	3/7/2019	28	4.01	4.02	12.66	105,290	8,316	333	2	
39	3/7/2019	28	4.02	4.00	12.63	102,921	8,149	326	5	
40	4/4/2019	56	4.00	4.01	12.60	118,326	9,393	376	1	
41	4/4/2019	56	4.01	3.99	12.57	115,413	9,184	367	1	
42	4/4/2019	56	4.00	4.02	12.63	111,595	8,836	353	1	

Remarks: Tests conducted as required by the following AASHTO Standards: AASHTO R39, T23, T22, T119, T121, T152, T309. Cylinder specimens were capped in accordance with ASTM 1231.

Comments: We appreciate the opportunity to be of service. If you should have any questions concerning this report, please do not hesitate to call us.

REPORTED BY: Scott Bivings
Concrete Materials Manager

REVIEWED BY: Robert Varner
Engineer

Final Report

BURNS COOLEY DENNIS, INC.
CONSTRUCTION MATERIALS AND ENGINEERING TESTING SERVICES

Ridgeland Lab
278 COMMERCE PARK DRIVE
RIDGELAND, MISSISSIPPI 39157

Phone: (601) 856-2332
Fax: (601) 856-3552

CONCRETE CYLINDER COMPRESSIVE STRENGTH REPORT

To: Mississippi Department of Transportation
Post Office Box 1850
Jackson, Mississippi 39215

Report Date: December 26, 2019

BCD Project No.: 180143

Attn: Cynthia Smith
Project: SPR-2017(018)/107-461-101000 Phase I

Set Number: 52637

FIELD TEST CONDITIONS AND RESULTS				
Date Sampled:	2/7/2019	Field Test(s):	Specimens	Additional Tests
Supplier:	BCD Lab	Time Sampled:	2:42 PM	
Mix Number:	Mix 3	Ticket Number:	NA	
Specified Strength (psi) in 24 Hours:	2,500	Water Added (gal):	0	
Specimen Type:	4-in. Diam. Cylinder	Air Content (%):	5.8	
Concrete Quantity, (ft^3):	3	Concrete Temp. (°F)	75	
Initial Curing Temperatures, (°F):		Slump (in.)	6.75	
Minimum:	NA	Unit Weight (pcf):	140.8	
Maximum:	NA	Technician:	RV/CB/SB	
Mix with CWA2				

COMPRESSION TESTS RESULTS

Sample Number	Test Date	Age Days	Dim 1 (in.)	Dim 2 (in.)	Area ($in.^2$)	Max Load (lbs)	Strength (psi)	% of Specified Strength	Type Fracture	Comments
43	2/8/2019	1	4.01	4.02	12.66	24,870	1,964	79	5	
44	2/8/2019	1	4.01	4.01	12.63	25,957	2,055	82	5	
45	2/8/2019	1	4.01	4.00	12.60	27,123	2,153	86	5	
46	2/10/2019	3	4.01	4.02	12.66	63,356	5,004	200	5	
47	2/10/2019	3	4.00	4.00	12.57	64,774	5,155	206	3	
48	2/10/2019	3	4.00	4.01	12.60	64,776	5,142	206	5	
49	2/14/2019	7	4.01	4.00	12.60	78,430	6,226	249	3	
50	2/14/2019	7	4.01	4.00	12.60	78,115	6,201	248	5	
51	2/14/2019	7	4.00	4.00	12.57	83,263	6,626	265	3	
52	2/21/2019	14	4.01	4.01	12.63	89,735	7,105	284	2	
53	2/21/2019	14	4.01	4.01	12.63	94,302	7,467	299	3	
54	2/21/2019	14	4.00	4.00	12.57	90,187	7,177	287	1	
55	3/7/2019	28	4.01	4.00	12.60	100,099	7,946	318	1	
56	3/7/2019	28	4.00	4.02	12.63	103,495	8,195	328	2	
57	3/7/2019	28	4.01	4.01	12.63	103,249	8,175	327	5	
58	4/4/2019	56	4.00	4.01	12.60	109,466	8,689	348	1	
59	4/4/2019	56	4.00	4.00	12.57	108,990	8,673	347	1	
60	4/4/2019	56	4.00	4.00	12.57	113,611	9,041	362	1	

Remarks: Tests conducted as required by the following AASHTO Standards: AASHTO R39, T23, T22, T119, T121, T152, T309. Cylinder specimens were capped in accordance with ASTM 1231.

Comments: We appreciate the opportunity to be of service. If you should have any questions concerning this report, please do not hesitate to call us.

REPORTED BY: Scott Bivings
Concrete Materials Manager

REVIEWED BY: Robert Varner
Engineer

Appendix D – Rapid Chloride Ion Permeability and Surface Resistivity

Final Report

BURNS COOLEY DENNIS, INC.
GEOTECHNICAL & MATERIALS CONSULTANTS

278 COMMERCE PARK DRIVE **BUS: (601) 856-2332**

RIDGELAND, MS 39157 **FAX: (601) 856-3552**

To: Mississippi Department of Transportation
Post Office Box 1850
Jackson, Mississippi 39215

Report Date: 4/4/2019

BCD Project No.: 180143

Attn: Cynthia Smith

Project: SPR-2017(018)/107-461-101000 Phase I

Mix Number Mix 1

Date Sampled: Thursday, February 07, 2019

PERMEABILITY - AASHTO T 277						
Specimen Age	**Specimen Number**	**Test date**	**Diameter 1 (.001 in.)**	**Diameter 2 (.001 in.)**	**Measured Coulombs**	**Adjusted Coulombs**
28	1A	Thursday, March 07, 2019	4.019	4.049	2365	2044
30	1B	Saturday, March 09, 2019	4.006	4.017	3104	2713
					Average	**2378**
					Penetrability Based on Test	**Moderate**

56	1C	Thursday, April 04, 2019	4.016	4.002	1679	1469
56	1D	Thursday, April 04, 2019	4.013	4.028	1557	1355
					Average	**1412**
					Penetrability Based on Test	**Low**

Reported By: Mark Reece **Reviewed By:** Robert Varner

Final Report

BURNS COOLEY DENNIS, INC.
GEOTECHNICAL & MATERIALS CONSULTANTS
278 COMMERCE PARK DRIVE **BUS: (601) 856-2332**
RIDGELAND, MS 39157 **FAX: (601) 856-3552**

To: Mississippi Department of Transportation
Post Office Box 1850
Jackson, Mississippi 39215

Report Date: 4/4/2019

BCD Project No.: 180143

Attn: Cynthia Smith
Project: SPR-2017(018)/107-461-101000 Phase I

Mix Number: Mix 2

Date Sampled: Thursday, February 07, 2019

PERMEABILITY - AASHTO T 277

Specimen Age	Specimen Number	Test date	Diameter 1 (.001 in.)	Diameter 2 (.001 in.)	Measured Coulombs	Adjusted Coulombs
28	2A	Thursday, March 07, 2019	4.017	4.026	2243	1950
30	2B	Saturday, March 09, 2019	4.010	4.005	2495	2185

Average **2068**

Penetrability Based on Test **Moderate**

56	2C	Thursday, April 04, 2019	4.026	4.009	1528	1331
56	2D	Thursday, April 04, 2019	4.033	4.015	1505	1307

Average **1319**

Penetrability Based on Test **Low**

Reported By: Mark Reece **Reviewed By:** **Robert Varner**

Final Report

BURNS COOLEY DENNIS, INC.
GEOTECHNICAL & MATERIALS CONSULTANTS
278 COMMERCE PARK DRIVE **BUS: (601) 856-2332**
RIDGELAND, MS 39157 **FAX: (601) 856-3552**

To: Mississippi Department of Transportation
Post Office Box 1850
Jackson, Mississippi 39215

Report Date: 4/4/2019
BCD Project No.: 180143

Attn: Cynthia Smith
Project: SPR-2017(018)/107-461-101000 Phase I
Mix Number: Mix 3

Date Sampled: Thursday, February 07, 2019

PERMEABILITY - AASHTO T 277						
Specimen Age	**Specimen Number**	**Test date**	**Diameter 1 (.001 in.)**	**Diameter 2 (.001 in.)**	**Measured Coulombs**	**Adjusted Coulombs**
28	3A	Thursday, March 07, 2019	4.017	4.016	2364	2061
30	3B	Saturday, March 09, 2019	4.021	4.016	2759	2403

Average 2232

Penetrability Based on Test **Moderate**

56	3C	Thursday, April 04, 2019	4.037	3.993	1590	1387
56	3D	Thursday, April 04, 2019	3.981	4.033	1610	1410

Average 1399

Penetrability Based on Test **Low**

Reported By: Mark Reece **Reviewed By:** Robert Varner

Final Report

BURNS COOLEY DENNIS, INC.
GEOTECHNICAL & MATERIALS CONSULTANTS

278 COMMERCE PARK DRIVE
RIDGELAND, MS 39157

BUS: (601) 856-2332
FAX: (601) 856-3552

To: Mississippi Department of Transportation
Post Office Box 1850
Jackson, Mississippi 39215

Report Date: 4/4/2019

BCD Project No.: 180143

Attn: Cynthia Smith
Project: SPR-2017(018)/107-461-101000 Phase I

Mix Number: Mix 1

Date Sampled: Thursday, February 07, 2019

Surface Resistivity Readings and Calculations												
Specimen Age	Sample Number	0°	90°	180°	270°	0°	90°	180°	270°	Average	Standard Deviation	%RSD
28	1A	18.2	18.0	16.7	17.6	18.5	17.3	16.8	17.6	17.6	0.6	3.6
28	1B	17.3	16.6	16.9	17.1	17.2	16.8	16.7	17.0	17.0	0.2	1.4
28	1C	17.8	17.4	17.1	17.5	17.8	17.2	17.5	17.6	17.5	0.3	1.4

Set Average 17

Curing Condition Correction 1.0

Penetrability Based on Test Moderate

Surface Resistivity Readings and Calculations												
Specimen Age	Sample Number	0°	90°	180°	270°	0°	90°	180°	270°	Average	Standard Deviation	%RSD
56	1D	22.8	24.1	22.3	22.8	23.4	24.0	23.1	23.6	23.3	0.6	2.7
56	1E	22.8	23.4	22.1	22.6	22.0	22.6	23.2	22.9	22.7	0.5	2.1
56	1F	22.8	24.0	22.4	22.6	22.9	22.5	23.4	24.5	23.1	0.8	3.3

Set Average 23

Curing Condition Correction 1.0

Penetrability Based on Test Low

REPORTED BY: Mark Reece

REVIEWED BY: Robert Varner

BURNS COOLEY DENNIS, INC.
GEOTECHNICAL & MATERIALS CONSULTANTS
278 COMMERCE PARK DRIVE **BUS: (601) 856-2332**
RIDGELAND, MS 39157 **FAX: (601) 856-3552**

To: Mississippi Department of Transportation
Post Office Box 1850
Jackson, Mississippi 39215

Report Date: 4/4/2019

BCD Project No.: 180143

Attn: Cynthia Smith
Project: SPR-2017(018)/107-461-101000 Phase I

Mix Number: Mix 2

Date Sampled: Thursday, February 07, 2019

Surface Resistivity Readings and Calculations												
Specimen Age	Sample Number	0°	90°	180°	270°	0°	90°	180°	270°	Average	Standard Deviation	%RSD
28	2A	17.6	17.3	17.6	17.3	16.9	17.4	17.8	17.5	17.4	0.3	1.6
28	2B	17.2	17.5	17.0	16.9	17.4	17.6	17.2	17.5	17.3	0.3	1.5
28	2C	17.8	18.1	16.9	17.8	17.3	17.9	17.0	17.8	17.6	0.4	2.5

Set Average 17

Curing Condition Correction 1.0

Penetrability Based on Test Moderate

Surface Resistivity Readings and Calculations												
Specimen Age	Sample Number	0°	90°	180°	270°	0°	90°	180°	270°	Average	Standard Deviation	%RSD
56	2D	23.2	23.6	23.4	23.4	24.4	25.1	25.2	24.6	24.1	0.8	3.4
56	2E	23.7	23.7	23.9	22.5	25.1	25.7	24.0	23.2	24.0	1.0	4.2
56	2F	23.3	23.4	23.3	23.5	24.9	25.0	24.8	24.4	24.1	0.8	3.2

Set Average 24

Curing Condition Correction 1.0

Penetrability Based on Test Low

REPORTED BY: Mark Reece

REVIEWED BY: Robert Varner

BURNS COOLEY DENNIS, INC.
GEOTECHNICAL & MATERIALS CONSULTANTS
278 COMMERCE PARK DRIVE
RIDGELAND, MS 39157
BUS: (601) 856-2332
FAX: (601) 856-3552

To: Mississippi Department of Transportation
Post Office Box 1850
Jackson, Mississippi 39215

Report Date: 4/4/2019

BCD Project No.: 180143

Attn: Cynthia Smith
Project: SPR-2017(018)/107-461-101000 Phase I

Mix Number: Mix 3

Date Sampled: Thursday, February 07, 2019

Surface Resistivity Readings and Calculations

Specimen Age	Sample Number	0°	90°	180°	270°	0°	90°	180°	270°	Average	Standard Deviation	%RSD
28	3A	14.8	15.6	15.7	16.3	14.7	15.2	14.6	15.4	15.3	0.6	3.8
28	3B	15.3	15.4	15.1	14.8	15.0	14.2	15.0	14.7	14.9	0.4	2.5
28	3C	15.4	15.4	15.2	15.3	15.2	15.0	15.0	15.0	15.2	0.2	1.1

Set Average 15

Curing Condition Correction 1.0

Penetrability Based on Test Moderate

Surface Resistivity Readings and Calculations

Specimen Age	Sample Number	0°	90°	180°	270°	0°	90°	180°	270°	Average	Standard Deviation	%RSD
56	3D	22.1	20.7	22.9	24.2	22.0	23.0	23.3	24.6	22.9	1.3	5.5
56	3E	22.1	23.2	22.3	23.9	23.0	22.6	23.4	22.4	22.9	0.6	2.7
56	3F	21.8	21.3	21.9	21.6	21.7	22.5	22.5	21.5	21.9	0.4	2.0

Set Average 23

Curing Condition Correction 1.0

Penetrability Based on Test Low

REPORTED BY: Mark Reece

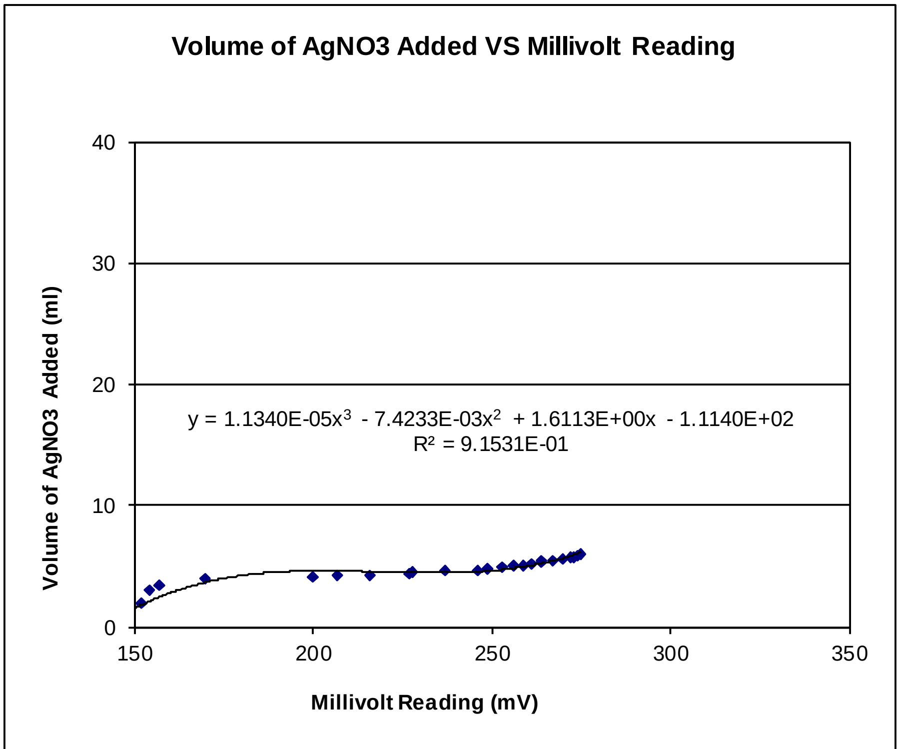
REVIEWED BY: Robert Varner

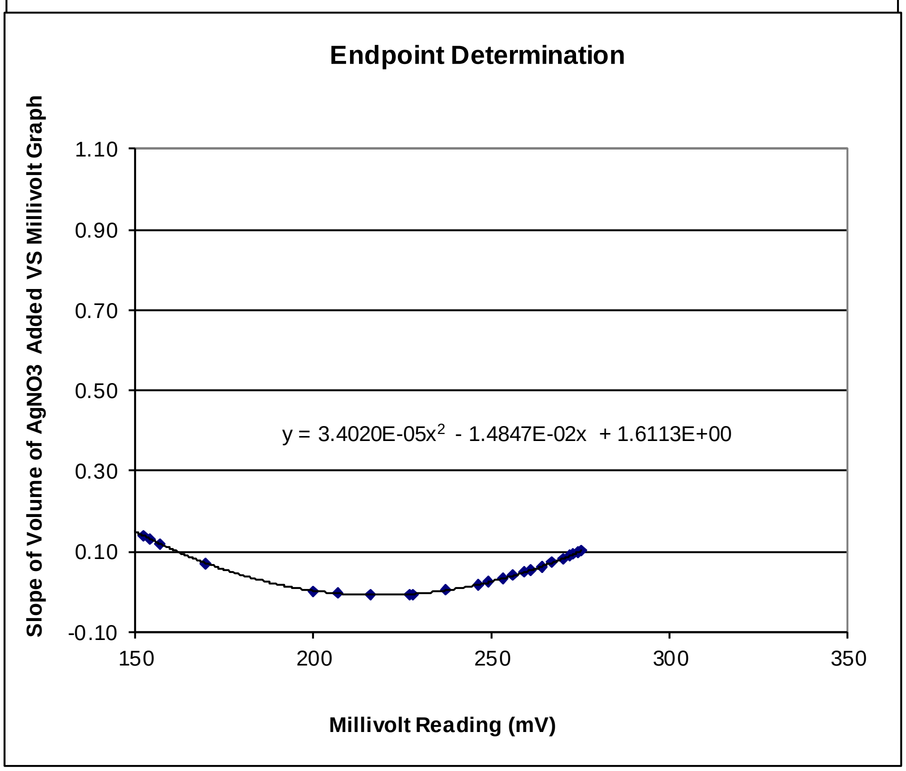
Appendix E – Chloride Ion Content

Final Report

AASHTO 260 "Standard Method of Test for Sampling and Testing for Chloride Ion In Concrete

BCD Sample No. 1 REPEAT





mV Value Where Slope = Zero: 218.20 Titration End Point: 4.55

Mass of Concrete Sample (g) 3.0045

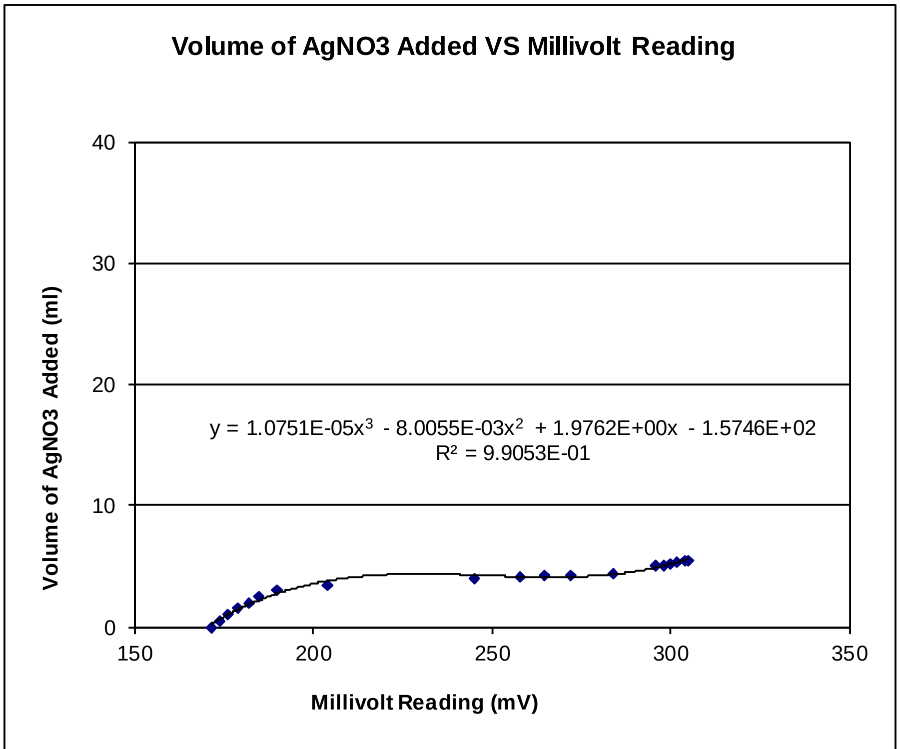
Percent Chloride Ion: 0.0065

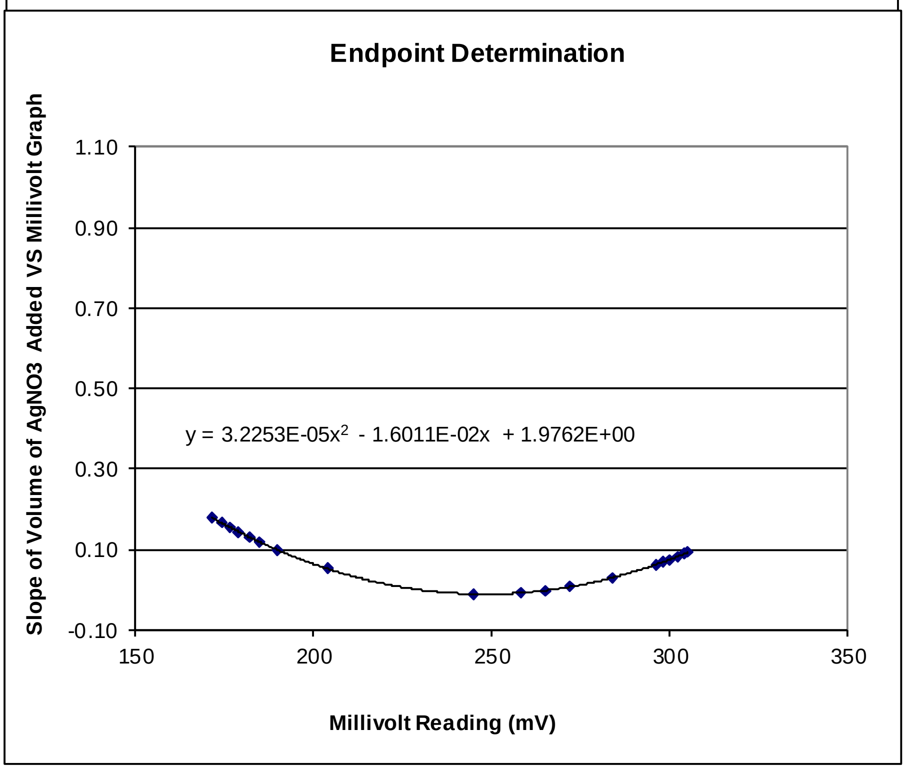
REPORTED BY: Jason Powers, Technician REVIEWED BY: Robert Varner, Engineer

Final Report

AASHTO 260 "Standard Method of Test for Sampling and Testing for Chloride Ion In Concrete

BCD Sample No. 2- Repeat





mV Value Where Slope = Zero: 248.20 Titration End Point: 4.25

Mass of Concrete Sample (g) 3.0794

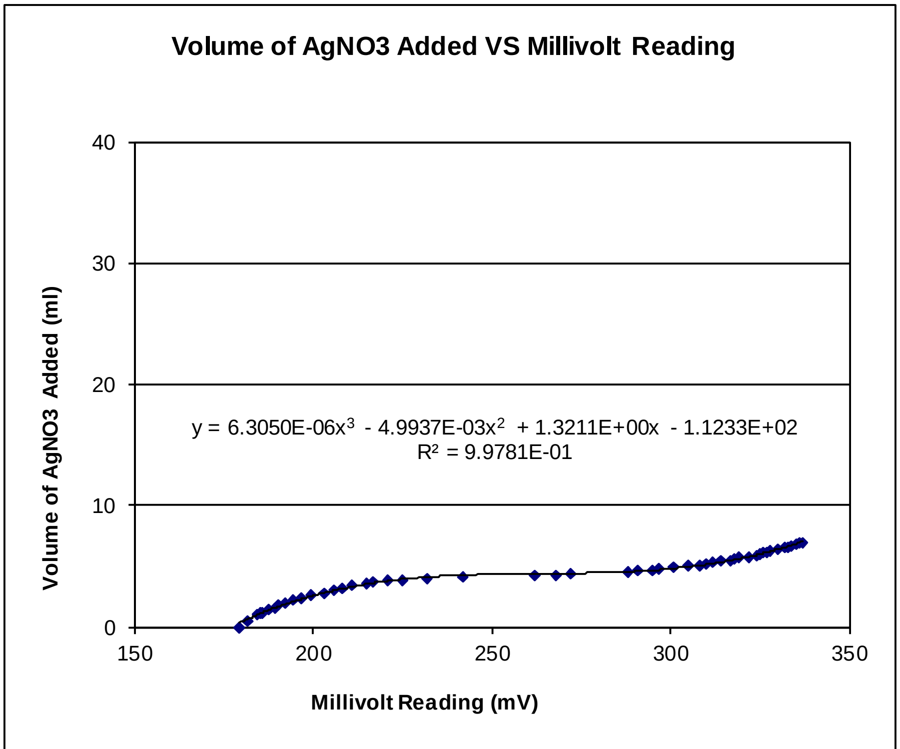
Percent Chloride Ion: 0.0028

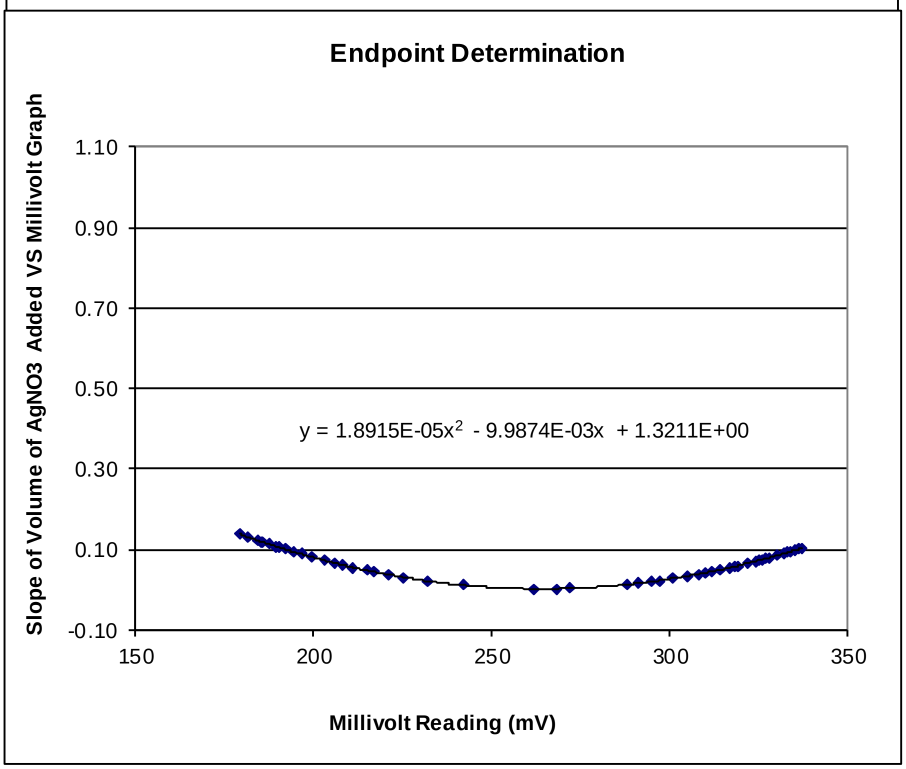
REPORTED BY: Jason Powers, Technician REVIEWED BY: Robert Varner, Engineer

Final Report

AASHTO 260 "Standard Method of Test for Sampling and Testing for Chloride Ion In Concrete

BCD Sample No. 3





mV Value Where Slope = Zero: 264.00 Titration End Point: 4.41

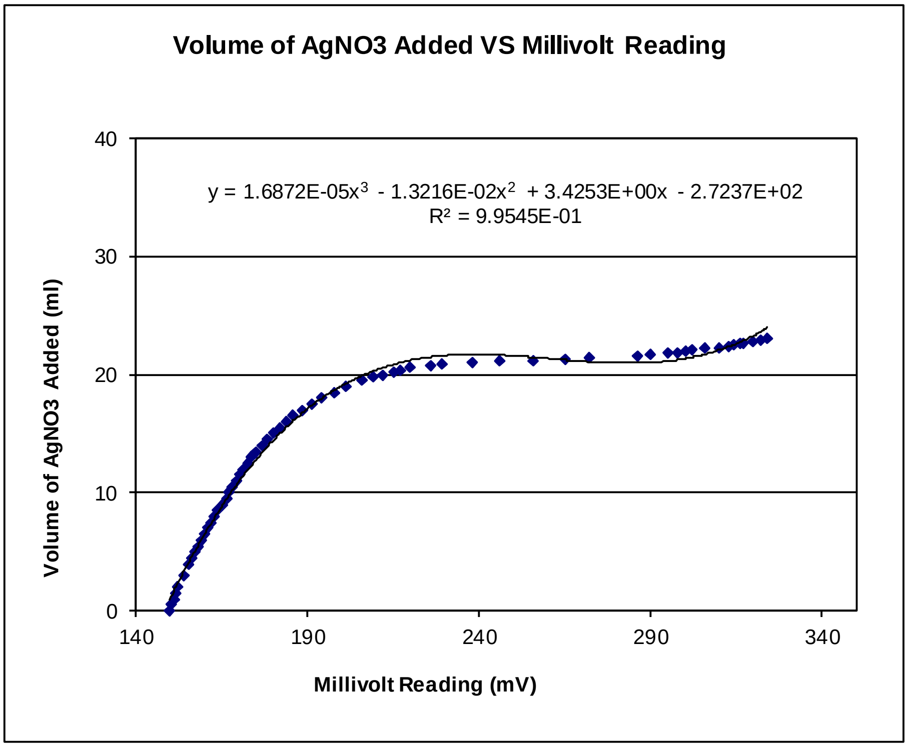
Mass of Concrete Sample (g) 3.0614

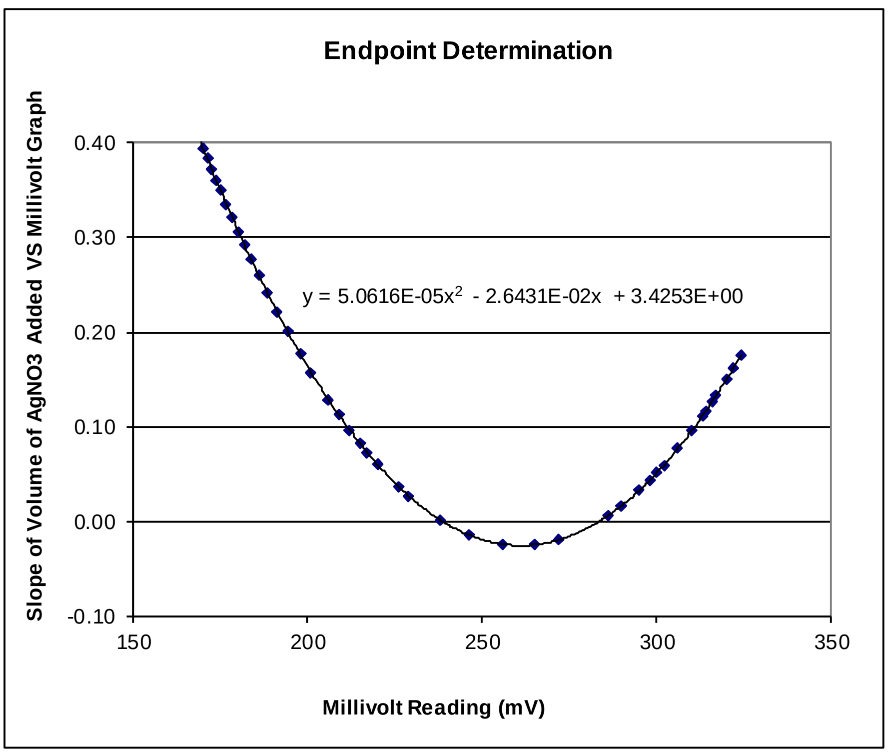
Percent Chloride Ion: 0.0047

REPORTED BY: Jason Powers, Technician REVIEWED BY: Robert Varner, Engineer

AASHTO 260 "Standard Method of Test for Sampling and Testing for Chloride Ion In Concrete Raw Materials

BCD Sample No. 4





mV Value Where Slope = Zero: 261.1 Titration End Point: 21.34

Mass of Concrete Sample (g) 3.0359

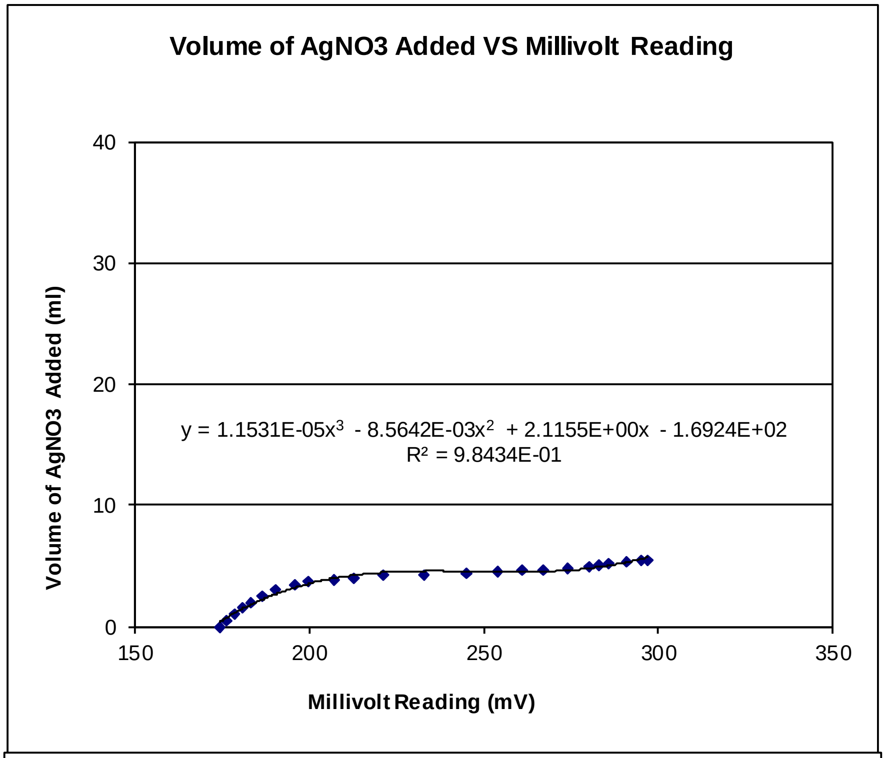
Percent Chloride Ion: 0.2025

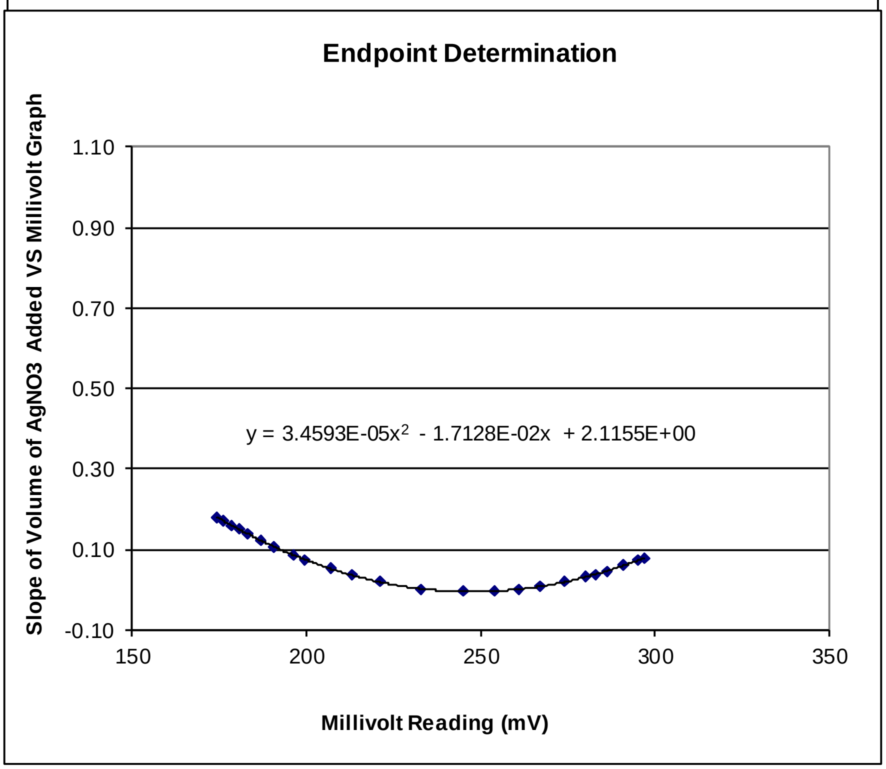
REPORTED BY: Jason Powers, Technician REVIEWED BY: Robert Varner, Engineer

Final Report

AASHTO 260 "Standard Method of Test for Sampling and Testing for Chloride Ion In

BCD Sample No. 5 Repeat





mV Value Where Slope = Zero: 247.60 Titration End Point: 4.55

Mass of Concrete Sample (g) 3.0614

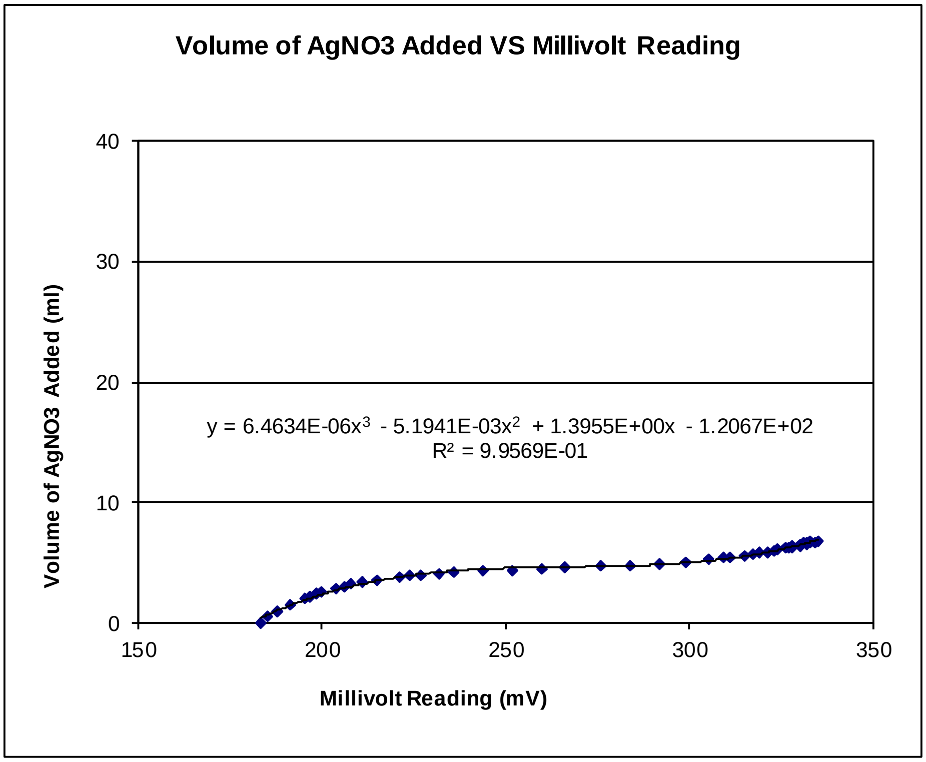
Percent Chloride Ion: 0.0064

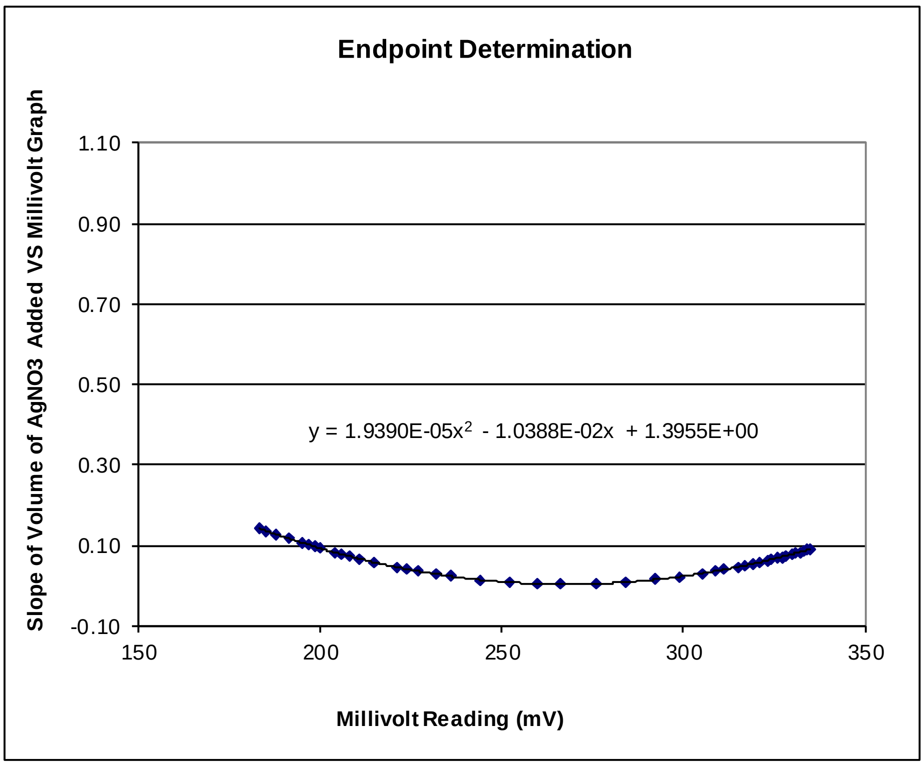
REPORTED BY: Jason Powers, Technician

REVIEWED BY: Robert Varner, Engineer

AASHTO 260 "Standard Method of Test for Sampling and Testing for Chloride Ion In Concrete

BCD Sample No. 6





mV Value Where Slope = Zero: 267.90 Titration End Point: 4.68

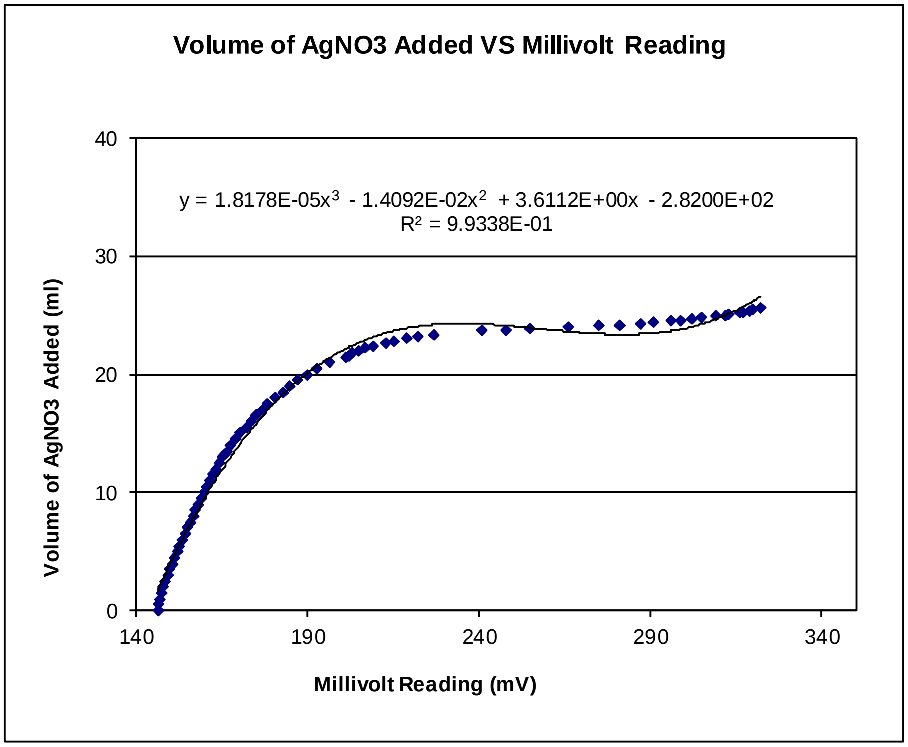
Mass of Concrete Sample (g) 3.0091

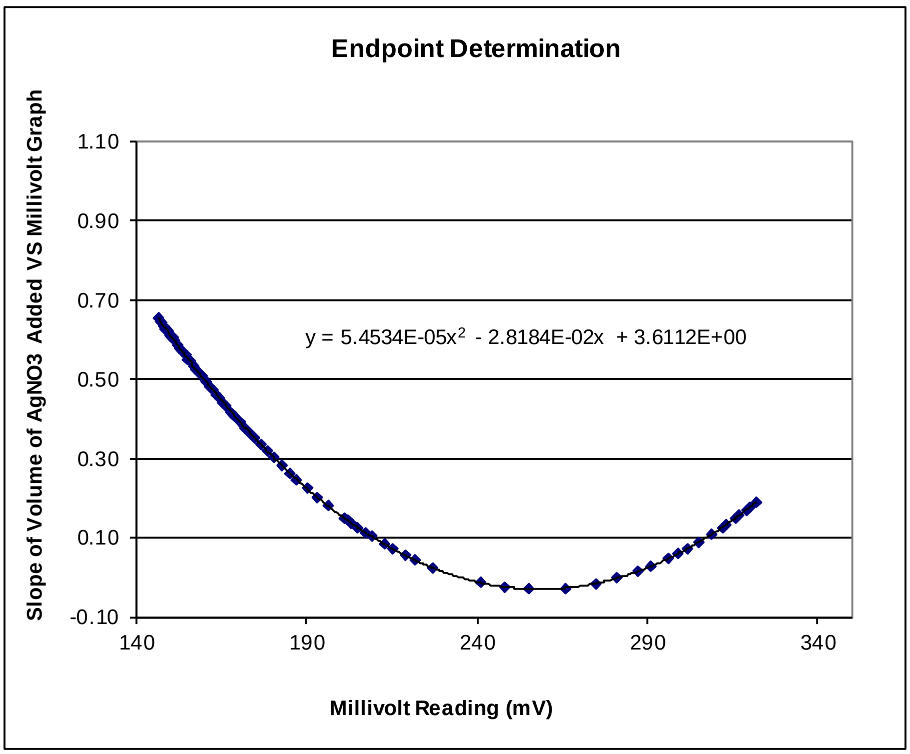
Percent Chloride Ion: 0.0080

REPORTED BY: Jason Powers, Technician REVIEWED BY: Robert Varner, Engineer

AASHTO 260 "Standard Method of Test for Sampling and Testing for Chloride Ion In Concrete Raw Materials

BCD Sample No. 7





mV Value Where Slope = Zero: 258.4 Titration End Point: 23.85

Mass of Concrete Sample (g) 3.0089

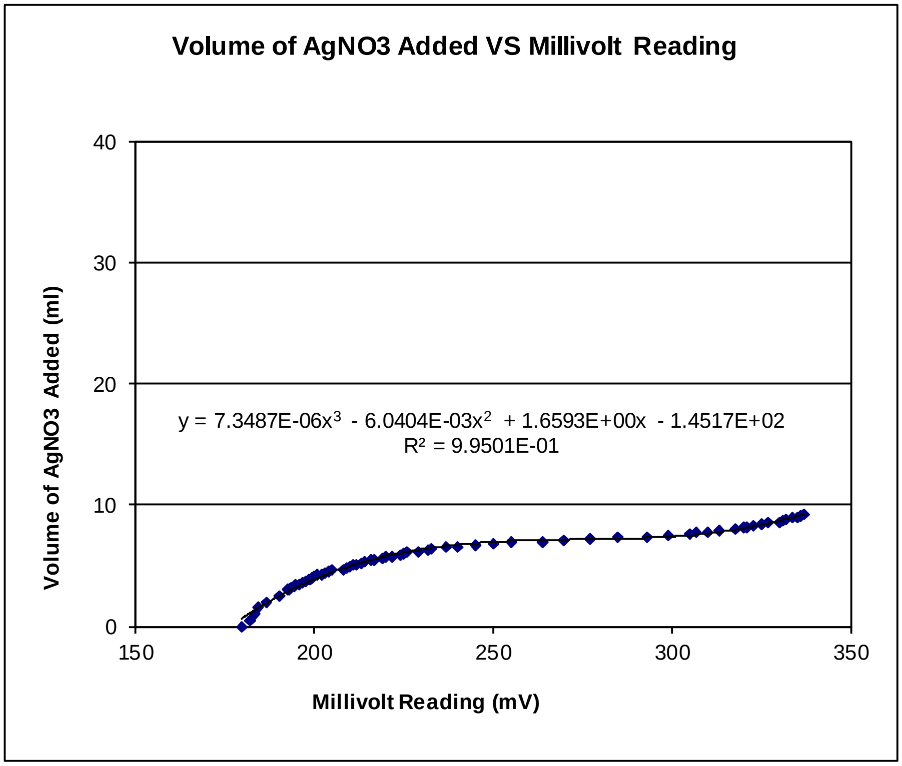
Percent Chloride Ion: 0.2338

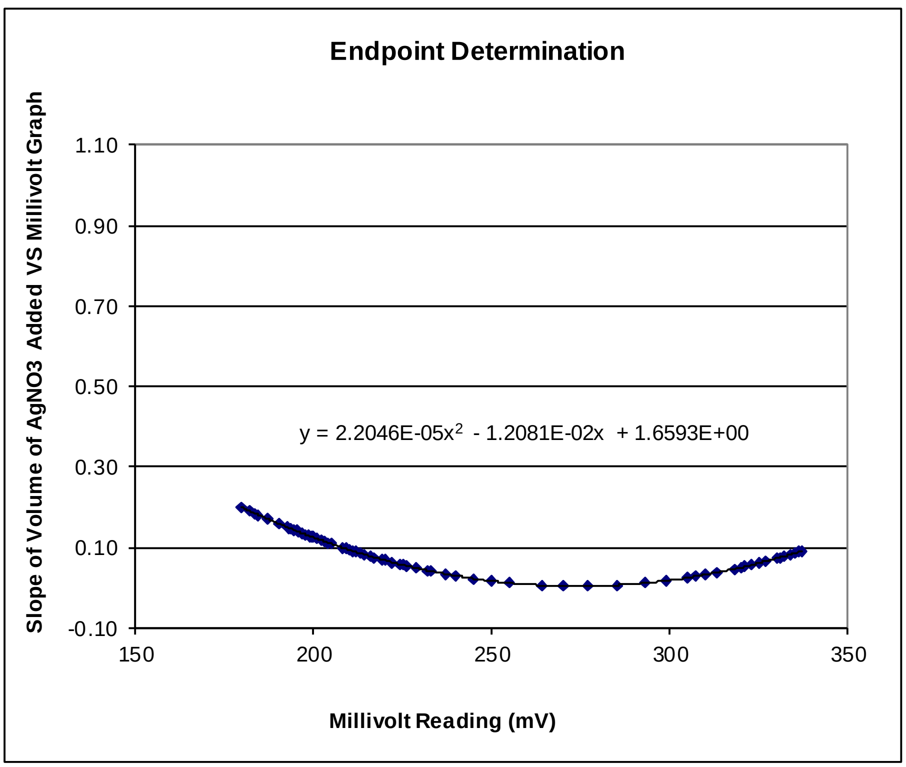
REPORTED BY: Jason Powers, Technician

REVIEWED BY: Robert Varner, Engineer

AASHTO 260 "Standard Method of Test for Sampling and Testing for Chloride Ion In Concrete

BCD Sample No. 8





mV Value Where Slope = Zero: 274.00 Titration End Point: 7.16

Mass of Concrete Sample (g) 3.086

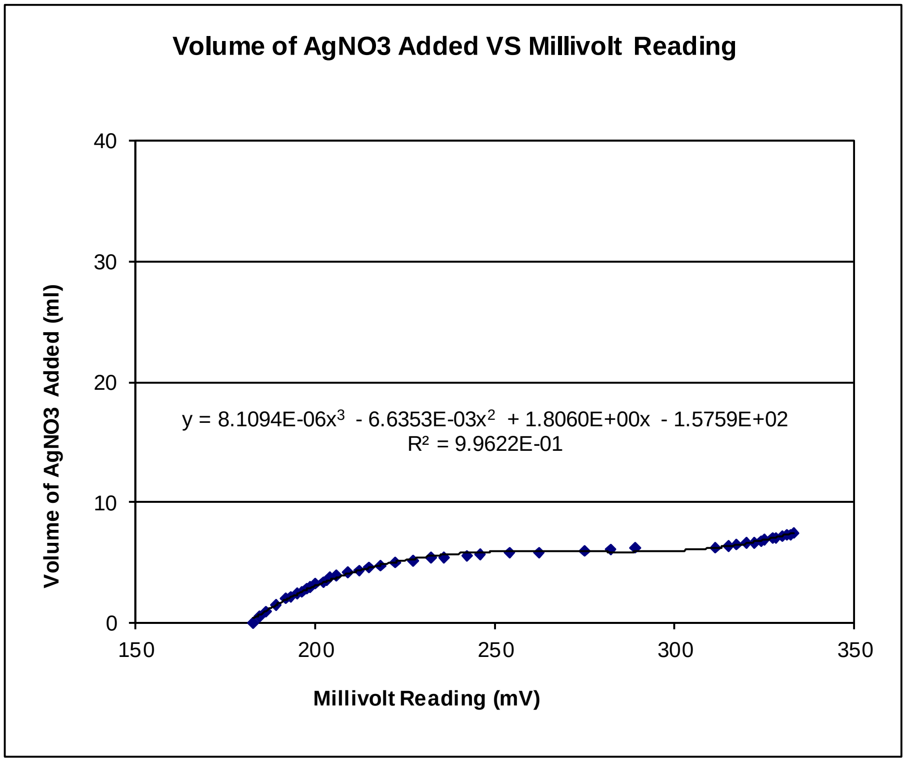
Percent Chloride Ion: 0.0363

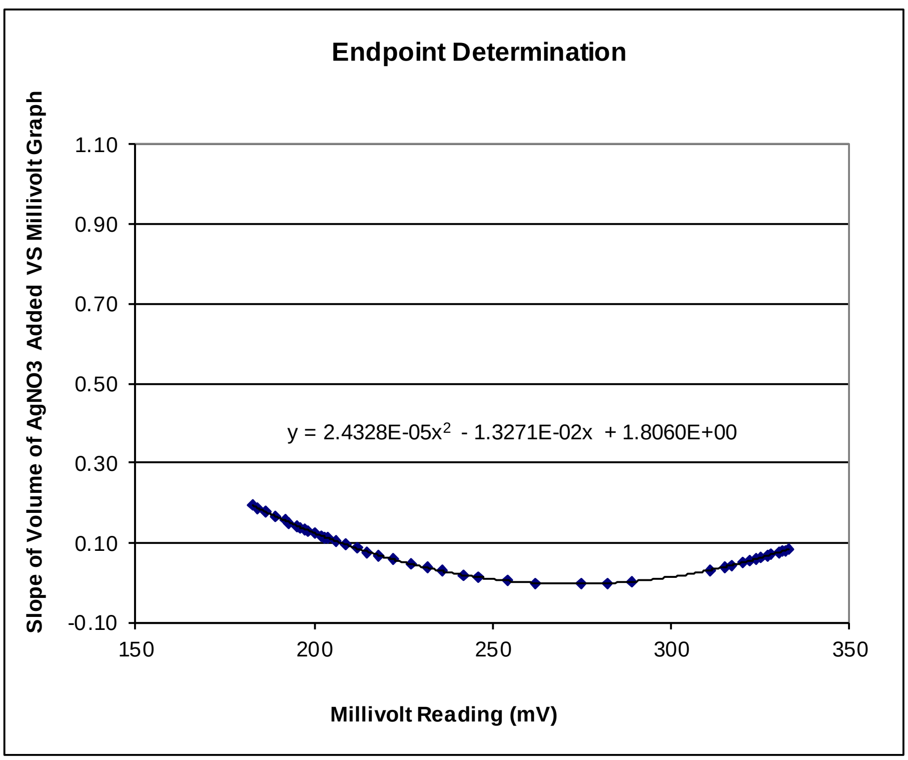
REPORTED BY: Jason Powers, Technician REVIEWED BY: Robert Varner, Engineer

Final Report

AASHTO 260 "Standard Method of Test for Sampling and Testing for Chloride Ion In Concrete

BCD Sample No. 9





mV Value Where Slope = Zero: 272.70 Titration End Point: 5.94

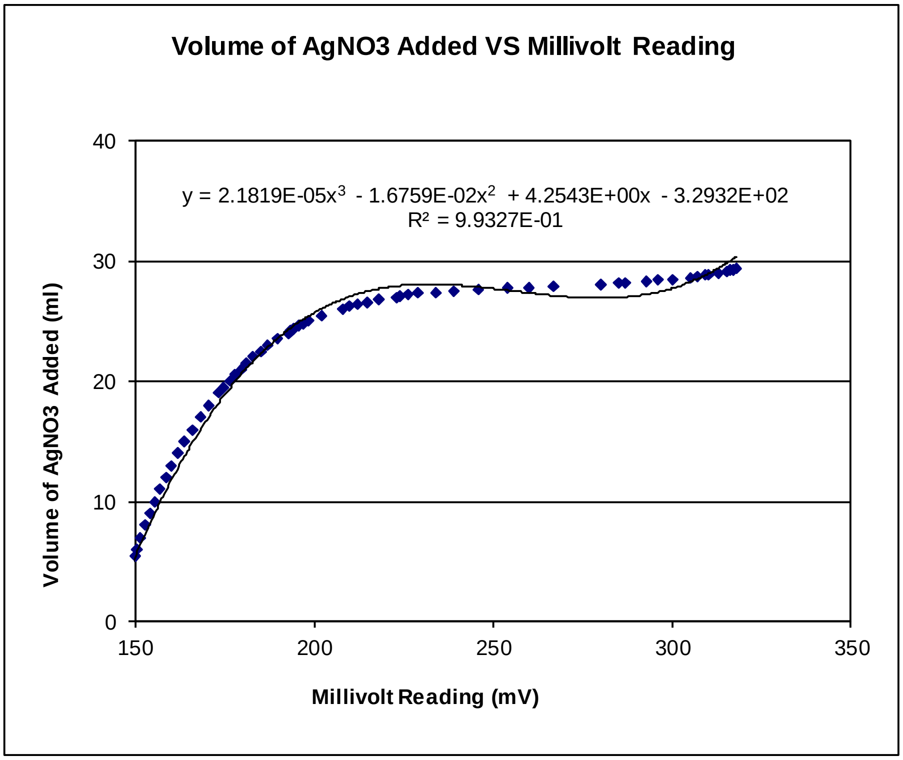
Mass of Concrete Sample (g) 3.0911

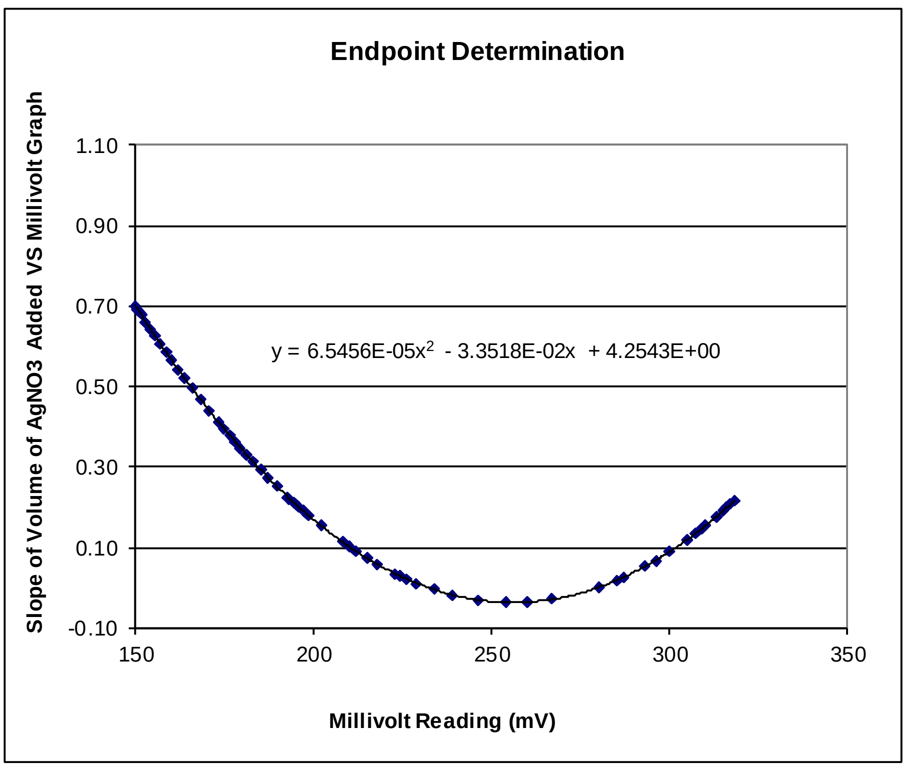
Percent Chloride Ion: 0.0222

REPORTED BY: Jason Powers, Technician REVIEWED BY: Robert Varner, Engineer

AASHTO 260 "Standard Method of Test for Sampling and Testing for Chloride Ion In Concrete

BCD Sample No. 10





mV Value Where Slope = Zero: 256.00 Titration End Point: 27.49

Mass of Concrete Sample (g) 3.0025

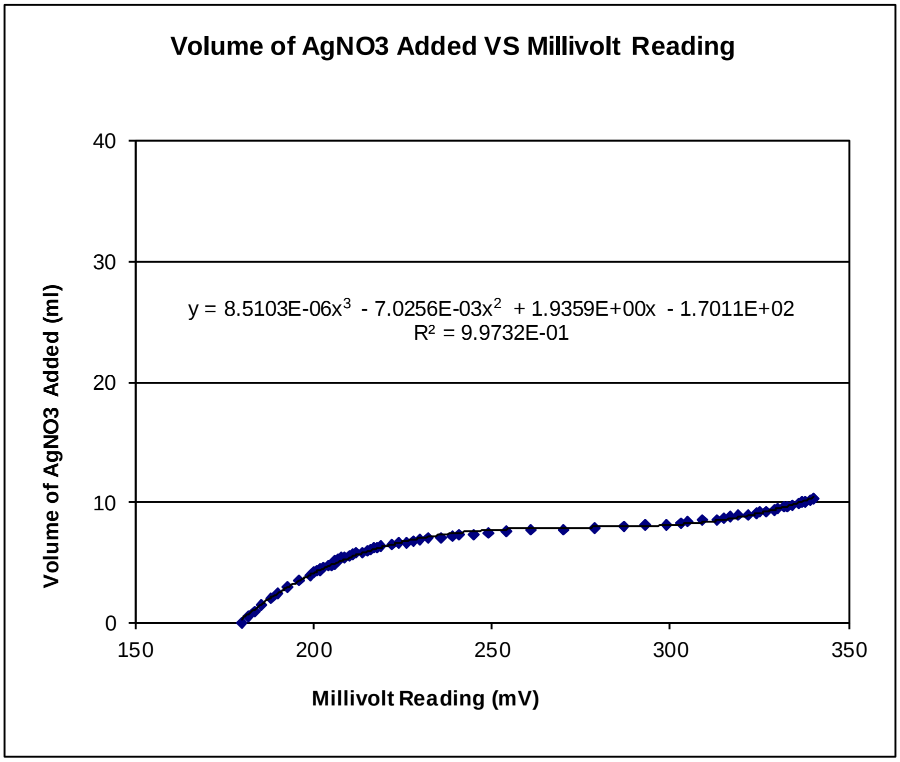
Percent Chloride Ion: 0.2774

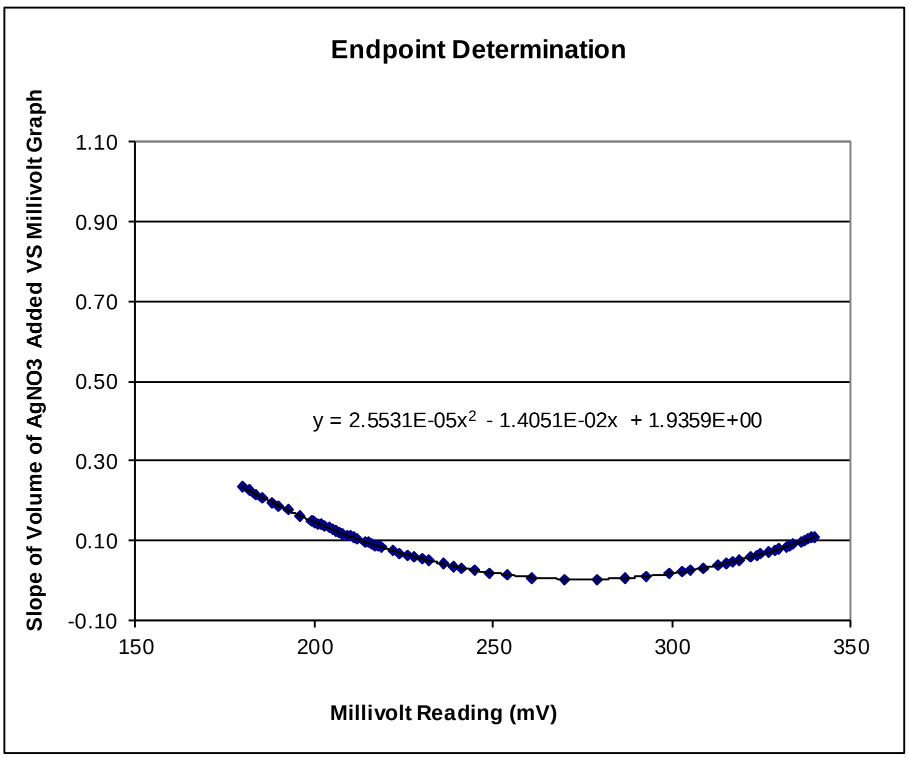
REPORTED BY: Jason Powers, Technician

REVIEWED BY: Robert Varner, Engineer

AASHTO 260 "Standard Method of Test for Sampling and Testing for Chloride Ion In Concrete

BCD Sample No. 11





mV Value Where Slope = Zero: 275.10 Titration End Point: 7.94

Mass of Concrete Sample (g) 3.0015

Percent Chloride Ion: 0.0465

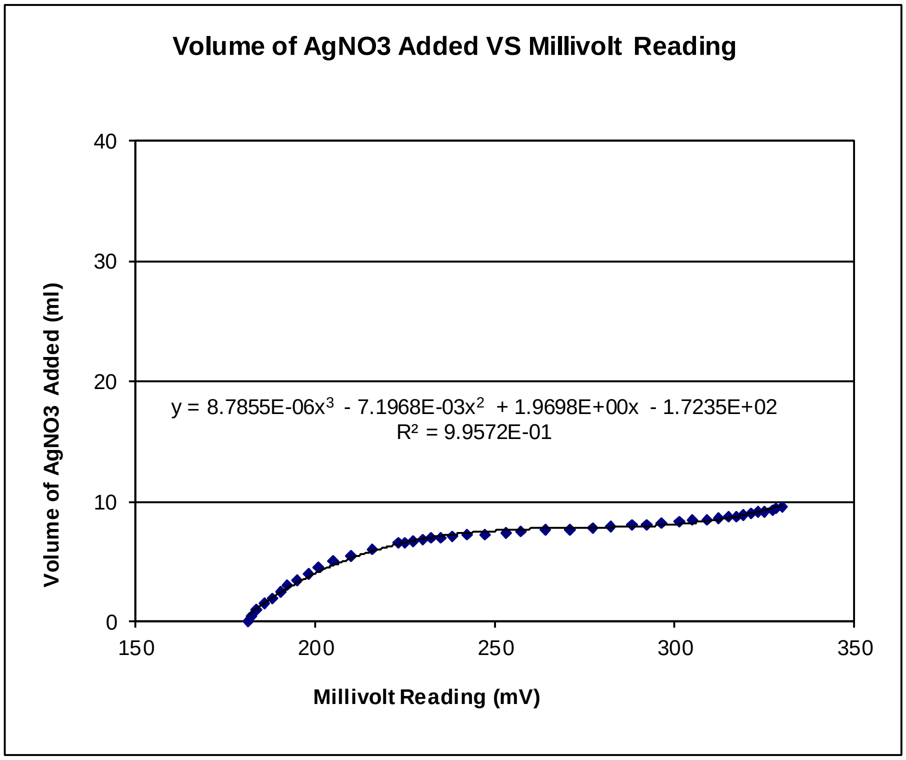
REPORTED BY: Jason Powers, Technician

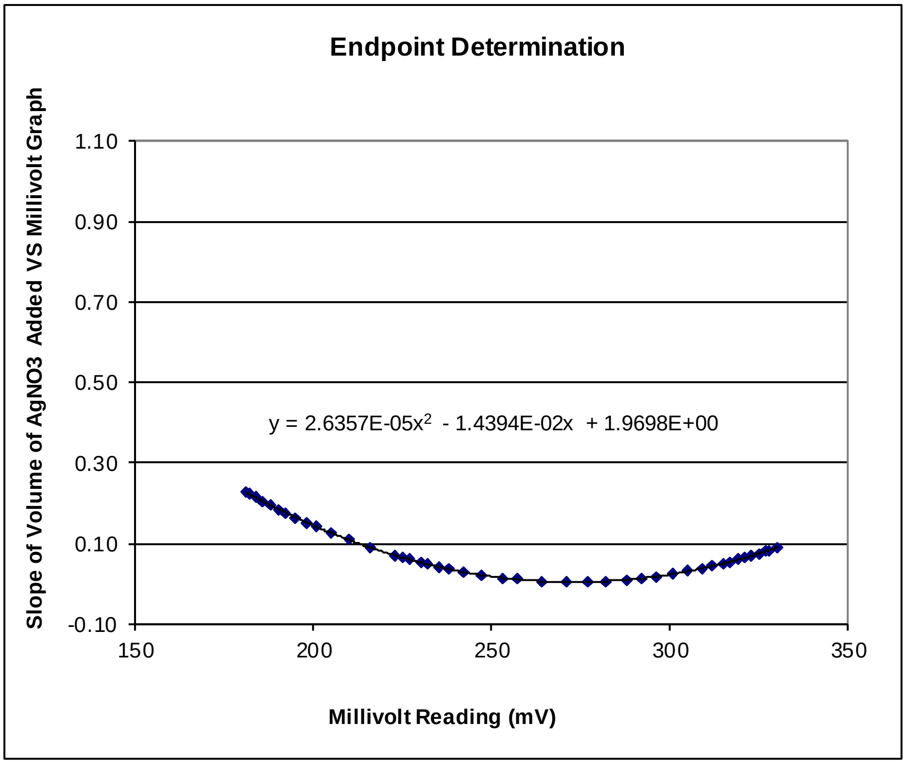
REVIEWED BY: Robert Varner, Engineer

Final Report

AASHTO 260 "Standard Method of Test for Sampling and Testing for Chloride Ion In Concrete

BCD Sample No. 12





mV Value Where Slope = Zero: 273.10 Titration End Point: 7.80

Mass of Concrete Sample (g) 3.0176

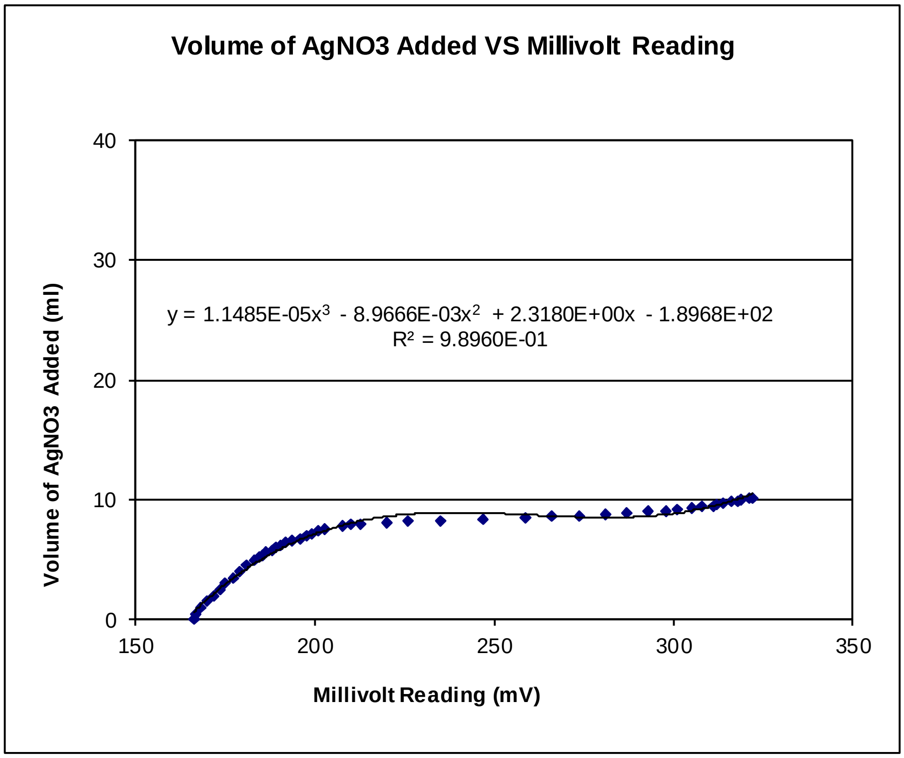
Percent Chloride Ion: 0.0446

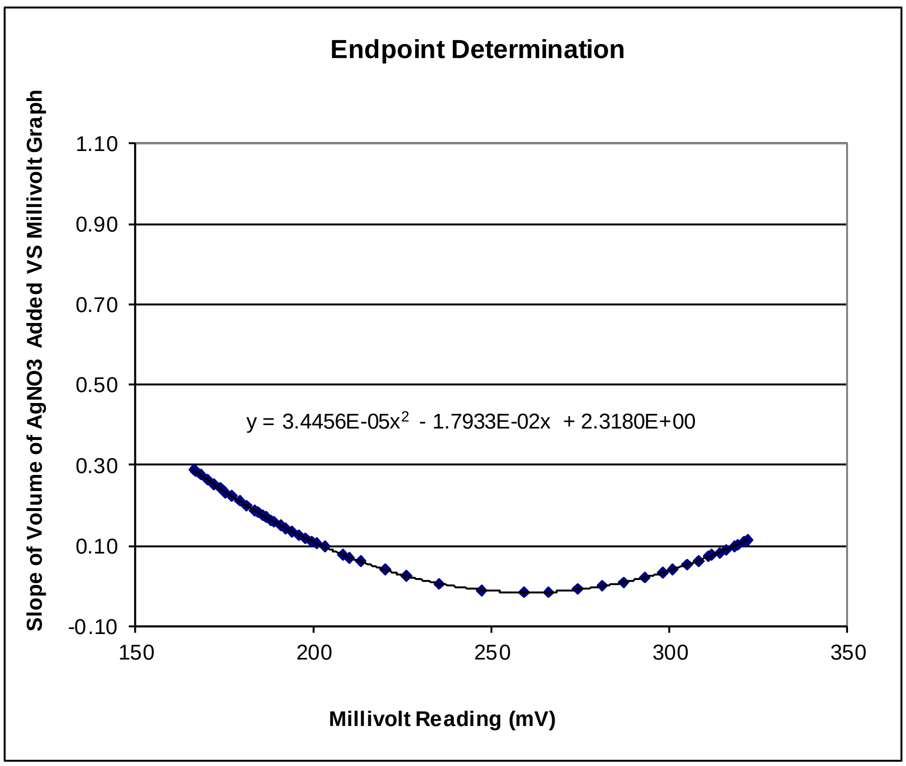
REPORTED BY: Jason Powers, Technician REVIEWED BY: Robert Varner, Engineer

Final Report

AASHTO 260 "Standard Method of Test for Sampling and Testing for Chloride Ion In Concrete

BCD Sample No. 13





mV Value Where Slope = Zero: 260.20 Titration End Point: 8.74

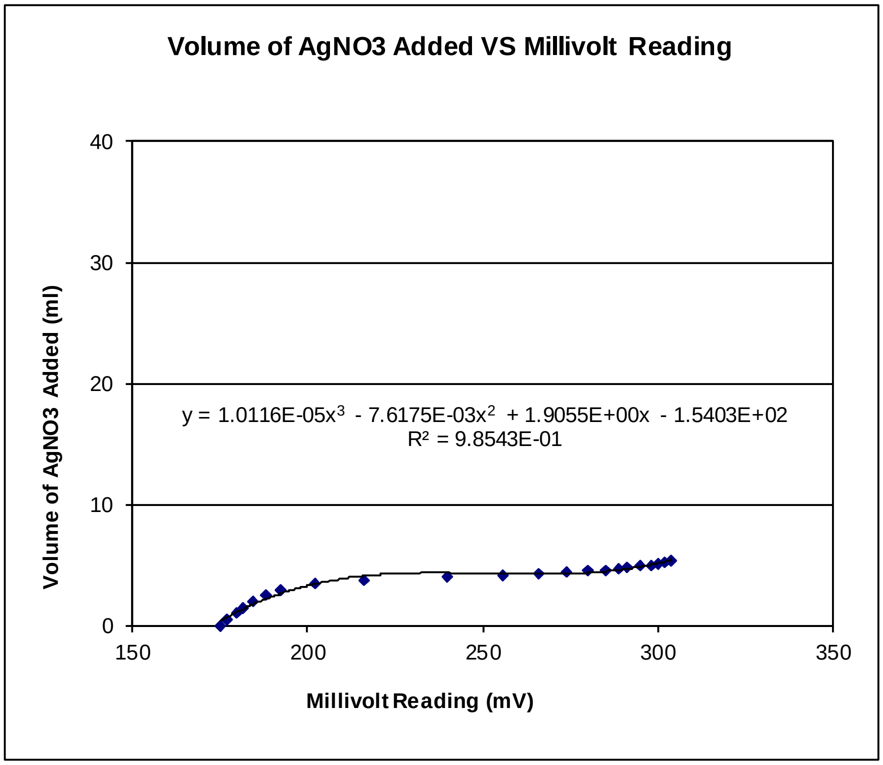
Mass of Concrete Sample (g) 3.0056

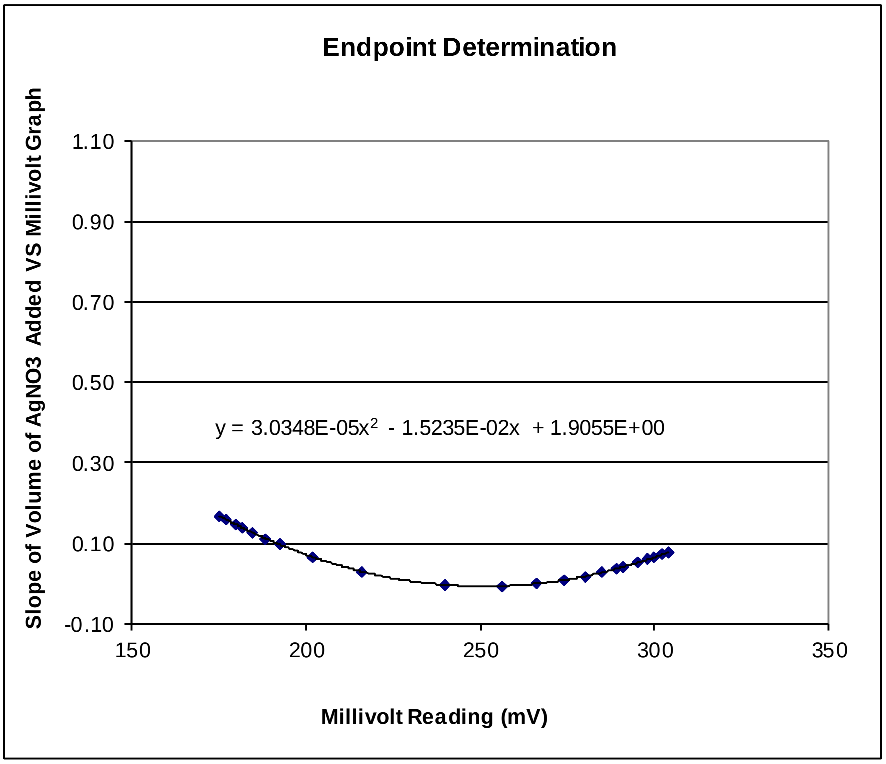
Percent Chloride Ion: 0.0559

REPORTED BY: Jason Powers, Technician REVIEWED BY: Robert Varner, Engineer

AASHTO 260 "Standard Method of Test for Sampling and Testing for Chloride Ion In

BCD Sample No. 14 Repeat





mV Value Where Slope = Zero: 251.00 Titration End Point: 4.30

Mass of Concrete Sample (g) 3.0214

Percent Chloride Ion: 0.0035

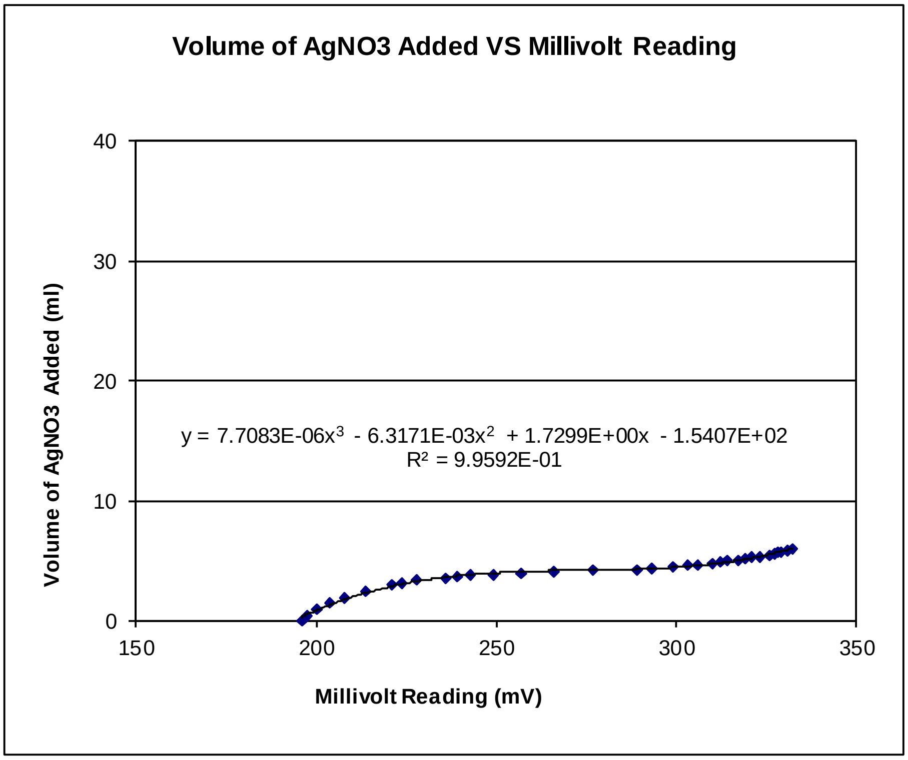
REPORTED BY: Jason Powers, Technician

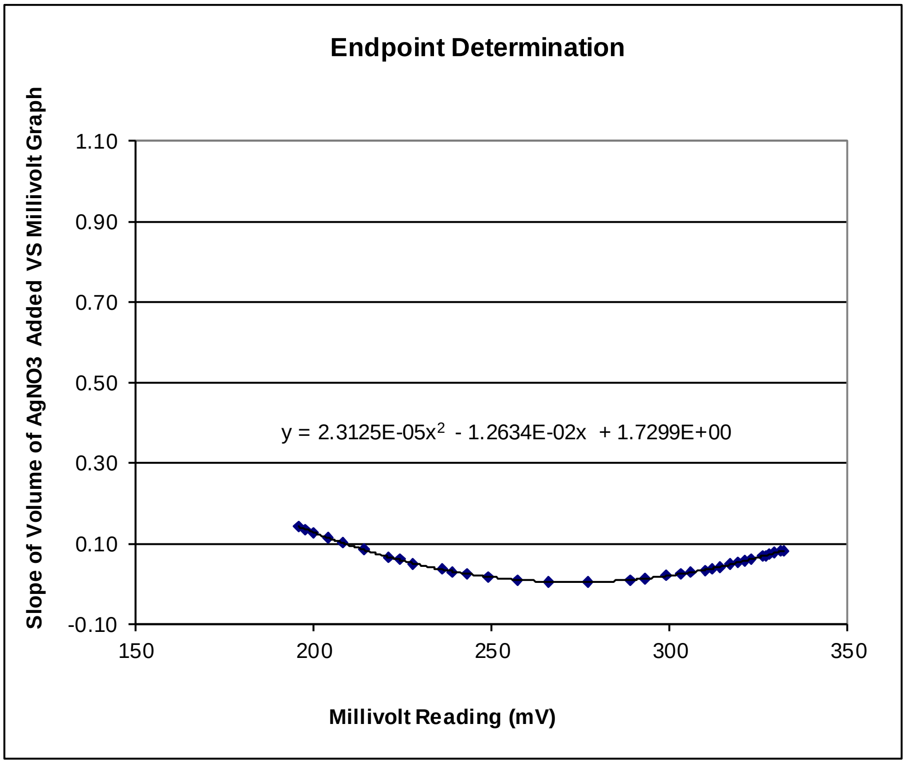
REVIEWED BY: Robert Varner, Engineer

Final Report

AASHTO 260 "Standard Method of Test for Sampling and Testing for Chloride Ion In Concrete

BCD Sample No. 15





mV Value Where Slope = Zero: 273.20 Titration End Point: 4.22

Mass of Concrete Sample (g) 3.0063

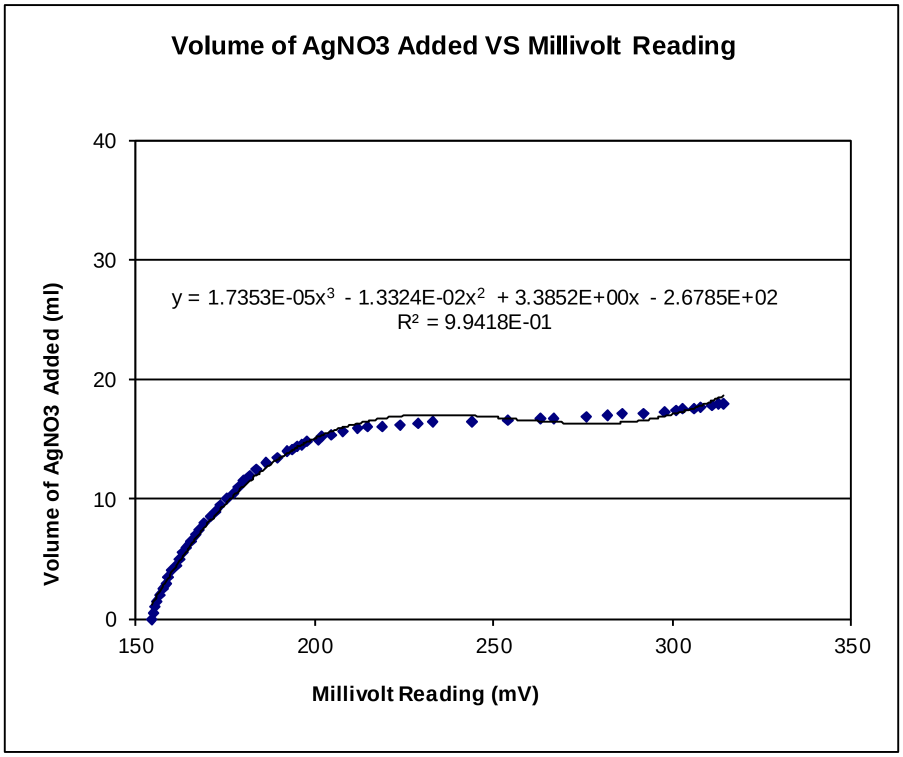
Percent Chloride Ion: 0.0026

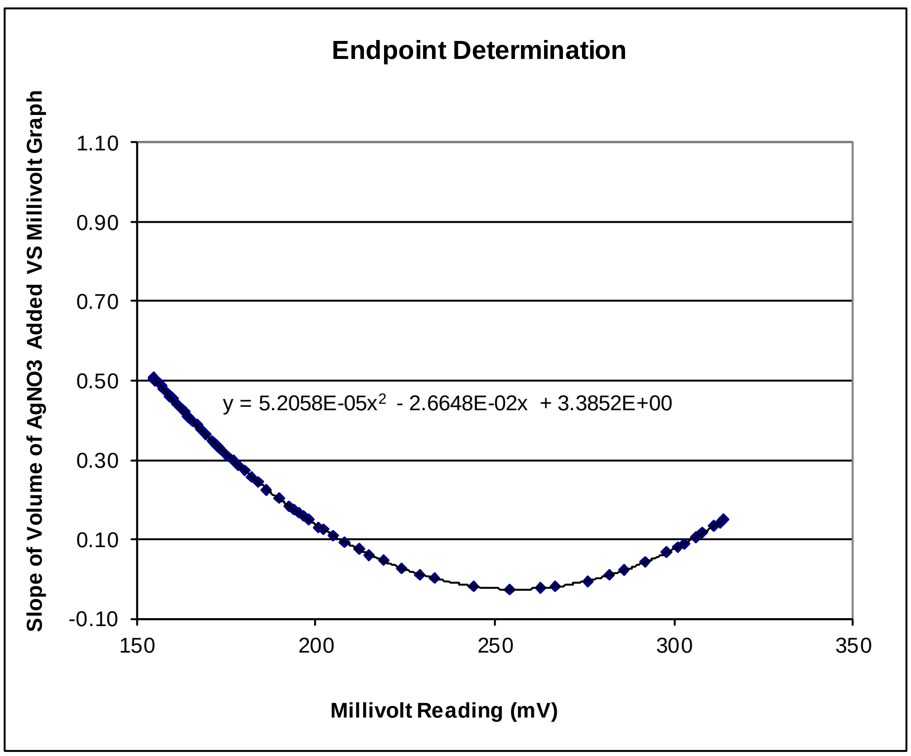
REPORTED BY: Jason Powers, Technician

REVIEWED BY: Robert Varner, Engineer

AASHTO 260 "Standard Method of Test for Sampling and Testing for Chloride Ion In Concrete

BCD Sample No. 16





mV Value Where Slope = Zero: 255.90 Titration End Point: 16.69

Mass of Concrete Sample (g) 3.0202

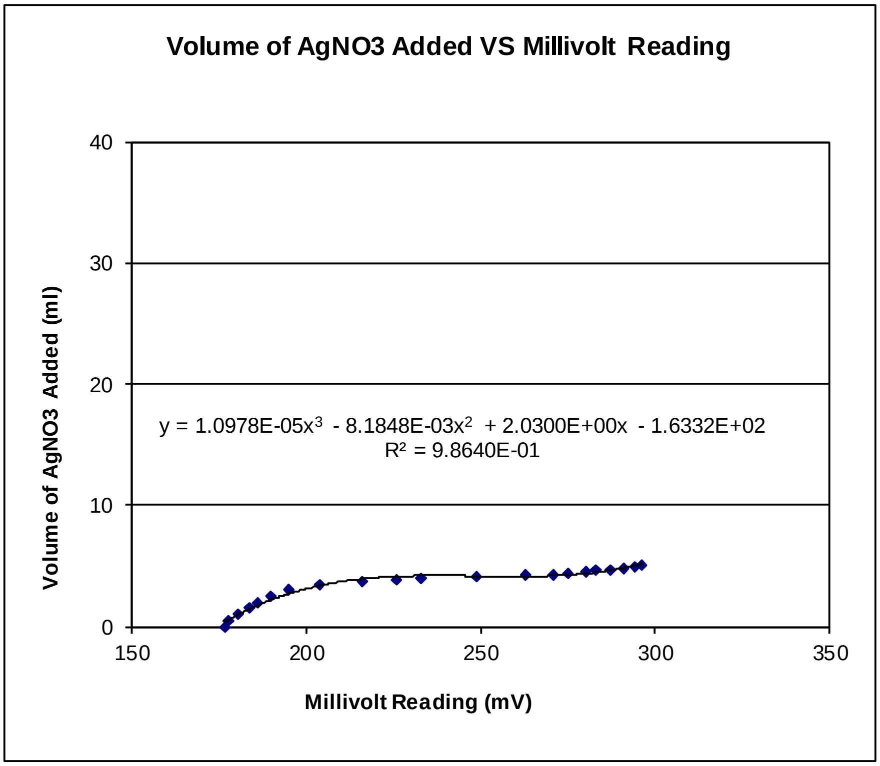
Percent Chloride Ion: 0.1490

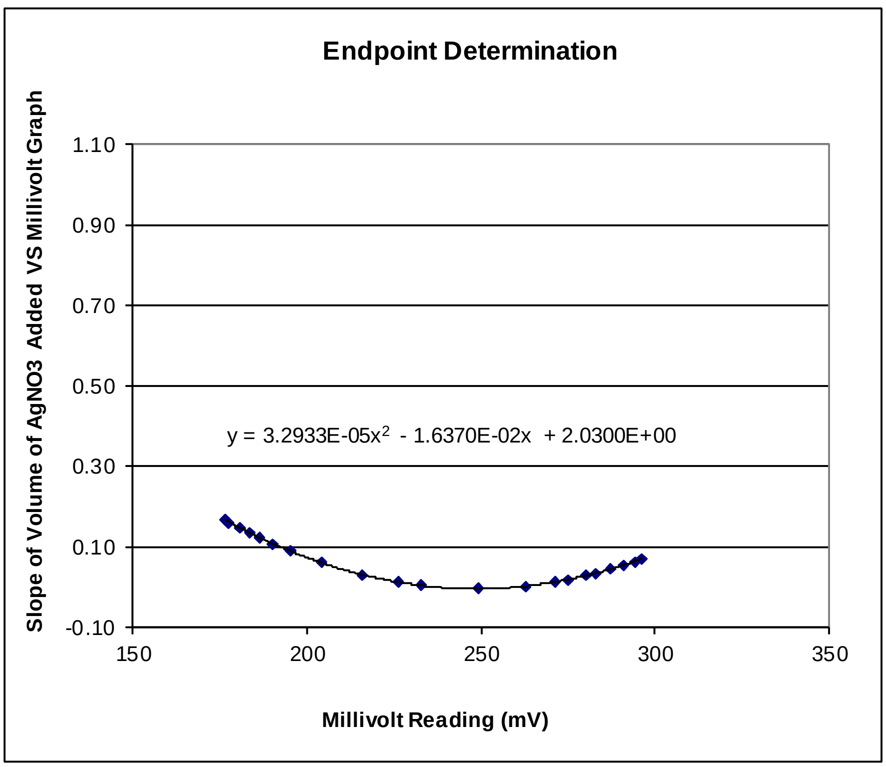
REPORTED BY: Jason Powers, Technician REVIEWED BY: Robert Varner, Engineer

Final Report

AASHTO 260 "Standard Method of Test for Sampling and Testing for Chloride Ion In

BCD Sample No. 17 Repeat





mV Value Where Slope = Zero: 248.50 Titration End Point: 4.17

Mass of Concrete Sample (g) 3.0096

Percent Chloride Ion: 0.0020

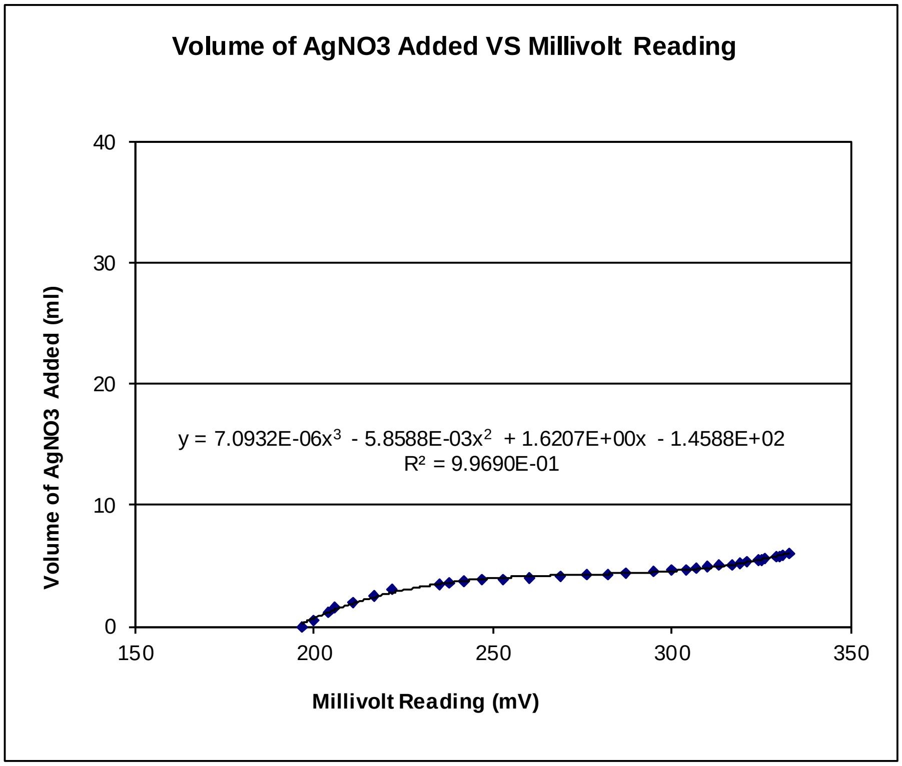
REPORTED BY: Jason Powers, Technician

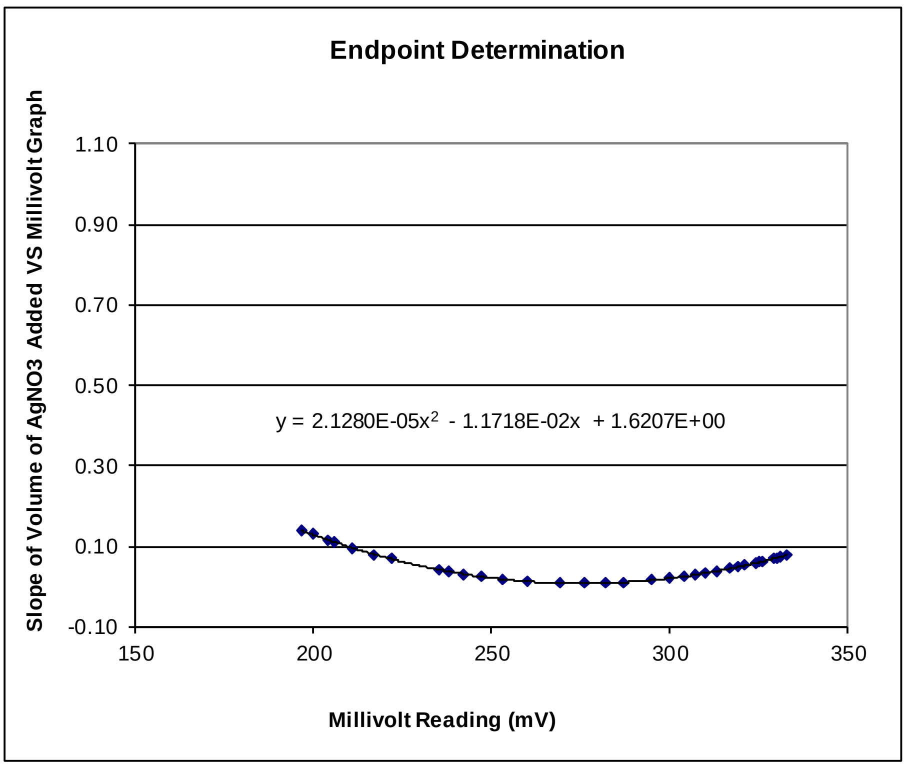
REVIEWED BY: Robert Varner, Engineer

Final Report

AASHTO 260 "Standard Method of Test for Sampling and Testing for Chloride Ion In Concrete

BCD Sample No. 18





mV Value Where Slope = Zero: 275.30 Titration End Point: 4.26

Mass of Concrete Sample (g) 3.0239

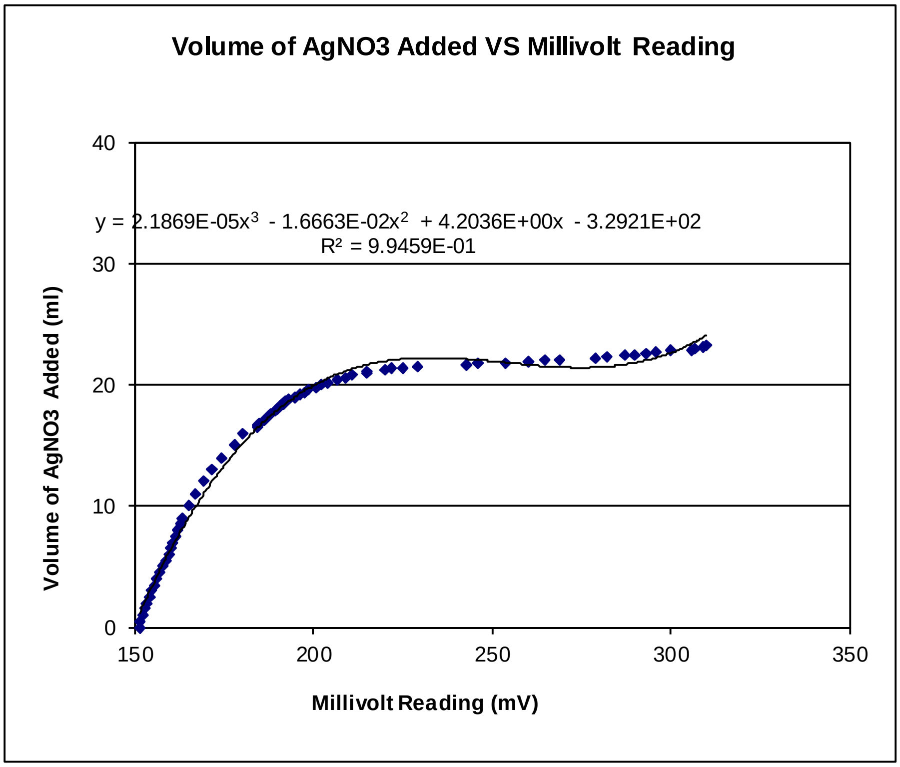
Percent Chloride Ion: 0.0030

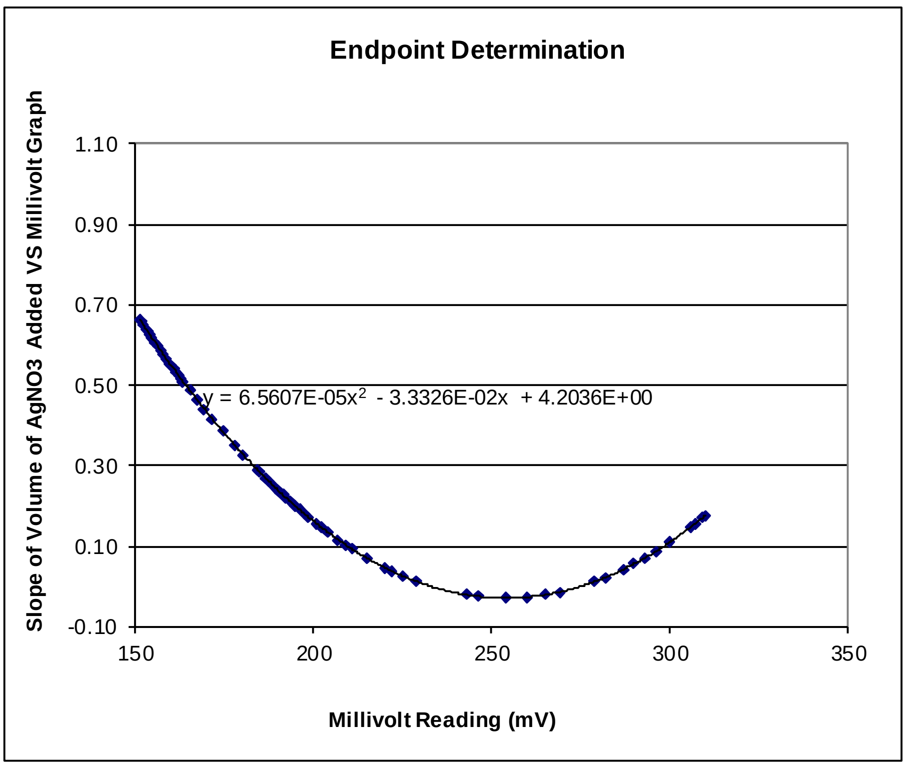
REPORTED BY: Jason Powers, Technician REVIEWED BY: Robert Varner, Engineer

Final Report

AASHTO 260 "Standard Method of Test for Sampling and Testing for Chloride Ion In Concrete

BCD Sample No. 19





mV Value Where Slope = Zero: 254.00 Titration End Point: 21.82

Mass of Concrete Sample (g) 3.0128

Percent Chloride Ion: 0.2097

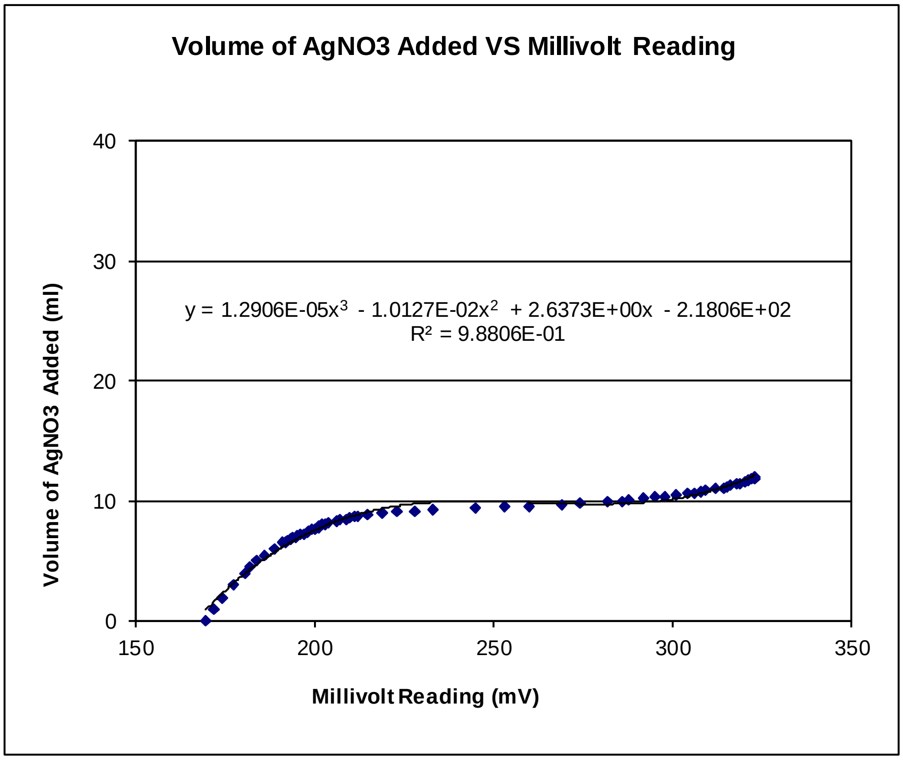
REPORTED BY: Jason Powers
Technician

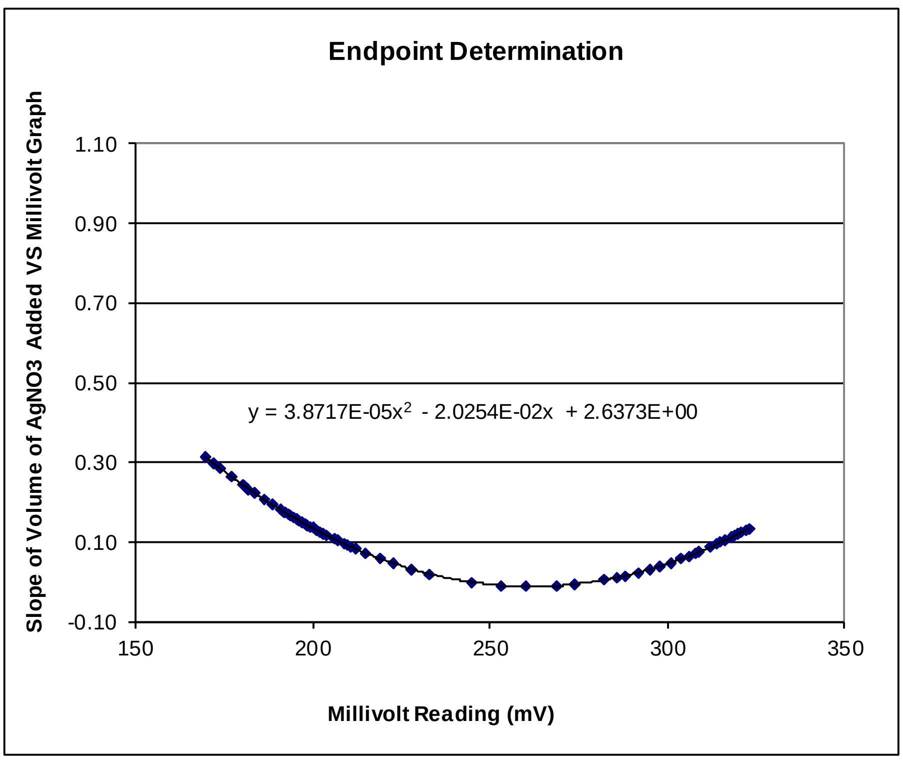
REVIEWED BY: Robert Varner
Engineer

Final Report

AASHTO 260 "Standard Method of Test for Sampling and Testing for Chloride Ion In Concrete

BCD Sample No. 20





mV Value Where Slope = Zero: 261.60 Titration End Point: 9.87

Mass of Concrete Sample (g) 3.0085

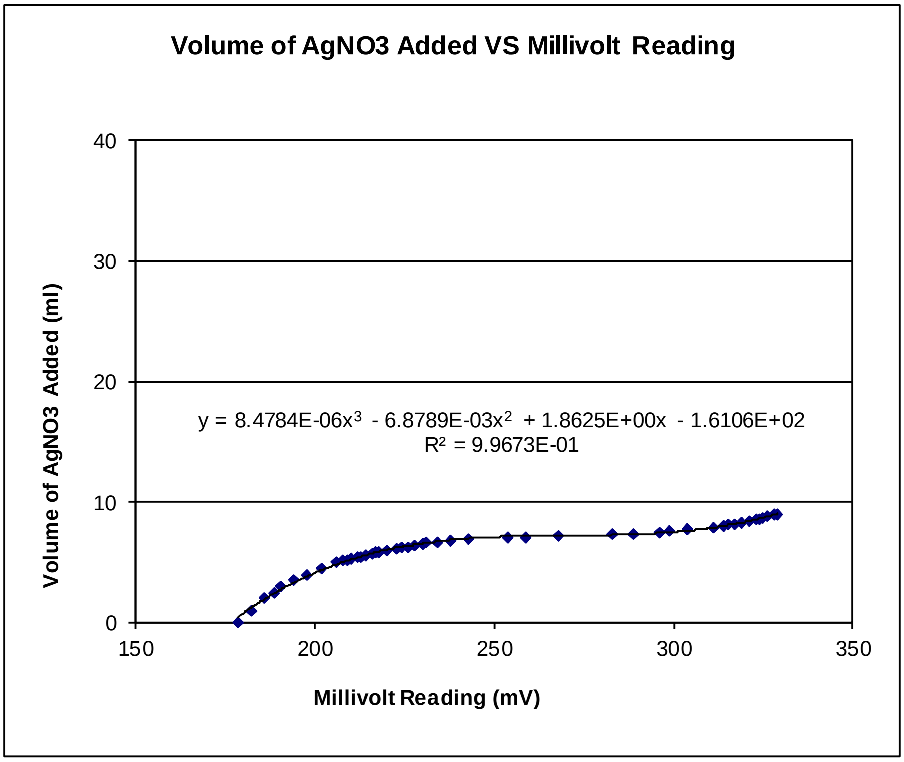
Percent Chloride Ion: 0.0692

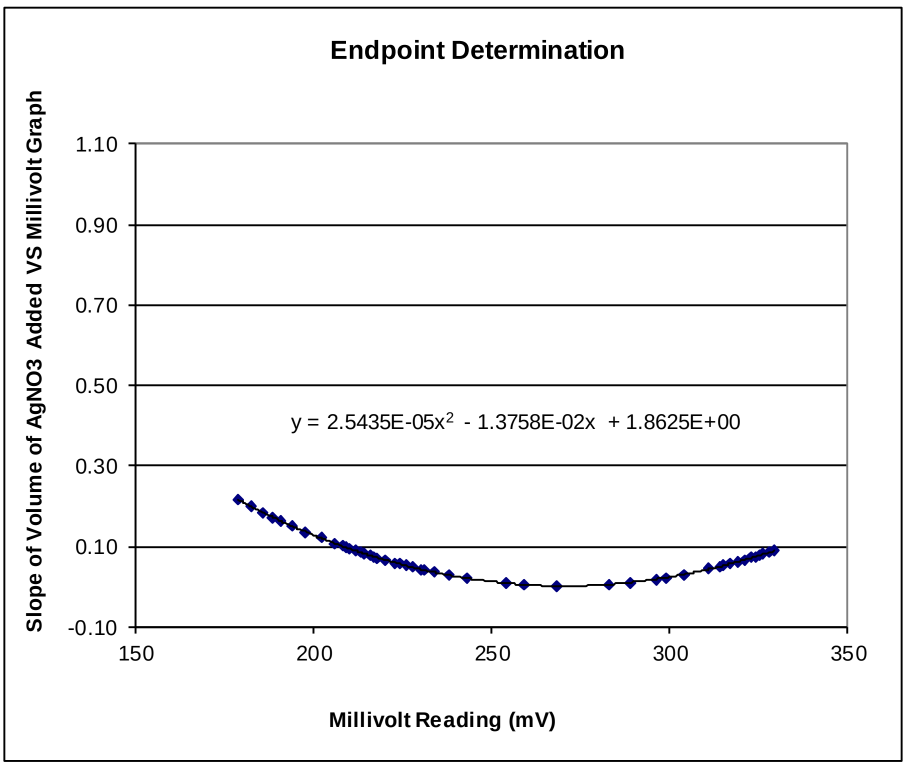
REPORTED BY: Jason Powers, Technician REVIEWED BY: Robert Varner, Engineer

Final Report

AASHTO 260 "Standard Method of Test for Sampling and Testing for Chloride Ion In Concrete

BCD Sample No. 21





mV Value Where Slope = Zero: 270.40 Titration End Point: 7.23

Mass of Concrete Sample (g) 3.0116

Percent Chloride Ion: 0.0380

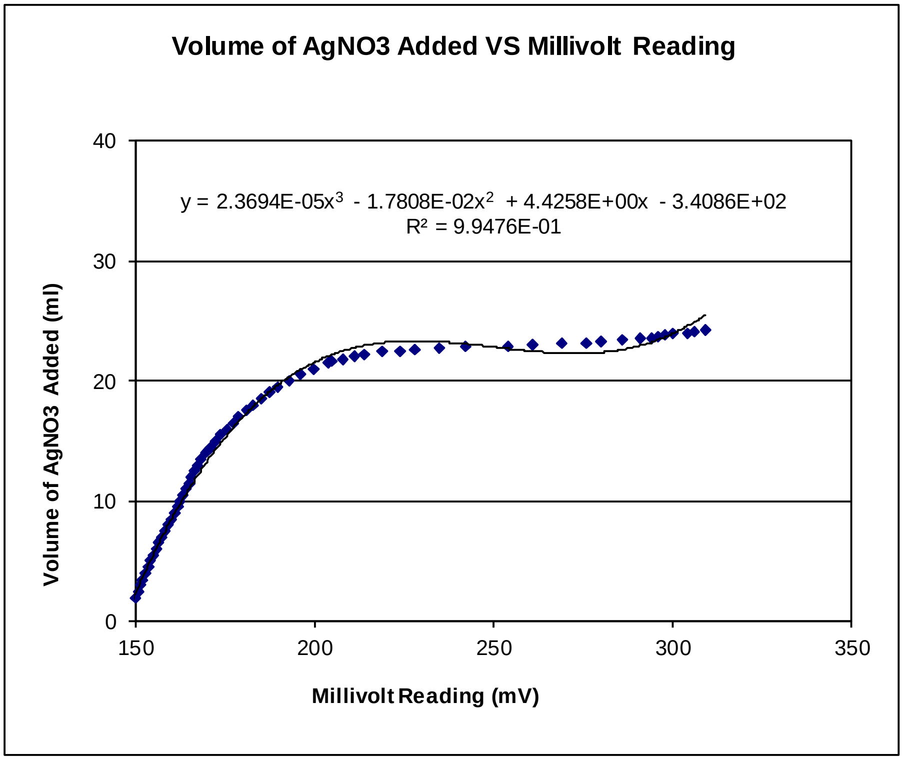
REPORTED BY: Jason Powers, Technician

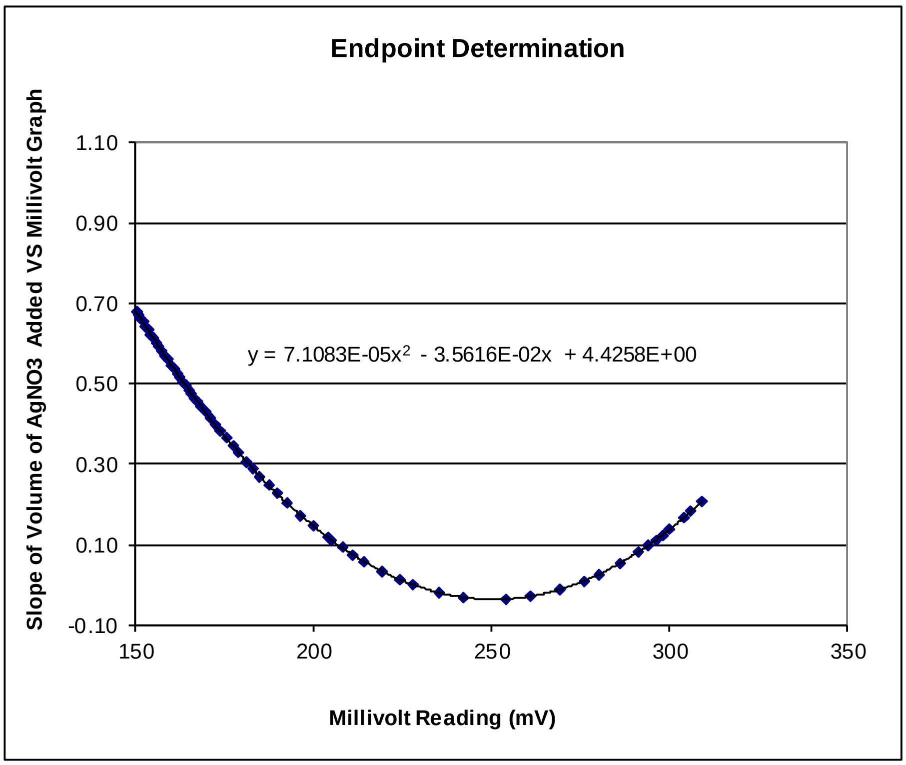
REVIEWED BY: Robert Varner, Engineer

Final Report

AASHTO 260 "Standard Method of Test for Sampling and Testing for Chloride Ion In Concrete

BCD Sample No. 22





mV Value Where Slope = Zero: 250.50 Titration End Point: 22.80

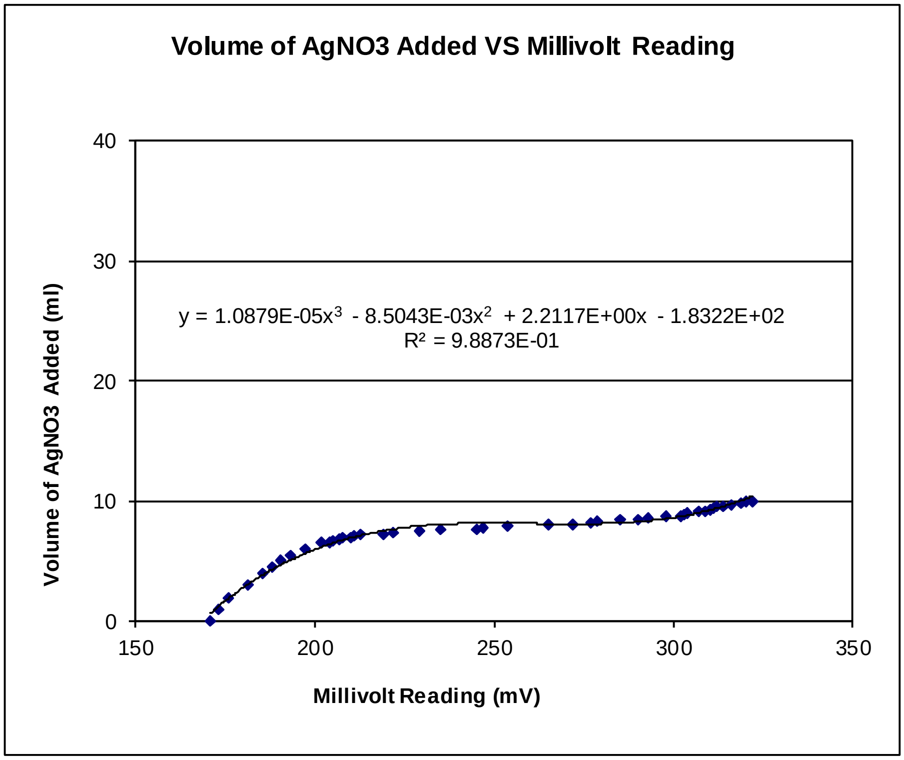
Mass of Concrete Sample (g) 3.0187

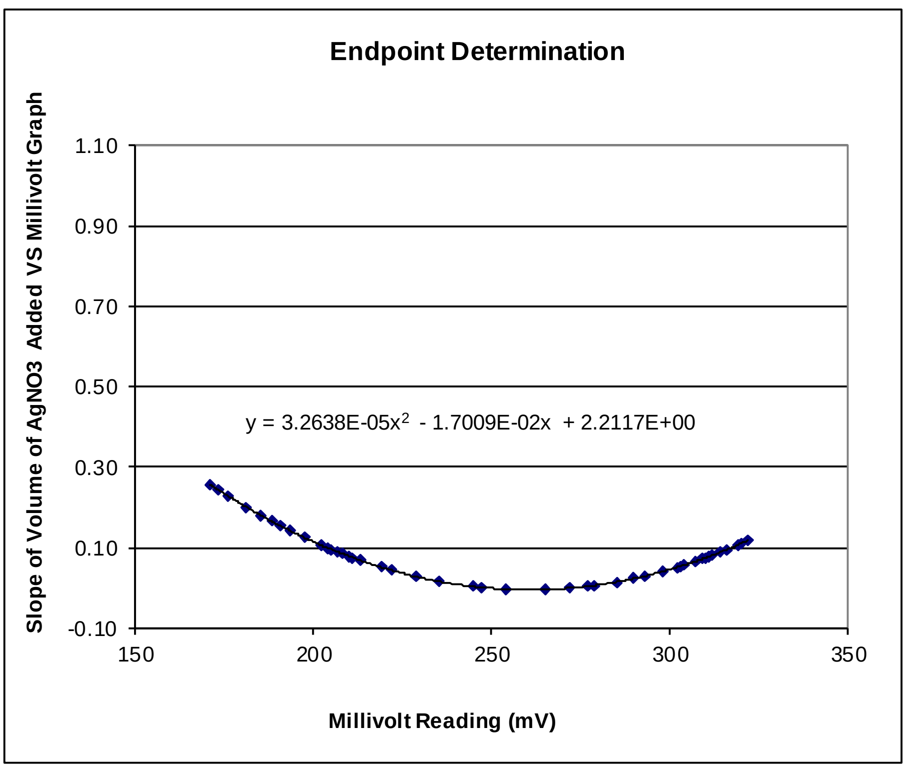
Percent Chloride Ion: 0.2209

REPORTED BY: Jason Powers, Technician REVIEWED BY: Robert Varner, Engineer

AASHTO 260 "Standard Method of Test for Sampling and Testing for Chloride Ion In Concrete

BCD Sample No. 23





mV Value Where Slope = Zero: 260.60 Titration End Point: 8.13

Mass of Concrete Sample (g) 3.0719

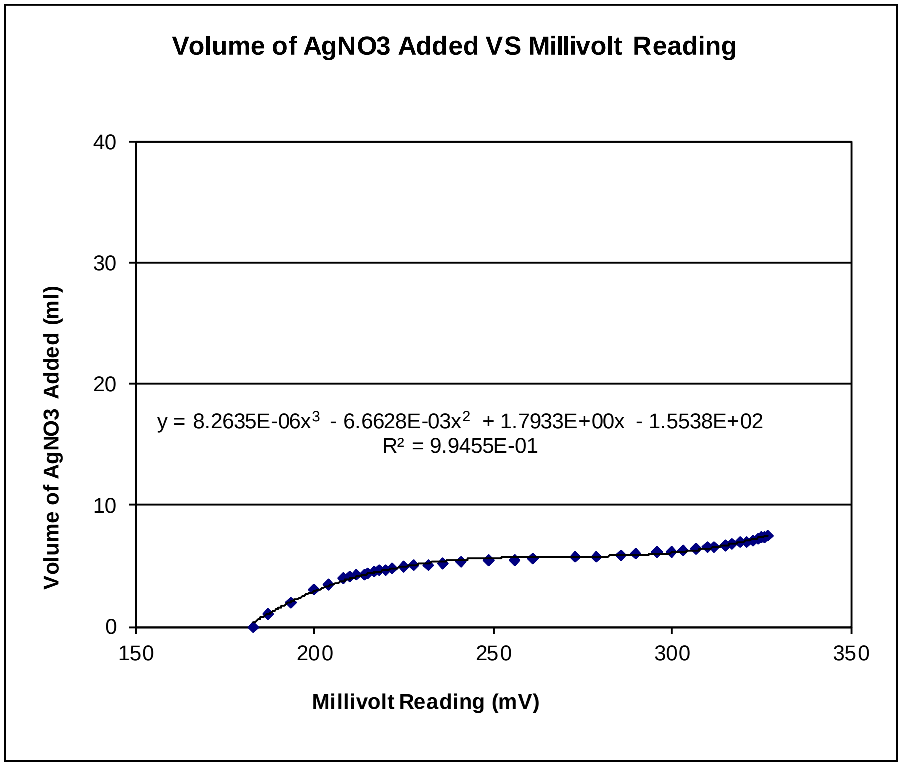
Percent Chloride Ion: 0.0476

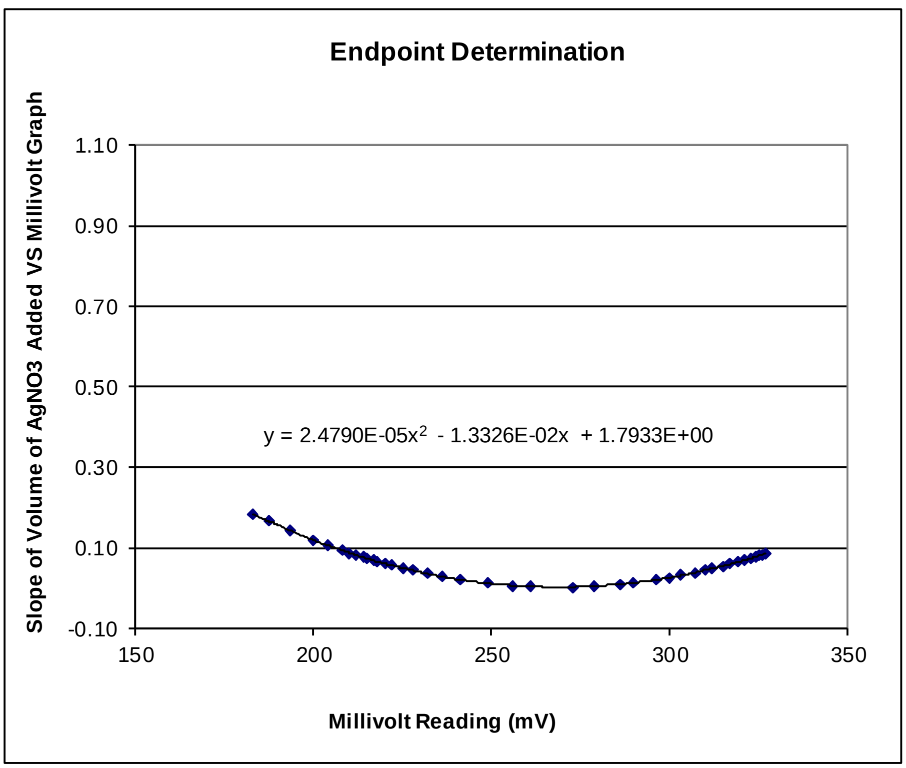
REPORTED BY: Jason Powers, Technician REVIEWED BY: Robert Varner, Engineer

Final Report

AASHTO 260 "Standard Method of Test for Sampling and Testing for Chloride Ion In Concrete

BCD Sample No. 24





mV Value Where Slope = Zero: 268.80 Titration End Point: 5.74

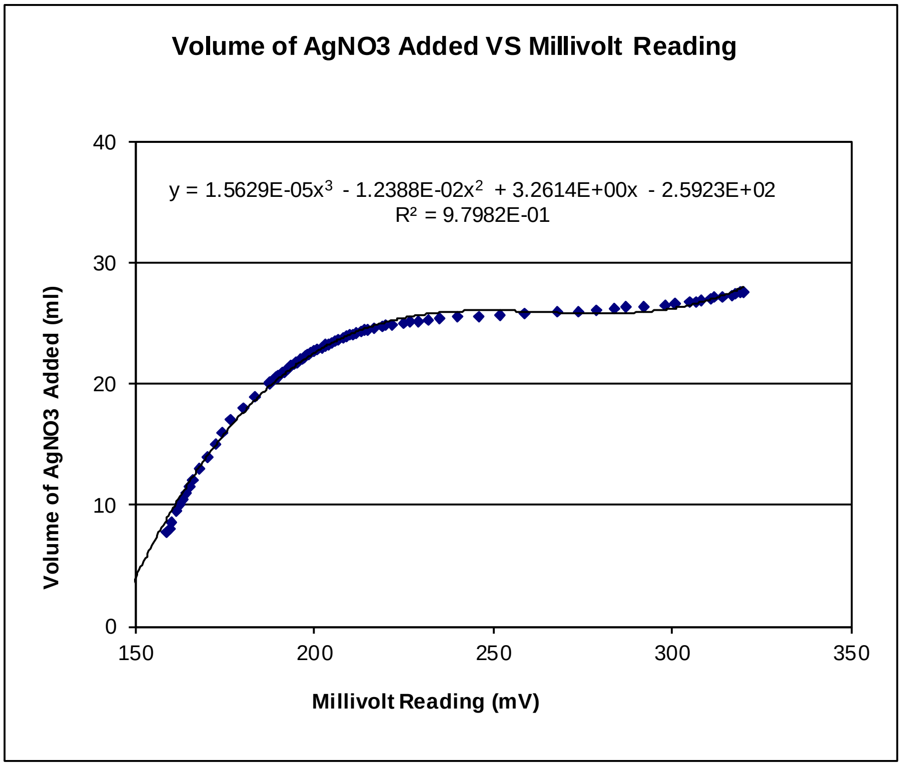
Mass of Concrete Sample (g) 3.021

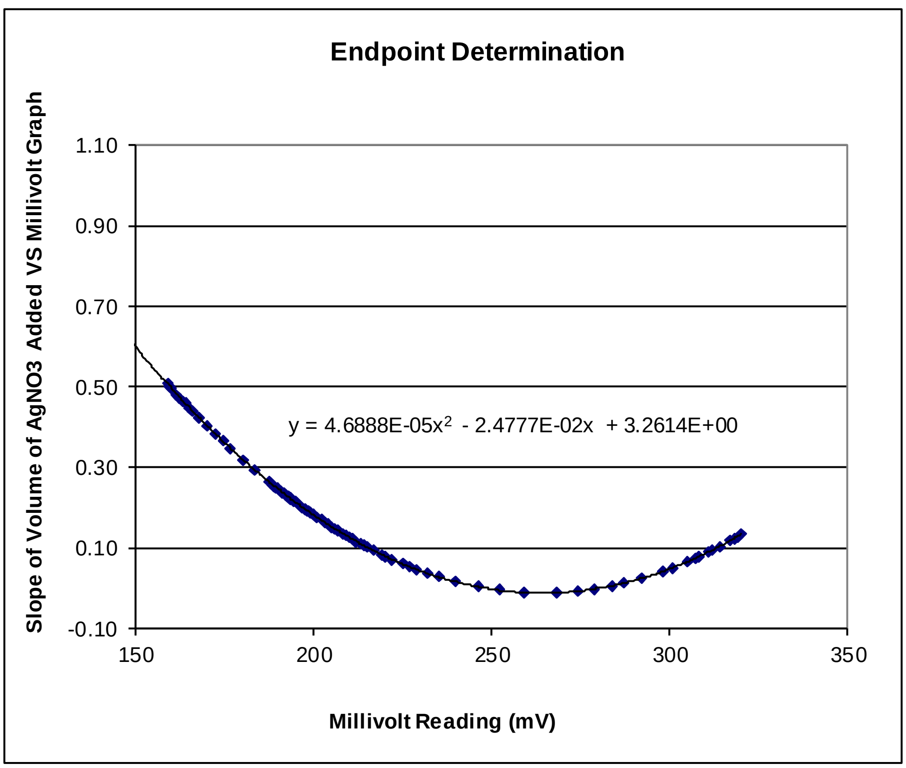
Percent Chloride Ion: 0.0205

REPORTED BY: Jason Powers, Technician REVIEWED BY: Robert Varner, Engineer

AASHTO 260 "Standard Method of Test for Sampling and Testing for Chloride Ion In Concrete

BCD Sample No. 25





mV Value Where Slope = Zero: 264.20 Titration End Point: 25.92

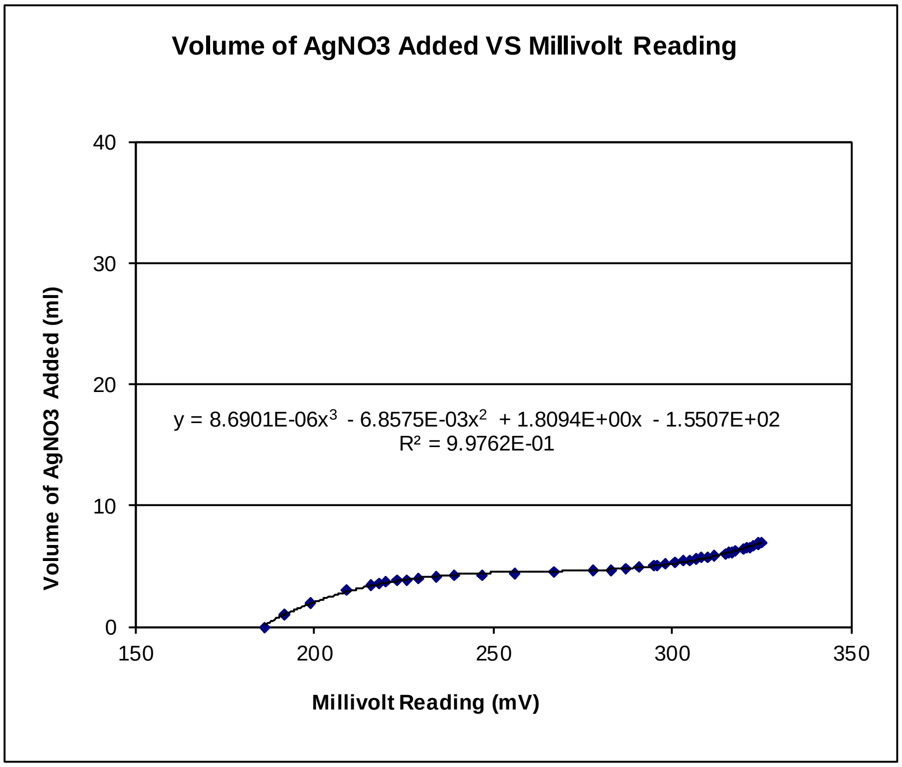
Mass of Concrete Sample (g) 3.011

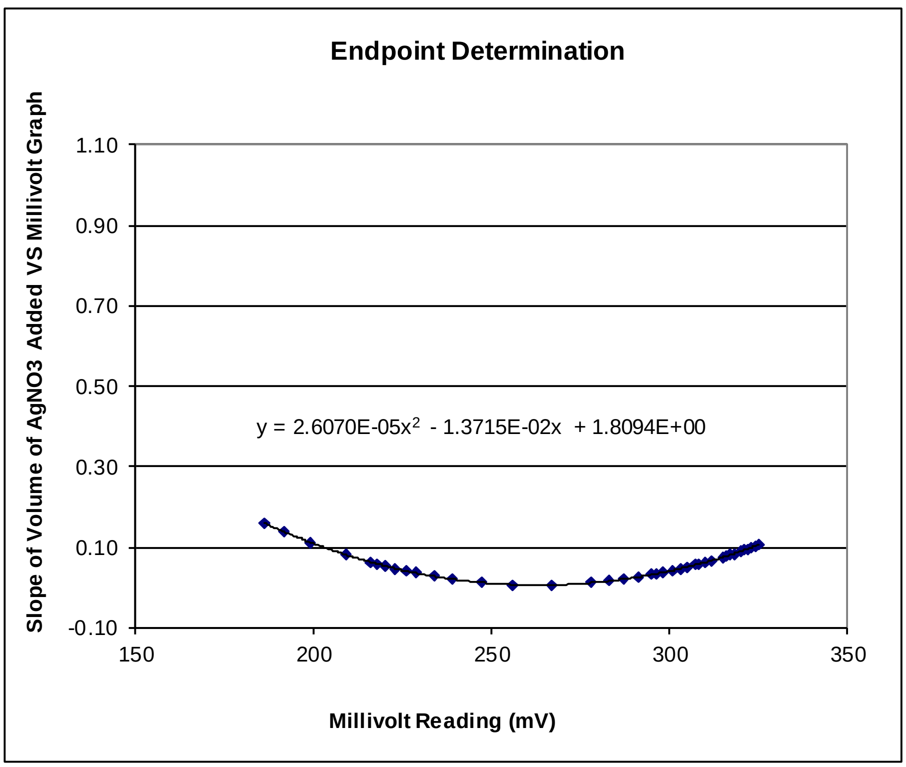
Percent Chloride Ion: 0.2581

REPORTED BY: Jason Powers, Technician REVIEWED BY: Robert Varner, Engineer

AASHTO 260 "Standard Method of Test for Sampling and Testing for Chloride Ion In Concrete

BCD Sample No. 26





mV Value Where Slope = Zero: 263.00 Titration End Point: 4.55

Mass of Concrete Sample (g) 3.0577

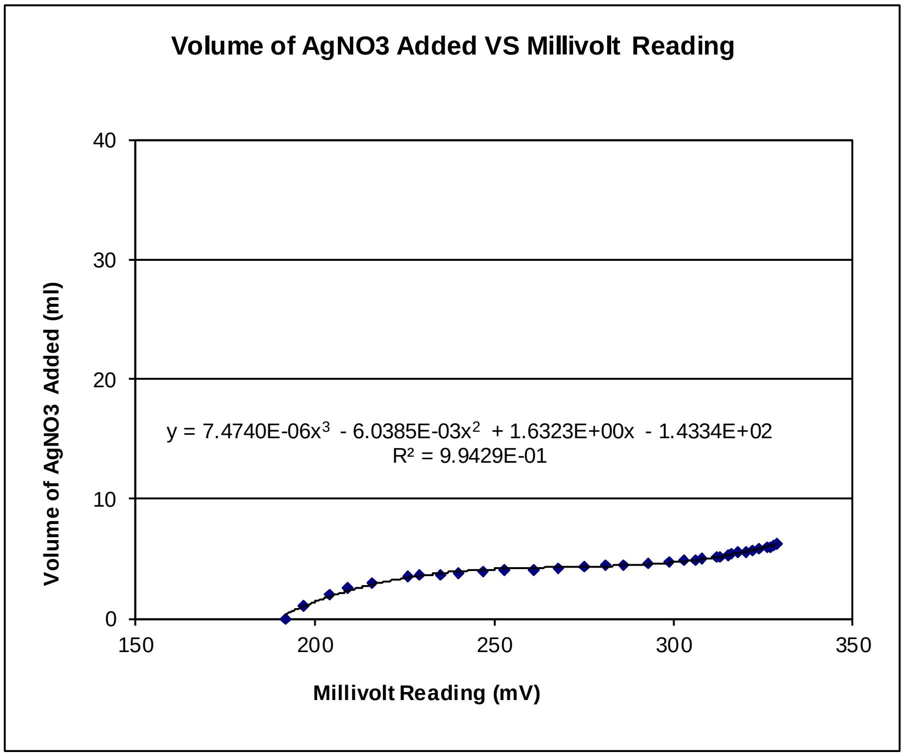
Percent Chloride Ion: 0.0064

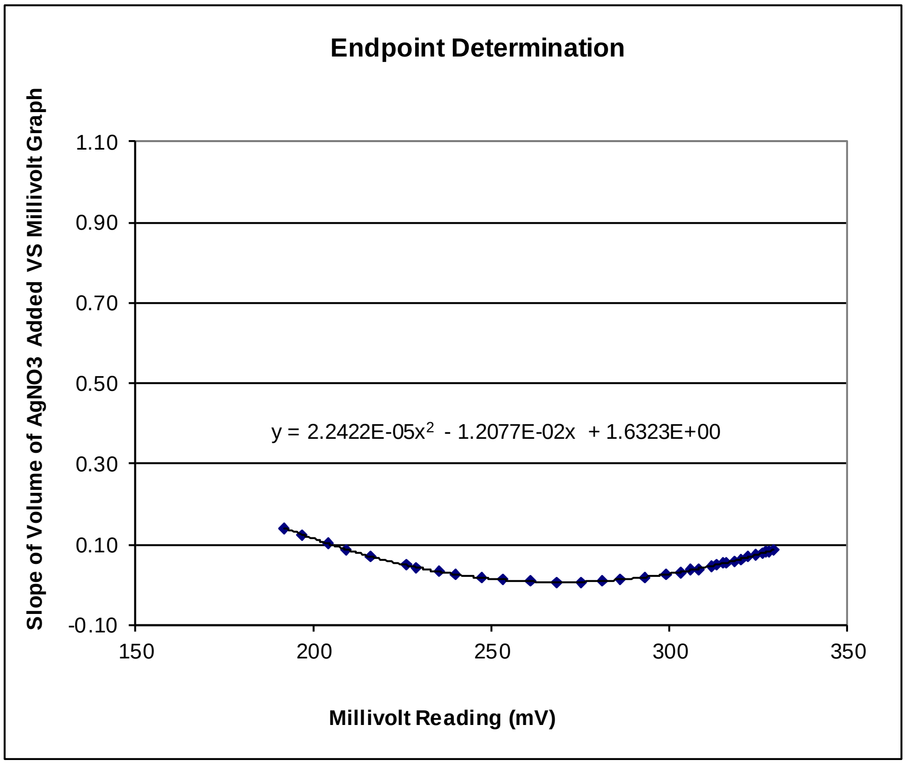
REPORTED BY: Jason Powers, Technician REVIEWED BY: Robert Varner, Engineer

Final Report

AASHTO 260 "Standard Method of Test for Sampling and Testing for Chloride Ion In Concrete

BCD Sample No. 27





mV Value Where Slope = Zero: 263.20 Titration End Point: 4.24

Mass of Concrete Sample (g) 3.0755

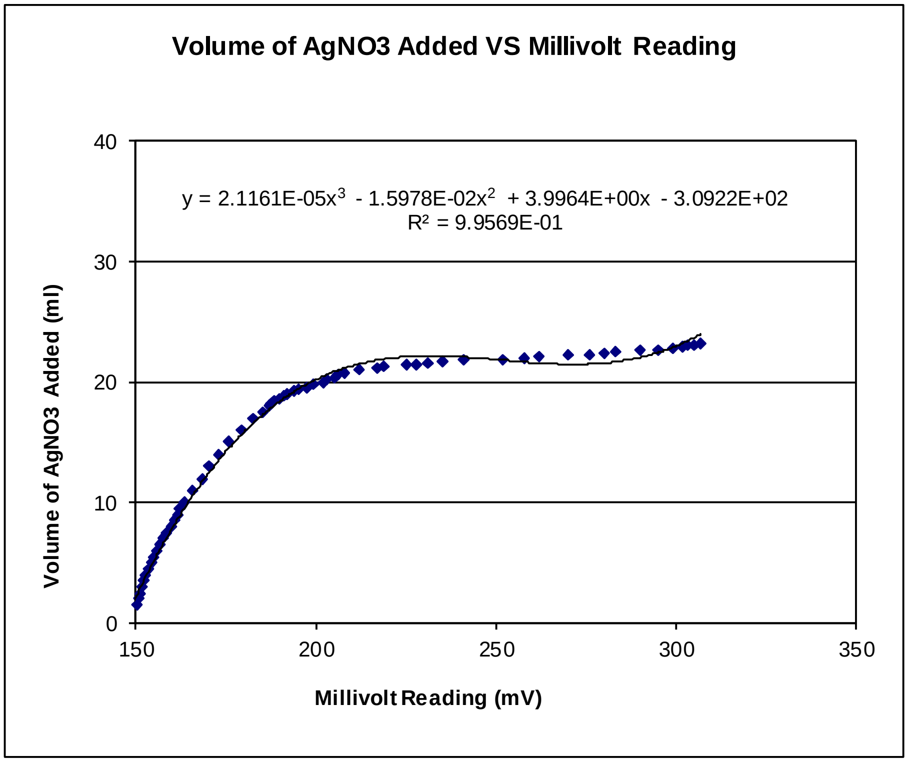
Percent Chloride Ion: 0.0028

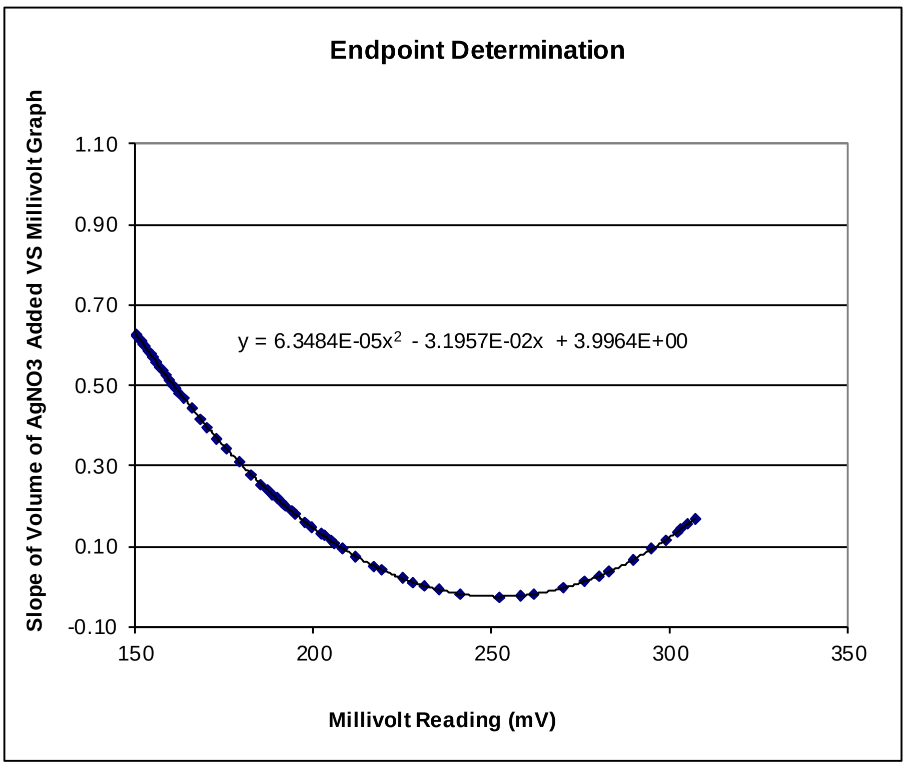
REPORTED BY: Jason Powers, Technician

REVIEWED BY: Robert Varner, Engineer

AASHTO 260 "Standard Method of Test for Sampling and Testing for Chloride Ion In Concrete

BCD Sample No. 28





mV Value Where Slope = Zero: 251.70 Titration End Point: 21.82

Mass of Concrete Sample (g) 3.0227

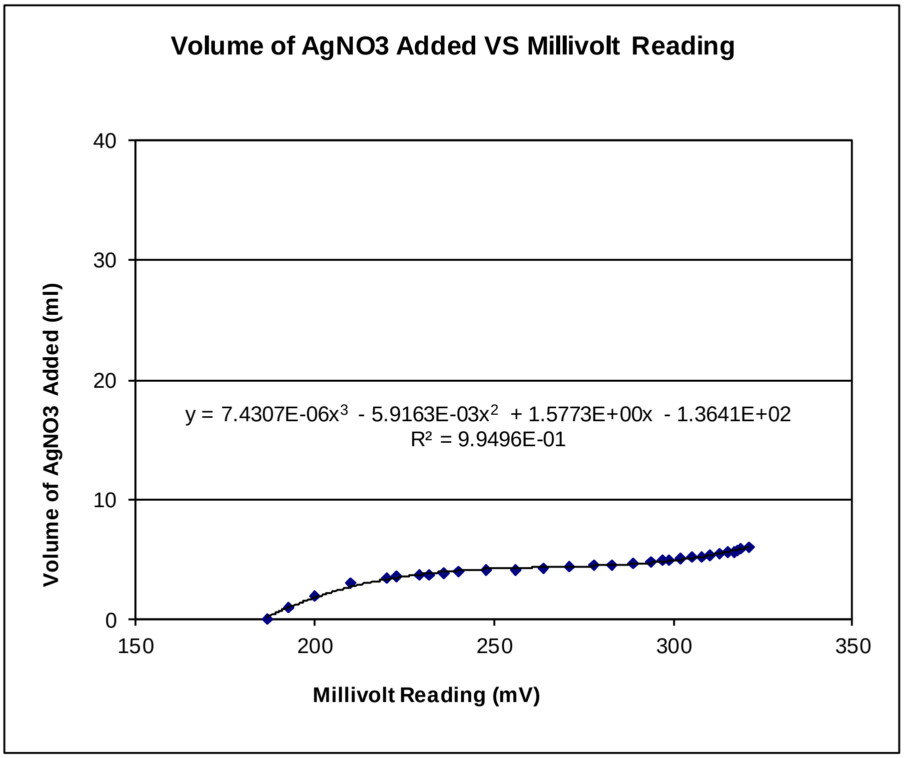
Percent Chloride Ion: 0.2090

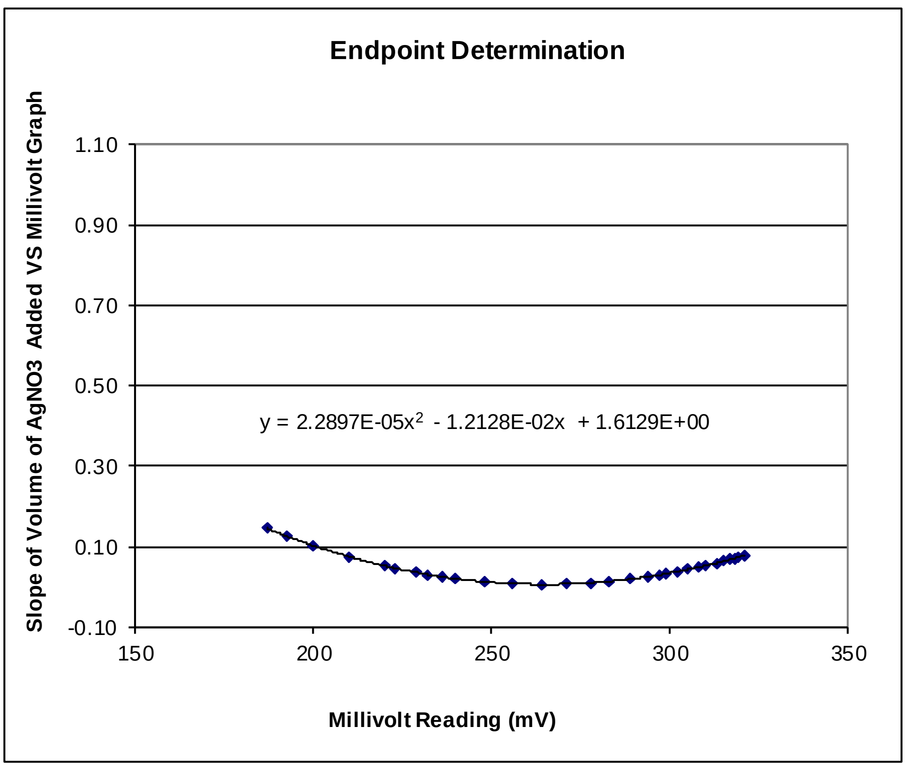
REPORTED BY: Jason Powers, Technician REVIEWED BY: Robert Varner, Engineer

Final Report

AASHTO 260 "Standard Method of Test for Sampling and Testing for Chloride Ion In Concrete

BCD Sample No. 29





mV Value Where Slope = Zero: 264.80 Titration End Point: 4.37

Mass of Concrete Sample (g) 3.0262

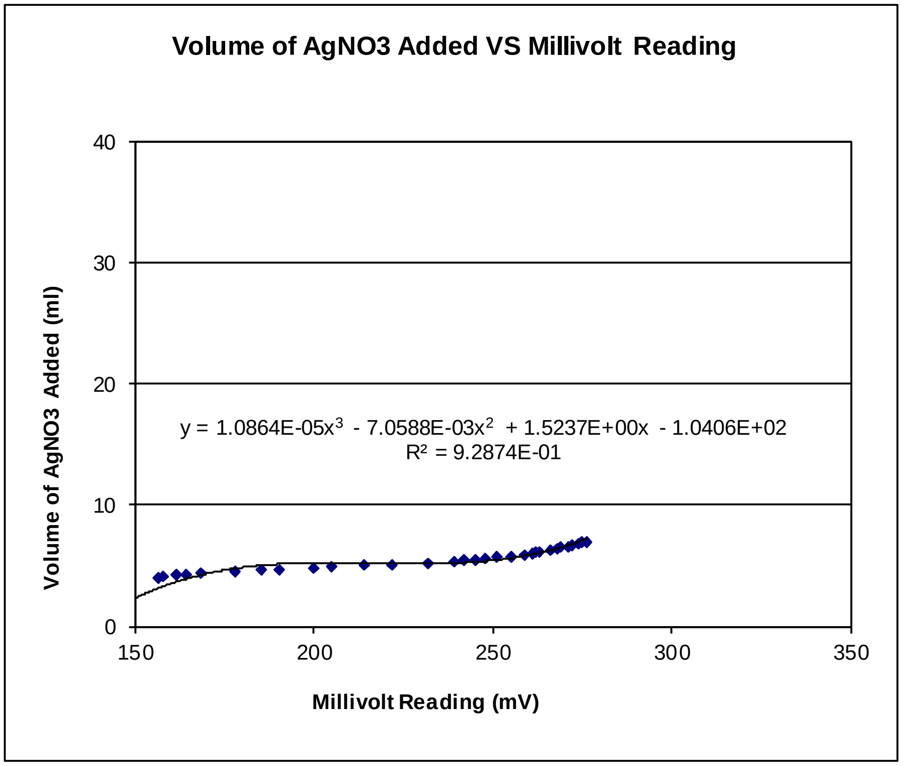
Percent Chloride Ion: 0.0044

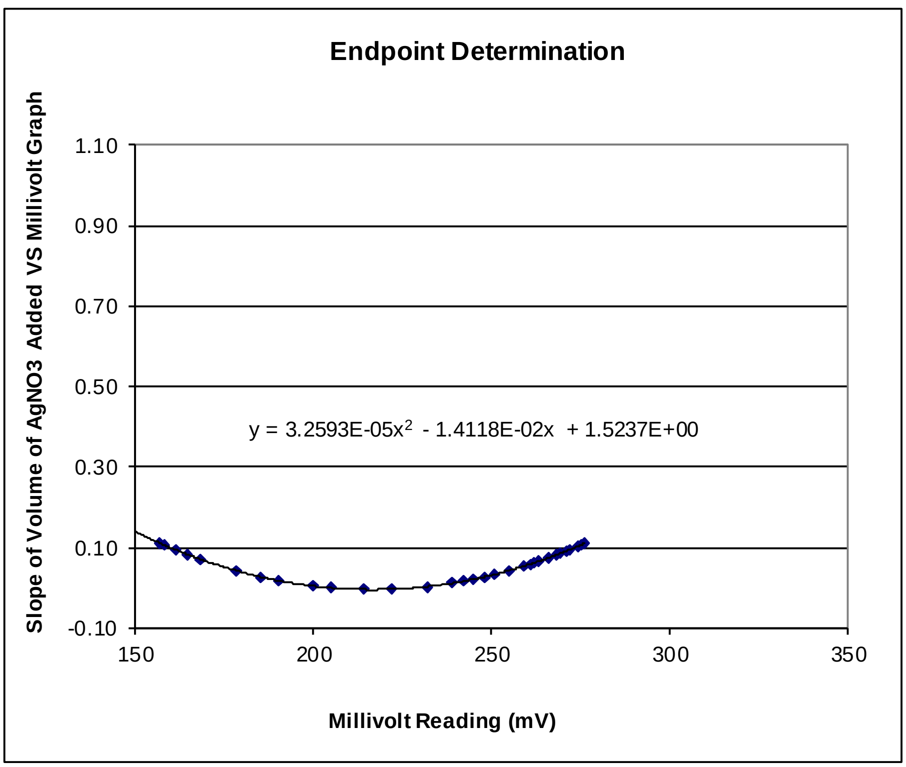
REPORTED BY: Jason Powers, Technician REVIEWED BY: Robert Varner, Engineer

Final Report

AASHTO 260 "Standard Method of Test for Sampling and Testing for Chloride Ion In Concrete

BCD Sample No. 30 Repeat





mV Value Where Slope = Zero: 216.60 Titration End Point: 5.20

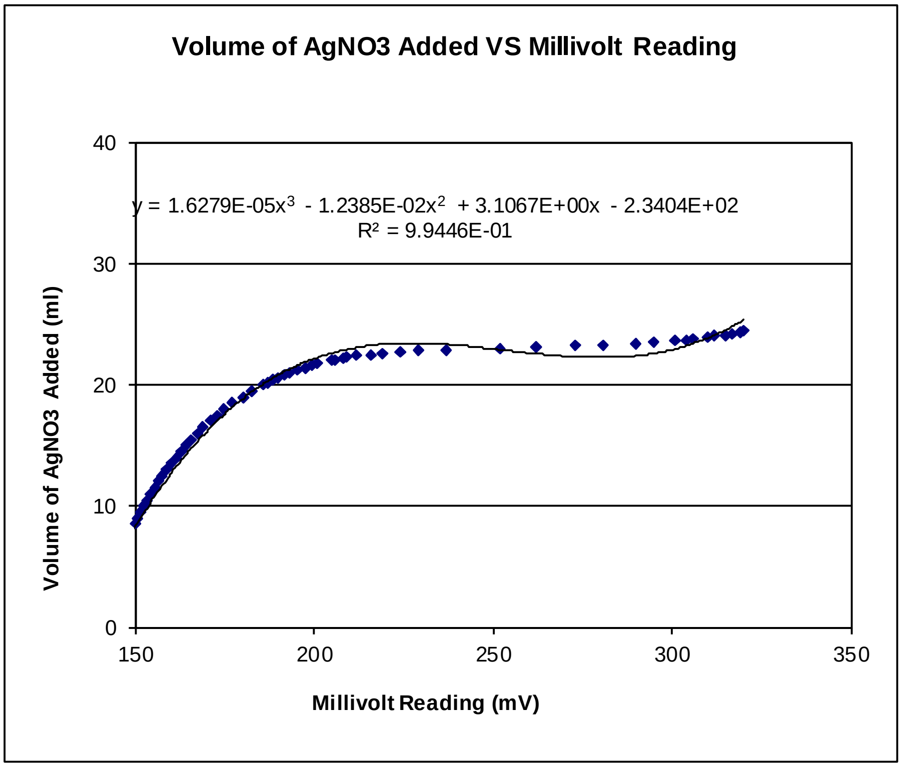
Mass of Concrete Sample (g) 3.0525

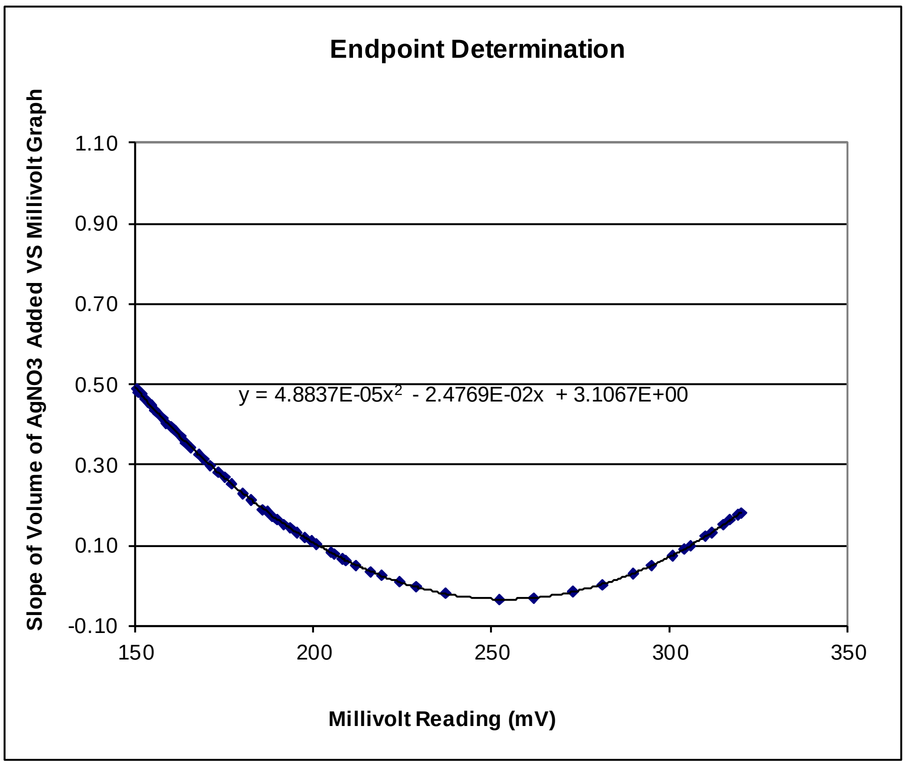
Percent Chloride Ion: 0.0140

REPORTED BY: Jason Powers, Technician REVIEWED BY: Robert Varner, Engineer

AASHTO 260 "Standard Method of Test for Sampling and Testing for Chloride Ion In Concrete

BCD Sample No. 31





mV Value Where Slope = Zero: 253.60 Titration End Point: 22.83

Mass of Concrete Sample (g) 3.0038

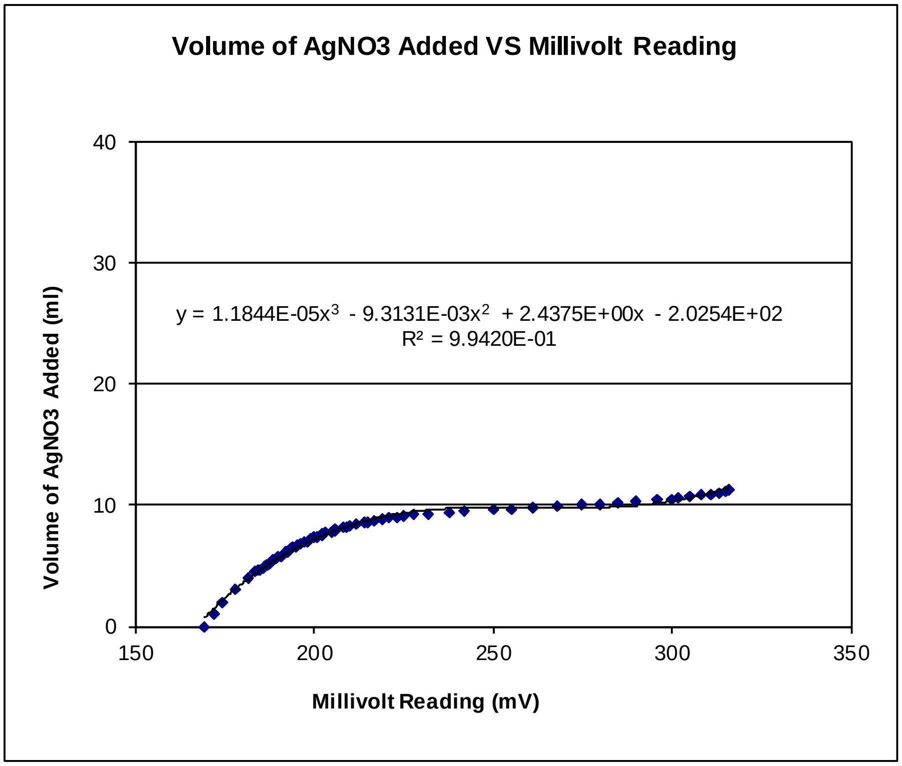
Percent Chloride Ion: 0.2223

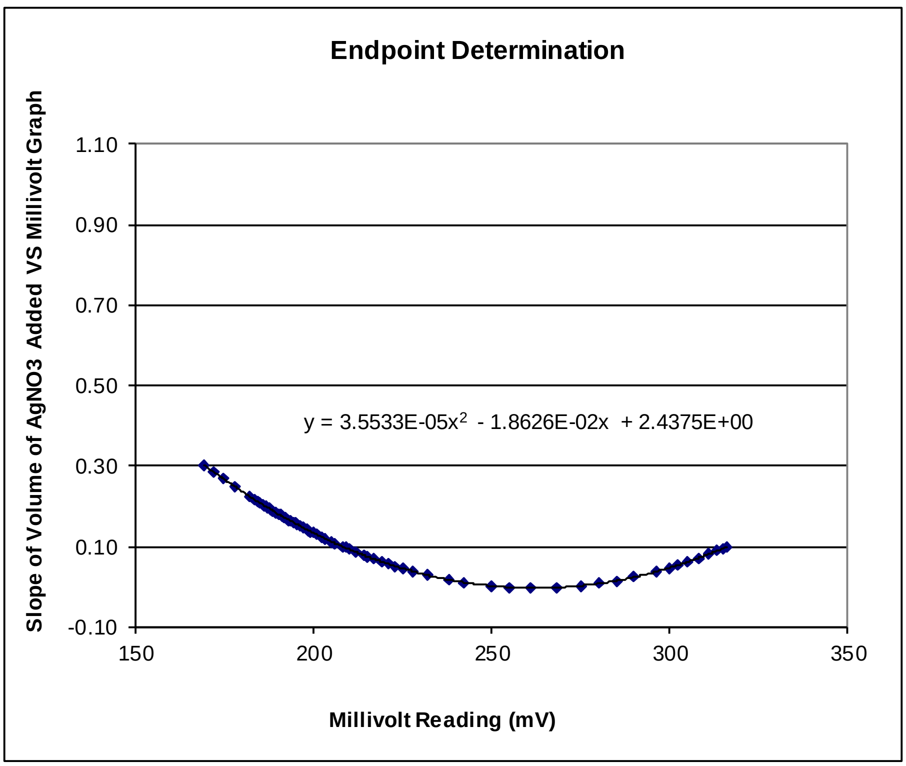
REPORTED BY: Jason Powers, Technician

REVIEWED BY: Robert Varner, Engineer

AASHTO 260 "Standard Method of Test for Sampling and Testing for Chloride Ion In Concrete

BCD Sample No. 32





mV Value Where Slope = Zero: 262.10 Titration End Point: 9.81

Mass of Concrete Sample (g) 3.023

Percent Chloride Ion: 0.0682

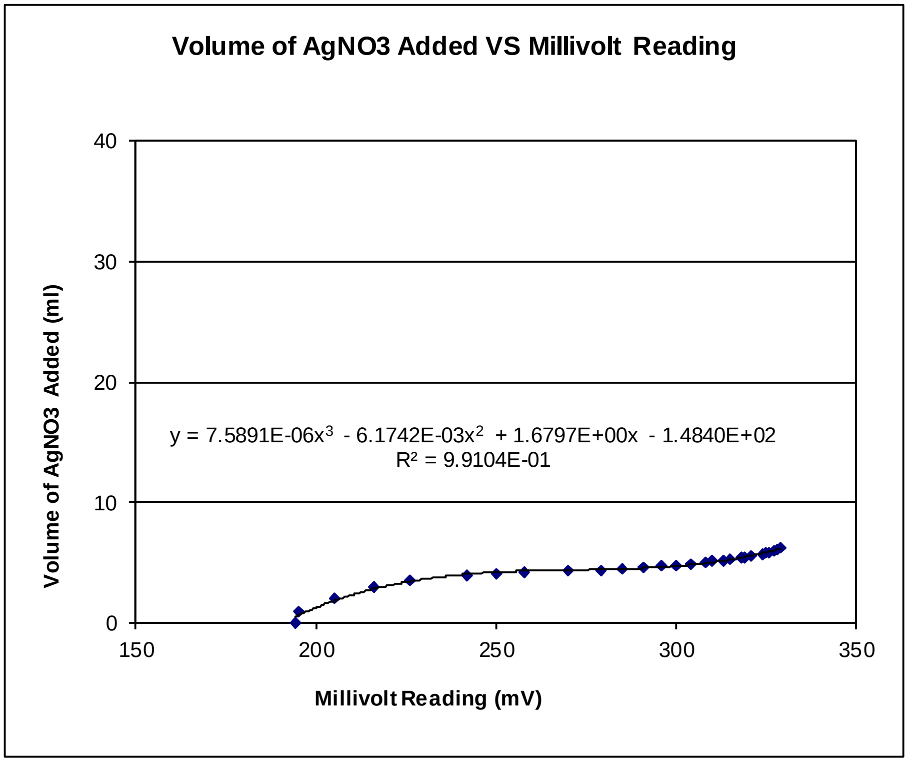
REPORTED BY: Jason Powers, Technician

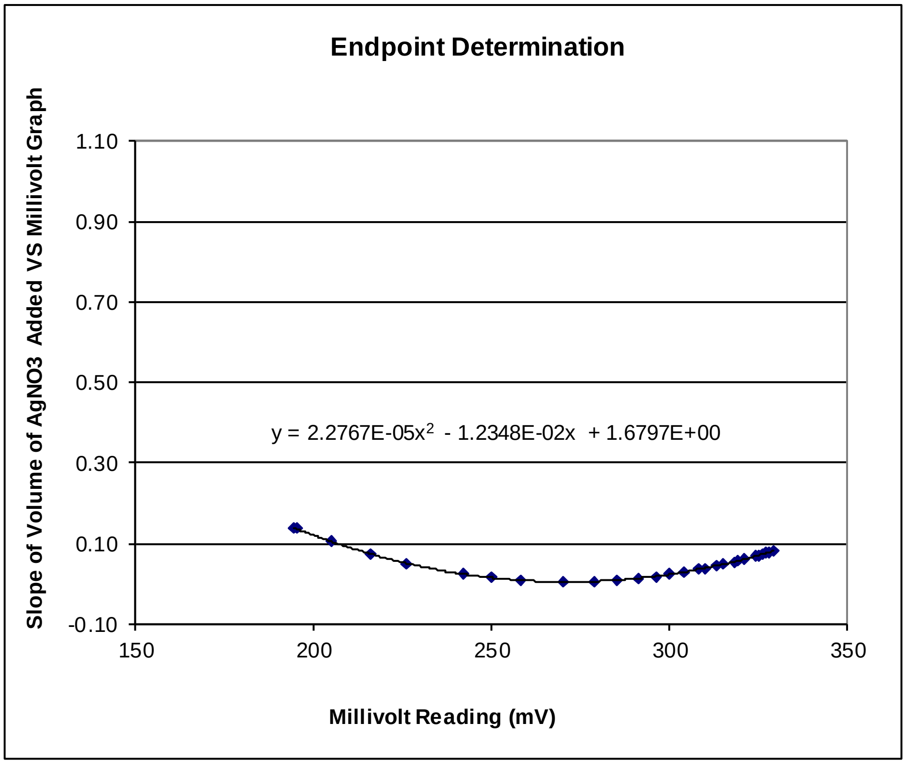
REVIEWED BY: Robert Varner, Engineer

Final Report

AASHTO 260 "Standard Method of Test for Sampling and Testing for Chloride Ion In Concrete

BCD Sample No. 33





mV Value Where Slope = Zero: 271.20 Titration End Point: 4.40

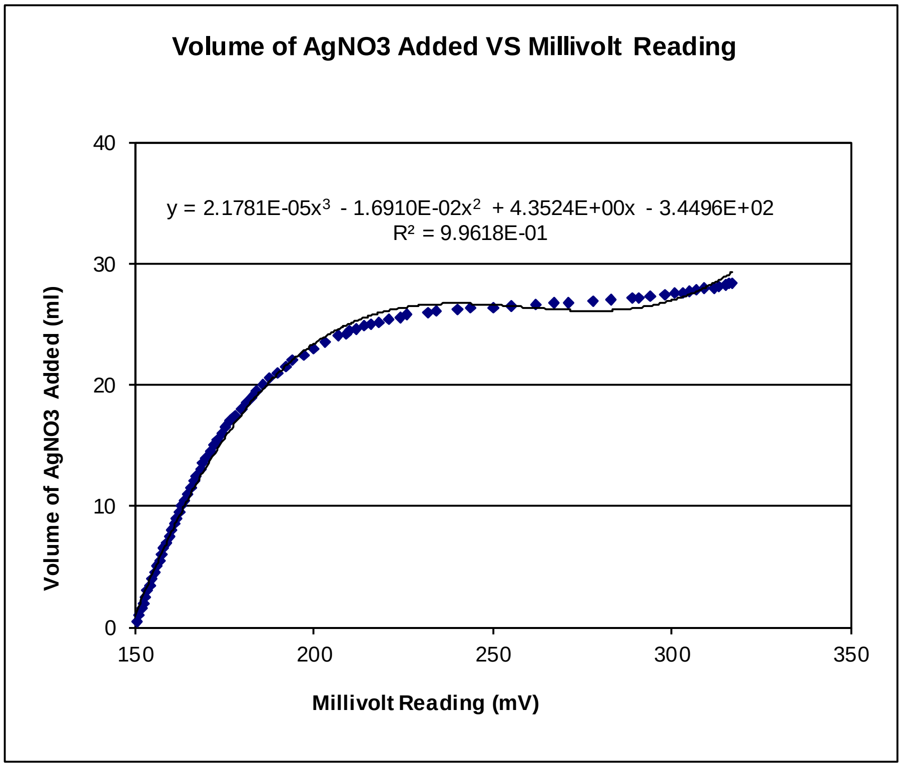
Mass of Concrete Sample (g) 3.057

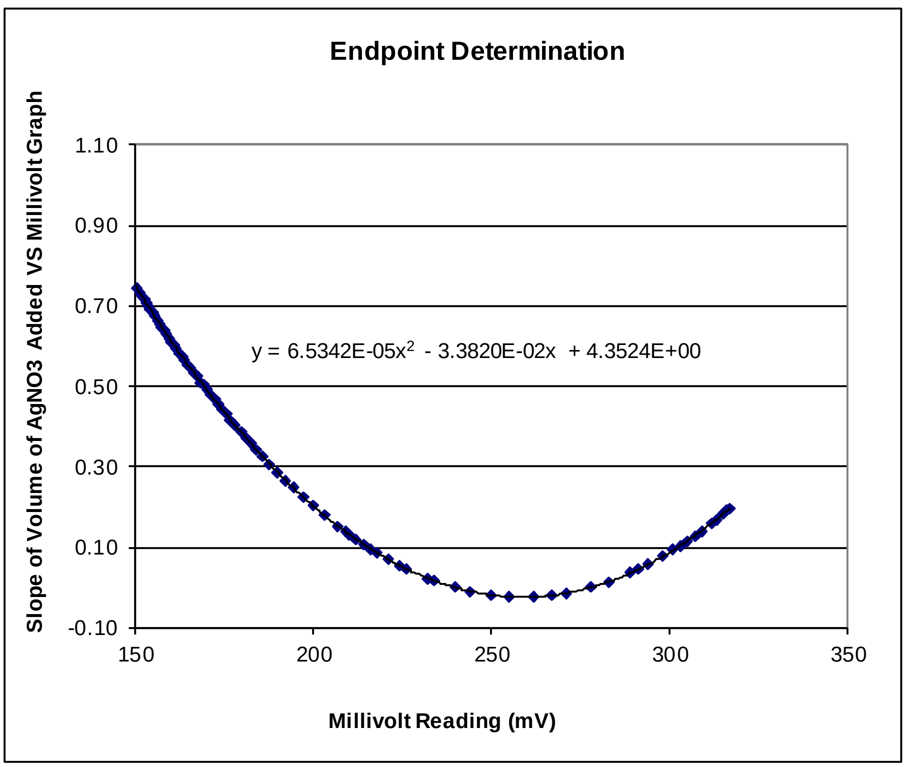
Percent Chloride Ion: 0.0046

REPORTED BY: Jason Powers, Technician   REVIEWED BY: Robert Varner, Engineer

AASHTO 260 "Standard Method of Test for Sampling and Testing for Chloride Ion In Concrete

BCD Sample No. 34





mV Value Where Slope = Zero: 258.80 Titration End Point: 26.40

Mass of Concrete Sample (g) 3.0218

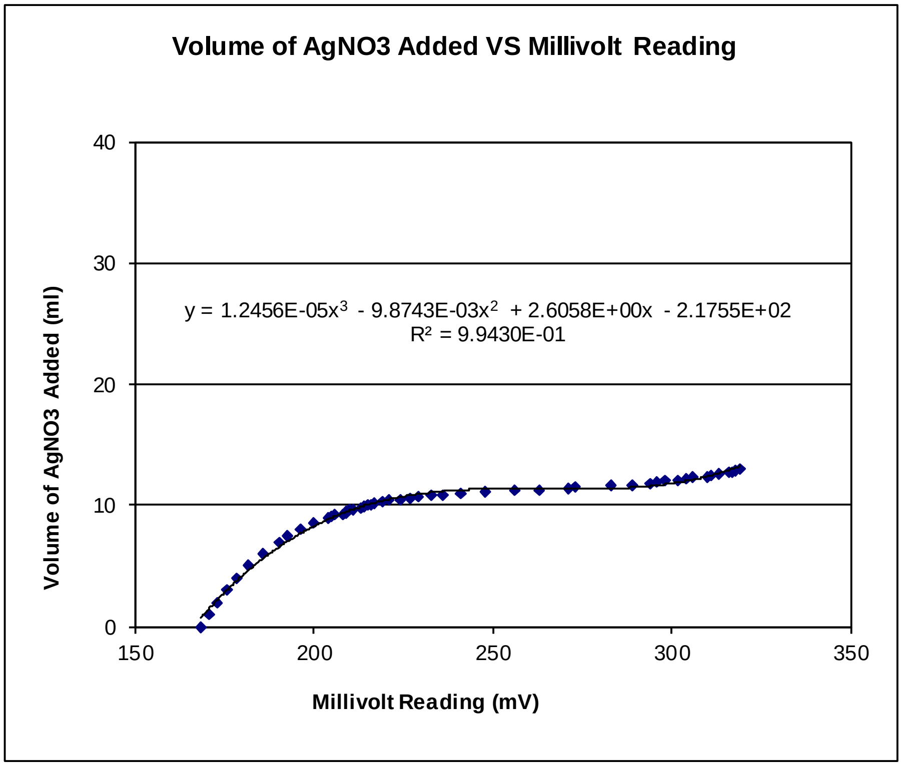
Percent Chloride Ion: 0.2629

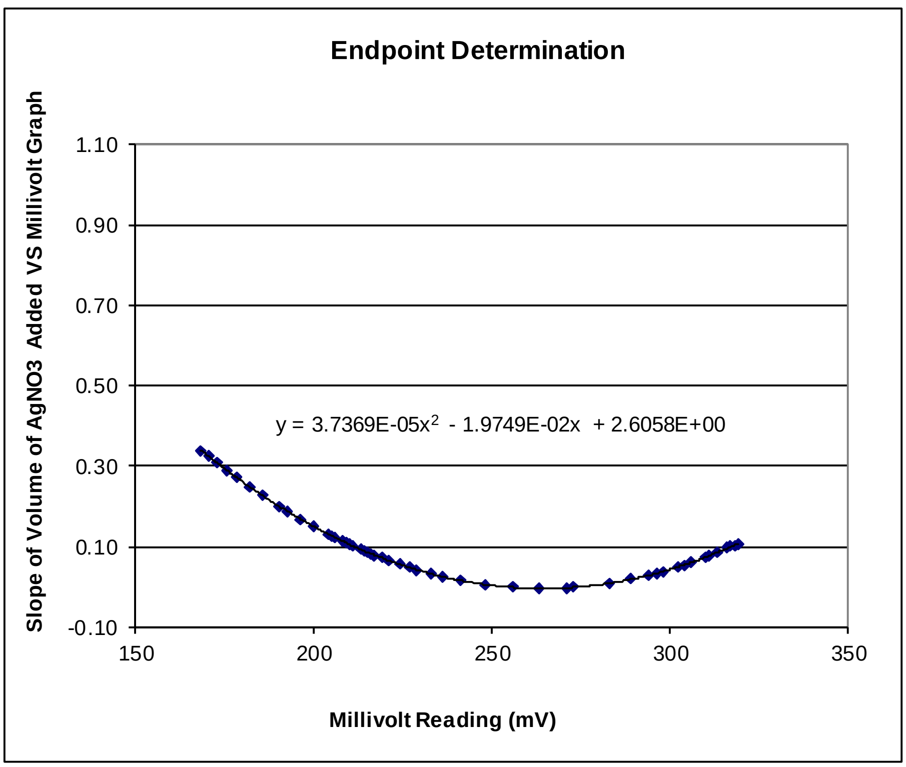
REPORTED BY: Jason Powers, Technician

REVIEWED BY: Robert Varner, Engineer

AASHTO 260 "Standard Method of Test for Sampling and Testing for Chloride Ion In Concrete

BCD Sample No. 35





mV Value Where Slope = Zero: 264.20 Titration End Point: 11.37

Mass of Concrete Sample (g) 3.017

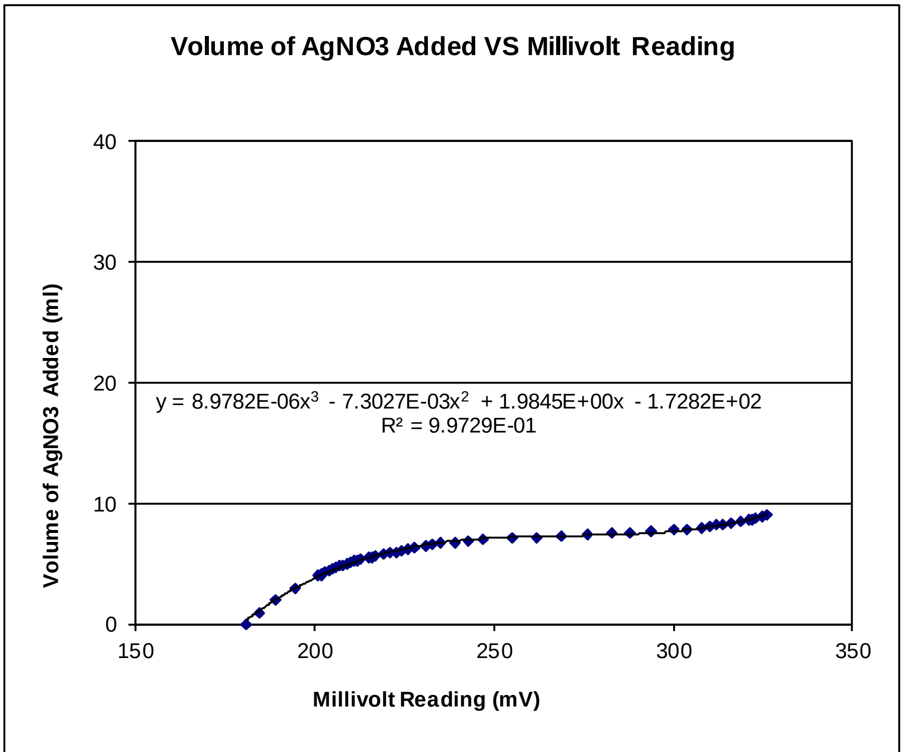
Percent Chloride Ion: 0.0866

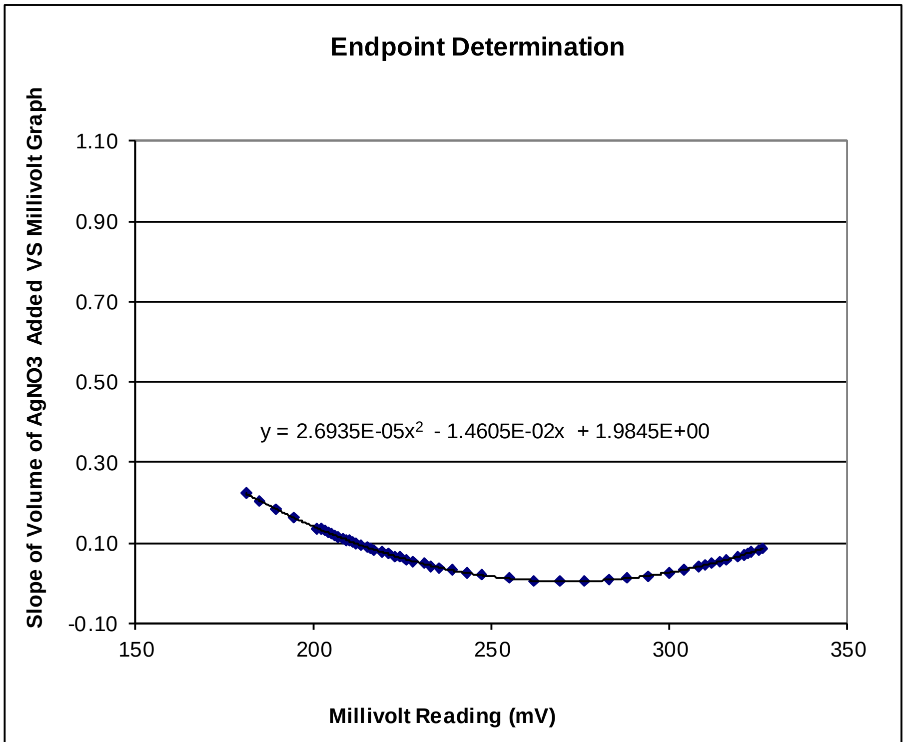
REPORTED BY: Jason Powers, Technician REVIEWED BY: Robert Varner, Engineer

Final Report

AASHTO 260 "Standard Method of Test for Sampling and Testing for Chloride Ion In Concrete

BCD Sample No. 36





mV Value Where Slope = Zero: 271.10 Titration End Point: 7.35

Mass of Concrete Sample (g) 3.0183

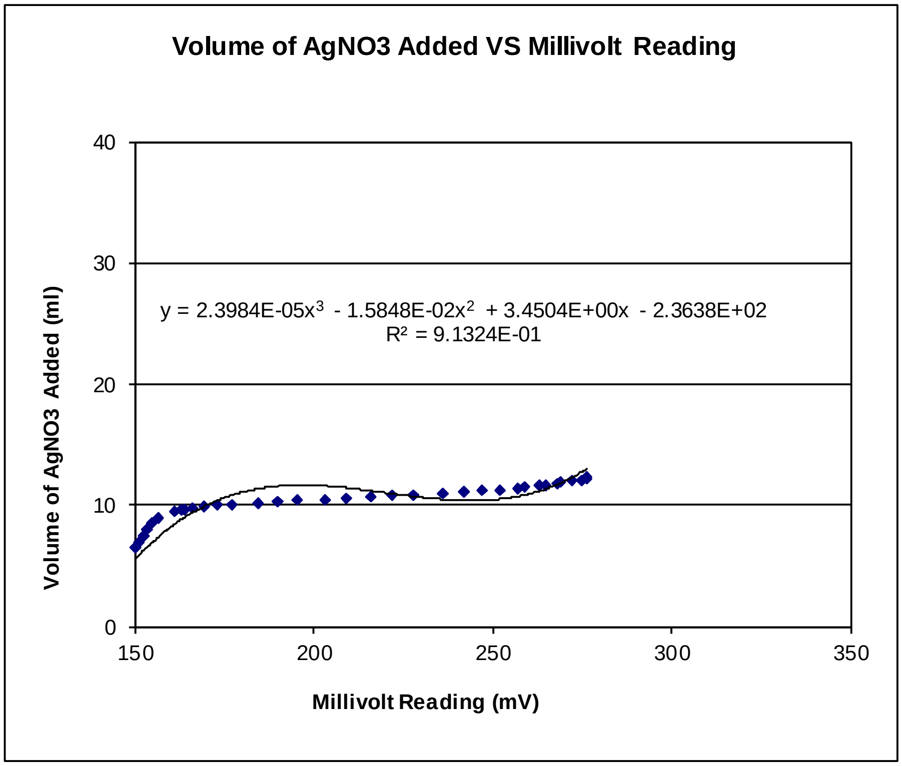
Percent Chloride Ion: 0.0393

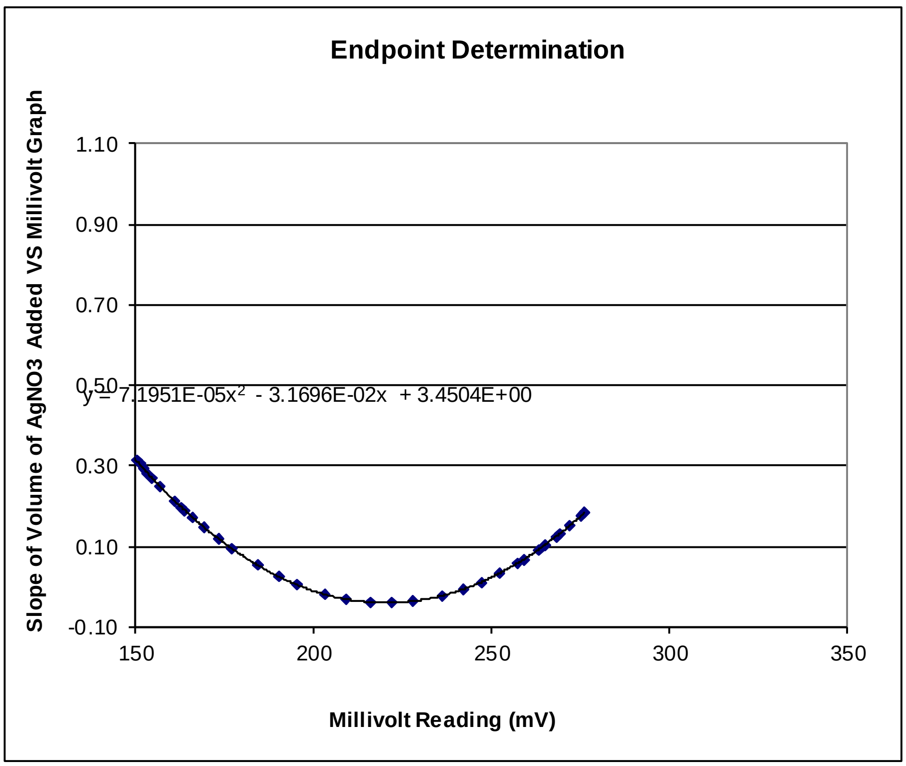
REPORTED BY: Jason Powers, Technician REVIEWED BY: Robert Varner, Engineer

Final Report

AASHTO 260 "Standard Method of Test for Sampling and Testing for Chloride Ion In Concrete

BCD Sample No. 37 Repeat





mV Value Where Slope = Zero: 220.30 Titration End Point: 11.03

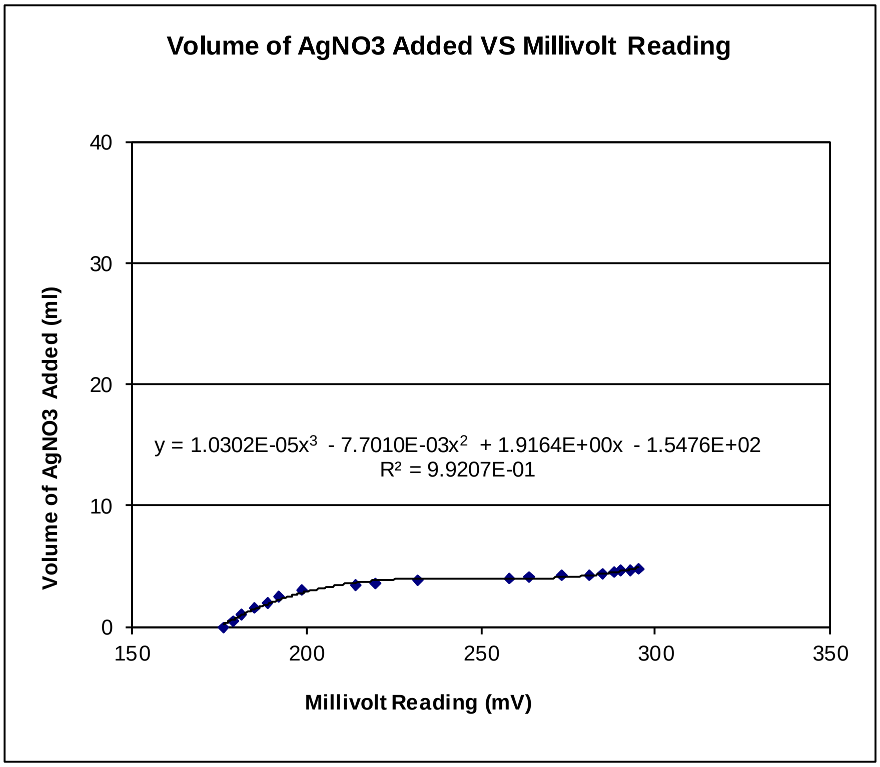
Mass of Concrete Sample (g) 3.0969

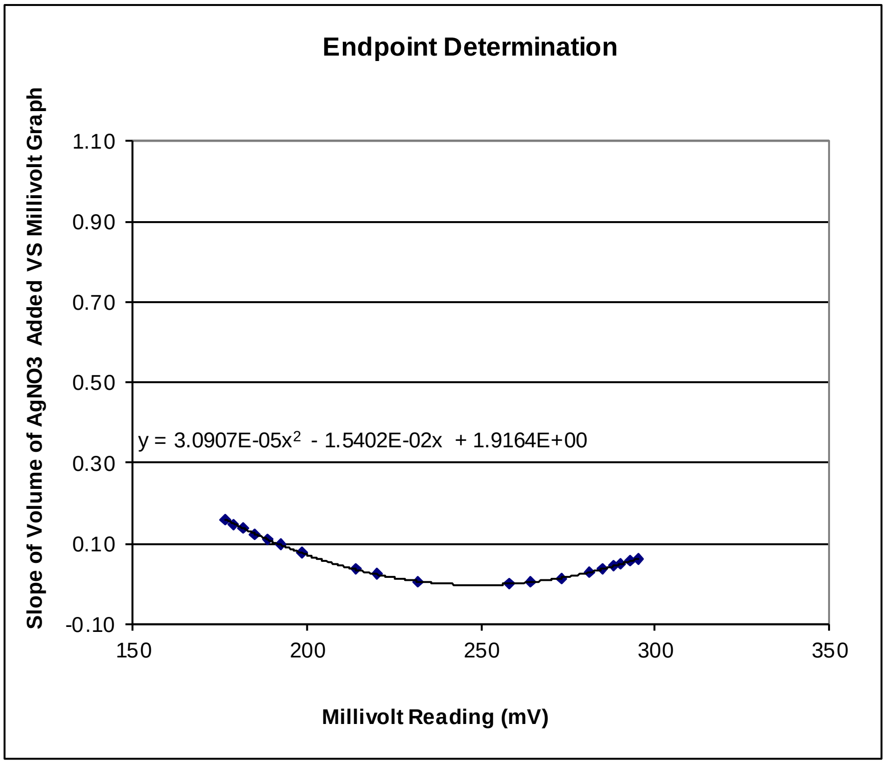
Percent Chloride Ion: 0.0805

REPORTED BY: Jason Powers, Technician REVIEWED BY: Robert Varner, Engineer

AASHTO 260 "Standard Method of Test for Sampling and Testing for Chloride Ion In

BCD Sample No. 38 Repeat





mV Value Where Slope = Zero: 249.20 Titration End Point: 4.00

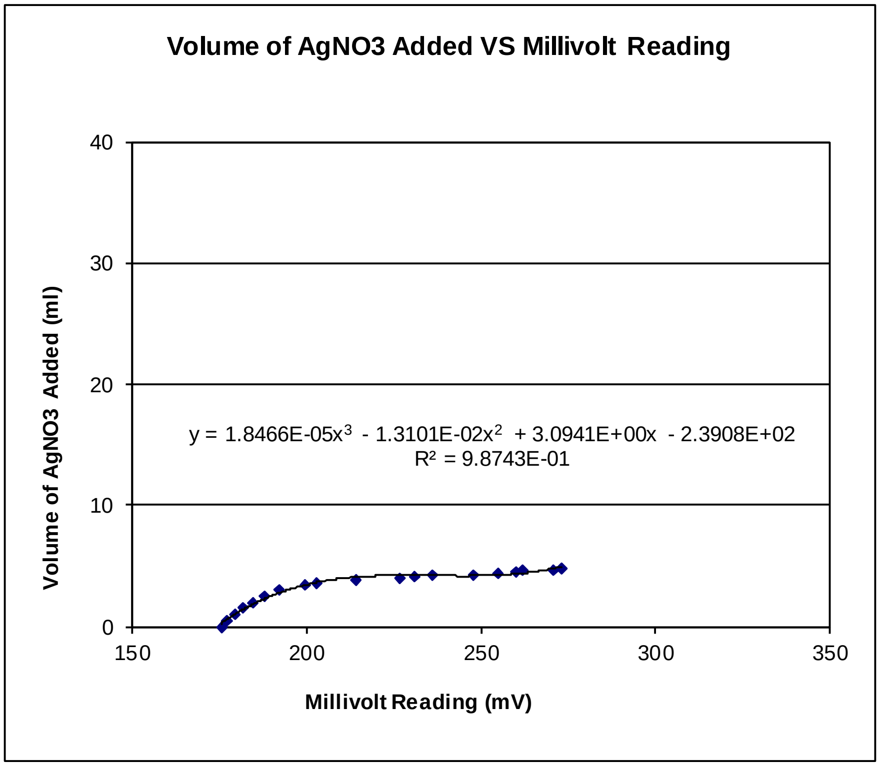
Mass of Concrete Sample (g) 3.0611

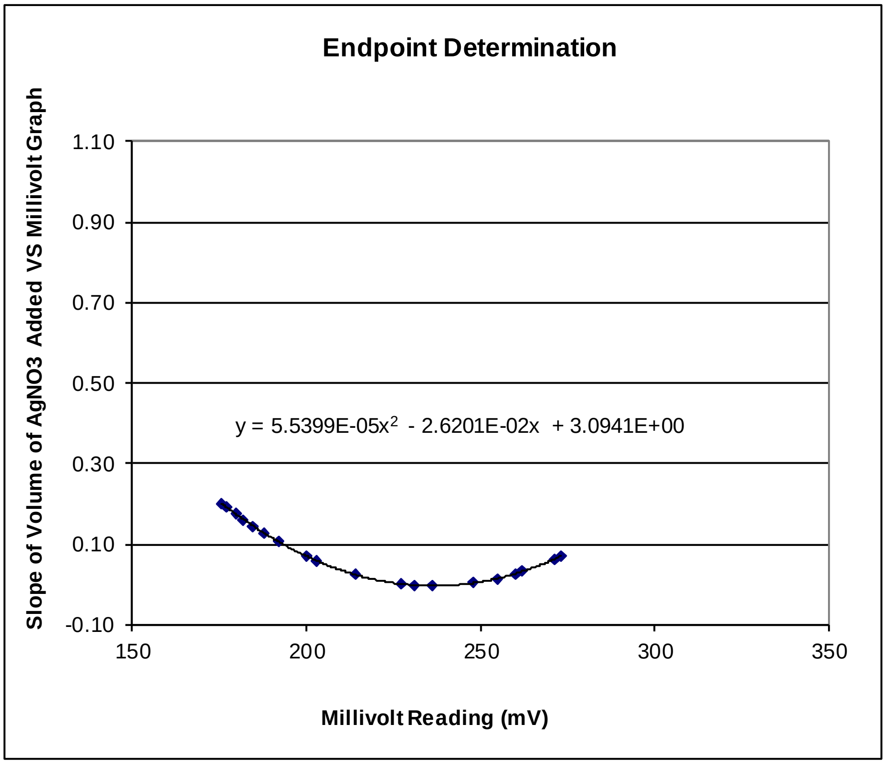
Percent Chloride Ion: 0.0000

REPORTED BY: Jason Powers, Technician REVIEWED BY: Robert Varner, Engineer

AASHTO 260 "Standard Method of Test for Sampling and Testing for Chloride Ion In

BCD Sample No. 39 Repeat





mV Value Where Slope = Zero: 236.50 Titration End Point: 4.20

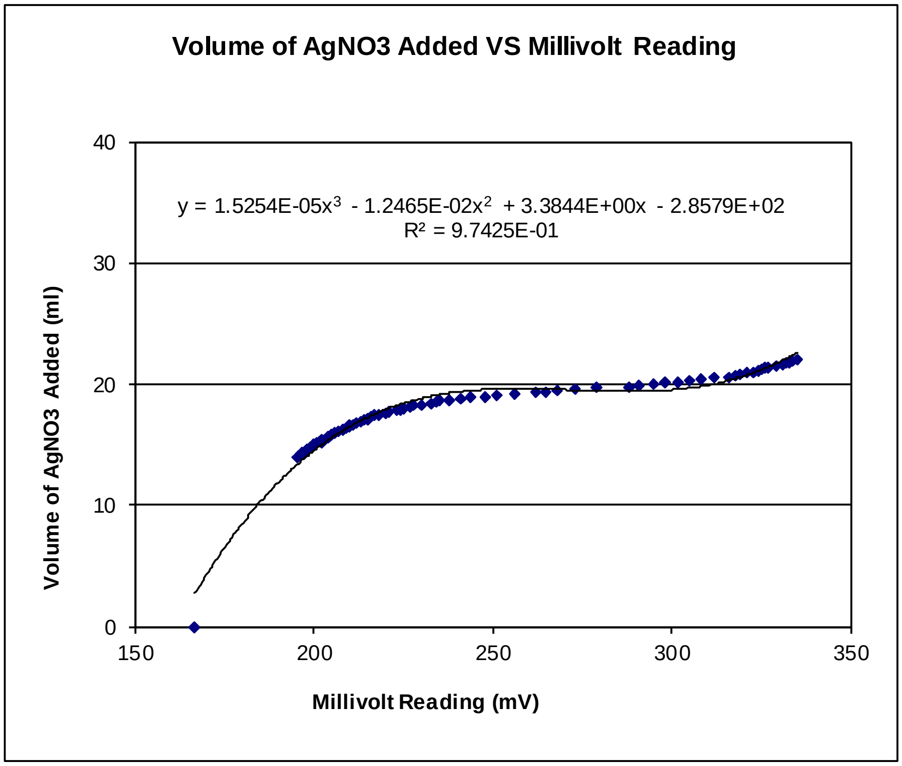
Mass of Concrete Sample (g) 3.0222

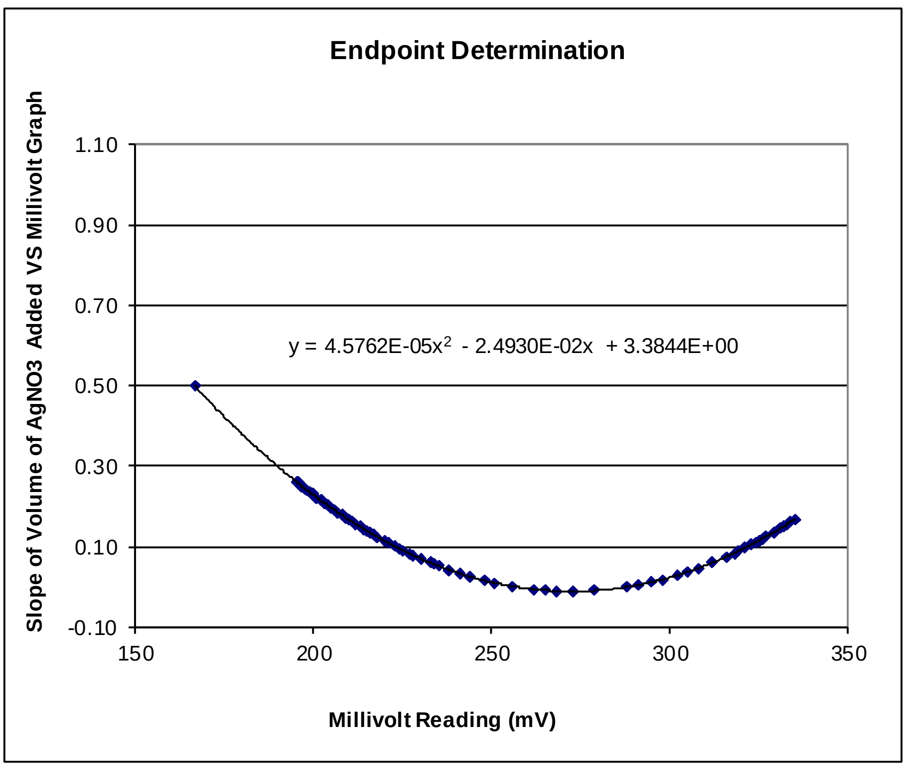
Percent Chloride Ion: 0.0024

REPORTED BY: Jason Powers, Technician REVIEWED BY: Robert Varner, Engineer

AASHTO 260 "Standard Method of Test for Sampling and Testing for Chloride Ion In Concrete

BCD Sample No. 40





mV Value Where Slope = Zero: 272.40 Titration End Point: 19.52

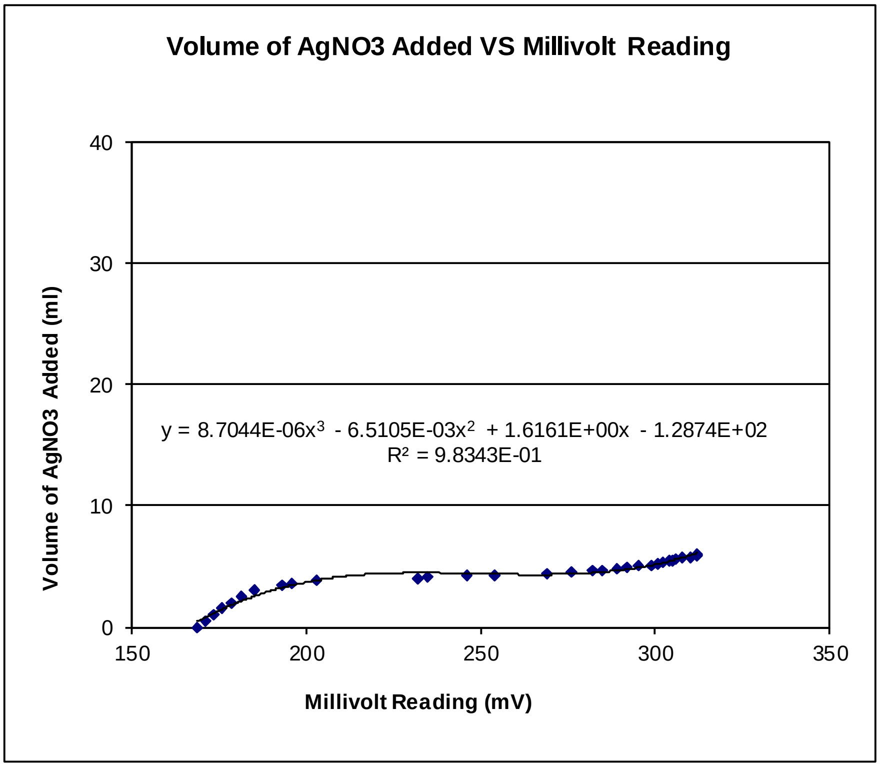
Mass of Concrete Sample (g) 3.0295

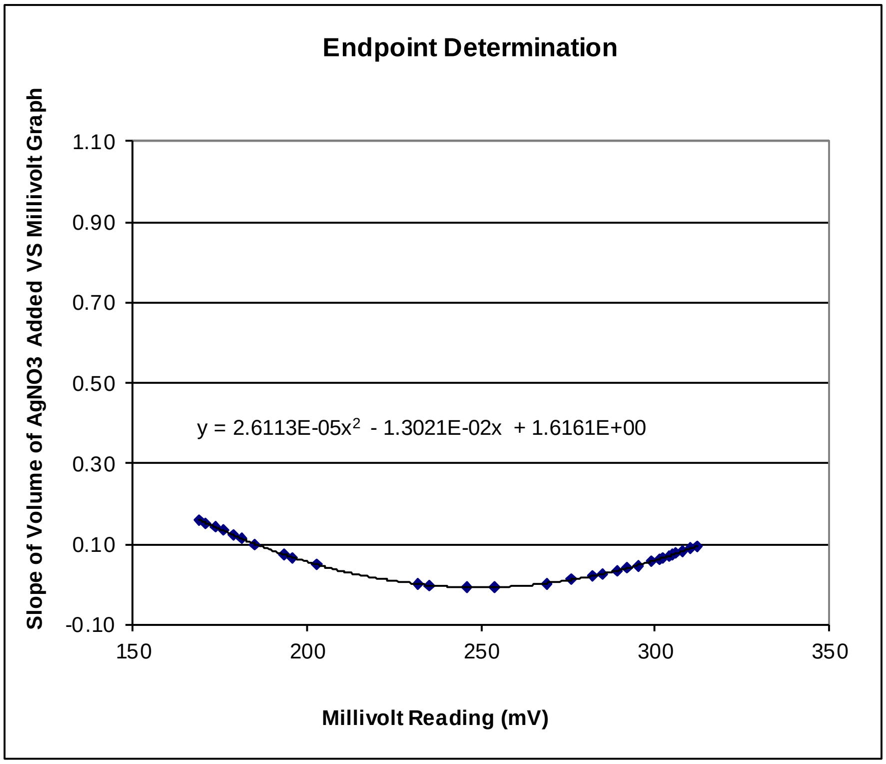
Percent Chloride Ion: 0.1816

REPORTED BY: Jason Powers, Technician REVIEWED BY: Robert Varner, Engineer

AASHTO 260 "Standard Method of Test for Sampling and Testing for Chloride Ion In

BCD Sample No. 41 Repeat





mV Value Where Slope = Zero: 249.30 Titration End Point: 4.39

Mass of Concrete Sample (g) 3.0292

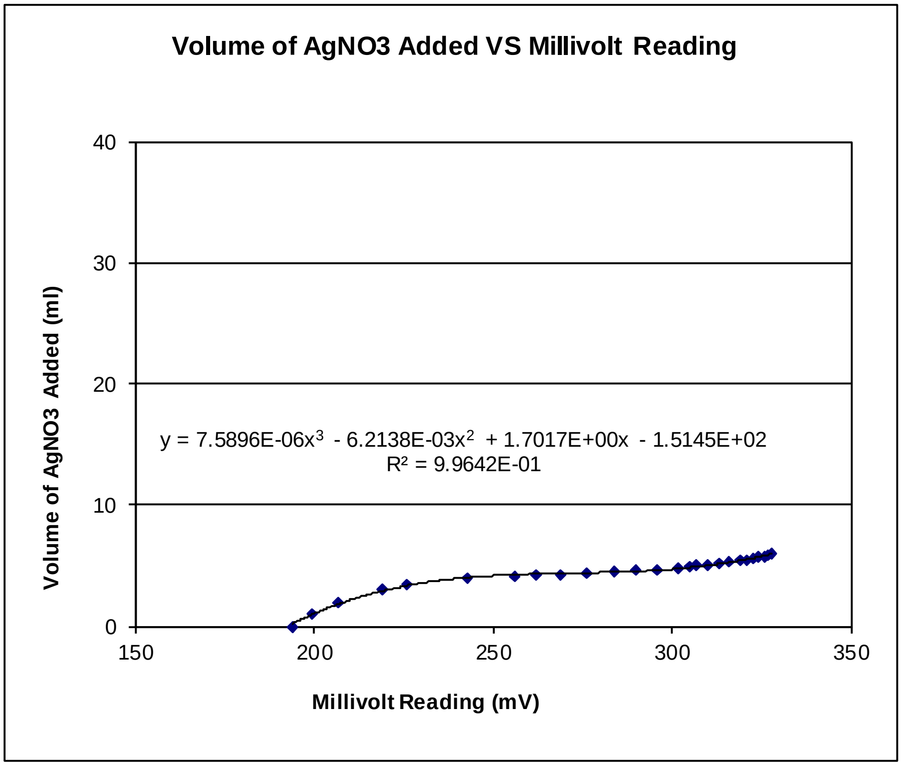
Percent Chloride Ion: 0.0045

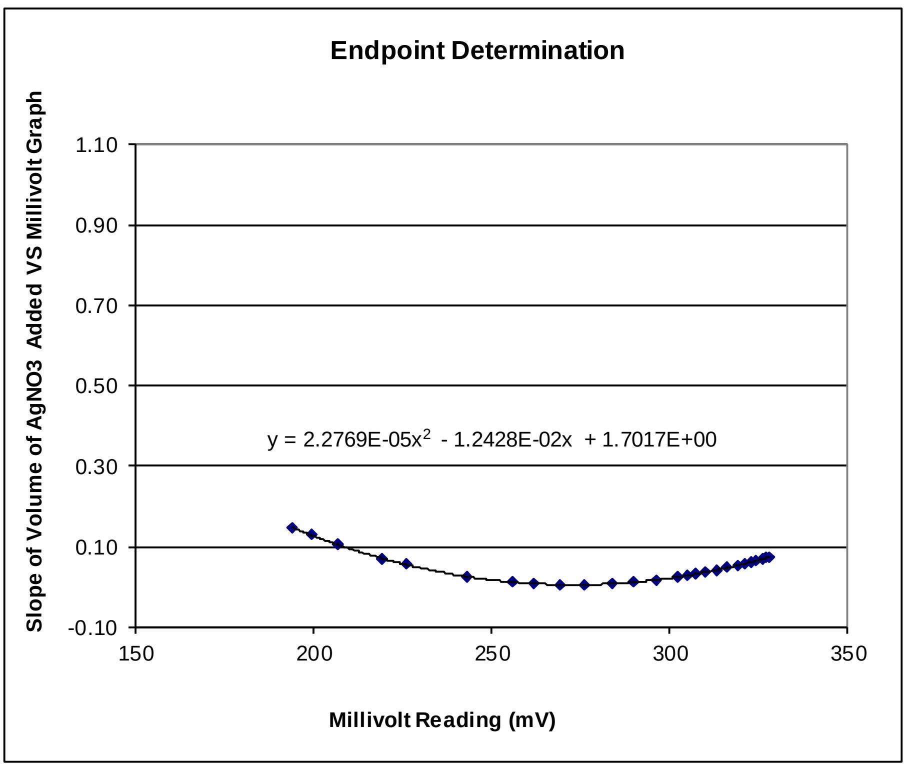
REPORTED BY: Jason Powers, Technician REVIEWED BY: Robert Varner, Engineer

Final Report

AASHTO 260 "Standard Method of Test for Sampling and Testing for Chloride Ion In Concrete

BCD Sample No. 42





mV Value Where Slope = Zero: 272.90 Titration End Point: 4.41

Mass of Concrete Sample (g) 3.0167

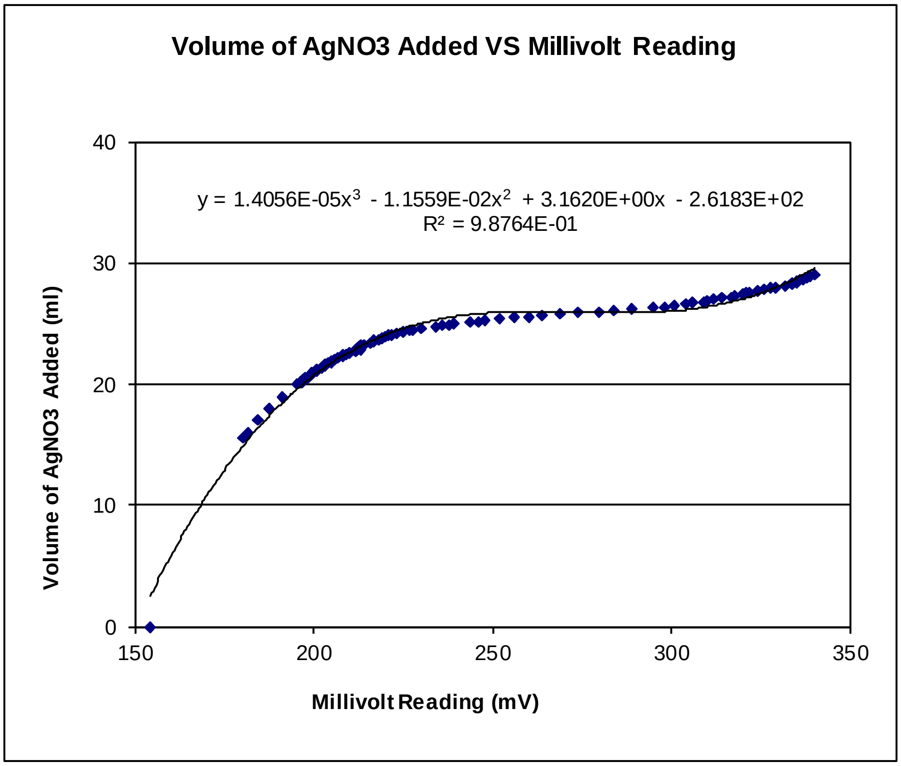
Percent Chloride Ion: 0.0048

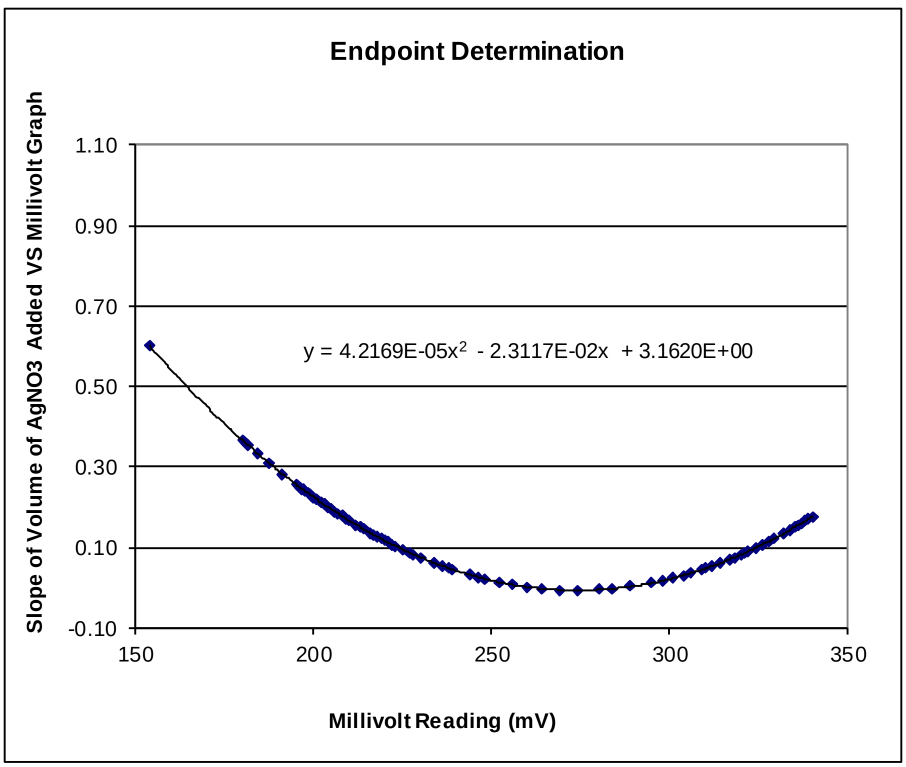
REPORTED BY: Jason Powers, Technician REVIEWED BY: Robert Varner, Engineer

Final Report

AASHTO 260 "Standard Method of Test for Sampling and Testing for Chloride Ion In Concrete

BCD Sample No. 43





mV Value Where Slope = Zero: 274.10 Titration End Point: 25.95

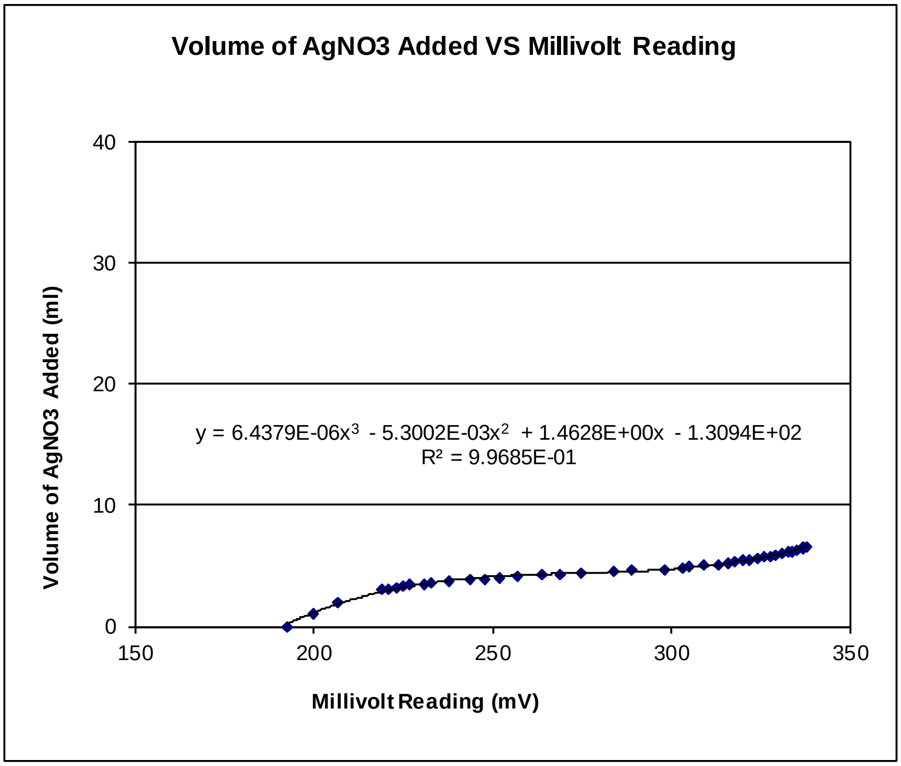
Mass of Concrete Sample (g) 3.0726

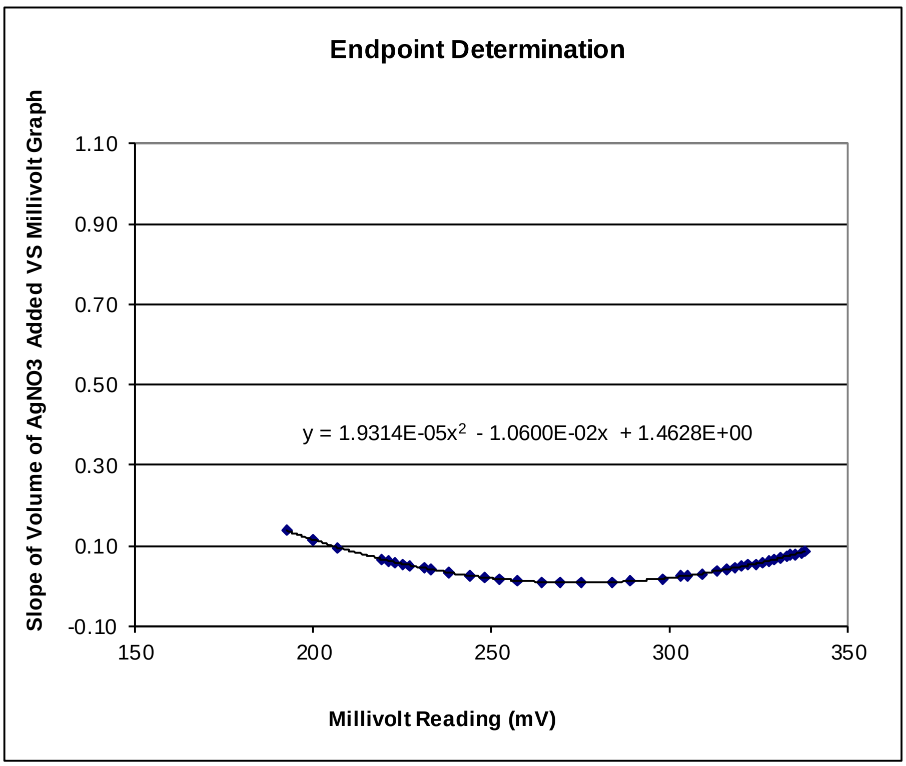
Percent Chloride Ion: 0.2533

REPORTED BY: Jason Powers, Technician REVIEWED BY: Robert Varner, Engineer

AASHTO 260 "Standard Method of Test for Sampling and Testing for Chloride Ion In Concrete

BCD Sample No. 44





mV Value Where Slope = Zero: 274.40 Titration End Point: 4.39

Mass of Concrete Sample (g) 3.0188

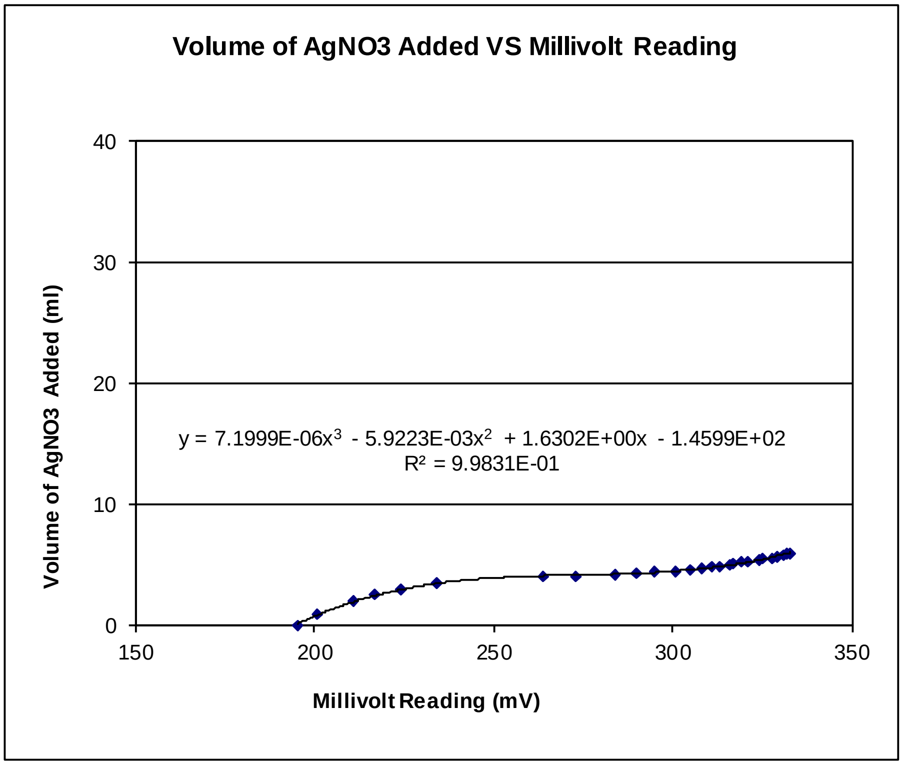
Percent Chloride Ion: 0.0045

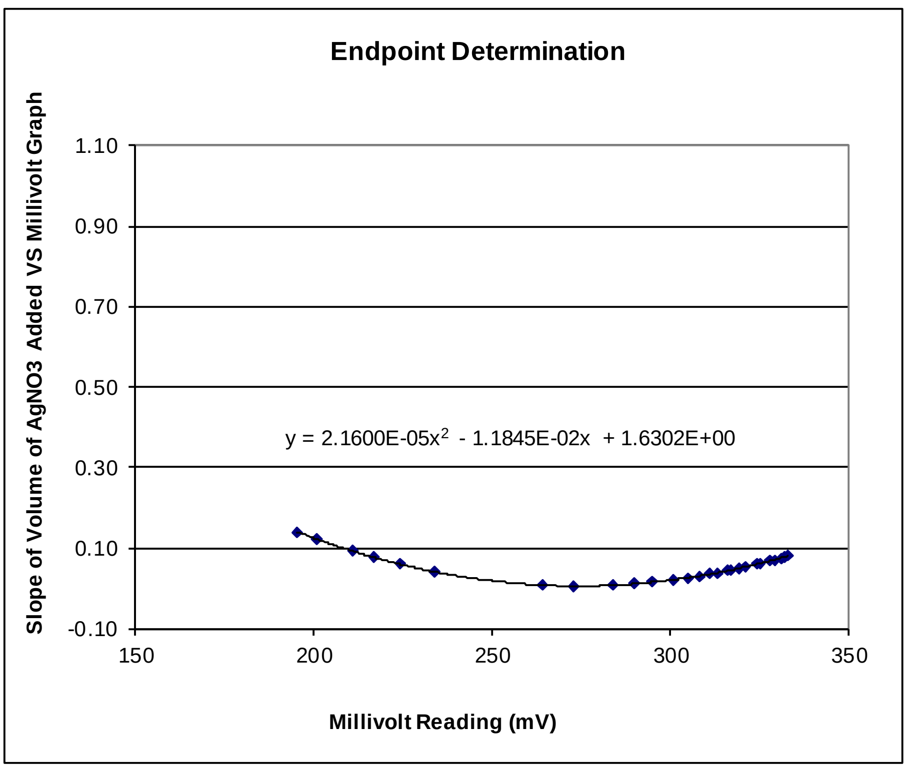
REPORTED BY: Jason Powers, Technician

REVIEWED BY: Robert Varner, Engineer

AASHTO 260 "Standard Method of Test for Sampling and Testing for Chloride Ion In Concrete

BCD Sample No. 45





mV Value Where Slope = Zero: 274.20 Titration End Point: 4.19

Mass of Concrete Sample (g) 3.0483

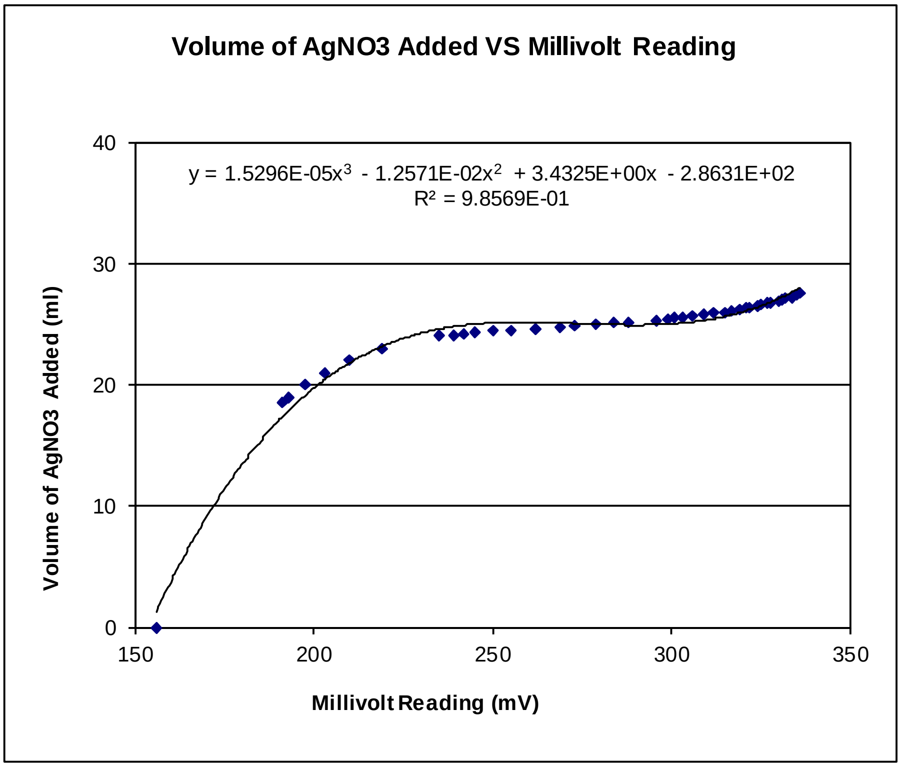
Percent Chloride Ion: 0.0022

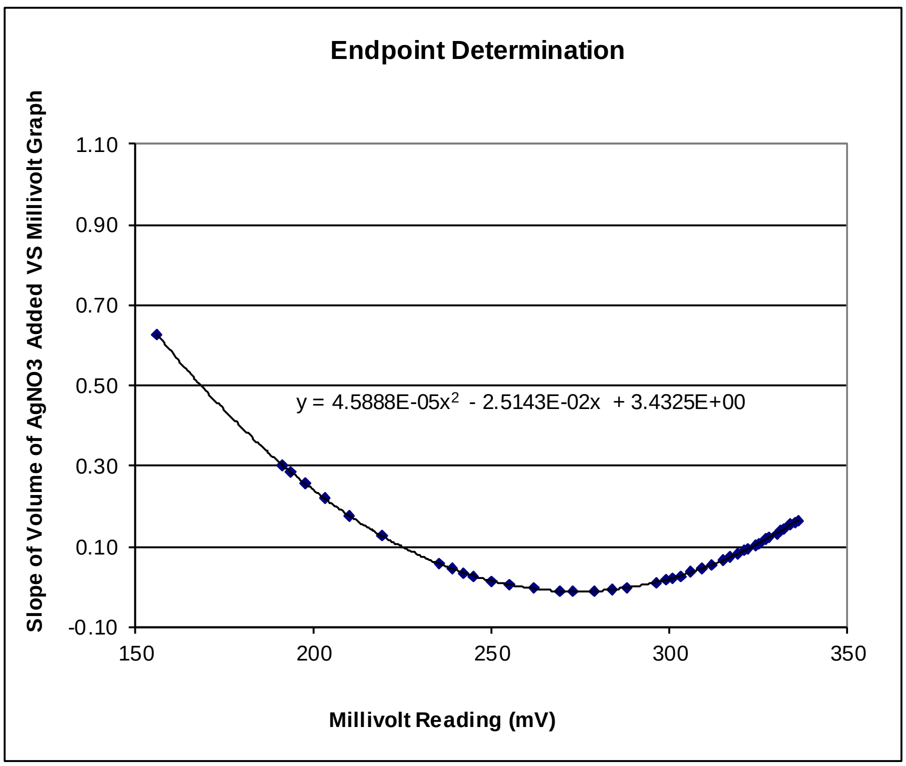
REPORTED BY: Jason Powers
Technician

REVIEWED BY: Robert Varner
Engineer

AASHTO 260 "Standard Method of Test for Sampling and Testing for Chloride Ion In Concrete

BCD Sample No. 46





mV Value Where Slope = Zero: 274.00 Titration End Point: 25.05

Mass of Concrete Sample (g) 3.081

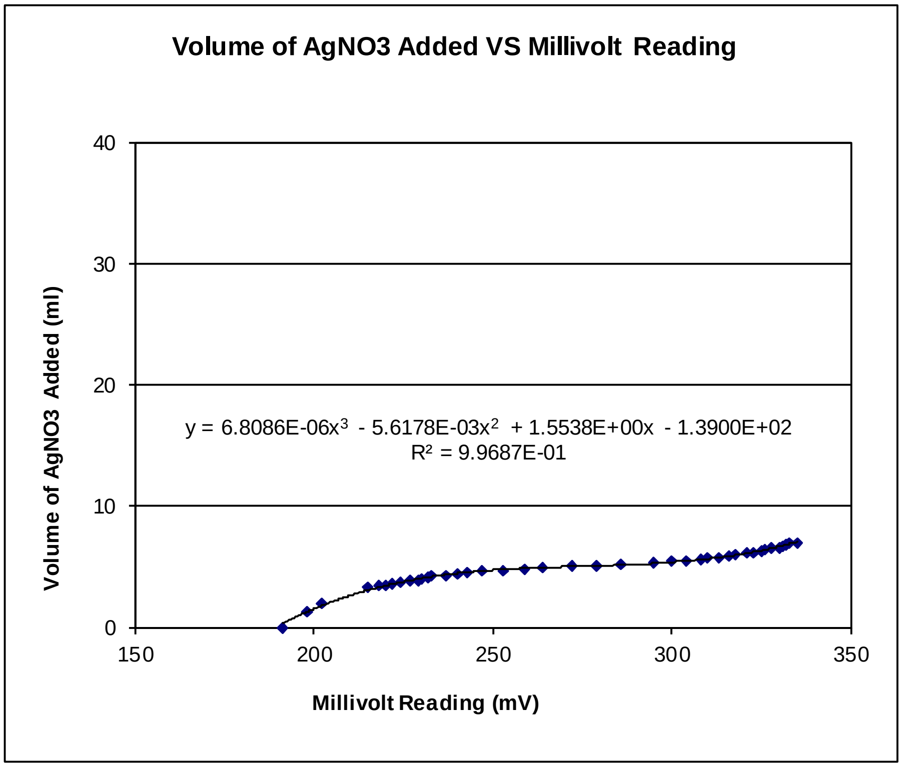
Percent Chloride Ion: 0.2422

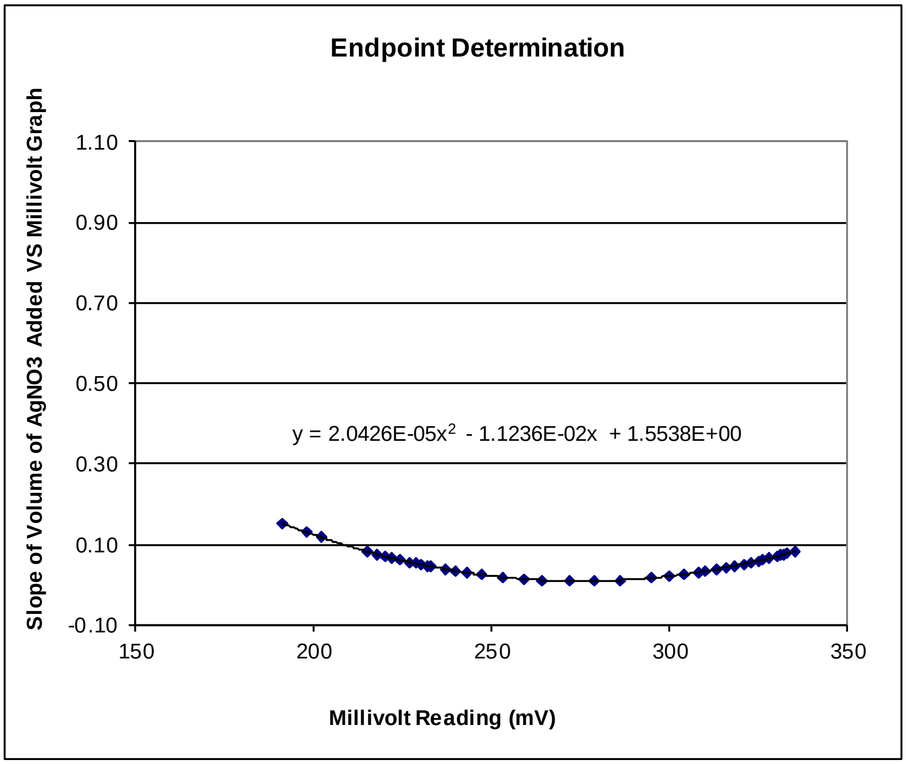
REPORTED BY: Jason Powers, Technician REVIEWED BY: Robert Varner, Engineer

Final Report

AASHTO 260 "Standard Method of Test for Sampling and Testing for Chloride Ion In Concrete

BCD Sample No. 47





mV Value Where Slope = Zero: 275.00 Titration End Point: 5.05

Mass of Concrete Sample (g) 3.0035

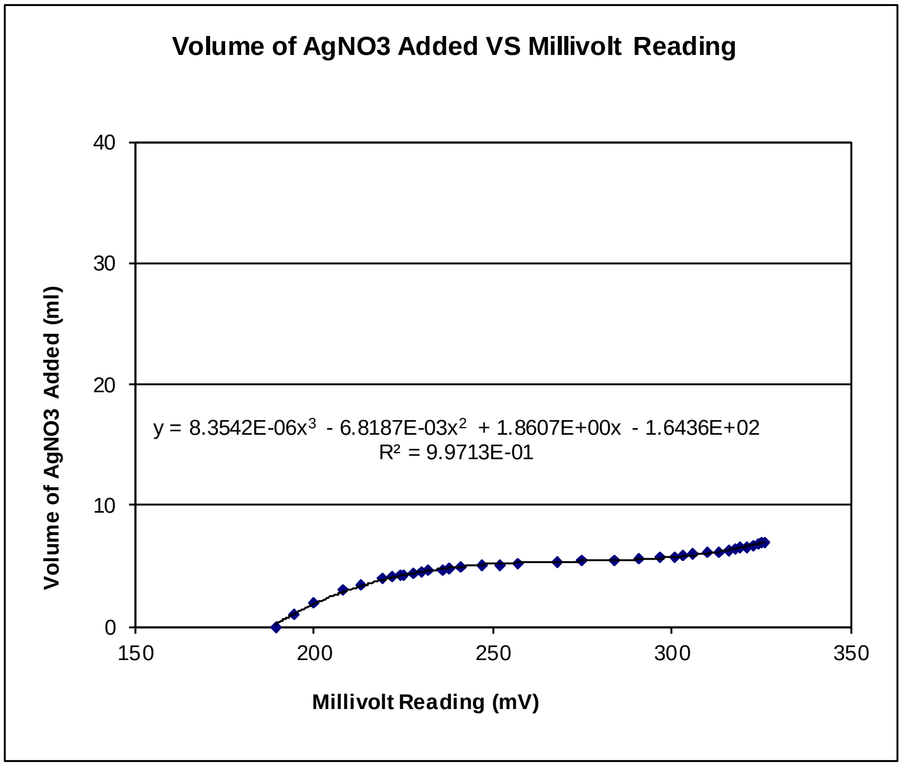
Percent Chloride Ion: 0.0124

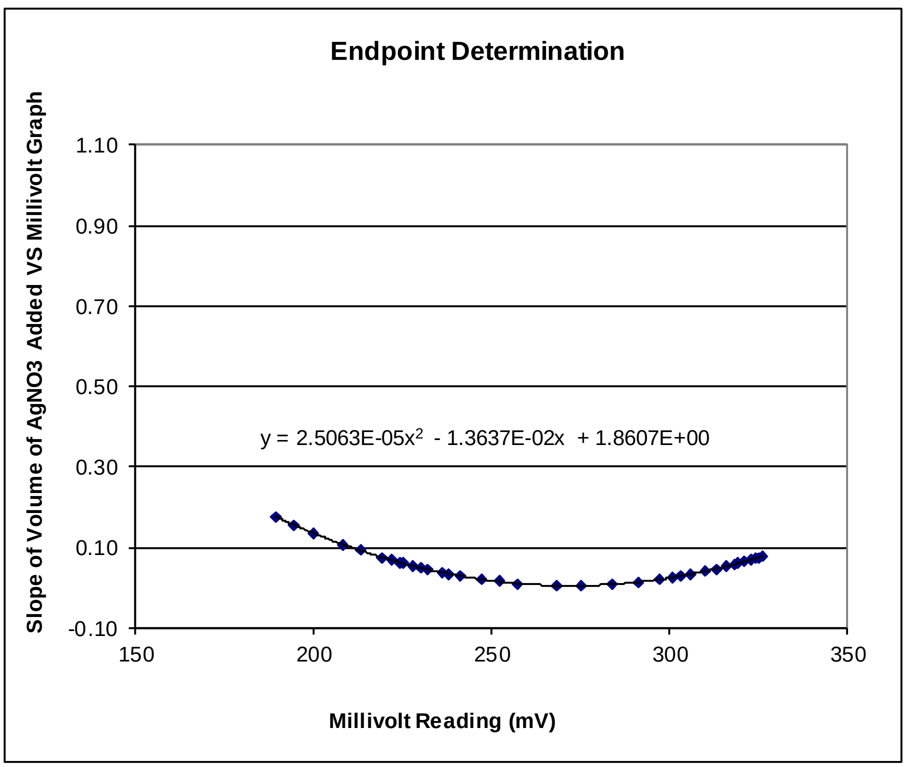
REPORTED BY: Jason Powers, Technician

REVIEWED BY: Robert Varner, Engineer

AASHTO 260 "Standard Method of Test for Sampling and Testing for Chloride Ion In Concrete

BCD Sample No. 48





mV Value Where Slope = Zero: 272.10 Titration End Point: 5.38

Mass of Concrete Sample (g) 3.02

Percent Chloride Ion: 0.0162

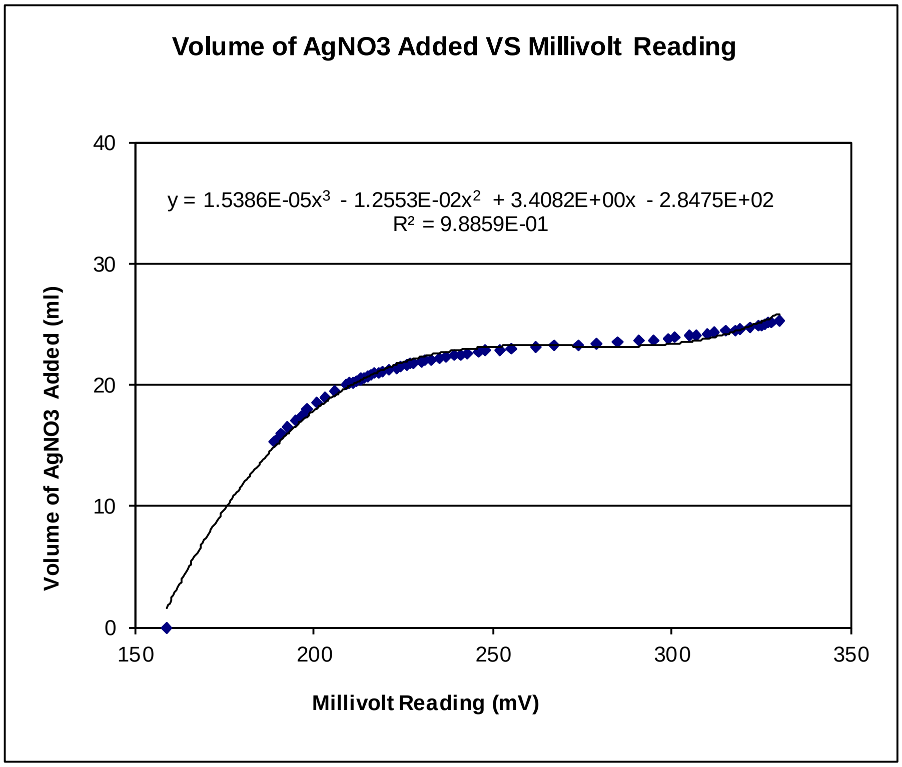
REPORTED BY: Jason Powers, Technician

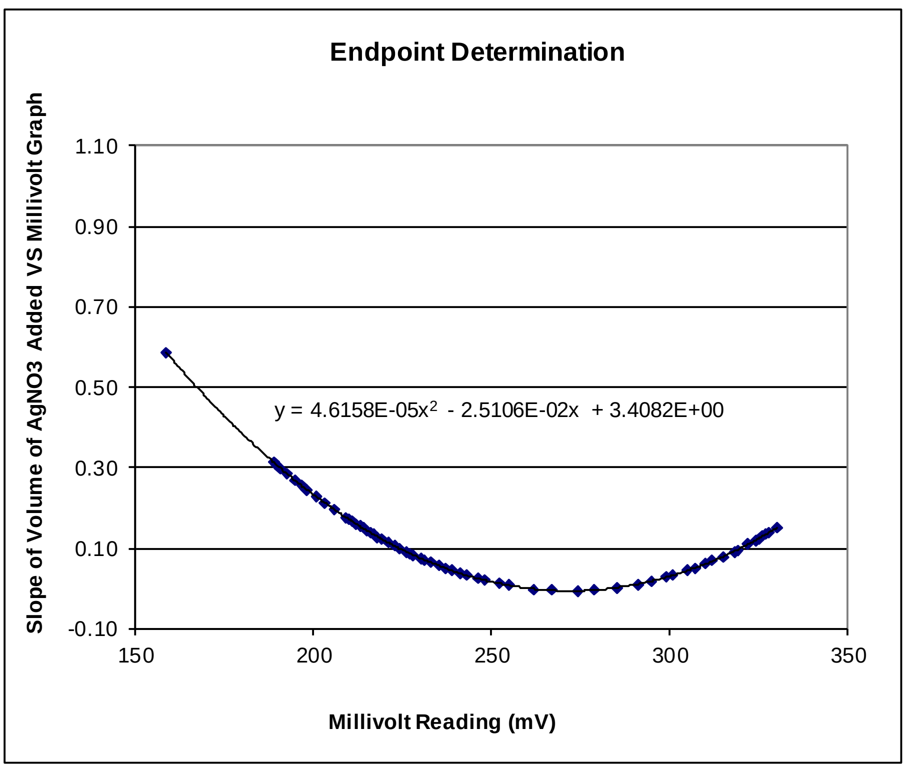
REVIEWED BY: Robert Varner, Engineer

Final Report

AASHTO 260 "Standard Method of Test for Sampling and Testing for Chloride Ion In Concrete

BCD Sample No. 49





mV Value Where Slope = Zero: 271.90 Titration End Point: 23.18

Mass of Concrete Sample (g) 3.0462

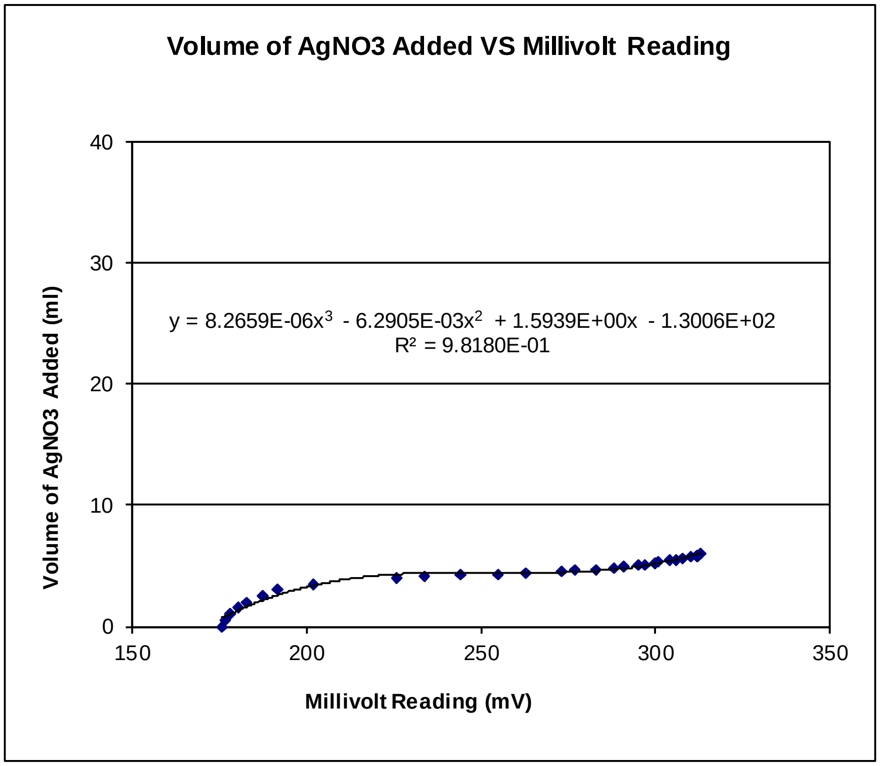
Percent Chloride Ion: 0.2233

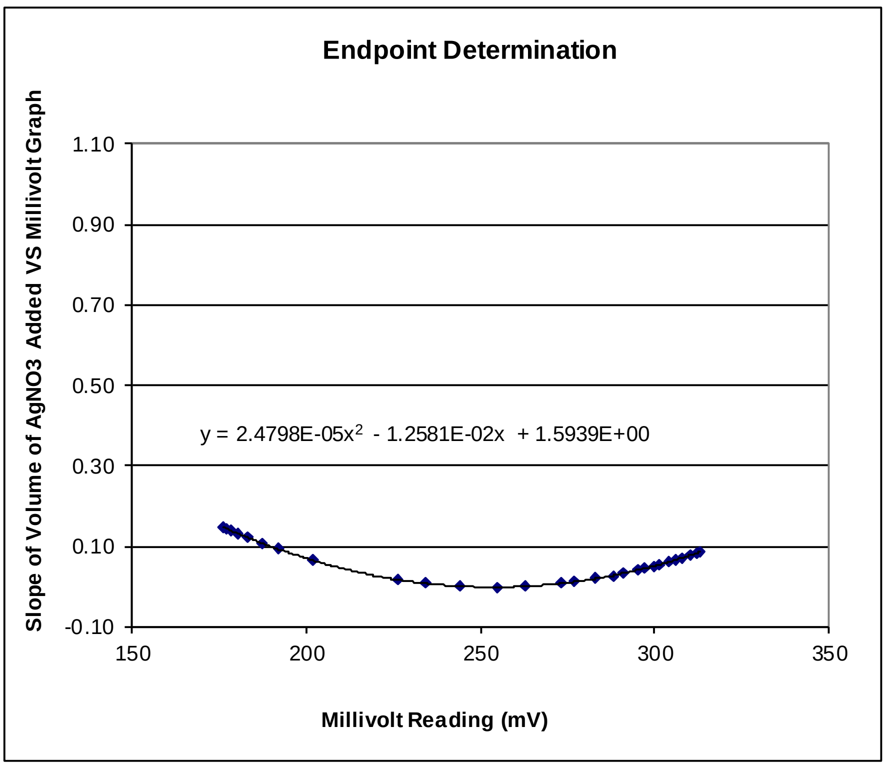
REPORTED BY: Jason Powers, Technician REVIEWED BY: Robert Varner, Engineer

Final Report

AASHTO 260 "Standard Method of Test for Sampling and Testing for Chloride Ion In

BCD Sample No. 50 Repeat





mV Value Where Slope = Zero: 253.70 Titration End Point: 4.42

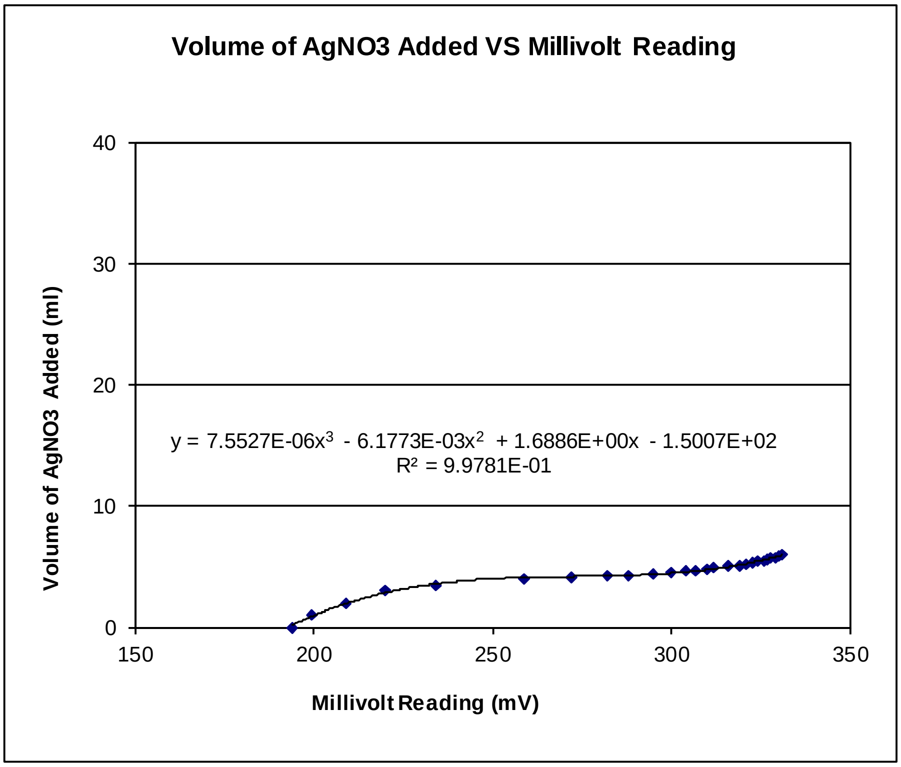
Mass of Concrete Sample (g) 3.0818

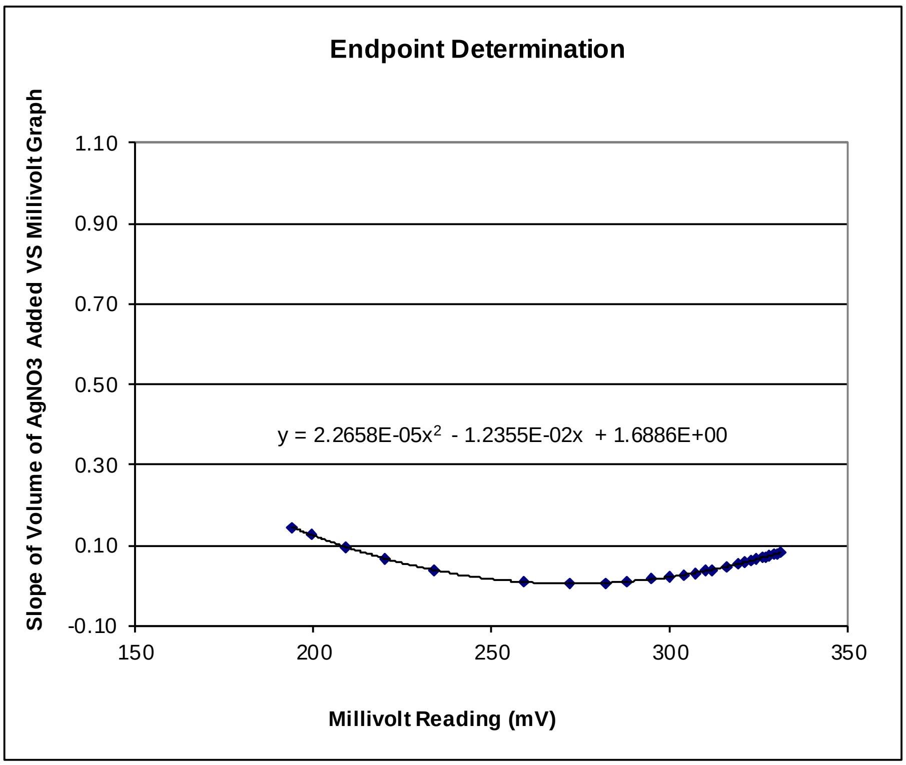
Percent Chloride Ion: 0.0048

REPORTED BY: Jason Powers, Technician REVIEWED BY: Robert Varner, Engineer

AASHTO 260 "Standard Method of Test for Sampling and Testing for Chloride Ion In Concrete

BCD Sample No. 51





mV Value Where Slope = Zero: 272.60 Titration End Point: 4.18

Mass of Concrete Sample (g) 3.0299

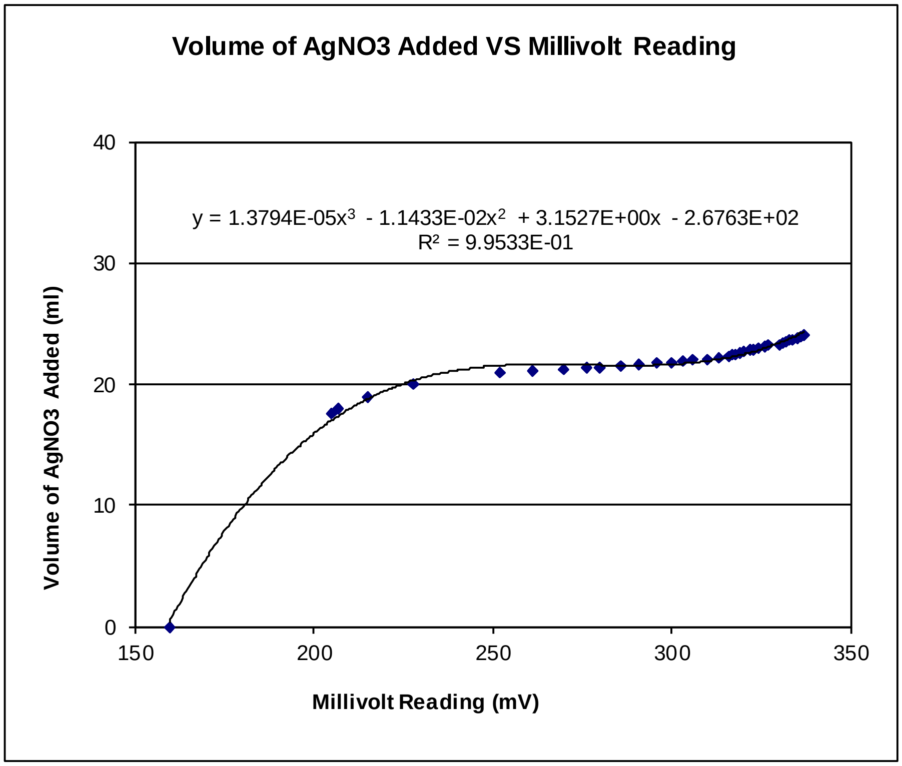
Percent Chloride Ion: 0.0021

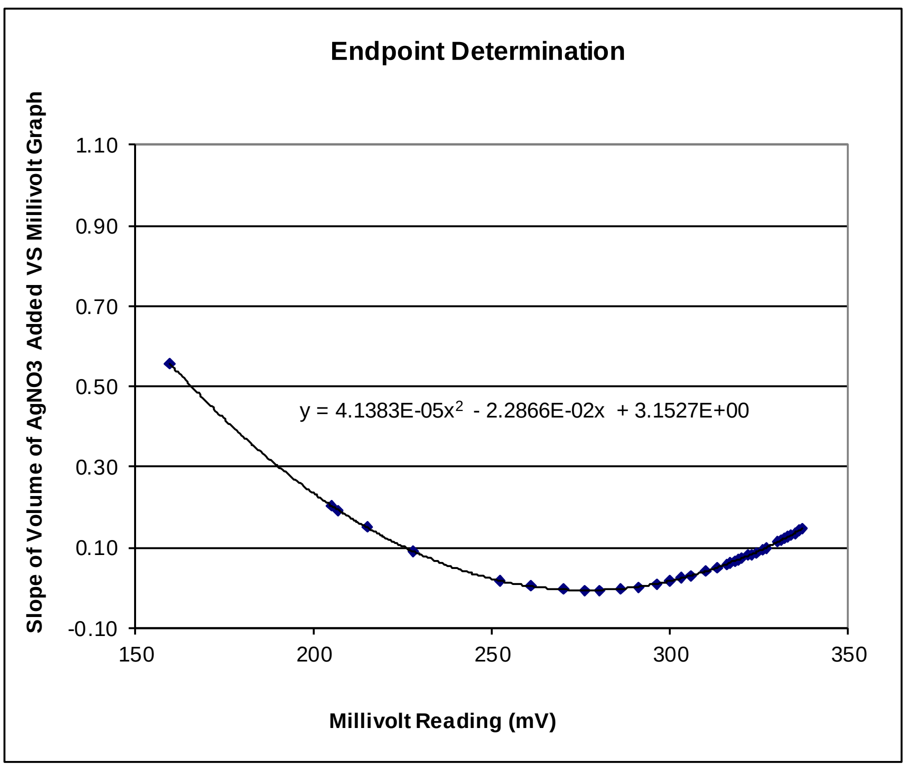
REPORTED BY: Jason Powers, Technician

REVIEWED BY: Robert Varner, Engineer

AASHTO 260 "Standard Method of Test for Sampling and Testing for Chloride Ion In Concrete

BCD Sample No. 52





mV Value Where Slope = Zero: 276.30 Titration End Point: 21.59

Mass of Concrete Sample (g) 3.045

Percent Chloride Ion: 0.2048

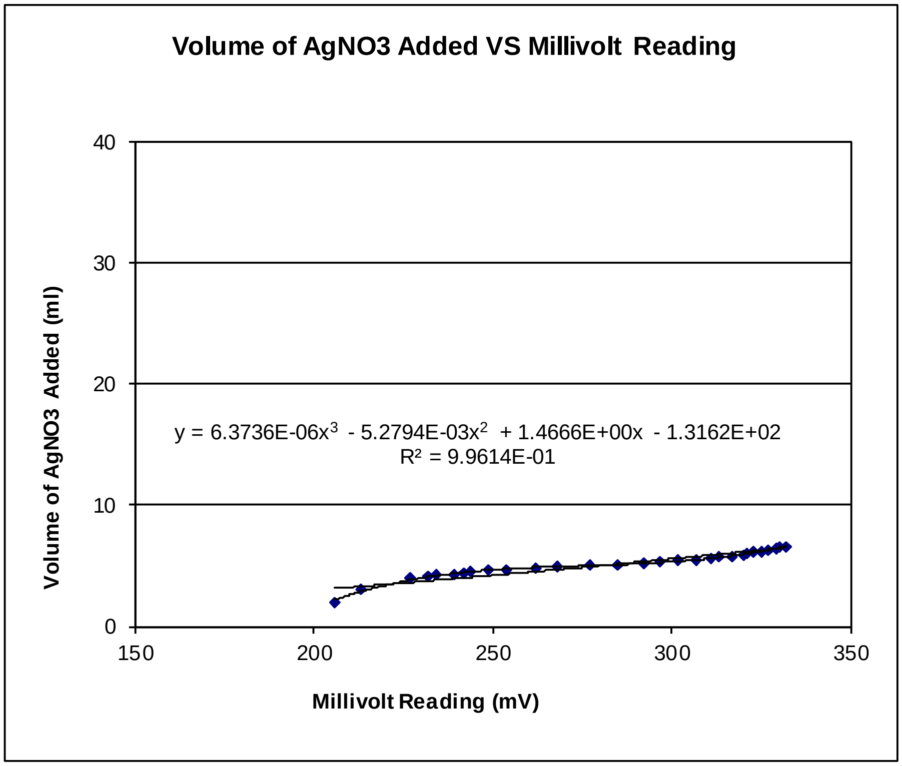
REPORTED BY: Jason Powers, Technician

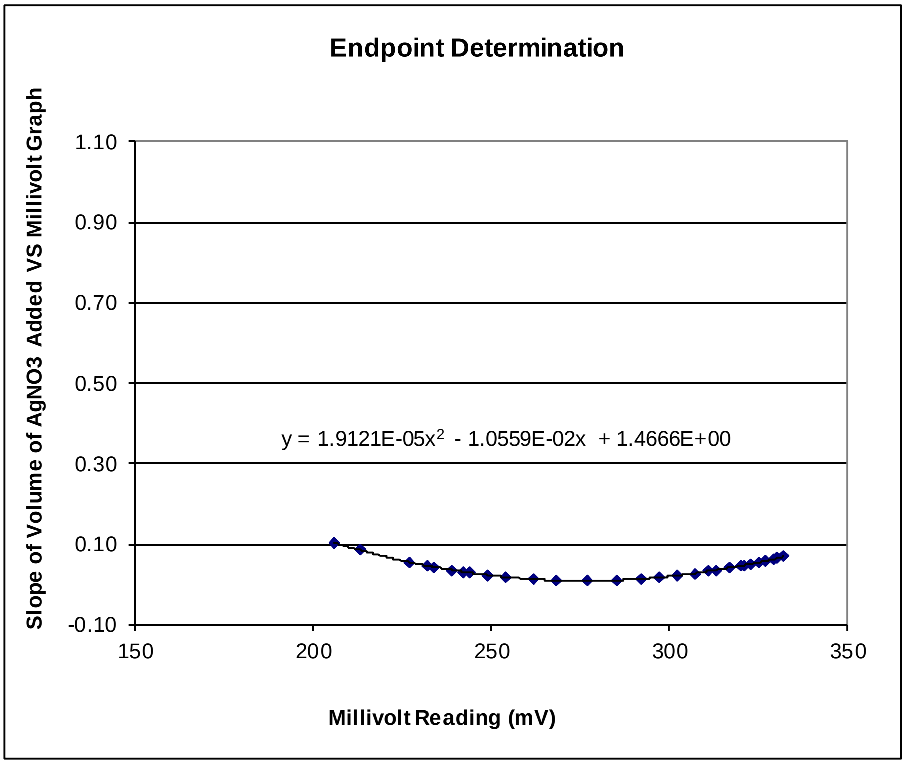
REVIEWED BY: Robert Varner, Engineer

Final Report

AASHTO 260 "Standard Method of Test for Sampling and Testing for Chloride Ion In Concrete

BCD Sample No. 53





mV Value Where Slope = Zero: 276.10 Titration End Point: 5.01

Mass of Concrete Sample (g) 3.0234

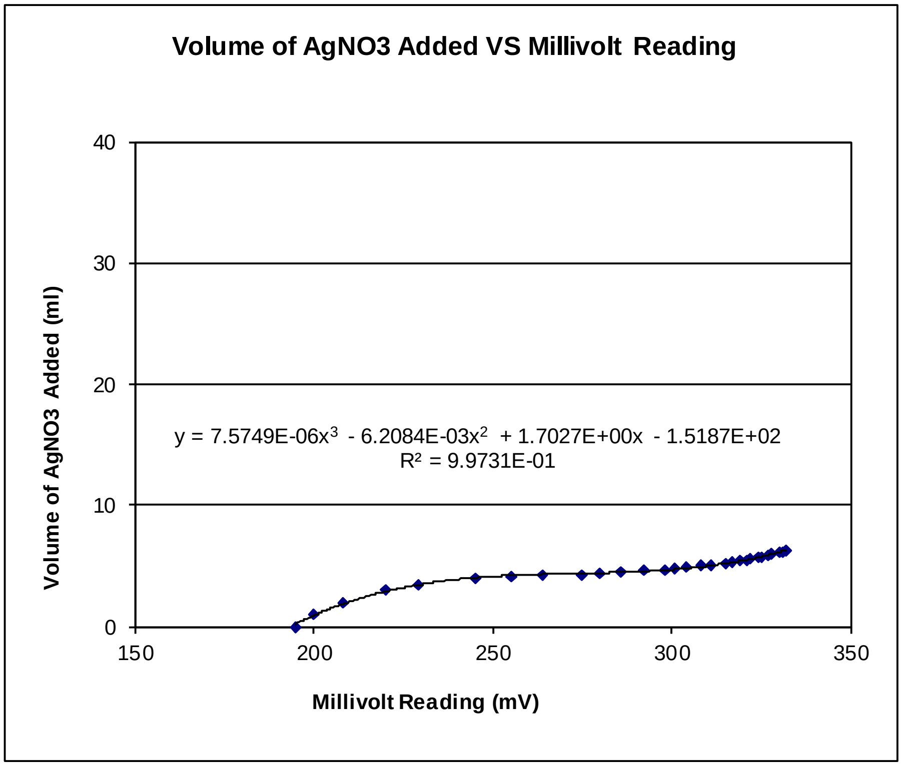
Percent Chloride Ion: 0.0119

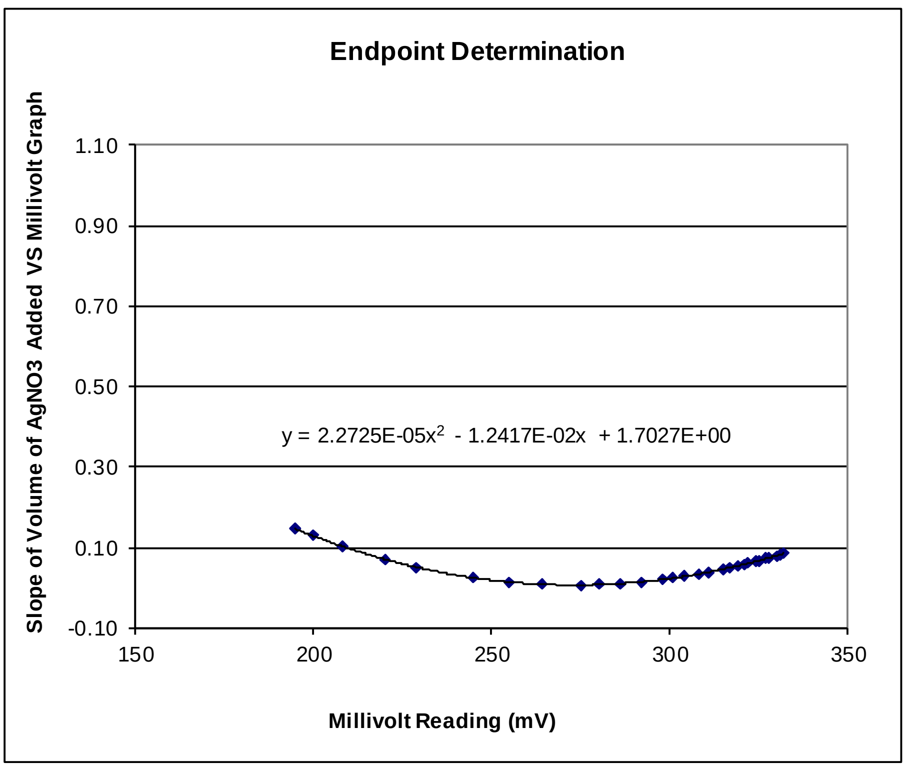
REPORTED BY: Jason Powers, Technician

REVIEWED BY: Robert Varner, Engineer

AASHTO 260 "Standard Method of Test for Sampling and Testing for Chloride Ion In Concrete

BCD Sample No. 54





mV Value Where Slope = Zero: 273.20 Titration End Point: 4.39

Mass of Concrete Sample (g) 3.0324

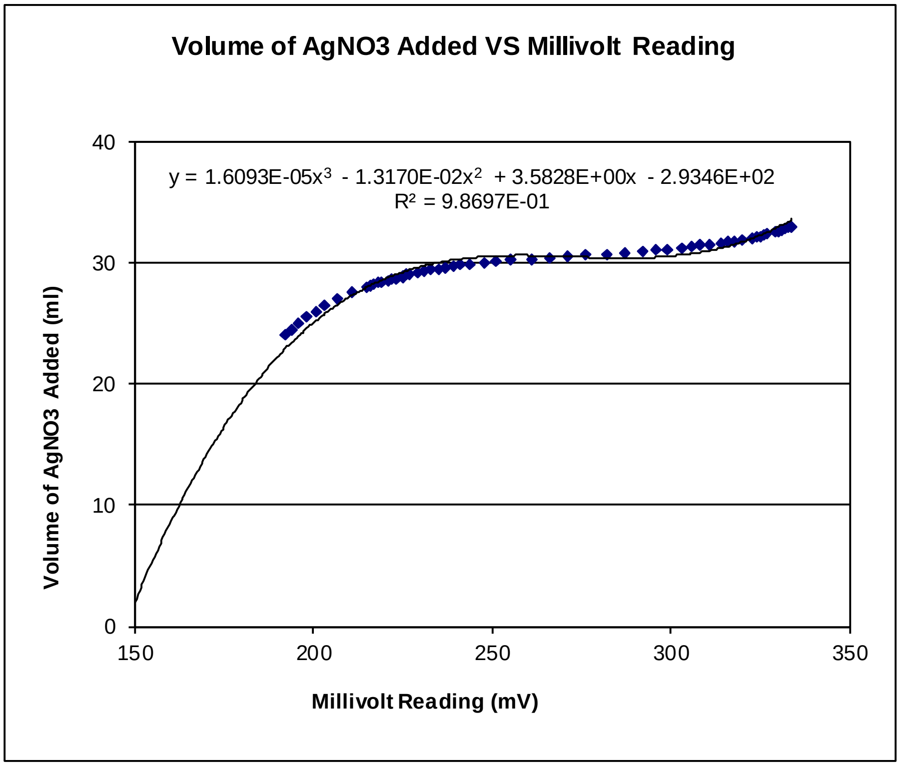
Percent Chloride Ion: 0.0045

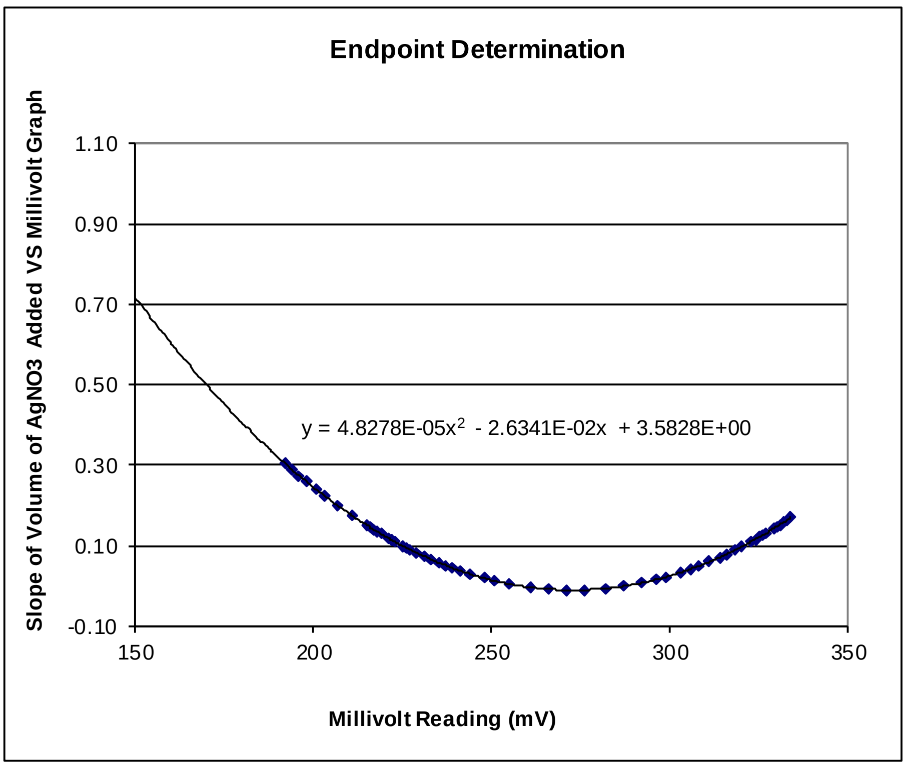
REPORTED BY: Jason Powers, Technician REVIEWED BY: Robert Varner, Engineer

Final Report

AASHTO 260 "Standard Method of Test for Sampling and Testing for Chloride Ion In Concrete

BCD Sample No. 55





mV Value Where Slope = Zero: 272.80 Titration End Point: 30.49

Mass of Concrete Sample (g) 3.0116

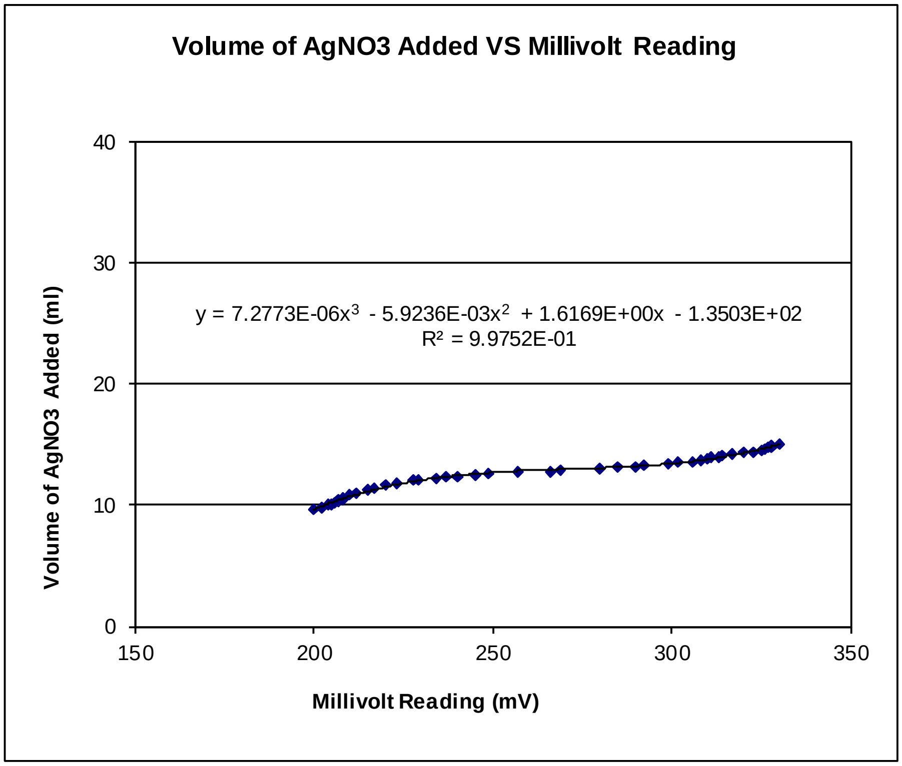
Percent Chloride Ion: 0.3119

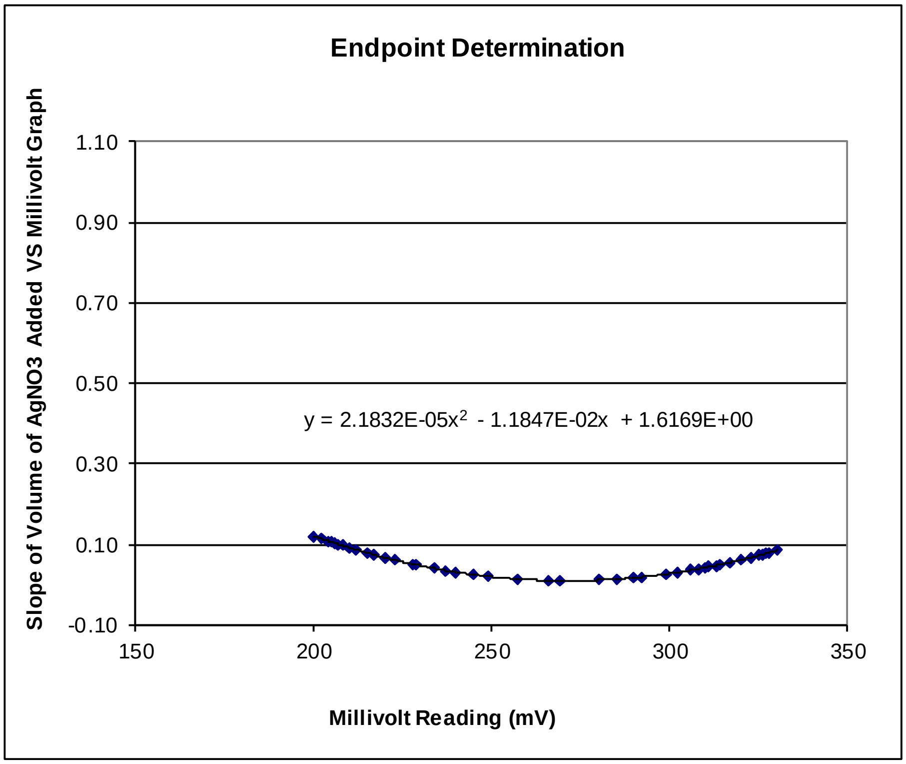
REPORTED BY: Jason Powers, Technician   REVIEWED BY: Robert Varner, Engineer

Final Report

AASHTO 260 "Standard Method of Test for Sampling and Testing for Chloride Ion In Concrete

BCD Sample No. 56





mV Value Where Slope = Zero: 271.30 Titration End Point: 12.97

Mass of Concrete Sample (g) 3.0092

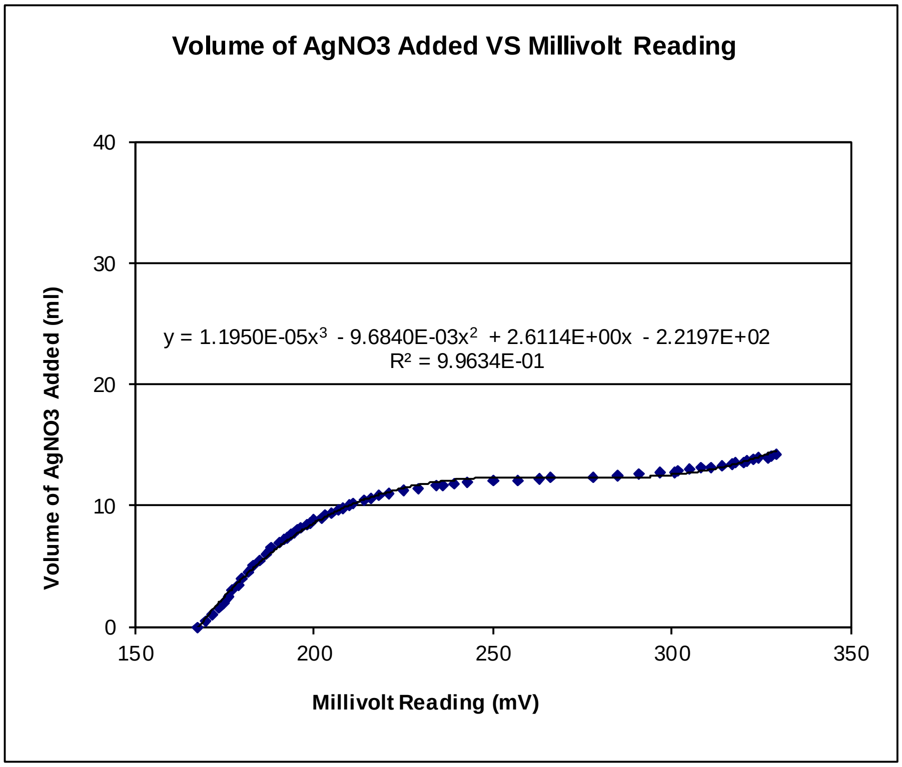
Percent Chloride Ion: 0.1057

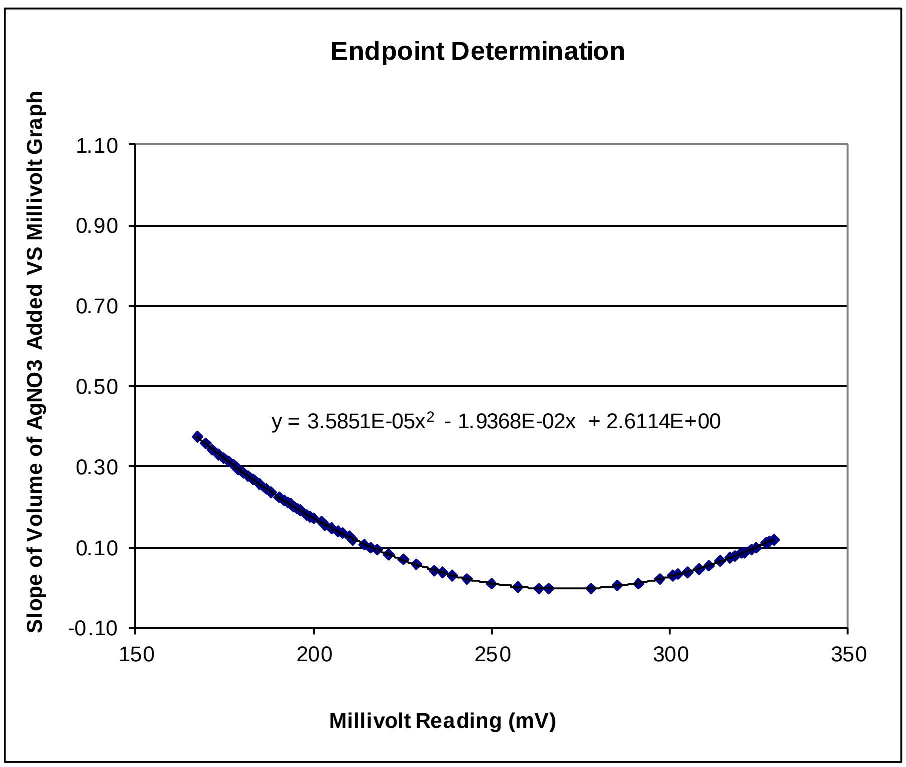
REPORTED BY: Jason Powers, Technician

REVIEWED BY: Robert Varner, Engineer

AASHTO 260 "Standard Method of Test for Sampling and Testing for Chloride Ion In Concrete

BCD Sample No. 57





mV Value Where Slope = Zero: 270.10 Titration End Point: 12.35

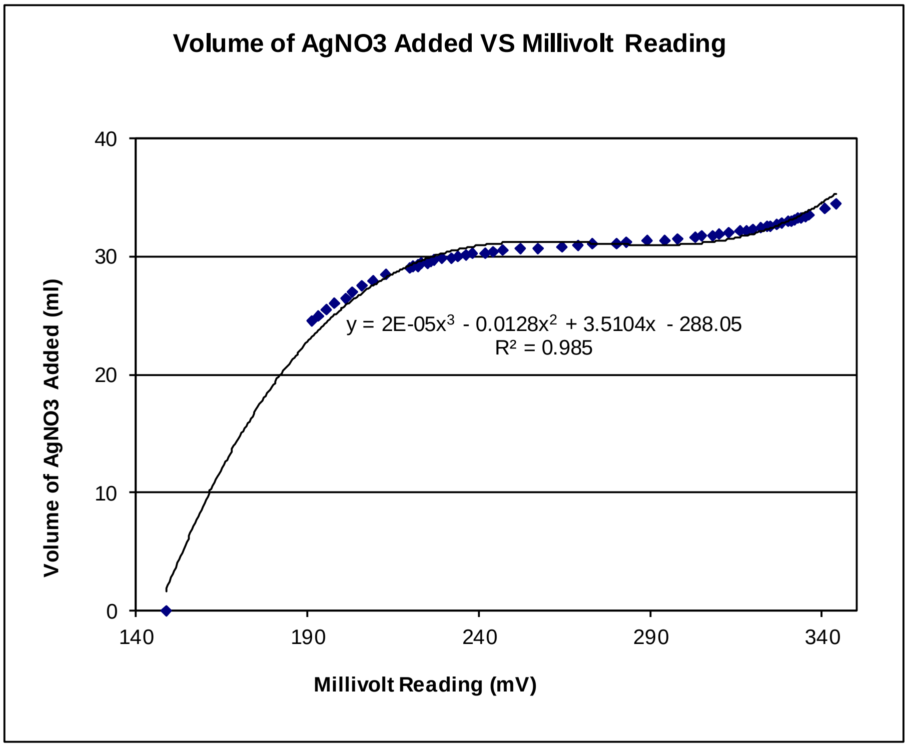
Mass of Concrete Sample (g) 3.0736

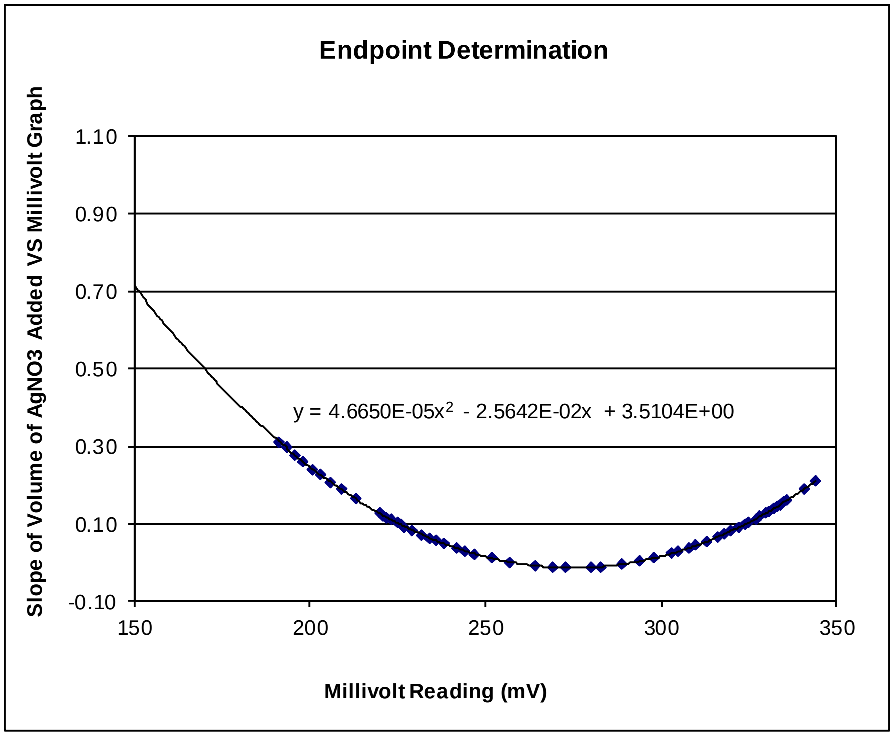
Percent Chloride Ion: 0.0963

REPORTED BY: Jason Powers, Technician REVIEWED BY: Robert Varner, Engineer

AASHTO 260 "Standard Method of Test for Sampling and Testing for Chloride Ion In Concrete Raw Materials

BCD Sample No. 58





mV Value Where Slope = Zero: 274.7 Titration End Point: 31.10

Mass of Concrete Sample (g) 3.086

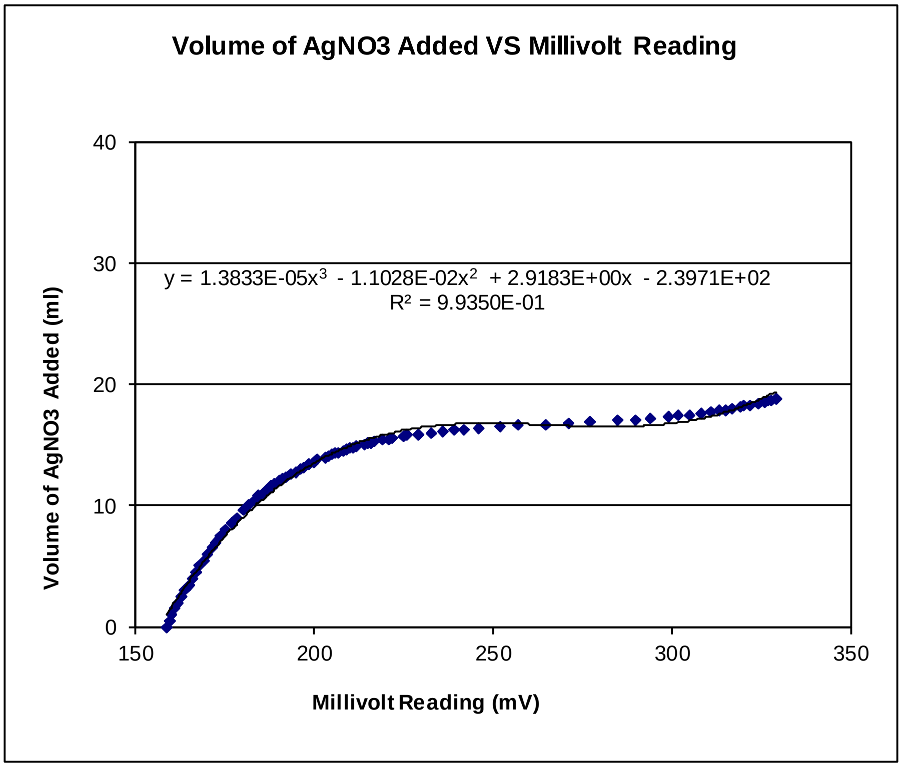
Percent Chloride Ion: 0.3114

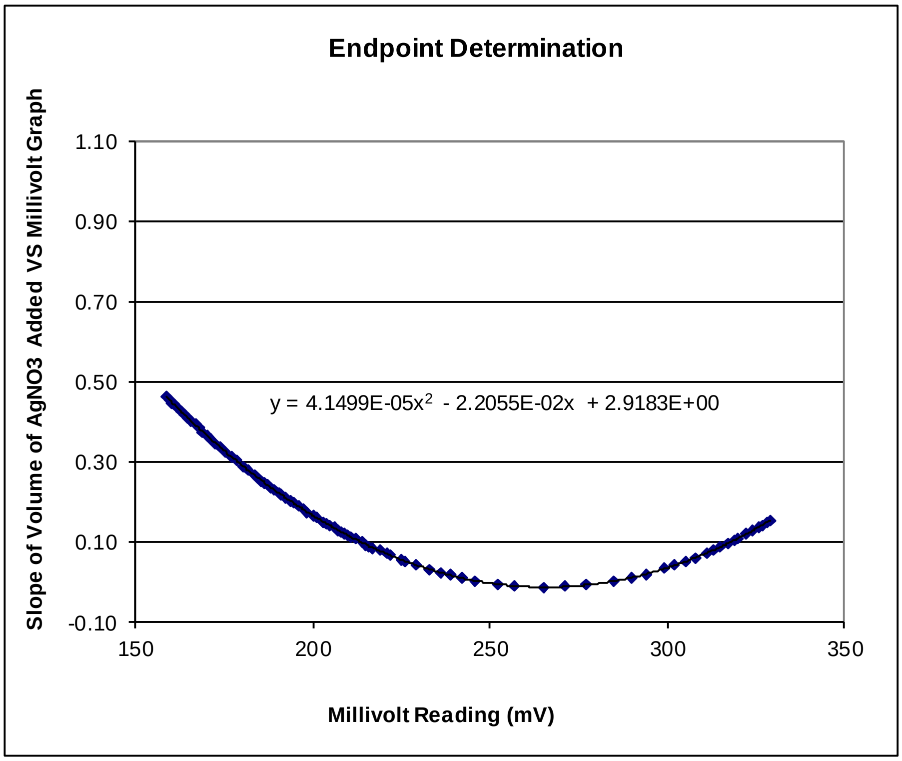
REPORTED BY: Jason Powers, Technician REVIEWED BY: Robert Varner, Engineer

Final Report

AASHTO 260 "Standard Method of Test for Sampling and Testing for Chloride Ion In Concrete

BCD Sample No. 59





mV Value Where Slope = Zero: 265.70 Titration End Point: 16.64

Mass of Concrete Sample (g) 3.6134

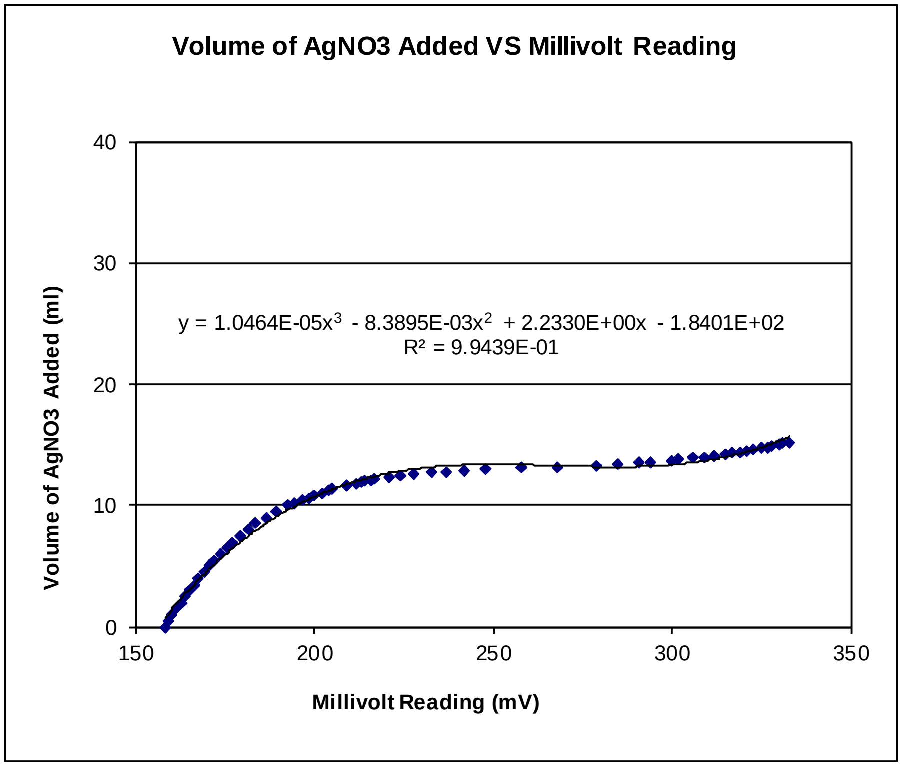
Percent Chloride Ion: 0.1241

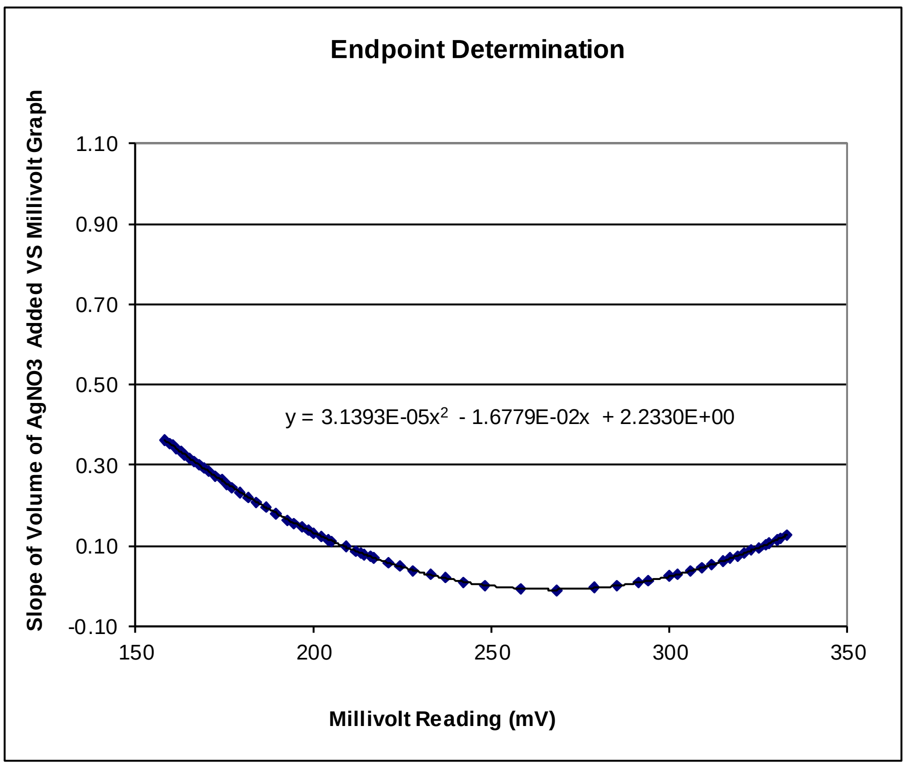
REPORTED BY: Jason Powers, Technician REVIEWED BY: Robert Varner, Engineer

Final Report

AASHTO 260 "Standard Method of Test for Sampling and Testing for Chloride Ion In Concrete

BCD Sample No. 60





mV Value Where Slope = Zero: 267.20 Titration End Point: 13.29

Mass of Concrete Sample (g) 3.044

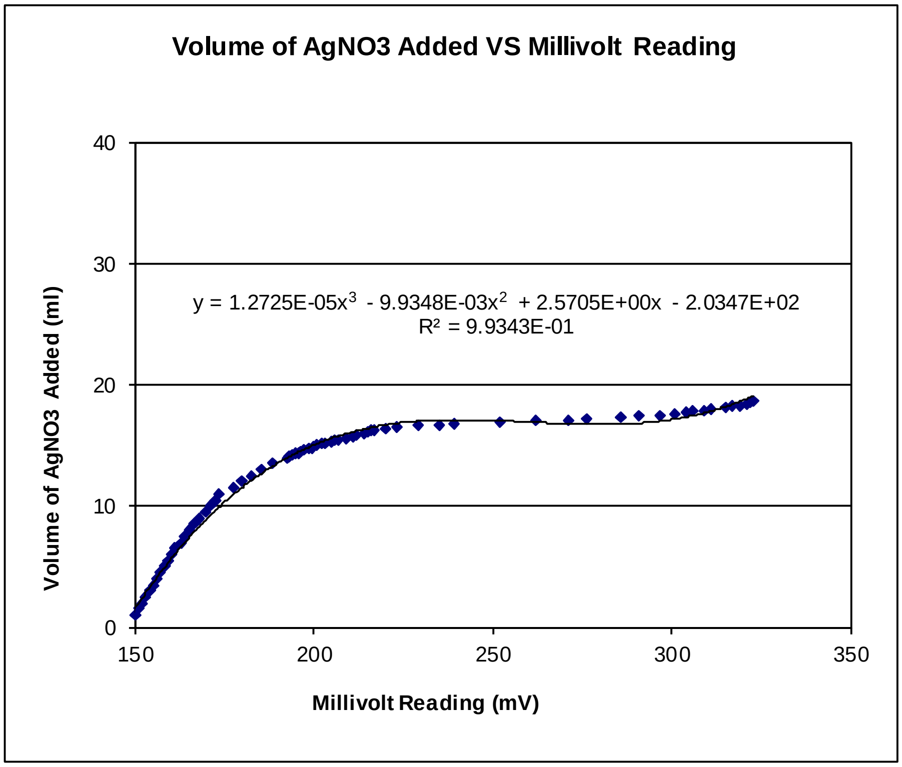
Percent Chloride Ion: 0.1082

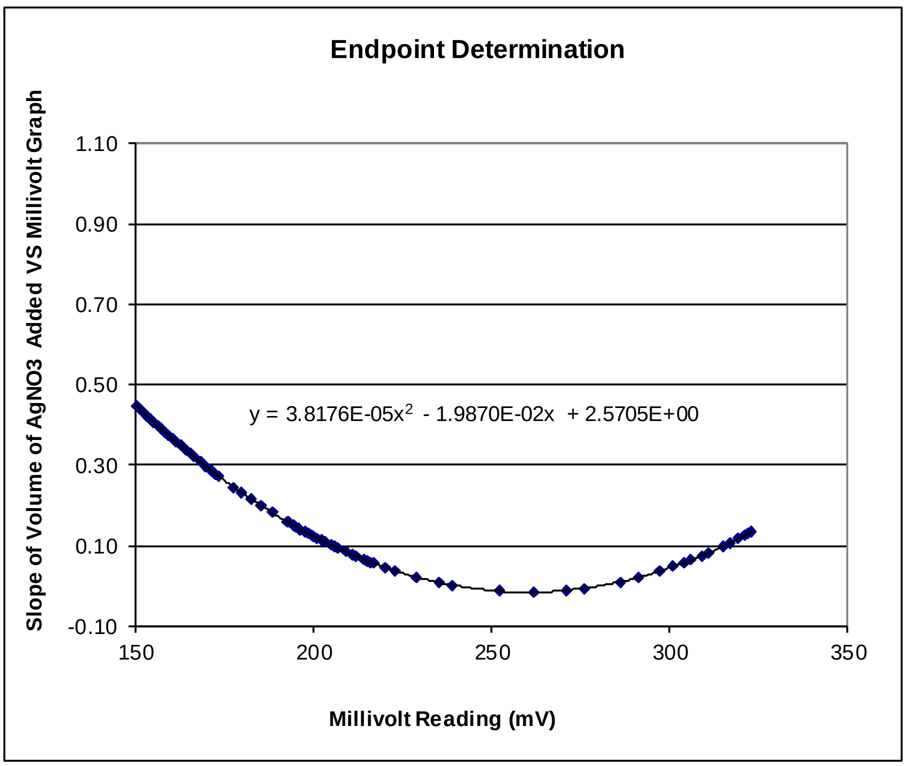
REPORTED BY: Jason Powers, Technician

REVIEWED BY: Robert Varner, Engineer

AASHTO 260 "Standard Method of Test for Sampling and Testing for Chloride Ion In Concrete

BCD Sample No. 61





mV Value Where Slope = Zero: 260.20 Titration End Point: 16.91

Mass of Concrete Sample (g) 3.0163

Percent Chloride Ion: 0.1518

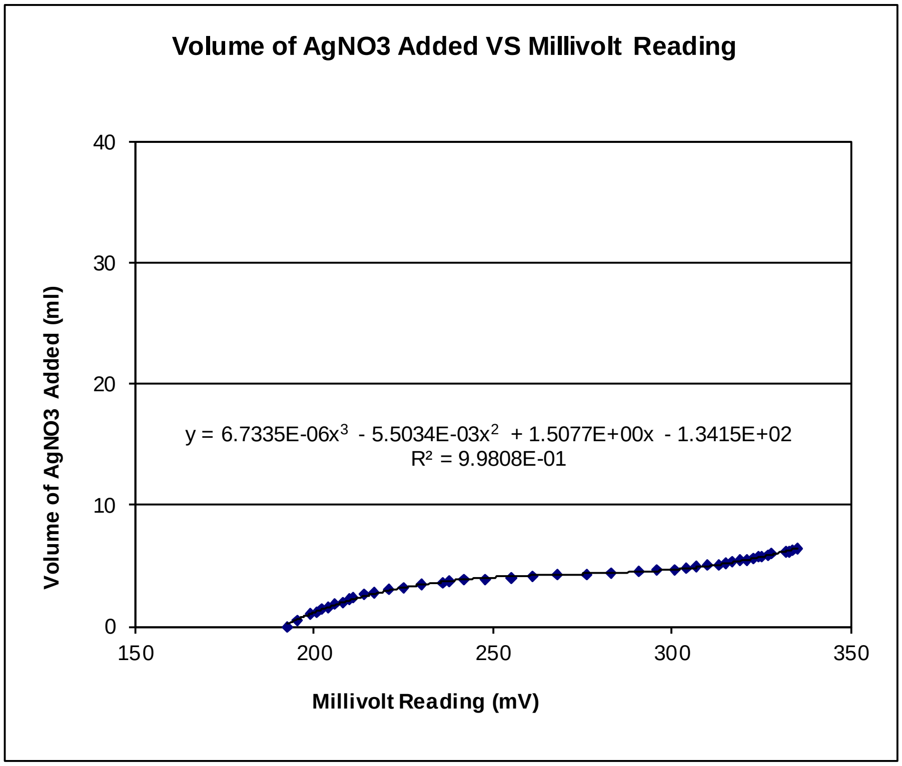
REPORTED BY: Jason Powers, Technician

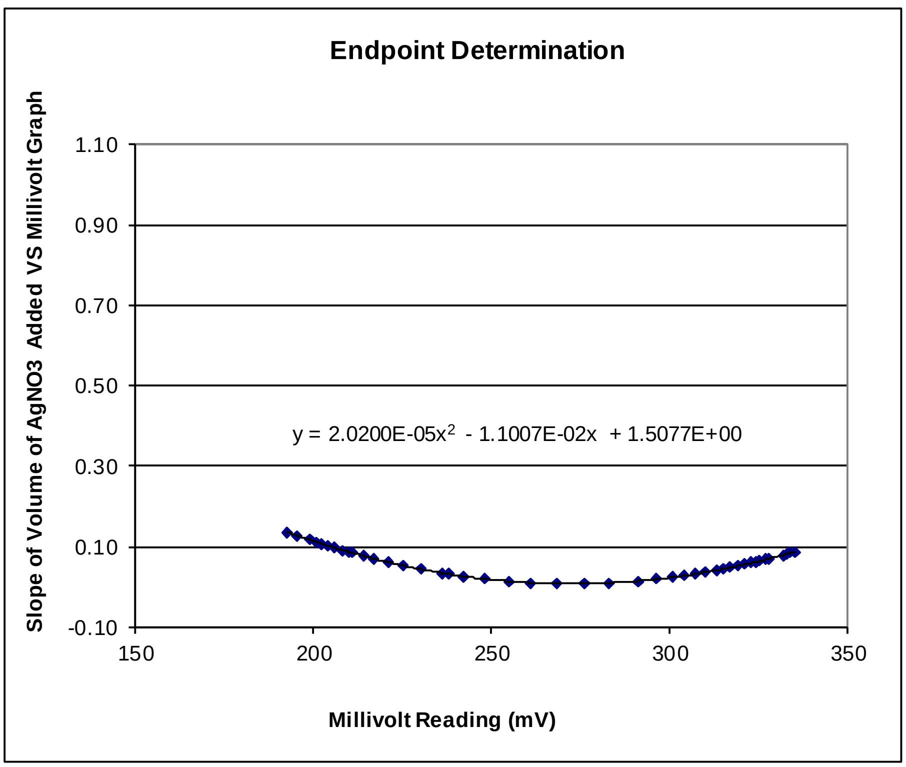
REVIEWED BY: Robert Varner, Engineer

Final Report

AASHTO 260 "Standard Method of Test for Sampling and Testing for Chloride Ion In Concrete

BCD Sample No. 62





mV Value Where Slope = Zero: 272.40 Titration End Point: 4.30

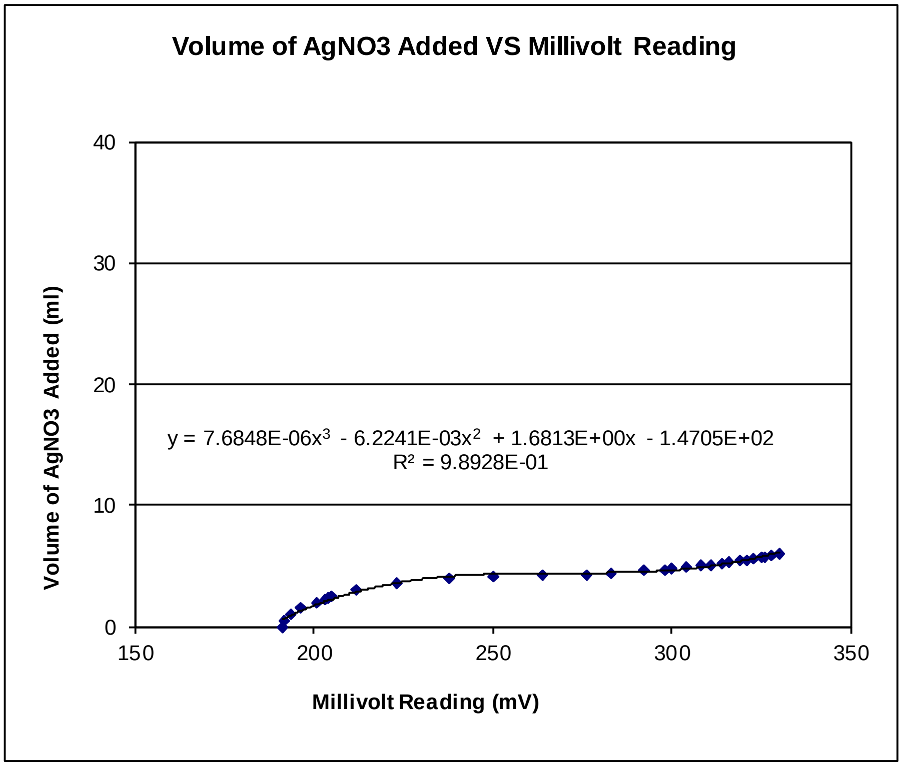
Mass of Concrete Sample (g) 3.0141

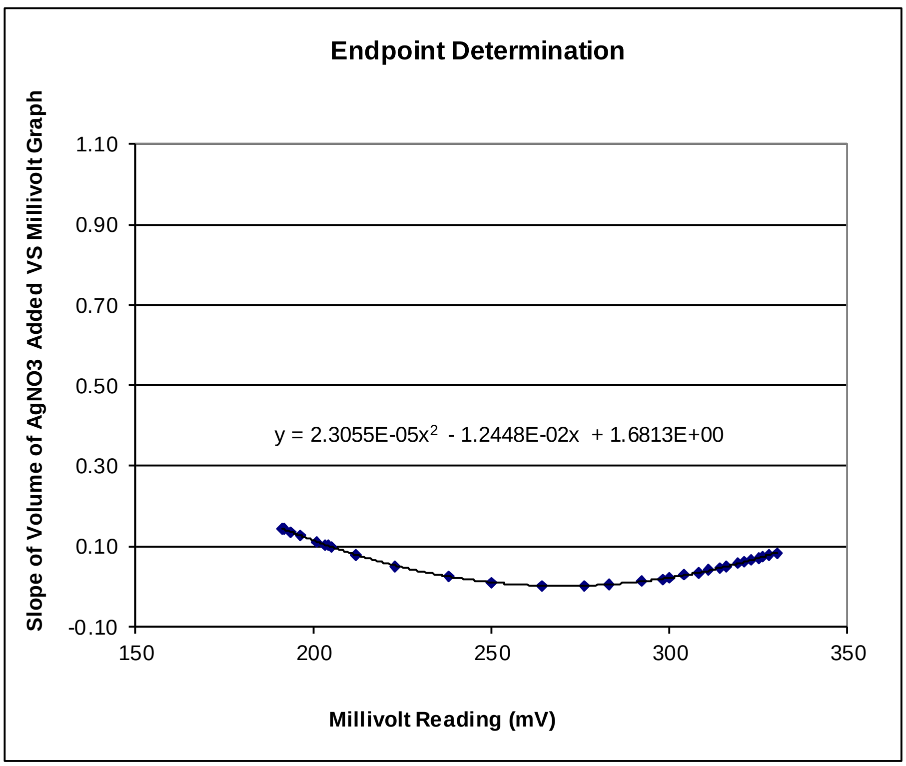
Percent Chloride Ion: 0.0035

REPORTED BY: Jason Powers, Technician REVIEWED BY: Robert Varner, Engineer

AASHTO 260 "Standard Method of Test for Sampling and Testing for Chloride Ion In Concrete

BCD Sample No. 63





mV Value Where Slope = Zero: 270.00 Titration End Point: 4.43

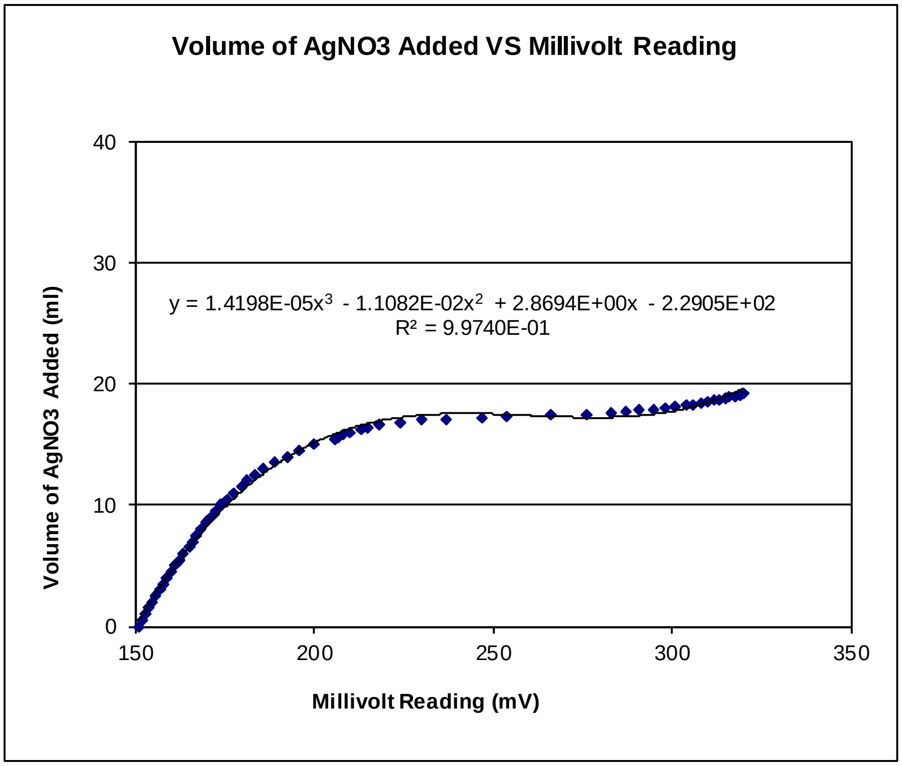
Mass of Concrete Sample (g) 3.186

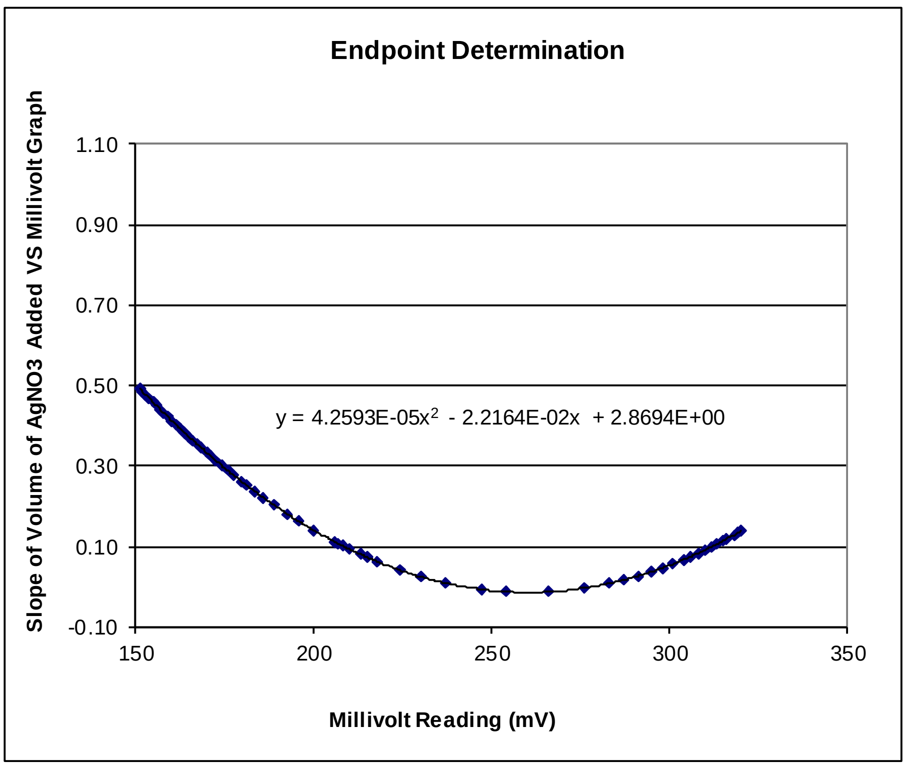
Percent Chloride Ion: 0.0048

REPORTED BY: Jason Powers, Technician REVIEWED BY: Robert Varner, Engineer

AASHTO 260 "Standard Method of Test for Sampling and Testing for Chloride Ion In Concrete

BCD Sample No. 64





mV Value Where Slope = Zero: 260.20 Titration End Point: 17.40

Mass of Concrete Sample (g) 3.0089

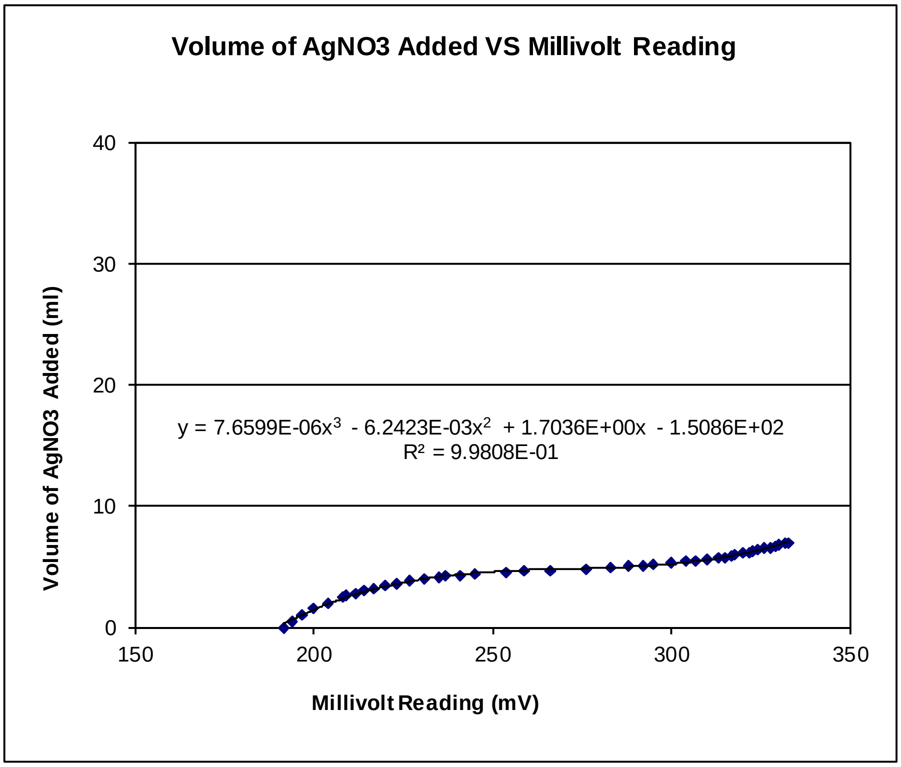
Percent Chloride Ion: 0.1578

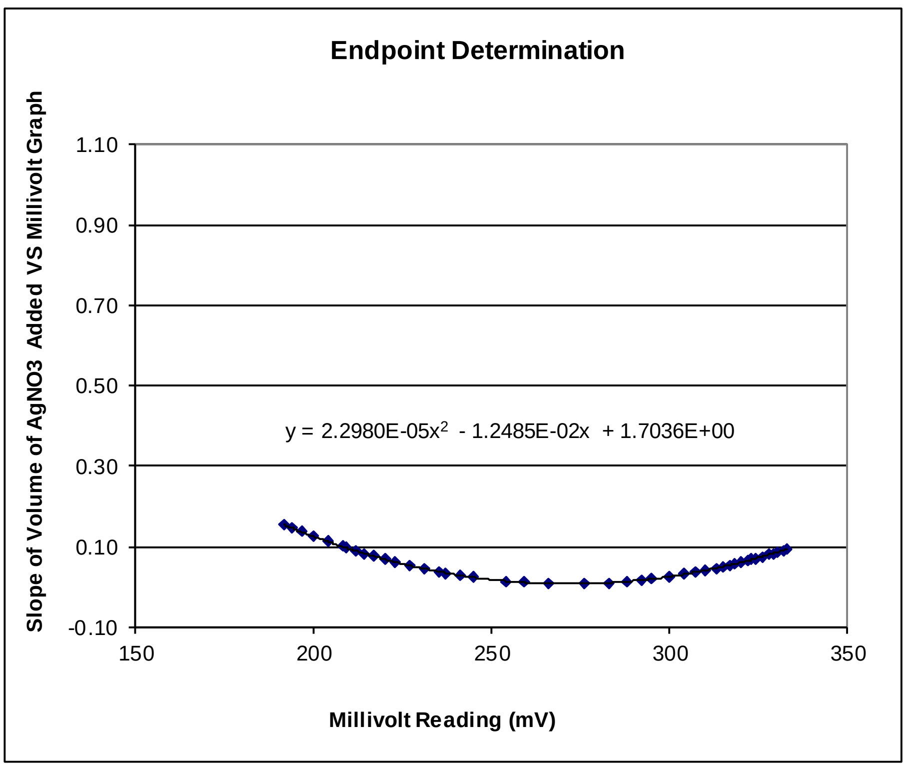
REPORTED BY: Jason Powers, Technician REVIEWED BY: Robert Varner, Engineer

Final Report

AASHTO 260 "Standard Method of Test for Sampling and Testing for Chloride Ion In Concrete

BCD Sample No. 65





mV Value Where Slope = Zero: 271.60 Titration End Point: 4.83

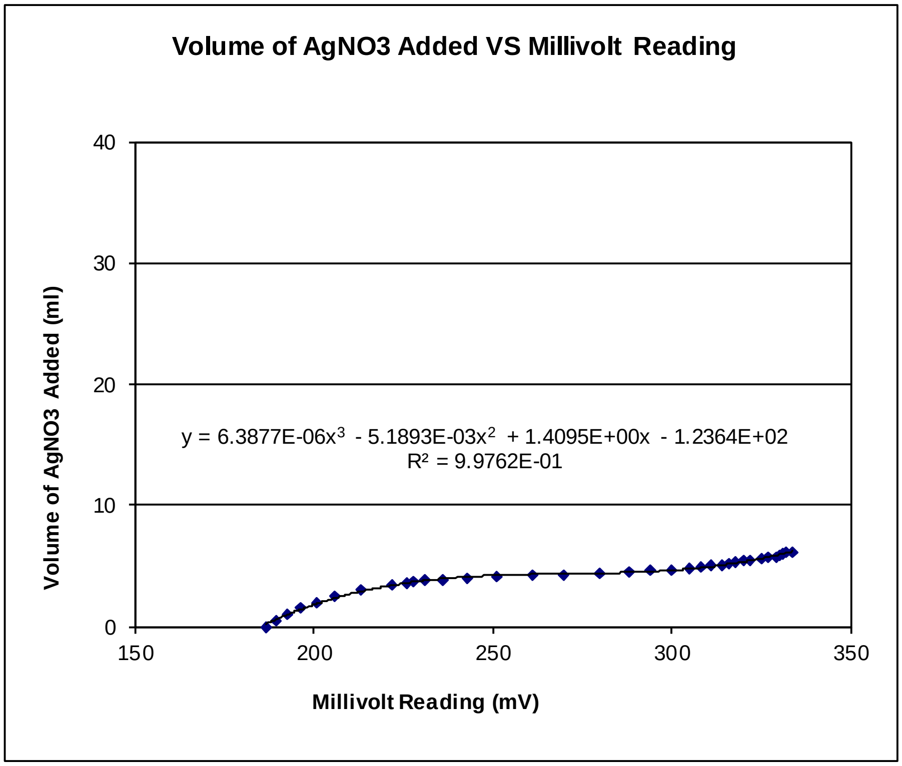
Mass of Concrete Sample (g) 3.0128

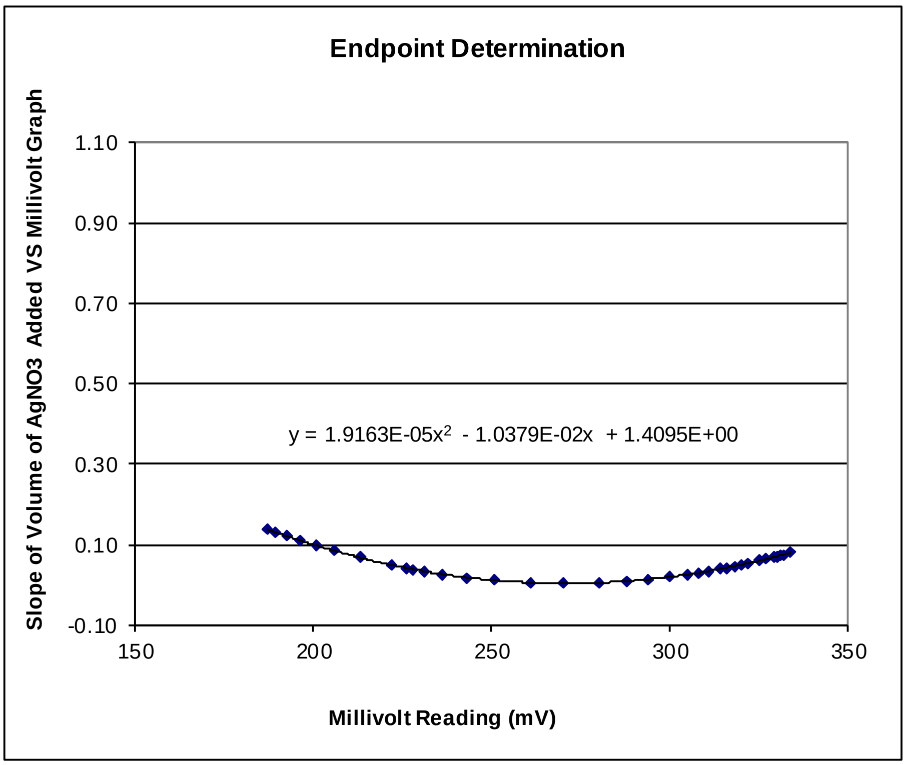
Percent Chloride Ion: 0.0097

REPORTED BY: Jason Powers, Technician REVIEWED BY: Robert Varner, Engineer

AASHTO 260 "Standard Method of Test for Sampling and Testing for Chloride Ion In Concrete

BCD Sample No. 66





mV Value Where Slope = Zero: 270.70 Titration End Point: 4.37

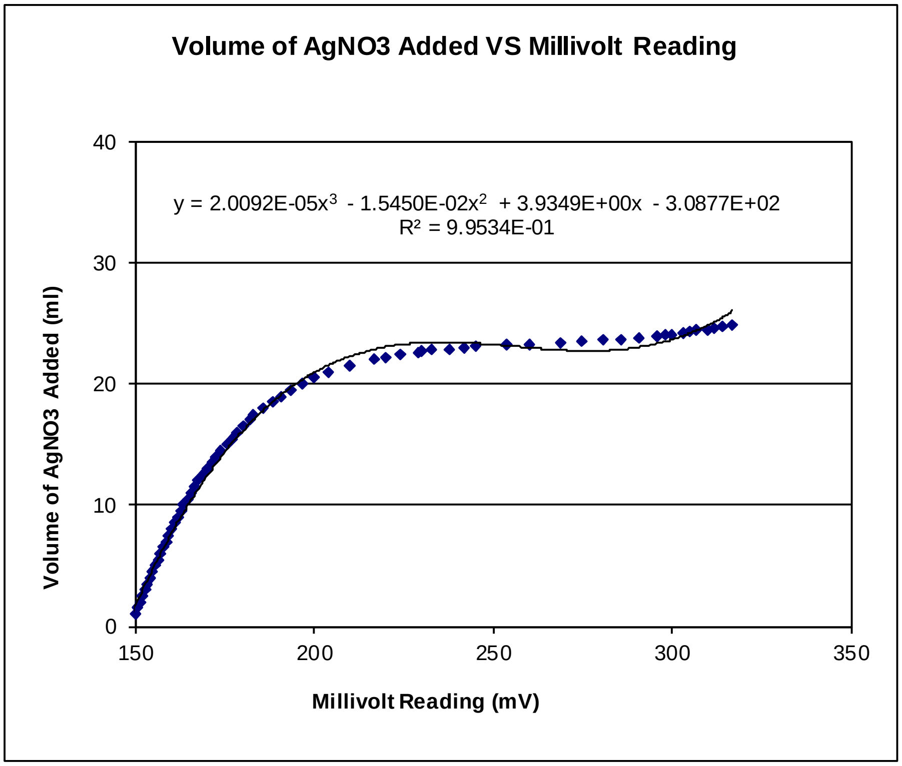
Mass of Concrete Sample (g) 3.0029

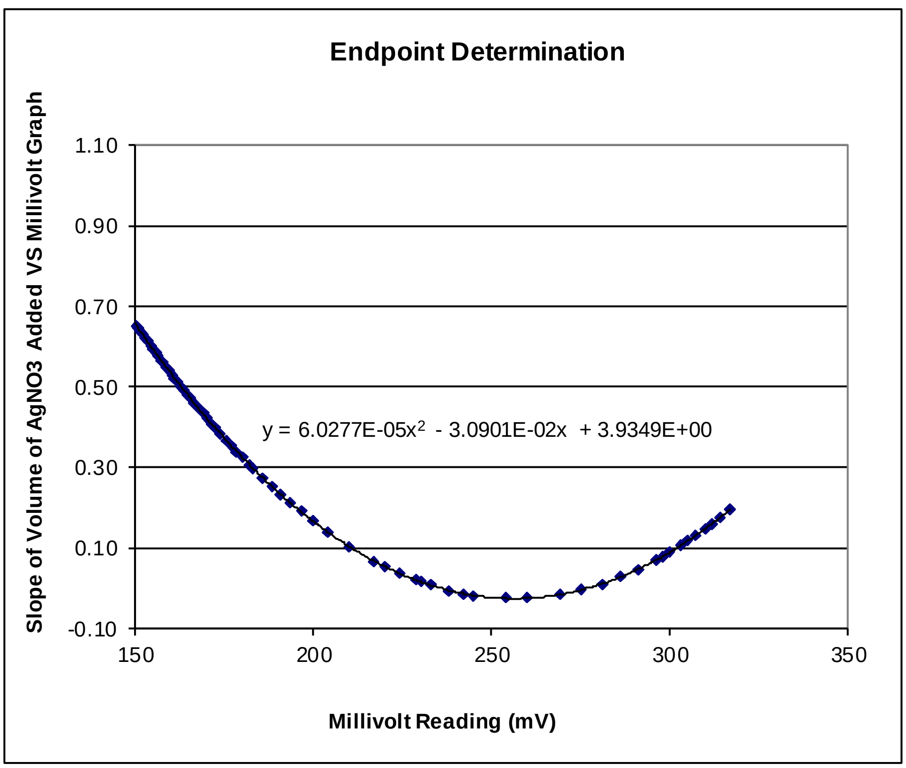
Percent Chloride Ion: 0.0044

REPORTED BY: Jason Powers, Technician REVIEWED BY: Robert Varner, Engineer

AASHTO 260 "Standard Method of Test for Sampling and Testing for Chloride Ion In Concrete

BCD Sample No. 67





mV Value Where Slope = Zero: 256.30 Titration End Point: 23.08

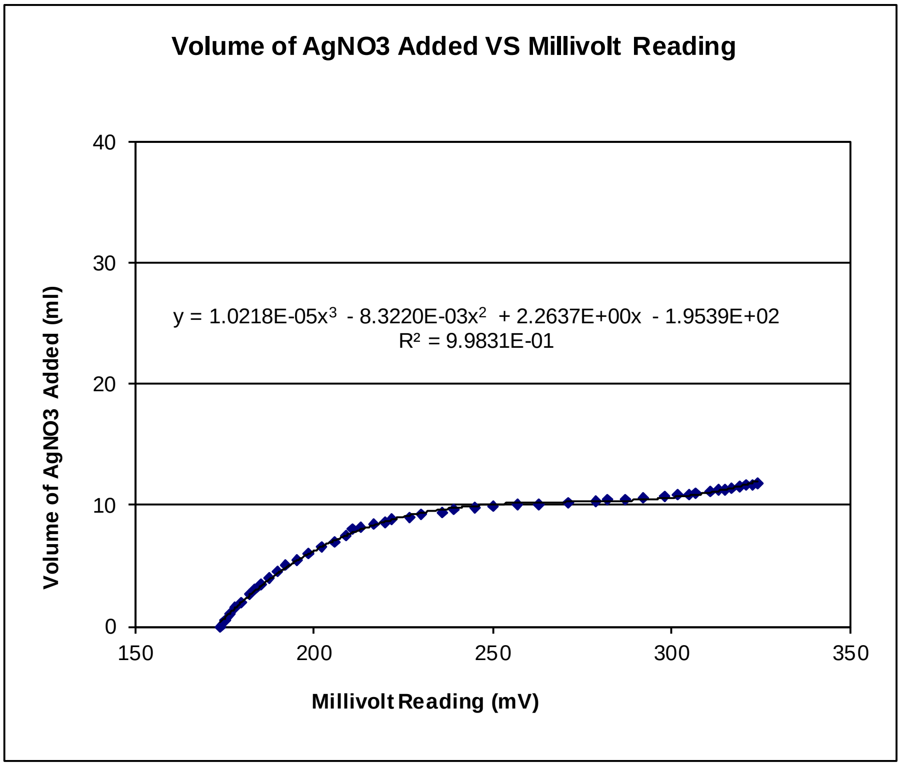
Mass of Concrete Sample (g) 3.0161

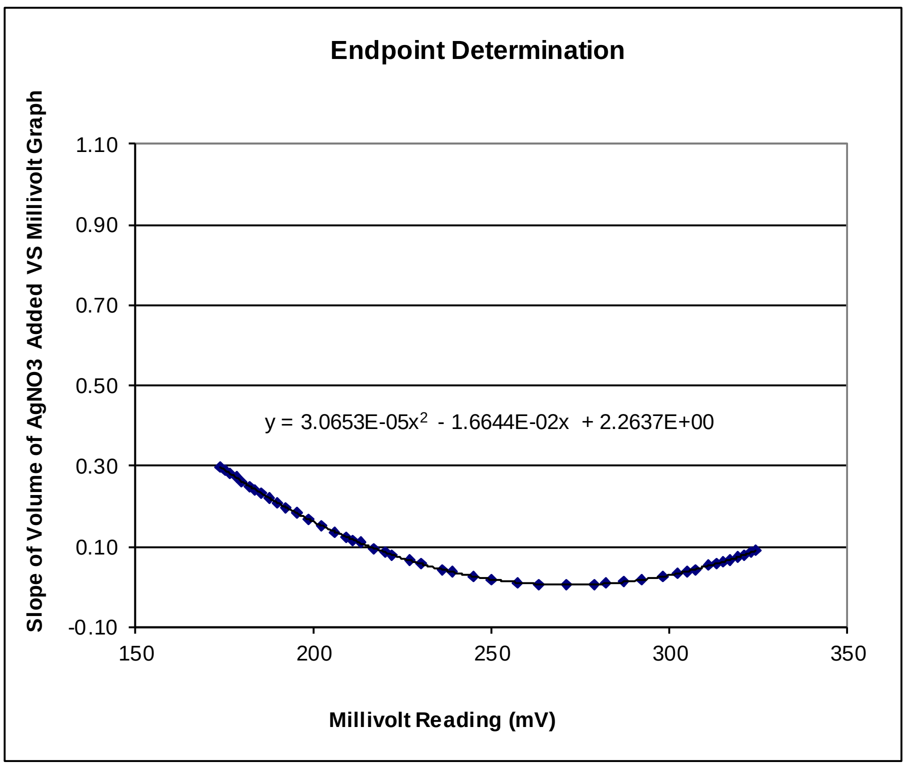
Percent Chloride Ion: 0.2243

REPORTED BY: Jason Powers, Technician REVIEWED BY: Robert Varner, Engineer

AASHTO 260 "Standard Method of Test for Sampling and Testing for Chloride Ion In Concrete

BCD Sample No. 68





mV Value Where Slope = Zero: 271.50 Titration End Point: 10.25

Mass of Concrete Sample (g) 3.0111

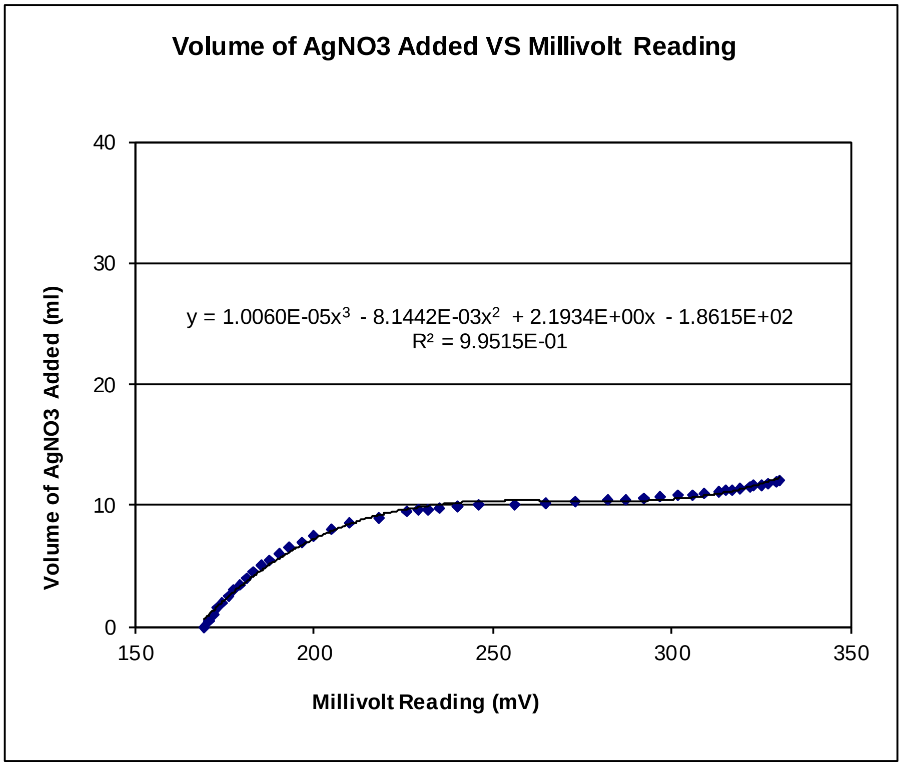
Percent Chloride Ion: 0.0736

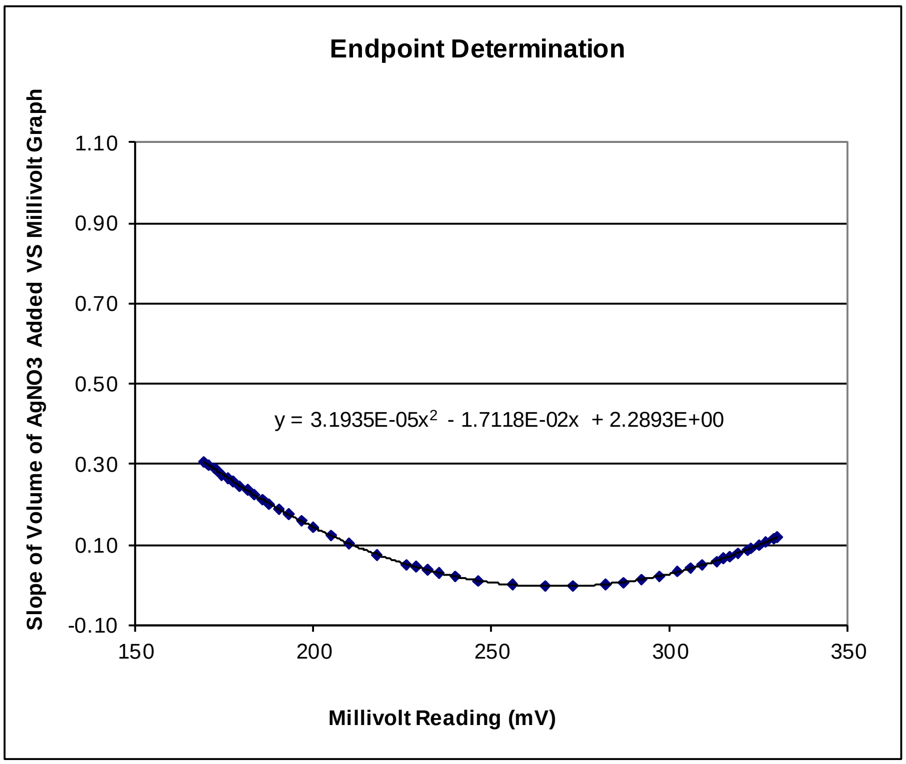
REPORTED BY: Jason Powers, Technician REVIEWED BY: Robert Varner, Engineer

Final Report

AASHTO 260 "Standard Method of Test for Sampling and Testing for Chloride Ion In Concrete

BCD Sample No. 69





mV Value Where Slope = Zero: 268.00 Titration End Point: 10.29

Mass of Concrete Sample (g) 3.0993

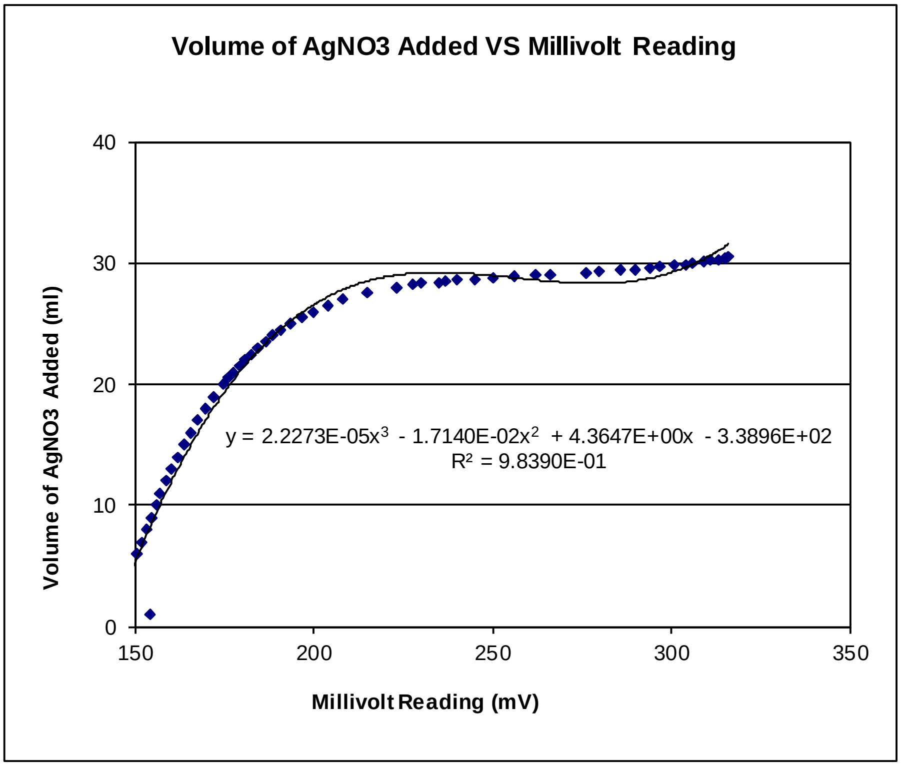
Percent Chloride Ion: 0.0720

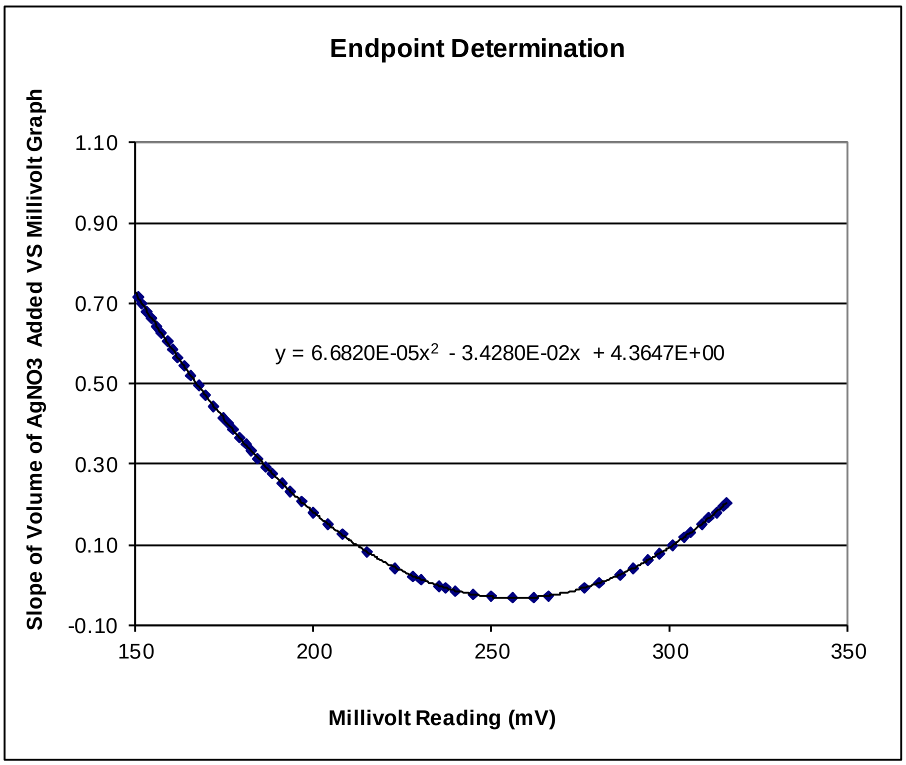
REPORTED BY: Jason Powers, Technician

REVIEWED BY: Robert Varner, Engineer

AASHTO 260 "Standard Method of Test for Sampling and Testing for Chloride Ion In Concrete

BCD Sample No. 70





mV Value Where Slope = Zero: 256.50 Titration End Point: 28.77

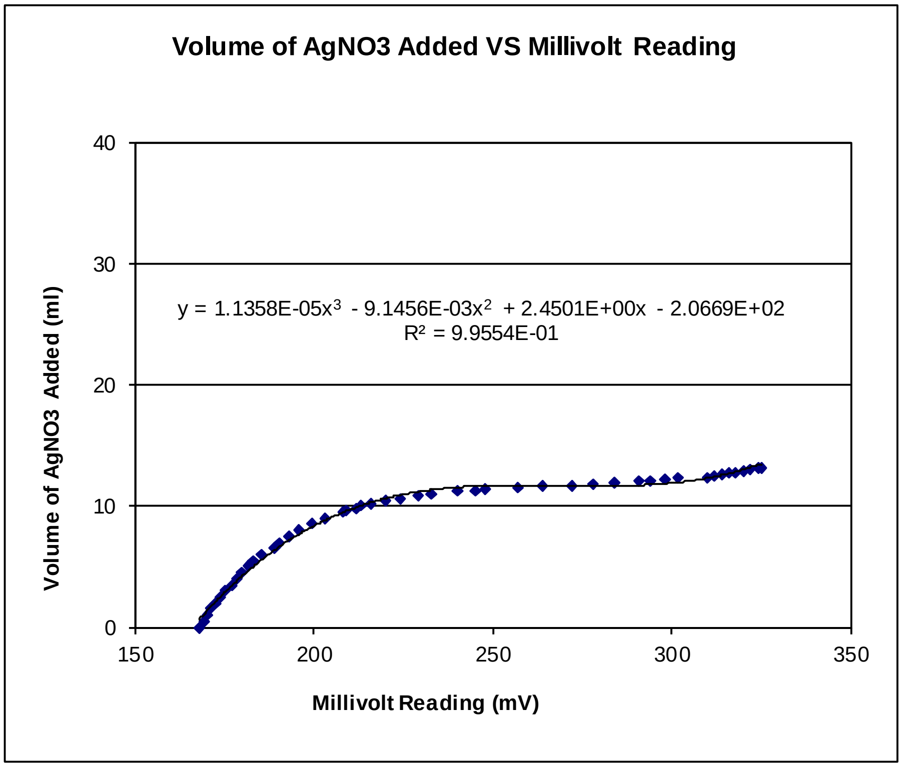
Mass of Concrete Sample (g) 3.0857

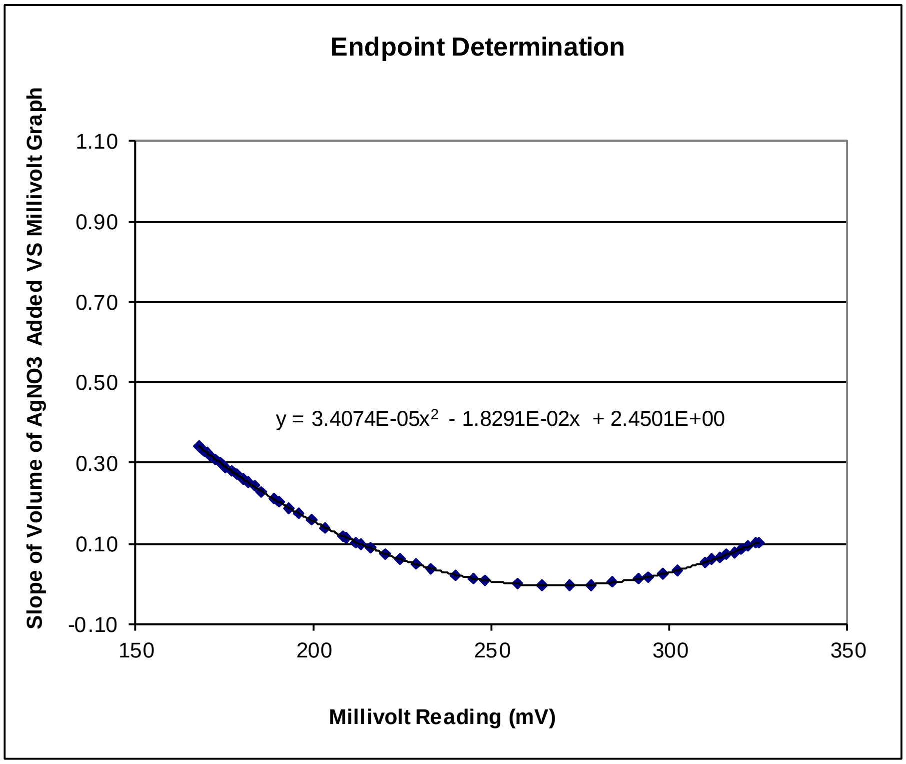
Percent Chloride Ion: 0.2846

REPORTED BY: Jason Powers, Technician REVIEWED BY: Robert Varner, Engineer

AASHTO 260 "Standard Method of Test for Sampling and Testing for Chloride Ion In Concrete

BCD Sample No. 71





mV Value Where Slope = Zero: 268.40 Titration End Point: 11.68

Mass of Concrete Sample (g) 3.005

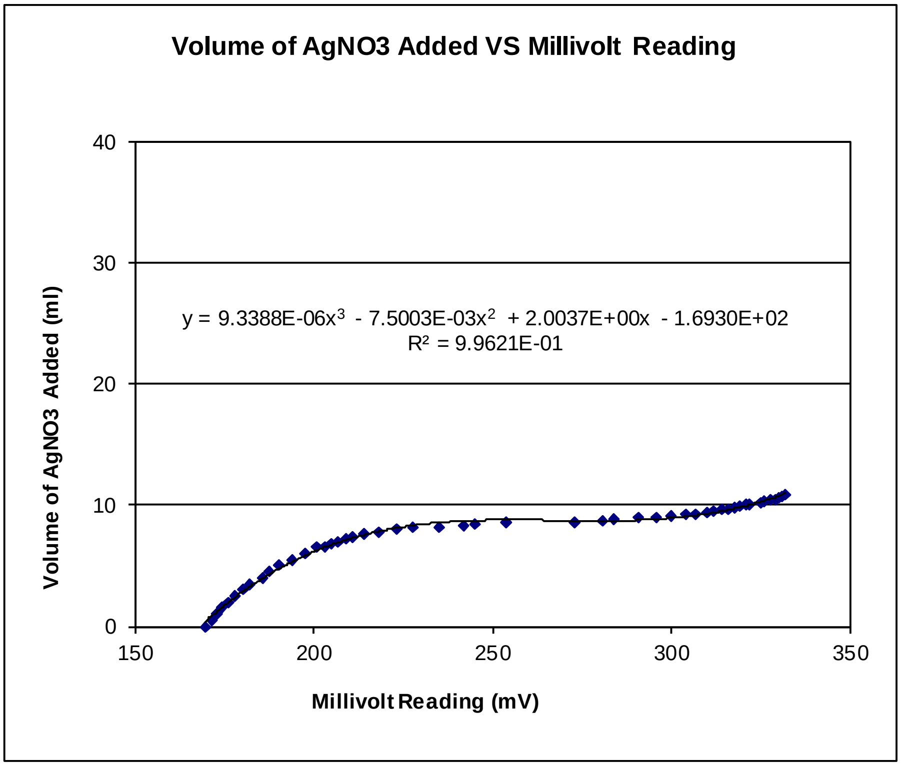
Percent Chloride Ion: 0.0906

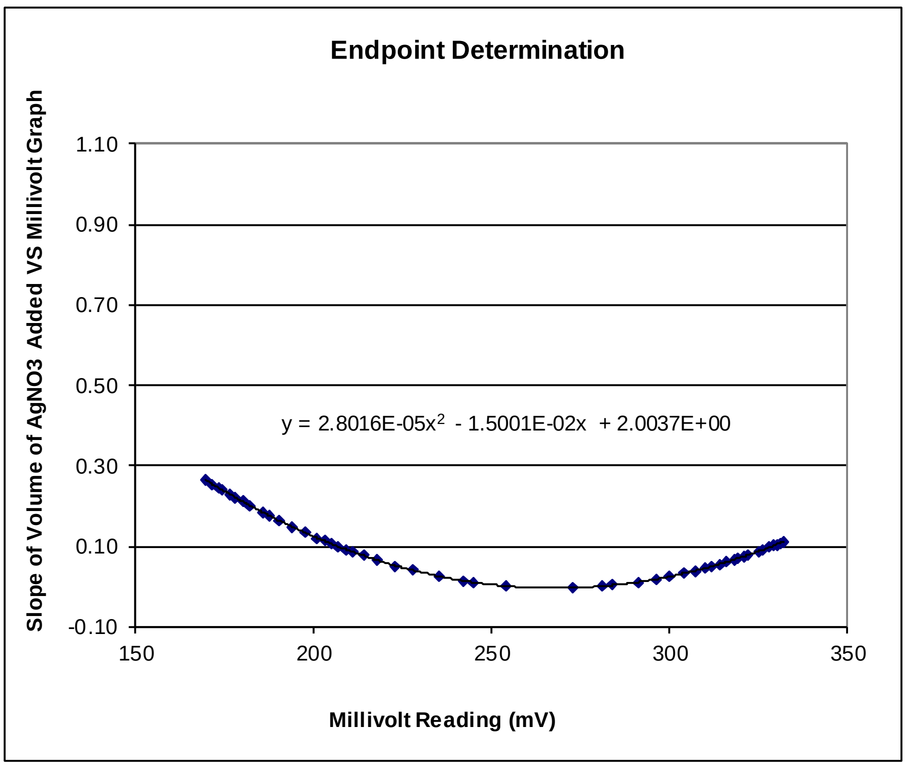
REPORTED BY: Jason Powers, Technician

REVIEWED BY: Robert Varner, Engineer

AASHTO 260 "Standard Method of Test for Sampling and Testing for Chloride Ion In Concrete

BCD Sample No. 72





mV Value Where Slope = Zero: 267.70 Titration End Point: 8.75

Mass of Concrete Sample (g) 3.0218

Percent Chloride Ion: 0.0557

REPORTED BY: Jason Powers, Technician REVIEWED BY: Robert Varner, Engineer