# MECHANICALLY STABILIZED EARTH WALL AGGREGATE SAMPLING AND TESTING PROCEDURES

**Materials and Tests Unit**

**12/18/2023**

**North Carolina**
**Department of Transportation**

## 1. SCOPE

1.1 The purpose of this manual is to provide a uniform procedure for obtaining aggregate samples used as backfill material for mechanically stabilized earth (MSE) walls.

1.2 The manual also describes the tests required on the backfill material.

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## 2. REFERENCED DOCUMENTS

2.1 North Carolina Department of Transportation (NCDOT) *Standard Specifications for Roads and Structures*.

2.2 NCDOT Policy for MSE Retaining Walls

2.3 NCDOT Standard MSE Retaining Walls Provision

2.4 AASHTO/NCDOT M&T Standards:

- Sections 11.10.6.4.2a and 11.10.6.4.2b, AASHTO LRFD Bridge Design Specifications
- T104, AASHTO Standard Method of Test for Soundness of Aggregate by Use of Sodium Sulfate
- T112, AASHTO Standard Method of Test for Clay Lumps and Friable Particles in Aggregate
- T267, AASHTO Standard Method of Test for Determination of Organic Content in Soils by Loss on Ignition
- T288, AASHTO Standard Method of Test for Determining Minimum Laboratory Soil Resistivity
- T289, AASHTO Standard Method of Test for Determining pH of Soil for Use in Corrosion Testing
- NCDOT M&T Chemical Procedure C-Elec, pH *Analysis of Washed Stone Backfill (MSE Wall)*
- T290, AASHTO Standard Method of Test for Determining Water-Soluble Sulfate Ion Content in Soil
- T291, AASHTO Standard Method of Test for Determining Water-Soluble Chloride Ion Content in Soil

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## 3. SAMPLING EQUIPMENT

3.1 Scoop, Shovel, or Tube

3.2 Distilled Water

3.3 5 Gallon Plastic Bag

3.3.1 Use of porous sample bags (cloth or woven plastic) is not allowed.

3.4 Plastic Ties

## 4. SAMPLING

4.1 **Sampling from Approved Sources Covered by QC/QA Program** – Samples shall be obtained by technicians certified as NCDOT Aggregate QC/QA Sampling Technicians or as NCDOT Aggregate QC/QA Sampling and Testing Technicians.

4.2 Physical requirements will be determined based on routine QC/QA sampling performed by the Materials and Tests Unit.

4.3 Chemistry/Electrochemical requirements will be based on samples taken on a wall specific basis. Take chemistry/electrochemical on all MSE walls except those utilizing Non-Coastal Plain Coarse Aggregate with steel reinforcement.

4.3.1 The Materials and Tests Unit's Aggregate QC/QA Engineer shall be notified, by the project and Aggregate Producer, that a sample needs to be obtained from the aggregate source prior to use. The initial sampling for each wall will be performed by the Materials and Tests Unit at the quarry (Appendix A, Example 1).

4.3.2 For walls exceeding 3000 $yd^3$, additional project samples shall be taken by a certified technician (Appendix A, Example 2). Take one sample for every additional 3000 $yd^3$

4.4 Samples for testing of Chemistry/Electrochemical shall adhere to the following:

4.4.1. The method and equipment used to obtain the sample will be the same used for obtaining QC Samples as described in the Aggregate QC/QA Program Manual and the guidelines that follow.

4.4.2 Sample size shall be 10 lbs.

4.4.3 Make sure the large plastic bag is clean and the aggregate is not contaminated. Use of porous sample bags (cloth or woven plastic) is not allowed.

4.4.4 Thoroughly clean and then rinse your scoop, shovel, or tube with distilled water prior to taking the sample.

4.4.5 After taking the sample, ensure that you seal the plastic bag with a plastic tie rap (no metal ties)

4.4.6 The type of reinforcement and connector material (steel or geosynthetic) for the MSE wall shall be stated on the sample card.

4.4.7 Samples shall be submitted to the Central Materials and Tests Laboratory for analysis.

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## 5. GENERAL REQUIREMENTS

5.1 Samples must meet both the chemical and physical requirements before being considered for acceptance.

## 6. CHEMICAL REQUIREMENTS

6.1 The fine aggregate shall conform to the chemical requirements in Tables 1 and 3. Electrochemical testing shown in Table 1 is only required for fine aggregate used with steel reinforcement or connectors.

6.2 The coarse aggregate shall conform to the chemical requirements in Tables 2 and 3. Electrochemical testing shown in Table 2 is only required for Coastal Plain coarse aggregate used with steel reinforcement or connectors.

6.3 pH testing shown in Table 3 is only required for the following three conditions: (1) fine aggregate regardless of reinforcement or connector material; (2) coarse aggregate used with geosynthetic reinforcement or connectors; and (3) Coastal Plain coarse aggregate used with steel reinforcement or connectors.

**Table 1 – Chemical Composition of Fine Aggregate used with Steel Reinforcement or Connectors**

| | Requirement* | | |
|---|---|---|---|
| **Property** | **Min.** | **Max.** | **Test Method** |
| **Resistivity, (Ω·cm)** | 3,000 | -- | AASHTO T288 (tested at 100% saturation) |
| **Chlorides, (ppm)** | -- | 100 | AASHTO T291 |
| **Sulfates, (ppm)** | -- | 200 | AASHTO T290 |

*Based on Section 11.10.6.4.2a of the AASHTO LRFD Bridge Design Specifications

**Table 2 – Chemical Composition of Coastal Plain* Coarse Aggregate used with Steel Reinforcement or Connectors**

| | Requirement | | |
|---|---|---|---|
| **Property** | **Min.** | **Max.** | **Test Method** |
| **Resistivity, (Ω·cm)** | 5,000 | -- | NCDOT Procedure, See Appendix B |
| **Chlorides, (ppm)** | -- | 100 | NCDOT Procedure, See Appendix B |
| **Sulfates, (ppm)** | -- | 200 | NCDOT Procedure, See Appendix B |

*Coastal Plain as defined by Subarticle 1018-2(B)(1) of the NCDOT Standard Specifications

**Table 3 – pH Composition of Aggregate**

| Aggregate Material | Reinforcement or Connector Material | pH Requirement* | | Test Method |
|---|---|---|---|---|
| | | Min. | Max. | |
| **Coarse or Fine** | **Steel** | 5 | 10 | AASHTO T289 (fine), NCDOT Procedure (coarse), See Appendix B |
| **Coarse or Fine** | **Geosynthetic** | 4.5 | 9 | AASHTO T289 (fine), NCDOT Procedure (coarse), See Appendix B |

*Based on the following:

- Section 11.10.6.4.2a of the AASHTO LRFD Bridge Design Specifications for steel reinforcement or connector material
- Section 11.10.6.4.2b of the AASHTO LRFD Bridge Design Specifications for geosynthetic reinforcement or connector material

## 7. PHYSICAL REQUIREMENTS

7.1 The fine aggregate shall conform to the physical requirements in Table 1005-2 and Article 1014-1 of the NCDOT Standard Specifications, as shown in Tables 4 and 5 except fine aggregate is exempt from mortar strength in Subarticle 1014-1(E).

**Table 4 – Fine Aggregate Physical Properties**

| Property | Requirement | Test Method |
|---|---|---|
| | Max. | |
| **Sodium Sulfate Soundness, 5 cycle weighted average loss, (%)** | 15 | AASTHO T104 |
| **Deleterious Substances, (% by weight)** | 2.0 (natural sand)<br>1.0 (manufactured sand) | AASHTO T112 |
| **Organic Impurities, (%)** | 1.0 | AASHTO T267 |

**Table 5 – Fine Aggregate Gradation Requirements**

| Std. Size # or Class/Type | Percentage of Total by Weight Passing | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 3/8” | #4 | #8 | #16 | #30 | #50 | #100 | #200 |
| **1S** | 100 | 90 - 100 | | 40 – 85 | | 0 – 20 | | 0 – 3 |
| **2S** | 100 | 95 – 100 | 80 – 100 | 45 – 95 | 25 – 75 | 5 – 30 | 0 - 10 | 0 - 3 |
| **2MS** | | 95 – 100 | 80 – 100 | 45 - 95 | 25 - 75 | 5 – 35 | 0 -20 | 0 – 8 |
| **4S** | | 100 | 95 - 100 | | | 15 - 45 | 0 - 10 | 0 - 5 |
| **Class III select material, Type 3** | 100 | 95 - 100 | 65 - 100 | 35 - 95 | 15 - 75 | 5 - 35 | 0 - 25 | 0 - 8 |

7.2 The coarse aggregate shall conform to the physical requirements in Table 1005-1 and Article 1014-2 of the NCDOT Standard Specifications for standard size No. 57, 57M, 67 or 78M except No. 57 or 57M stone may not be used in the reinforced zone of MSE walls with geosynthetic reinforcement.

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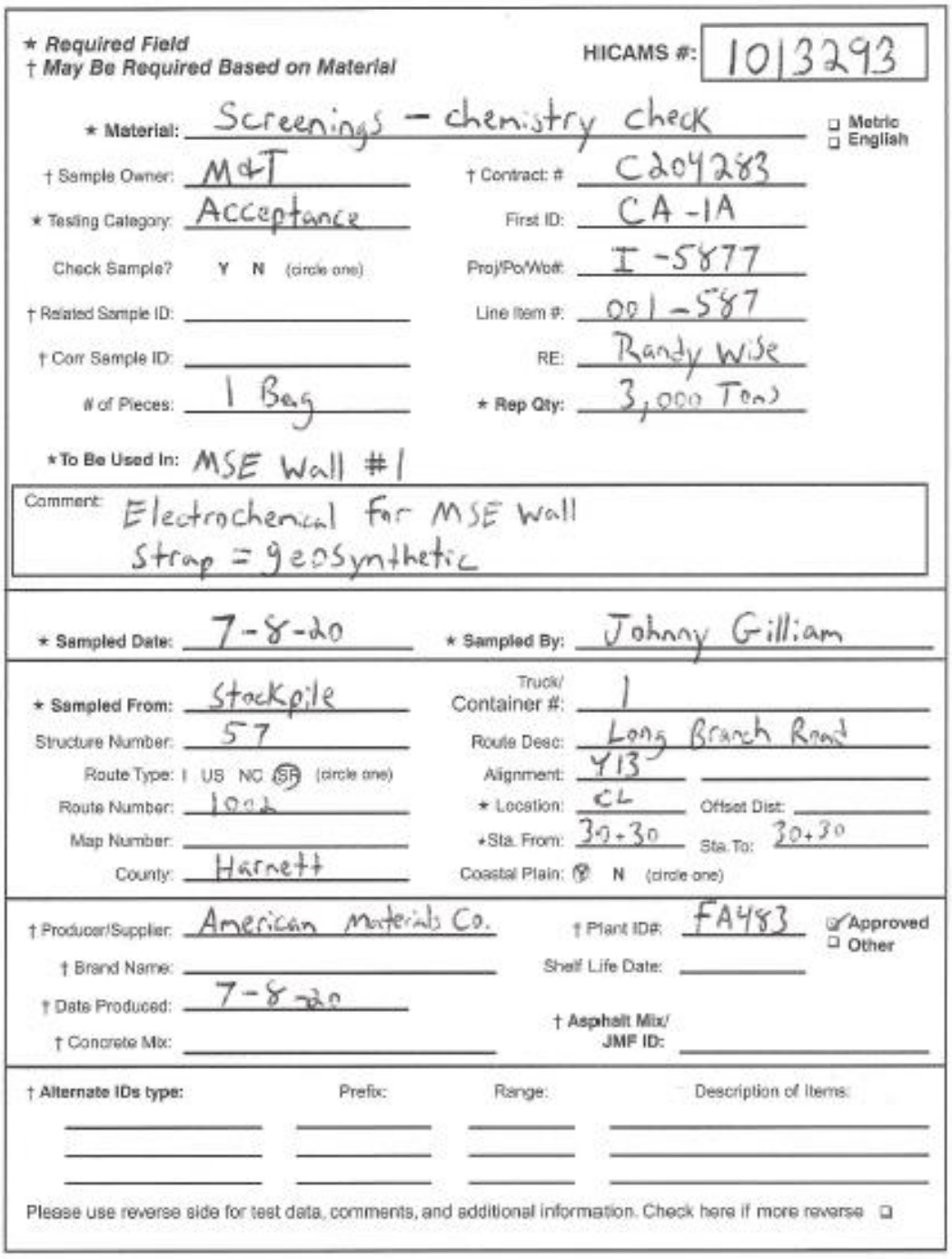
**8. REJECTION**

8.1 Samples not meeting specifications will be subject to possible removal and replacement or a pay reduction in accordance with Article 105-3 of the NCDOT Standard Specifications.

**APPENDIX A**



★ Required Field
† May Be Required Based on Material

HICAMS #: 1013293

★ Material: Screenings – chemistry check ☐ Metric ☐ English

† Sample Owner: M&T
† Contract #: C204283
★ Testing Category: Acceptance
First ID: CA-1A
Check Sample? Y N (circle one)
Proj/Po/Wo#: I-5877
† Related Sample ID:
Line Item #: 001-587
† Corr Sample ID:
RE: Randy Wise
# of Pieces: 1 Bag
★ Rep Qty: 3,000 Tons
★ To Be Used In: MSE Wall #1

Comment: Electrochemical for MSE Wall
Strap = geoSynthetic

★ Sampled Date: 7-8-20
★ Sampled By: Johnny Gilliam

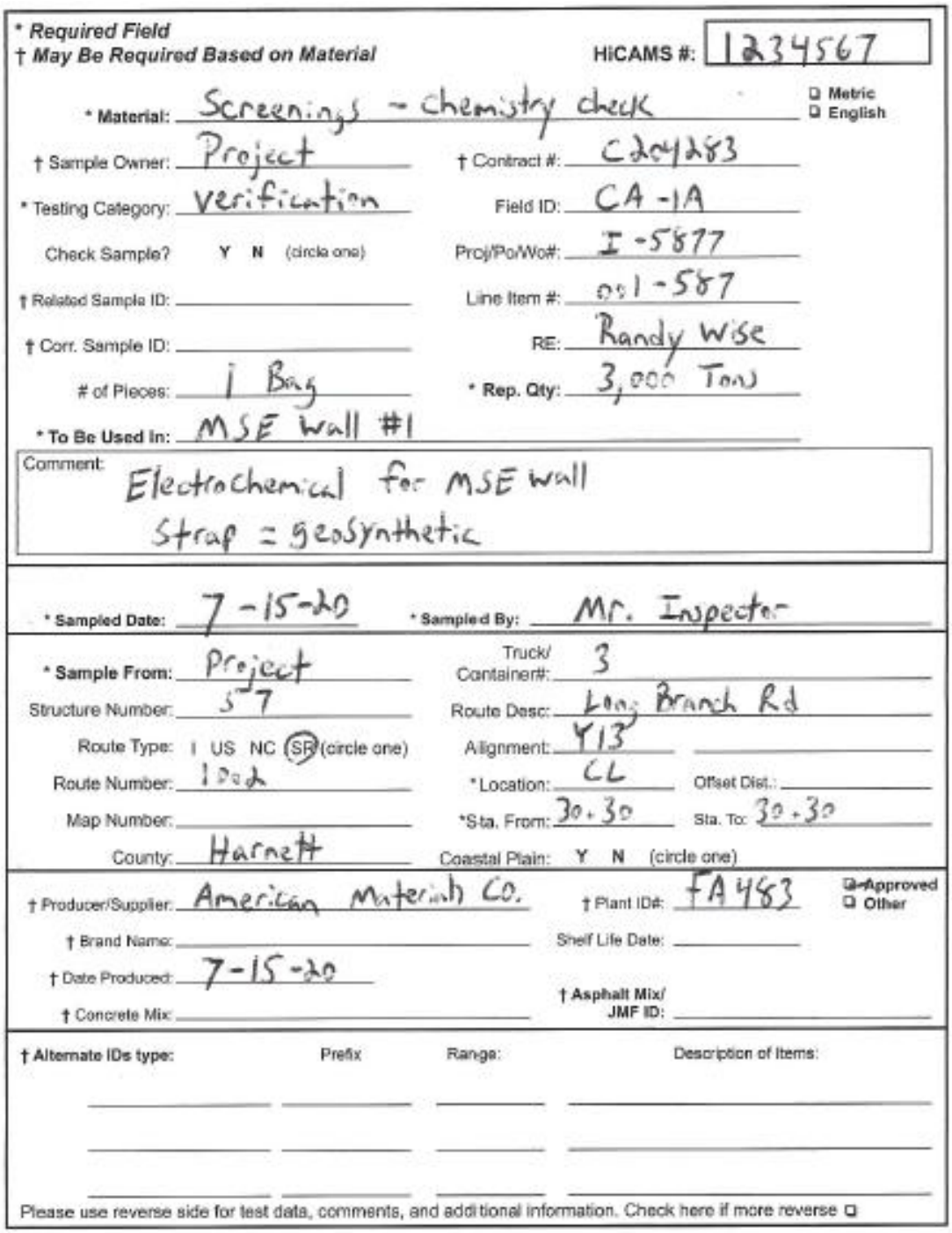
★ Sampled From: Stockpile
Truck/ Container #: 1
Structure Number: 57
Route Desc: Long Branch Road
Route Type: I US NC (SR) (circle one)
Alignment: Y13
Route Number: 1002
★ Location: CL
Offset Dist:
Map Number:
★ Sta. From: 30+30
Sta. To: 30+30
County: Harnett
Coastal Plain: (Y) N (circle one)

† Producer/Supplier: American Materials Co.
† Plant ID#: FA483
☑ Approved ☐ Other
† Brand Name:
Shelf Life Date:
† Date Produced: 7-8-20
† Asphalt Mix/ JMF ID:
† Concrete Mix:

| † Alternate IDs type: | Prefix: | Range: | Description of Items: |
|---|---|---|---|
| | | | |
| | | | |
| | | | |

Please use reverse side for test data, comments, and additional information. Check here if more reverse ☐

**Example 1 -** Initial chemistry/electrochemical sampled by M&T employee at quarry



* Required Field
† May Be Required Based on Material

HiCAMS #: 1234567

* Material: Screenings - chemistry check ☐ Metric ☐ English

† Sample Owner: Project
† Contract #: C204283
* Testing Category: verification
Field ID: CA-1A
Check Sample? Y N (circle one)
Proj/Po/Wo#: I-5877
† Related Sample ID:
Line Item #: 001-587
† Corr. Sample ID:
RE: Randy Wise
# of Pieces: 1 Bag
* Rep. Qty: 3,000 Tons
* To Be Used In: MSE Wall #1

Comment: Electrochemical for MSE wall
Strap = geosynthetic

* Sampled Date: 7-15-20
* Sampled By: Mr. Inspector

* Sample From: Project
Truck/ Container#: 3
Structure Number: S7
Route Desc: Long Branch Rd
Route Type: I US NC (SR) (circle one)
Alignment: Y13
Route Number: 1002
* Location: CL
Offset Dist.:
Map Number:
*Sta. From: 30+30
Sta. To: 30+30
County: Harnett
Coastal Plain: Y N (circle one)

† Producer/Supplier: American Materials Co.
† Plant ID#: FA483
☐ Approved ☐ Other
† Brand Name:
Shelf Life Date:
† Date Produced: 7-15-20
† Concrete Mix:
† Asphalt Mix/ JMF ID:

| † Alternate IDs type: | Prefix | Range: | Description of Items: |
|---|---|---|---|
| | | | |
| | | | |
| | | | |

Please use reverse side for test data, comments, and additional information. Check here if more reverse ☐

**Example 2 -** Additional chemistry/electrochemical sampled by project employee at project

**APPENDIX B**

**North Carolina Department of Transportation**
**Materials and Tests Unit**
**Chemical Laboratory**
1801 Blue Ridge Road
Raleigh, NC 27607
Phone: 919-329-4090

# Electrochemical Testing of Aggregates for MSE Wall Backfill

| |
|---|
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| Author: Ronald Lichtenwalner, Chemist II |
| Document Approver: |
| Version Release Date: |
| Next Review Date: |

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| 1 | 20230801 | Editor/Approver: Ronald Lichtenwalner | |
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** * This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this procedure to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use, which includes disposal of hazardous materials in an appropriate manner.*

## 1. SCOPE

1.1 This test method describes the procedures for testing the electrochemistry of coarse and fine aggregate to be used as backfill for MSE walls.

1.2 Aggregate samples are tested for pH, conductivity/resistivity, chlorides, and sulfates.

1.3 Testing shall be performed at approximately 77°F (room temperature) unless otherwise noted.

1.4 Final test report is submitted to HiCAMS for supervisor approval.

## 2. PURPOSE

2.1 The reinforcement used to provide strength to MSE walls is at risk of corrosion over time. A large component of the corrosion potential are the electrochemical properties of the aggregate used as backfill. Aggregates may leach compounds, such as chloride or sulfate that may specifically corrode steel or provide a generally more conducive environment for corrosion to occur from the leaching of ions into solution. Testing is done to minimize the possibility that an aggregate used on a project will contribute to corrosion and an earlier lifespan of the MSE wall.

## 3. REFERENCED DOCUMENTS

3.1 ASTM Standards

- D1125 – Standard Test Method for Electrical Conductivity and Resistivity of Water
- D1293 – Standard Test Method for pH of Water
- D516 – Standard Test Method for Sulfate Ion in Water

3.2 AASHTO Standards

- T 288 – Determining Minimum Laboratory Soil Resistivity

## 4. TERMINOLOGY

**4.1** **MSE:** Abbreviation for mechanically stabilized earth retaining walls. See Figure 1 for an example of a constructed MSE wall. The aggregate is compacted behind the wall facing to provide structural support and allow drainage. The backfill is further strengthened using reinforcement layers placed throughout the backfill.

**Figure 1: Example of a MSE Wall**

**4.2** **PPE:** Personal Protective Equipment.

**4.3** **pH:** Measure of the acidity or basicity of an aqueous solution.

**4.4** **Resistance:** Measure of the difficulty of passing an electrical current through a solution.

**4.5** **Supernatant:** The liquid laying above the solid residue after settling.

**4.6** **ppm (parts per million):** A measure of concentration. Equivalent to mg/L or µg/mL in most cases.

**4.7** **Filtrate:** The fluid that has passed through a filtration process.

## 5. LIMITATIONS AND SAFETY

5.1 Wear appropriate PPE: Safety Glasses, Lab Coat, and Latex/Nitrile Gloves.

5.2 Watch loose clothing and long hair when the rotary extractor is in operation.

## 6. EQUIPMENT / APPARATUS

6.1 Equipment

- *Balance,* Capable of reading to the nearest 0.1 g and capable of holding 2000 g, balance shall be verified by certified weight prior to use.
- *Lars Lande Rotary Extractor*
- *Conductivity meter*
- *pH Meter*
- *Soil resistivity meter*
- *Soil resistivity box*

6.2 Materials

- *2000 mL graduated cylinder*
- *1-Gallon wide-mouth plastic container with lid*
- *Hach chloride titrator strips (30 – 600 ppm $Cl^-$)*
- *Disposable plastic cups*
- *Metal spatula*
- *Pen and sharpie*
- *Fisher Q8 filter paper*
- *Funnel*
- *Stopwatch/Timer*
- *Aggregate testing book*

## 7. REAGENTS

7.1 Distilled Water

## 8. EXTRACTION PROCEDURE

8.1 Place an empty plastic container on to the balance and tare the balance.

8.2 Measure 2000 g of the material to be tested into the container.

8.3 Measure 2000 mL of distilled water in a graduated cylinder and add the water to the container with the 2000g of sample. Record the time and seal the container with the lid.

8.4 Place the container into the rotary extractor, but do not turn the extractor on until 30 minutes have passed since the water was added. Table 1 provides a quick reference for what steps to perform at the designated times after the water has been added.

**Table 1: Steps to Perform at Designated Times after Water Added**

| **Time** | 30 Minutes | 2 Hours | 4 Hours | 24 Hours |
|---|---|---|---|---|
| **Steps** | 7.5 | 7.5 | 7.5, 7.6 | 7.7 |

8.5 At the 30 minute, 2 hour, and 4 hour times after the water was added, start the extractor and allow the container to rotate for approximately 3 to 5 minutes. While the machine is operating, chain off access to the area to prevent potential injury.

8.6 After the final rotation performed at the 4 hour mark, remove the container from the rotary extractor and allow to sit on the benchtop for 20 hours (For a total of 24 hours since the water was added to the container).

8.7 After the 24 hour mark, use Fisher Q8 filter paper and a funnel to filter 50 to 100 mL of the supernatant water into a clean disposable plastic cup. **Note:** Using a separate 150 mL disposable cup to get the water for filtration is easier than trying to pour from the one-gallon jug.

## 9. ANALYSIS OF FILTRATE

9.1 Measurement of pH and conductivity should be completed within 1 hour of filtering solution in order to reduce the effects of atmospheric $CO_2$ contamination. If the samples are allowed to sit for longer than an hour before testing, the samples can be heated to release $CO_2$ and then promptly tested.

9.2 Measure and record the resistivity of the coarse aggregate filtrate using a conductivity meter that has first been calibrated. After calibration, record the resistivity of each sample in Ω *cm.

9.3 Measure and record the pH of the filtrate using a pH meter that has first been calibrated.

9.4 Measure the chloride ion concentration using a Hach chloride titrator strip. Insert the titrator strip into the water per the directions on the bottle and use the scale on the bottle to record the quantity in ppm.

## 10. DETERMINATION OF FINE AGGREGATE MINIMUM RESISTIVITY

10.1 This procedure follows AASHTO T 288 for determining the minimum soil resistivity and only needs to be performed on fine aggregates to be used with steel reinforcement.

10.2 Follow AASHTO T 288 instructions for drying the sample at temperatures not to exceed 60 °C, sieving the aggregate with the #10 sieve, and then curing approximately 1500 g of the dry sieved aggregate with 150 mL of distilled water.

10.3 Mix the sample thoroughly after the addition of 150 mL of distilled water, cover the sample with a damp cloth and allow the sample to stabilize until equilibrium has been reached or allow to cure a minimum of 12 hours.

10.4 Follow AASHTO T 288 instructions for determining the minimum resistivity, except that water is to be added in 50 mL increments, then compacted and the soil does not need to be removed from the soil resistivity box with each addition of water.

10.5 Continue adding water in 50 mL increments and recording the resistance until the soil reaches full saturation. This will be indicated when water pools on top of the fine aggregate after moderate pressure is applied.

## 11. WDXRF DETERMINATION OF SULFATE AND CHLORIDES

11.1 If levels appear to be elevated or as a secondary confirmation, chloride and sulfate concentration can be estimated by WDXRF analysis.

11.2 For each standard and sample, cut a piece of chromatographic paper into a size where it will fit into the WDXRF sample holder and fully cover the analysis aperture.

11.3 Pipette 300 µL onto a separate cut square of chromatographic paper for each sample and standard.

11.4 Perform a drift of the WDXRF calibration as necessary if the measured value of the standard deviates from the nominal significantly.

11.5 Analyze each sample by WDXRF and report the chloride and sulfate values in ppm.