Detection and Treatment of Organics and Sulfates in Soils

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Specifications updated with language requiring sampling & testing for organics and sulfates

- Item 260 – Lime Treatment (Road – Mixed)
- Item 265 – Fly Ash or Lime-Fly Ash Treatment (Road-Mixed)
- Item 275 – Cement Treatment (Road-Mixed)

2.2 Subgrade. The Engineer will determine the sulfate content in accordance with Tex-145-E and organic content in accordance with Tex-148-E before lime treatment begins.

Tex-145-E, Determining Sulfate Content in Soils – Colorimetric Method

Tex-148-E, Soil Organic Content Using UV-Vis Method (Draft)
4. Construction.

4.1. Preparation of Subgrade or Existing Base for Treatment.

When material is imported from a borrow source, notify the Engineer of the location of the borrow source well in advance to allow time for testing and approval to avoid delay to the project. Stockpile as directed. The Engineer will test the borrow source and determine the sulfate and organic contents. When the borrow source has a sulfate content greater than 3000 ppm or an organic content greater than 1.0%, proceed as directed.
General characteristics of soils with high organic contents

- Visual – dark color (black/brown), dead roots, high PI, high moisture
- Depth of 0-5 feet
- Poorly drained soils
- Climate - organic matter increases as precipitation increases; decreases as temperature increases
- State Soil Geographic database & maps illustrating % organic matter
**Detrimental effects of organic matter**

- Organic acids, specifically humic acid neutralizes calcium based stabilizers making them ineffective.
- Leaching of calcium-based stabilizers.
- Lowers pH impeding chemical reaction for resistance to swelling and moisture susceptibility.
- Strength gain through pozzolanic reaction will be affected.

*Detection Methods for Soils with Organics*
Laboratory test methods to measure the soil organic content

- Loss on Ignition tests (ASTM 2974)
- Tex-408-A, Organic Impurities in Fine Aggregate for Concrete
- Tex-148-E, Soil Organic Content Using UV-Vis Method (Draft - 2014 Specifications)
Detection Methods for Soils with Organics


- Dry combustion technique where soil is heated >750°F
- Easy to perform and inexpensive
- Produces higher percentages of organic matter
- Does not discriminate between organic and inorganic carbon
- Minerals can lose weight at these high temperatures
Detection Methods for Soils with Organics

Tex-408-A, Organic Impurities in Fine Aggregate for Concrete

- Soil sample soaks in a 3% sodium hydroxide solution for 24 hours
- Compare color of the liquid to Glass Color Standard, Organic Color No. 3
- Qualitative test, determines the presence of organic material in soil sample
- Not a quantitative test, does not determine % of soil organic content
Detection Methods for Soils with Organics

Tex-148-F, Soil Organic Content Using UV-VIS Method (Draft - New)

Portable unit manufactured by StellarNet Inc.

Bench top unit manufactured by Perkin Elmer
Detection Methods for Soils with Organics

Tex-148-F, Soil Organic Content Using UV-VIS Method (Draft - New)

Battery operated, can be used in the field or lab

- Halogen light source
- Green wave spectrometer
- Fiber optic cable
- Power regulator
- Battery (not shown)
Detection Methods for Soils with Organics

Tex-148-F, Soil Organic Content Using UV-VIS Method (Draft - New)
Detection Methods for Soils with Organics

Tex-148-F, Soil Organic Content Using UV-VIS Method (Draft - New)

Ultraviolet-Visible Spectroscopy

- Uses light energy and absorbance at a wavelength of 300 nm to measure organic content
- Capable of detecting and measuring the humic acid fraction of organic matter
Detection Methods for Soils with Organics

Tex-148-F, Soil Organic Content Using UV-VIS Method (Draft - New)

- Sample preparation includes use of three different solutions to extract organic matter
- 1 blank standard
- 3 known standards of approximately 0.5, 1.0, and 1.5% organic matter tested
- 3 replicates for each sample tested

Cuvette – Used for testing
Detection Methods for Soils with Organics

Tex-148-F, Soil Organic Content Using UV-VIS Method (Draft - New)

**Advantages**

- Able to detect harmful organic matter, specifically humic acid

**Challenges**

- Requires training and experience to become proficient
- Involved sample preparation procedure
- Sophisticated testing equipment
Treatment of Soils with Organics

- Soils with organic contents at or below 1.0% can be safely treated with standard practices.

- Soils with organic contents above 1.0% are recommended to be treated with a target additive content determined from a mix design.

- Complete a mix design according to the appropriate test method to meet compressive strength requirements:
  - Tex-120-E, Soil-Cement Testing
  - Tex-121-E, Soil-Lime Testing
  - Tex-127-E, Lime Fly-Ash Compressive Strength Test Methods
Treatment of Soils with Organics

- Use Tex-121-E, Part III, *Determining Stabilization Ability of Lime by Soil pH* to determine a target lime content at pH of 12.4

- Recommend a target lime content with a ratio of organic matter % (Tex-148-E, UV-Vis) to lime % (Tex-121-E, Part III) of 0.5 or less
  - Ratio of Organic Matter % / Lime % ≤ 0.5
  - Verify compressive strength

- Calcium chloride (CaCl₂) added to soil with lime improved strength
  - Concluded by research, not validated in field
Detection Methods for Soils with Sulfates

**General characteristics of sulfates**

- Mineral salts containing sulfur
- Sulfate bearing crystals, typically gypsum are diamond-like, soft minerals
- May exist in locations of different climates, soil types, & depth
- May be dispersed or located in veins & seams
- Vary in grain-size
Detection Methods for Soils with Sulfates

Methods to detect sulfates

- **Visual Inspection** – sparkling crystals, noticeable by sight in sunlight
  - Naturally occurring on surface, excavated areas, or natural slopes

- **Field Test** – Conductivity measurements
  - *Tex-146-E, Conductivity Test for Field Detection of Sulfates in Soils*
  - *Veris Soil Mapping System*

- **Field/Lab Test** – *Tex-145-E, Determining Sulfate Content in Soils*

- **Soil survey & geologic maps** – *Potential sources of sulfate minerals*
Tex-146-E, Conductivity Test for Field Detection of Sulfates in Soils

- Screening tool to determine sampling locations for Tex-145-E lab test
- Fast and easy test to perform in the field
- Mix 5 grams of soil to 100 ml of distilled water
- Measure conductivity with pH/conductivity meter
- Test completed in 3 minutes – *No filtering of soil solution required*
Detection Methods for Soils with Sulfates

Veris 3150 Soil Mapping System used to measure soil conductivity

- Screening tool
- Measures within 2’ to 4’ in depth
- May be used during any stage of construction
- Rapid test covering large areas
Detection Methods for Soils with Sulfates

Discs embedded in soil ~1-2 inches
Tex-145-E, Determining Sulfate Content in Soils

- Part I, Field Determination of Sulfates
  - Used for quality control during construction
  - Accurate for concentrations below 7,000 ppm
  - Smaller sample size to process, air dry to constant weight, & less time for filtering soil solution

- Part II, Laboratory Test
  - Pre-design & soil exploration
  - Accurate for concentrations in excess of 7,000 ppm
  - Larger sample size to process (from Shelby tube or bagged sample), oven dry to constant weight, filtering soil solution for a minimum of 12 hours
Detection Methods for Soils with Sulfates

Tex-145-E, Determining Sulfate Content in Soils

- **Parts I & II**
  - Uses turbidimetric technique – measures the cloudiness of a liquid and translates it into a concentration
  - Sample is tested using a colorimeter
  - Sulfate test tablets are used to react with sulfates to cause cloudiness or turbidity
  - Soil pulverized to pass the No. 40 sieve
  - Distilled water added to soil and solution is filtered
  - Sulfate tablet is added to filtrate and crushed until dissolved
Detection Methods for Soils with Sulfates

Tex-145-E, Determining Sulfate Content in Soils

- Colorimeter
- Sulfate Test Tablets
- Glass Sample Vial
- Filtered Soil/Distilled Water Solution
- Filtered Solution w/Sulfate Tablet
Detrimental effects of sulfates

- Sulfate-induced heave from formation of \textit{ettringite} using calcium-based stabilizer
- Highly expansive mineral that can expand twice its original size
- May occur during construction or anytime during in service
Moderately to Highly Expansive Soils (PI > 15)

- Level 1 – Sulfate Concentration ≤ 3,000 ppm
- Level 2 – Sulfate Concentration between 3,000 and 7,000 ppm
- Level 3 – Sulfate Concentration > 7,000 ppm

Smooth Ride Quality & Good Performance
Level 1 – Sulfate Concentration $\leq 3,000$ ppm

- Low potential for sulfate-induced heave
- Standard construction and mix design practices as specified in applicable specification items
Level 2 – Sulfate Concentration Between 3,000 and 7,000 ppm

- Moderate to high risk

- Emphasis on mix design & construction techniques

- Mix Design
  
  ✓ Use Tex-121-E, Soil-Lime Testing to determine optimum lime content using soil with the most representative sulfate concentration

  ✓ Estimate the amount of mellowing time and moisture content using Tex-145-E, Part II Determining Sulfate Content in Soils (colorimeter)

  ✓ Mix multiple samples at different moisture contents above optimum moisture and test them daily until sulfate level falls below 3,000 ppm
Level 2 – Sulfate Concentration Between 3,000 and 7,000 ppm

- Construction Techniques
  - Apply total lime content in one application
  - Thorough mixing is critical for complete and rapid reaction to occur between soil, sulfates, and water
  - Use mixers with in-line water application or lime in slurry form to achieve thorough mixing
  - Light compaction to seal soil-lime mixture for mellowing
  - Use estimated mellowing time and moisture content from mix design
Treatment of Soils with Sulfates

Level 2 – Sulfate Concentration Between 3,000 and 7,000 ppm

- Construction Techniques Cont’d

- Mellowing is a period of time for lime to react with clay particles and sulfates to form ettringite

- Lime treated soil remains uncompacted during this time

- Maintain in a continuously moisture condition by sprinkling to prevent excessive evaporation
2014 Specifications, Item 260 Lime Treatment (Road-Mixed)

Section 4.4 Mixing

When the material to be treated has a sulfate content greater than 3000 ppm but ≤ 7000 ppm, *mellow for a minimum of 7 days*. Maintain in a continuously moist condition by sprinkling in accordance with Item 204, “Sprinkling”, as approved.

When sulfates are not a concern, mellowing is 1 – 4 days.
Level 3 – Sulfate Concentration > 7,000 ppm

- High risk for lime treatment
- Remove and replace sulfate-rich soil with select fill
- Blend soil with non-plastic granular material, sand or aggregate to lower plasticity, swell, and potential vertical rise (PVR)
- No treatment is necessary if PVR is 1 inch or less and strength meets specification requirements
- Alternative additives, ground granulated blast furnace slag and lime/fly ash blends may also be used
Paris District, US 82–Lime/fly ash blend mitigation schedule for sulfate-rich soil

<table>
<thead>
<tr>
<th>Day</th>
<th>Mitigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Lime Treatment (6%) &amp; Light Compaction</td>
</tr>
<tr>
<td>2-3</td>
<td>Mellowing Period</td>
</tr>
<tr>
<td>4</td>
<td>Recut &amp; Light Compaction</td>
</tr>
<tr>
<td>5</td>
<td>Mellowing Period</td>
</tr>
<tr>
<td>6</td>
<td>Recut &amp; Light Compaction</td>
</tr>
<tr>
<td>7</td>
<td>Mellowing Period</td>
</tr>
<tr>
<td>8</td>
<td>Fly Ash (Cl F) Treatment (3%) &amp; Light Compaction</td>
</tr>
<tr>
<td>9</td>
<td>Mellowing Period</td>
</tr>
<tr>
<td>10</td>
<td>Remix and Final Compaction</td>
</tr>
</tbody>
</table>
Treatment of Soils with Sulfates

- Moisture content 29-36%
- PI 45-57
- Sulfates 8,440 - 27,440 ppm
Treatment of Soils with Sulfates

*Extensive laboratory testing & evaluation*

- Tex-121-E, Part III – 6.3% lime content to achieve pH of 12.4
- Samples rewetted and reworked every other day, sulfates reduced to less than 3,000 ppm after 8 days
- 3% fly ash added
- 3D Swell measurements after 25 days less than 6% (PVR less than 1 inch)
- Unconfined compressive strength before & after 10-day capillary moisture
- Indirect tensile strength before & after 4-hour soak
Treatment of Soils with Sulfates

3D Swell Test & Measurements

- Samples molded with a Superpave Gyratory Compactor (4” x 4-1/2”)
- 28 day moisture conditioning
- Weight, volume, and length measured daily
Treatment of Soils with Sulfates

3D Swell Measurements

Weight measurement

Volume measurement

Length measurement
Treatment of Soils with Sulfates

Typical swell behavior

Swell %

Heaving Time

Shrink %

3-Day Drying

Swell Potential

Time
Detection and Treatment of Organics and Sulfates in Soils

Questions or Comments?