Crystal Size Varies

Gypsum on US 82, Grayson County
Covered

- Determination of the Potential for Sulfate Issues
- Detecting Sulfates
- Design / Construction Procedures to Reduce Risk
- Key Points

Not Covered

- TXDOT General Soil Stabilization Methods & Criteria (Non-High Sulfates)
- All soil stabilization methods that may be used to treat High Sulfate Soils
Sulfate Heave

Lime/Cement/Fly Ash
   \textbf{(Calcium, high pH)}
   +

Clay minerals
   \textbf{(Alumina, at high pH)}
   +

Sulfate minerals
   \textbf{(Sulfur)}
   +

Water (H$_2$O)

=Ettringite \textbf{(C-A-S-H, Calcium-Aluminate-Sulfate-Hydrate)}
Texas Counties with Problematic Sulfate Concentrations

Paris District
Veins of hydrated calcium sulfates

Sediments with basaltic composition

"Sheepbed rock"
- Web Soil Survey
  (Natural Resources Conservation Service)
- Geologic Atlas of Texas: Sulfate Bearing Soil Minerals
- TXDOT Guidelines for Treatment of Sulfate-Rich Soils & Bases in Pavement Structures
  *(Linked within TXDOT Pavement Design Guide)*
- Sulfate Heave Research Publications (RTI, TTI, CTR, etc.)
- Project Site Visit: Visual Analysis and Soil Testing
ONLINE SOIL DATA

Search
Area of Interest
Import AOI

Quick Navigation
Address
State and County
Soil Survey Area
Latitude and Longitude
PLSS (Section, Township, Range)
Bureau of Land Management
Department of Defense
Forest Service
National Park Service
Hydrologic Unit

Area of Interest Interactive Map
View Extent: Contiguous U.S.  Scale: (not to scale)
Description – Gypsum

The content of gypsum is the percent, by weight, of hydrated calcium sulfates in the fraction of the soil less than 20 millimeters in size. Gypsum is partially soluble in water. Soils high in content of gypsum, such as those with more than 10 percent gypsum, may collapse if the gypsum is removed by percolating water. Gypsum is corrosive to concrete.

For each soil layer, this attribute is actually recorded as three separate values in the database. A low value and a high value indicate the range of the attribute for the soil component. A “representative” value indicates the expected value of this attribute for the component. For this soil property, only the representative value is used.
## Report—Chemical Soil Properties

<table>
<thead>
<tr>
<th>Map symbol and soil name</th>
<th>Depth</th>
<th>Cation-exchange capacity</th>
<th>Effective cation-exchange capacity</th>
<th>Soil reaction</th>
<th>Calcium carbonate</th>
<th>Gypsum</th>
<th>Salinity</th>
<th>Sodium adsorption ratio</th>
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</thead>
<tbody>
<tr>
<td>26—Crossett fine sandy loam, 2 to 5 percent slopes, eroded</td>
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<td>Crossett, eroded</td>
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<td>5.6-7.8</td>
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<td>52—Normangee clay loam, 1 to 4 percent slopes</td>
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<td>0-5</td>
<td>2.0-8.0</td>
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<td>71—Vertel clay, 3 to 5 percent slopes</td>
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<tr>
<td>Vertel</td>
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<tr>
<td>72—Vertel clay, 5 to 12 percent slopes</td>
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<td>Vertel</td>
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<td>0-1</td>
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<td>0.0-2.0</td>
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</tbody>
</table>
Diamonds sparkling on hillside
Sulfate Detection

- Determining Sulfate Concentration
  - Conductivity test (Tex-146-E)
    (~ Three Minute Field Test)
Sulfate Detection
Veris Testing

US 82 Fannin County
Benefits of Veris Testing

- **Increased Efficiency vs. Traditional Testing**
  - Complete Project Soils Testing
  - Final Grade Testing of Soils
  - Quickly Locates Soil to be Lab Tested
  - Eliminates Random Sampling of Soils for Lab Testing
  - Allows Focused Effort of Lab Personnel
Sulfate Detection

- Colorimetric Test (Tex-145-E) (~Three Day Test)
  - Verification of Conductivity Screening Tests
Design & Construction Mitigation Resources

- TXDOT Guidelines for Treatment of Sulfate-Rich Soils & Bases in Pavement Structures
- General Notes to Address Sulfates Mitigation Procedures
- Veris Machine
- Consultation with TXDOT – CST / M&P
Design & Construction Mitigation Resources

- Basic Mechanisms and Causes of Sulfate Heave
- Risk Assessment
- Stabilizing Additives
- Best Management Practices

Guidelines for Treatment of Sulfate-Rich Soils and Bases in Pavement Structures

Construction Division
Materials & Pavements Section
Geotechnical, Soils & Aggregates Branch

Linked within TXDOT Pavement Design Guide
Vertical Sulfate Seams

Sulfate crystalline formations in desiccated clay.
TXDOT Treatment by Concentration (Parts-Per-Million)

- **Sulfate Concentration (SC)**
  - SC<3,000 ppm: Traditional Treatment
  - 3,000<SC<8,000: Modified Treatment
  - SC>8,000 ppm: Alternative Treatment

The SC>8,000 ppm concentration is highlighted.
Sulfates > 8,000 ppm

**High Risk**

- Remove and Replace Sulfate-Rich Soil
- Blend in Non-Plastic Low Sulfate Soil
- Use Alternative Additives or Stabilizers such as Ground Granulated Blast Furnace Slag + Lime or Lime + Fly Ash
- Mechanical Stabilization (Geogrid)
- No Treatment
Chemical Additives

- Soils are different
- Additives are different
- Reactions between soils and additives are different
- DO A MIX DESIGN

Treatment

- Treat each area based upon sulfates concentrations
- Evaluate the material properties and field performance
Soil Sulfates Mitigation - The following notes are referenced hereafter by Items 110, 132 & 260:

Subgrade Sulfate Testing ~ Once proposed subgrade elevations are obtained TXDOT may test subgrade using an in-field continuous conductivity machine to determine where necessary soil samples will be collected for laboratory testing. Laboratory testing will determine necessary high sulfate mitigation techniques.

0 – 3,000 ppm of sulfates - no restrictions.

3,001 – 7,000 ppm of sulfates - In a single application, add the prescribed total amount of lime. Uniformly mix the lime into the soil being treated. Lightly compact the mixture to seal and minimize carbonation. Maintain moisture content above optimum. Three days after initial addition of lime, determine soluble sulfate concentration sampled at locations as directed using Tex-145-E, and if the sulfate measurement has been reduced to 3,000 ppm or less, then no additional lime or mellowing time is necessary; however, if sulfate measurement has not been reduced to 3,000 ppm or less, then
add 4% additional lime. Uniformly mix the lime into the pretreated soil. Lightly compact the mixture to seal and minimize carbonation and mellow an additional 7 days while maintaining moisture content above optimum. Reprocess the soil-lime mixture to meet the gradation requirements in Item 260, Table 1, and compact it at the optimum moisture content.

**Greater than 7,000 ppm of sulfates** - Do not bring this soil onto project. Remove or process as directed.

The Department will pay for additional lime treatment of material originating in TXDOT right-of-way when sulfate concentrations are greater than 3,000 ppm and such material is required to be used as shown in the plans.
Item 110 Excavation:
Material below finished subgrade elevation suspected of containing sulfates will be tested in accordance with Tex -145-E by the Department. Treat subgrade material to the required depth and width in accordance with the Soil Sulfates Mitigation General Notes.

Item 132 Embankment:
Test potential embankment sources using Tex-145-E to determine the presence and concentration of sulfates.

Embarkment sources containing sulfates that meets specification requirements may be used as fill material provided it is placed with at least one foot of separation from materials to be treated with lime, cement, or other calcium-based stabilizers. When soils are to be placed with less than one foot of separation from material to be treated with lime, cement, or other calcium based stabilizers, process and treat such soils according to the Soil Sulfates Mitigation General Notes.

No additional compensation will be made for stabilizing and treating embankment material obtained outside TXDOT right-of-way which has a sulfate concentration exceeding 3,000 ppm
Item 260 Lime Treatment (Road Mixed):
A minimum mellowing period of three days is required for this project.
Subgrade, embankment or backfill suspected of containing sulfates will be tested in accordance with Tex-145-E by the Department. Treat subgrade, embankment or backfill material to the required depth and width in accordance with the Soil Sulfates Mitigation General Notes.

Item 275 Cement Treatment (Road Mixed):
Subgrade, embankment or backfill suspected of containing sulfates will be tested in accordance with Tex-145-E by the Department. Subgrade, embankment or backfill material within one foot of any area to be treated using cement is subject to the following restriction:

Greater than 7,000 ppm – Do not treat with any cement or other calcium based stabilizers. Material within one foot of any area to be treated with cement or other calcium based stabilizers must be removed or processed as directed.

Reduces Risk!
Paris District
“High Risk” Location

Blackland Prairies
Coastal Sand Plains
Edwards Plateau
Gulf Coast Prairies & Marshes
High Plains
Llano Uplift
Oak Woods & Prairies
Piney Woods
Rolling Plains
South Texas Brush Country
Trans Pecos
The Houston Black series occurs on about 1.5 million acres in the Blackland Praire, which extends from north of Dallas south to San Antonio. Because of their highly expansive clays, Houston Black soils are recognized throughout the world as the classic Vertisols, which shrink and swell markedly with changes in moisture content. These soils formed under prairie vegetation and in calcareous clays and marls. Water enters the soils rapidly when they are dry and cracked and very slowly when they are moist.

Houston Black soils are used extensively for grain sorghum, cotton, corn, small grain, and forage grasses. They also occur in several metropolitan areas, where their very high shrink-swell potential commonly is a limitation affecting building site development.

The Professional Soil Scientist Association of Texas has recommended to the State Legislature that the Houston Black series be designated the State soil. The series was established in 1902.
Construction without Lime Treatment!
Calcium from Lime + Sulfate from Gypsum = Ettringite

Ettringite = Sulfate Heave

- Ettringite
  - Formation can double in original volume!
  - Can cause pressures of 30,000 psi!
Mitigation of High Sulfate Soil when Lime Stabilization is Desired

LAB Work

- Determine Optimum Lime Content
  - Sulfate Reduction / Strength

- Test for Sulfate Reduction to 3,000 ppm over Time

- Determine Acceptable Remixing Interval during Mellowing
  - Increased Remixing Reduces Mellowing Time, but Increases Cost
Mitigation of High Sulfate Soil when Lime Stabilization is Desired

LAB Work

- Test particular soils using 3D Swell Lab Testing
  - Use Lime, Lime/Fly Ash, and Blast Furnace Slag, etc.

- Choose Treatment Method that provides adequate strength and acceptable swell reduction
Characterization of Mellowing Process to Stabilize High Sulfate-Bearing Soil

6% Lime for Mellowing

Select Remixing Interval during Mellowing

1-day Interval          2-day Interval          4-day Interval          No remixing

Addition of Stabilizer to Improve Strength

- 3% lime
- 3% Class F fly ash
- 1.5% lime + 1.5% F fly ash
- 2.0% lime + 2.0% F fly ash

Apply the best stabilizer content obtained from 1-day interval (proper sulfate resistance & strength development)

Sulfate content (ppm)

Mellowing condition: 6% lime & 73°F

Control & Mellowing samples

Addition of Stabilizer

- 3% lime
- 3% Class F fly ash
- 1.5% lime + 1.5% F fly ash
- 2.0% lime + 2.0% F fly ash

Apply the best stabilizer content obtained from 1-day interval (proper sulfate resistance & strength development)

Sulfate content (ppm)

Mellowing condition: 6% lime & 73°F

Control & Mellowing samples

Addition of Stabilizer

- 3% lime
- 3% Class F fly ash
- 1.5% lime + 1.5% F fly ash
- 2.0% lime + 2.0% F fly ash

Apply the best stabilizer content obtained from 1-day interval (proper sulfate resistance & strength development)
6% Lime Mellowing
- Effect of Remixing Interval

US 82 Example Lab Testing – TTI

Chang-Seon Shon, Ph.D, Texas A&M Transportation Institute
<table>
<thead>
<tr>
<th>Day</th>
<th>Lime + Fly Ash Mitigation Schedule</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Lime Treat Subgrade (6%) Lightly Compact</td>
</tr>
<tr>
<td>2-3</td>
<td>Mellowing Period</td>
</tr>
<tr>
<td>4</td>
<td>Remix &amp; Lightly Compact</td>
</tr>
<tr>
<td>5</td>
<td>Mellowing Period</td>
</tr>
<tr>
<td>6</td>
<td>Remix &amp; Lightly Compact</td>
</tr>
<tr>
<td>7</td>
<td>Mellowing Period</td>
</tr>
<tr>
<td>8</td>
<td>Fly Ash Trt Sbgrd (3% Cl F) – Lightly Compact</td>
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<tr>
<td>9</td>
<td>Mellowing Period</td>
</tr>
<tr>
<td>10</td>
<td>Remix and Final Compaction</td>
</tr>
</tbody>
</table>
Keys to Mitigating High Sulfate Soil when Stabilizing with Lime

- Use Lime Slurry
  - Check Mixing Depth & pH

- Provide Additional Mellowing Time

- Maintain Moisture above Optimum
  - Inform Contractor of Importance

- Remix Often

(What Gets Measured, Gets Managed)
General Sulfate Mitigation Points

- Visually Inspect Project / Borrow Sources for Sulfates
  - Train Field Personnel to Watch for Sulfates
  - Field Test Samples using Tex-146-E Conductivity Test

- Lab Test Visually Suspect Materials
  - Colorimetric (Turbidity Test) Tex-145

- Use Veris Machine to Test Soils @ Final Grade
  - Verify Veris Data by Lab Testing (Colorimetric)
Thank you!