Practical Issues in Grounding: Bentonite vs. Conductive Concrete

Presented by:

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Sankosha
Agenda

• Overview of Bentonite and Conductive Cement
• Benefits in grounding applications
• Issues in grounding applications
• Questions
What is Bentonite?

- Discovered by Wilbur C. Knight in the 19th century near Fort Benton in Montana. Named it Bentonite.
- At the same time it was discovered near Montmorillon in France. Named it Montmorillonite.
- Bentonite is now used as a general name for water absorbing clay which usually contains mostly montmorillonite.
- Can contain many other elements.
- Found all over the world.
- Mainly coming from volcanic ash.
Bentonite From Volcanic Ash

Volcanic ash layer covered by sediments and over time with increasing temperature and pressure the ash forms bentonite.
Types of Bentonite

- Four Types: Magnesium, Potassium, Calcium and Sodium
- Two main types of bentonite: Calcium and Sodium
- Sodium bentonite has high water absorption properties and will expand many times its size. Also known as “swelling bentonite”.
- Calcium bentonite has much lower absorption properties and generally flakes off. Also known as “nonswelling bentonite”.
- Calcium bentonite is the most common type found in the world.
- Calcium bentonite can be converted into sodium bentonite through sodium activation. (Calcium ions are exchanged for sodium carbonate.)
## World Production of Bentonite

*(in metric tons)*

<table>
<thead>
<tr>
<th>Country</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
</tr>
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<tbody>
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<td>United States</td>
<td>3,650,000</td>
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<td>4,980,000</td>
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<td>Turkey</td>
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<td>798,397</td>
<td>471,528</td>
<td>1,033,568</td>
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<tr>
<td>India</td>
<td>671,000</td>
<td>561,000</td>
<td>739,000</td>
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<td>590,998</td>
<td>563,795</td>
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<td>Iran</td>
<td>387,437</td>
<td>350,208</td>
<td>377,398</td>
<td>400,000</td>
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<tr>
<td>Japan</td>
<td>432,000</td>
<td>430,000</td>
<td>425,000</td>
<td>420,000</td>
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<tr>
<td>Germany</td>
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<td>362,623</td>
<td>375,332</td>
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<td>Australia</td>
<td>240,000</td>
<td>230,000</td>
<td>230,000</td>
<td>230,000</td>
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<tr>
<td>Czech Republic</td>
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<td>183,000</td>
<td>160,000</td>
<td>221,000</td>
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<tr>
<td>Ukraine</td>
<td>195,000</td>
<td>185,000</td>
<td>211,000</td>
<td>210,000</td>
<td>210,000</td>
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<tr>
<td>Argentina</td>
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<td>229,301</td>
<td>228,357</td>
<td>193,795</td>
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<td>South Africa</td>
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<td>54,311</td>
<td>120,417</td>
<td>120,566</td>
<td>174,786</td>
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<td>Cyprus</td>
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<td>150,000</td>
<td>150,000</td>
<td>160,180</td>
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<tr>
<td>Slovakia</td>
<td>109,000</td>
<td>130,521</td>
<td>119,323</td>
<td>129,930</td>
<td>130,000</td>
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<tr>
<td>Spain</td>
<td>140,000</td>
<td>157,001</td>
<td>110,271</td>
<td>115,000</td>
<td>115,000</td>
</tr>
<tr>
<td>Italy</td>
<td>146,318</td>
<td>111,000</td>
<td>110,000</td>
<td>110,000</td>
<td>110,000</td>
</tr>
<tr>
<td>Other</td>
<td>753,000</td>
<td>563,304</td>
<td>563,870</td>
<td>600,657</td>
<td>649,196</td>
</tr>
</tbody>
</table>

*Note: Not included are China, Canada, and Russia because their output is not reported.*
# US Production of Bentonite 2011-2015

## Production (sold or used) (in thousand metric tons):

<table>
<thead>
<tr>
<th></th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
<th>2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ball clay</td>
<td>886</td>
<td>973</td>
<td>1,000</td>
<td>1,030</td>
<td>1,070</td>
</tr>
<tr>
<td>Bentonite</td>
<td>4,990</td>
<td>4,980</td>
<td>4,350</td>
<td>4,800</td>
<td>4,320</td>
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<tr>
<td>Common clay</td>
<td>11,700</td>
<td>11,900</td>
<td>11,100</td>
<td>11,600</td>
<td>11,700</td>
</tr>
<tr>
<td>Fire clay</td>
<td>215</td>
<td>183</td>
<td>151</td>
<td>217</td>
<td>235</td>
</tr>
<tr>
<td>Fuller’s earth</td>
<td>1,950</td>
<td>1,980</td>
<td>1,990</td>
<td>1,990</td>
<td>1,970</td>
</tr>
<tr>
<td>Kaolin</td>
<td>5,950</td>
<td>5,900</td>
<td>6,140</td>
<td>6,310</td>
<td>6,160</td>
</tr>
<tr>
<td>Total</td>
<td>25,700</td>
<td>25,900</td>
<td>24,700</td>
<td>25,900</td>
<td>25,500</td>
</tr>
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## Exports:

<table>
<thead>
<tr>
<th></th>
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<th>2013</th>
<th>2014</th>
<th>2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ball clay</td>
<td>49</td>
<td>77</td>
<td>52</td>
<td>33</td>
<td>54</td>
</tr>
<tr>
<td>Bentonite</td>
<td>1,020</td>
<td>1,030</td>
<td>890</td>
<td>901</td>
<td>922</td>
</tr>
<tr>
<td>Clays, not elsewhere classified</td>
<td>209</td>
<td>315</td>
<td>304</td>
<td>282</td>
<td>274</td>
</tr>
<tr>
<td>Fire clay</td>
<td>371</td>
<td>289</td>
<td>268</td>
<td>237</td>
<td>206</td>
</tr>
<tr>
<td>Fuller’s earth</td>
<td>102</td>
<td>107</td>
<td>86</td>
<td>92</td>
<td>77</td>
</tr>
<tr>
<td>Kaolin</td>
<td>2,490</td>
<td>2,450</td>
<td>2,540</td>
<td>2,640</td>
<td>2,420</td>
</tr>
<tr>
<td>Total</td>
<td>4,240</td>
<td>4,270</td>
<td>4,140</td>
<td>4,190</td>
<td>3,950</td>
</tr>
</tbody>
</table>

## Price, average, dollars per ton:

<table>
<thead>
<tr>
<th></th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
<th>2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ball clay</td>
<td>46</td>
<td>46</td>
<td>43</td>
<td>44</td>
<td>44</td>
</tr>
<tr>
<td>Bentonite</td>
<td>61</td>
<td>62</td>
<td>65</td>
<td>67</td>
<td>60</td>
</tr>
<tr>
<td>Common clay</td>
<td>12</td>
<td>12</td>
<td>11</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Fire clay</td>
<td>30</td>
<td>27</td>
<td>23</td>
<td>18</td>
<td>18</td>
</tr>
<tr>
<td>Fuller’s earth</td>
<td>100</td>
<td>92</td>
<td>90</td>
<td>86</td>
<td>86</td>
</tr>
<tr>
<td>Kaolin</td>
<td>143</td>
<td>149</td>
<td>146</td>
<td>143</td>
<td>143</td>
</tr>
</tbody>
</table>

1 metric ton = 2204.62 pounds

In 2015, Bentonite at $60 per metric ton => $0.027 per pound
Where Does US Bentonite Come From?

- It is naturally occurring, so it is just mined or gathered.
- Biggest source in the US is in Wyoming where 97% of the US production comes from.
- 70% of the sodium bentonite in the world is produced in the US.
- Layers up to 50ft deep
- This particular bentonite is known as Wyoming Bentonite.
- Wyoming Bentonite can swell up to 16 times its original size and absorb up to 10 times its weight in water.
Applications of Bentonite

- Molds in Foundries
- Drilling for Oil
- Civil Engineering – land fills, ponds, walls
- Feedstuff – European regulations say it can be used as animal feed
- Water Treatment – water clarification
- Gardening
- Ceramics
- Paper – turning pulp into paper
- Wine Making – enhance clarification and protein stabilization
- Cat Litter
- Pharmaceuticals – digestive agents
- Beauty Products – creams, face-powders, mud packs
- Detergent Additive – fabric softener and suspension agent
- Paints and Varnishes – as a thickener
Ancient people from the Andes and Central Africa along with the Aborigines of Australia have used bentonite clay as a supplement, dietary staple and for healing aches and pains.

Early Americans found bentonite vital to their lives. Pioneers found moistened bentonite to be an ideal lubricant for squeaky wagon wheels. The mixture was also used as a sealant for log cabin roofing. The Indians found bentonite useful as a soap.
Drilling mud, or drilling gel, is a major component in the well drilling process. Drilling mud is crucial in the extraction of drill cuttings during the drilling process. Bentonite, when mixed with water, forms a fluid (or slurry) that is pumped through the drill stem, and out through the drill bit. The bentonite extracts the drill cuttings from around the bit, which are then floated to the surface. The drilling mud, or gel, also serves to cool and lubricate the drill bit as well as seal the drill hole against seepage and to prevent wall cave-ins.
Kitty Litter (29% in 2015)

- Absorbs acids well
- Forms clumps making it scoop-able
- Inexpensive
Foundry Molds (10% in 2015)

Used in non-ferrous metal casting
Iron Ore Pelletizing (10% in 2015)
Paper Manufacturing

- Bentonite is important to paper making, where it is used in pitch control (absorption of wood resins that tend to obstruct the machines)
- Helping turn the pulp into paper.
- De-inking for paper recycling.
- Acid activated bentonite is used as the active component in the manufacture of carbonless copy paper
Bentonite is used to help detoxify skin by absorbing oils and dirt and cleaning pores. Since it absorbs a large amount of moisture from the skin as well, it is recommended to apply a moisturizer after using.
It is used as an antidote in heavy metal poisoning. Other medical applications include industrial protective creams, calamine lotion, wet compresses, and anti-irritants for eczema.
Daily Digestive Agents

Bentonite provides strong detoxification in the digestive tract, with the ability to bind herbicides, pesticides, viruses, heavy metals, aflatoxin and other potentially harmful substances by adsorbent action. Bentonite’s mechanism of action is physical, due to its colloidal structure and charged particles of sodium, calcium, magnesium and potassium ions, which allow it to bind with toxins in the stomach, small intestine and colon. It is not digested, nor is it absorbed into the bloodstream. Since toxins are bound to the bentonite, they are excreted from the body when the bentonite is eliminated through bowel movements.
Agriculture

- Animal feed supplement.
- Pelletizing aid in the production of animal feed pellets.
- Flow-ability aid for unconsolidated feed ingredients such as soy meal.
- Absorbs harmful micro-toxins.
- Carrier for various herbicides and pesticides.
- Ion exchanger for soil improvement and conditioning.
- To line the base of landfills and ponds.

Fullerton will try to plug leaky lake

FULLERTON – City officials figure that dropping clay pebbles to the bottom of Laguna Lake has a good chance to save thousands of gallons of water a day.

The Fullerton City Council agreed this week to spend $500,000 to drop a sealant called Bentonite into the lake to plug up leaks. In the summer, the lake's loss reached 90,000 gallons a day, about a third of that from evaporation.
Detergents and Soaps

Some laundry detergents and liquid hand cleansers/soaps rely on the inclusion of bentonite to remove the impurities in solvents and to soften fabrics.
Wine, Water and Juice Clarification

- Bentonite is a clarifying agent that produces the superior clarity and heat stability that fine wines and juices deserve.
- For wines, it also acts as a protein stabilization.
- Due to its ion exchange, flocculation, and sedimentation properties, bentonite is used in environmental protection for water clarification, and as an aid to polyelectrolytes and inorganic flocculants.
Environmental Markets

Bentonite's absorption properties are very useful for wastewater purification.

Used in products to clean up oil and dangerous chemical spills.
Asphalt Emulsifiers

Functions as a thickening or suspension agent in water based coatings and enhances stability of asphalt emulsified coatings.
Why Use Bentonite as a Grounding Enhancing Material?
What Is Conductive Cement?

- In the mid 1970’s, Chubu Electric Power Co. in Japan had need for a grounding material that could be used mountainous areas where access and construction was difficult and soil resistivity was typically high.

- The grounding material needed to:
  - have low resistivity
  - conform to the rocky uneven environment
  - be useable above ground as well as below
  - provide protection to the copper electrode
  - not to move or wash away
  - be environmentally safe
  - be maintenance free

- Sankosha and the power company developed a conductive concrete, which they named SAN-EARTH.

- Mainly a mixture of fine carbon powder and Portland cement.

- Patented in Japan in the mid 1970’s and sold commercially starting in 1979.
Types of Conductive Cement

• Since then, many similar products have appeared on the market.

• Before the invention of conductive cement, carbon powder alone was a common grounding material. Although it was a very low resistance material, it had the problems of being:
  – highly corrosive due to its acidic properties
  – could easily wash away or mix into the surrounding soil
  – no protection from theft

• Some of the “copies” have increased the ratio of carbon to cement in an effort to lower resistivity and cost. In the process, they have reintroduced the disadvantages of pure carbon backfills.

• The carbon is the highly conductive material and the cement helps make the mixture non-corrosive and stable.

• The cement also acts as a theft deterrent.
Properties of Conductive Cement

- Resistivity is basically the same, as a dry powder, a wet mortar, a wet slurry or a cured solid because the carbon is main conductor.
- Can be installed in many different ways.
- It is typically a very fine powder that makes excellent surface contact with surrounding material.
- Its resistivity, pH level, and hardness when it dries are dependent on the ratio of carbon to cement.
- Has the properties of cement – anti-theft, resistant to erosion, chemical resistant, and environmentally safe.
Applications of Conductive Cement

99% used in grounding systems
What Makes Good Grounding Material

- Low Resistance
- Makes Good Contact with Surrounding Soil & Electrode
- Helps Prevent Electrode Corrosion
- Long Life – Stays In Place & Doesn’t Wash Away
- Theft Deterrent
- Low Cost
- Maintenance Free
- Easy To Install
- Environmentally Safe
- Consistent Performance
- Chemical Resistant
When Is Grounding Enhancing Material Used?

**High Soil Resistivity**
- When measured soil resistivity is high, making it difficult to reach the required / target resistance.

**Low or High Soil Resistivity**
- Want a long life grounding system (anti-corrosion and chemical protection).
- Want security against theft.
Average Soil Resistivity in US (ohm m)

Estimated Average Earth Resistivity in U.S. (ohm meters)
What Affects Soil Resistivity?

1. Soil Type

<table>
<thead>
<tr>
<th>Soil Description</th>
<th>Average Resistivity (Ω – m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Topsoil, Loam</td>
<td>26</td>
</tr>
<tr>
<td>Inorganic Clays</td>
<td>33</td>
</tr>
<tr>
<td>Fills – ashes, cinders, brine wastes</td>
<td>38</td>
</tr>
<tr>
<td>Gravelly, Sandy, Silty and Lean Clays</td>
<td>43</td>
</tr>
<tr>
<td>Slates, Shales</td>
<td>55</td>
</tr>
<tr>
<td>Silty or Fine Sands with slight absorption</td>
<td>55</td>
</tr>
<tr>
<td>Clayey Sands</td>
<td>125</td>
</tr>
<tr>
<td>Fine Sandy or Silty Clays, Lean Clays</td>
<td>190</td>
</tr>
<tr>
<td>Decomposed Gneisses</td>
<td>275</td>
</tr>
<tr>
<td>Silty Sands, Poor Sand-Silt Mixtures</td>
<td>300</td>
</tr>
<tr>
<td>Clayey Gravel, Poor Gravel, Sand-Clay Mixtures</td>
<td>300</td>
</tr>
<tr>
<td>Well Graded Gravel, Gravel-Sand Mixtures</td>
<td>800</td>
</tr>
<tr>
<td>Granites, Basalts</td>
<td>1,000</td>
</tr>
<tr>
<td>Sandstone</td>
<td>1,010</td>
</tr>
<tr>
<td>Poor Gravel, Gravel-Sand Mixtures</td>
<td>1,750</td>
</tr>
<tr>
<td>Gravel, Sand, Stones, Little Clay or Loam</td>
<td>2,585</td>
</tr>
<tr>
<td>Surface Limestone</td>
<td>5,050</td>
</tr>
</tbody>
</table>
What Affects Soil Resistivity?

2. Moisture Content

<table>
<thead>
<tr>
<th>Type of Water</th>
<th>Resistivity (Ω – m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pure Water</td>
<td>200,000</td>
</tr>
<tr>
<td>Distilled Water</td>
<td>50,000</td>
</tr>
<tr>
<td>Rain Water</td>
<td>200</td>
</tr>
<tr>
<td>Tap Water</td>
<td>70</td>
</tr>
<tr>
<td>Well Water</td>
<td>20 - 70</td>
</tr>
<tr>
<td>Mixture of River &amp; Sea Water</td>
<td>2</td>
</tr>
<tr>
<td>Sea Water (Inshore)</td>
<td>0.3</td>
</tr>
<tr>
<td>Sea Water (Ocean 3%)</td>
<td>0.2 – 0.25</td>
</tr>
<tr>
<td>Sea Water (Ocean 5%)</td>
<td>0.15</td>
</tr>
</tbody>
</table>
### What Affects Soil Resistivity?

#### 3. Temperature

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Ground Resistivity ($\Omega \cdot m$)</th>
<th>Factor (vs. 68°F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>68°F (20°C)</td>
<td>72</td>
<td>1.00 x</td>
</tr>
<tr>
<td>50°F (10°C)</td>
<td>99</td>
<td>1.38 x</td>
</tr>
<tr>
<td>32°F (0°C) - Water</td>
<td>130</td>
<td>1.81 x</td>
</tr>
<tr>
<td>32°F (0°C) - Ice</td>
<td>300</td>
<td>4.17 x</td>
</tr>
<tr>
<td>23°F (-5°C)</td>
<td>790</td>
<td>10.97 x</td>
</tr>
<tr>
<td>5°F (-15°C)</td>
<td>3,300</td>
<td>45.83 x</td>
</tr>
</tbody>
</table>

Keep grounding system below frost line.
Typical Soil Resistivity Correlation

• Soil that can hold water generally has low resistivity.
• Rocky or sandy areas where water drains quickly has high resistivity.
• Areas where there is a lot of rainfall, moisture and warm temperatures have low soil resistivity.
• Areas where it’s dry or temperatures are low tend to have high soil resistivity. (deserts, mountains, icy places)
• Seasons and weather affect soil resistivity.
Soil Resistivity vs. Corrosion

- Soil resistivity is a function of soil moisture and the concentrations of ionic soluble salts and is considered to be most comprehensive indicator of a soil’s corrosivity. Typically, the lower the resistivity, the higher the corrosivity will be as indicated in the following Table.

<table>
<thead>
<tr>
<th>Soil Resistivity (Ω - m)</th>
<th>Corrosivity Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt; 200</td>
<td>Essentially non-corrosive</td>
</tr>
<tr>
<td>100 to 200</td>
<td>Mildly corrosive</td>
</tr>
<tr>
<td>50 to 100</td>
<td>Moderately corrosive</td>
</tr>
<tr>
<td>30 to 50</td>
<td>Corrosive</td>
</tr>
<tr>
<td>10 to 30</td>
<td>Highly corrosive</td>
</tr>
<tr>
<td>&lt; 10</td>
<td>Extremely corrosive</td>
</tr>
</tbody>
</table>

- Since ionic current flow is associated with soil corrosion reactions, high soil resistivity will arguably slow down corrosion reactions. Soil resistivity generally decreases with increasing water content and the concentration of ionic particles. Sandy soils are high up on the resistivity scale and therefore considered the least corrosive. Clay soils, especially those contaminated with saline water, are highly corrosive.
Easiest Way To Improve Soil Resistivity

Use a grounding enhancing material in the grounding system.

Two of the most common ones are:
- Bentonite
- Conductive Cement

Lateral Electrode
Vertical Electrode
Perimeter Electrode
Grid Electrode
Measuring The Resistivity of Bentonite & Conductive Cement

- Sent out samples of bentonite material and conductive cement to a lab to have resistivity measured.

\[ \rho = \frac{R}{S/L} \]

- \( \rho \) – Resistivity (\( \Omega \cdot m \))
- \( R \) – Resistance Measured By Ohm-meter (\( \Omega \))
- \( S \) – Surface Area of Electrode (\( m^2 \))
- \( L \) – Length of Cylinder (m)
Resistivity of Powdered Bentonite & Conductive Cement

Bentonite Dry Powder

Resistivity ($\Omega$-m) vs Pressure (psi)

- Bentonite Sample 1
- Bentonite Sample 2
- Bentonite Sample 3
- Bentonite Sample 4

Bentonite Average: 42,557 $\Omega$-m

Conductive Cement Dry Powder

Resistivity ($\Omega$-m) vs Pressure (psi)

- Conductive Cement Sample 1
- Conductive Cement Sample 2

Conductive Cement Average: 2.17 $\Omega$-m
Resistivity of Powdered Bentonite & Conductive Cement

Bentonite Powder Stored at 40% Relative Humidity - 4 Days

- Bentonite Sample 1
- Bentonite Sample 2
- Bentonite Sample 3
- Bentonite Sample 4

Conductive Cement at 40% RH - 4 Days

- Conductive Cement Sample 1
- Conductive Cement Sample 2

Bentonite Average: 36,333 Ω-m
Conductive Cement Average: 2.13 Ω-m
Resistivity of Powdered Bentonite & Conductive Cement

**Bentonite Powder Stored at 98% Relative Humidity - 4 Days**

- Bentonite Sample 1
- Bentonite Sample 2
- Bentonite Sample 3
- Bentonite Sample 4

**Conductive Cement at 98% RH - 4 Days**

- Conductive Cement Sample 1
- Conductive Cement Sample 2

Bentonite Average: 356.9 Ω-m
Conductive Cement Average: 2.13 Ω-m
Resistivity & pH of Mixed Bentonite & Conductive Cement

Due to the softness of the materials, pressure for test was 10psi

<table>
<thead>
<tr>
<th>Sample</th>
<th>Resistivity (Ω – m)</th>
<th>pH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bentonite Sample 1</td>
<td>15.5179</td>
<td>9.3</td>
</tr>
<tr>
<td>Bentonite Sample 2</td>
<td>13.6271</td>
<td>9.6</td>
</tr>
<tr>
<td>Bentonite Sample 3</td>
<td>12.7418</td>
<td>4.9</td>
</tr>
<tr>
<td>Bentonite Sample 4</td>
<td>16.3495</td>
<td>9.2</td>
</tr>
<tr>
<td>Conductive Cement 1</td>
<td>2.2984</td>
<td>10.6</td>
</tr>
<tr>
<td>Conductive Cement 2</td>
<td>3.8825</td>
<td>11.8</td>
</tr>
</tbody>
</table>
Why Use Bentonite as a Ground Enhancing Material?

- Bentonite in its powder or dry form is a very poor grounding enhancing material due to its high resistivity.

+ The water that the bentonite can store is a very good ground enhancing material due to its low resistivity.
How Are They Typically Installed - Bentonite

- Since Bentonite has a high resistivity in its dry form, it is typically mixed with large amounts of water before installing.

- Then it is poured as a liquid or gel into the grounding system.
How Are They Typically Installed – Conductive Cement

- Since Conductive Cement has a low resistivity in its powder form, slightly wet form, very wet form, or hardened form - it can be installed in many different ways.
Bentonite and The Donald
60 years ago, Edward Zuckerman bought a sloping 150 acre garbanzo bean field rising up from the cliffs of the ocean on the Palos Verdes Peninsula south of Los Angeles.

He planned to build 1,200 apartments, a 200 room resort hotel and a nine hole golf course.

The city of Rancho Palos Verdes fought him all the way.
Many years later, Edward’s sons purchased another 100 acres and finally got approval from the city to build a golf course in 1994.

- 75 one acre home sites were also allowed.
Disaster! On June 2, 1999, just before its scheduled grand opening, about 17 acres of the cliff-top 18th fairway slipped towards the ocean creating a huge chasm.
• Original Budget: $126 million
• Damages: $61 million
• Lawsuits followed.
What was the cause of the slippage? Bentonite!

Continuous long term watering of the greens in preparation for the grand opening caused the bentonite to absorb so much water that it softened up and slid.

Other nearby bentonite related slippage
Who saved the day? Donald Trump!

- The Zuckerman brothers were forced to declare bankruptcy.
- Property was taken over by Credit Suisse in February 2002.
- August 2002, Trump acquired the project for a reported $27 million.
- Trump made substantial improvements.
- The course opened as Trump National Golf Course on January 20, 2006.
- Total investment by Trump and the Zuckerman's: Over $300 million
- The most expensive golf course ever constructed
Bentonite Vs. Conductive Cement: Experiment 1 - Preparing

Manufacturers Mixing Instructions:
1 part Bentonite : 4 parts Water

Manufacturers Mixing Instructions:
3 parts Conductive Cement : 2 parts Water

2 – 500mL Glass Beakers - 3.75in (Dia) x 5in (H)
100 mL Bentonite & 300 mL Conductive Cement
Bentonite vs. Conductive Cement: Experiment 1 - Mixing

**Bentonite**
Upon mixing with water, clumped up into globs of clay. Water and clay were very separate and hard to stir. After 15-20 min of stirring, it finally became consistent. Almost like a pudding or cake batter consistency.

**Conductive Cement**
Upon mixing with water the contents quickly absorbed the water and was easy to stir. After 30sec – 1min contents were consistent. Almost like very wet fine sand. After about 10min a thin layer of water formed on top as contents settled.
Bentonite vs. Conductive Cement: Experiment 2 - Preparing

- 2 - 2000mL Glass Graduated Cylinders
  3.5in (Dia) x 20in (H)

- 2 - Copper Pipes
  0.5in (Dia) x 21in (H)

- 2 - Vertical Grounding Rods
Bentonite vs. Conductive Cement: Experiment 2 - Mixing
Bentonite Vs. Conductive Cement: Experiment 2

Day 1 – Cracks start forming
Day 5 – Separating from Electrode
Day 36 – White crystals form
Day 90

PEG CONFERENCE
Analysis of White Crystals

Sodium Sulfate (Na$_2$SO$_4$) - aka Glauber's Salt

The rates of corrosion of iron and steel in water are a function of the specific mineral quality as well as the alkalinity and pH values. Sodium sulfate ... is a strong contributor to the rate of corrosion. For example, in water with 400 mg/l of alkalinity (as CaCO$_3$) at pH 7, the corrosion rate will be zero at 200 mg/l of Na$_2$SO$_4$, but when the concentration of sodium sulfate is 400 mg/l, the corrosion rate will be about 100 mg per square cm per day.
Bentonite Vs. Conductive Cement: Experiment 3
Bentonite Vs. Conductive Cement: Experiment 3

Day 1 – Cracks Start Forming

Day 3 – Separating

Day 15 – White Crystals Form

Day 55 – Crystals Expanded & Hiding Separation

Day 55 – Separation

Day 74
Bentonite vs. Conductive Cement: Experiment 4 - Preparing

Plastic Trays to Simulate Horizontal Grounding

Wood Blocks to Suspend Grounding Wire

Grounding Wire at 1 inch height

12in (L) x 8in (W) x 1.5in (D)
Bentonite vs. Conductive Cement: Experiment 4 - Mixing

Mixing of Conductive Cement

Pouring of Bentonite

Both Filled to Top Covering Grounding Wire

Ready for Experiment
Bentonite vs. Conductive Cement: Experiment 4

DAY 0  Bentonite  Conductive Cement
Bentonite vs. Conductive Cement: Experiment 4

Day 3 – Shrinking & Cracking

Day 13 – Extensive Cracking

Day 15 – Electrode Completely Exposed & Crystals Start to Form

Day 31
Day 15: Cracking in Bentonite caused resistance to spike due to gaps. Required high compression to remove gaps to get consistent results.
Long Term Stability of Conductive Cement

SAN-EARTH M5C Grounding Electrodes
Thirty Three Years of Monthly Resistance Measurements

<table>
<thead>
<tr>
<th>Time in Years</th>
<th>Resistance in Ω</th>
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</thead>
<tbody>
<tr>
<td>1979 - 1989</td>
<td>Electrode A</td>
</tr>
<tr>
<td>1990 - 2000</td>
<td>Electrode B</td>
</tr>
<tr>
<td>2001 - 2011</td>
<td>Electrode A</td>
</tr>
<tr>
<td></td>
<td>Electrode B</td>
</tr>
</tbody>
</table>

- Square Electrode - 3m (L) x 3m (W) at 0.5m (D)
- Horizontal Electrode - 30m (L) x 0.5m (W) at 0.5m (D)
## Conclusion: Bentonite vs. Conductive Cement

<table>
<thead>
<tr>
<th>Grounding Property</th>
<th>Bentonite</th>
<th>Conductive Cement</th>
<th>Winner</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Resistance</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Makes Good Contact With Surrounding Soil &amp; Electrode</td>
<td></td>
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</tr>
<tr>
<td>Helps Prevent Electrode Corrosion</td>
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<tr>
<td>Long Life – Stays In Place</td>
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<tr>
<td>Theft Deterrent</td>
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<td></td>
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<tr>
<td>Low Cost</td>
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<tr>
<td>Maintenance Free</td>
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<td></td>
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<tr>
<td>Easy To Install</td>
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<td></td>
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<tr>
<td>Environmentally Safe</td>
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<tr>
<td>Consistent Performance</td>
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<td></td>
</tr>
<tr>
<td>Chemical Resistant</td>
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</tbody>
</table>
• Bentonite is very general term and not all types are the same.
• Bentonite performance is based on its water content. High soil resistivity areas are typically dry.
• Bentonite will initially give good results right after installation when it is fully hydrated and as the water leaks out hydrating the surrounding soil and lowering its resistivity.
• However, resistance will climb as the bentonite shrinks, loses contact and cracks develop possibly creating infinite resistance.
• Bentonite has great water absorption properties, but not very good water retention properties.
• Conductive concrete gives consistent performance.
• The only advantage of using bentonite over conductive concrete as a grounding material is the savings in cost.
• Is that small savings worth the risk of the value of the equipment or service that is provided?
• Is it worth the risk of personal injury or loss of life?

Conclusion
Thank You!

Questions?