Practical Issues in Grounding: Bentonite vs. Conductive Concrete

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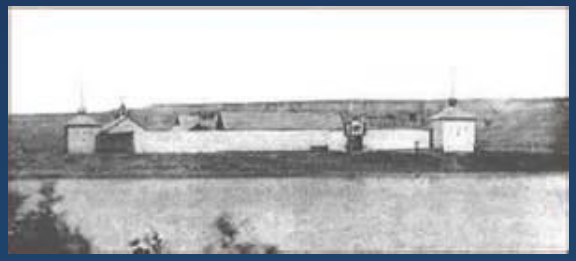
Sankosha

Agenda

- Overview of Bentonite and Conductive Cement
- Benefits in grounding applications
- Issues in grounding applications
- Questions

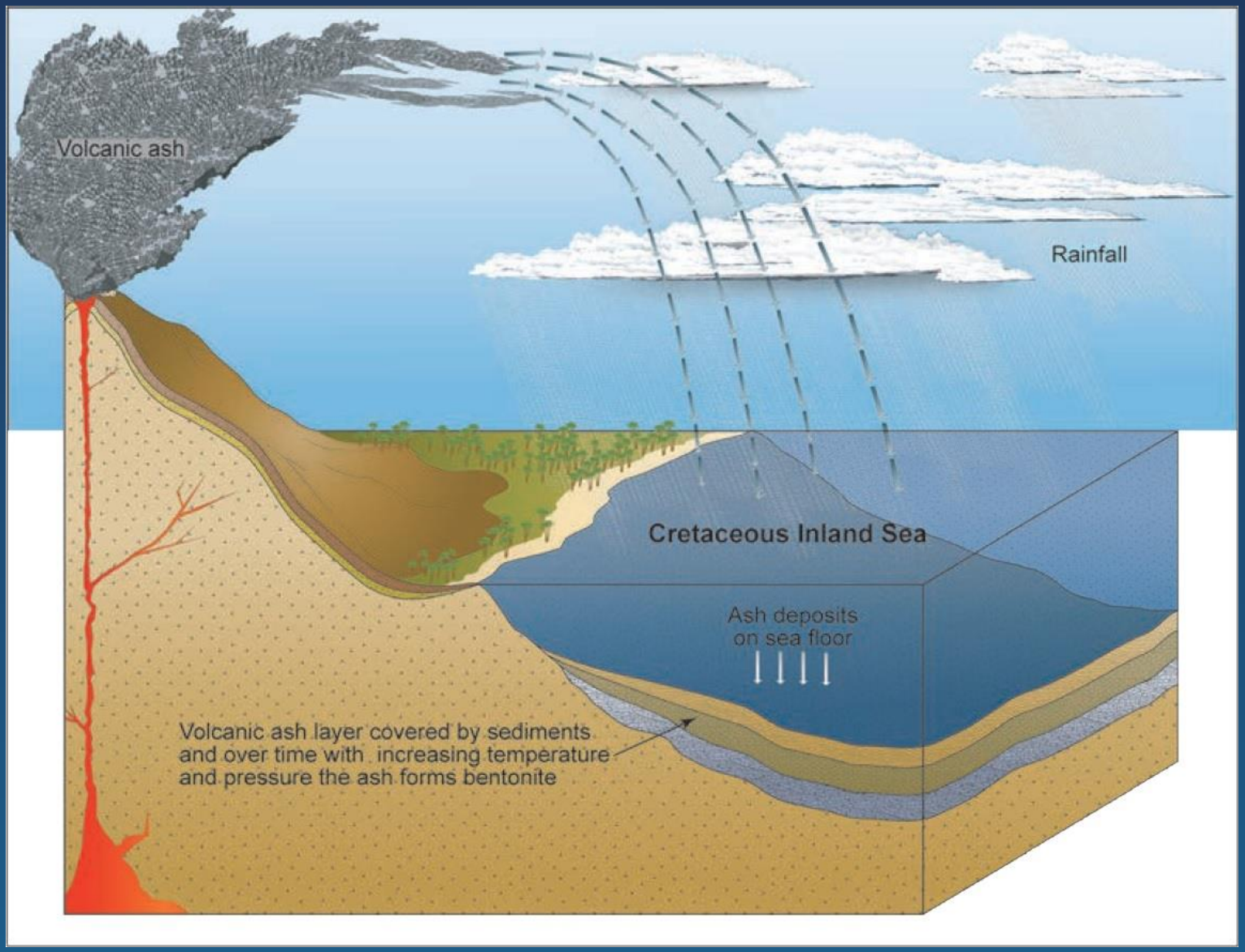
What is Bentonite?

- 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



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)

Country	2009	2010	2011	2012	2013
United States	3,650,000	4,600,000	4,990,000	4,980,000	4,350,000
Turkey	932,487	798,397	471,528	1,033,568	1,100,000
India	671,000	561,000	739,000	996,000	1,081,000
Greece	926,186	1,381,643	1,188,442	1,235,105	1,000,000
Mexico	511,429	590,998	563,795	956,224	617,632
Brazil	264,243	531,693	566,267	512,975	513,000
Iran	387,437	350,208	377,398	400,000	400,000
Japan	432,000	430,000	425,000	420,000	400,000
Germany	326,461	362,623	375,332	375,000	375,000
Australia	240,000	230,000	230,000	230,000	230,000
Czech Republic	177,000	183,000	160,000	221,000	226,000
Ukraine	195,000	185,000	211,000	210,000	210,000
Argentina	148,099	229,301	228,357	193,795	200,000
South Africa	40,340	54,311	120,417	120,566	174,786
Cyprus	150,000	150,000	150,000	160,180	158,386
Slovakia	109,000	130,521	119,323	129,930	130,000
Spain	140,000	157,001	110,271	115,000	115,000
Italy	146,318	111,000	110,000	110,000	110,000
Other	753,000	563,304	563,870	600,657	649,196

Note: Not included are China, Canada, and Russia because their output is not reported.

US Production of Bentonite 2011- 2015

	2011	2012	2013	2014	2015
Production (sold or used)(in thousand metric tons):					
Ball clay	886	973	1,000	1,030	1,070
Bentonite	4,990	4,980	4,350	4,800	4,320
Common clay	11,700	11,900	11,100	11,600	11,700
Fire clay	215	183	151	217	235
Fuller's earth	1,950	1,980	1,990	1,990	1,970
Kaolin	5,950	5,900	6,140	6,310	6,160
Total	25,700	25,900	24,700	25,900	25,500
Exports:					
Ball clay	49	77	52	33	54
Bentonite	1,020	1,030	890	901	922
Clays, not elsewhere classified	209	315	304	282	274
Fire clay	371	289	268	237	206
Fuller's earth	102	107	86	92	77
Kaolin	2,490	2,450	2,540	2,640	2,420
Total	4,240	4,270	4,140	4,190	3,950
Price, average, dollars per ton:					
Ball clay	46	46	43	44	44
Bentonite	61	62	65	67	60
Common clay	12	12	11	10	10
Fire clay	30	27	23	18	18
Fuller's earth	100	92	90	86	86
Kaolin	143	149	146	143	143

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.



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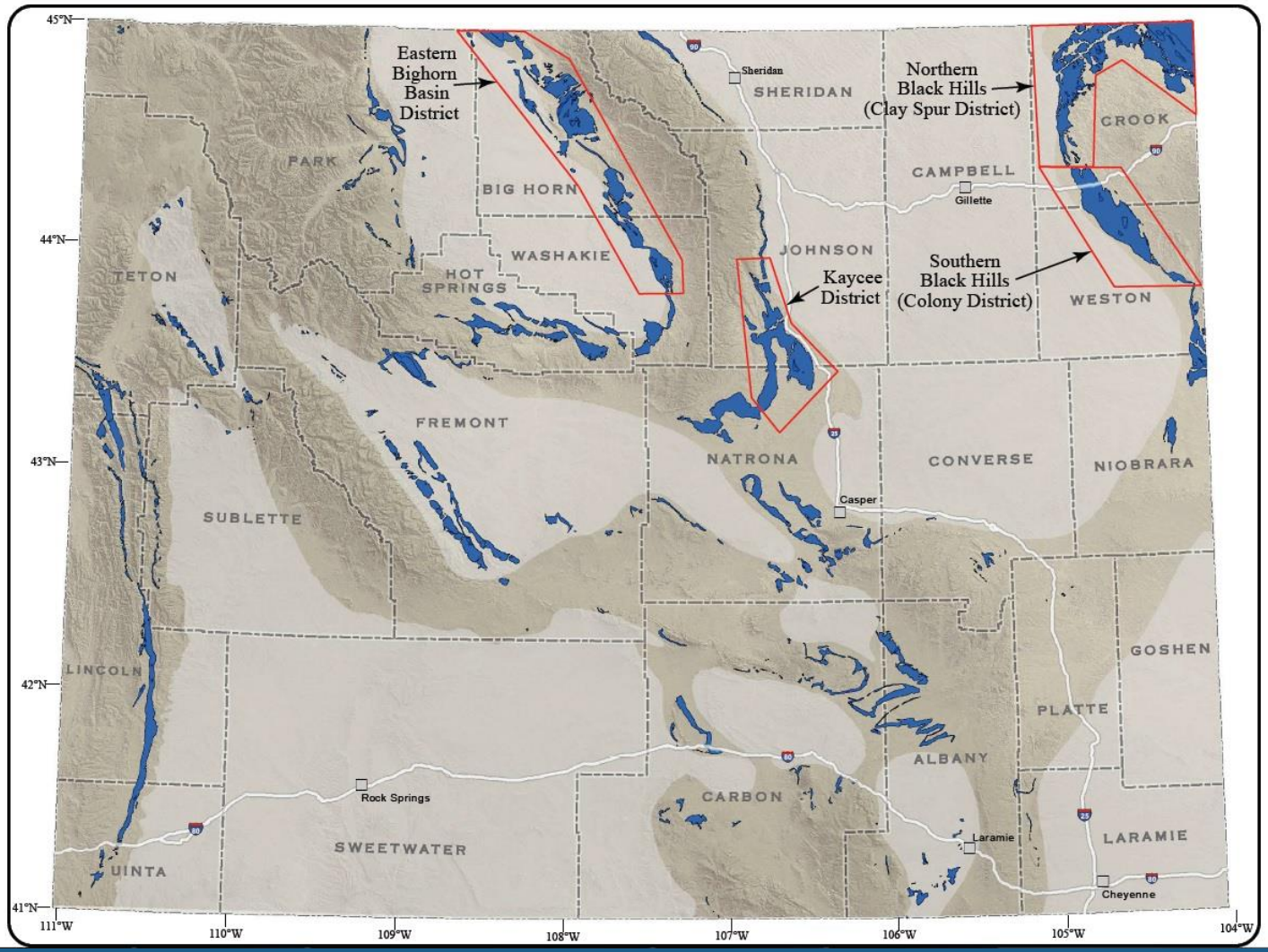
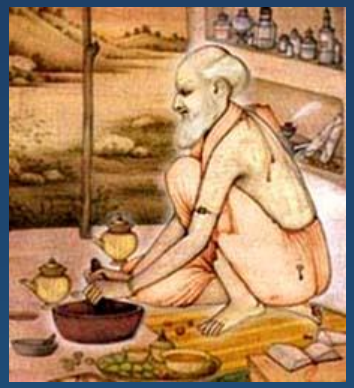


Applications of Bentonite

- 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

Used Throughout History All Over The World

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.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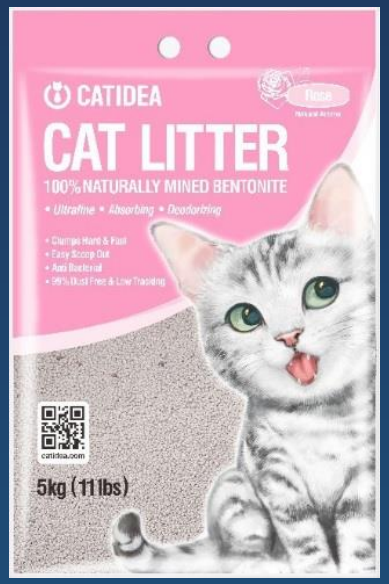
Well Drilling (32% in 2015)

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

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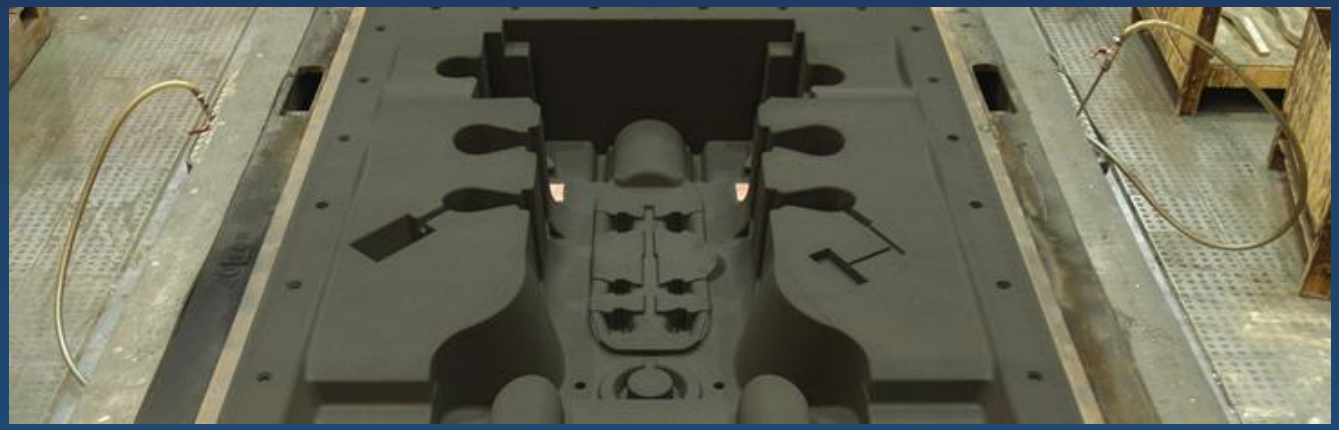
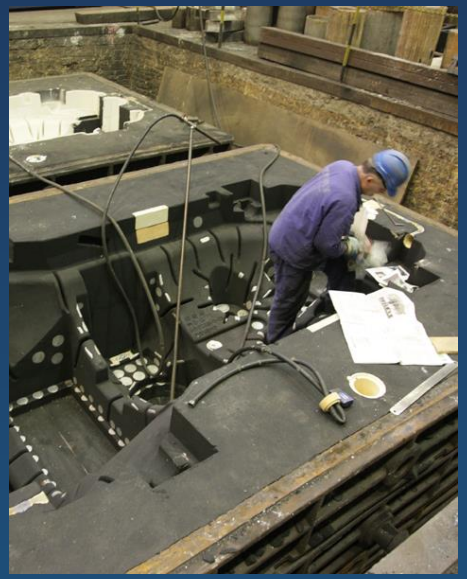
Foundry Molds (10% in 2015)





Used in non-ferrous metal casting

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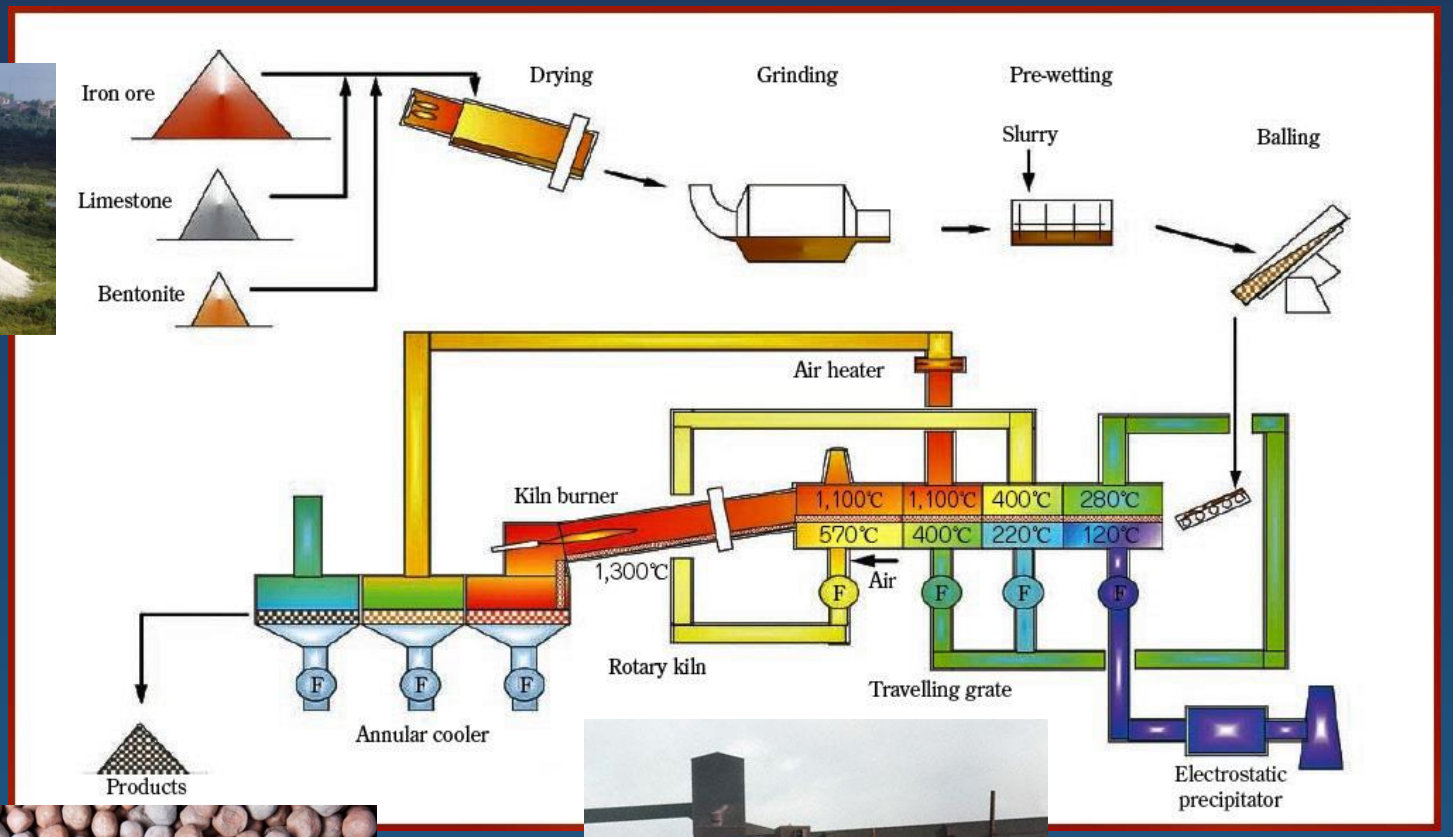
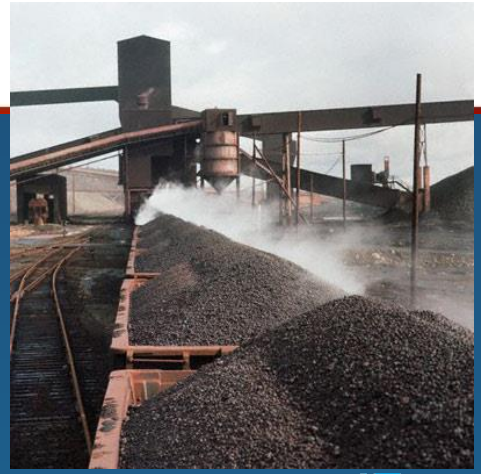
Iron Ore Pelletizing (10% in 2015)





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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

Beauty Products

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.

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Pharmaceuticals

Supplement Facts

Serving Size 1 Capsule
Servings Per Container 90

Amount Per Serving	% Daily Value
Calcium Bentonite ..... 454 mg	*

*Daily Value Not Established

Other Ingredients: None

An outstanding quality clay that delivers the **"Premier Quality Effect"™**

Tamper Seal: Use only if seal is intact. If pregnant or nursing, consult a health professional before taking this or any other product. Store in a cool, dry place.

Manufactured in a cGMP compliant facility for superior quality assurance

Keep out of reach of children.

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

Jan. 20, 2016 | Updated Jan. 21, 2016 8:36 p.m.

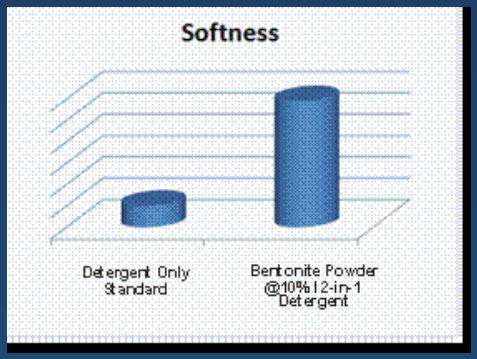
The city has settled on a $500,000 project to apply a granulated clay sealant to the bottom of Laguna Lake.

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.



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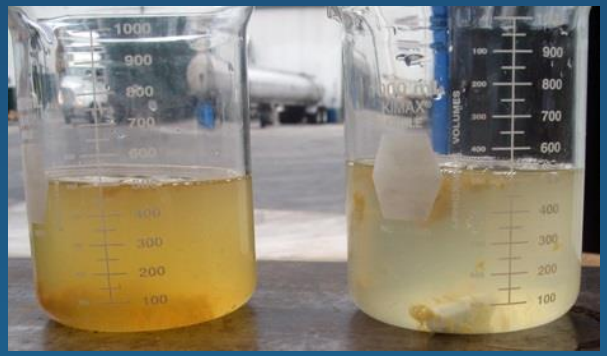
Wine, Water and Juice Clarification

- 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 polyelectrolites and inorganic flocculants.



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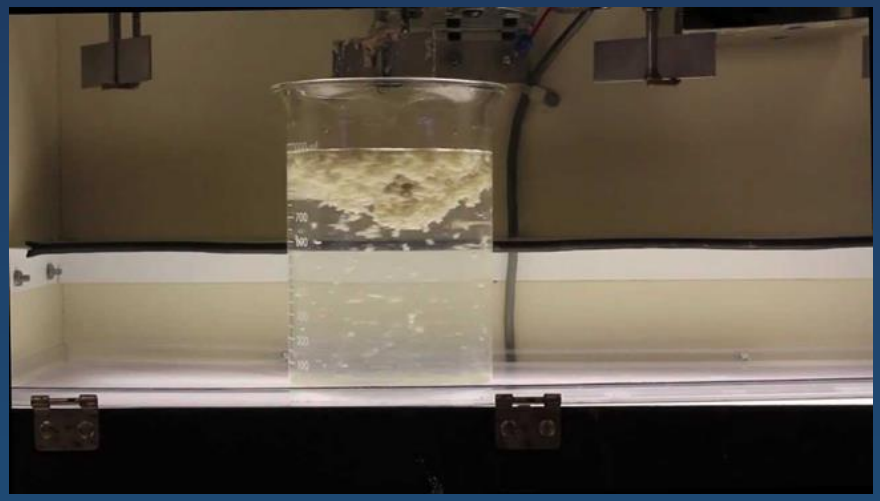
Environmental Markets



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

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

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Asphalt Emulsifiers

Functions as a thickening or suspension agent in water based coatings and enhances stability of asphalt emulsified coatings.

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Why Use Bentonite as a Grounding Enhancing Material?

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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?

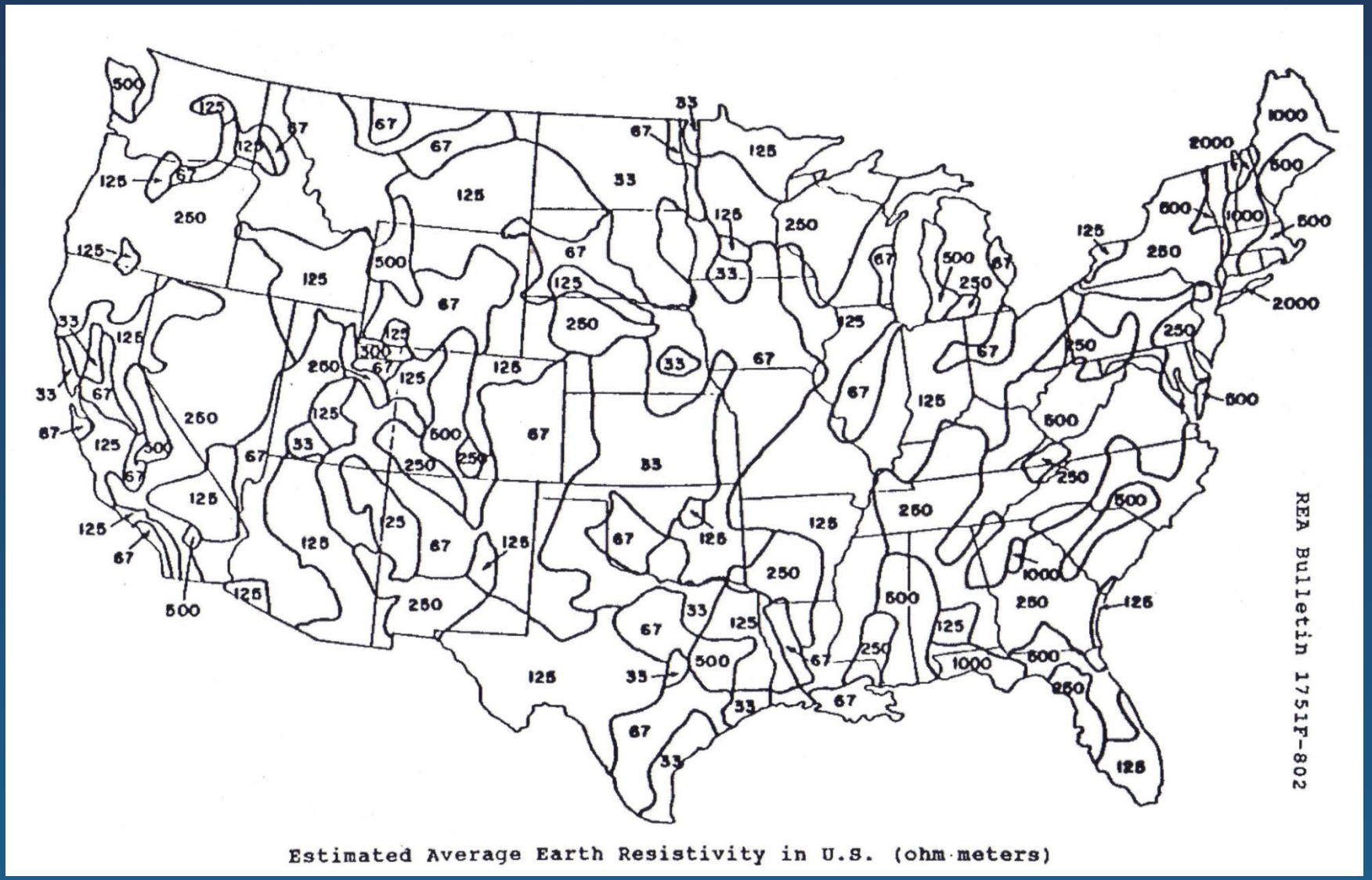
High Soil Resistivity

- 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)

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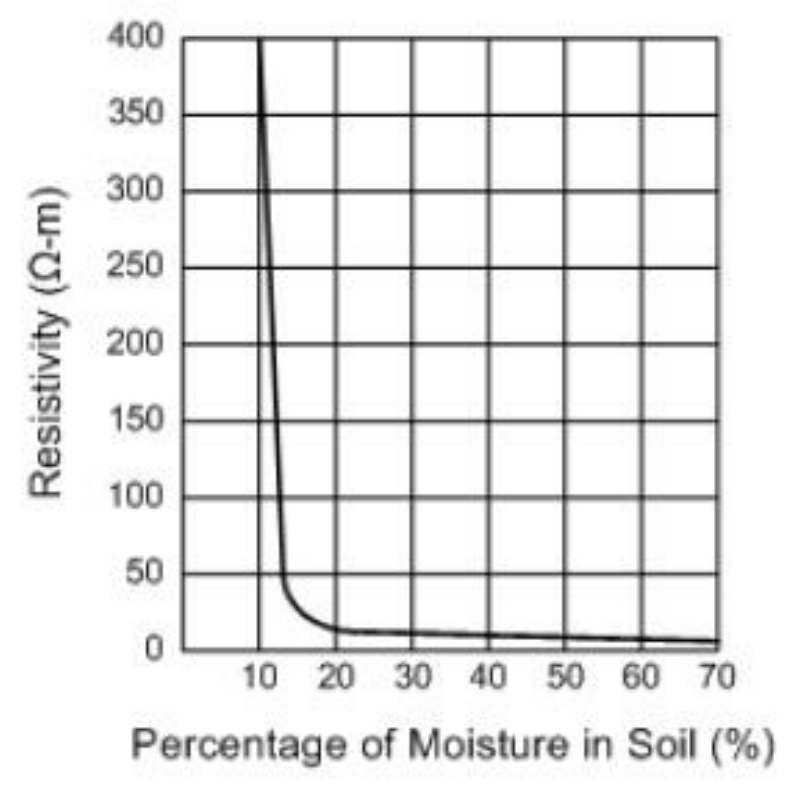
What Affects Soil Resistivity?

1. Soil Type

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

What Affects Soil Resistivity?

2. Moisture Content



Type of Water	Resistivity (Ω – m)
Pure Water	200,000
Distilled Water	50,000
Rain Water	200
Tap Water	70
Well Water	20 - 70
Mixture of River & Sea Water	2
Sea Water (Inshore)	0.3
Sea Water (Ocean 3%)	0.2 – 0.25
Sea Water (Ocean 5%)	0.15

What Affects Soil Resistivity?

3. Temperature

Temperature	Ground Resistivity (Ω - m)	Factor (vs. 68°F)
68°F (20°C)	72	1.00 x
50°F (10°C)	99	1.38 x
32°F (0°C) - Water	130	1.81 x
32°F (0°C) - Ice	300	4.17 x
23°F (-5°C)	790	10.97 x
5°F (-15°C)	3,300	45.83 x

Keep grounding system below frost line.

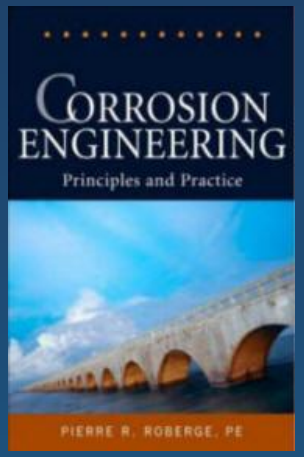
Typical Soil Resistivity Correlation

- 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.

Soil Resistivity (Ω - m)	Corrosivity Rating
> 200	Essentially non-corrosive
100 to 200	Mildly corrosive
50 to 100	Moderately corrosive
30 to 50	Corrosive
10 to 30	Highly corrosive
< 10	Extremely corrosive



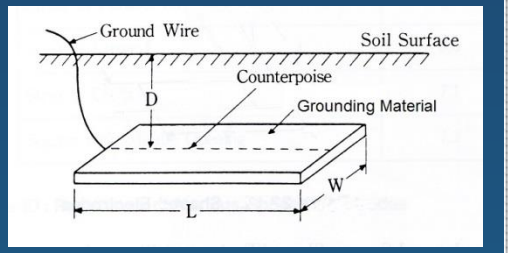
- Since ionic current flow is associated with soil corrosion reactions, high soil resistivity will arguably slow down corrosion reactions. Soil resistivity generally decreases with increasing water content and the concentration of ionic particles. Sandy soils are high up on the resistivity scale and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

Easiest Way To Improve Soil Resistivity

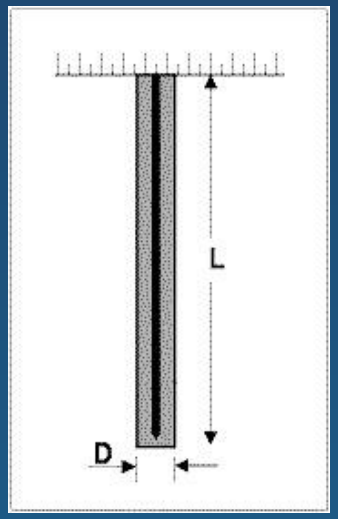
Use a grounding enhancing material in the grounding system.

Two of the most common ones are:

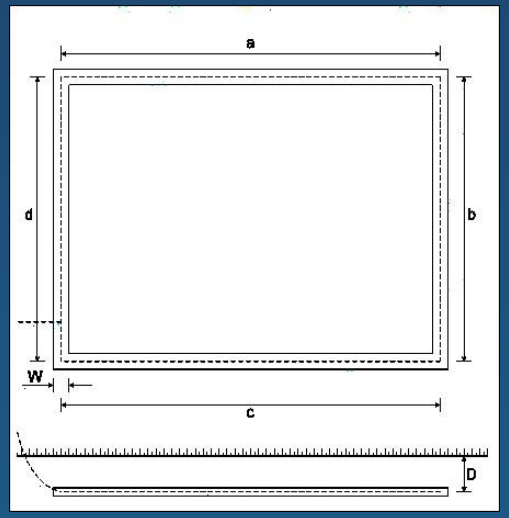
Bentonite and Conductive Cement



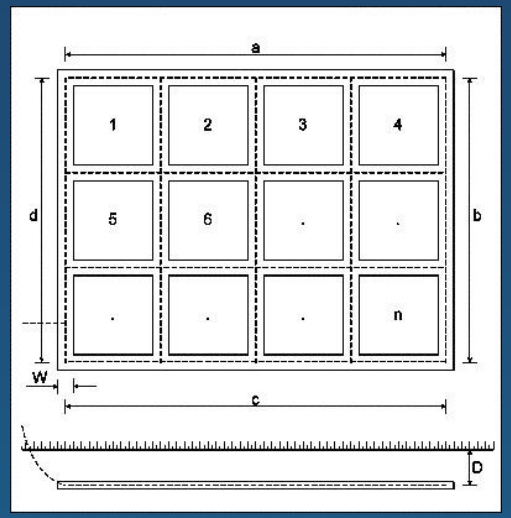
Lateral Electrode



Vertical Electrode



Perimeter Electrode



Grid Electrode

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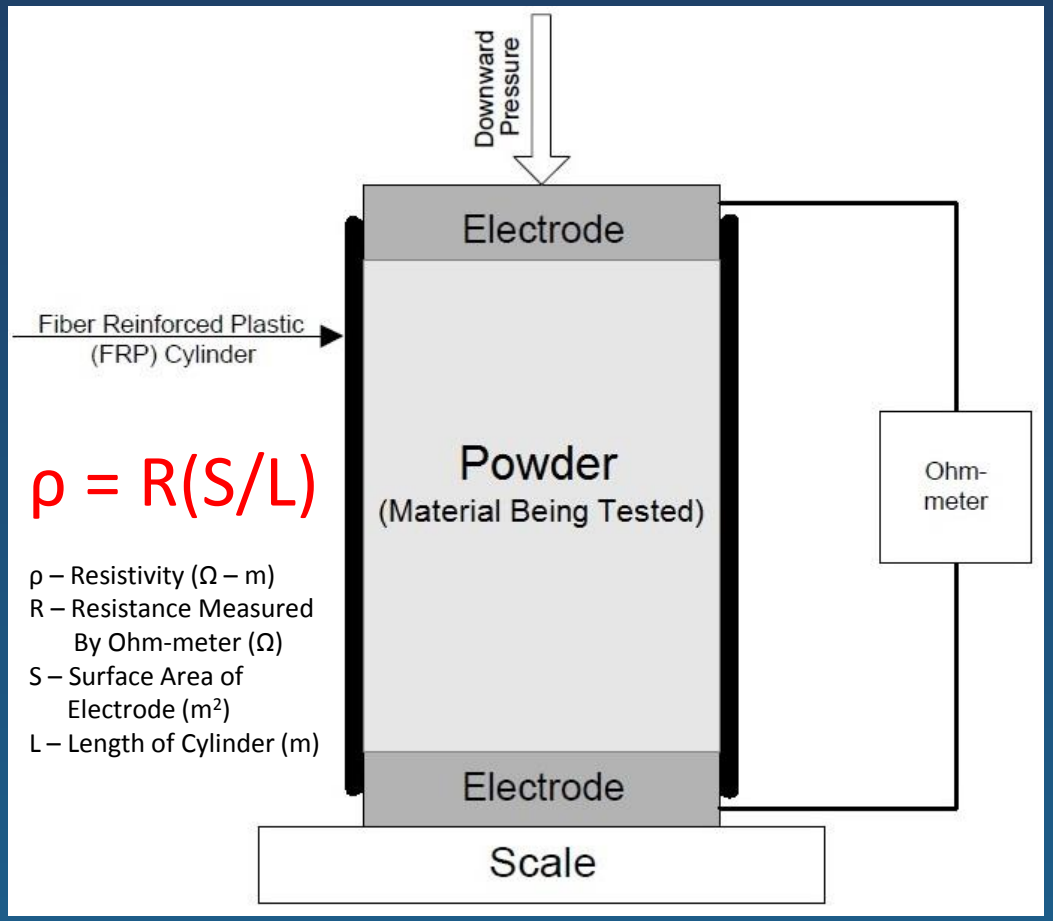
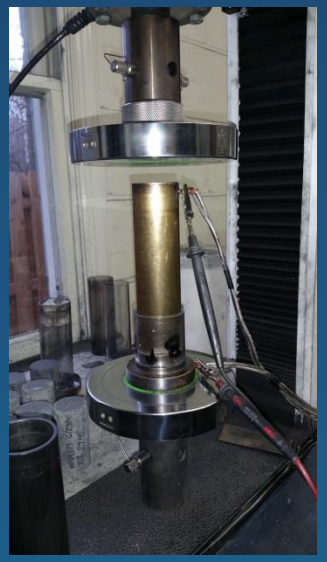
Measuring The Resistivity of Bentonite & Conductive Cement

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



$\rho = R(S/L)$

ρ – Resistivity (Ω – m)
R – Resistance Measured By Ohm-meter (Ω)
S – Surface Area of Electrode (m^2)
L – Length of Cylinder (m)



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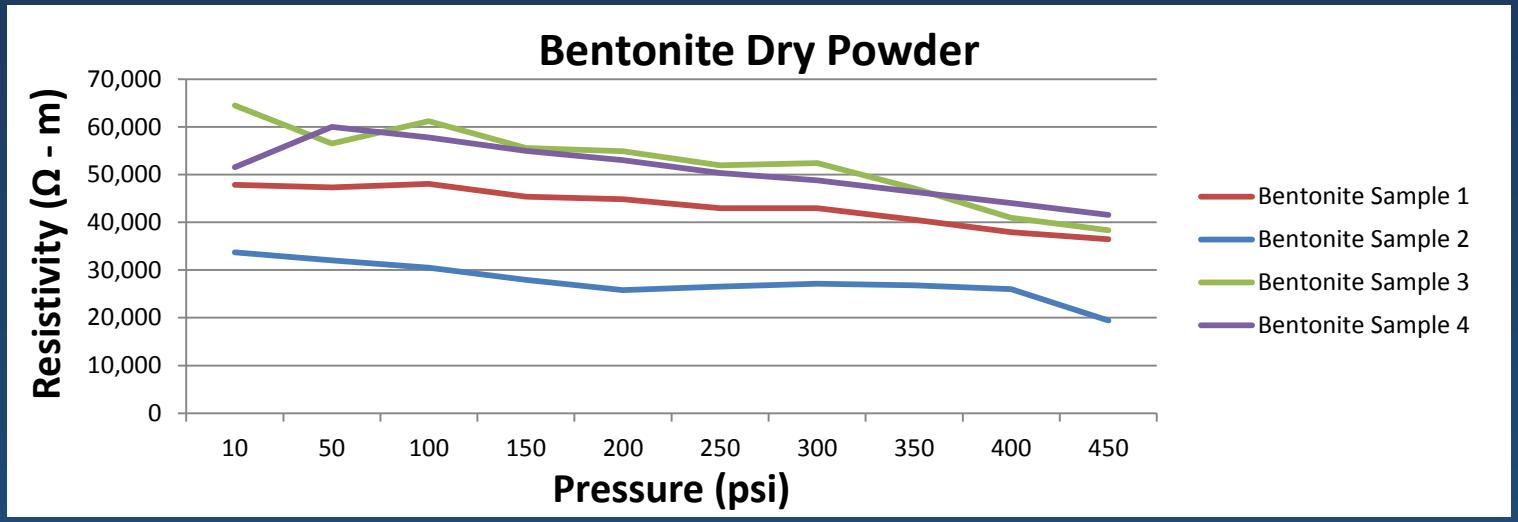
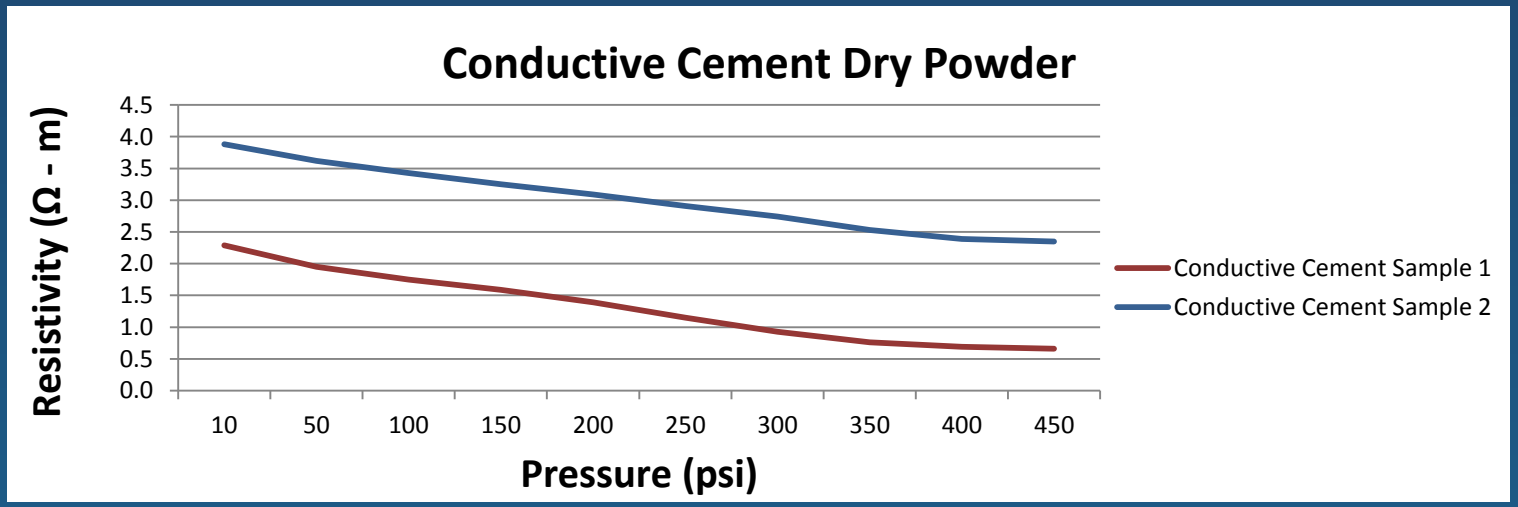
Resistivity of Powdered Bentonite & Conductive Cement





Bentonite Average: 42,557 Ω-m

Conductive Cement Average: 2.17 Ω-m

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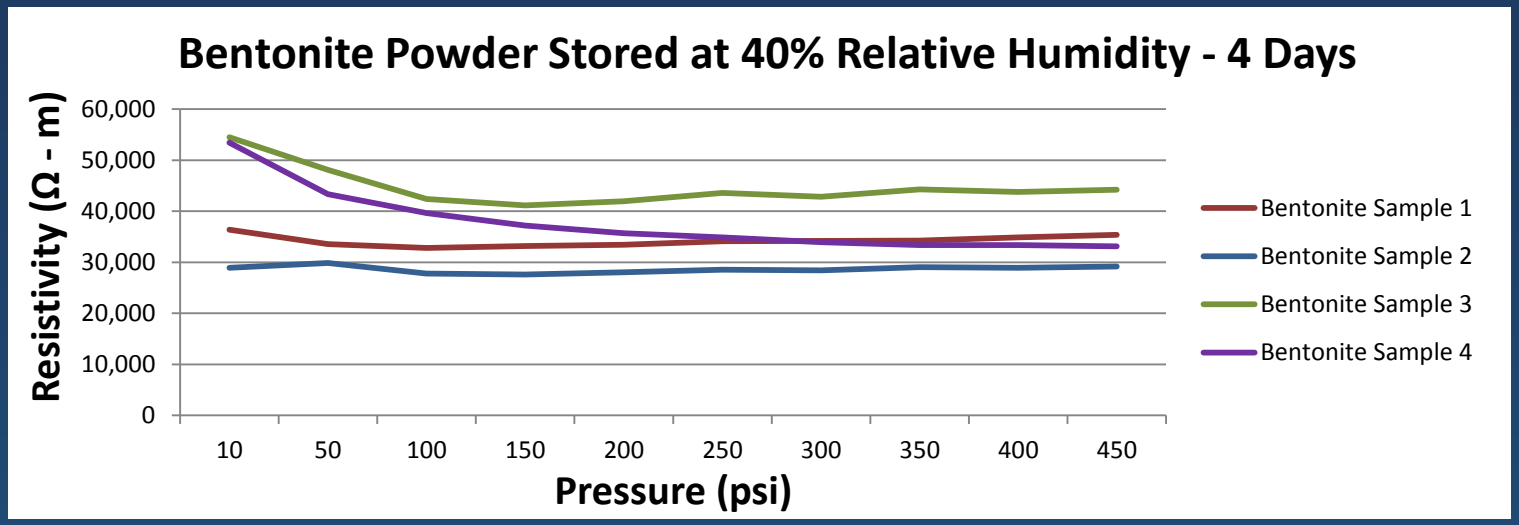
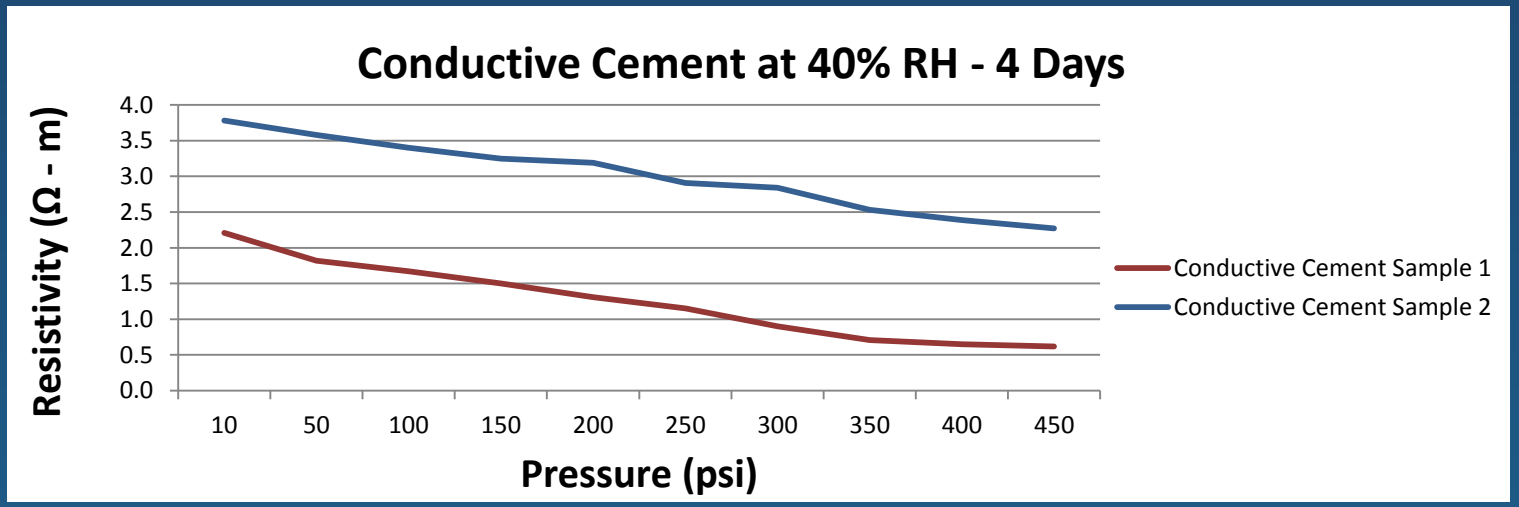
Resistivity of Powdered Bentonite & Conductive Cement





Bentonite Average: 36,333 Ω-m

Conductive Cement Average: 2.13 Ω-m

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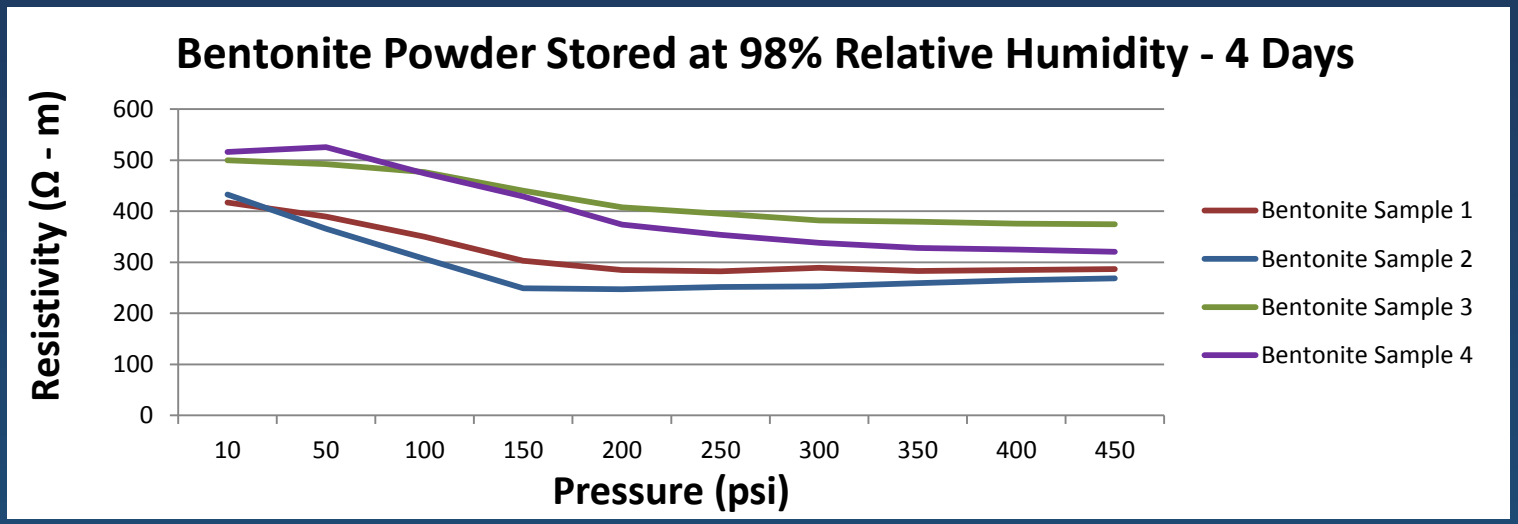
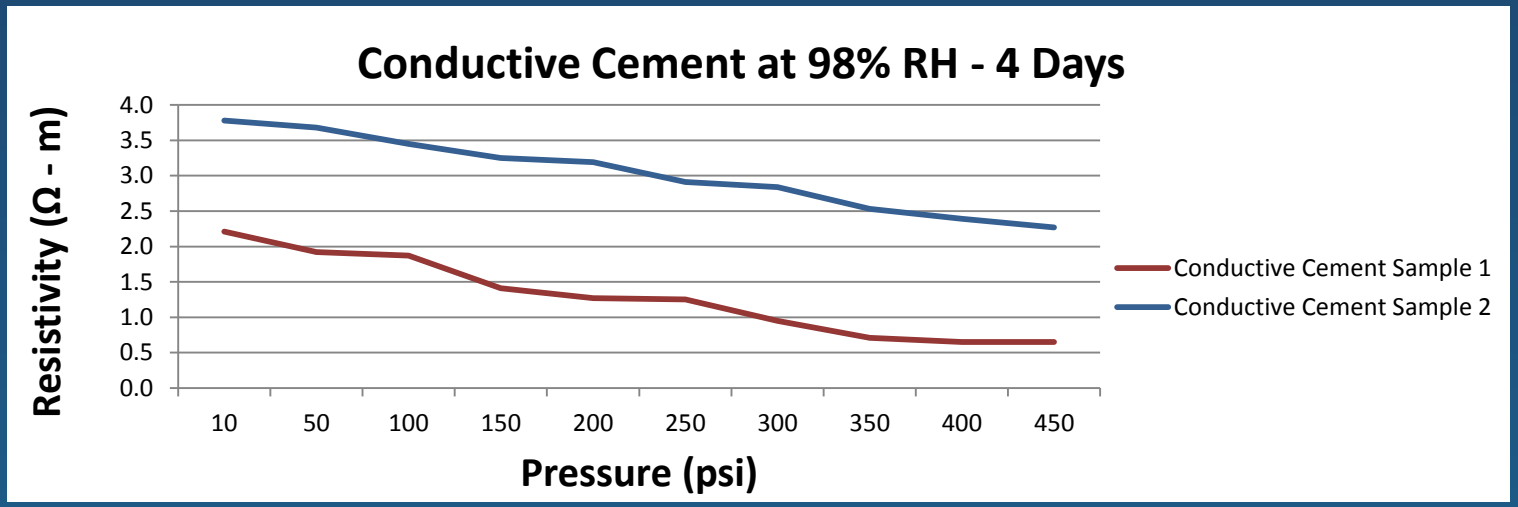
Resistivity of Powdered Bentonite & Conductive Cement





Bentonite Average: 356.9 Ω-m

Conductive Cement Average: 2.13 Ω-m

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Resistivity & pH of Mixed Bentonite & Conductive Cement

Mixed according to manufactures installation instructions.

Sample	Resistivity (Ω – m)	pH
Bentonite Sample 1	15.5179	9.3
Bentonite Sample 2	13.6271	9.6
Bentonite Sample 3	12.7418	4.9
Bentonite Sample 4	16.3495	9.2
Conductive Cement 1	2.2984	10.6
Conductive Cement 2	3.8825	11.8

Acidic !

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

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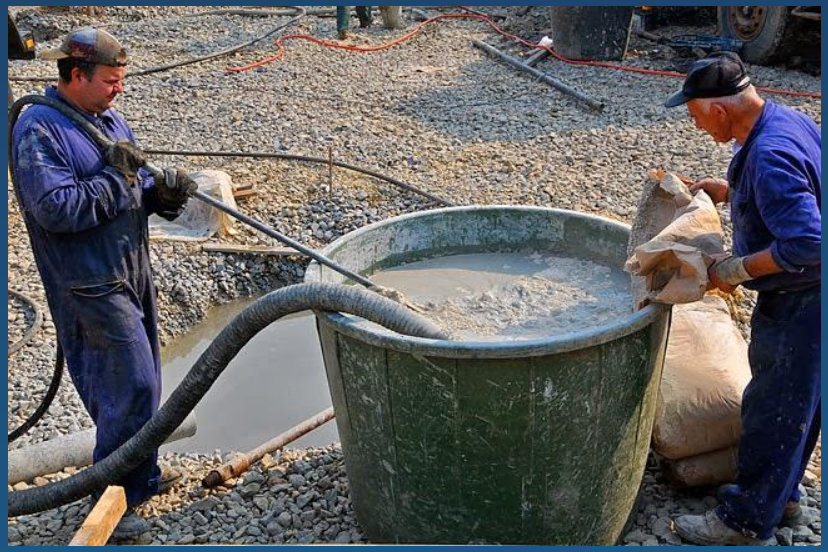
Why Use Bentonite as a Ground Enhancing Material?

- 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.

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Bentonite and The Donald

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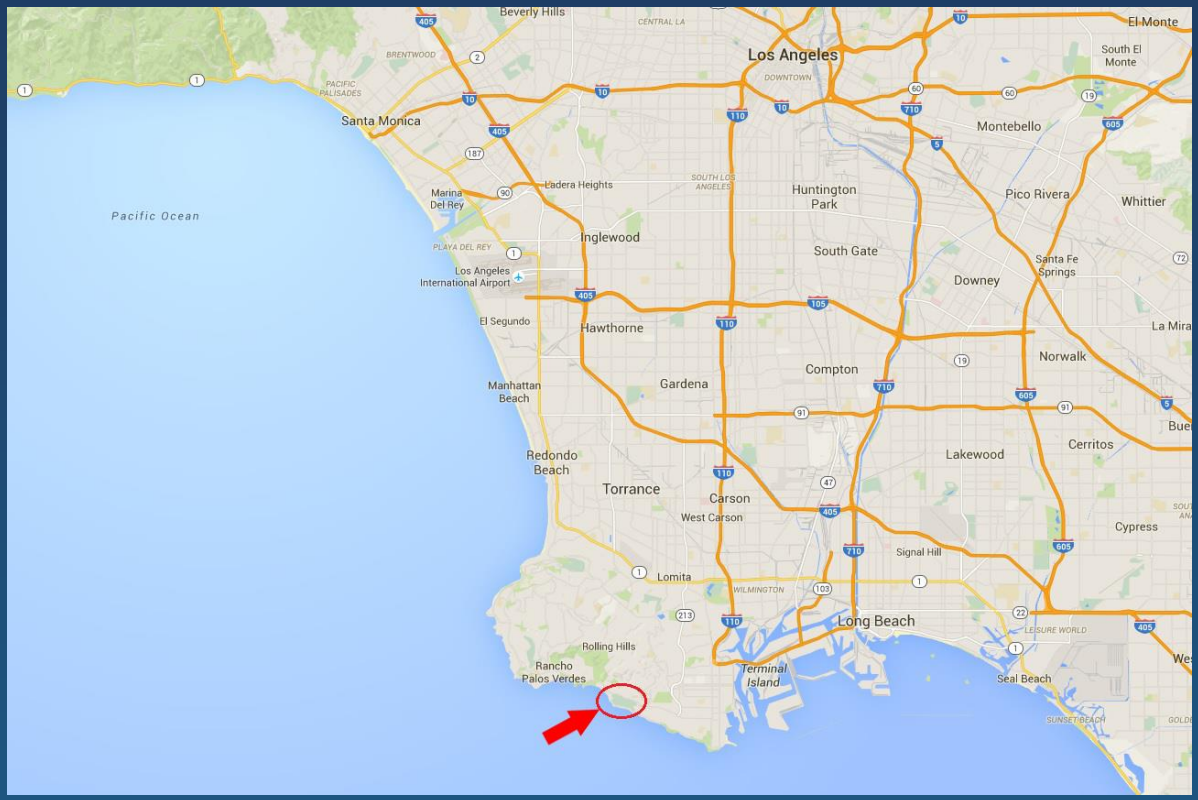
- 60 years ago, Edward Zuckerman bought a sloping 150 acre garbanzo bean field rising up from the cliffs of the ocean on the Palos Verdes Peninsula south of Los Angeles.



- 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.

Ocean Trails Golf Course

- 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.
- Construction began in 1998.

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.

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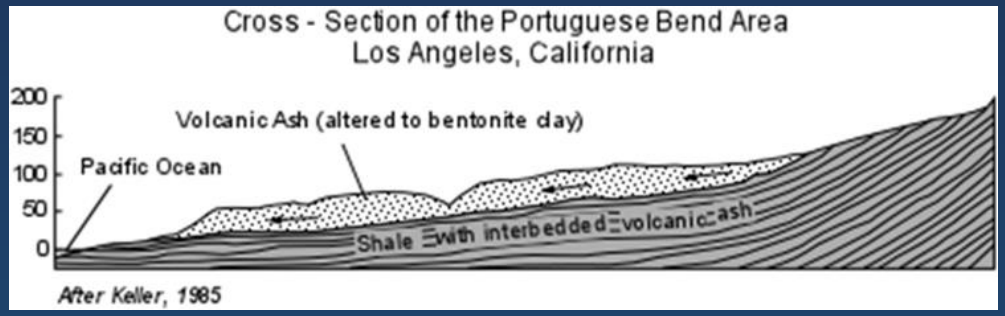
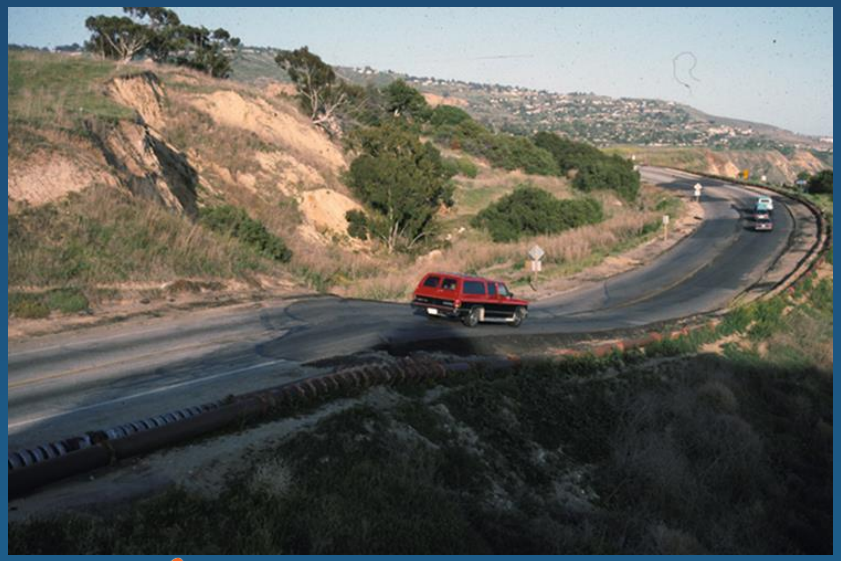
- Original Budget: $126 million
- Damages: $61 million
- Lawsuits followed.

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



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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

2 – 500mL Glass Beakers - 3.75in (Dia) x 5in (H)

100 mL Bentonite & 300 mL Conductive Cement

Manufacturers Mixing Instructions:
1 part Bentonite : 4 parts Water

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

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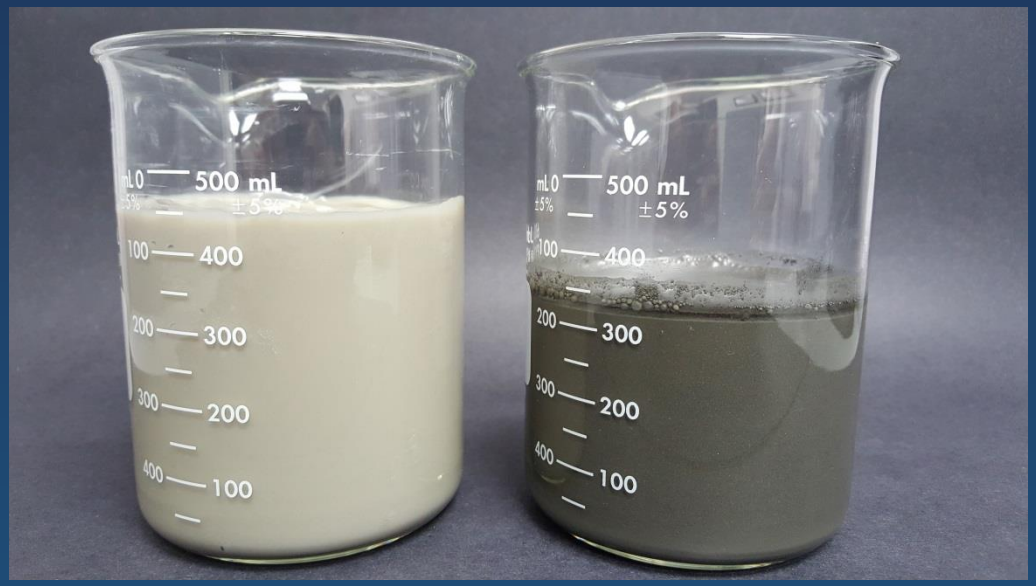
Bentonite vs. Conductive Cement: Experiment 1 - Mixing

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.

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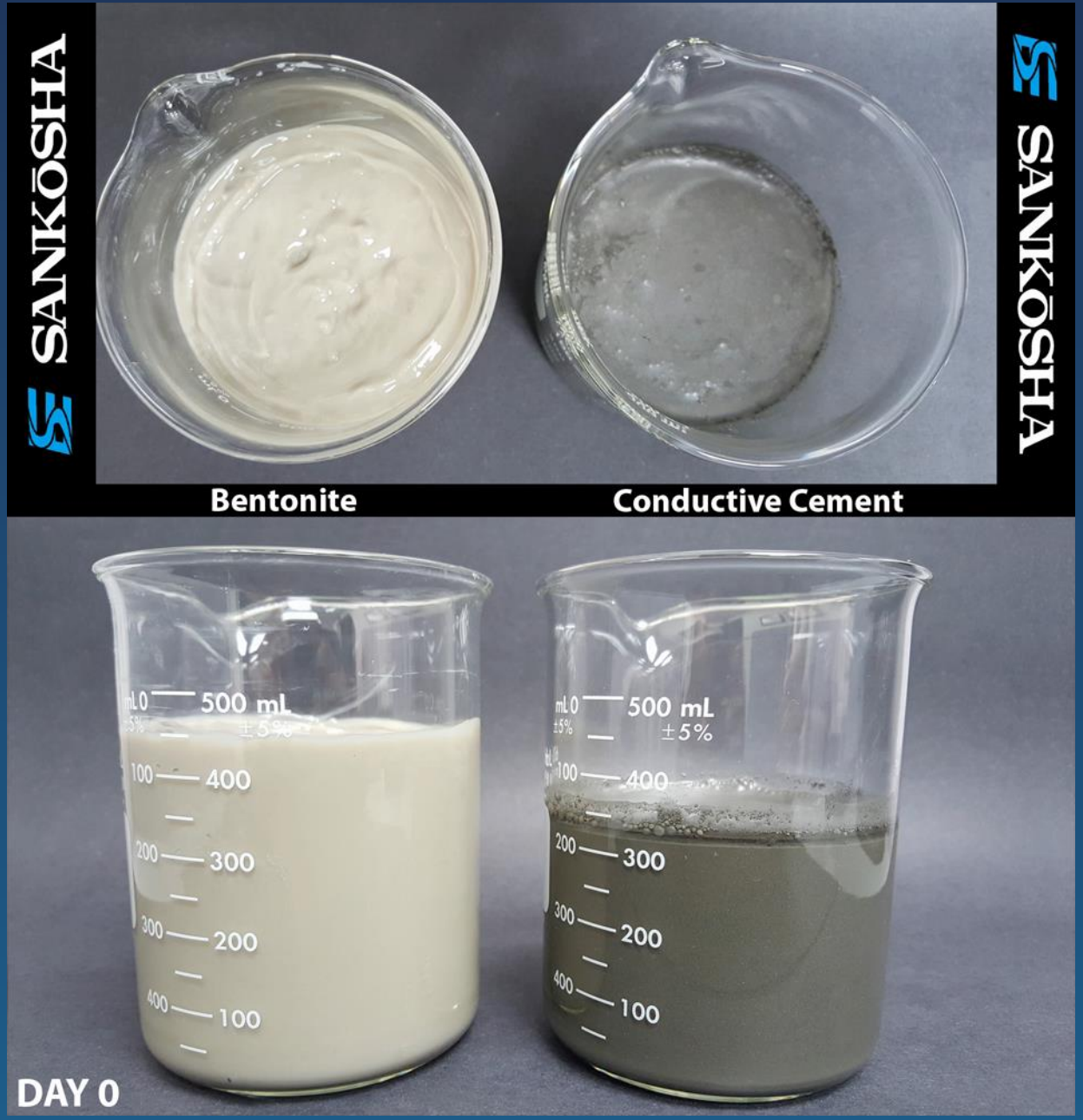

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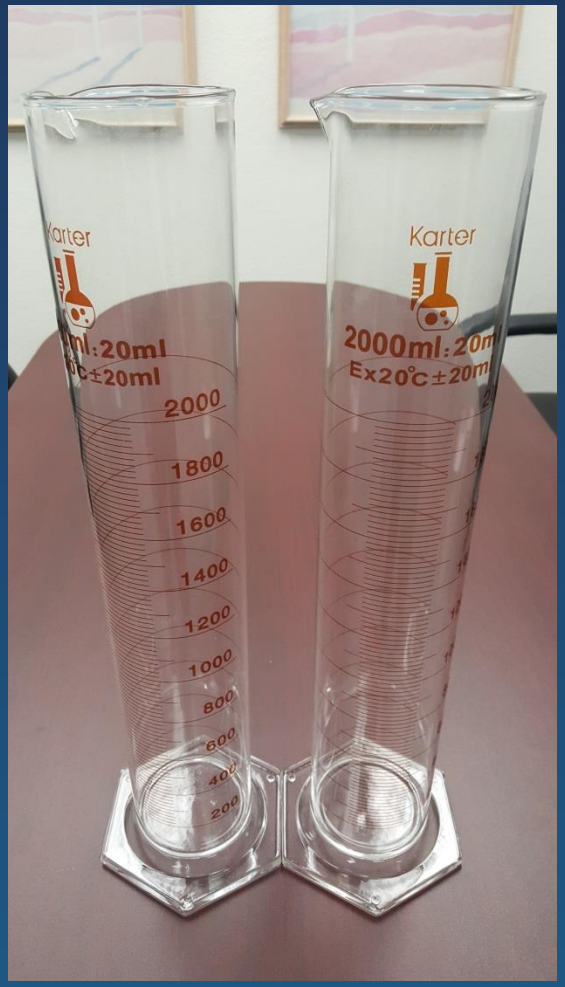
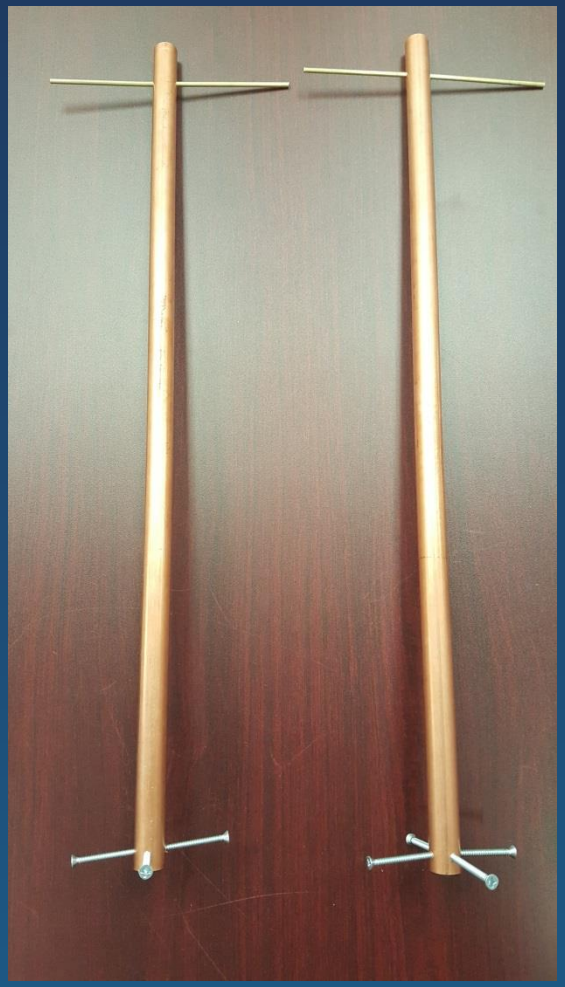
Bentonite vs. Conductive Cement: Experiment 2 - Preparing



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



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

2 - Vertical Grounding Rods

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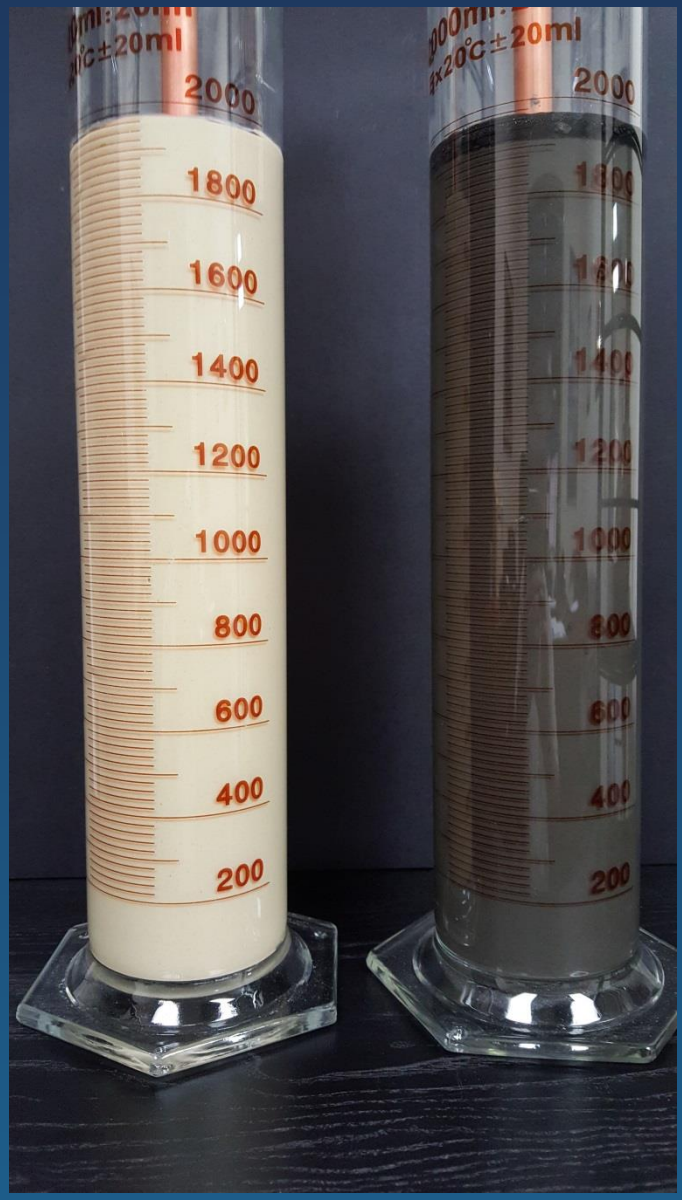
Bentonite vs. Conductive Cement: Experiment 2 - Mixing



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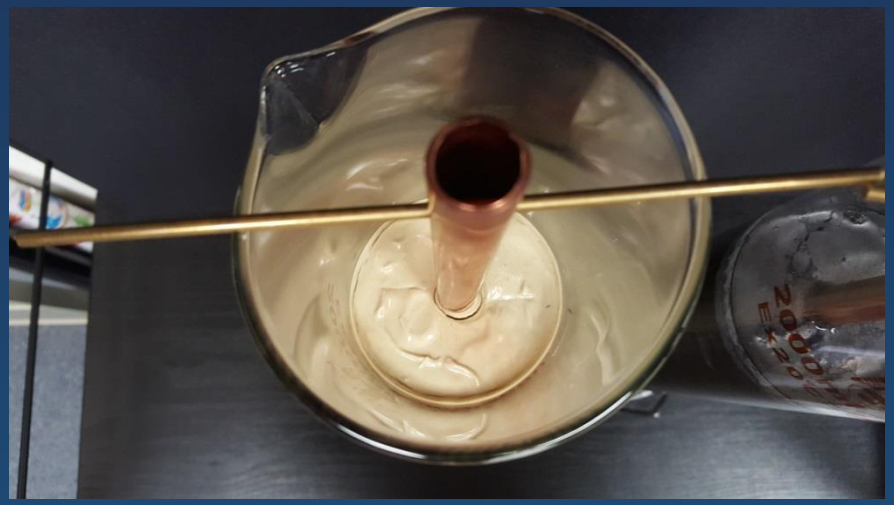
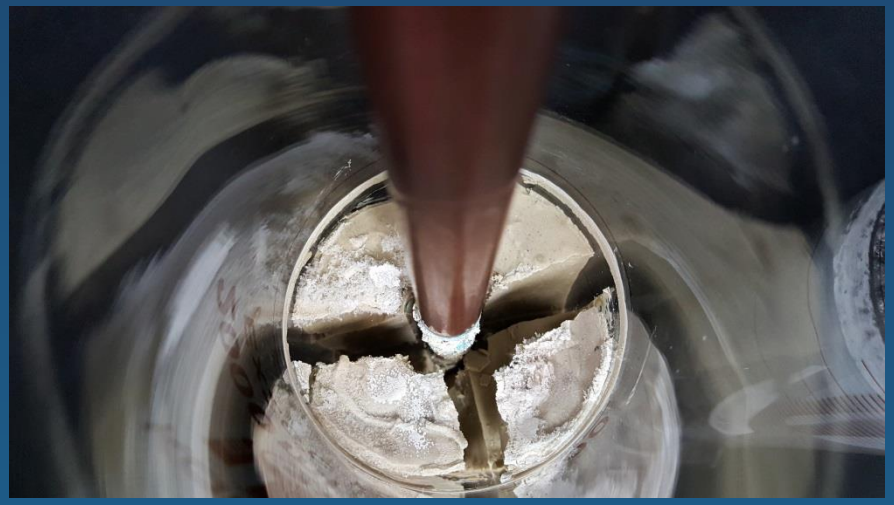
Bentonite
2000
1800
1600
1400
1200
1000
800
600
400
200
SANKŌSHA
Conductive
Cement
DAY 0

Bentonite Vs. Conductive Cement: Experiment 2

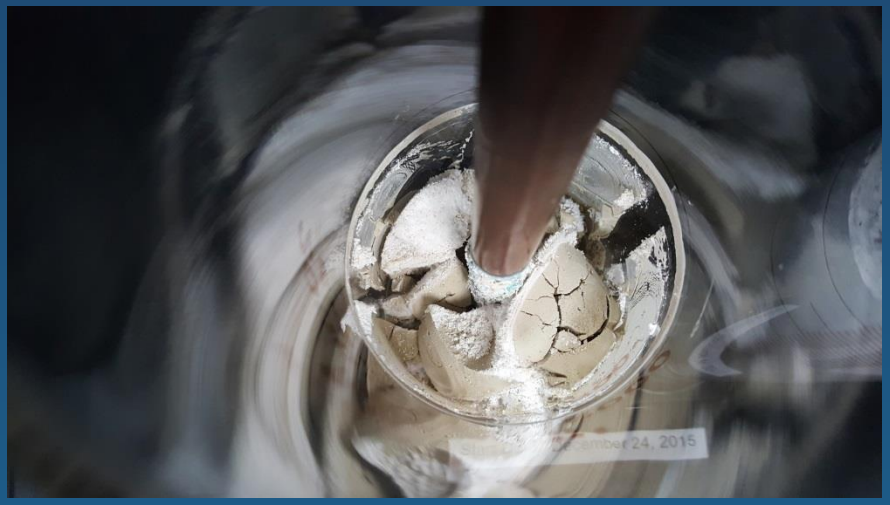


Day 1 – Cracks start forming

Day 5 – Separating from Electrode



Day 36 – White crystals form



Day 90

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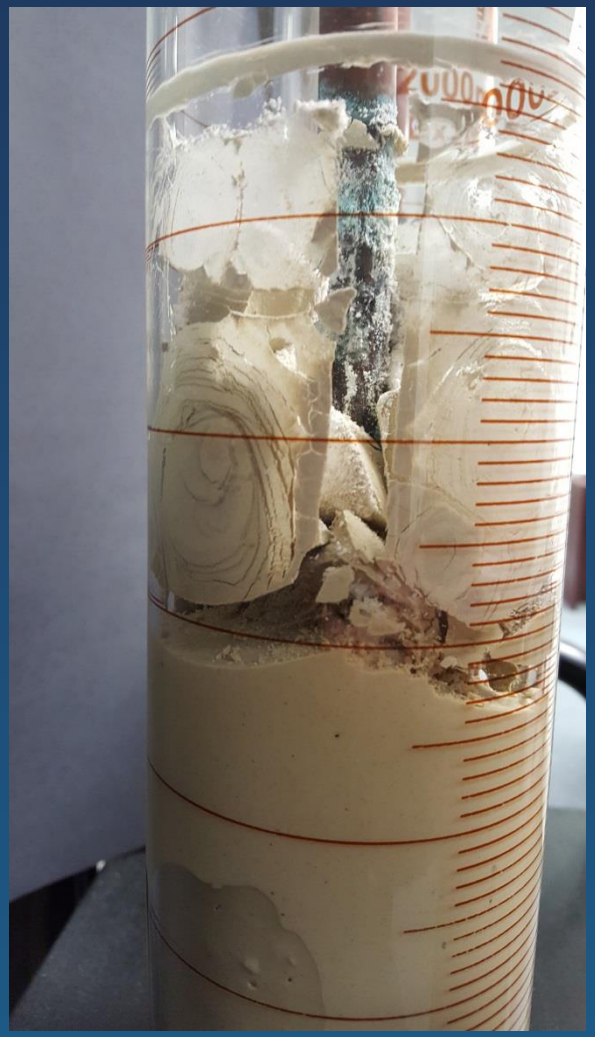
Bentonite Vs. Conductive Cement: Experiment 2

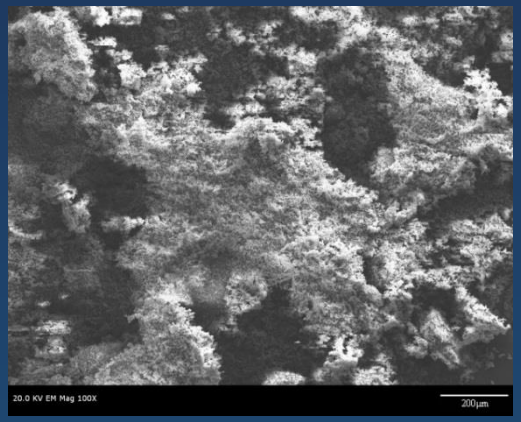
Day 21 – Side View

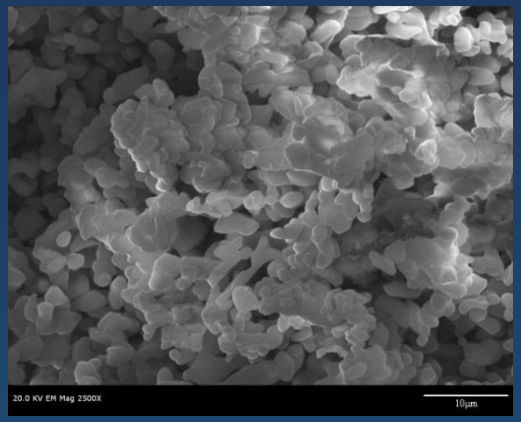


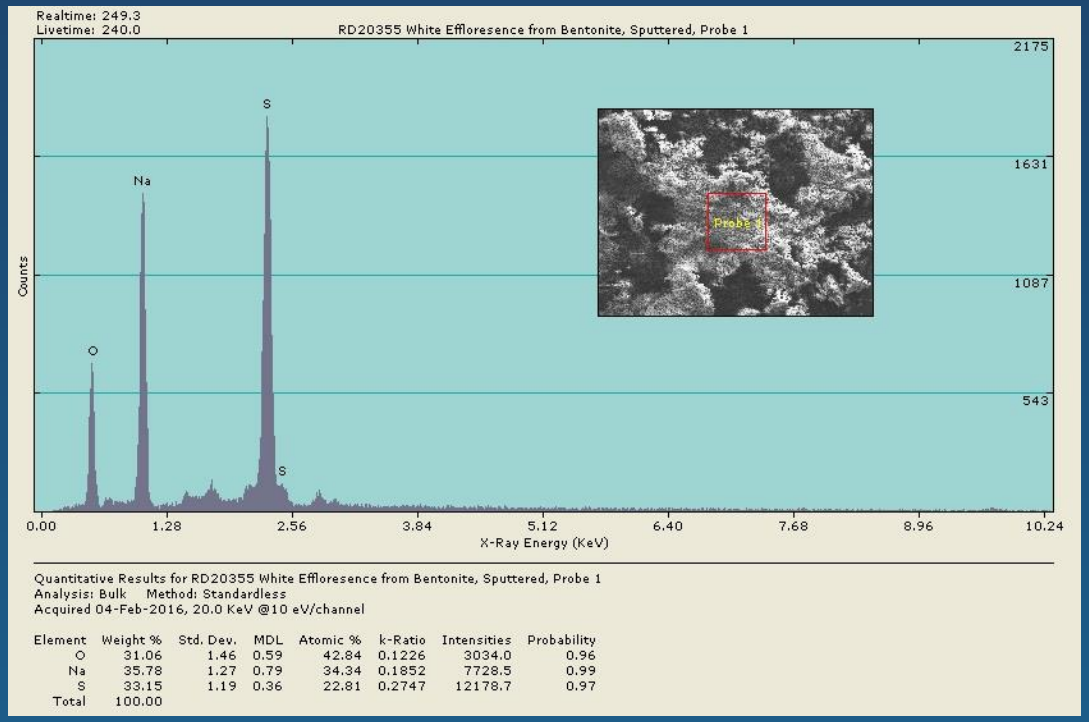
Day 74 – Side View

Day 74 – Front View

Analysis of White Crystals







Sodium Sulfate (Na_2SO_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_2SO_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.

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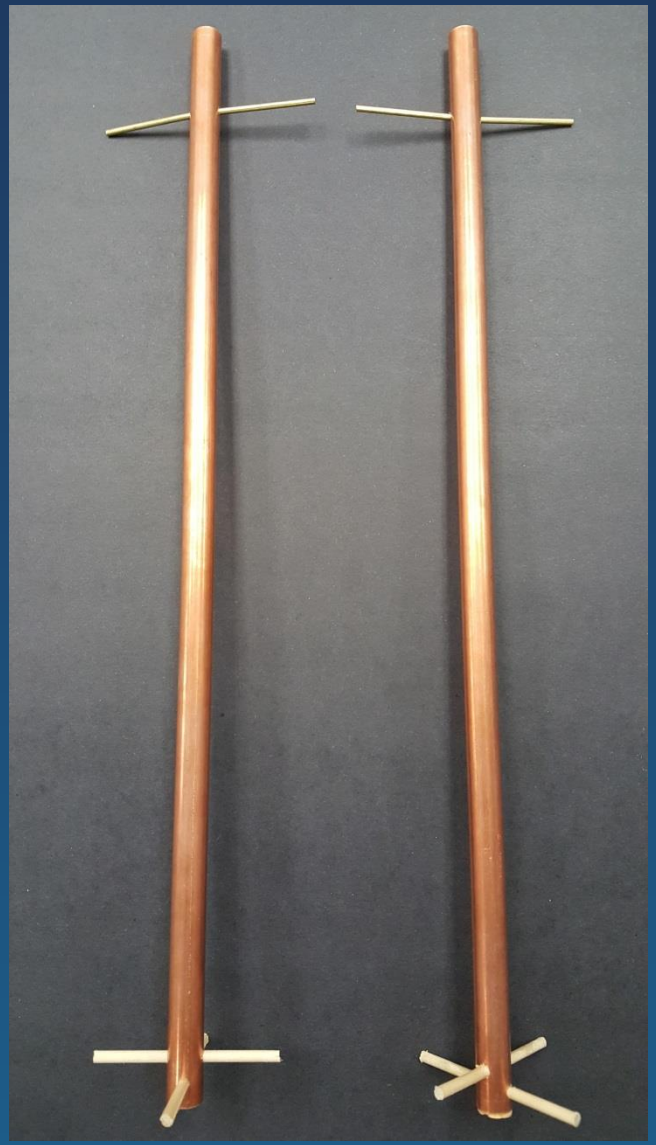
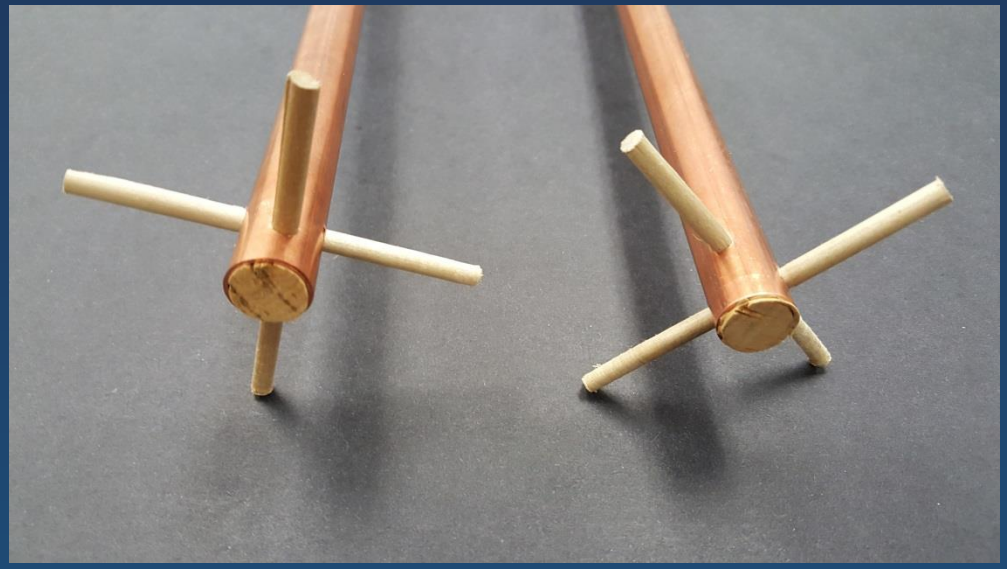
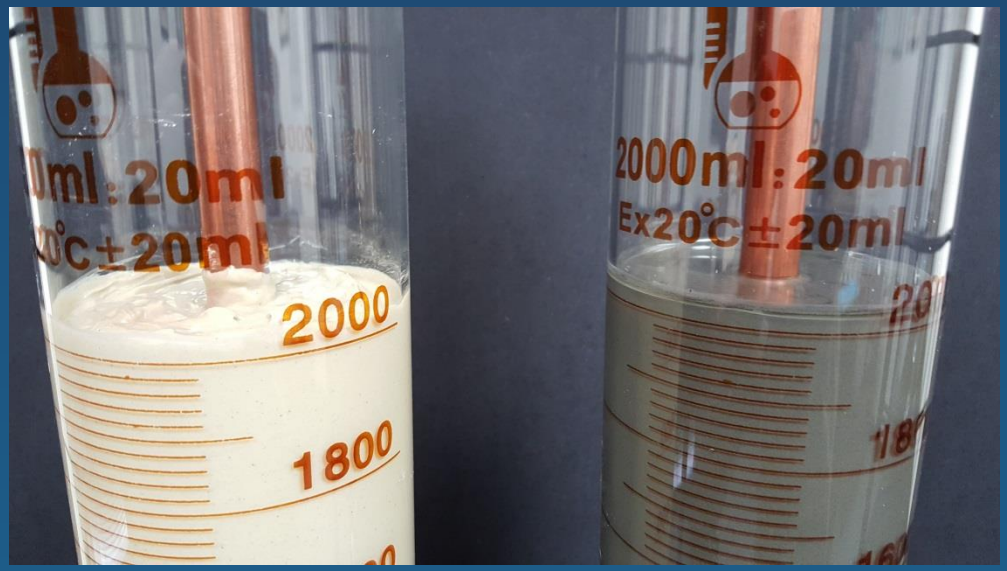
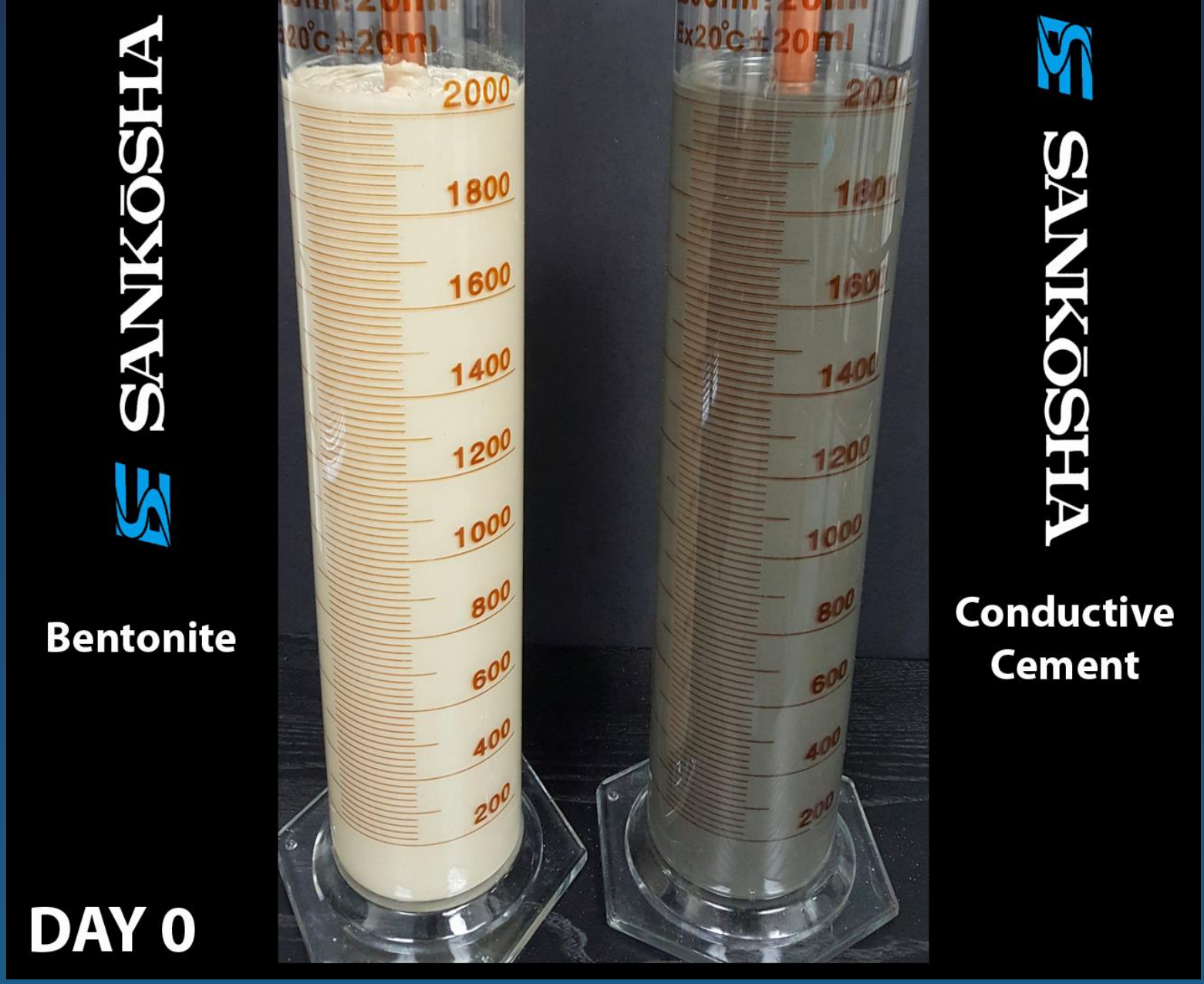
Bentonite Vs. Conductive Cement: Experiment 3








SANKŌSHA
Bentonite
DAY 0
SANKŌSHA
Conductive
Cement
2000
1800
1600
1400
1200
1000
800
600
400
200

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

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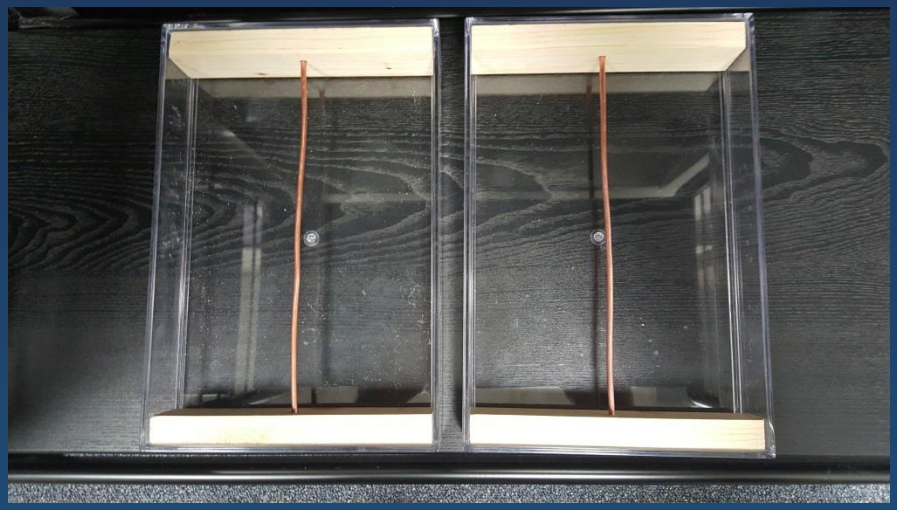
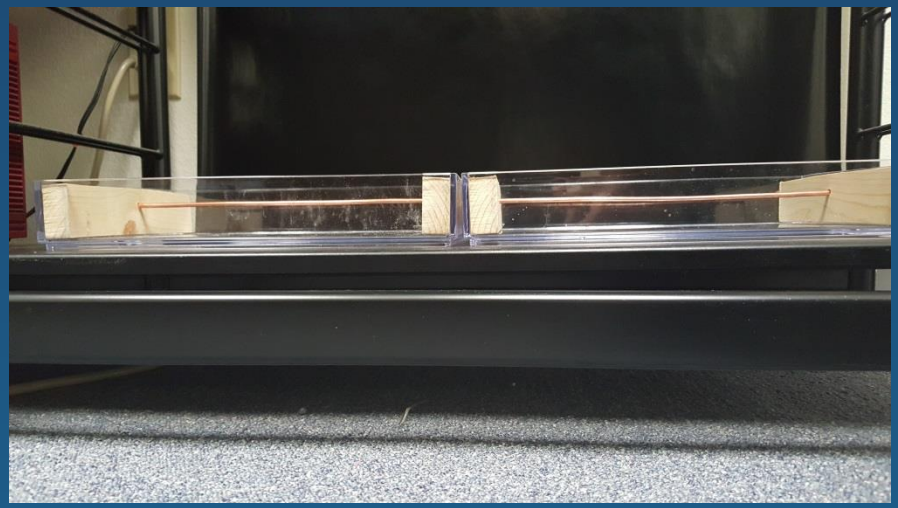
Bentonite vs. Conductive Cement: Experiment 4 - Preparing



Plastic Trays to Simulate Horizontal Grounding

Wood Blocks to Suspend Grounding Wire

12in (L) x 8in (W) x 1.5in (D)



Grounding Wire at 1 inch height

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Bentonite vs. Conductive Cement: Experiment 4 - Mixing

Mixing of Conductive Cement

Pouring of Bentonite

Both Filled to Top Covering Grounding Wire

Ready for Experiment

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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

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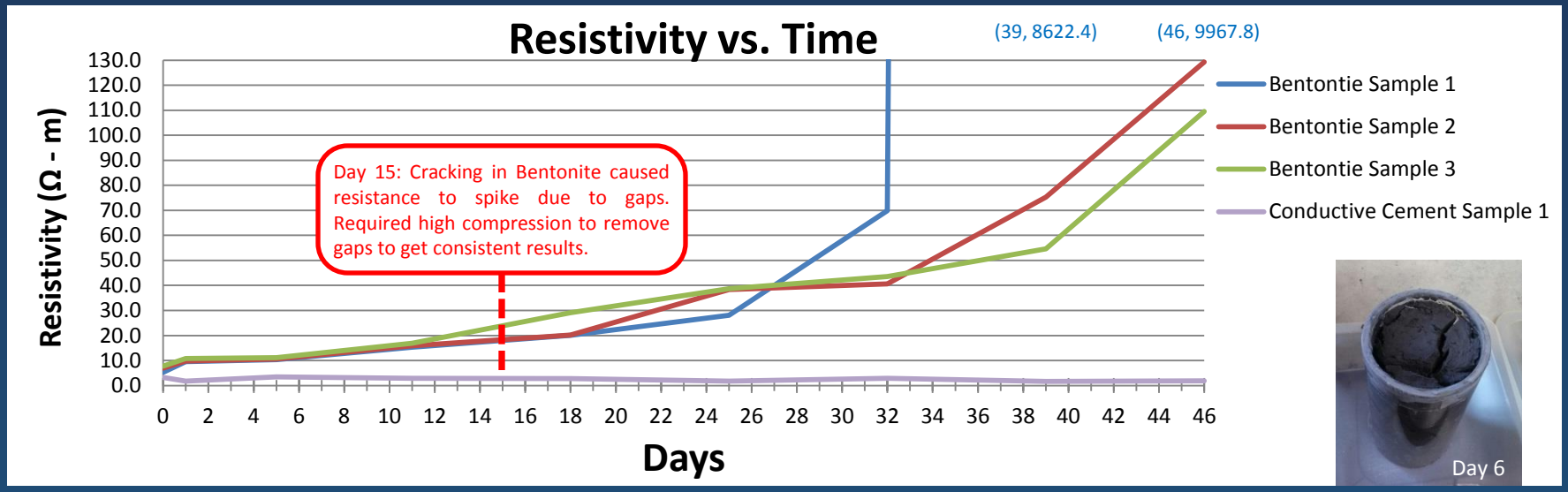
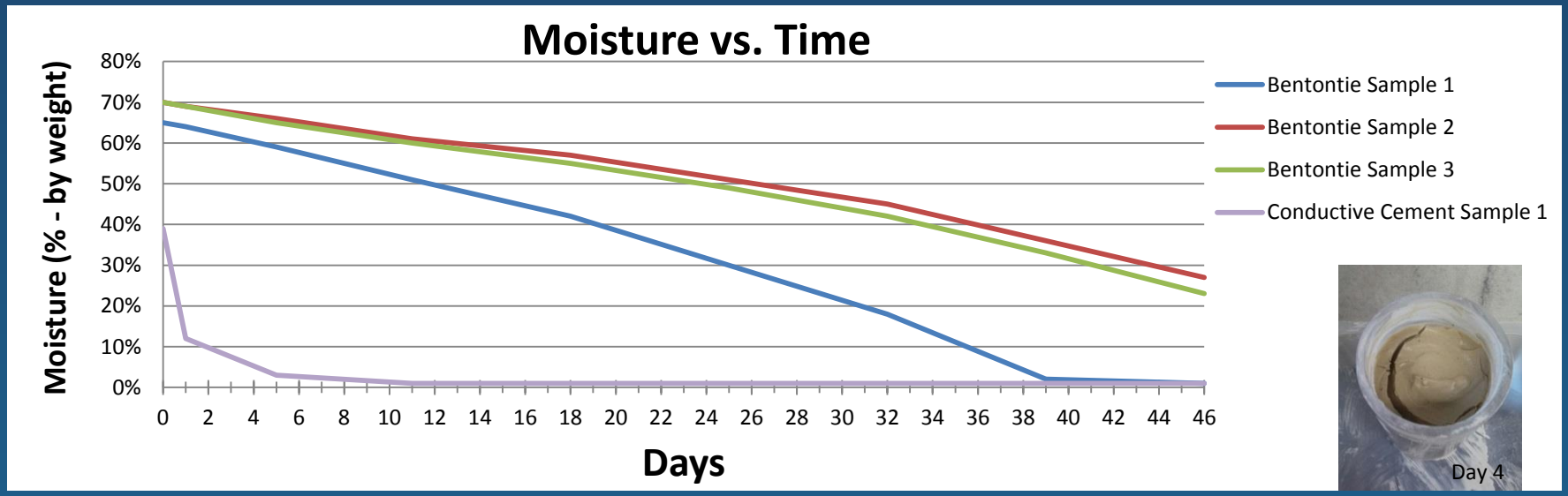
Lab Testing of Resistance & Moisture vs. Time





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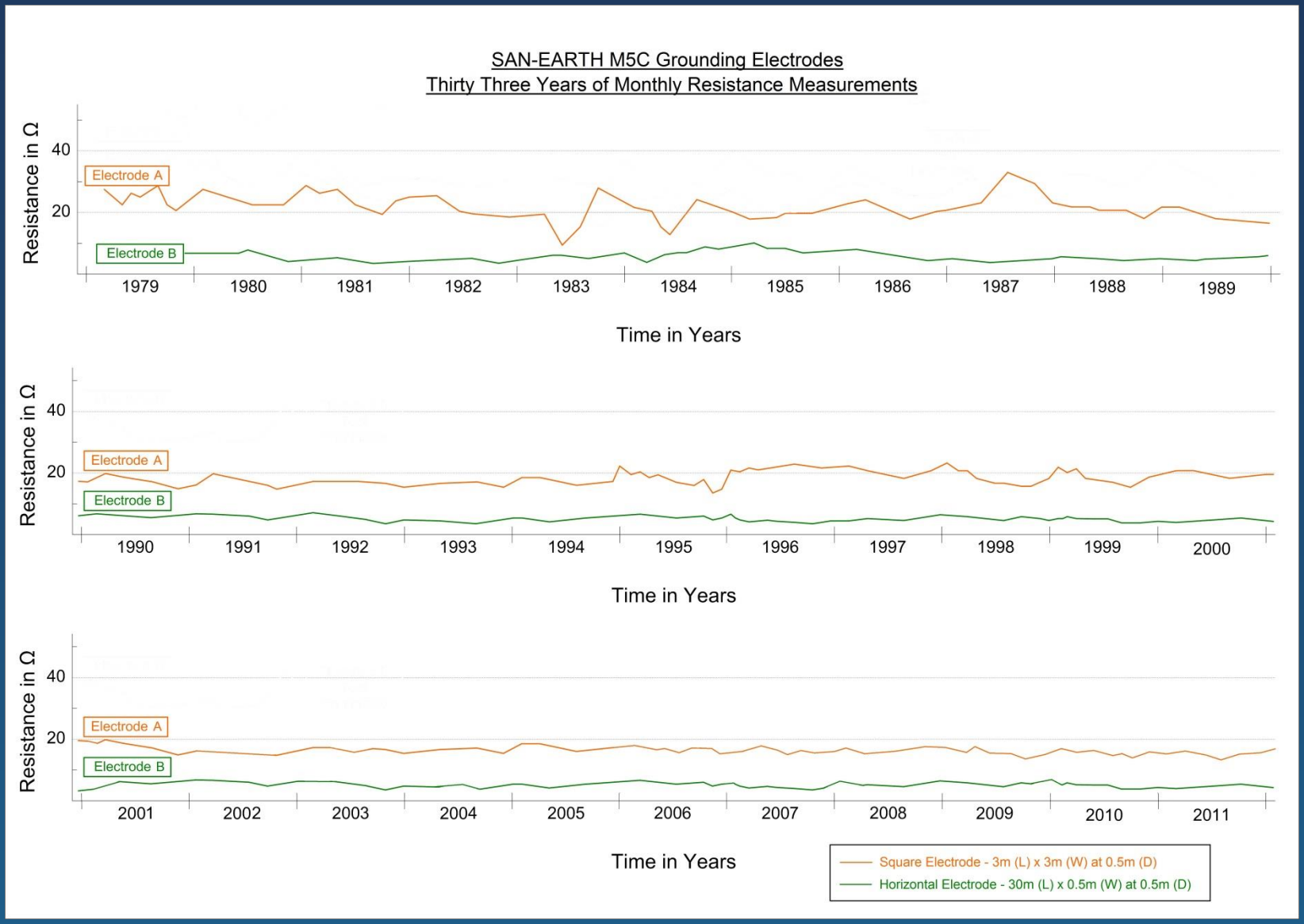
Long Term Stability of Conductive Cement



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Conclusion: Bentonite vs. Conductive Cement

Grounding Property	Bentonite	Conductive Cement	Winner
Low Resistance			
Makes Good Contact With Surrounding Soil & Electrode			
Helps Prevent Electrode Corrosion			
Long Life – Stays In Place			
Theft Deterrent			
Low Cost			
Maintenance Free			
Easy To Install			
Environmentally Safe			
Consistent Performance			
Chemical Resistant			

Conclusion

- 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 lowing 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?

Thank You!

Questions?