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Environmental Soil Stabilization, L.L.C.

# *Expansive Soils: Can't Live Without Them, But Can Live With Them*

*Use of EcSS 3000™ to Treat Expansive Clays*

*Presented To:*
*Foundation Performance Association*
*Houston, Texas*

*November 14, 2007*

**Presented by:**
**Russell J. Scharlin, P.E.**
**Environmental Soil Stabilization, LLC**

# Introduction to ESSL

- ESSL established 1993 by Johnny Sherwood
- Sole purpose:  Stabilize expansive clays
- Nearly 40 million square feet stabilized
- Building pads, pavement subgrades, swimming pools, flatwork
- New construction and existing structures/pavements

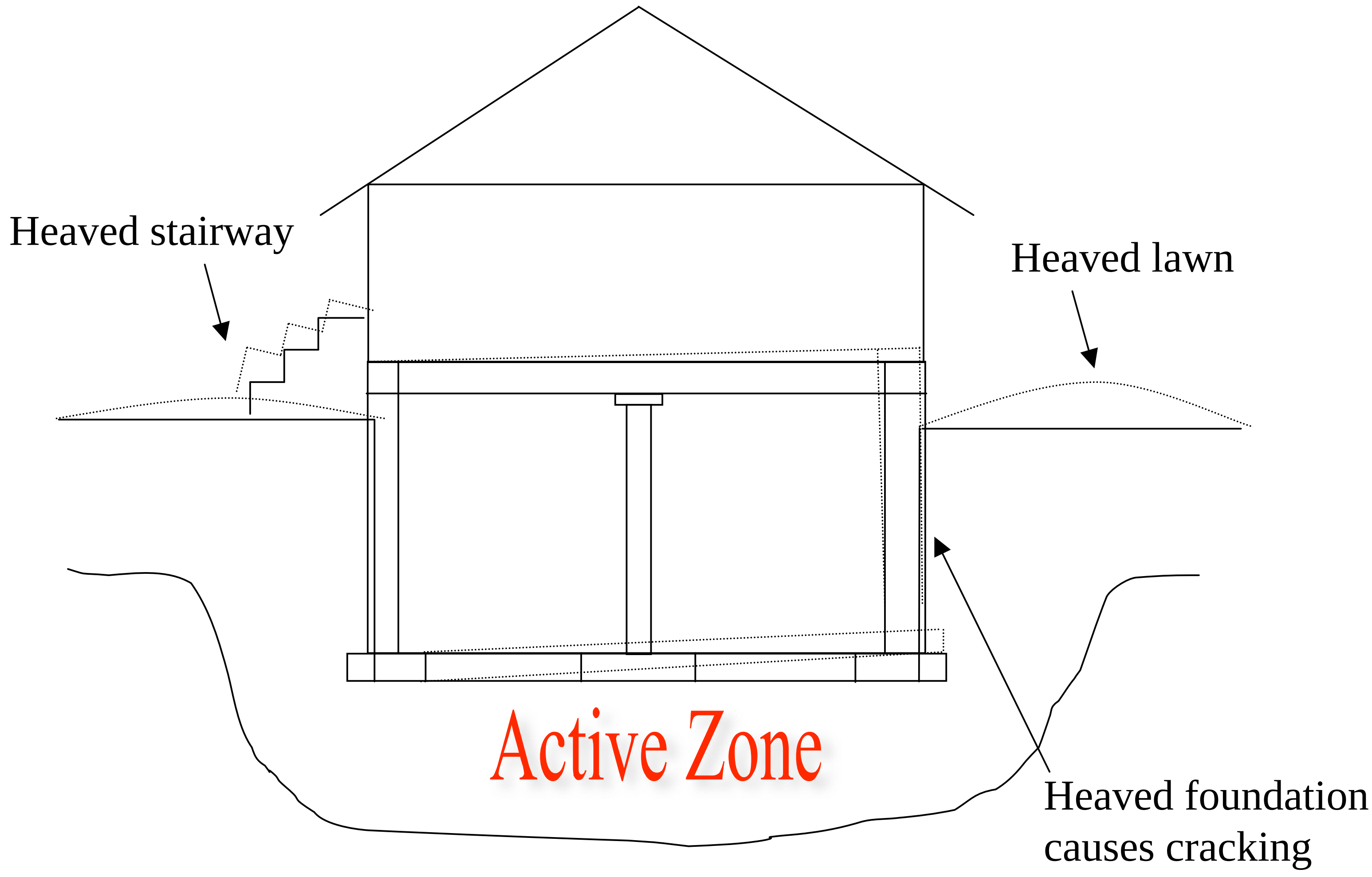
# Clients/Owners (Partial List)

- D/FW International Airport
- Dr. Pepper Bottling Company
- Exxon Corp.
- Granite Construction Co.
- Granite Properties
- Holiday Inn Express
- JPI Construction
- Kentucky Fried Chicken
- Krispy Kreme Doughnuts
- North Texas Tollway Authority
- Plano ISD
- 7-Up Bottling Company
- Tarrant County College District
- Texas Instruments
- Texas Dept. of Transportation
- 24-Hour Fitness
- USDA, Rural Develop. Agency
- U.S. Forest Service
- U.S. Postal Service
- Virgin Islands Housing Finance Authority

# Presentation

- Problems with Clays
- Stabilization of Clays - General
- Why do Clays Expand and Shrink?
- Stabilization of Clays Using EcSS 3000™
- Summary of Texas A&M and Penn State Research to Date
- Case Histories

# Problems With Expansive Soils



# Stabilization of Clays

- Types of Stabilization
  - Mechanical Compaction
  - Injection Techniques
- Performance Goals

# Mechanical Compaction

Technique:

- Mix EcSS 3000™ into the soil

Used for:

- Pavement Subgrades (generally 6” – 2’ deep)
- Building Pads (generally 2’ – 4’ deep)

# Injection Technique

Technique

- Hydrogen Ion Exchange Solution Injection (treatment with EcSS 3000™)

Used For:

- Building Pads (7’ - 10’ deep)
- Pavement Subgrades (2’ - 5’ deep)
- Sidewalks/Swimming Pools (3’ - 7’ deep)

# Stabilization Performance Goals

## For Building Pads, Sidewalks / Swimming Pools:

- Normally reduce swell potential to an average of 1% to 2%

## For Pavement Subgrades:

- Requirements vary, depending on stabilization technique
- All typically require compaction to 95% - 100% of the standard Proctor maximum dry density (ASTM D 698).

# Why Do Clays Expand and Shrink?

Basic Molecular Building Blocks

- Silica oxide tetrahedra sheet ($SiO_4$)
- Alumina hydroxide octahedra sheet ($Al(OH)_6$)
- Clay minerals made up of repeating layers of silica and hydrated alumina sheets in a lattice structure

Clay Minerals - Most Common

- Kaolinite: least expansive
- Illite: moderately expansive
- Smectite (montmorillonite): highly expansive

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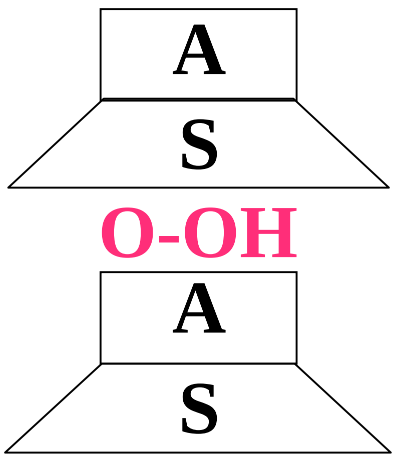
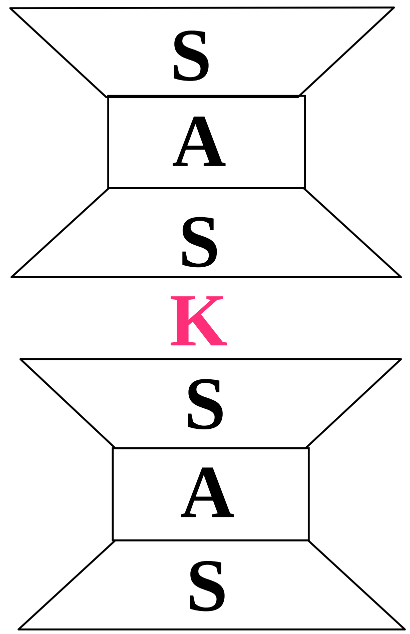
# Most Common Clay Minerals

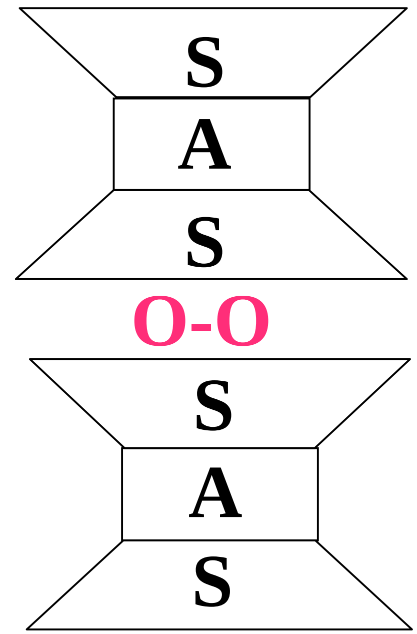
## Kaolinite




## Illite




## Montmorillonite




Alumina Sheet Above Silica Sheet
O-OH Interlayer Bond =
Hydrogen Bond: Very Strong

Alumina Sheet Sandwiched by Two Silica Sheets
K Interlayer Bond =
Potassium Bond: Strong

Alumina Sheet Sandwiched by Two Silica Sheets
O-O Interlayer Bond =
Van der Waal's Bond =
Oxygen Bond: Very Weak
Expanding Lattice

Note: Alumina Sheet also known as Gibbsite Sheet

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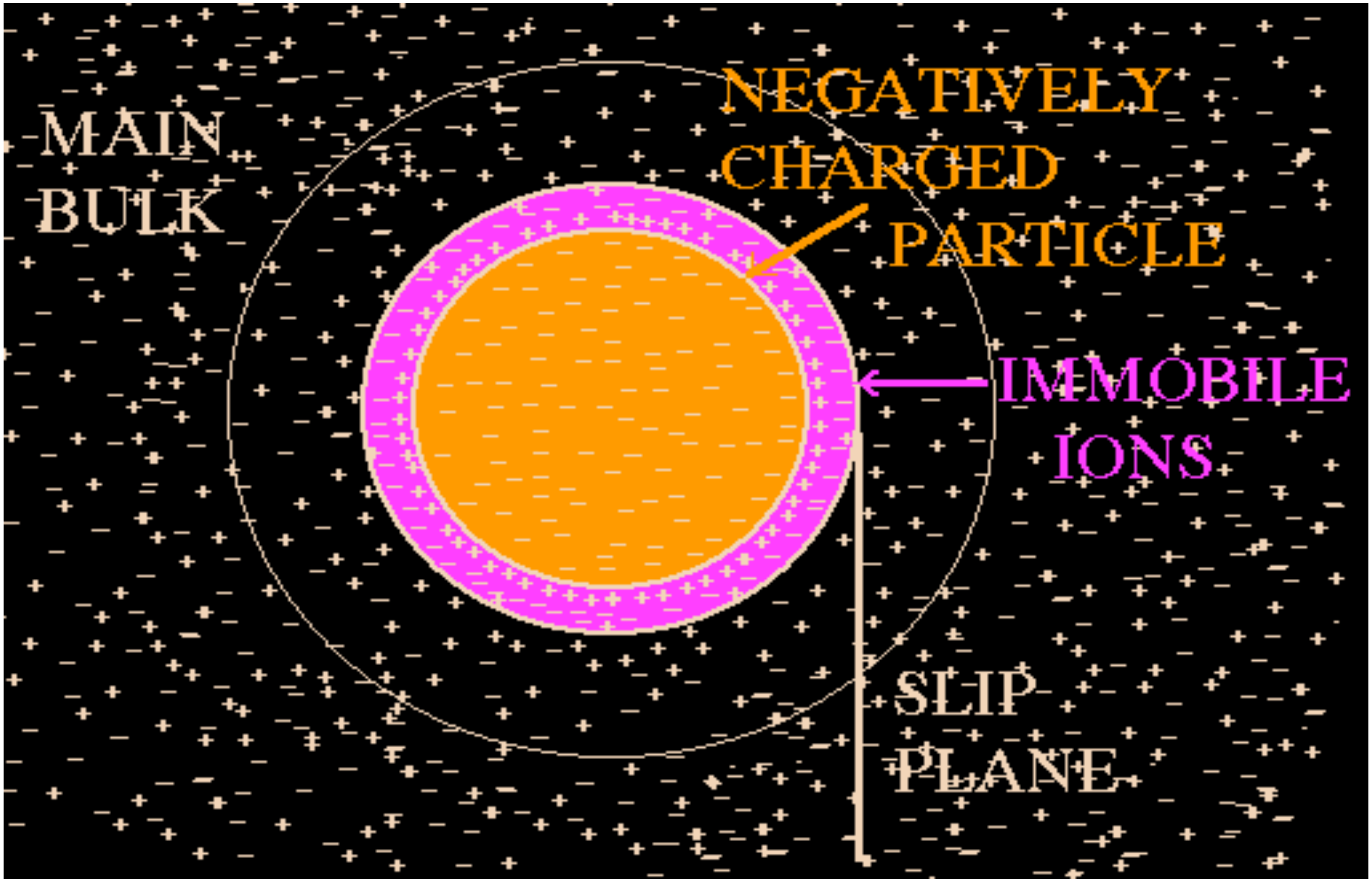
# Charged System

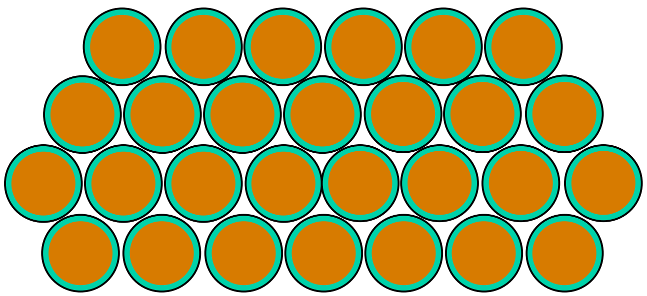


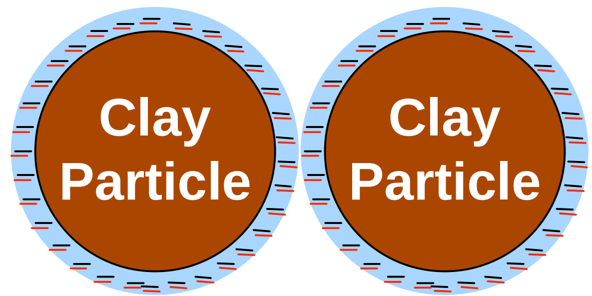
Prepared for
Russ Scharlin 7/5/06
RE: animation
showing EcSS 3000
at molecular levels.

The animation in this presentation will work on MS PowerPoint 2002 versions or later. As you go through each slide, some animation is automatic – it does not require continuous mouse clicks.

# FIRST SWELL MECHANISM

# BEFORE TREATMENT OF CLAY PARTICLES



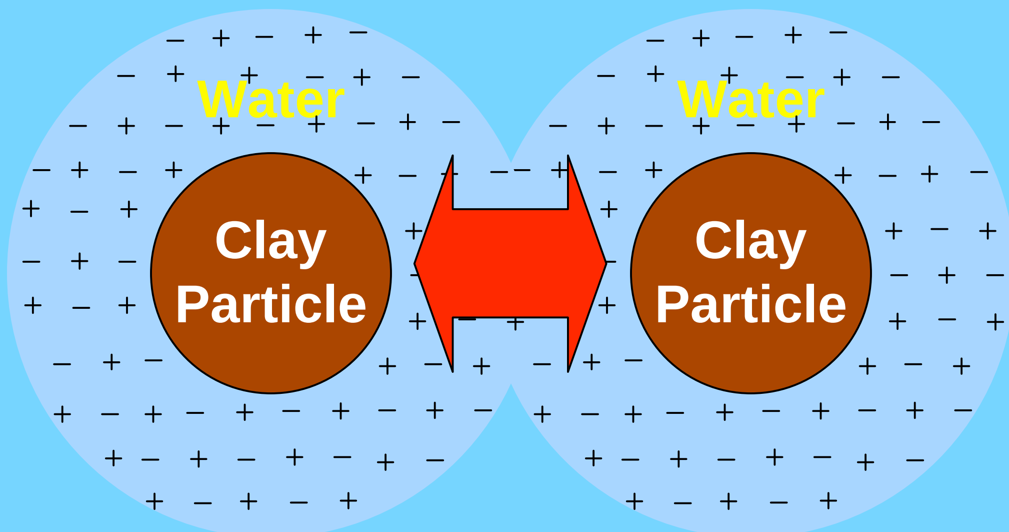



**CLAY: Particles exhibit a net negative charge**

# FIRST MECHANISM OF SWELL

# WHEN WATER BECOMES AVAILABLE

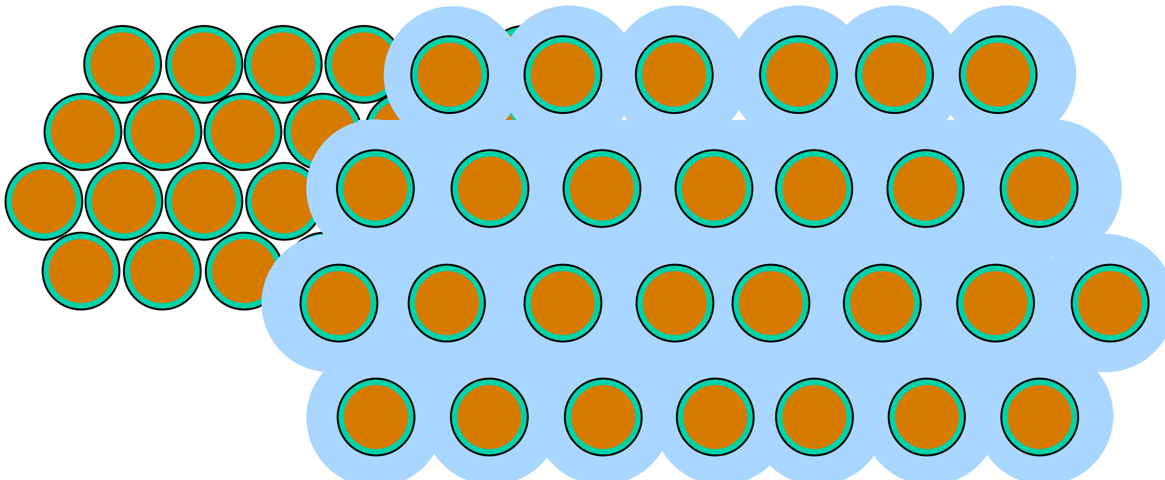
The water is attracted by the clay's negative charges.




As the water is **adsorbed**, it pushes the clay particles apart, causing an expansion or swelling of the clay.

## FIRST MECHANISM OF SWELL

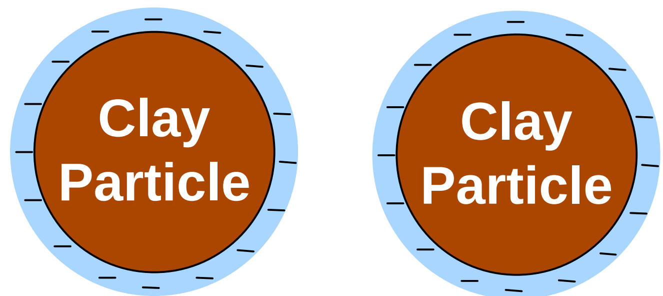
## WHEN WATER BECOMES AVAILABLE



As the water is **adsorbed**, it pushes the clay particles apart, causing an expansion or swelling of the clay.

## FIRST MECHANISM OF SWELL

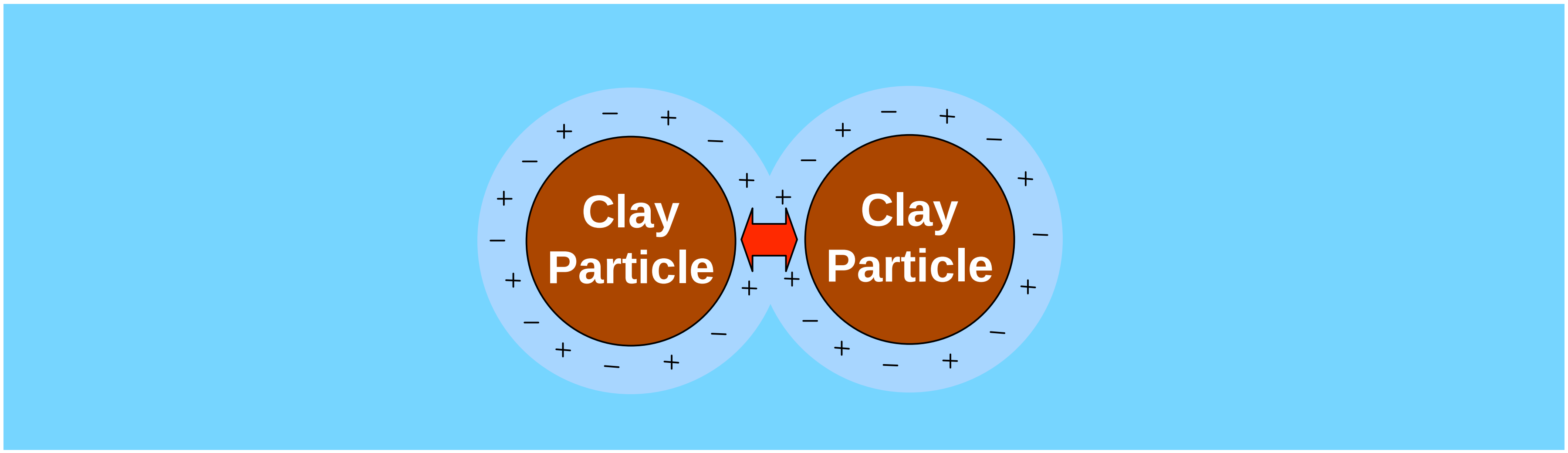
# AFTER TREATMENT WITH ECSS 3000™




**After Treatment, the number of negative charges is reduced**

# FIRST MECHANISM OF SWELL

# AFTER TREATMENT WITH EcSS 3000™
# WHEN WATER BECOMES AVAILABLE



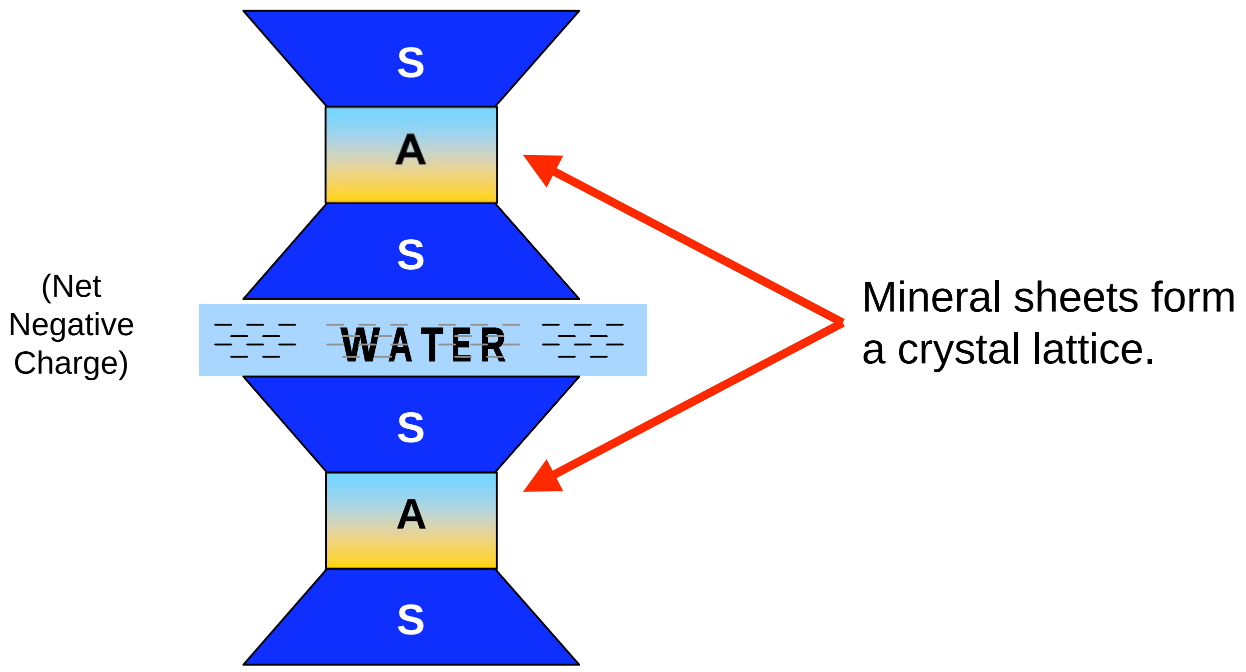

**Reduced attraction of water results in reduced swelling – all due to fewer negative charges.**

**REDUCED or ELIMINATED**

## FIRST M [illegible] UM OF SWELL

# SECOND SWELL MECHANISM

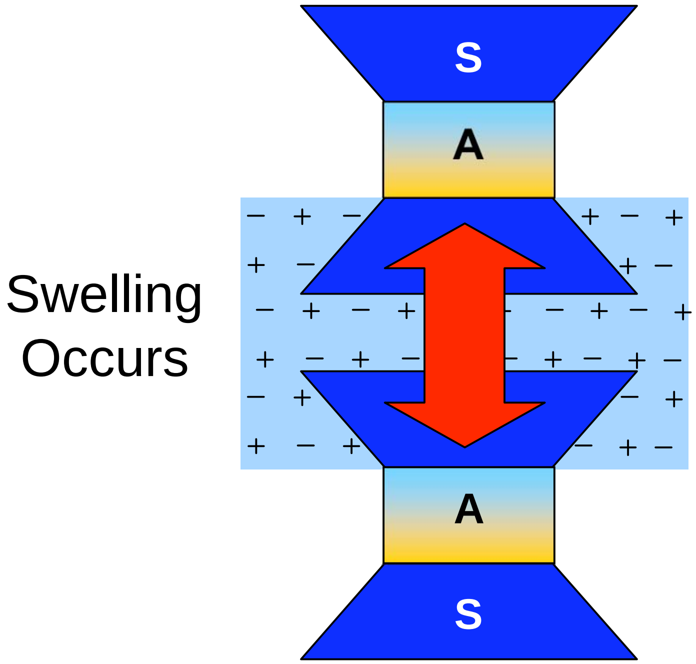
# INTERNAL STRUCTURE OF CLAY PARTICLES BEFORE TREATMENT




## SECOND MECHANISM OF SWELL

# INTERNAL STRUCTURE OF CLAY PARTICLES BEFORE TREATMENT

## THEN, WHEN WATER BECOMES AVAILABLE

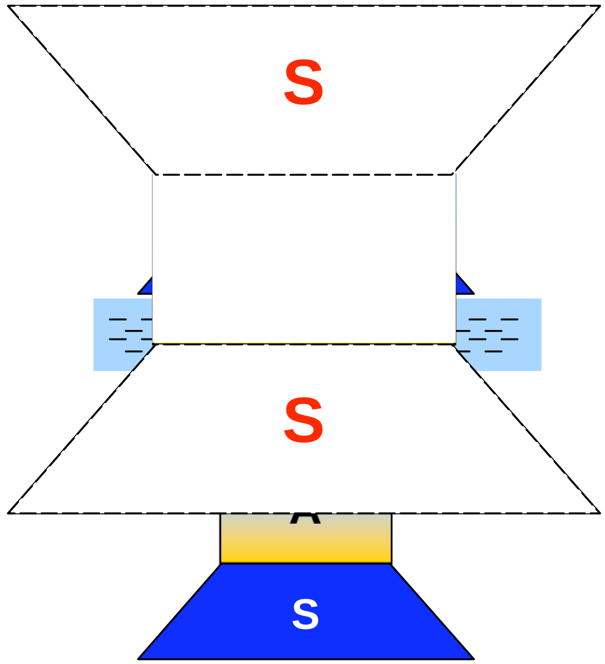



As water is attracted by negative charges, it pushes the mineral sheets apart.

## SECOND MECHANISM OF SWELL

# INTERNAL STRUCTURE OF CLAY PARTICLES AFTER EcSS™ TREATMENT

**So, when water becomes available…**




Silica sheets disintegrate…

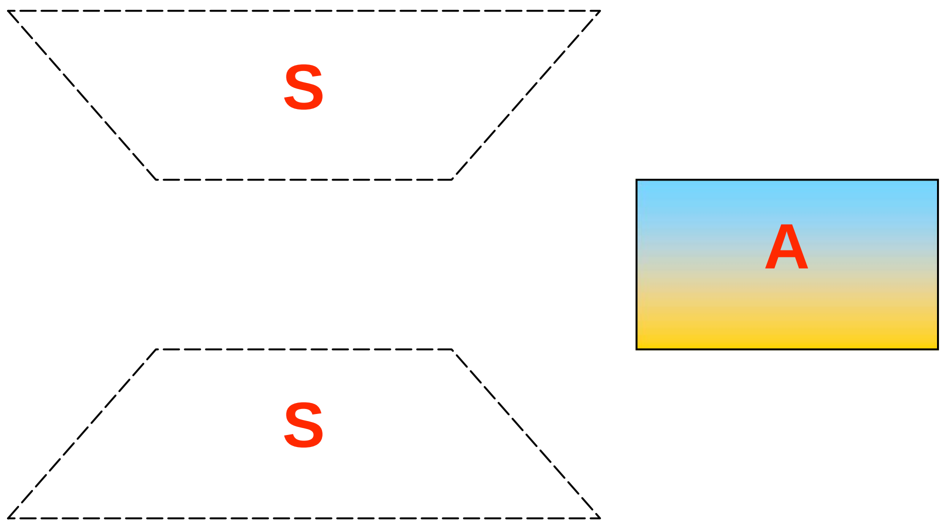
Alumina sheets disconnect from Silica sheets…

**Structure is no longer a crystal lattice with swell potential.**

**SECOND MECHANISM OF SWELL**

## INTERNAL STRUCTURE OF CLAY PARTICLES AFTER EcSS™ TREATMENT

**When the internal structure is changed…**




**The swell potential is reduced or eliminated.**

**SECOND… …ISM OF SWELL**

**REDUCED or ELIMINATED**

**BOTH SWELL MECHANISMS ARE REDUCED OR ELIMINATED**

# Stabilization of Clays Using EcSS 3000™

- What Is EcSS 3000™?
- How Is EcSS 3000™ Applied?
- How Does EcSS 3000™ Migrate in Soil?
- How Does EcSS 3000™ Work?

# What Is EcSS 3000™?

EcSS 3000™ :

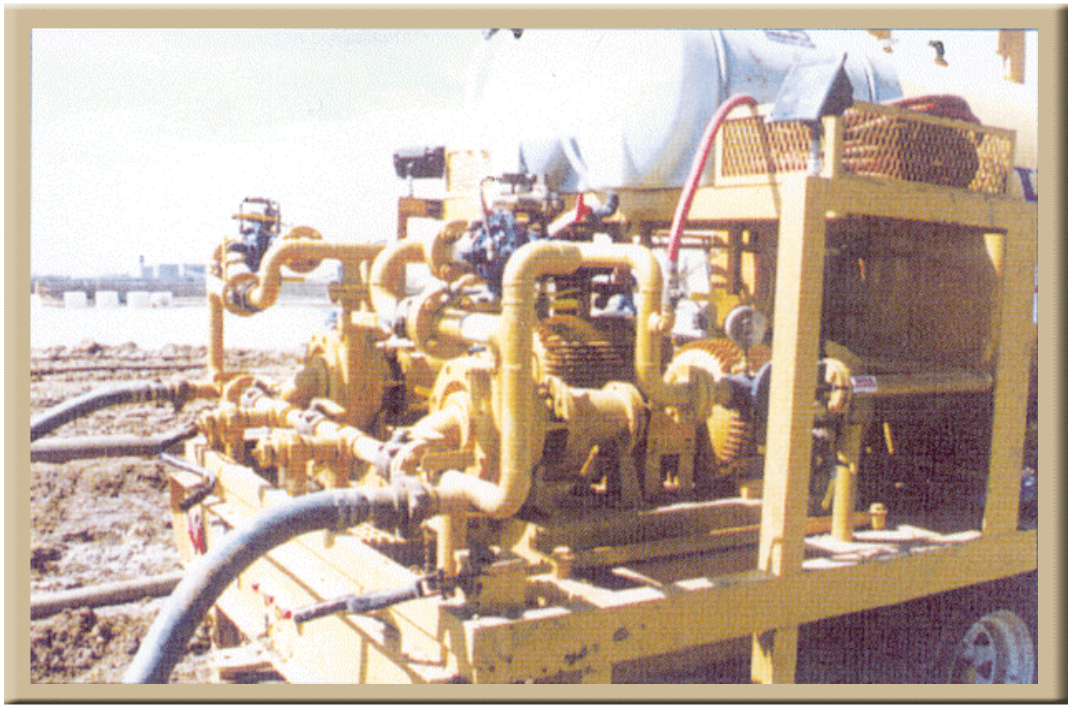
- Developed in the mid-60's
- Acts as a catalyst to clay structure change
- Is a hydrogen ion exchange chemical
- Is acidic and non-hazardous when applied

# How is EcSS 3000™ Applied?

New Construction - Buildings/Roads

- Track loader injection rig
- Diluted 1 gallon EcSS 3000™ to 300 gallons water
- Injected through 6 injection rods spaced on 3-foot centers
- Up to 147 gallons/minute at 250 psi pressure injected using turbo pumps
- Depths up to 10 feet

# Track Loader Injection of EcSS 3000™




**<u>Double Pump Unit</u>**

**<u>Sending Chemical and Water to the Injection Rigs</u>**

# Track Loader Injection of EcSS 3000™

**<u>Track Loader Injection Rigs</u>**

# How is EcSS 3000™ Applied?

**Continued**

Existing Structures/Limited Access Areas

- Hand-held single injection rods on 3-foot centers
- Same 1:300 dilution
- 5.5 gallons/minute at 500-800 psi pressure
- Depths up to 7-8 feet

# Hand Injection of EcSS 3000™

**<u>Hand Injection Rig</u>**

# How is EcSS 3000™ Applied?

**(Continued)**

<u>Surface Application - Generally for Roads</u>

- Using water truck containing 1:300 diluted chemical
- Mix into thin clay layers
- Compact soils

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# Surface Application of EcSS 3000™

1. Rip Existing Clays

2. Spray Diluted EcSS 3000

3. Mix Treated Soils

4. Compact to Rough Grade

# Summary of Texas A&M and Penn State Research to Date

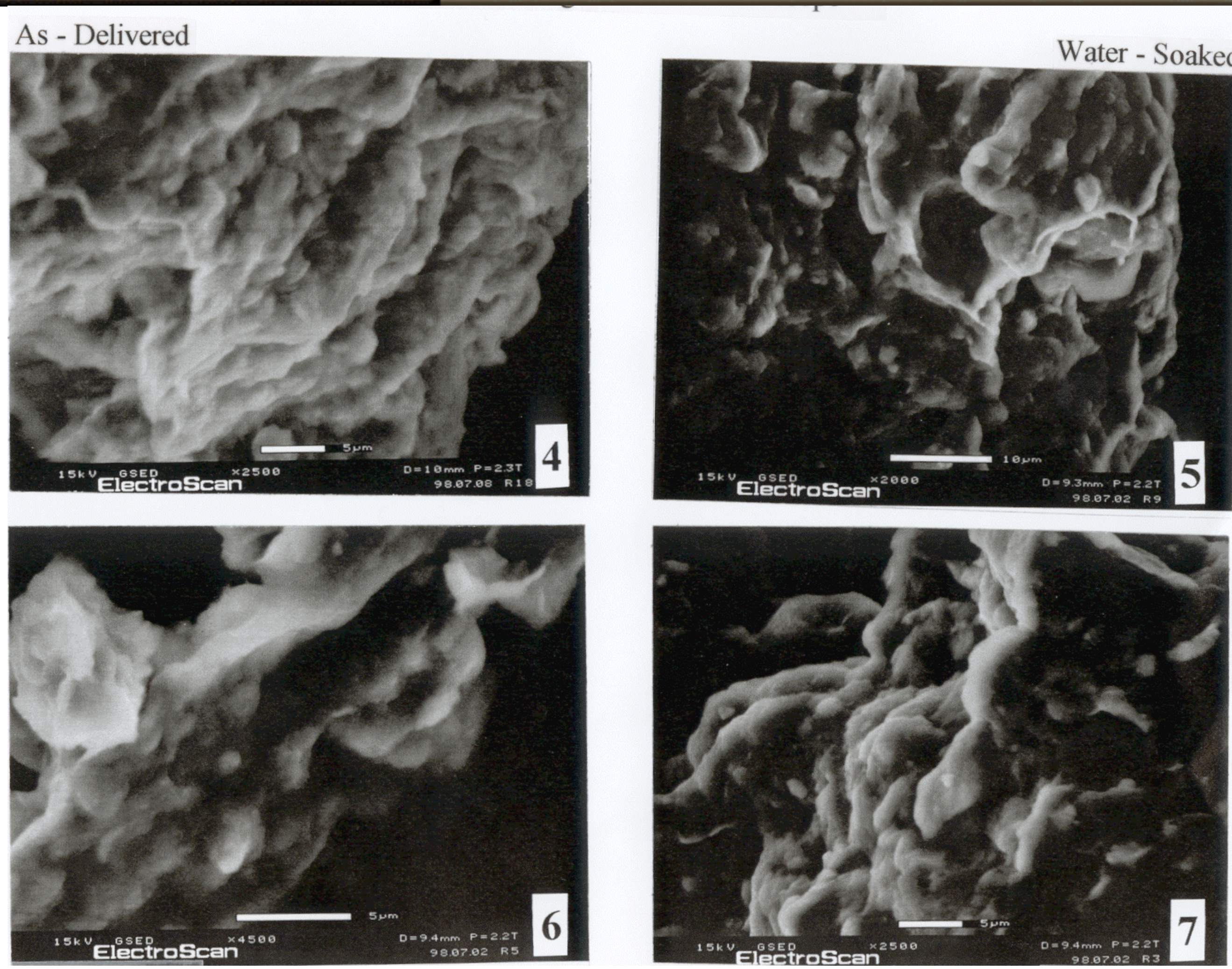
Research Results

- The EcSS 3000™ solution does not cause expansion of the clay lattice and adsorbed water (double layer) as water alone, does. In fact, the soil layering remains similar to the soil structure of the untreated soil

- The EcSS 3000™ solution permanently changes the molecular structure of the clay particle from an expansive crystalline lattice to a collapsed, stable amorphous (noncrystalline) structure

- The EcSS 3000™ solution reduces the net negative surface charge of the clay, therefore reducing the attraction to water

# Environmental Scanning Electron Microscope




**Water-Soaked** **Water-Soaked**

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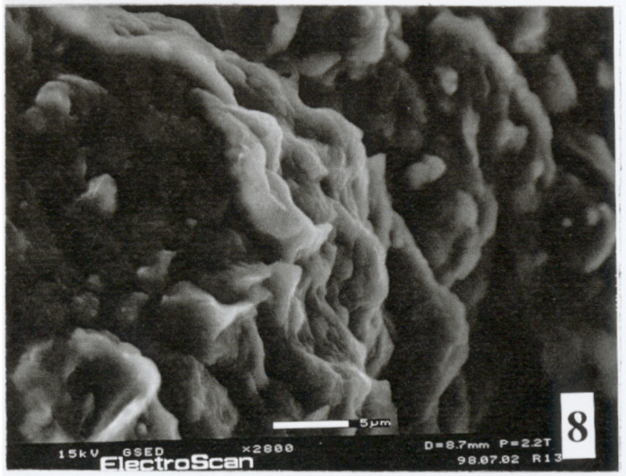
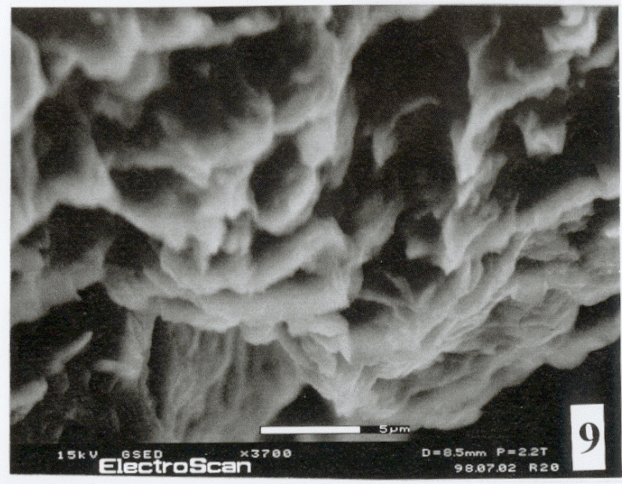
# Environmental Scanning Electron Microscope

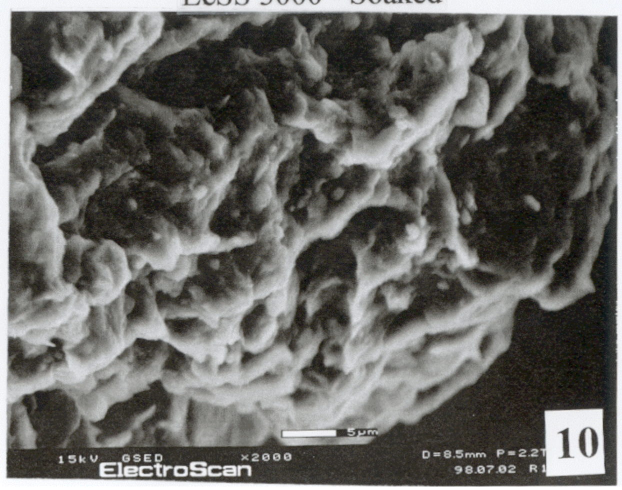
EcSS 3000 - Soaked




EcSS 3000 - Soaked

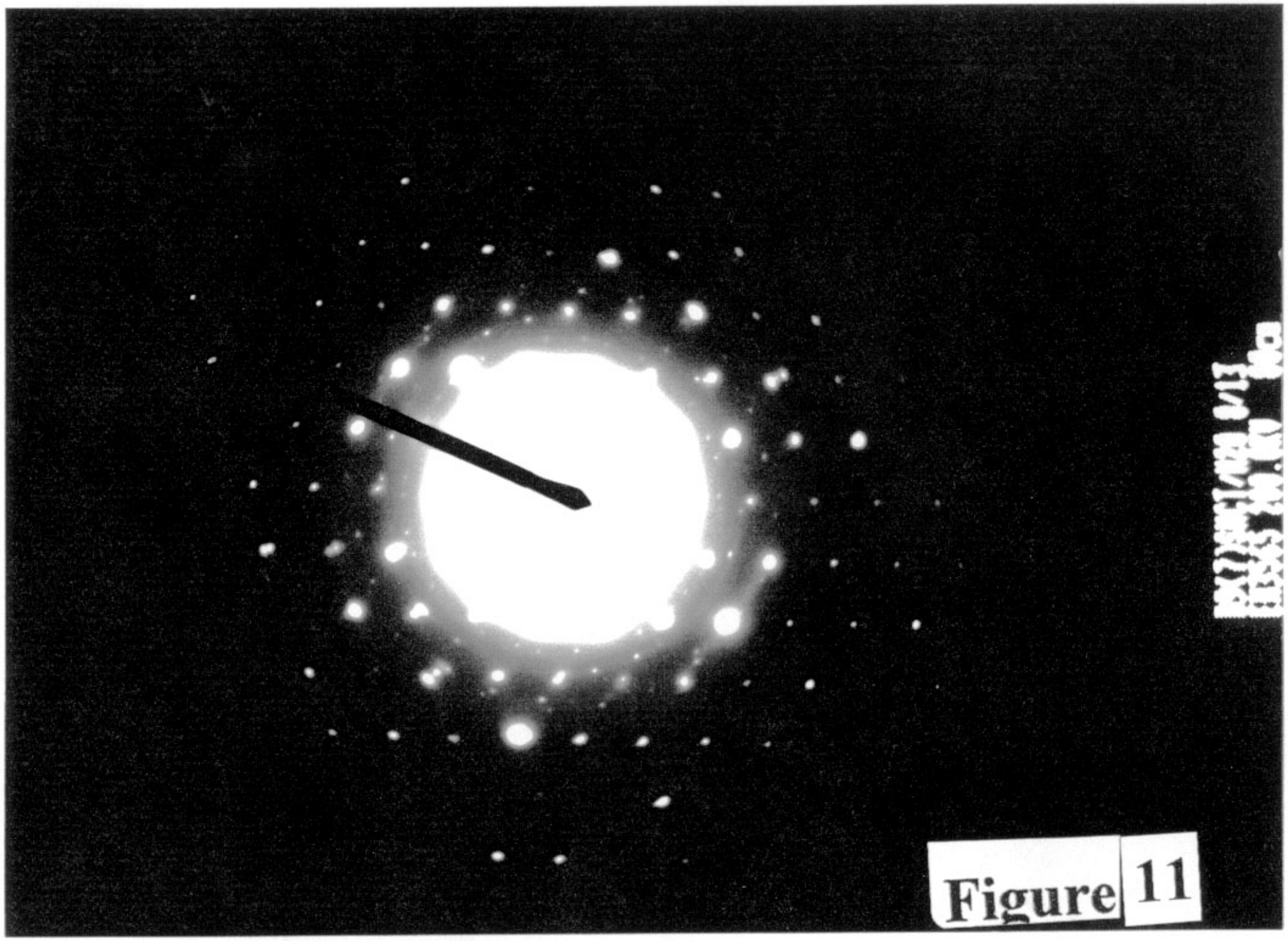



EcSS 3000 - Soaked



# Transmission Electron Microscope

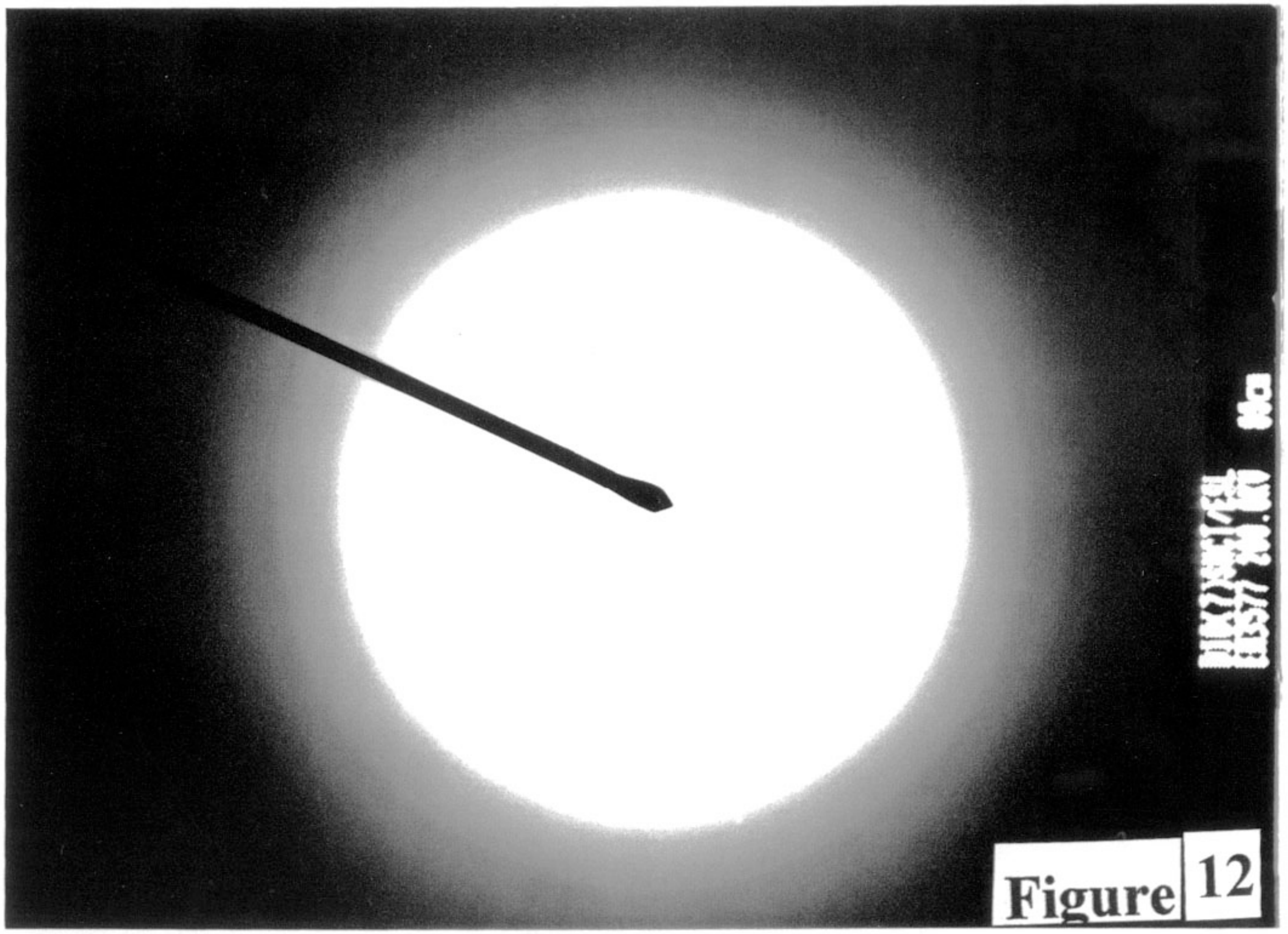
**Crystalline Structure**




**Water-Soaked Sample**

# Transmission Electron Microscope

**Amorphous (Noncrystalline Structure)**




**EcSS 3000™-Soaked Sample**

Texas A&M Research
Crowley Street Samples

## Zeta Potential (millivolts)

| 1 KGa-1b w/o EcSS | 2 KGa-1b with EcSS | 3 STx-1 w/o EcSS | 4 STx-1 with EcSS | 6 TTI-U w/o EcSS | 5 TTI-T with EcSS |
|---|---|---|---|---|---|
| -20.76 | -17.87 | -26.01 | -21.95 | -38.51 | -26.94 |
| -19.98 | -17.22 | -26.52 | -21.16 | -38.64 | -21.42 |
| -21.55 | -18.79 | -26.50 | -21.95 | -37.19 | -29.83 |

KGa-1b = Kaolinite Standard

STx-1 = Calcium Montmorillonite

# Latest Penn State Research 2006

- Arizona Montmorillonite selected to identify treatment mechanism without natural interferences to observations
- Same structure changes and negative charge reduction previously identified during earlier research
- Engineering properties testing on 80% fine sand/20% Arizona Montmorillonite mixture compacted in molding rings – untreated and EcSS 3000TM-treated

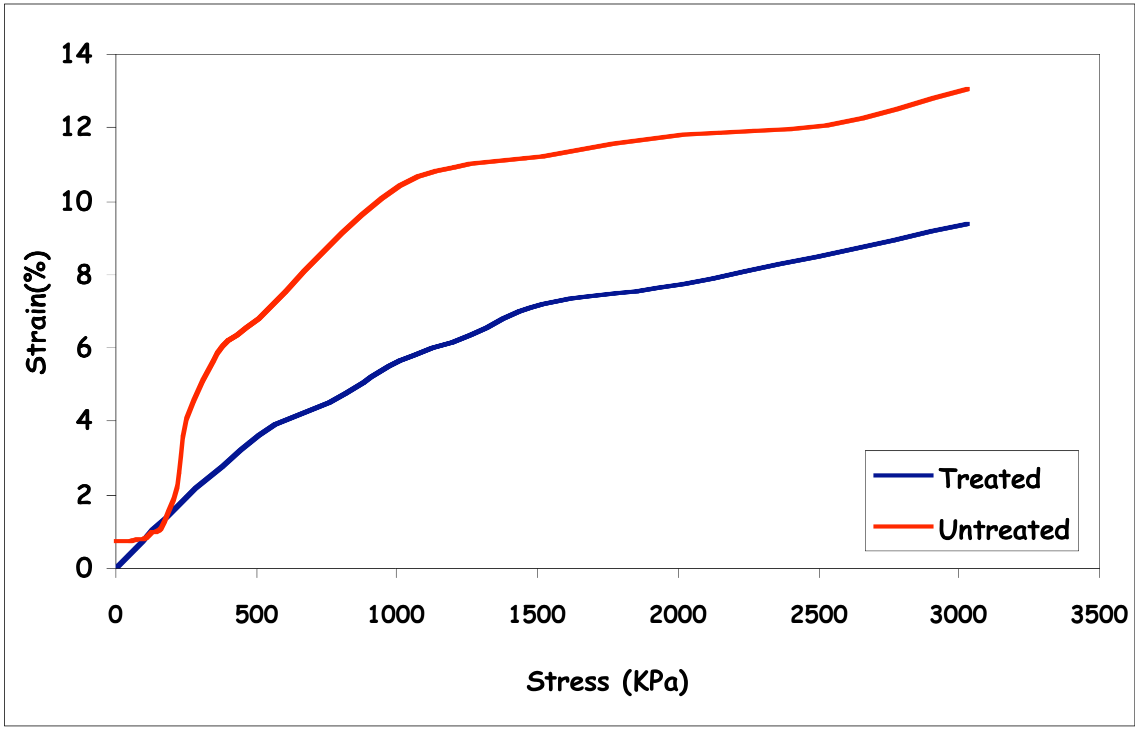
# Engineering Properties Tests
# Penn State Research

- **Swell test(ASTM D 4546):**
  Unidimensional swell tests of the treated and untreated montmorillonite samples were measured using the consolidemeter according to the ASTM method D 4546. The unidimensional increase for the untreated montmorillonite was found to be 8.85%, and after treatment with EcSS 3000 TM soil stabilizer, it dropped to 1.48%.

- **Uniaxial compression test (ASTM D 2435):**
  The results of the unidirectional compression tests of the treated and untreated montmorillonite samples are shown in figure 11. It is clear that the two curves are parallel. But the treated sample shows a much less strain percent indicating increase in strength of the montmorillonite as a result of treatment with EcSS 3000TM soil stabilizer.

# Stress-Strain Curves
# Penn State Research

- **Figure 11: Stress-strain curves of the treated and untreated montmorillonite samples.**



# Latest Penn State Research 2006

- **SUMMARY AND CONCLUSONS**
- When montmorillonite is treated with EcSS 3000TM soil stabilizer, the following is observed:
- The treatment processes are irreversible and do not cause preswelling of the clay.
- The interlayer spacing is reduced and the interlayer cations are exchanged.
- Si-O-Al bonds are broken resulting in the separation of amorphous silicon and soluble aluminum from the structure.
- The surface charge (zeta potential) is reduced.
- Water originally bound by the clay particles, and within the mineral interlayer is released.
- Particle size is reduced and surface area is reduced due to flocculation.
- Cation exchange capacity (CEC) is reduced.
- Liquid limits (LL), Plasticity limit (PL) and Plasticity index are reduced indicating lower plasticity, swelling and compressibility characteristics.
- The extent of swelling is greatly reduced.
- Uniaxial compression test shows an increase in strength of montmorillonite as a result of the treatment with EcSS 3000TM soil stabilizer.

# Latest Penn State Research 2006

- **It appears that the mechanism of action of EcSS 3000TM soil stabilizer can be explained as follows:**

  When EcSS 3000TM solution is added to clay or soil, it has an immediate effect on the properties of the soil as cation exchange begins to take place between interlayer cations and hydrogen ions in solution. This reduces the density of the electrical charge around the clay particles which leads to them being attracted closer to each other to form flocs, the process is termed flocculation. It is this process which is primarily responsible for the modification of the engineering properties of the clay. So, montmorillonite loses its plasticity immediately. In the meantime, a catalyzed attack on the Si-O-Al bonds in the tetrahedral sheets takes place (organic sulfonate acts as catalyst) causing disintegration and separation of amorphous Si into the floc making them dense and impermeable. These two processes are responsible for the enhanced strength, reduced CEC and stopping expansion.

# Sulfate-Induced Heave in Clay Soils at DFW Int'l Airport

Sulfate-Induced Heave **"Speed Bumps"** in Lime-Stabilized Subgrade

Nearby **EcSS 3000™** Stabilized Subgrade - No Sulfate-Induced Heave

# Sulfate Induced Heave in Clay Soils

Sulfate-Induced Heave (SIH) Can Occur When:

- Soil pH > 10.5
- Soluble Sulfates > 2,000-10,000 ppm
- Moisture is present
- Temperature is above $40^{o}$ F

When clay soils are mixed with lime or cement, pH is increased from natural values of 7 to 8 up to about 12. Sulfate-induced heave can occur when all above conditions are met.

**EcSS 3000™ is not calcium based, but is a mild acid that does not increase the natural soil pH and, therefore, cannot cause sulfate-induced heave.**

# Case Histories

- Indian Springs Subdivision, Carrollton, Texas:
  - 2-year moisture content and swell testing on EcSS 3000™-injected lot. Showed a 70% reduction in swell potential over time
- Iscar Metals, Arlington, Texas:
  - Minimum 80% reduction in swell potential by EcSS 3000™ with a single injection - Eagle Ford Shale residual clays
- DFW Airport, Terminal 5E Roadway Subgrade Stabilization:
  - Swell potential reduced to less than 1% average. Deflection/Falling Weight testing at location of previously failed lime stabilized subgrade, before and after injection testing, showed an increase in subgrade modulus (strength) of 240%, two months after EcSS 3000™ injection

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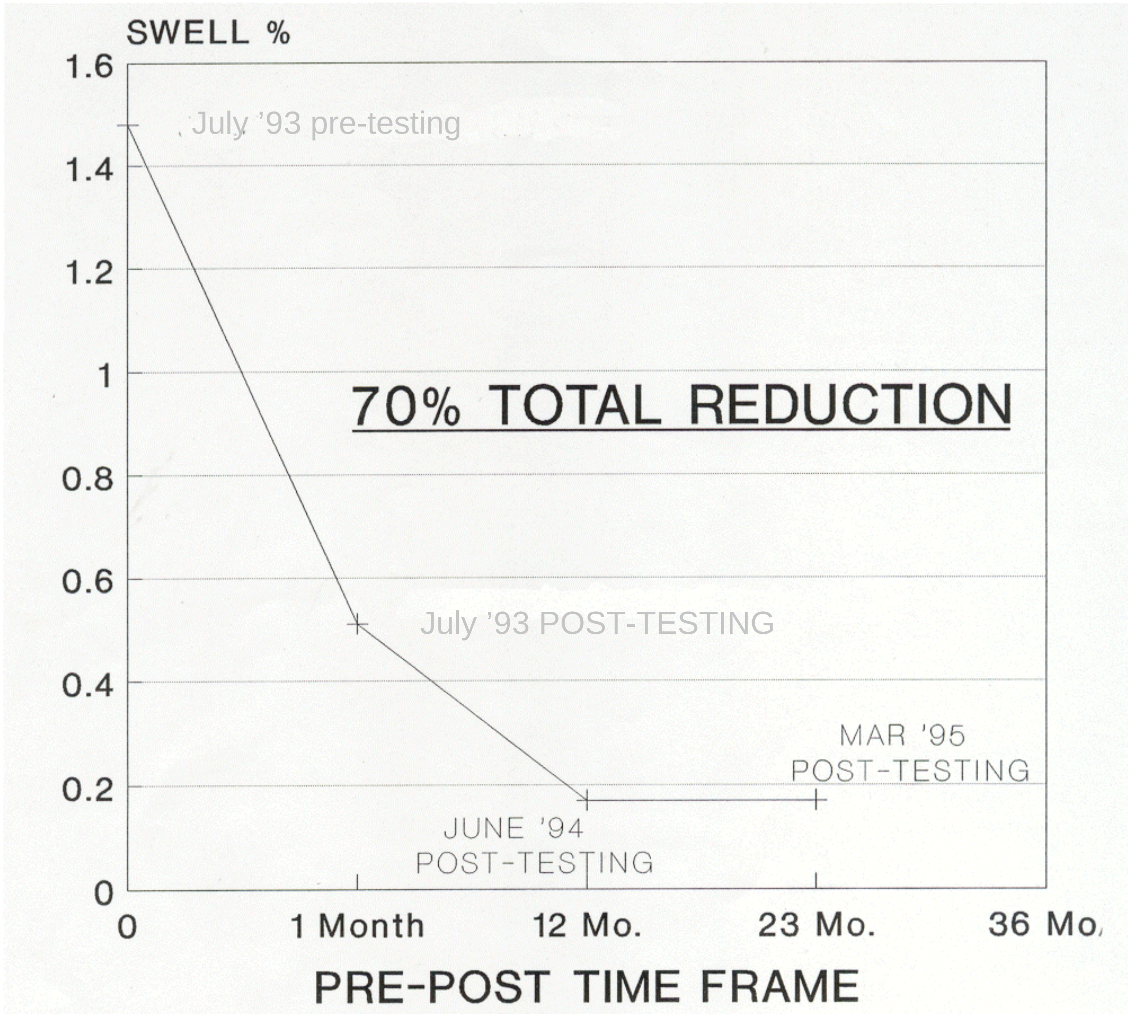
# Case History No. 1

Indian Springs Subdivision

Lot 9, Block F, Phase 3, Carrollton, Texas

- Soil Types:
  1. Clay Fill in upper 6’ - 7’, plasticity index = 18 - 36
  2. Native Clay below 6 - 7’, plasticity index = 34 - 62
- Depth of Injection:
  - 8 feet (on 3-foot centers)
- Injection Technique:
  - Hand-held single injection rods
- Performance Goals:
  - Reduce potential swell to an average of 1% or less within injected zone. (actual average = 0.5% after injection, reduced to 0.2% two years later)
- Injection Date: July, 1993

# Case History No. 1
# Indian Springs Subdivision



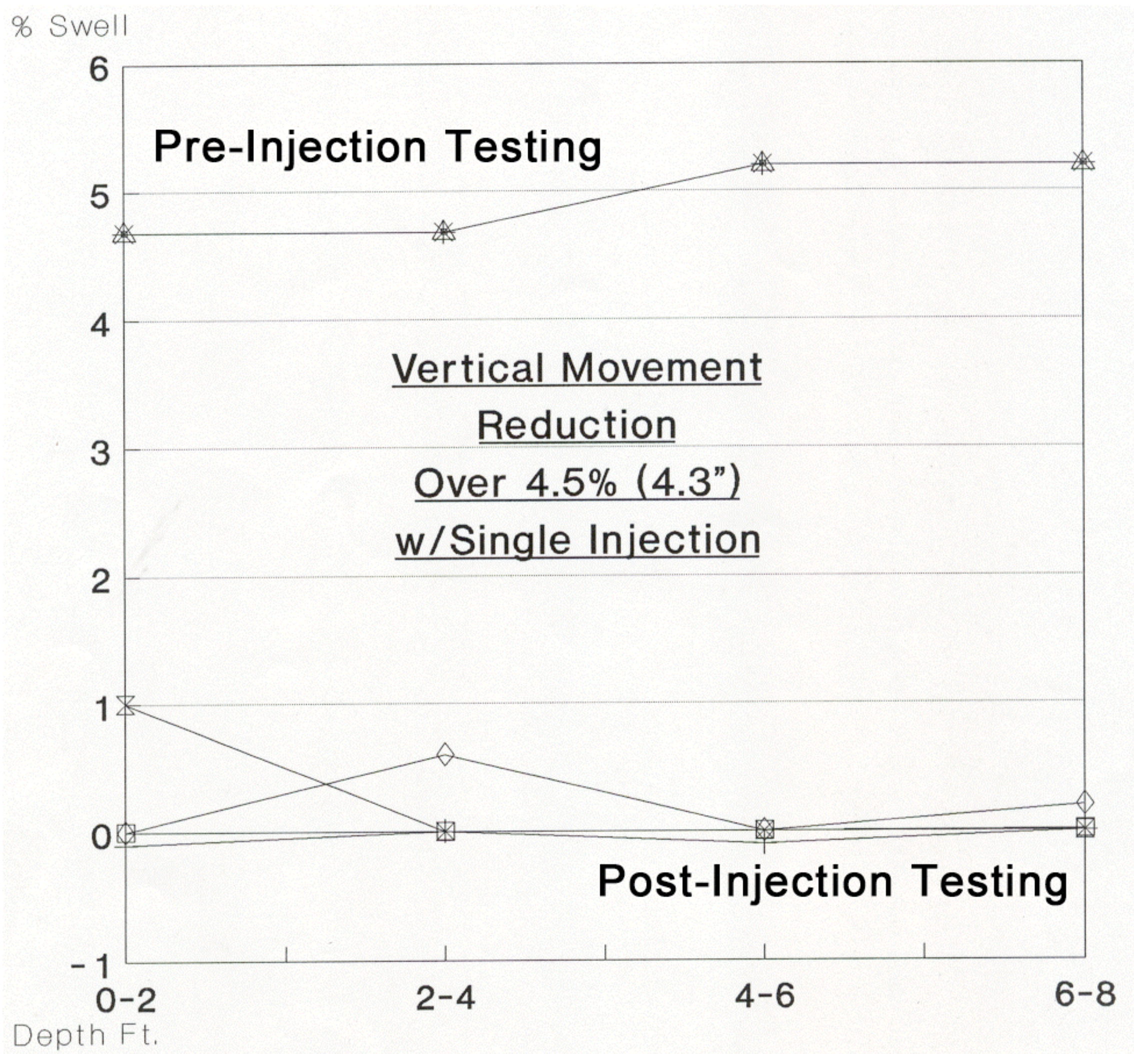
# Case History No. 2

Iscar Metals

East Stephens, Arlington, Texas

- Soil Type:
  - High plasticity clays, Eagle Ford Shale residual soils, plasticity index = 30's to 40's
- Depth of Injection:
  - 10 feet (on 3-foot centers)
- Injection Technique:
  - Track loader injection rig, mounted with 6 injection rods
- Performance Goals:
  - Reduce potential swell to an average of 1% or less within injected zone (actual average = 0.19%).
- Injection Date: April, 1995

# Case History No. 2
# Iscar Metals



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# Case History No. 3

DFW Airport, Terminal 5E Roadway

- Soil Type:
  - Clay and Shaley Clay (Eagle Ford Shale residual soil), plasticity index = 39 - 48
- Depth of Injection:
  - 5 feet (on 3-foot centers)
- Injection Technique:
  - Hand-held single injection rods, through existing pavement
- Performance Goals:
  - Reduce potential swell to an average of 1% or less within injected zone, with no loss in strength (actual average swell = 0.97%; strength gain of 240% over pre-treated value)
- Injection Date: May, 1994

Note: Subgrade had originally been lime-stabilized, but much of the roadway had failed. EcSS 3000 was used to stabilize failed subgrade

# Case History No. 3 DFW Airport, Terminal 5E Roadway

Dallas/Fort Worth International Airport May 10, 1994

## SUMMARY OF PRESSURE SWELL TEST

CHEMICAL INJECTION CORE SAMPLES – 5E PUBLIC ROAD
D/FW AIRPORT, TEXAS
MAY 9, 1994

P.I.R. NO. 5394000576

| Boring Number: | B1 | B1 | B2 | B2 |
|---|---|---|---|---|
| Depth: | 2.5 – 3.5' | 4 – 5' | 2.5 – 3.5' | 4 – 5' |
| Soil Description: | Dark Brown Clay | Dark Brown Clay | Brown & Yellowish brown clay | Yellowish brown clay |
| Initial Moisture Content: | 31.4% | 27.2% | 28.0% | 33.2% |
| Final Moisture Content: | 32.4% | 28.7% | 29.6% | 35.3% |
| Applied Surcharge Load: | 300 psf | 450 psf | 300 psf | 450 psf |
| Vertical Swell w/Surcharge Load: | .95% | 1.03% | .89% | 1.02% |
| Liquid Limit: | 70 | 61 | 62 | 71 |
| Plastic Limit: | 22 | 20 | 23 | 23 |
| Plasticity Index: | 48 | 41 | 39 | 48 |

**Average Swell** **.97%**

# Case History No. 3
# DFW Airport, Terminal 5E Roadway

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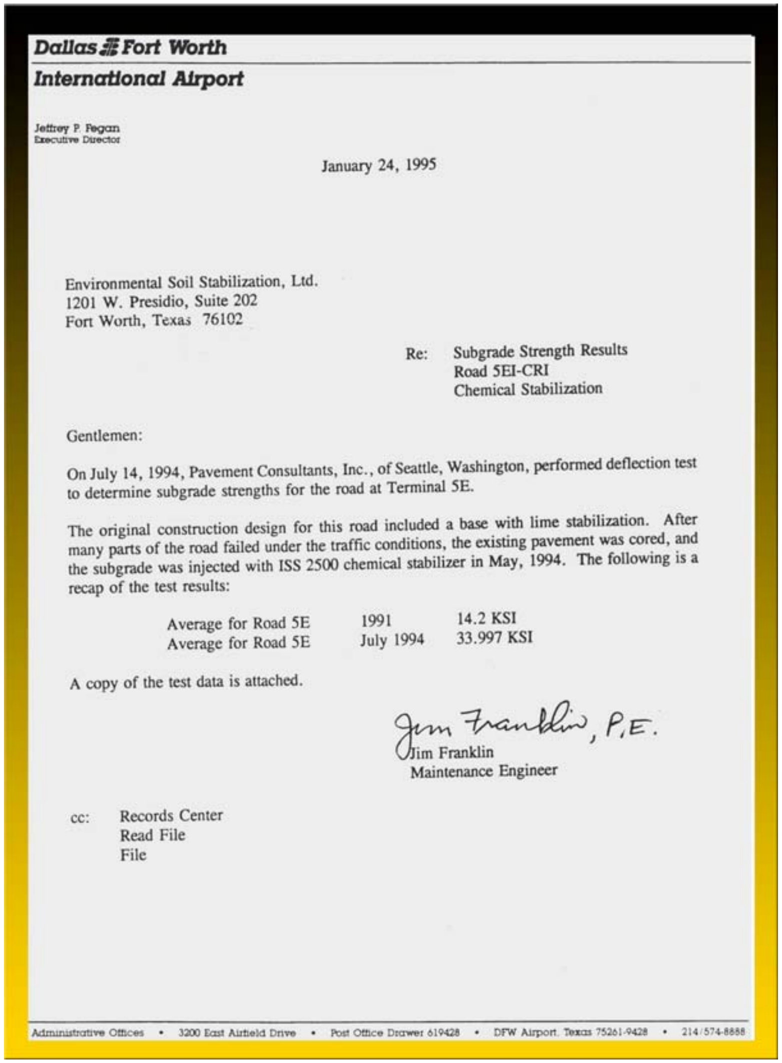


**Dallas/Fort Worth International Airport**

Jeffrey P. Fegan
Executive Director

January 24, 1995

Environmental Soil Stabilization, Ltd.
1201 W. Presidio, Suite 202
Fort Worth, Texas 76102

Re: Subgrade Strength Results
Road 5EI-CRI
Chemical Stabilization

Gentlemen:

On July 14, 1994, Pavement Consultants, Inc., of Seattle, Washington, performed deflection test to determine subgrade strengths for the road at Terminal 5E.

The original construction design for this road included a base with lime stabilization. After many parts of the road failed under the traffic conditions, the existing pavement was cored, and the subgrade was injected with ISS 2500 chemical stabilizer in May, 1994. The following is a recap of the test results:

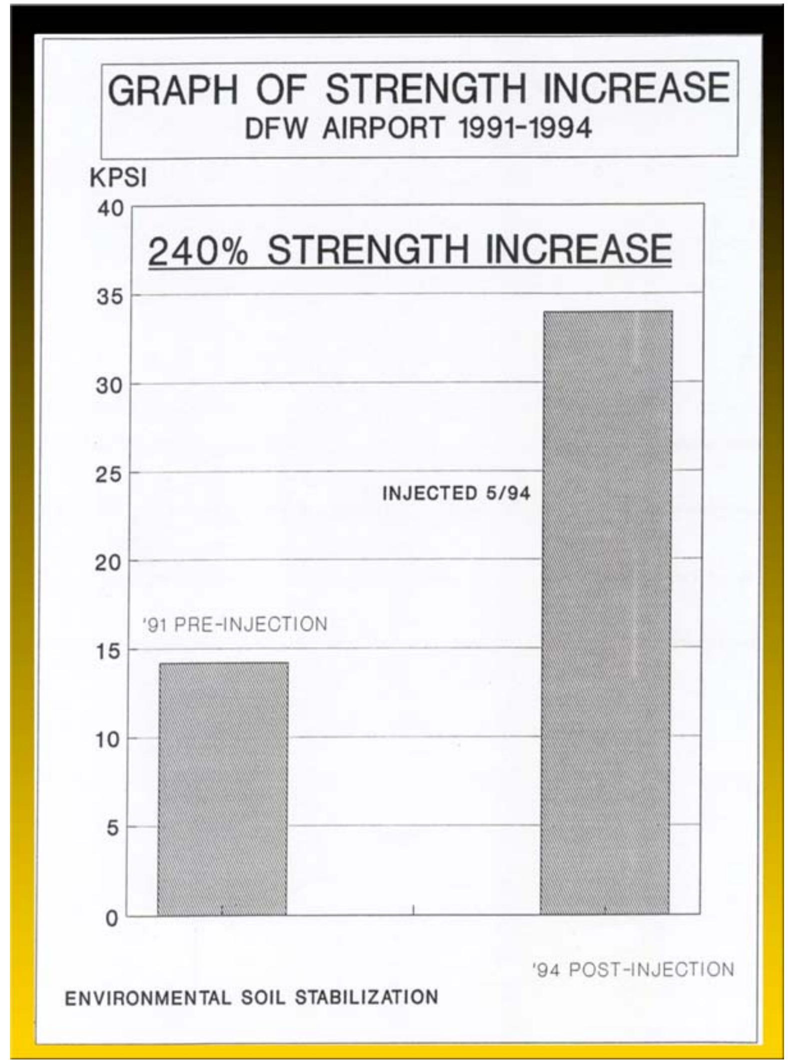
| | | |
|---|---|---|
| Average for Road 5E | 1991 | 14.2 KSI |
| Average for Road 5E | July 1994 | 33.997 KSI |

A copy of the test data is attached.

Jim Franklin, P.E.
Jim Franklin
Maintenance Engineer

cc: Records Center
Read File
File

Administrative Offices • 3200 East Airfield Drive • Post Office Drawer 619428 • DFW Airport, Texas 75261-9428 • 214/574-8888



# Summary

- Theory
- Research
- Case Histories
- Experience