23rd International Convention & Trade Show

2008 February 28 - March 4
Phoenix, Arizona

Bentonite HDPE Composite Waterproofing Systems; Below-grade Applications, Failures, and Solutions

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Introduction

Sodium Bentonite based Waterproofing Systems

- Steadily gained popularity for below-grade applications for both blind-side and positive-side construction
- Applications include:
  - Underslab
  - Zero property line (blindside)
  - Back-filled walls
  - Earth-covered structures
  - Tunnels
  - Split-slab deck construction
  - Hydrostatic and non-hydrostatic site conditions

Introduction cont.

Sodium Bentonite based Waterproofing Systems

- Many manufacturers offer a variety of bentonite waterproofing systems
- Some variations include:
  - Standard bentonite sheeting – basic water repulsion
  - Multi-layer sheeting combinations – water & gas repulsion
- Sheeting is designed based on the application

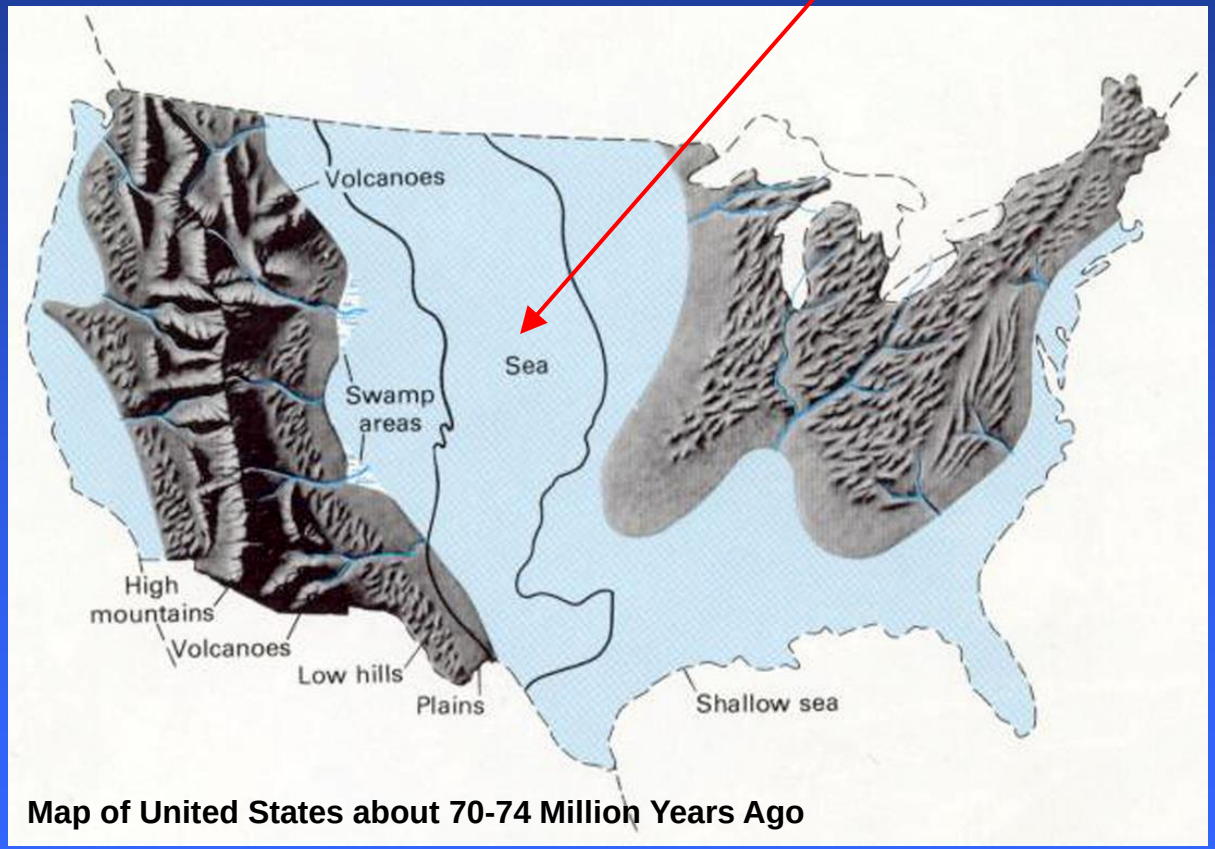
Introduction cont.

Focus of the presentation:

- Soil retention systems and their impact on waterproofing
- Sodium bentonite based waterproofing systems used in blind-side construction
- Different types of blindside construction procedures and how they impact bentonite based waterproofing systems
- Case Study of a failed blindside waterproofing system

History of Sodium Bentonite

- Sodium Bentonite is an absorbent clay that was geologically modified volcanic ash originally deposited in an ancient sea bed as bentonite around 70-74 million years ago



Map of United States about 70-74 Million Years Ago

History of Sodium Bentonite Cont.

- Bentonite was named by American Geologist W.C. Knight about 1890
- Discovered in Montana's Rock Creek area at the Benton Formation (a geological stratum at Fort Benton)
- Commercially known as Sodium Bentonite
- Mined in South Dakota and Wyoming
- United States - 2005 top producer world wide with almost 1/3 world share

History of Sodium Bentonite Cont.

Properties of Bentonite

- An absorbent aluminum phyllosilicate generally composed of impure clay
- Two types of Bentonite – swelling (sodium bentonite) and non-swelling (calcium bentonite)
- Sodium bentonite absorbs up to 8x's it's dry mass in water
- Contains exchangeable sodium cations
- Calcium Bentonite can be converted to Sodium Bentonite through "ion exchange"

Bentonite Seals When Wetted Cont.

Sodium Bentonite Granules Transform into a seamless, monolithic membrane to provide an excellent barrier to water

Time Sequence Photography

1. Bentonite Installed Dry

2. Granules quickly transform when wet

3. Seamless Bentonite Membrane


Upon hydration, bentonite extrudes out
and seals the overlap seams

Bentonite is Dispersive

When hydrated, bentonite expands and conforms to irregular surfaces, penetrations, and infiltrates cracks and voids in the concrete

Bentonite is Natural

- Non-toxic
- No Volatile Organic Compounds (VOC's)
- Used in toothpaste, skin lotions, soap, pharmaceuticals, cattle feed, even used to filter fine wines and fruit juices

History of Sodium Bentonite Cont.

The clay of a thousand uses, besides below-grade waterproofing, also used in:

- Drilling mud for oil and gas
- Sealing of sub-surface disposal systems for spent nuclear fuel
- Quarantining metal pollutants of groundwater
- Making slurry walls
- Lining the base of landfills
- Absorbing protein molecules, useful in winemaking

Mining Process

- Mining for Sodium Bentonite is different from traditional mining methods.
- Allows reclamation of the mining site to be restored to it's near original condition
- Begins by removing the overburden with large earth movers
- Overburden is stockpiled
- Bentonite is excavated from bed
- Upon completion, overburden is restored and surface is returned to equal or superior condition

Historical Use in Below-grade Waterproofing

- Introduced as a product in the mid 1920's
- Primarily used in granular form to seal ponds and compacted earth dams until the late 1950's
- Introduced into building waterproofing market in the mid 1960's
- Available product lines included panels, sheets, trowelable, and sprayed forms

Historical Use in Below-grade Waterproofing
Cont.

- Sprayed and trowelable went away due to premature hydration and difficulty in applying uniform thickness
- First commercially available bentonite panel systems were bentonite filled cardboard sheets, which are not widely used today
- Replaced by composite products consisting of a combination of materials, HDPE, geo-membranes, or durable textiles
- Composite Materials are:
  - Easier to install
  - Provide better barrier performance

Historical Use in Below-grade Waterproofing
Cont.

- Common forms of bentonite waterproofing products
- granules encapsulated between polypropylene geotextile fabrics
- Laminated to one side of a HDPE geomembrane
- Typical rolls size are 4’ wide and vary in length from 15’-24’
- Contains, roughly, 1LB of bentonite per SQ FT
- Both forms are appropriate for blind-and positive-side construction

Soil Retention Systems

- Common soil retention systems include:
- Wood Lagging & Soldier Piles
- Shotcrete Lagging
- Soil Nailing
- Other systems

Original Bentonite Waterproofing System

Positive & Negative Side Waterproofing

Defined – Positive-side waterproofing is applied to the outside (wet) face of the subsurface building components in contrast to Negative-side waterproofing, which is applied to the inside (dry) face of the subsurface walls and slabs.

Blind-side Waterproofing

- Defined – Blind-side is positive-side
- Blind-side waterproofing systems are required where the exterior faces of foundation walls are not accessible, which requires application of the waterproofing system to the formwork surface facing the excavation.
- This results in the waterproofing's final location to be on the outside of the foundation wall.

When is Blind-side Waterproofing Necessary

- Common situations dictating blind-side waterproofing are:
  - Proximity of adjacent property line, which preclude excavation outside the foundation walls
  - May be more convenient or economical
- Required when concrete foundation is cast against soil retention systems such as wood lagging and soldier piles, steel or wood sheet piling, concrete caisson retaining walls, and slurry or shotcreted rock


Property Line Applications

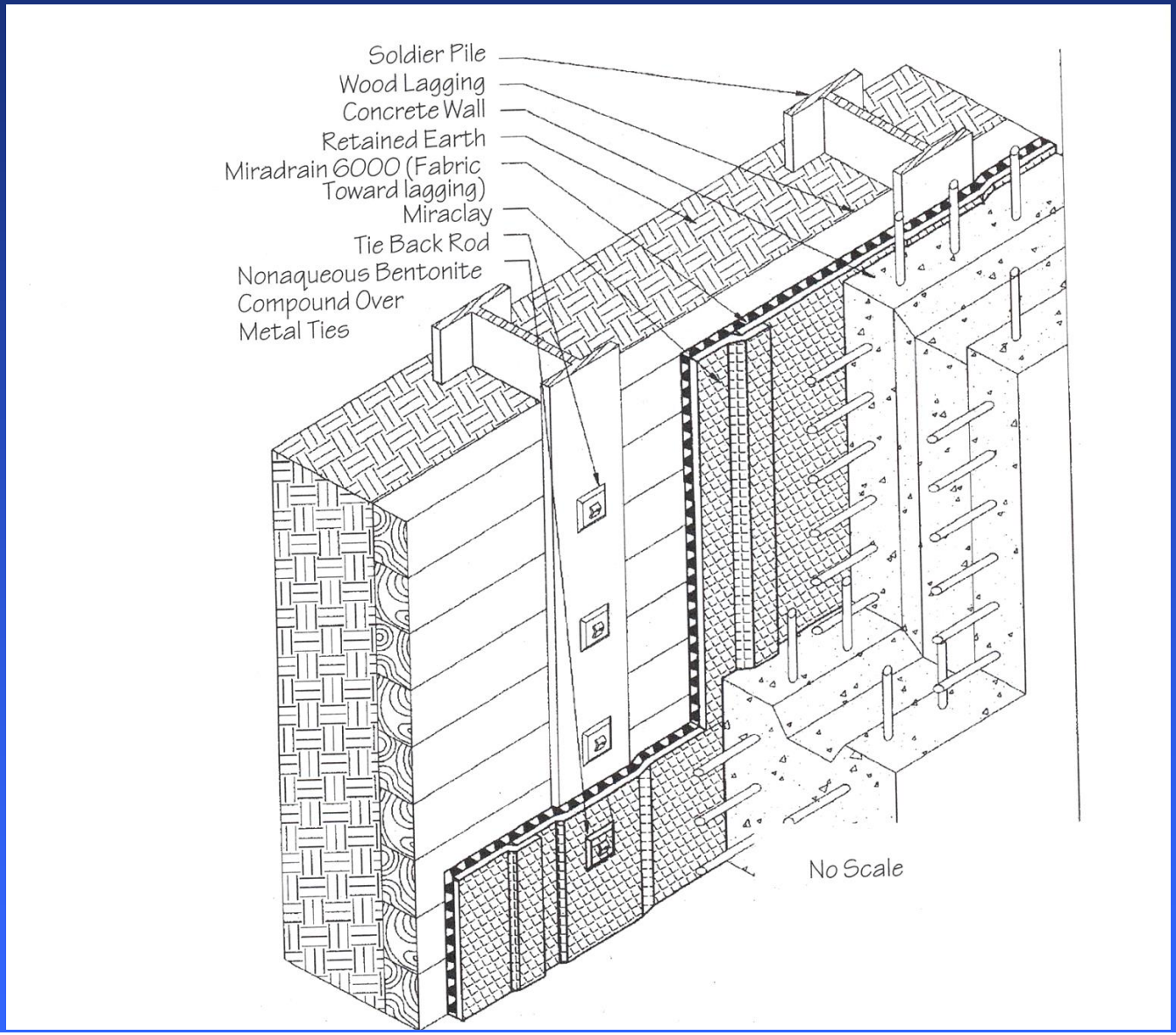
Earth Retention Systems

- Review different types of Lagging systems used for blind side waterproofing
- Review issues associated with lagging that impact sodium bentonite waterproofing systems

Wood Lagging & Soldier Piles

- Soldier piles, which are heavy, wide flange steel section, are driven into the ground at five to ten foot intervals, depending upon the soil makeup and lagging cross-section. As excavation proceeds, wood lagging is erected in place and tie rods or soil anchors are drilled into the earth for stabilization of solider piles against soil pressure.

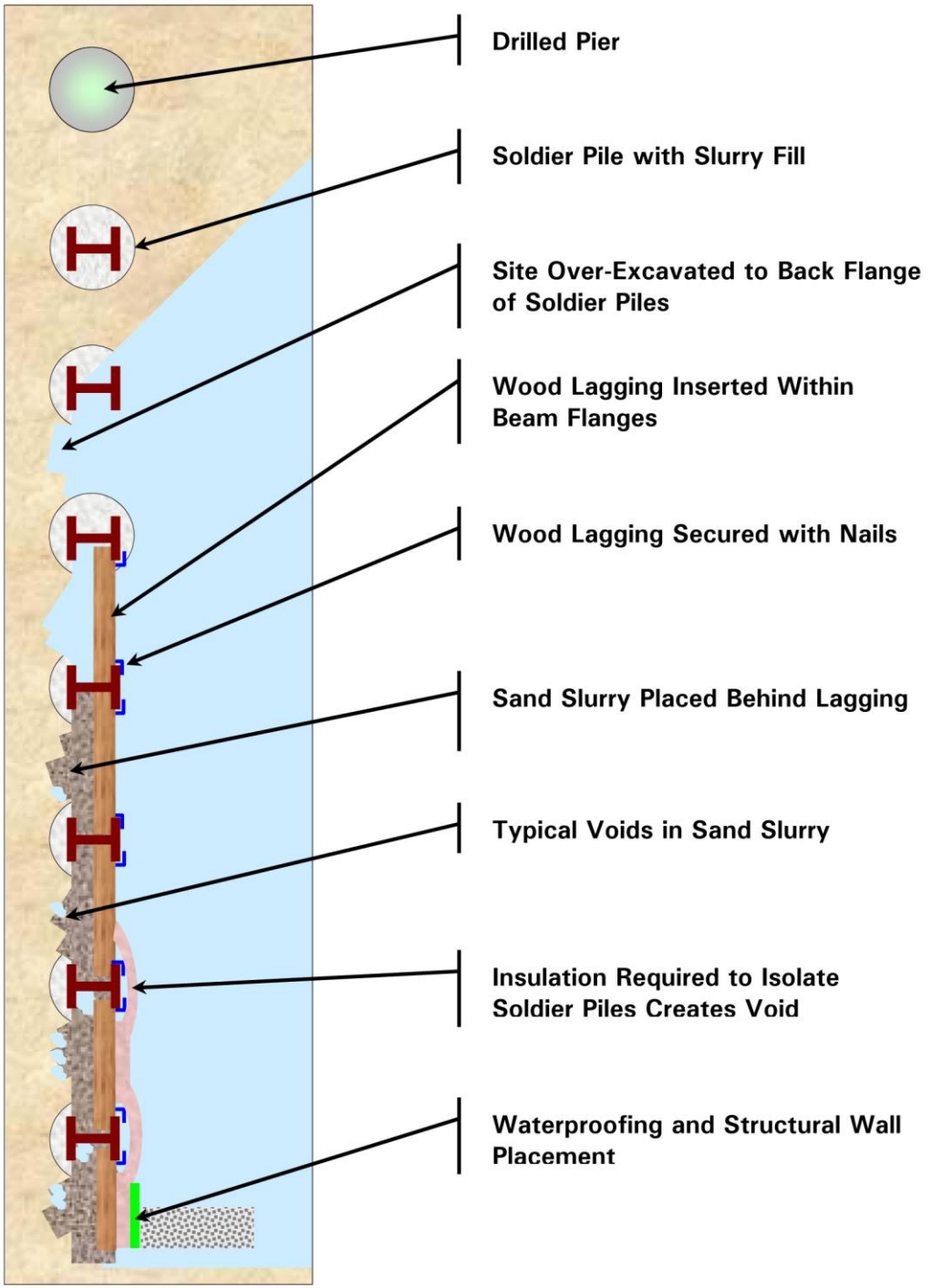
Wood Lagging - Earth Retention System



Wood Lagging & Soldier Piles

- WP system is applied directly to the wood lagging and the concrete is poured directly against the WP system.
- Bentonite clay or HDPE composite products are usually specified for this construction process.
- Joints in lagging must be maintained at ½ inch or less. If joints become larger, plywood is typically nailed over lagging or sometimes the gaps are grouted and then waterproofing system is applied.

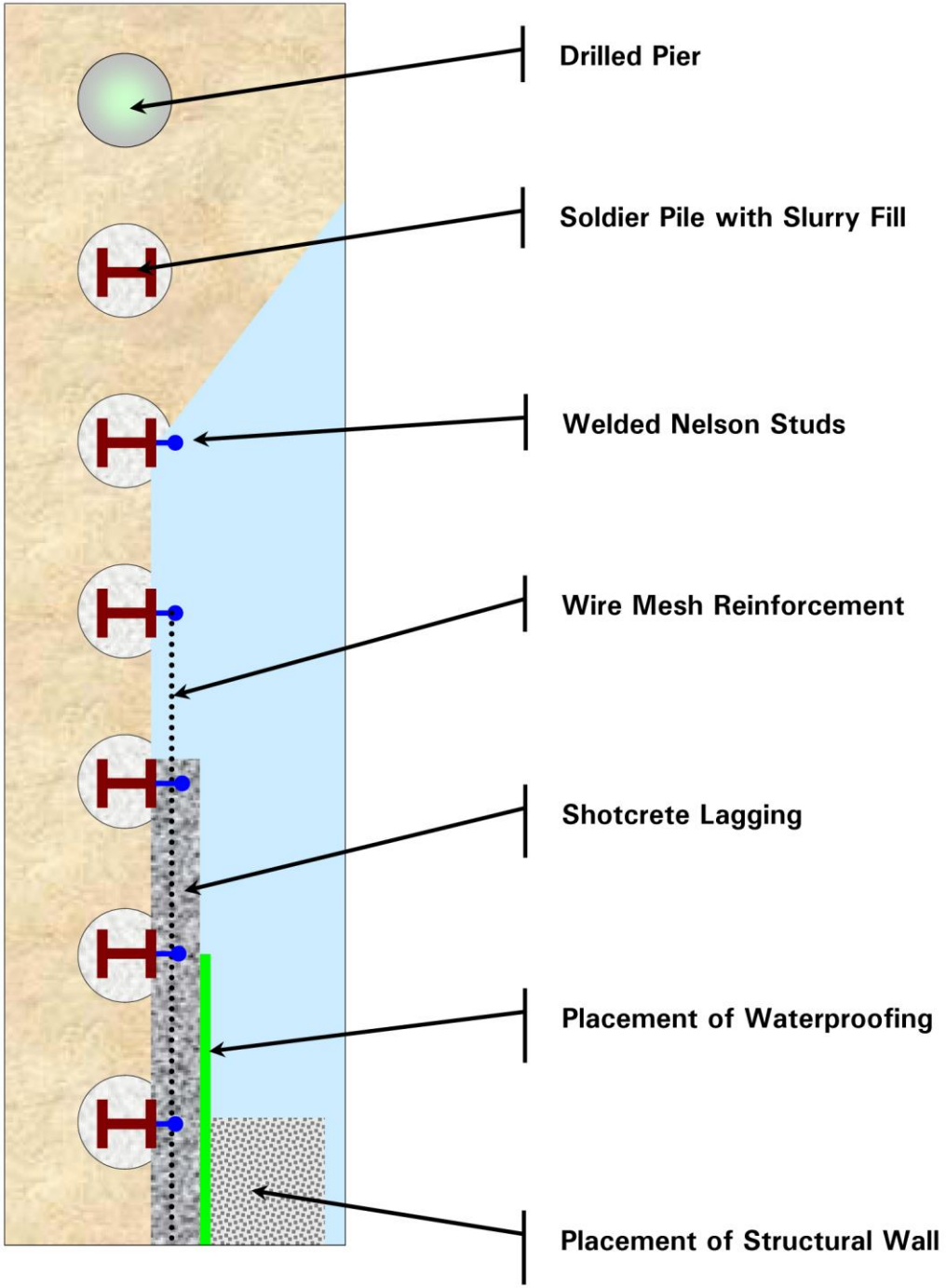
Conventional Wood Lagging



Shotcrete Lagging

- Soldier piles are predrilled at intervals along the wall's baseline. The piles are placed in the hole and backfilled with lean-mix concrete. As the excavation in front of the wall proceeds, shotcrete lagging is installed between the soldier piles in lifts. Tieback anchors may be installed and stressed to provide lateral restraint.

Shotcrete Lagging



Shotcrete Lagging

Shotcrete Lagging

Soil Nailing

- An insitu reinforcing of the soil while it is excavated from the top down.
- An array of soil nails which are passive inclusions are installed in a grid that functions to create a stable mass of soil.
- In many applications soil nailing can be the least disruptive way to construct a retaining wall.
- Soil Nailing requires an unusual amount of hand work, craftsmanship and geotechnical knowledge to construct.

Other Types of Soil Retention Systems

- Sheet piling
  - Steel sheet piles are long structural sections with a vertical interlocking system that creates a continuous wall.

Other Types of Soil Retention Systems Cont.

- Caissons
  - Series of drilled holes filled with re-enforced concrete that are most often used when shallow, spread footings are not feasible.

Bentonite Waterproofing Systems

- Property-line Construction Applications
- Can be applied as soon as the forms are removed
- Can be installed in freezing weather
- Can seal small cracks
- No special installation equipment required
- Natural mineral – not harmful to the environment
- Self-healing (sealing) characteristics
- No product mixing required by applicator

Included in This Presentation

- Review 2 of the most widely used bentonite systems on the market
- Different makeup of the systems and specific uses
- Benefits and Limitations
- Author not endorsing any product or system

Sodium Bentonite Limitations.

Inherent limitations of Bentonite HDPE

- Application in brackish or slightly salt groundwater
- Standing water during construction – premature hydration
- Over snow – premature hydration
- Requires compaction/confinement to be effective – a minimum of 24 psf is required

Commercial Bentonite/HDPE Products

Product Reviewed :

- Tremco - Paraseal LG
  - Multi-layer sheet membrane waterproofing system
- CETCO – Volclay Voltex DS
  - Interlocking Geotextile waterproofing panel system

Tremco – Paraseal LG

- Multi-layer (3-layer) sheet membrane waterproofing system
  1. Consists of self-sealing, expandable layer of granular bentonite
  2. Bentonite layer is laminated to HDPE sheet
  3. Covered with a protective layer of spun polypropylene
- Controlled thicknesses of 170 mils to 200 mils
- Designed for blind-side installations

Tremco – Paraseal LG Cont.

Blindside application

- Applied before walls are poured
- Designed to resist damage from:
  - Some exposure to inclement weather
  - Normal concrete pours
  - Direct installation of shotcrete
- Can be used in hydrostatic head conditions

Prehydration Due to Rain can Lead to Failure

Tremco – Paraseal LG Cont.

Installation in Lagging (blindside) Applications

- All installations have bentonite side facing concrete to be waterproofed
- Critical all voids/spaces between lagging and soil are grouted or filled with sand to achieve confinement
- Can be installed vertically or horizontally
  - Cast-in-place – overlap 3” shingle fashion (top over bottom when pouring against
  - Shotcrete – overlap 4” shingle fashion (bottom over top) when shotcreting against
- Fasten all seams at 4”
- Apply paramastic around tiebacks and pentrations

Tremco – Paraseal LG Cont.

Additional Specifications

- HDPE Laps can be sealed with butyl tape for gas membrane and additional level of waterproofing
- Penetrations need to be detailed properly
- Puncture resistant HDPE liner of 169 lb point load
- Protect from moisture during storage. Do not double stack

Typical Paraseal Membrane Application

Seam Tape Being Applied

Witches Hat Over a Tieback Head

- The penetration is detailed with Parastick n' Dry (bentonite waterstop), and the witches hat (molded polyethelyne) is filled with Paramastic
- The hat is nailed over the tieback, and another target sheet of Paraseal is installed over it
- Double protection of bentonite.

Paraseal Tie-Back Detail

- The penetration is detailed with Parastick n' Dry (bentonite waterstop),

The witches hat (molded polyethelyne) is filled with Paramastic and the hat is nailed over the tieback

Another target sheet of Paraseal is installed over it


Another target sheet of Paraseal is installed over it…..


.....and nailed

CETCO – Volclay Voltex DS

- Interlocking Geotextile Waterproofing System
  1. Comprised of two high-strength geotextiles sandwiching bentonite, which are interlocked through a needle punching process
  2. Includes a integrated polyethylene liner for added protection and vapor barrier
- Sandwiches 1.10lbs of bentonite per square foot
- Designed for waterproofing under slabs and blind-side applications

CETCO – Volclay Voltex DS Cont.

- Can be installed directly over a properly prepared substrate without the need of a concrete mud slab
  - Although mud slab does provide a more consistent and sound substrate
- Durable composite construction resists damage
  - Although a 3” protection slab can be provided for better under-slab protection

CETCO – Volclay Voltex DS Cont.

- Blindside applications
- Installed against the retention wall
- Concrete is poured against it using a single-sided form
- Recommended for shotcrete application that 2 layers of bentonite be used
  - Cardboard type panel +Voltex DS

CETCO – Volclay Voltex DS Cont.

Installation

- Woven geotextile side is installed facing installer
- Shotcrete is shot against geotextile side
- Panels are secure with washer head mechanical fasteners
- Can be installed to green concrete without primers or adhesives
- Can be installed in freezing or slightly damp conditions

CETCO – Volclay Voltex DS Cont.

- Unique Design Feature
- Concrete/shotcrete clings to geotextile fibers
- Allows waterproofing panels to stay in place, against concrete and shotcrete walls
- Designed only for below-grade waterproofing applications

VOLTEX DS

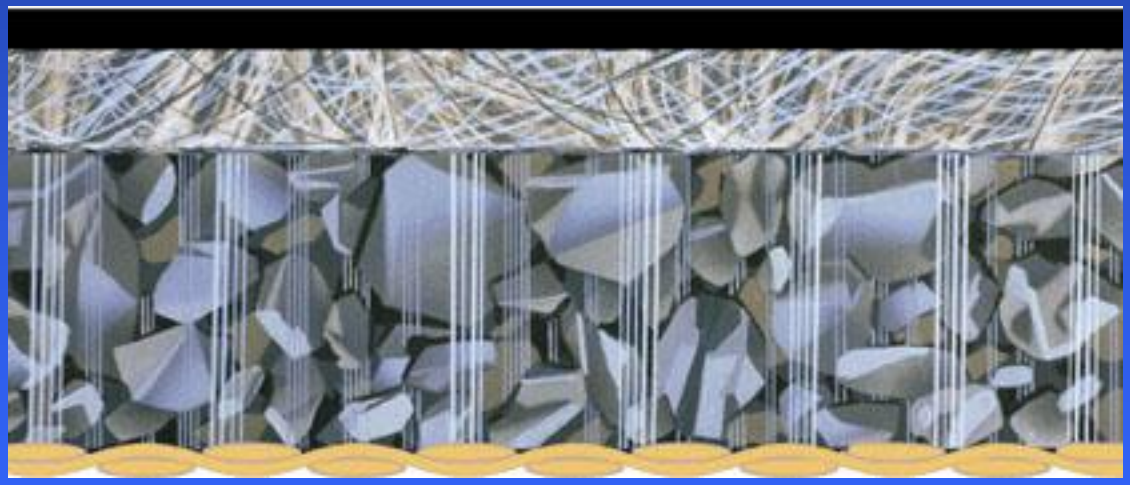
CROSS-SECTION ILLUSTRATION

HDPE LINER

NON-WOVEN FABRIC

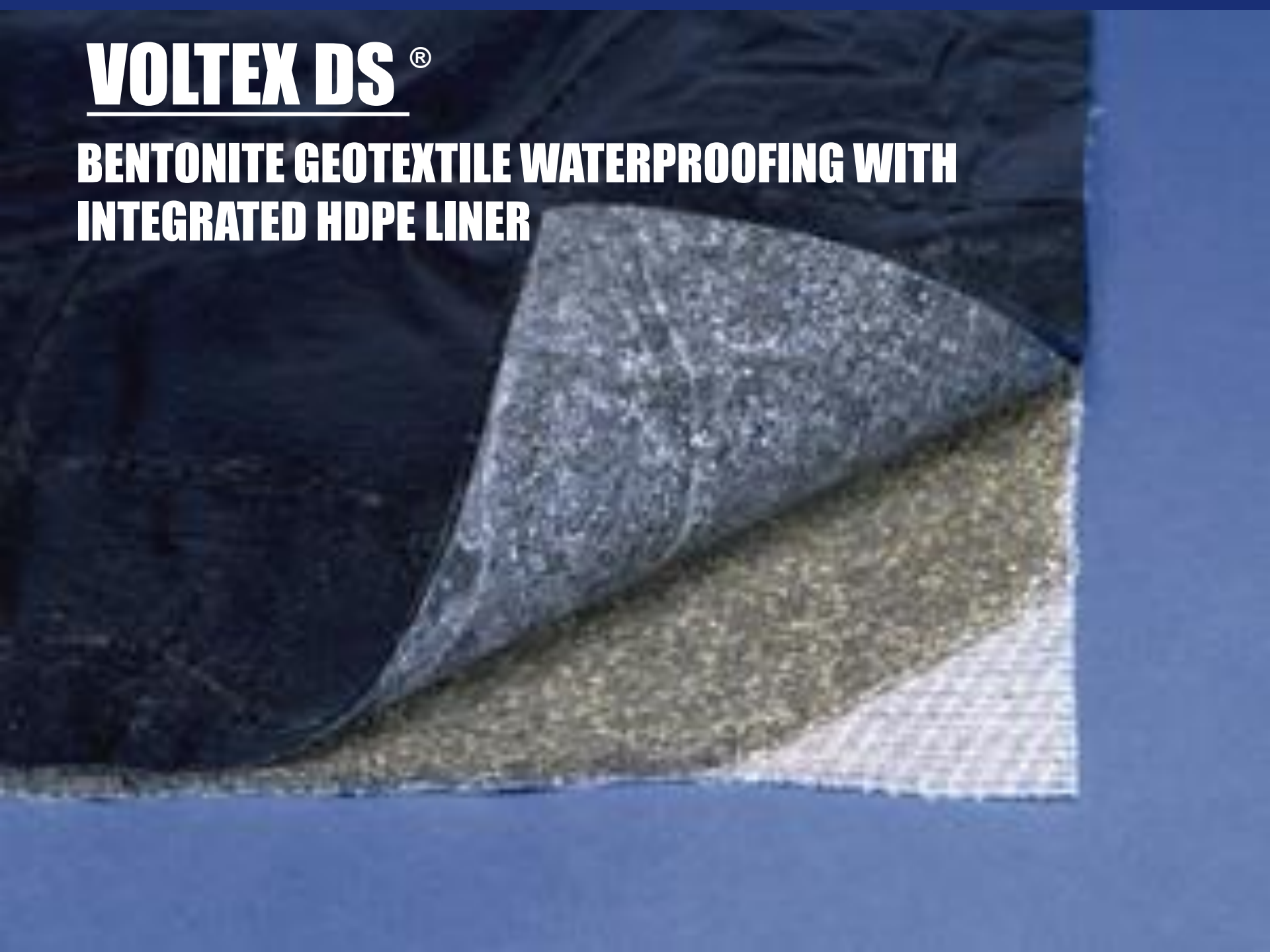
GRANULAR BENTONITE
1.1-LBS./SF

WOVEN FABRIC



VOLTEX DS®

BENTONITE GEOTEXTILE WATERPROOFING WITH INTEGRATED HDPE LINER

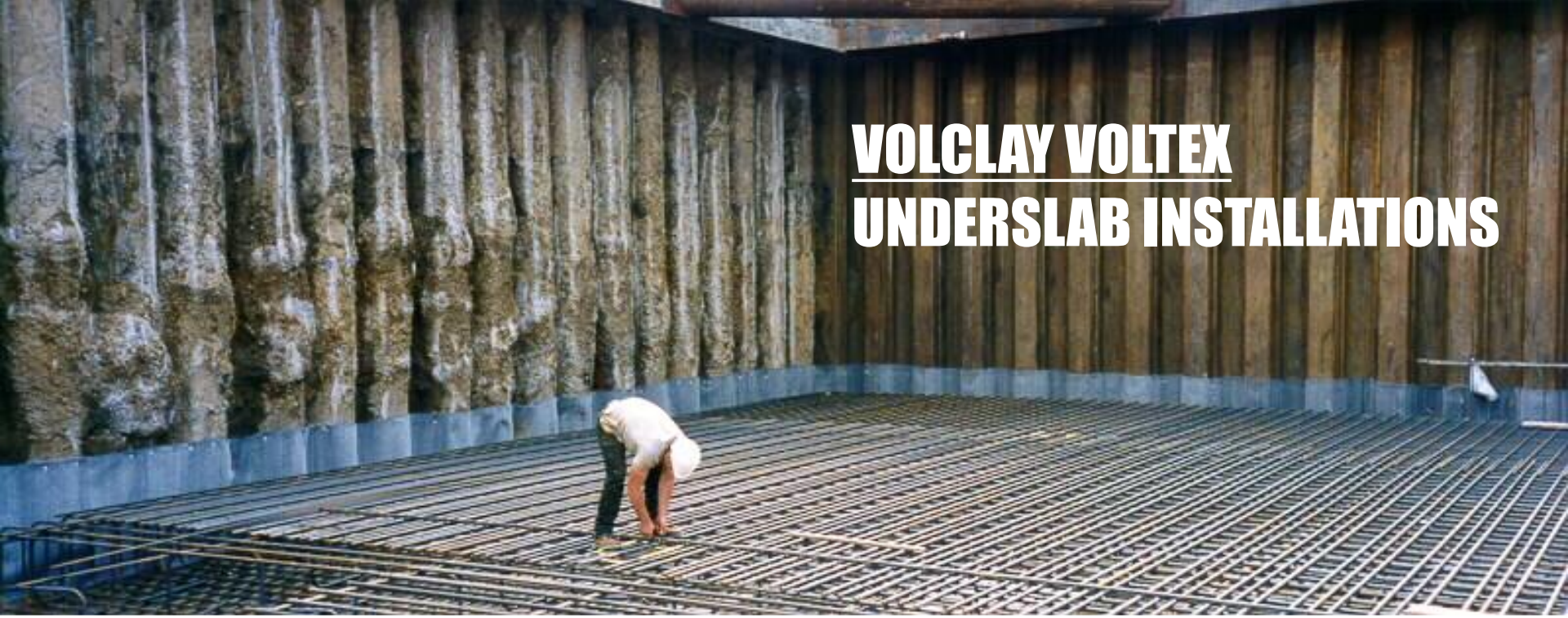


VOLTEX IS FASTENED TO CONCRETE FOUNDATION WALLS WITH WASHER-HEAD FASTENERS POSITIONED 24” ON CENTER


VOLCLAY VOLTEX
UNDERSLAB INSTALLATION
OVER A MUD SLAB

VOLCLAY VOLTEX
UNDERSLAB INSTALLATION OVER COMPACTED EARTH SUBSTRATE

VOLCLAY VOLTEX
UNDERSLAB INSTALLATIONS




VOLCLAY VOLTEX
CONCRETE FOUNDATION
WALL APPLICATION

VOLCLAY VOLTEX
SOLDIER PILE & LAGGING APPLICATION

VOLCLAY VOLTEX
METAL SHEET PILING APPLICATION

Paraseal / Voltex Comparison

TECHNICAL DATA		
Physical Properties Method	Paraseal LG Value	Voltex Volclay Value
Tensile Strength: Membrane (PSI)	4,000 PSI (27.6MPa)	N/A
Resistance to microorganisms (bacteria, fungi, mold, yeast)	unaffected	unaffected
Elongation-ultimate failure of membrane	700%	N/A
Puncture Resistance	169 lbs (76.6kg)	140 lbs (63.5kg)
Hydrostatic Pressure Resistance	150 Ft (45.6m)	231 ft. (70 m)
Resistance to water migration under membrane: zero leakage	150 Ft (45.6m)/Head	150 Ft (45.6m)/Head
Grab Tensile Strength	N/A	95 lbs. (422 N)
Permeance	2.7x10-13cm/sec	1 x 10-10 cm/sec.
Installation Temperatures	-25°F to 130°F (-31.7°C to 54.4°C)	
Low Temperature Flexibility	No effect before or after installation	Unaffected at -25°F (-32°C)

Source, Manufacturer's published data

Project Case Study

- Forensic Case Study Sunnyvale, California
- Waterproofing failure of Downtown Sunnyvale Garage
- Work performed for a construction defect litigation case
- Bentonite/HDPE composite system was installed and had failed
- 2nd largest below-grade structure in Northern California
- Largest below-grade waterproofing repair of it's kind in California

Project Case Study Cont.

- Structure experience extensive leaking throughout below-grade perimeter walls
- Built on zero lot line with shotcrete foundation walls against wood lagging and soldier pile retention walls

Project Case Study Cont.

- Core samples taken from 18” thick shotcrete walls
- Partial excavation behind lagging
- Reviewed original construction drawings
- Reviewed lagging installation photos
- Reviewed soil consolidation
- Visual observations of leaks and water testing

Garage Structure is 2 stories Below the Water Table

Downtown Sunnyvale Garage Leaked Throughout From Day 1

Chemical Grout was Injected 24” O.C.

Project Case Study Cont.

Repairs included:

- Drilling 5/8” diameter holes on a 4’ on center grid formation through 18” thick shotcrete foundation wall
- Several types of hydro-active grouts were injected through the holes

Repair work in progress

Typical Injection Equipment

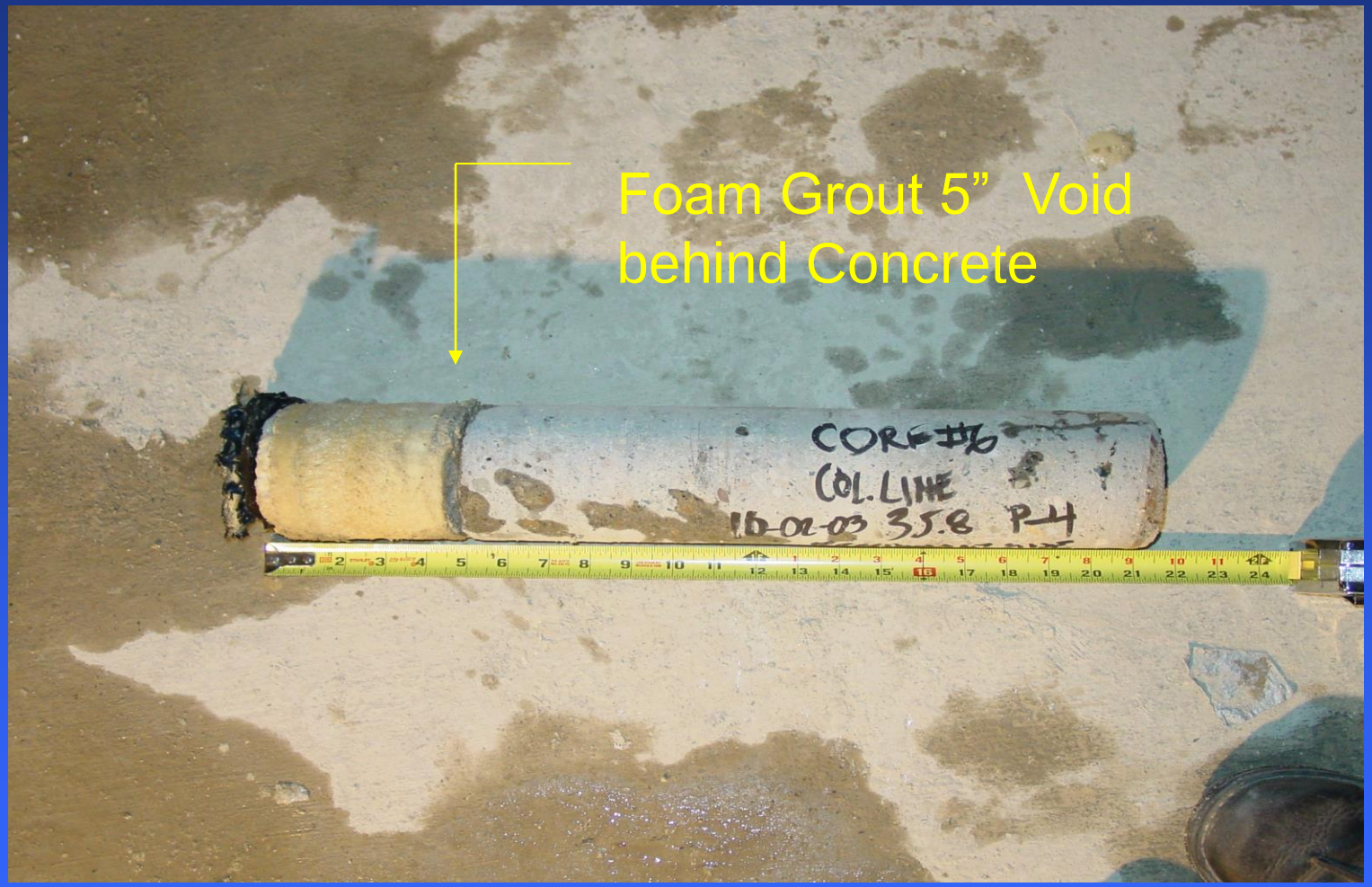
The Repair of Failed Garage Cost Over $3M

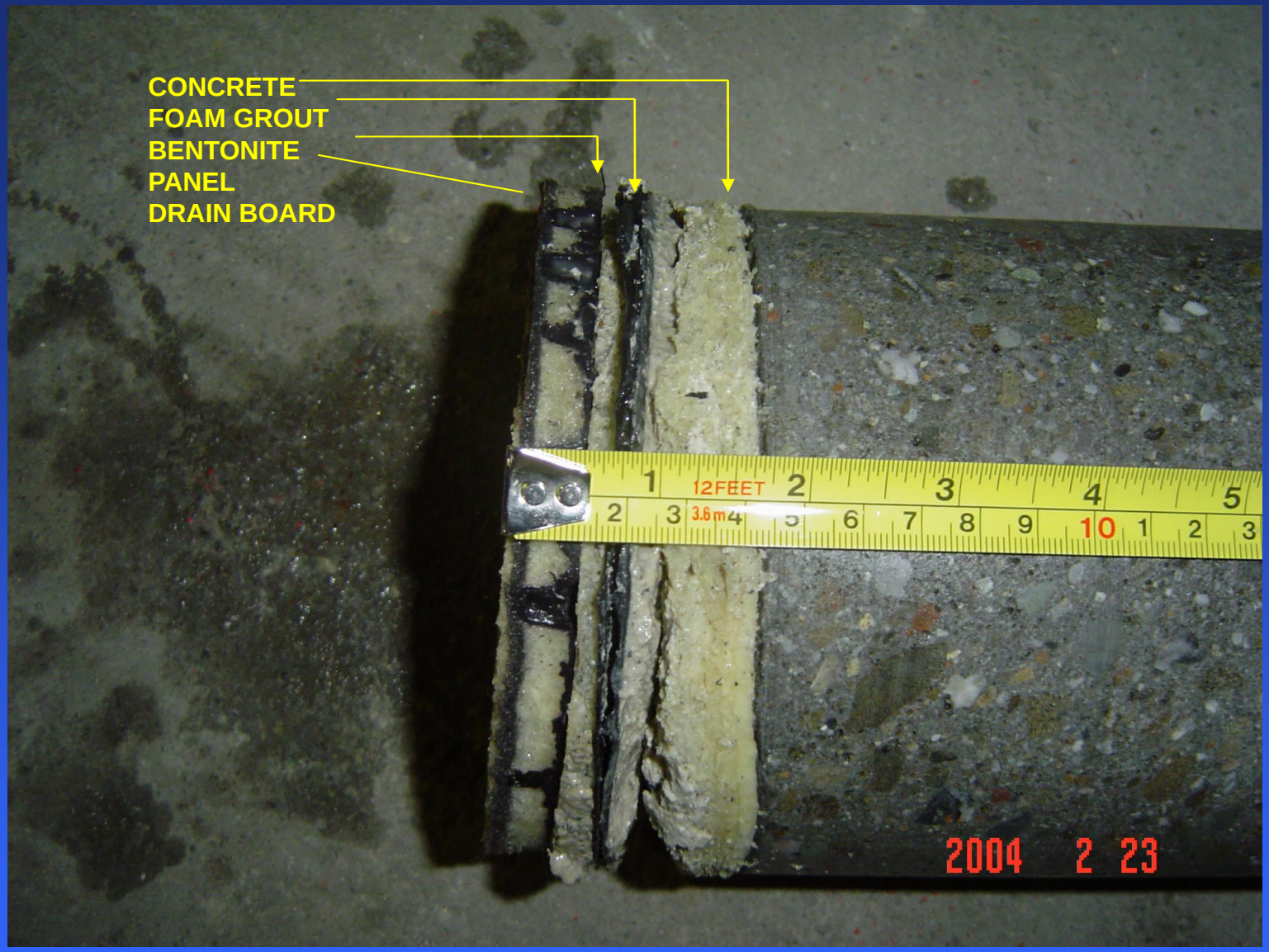
Grout Creates a “Curtain” Behind Concrete

Foam Sometimes Leaves a Mess

Concrete Cores Were Taken To Asses Performance

Cores Showed Large Voids Behind Shotcrete





Voids were present on both sides of the retaining wall and ranged from 1” thick to up to 4” thick. Grout in post-repair picture shows measurable void.

Site was Excavated to Forensically Analyze Failure

Site was Excavated to Forensically Analyze Failure

Hydrated Bentonite

Hydrated Bentonite

Seams in Membrane Were Sealed With Butyl Tape

Gap Between Lagging and Shotcrete

Wood Lagging Issues with Bentonite

Excavation of the soil behind the wood lagging revealed that once the wood gets wet, it swells, bends and twists, especially if there are voids between the soil and wood.

Voids at Solder Piles

Void between solder pile and foam protection board was also evident and may have contributed to the failure of the bentonite waterproofing system.

Void behind foam protection board

Void Behind Protection Board

Section of Concrete Was Jack Hammered and Removed Inside

Found Some Laps in Membrane Where Butyl Tape Had Failed

Lessons Learned from Failure

- Bentonite requires confinement to work
- Wood lagging can have gaps and voids in the behind it which can allow lagging to move back
- Wood twists and cups when it gets wet, leaving voids
- Protection board at solder pile left voids and potentially reduced the system's effectivenss

Project Case Study Cont.

- Grout Characteristics
- Quickly expands and cures upon contact with water to form a water barrier behind the surface of the wall and under portions of the slab
- Designed to fill an voids behind foundation wall
- Upon reaching maximum confinement, grout continues to internally expand thus increasing in density

Project Case Study Cont.

- Case Study Conclusion
- Potential factors in failure
  - Cast-in-place concrete
  - Lagging
  - Soil consolidation
- Care must be taken to fill voids behind lagging to ensure good consolidation
- Lessons learned – led to change in manufacturers specifications

Presentation Conclusion

Sodium Bentonite is very effective below-grade waterproofing system if:

- Appropriate products are specified and installed properly
- Soil testing is performed
- Quality control processes are implemented during construction

Thank You

Questions?