ALLANA BUICK & BERS

Making Buildings Perform Better

- Architectural Engineering firm established in 1987
- Karim P. Allana, PE, RRC, RWC
- 104 employees in in California, Nevada and Hawaii, Washington with Expertise in:

Construction Forensics; Exterior walls systems; Remedial design and engineering; Roofing; Waterproofing; Structural engineering; Mechanical engineering; Construction

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Introduction

Case History, Downtown Sunnyvale Garage, Below Grade Waterproofing Failure

- 2nd Largest Below Grade Structure in Northern California
- 4 stories underground
- 12 to 14 feet in the water table
- Started Leaking as soon as dewatering pumps were turned off

Introduction cont.

Focus of the presentation:

- Case Study of a failed blindside waterproofing system
- Soil retention systems and their impact on waterproofing Failure
- Sodium bentonite based waterproofing systems used in blind-side construction
- DeNeef Hydroactive Grout Injection Repair. One of the largest injection repair projects in the country

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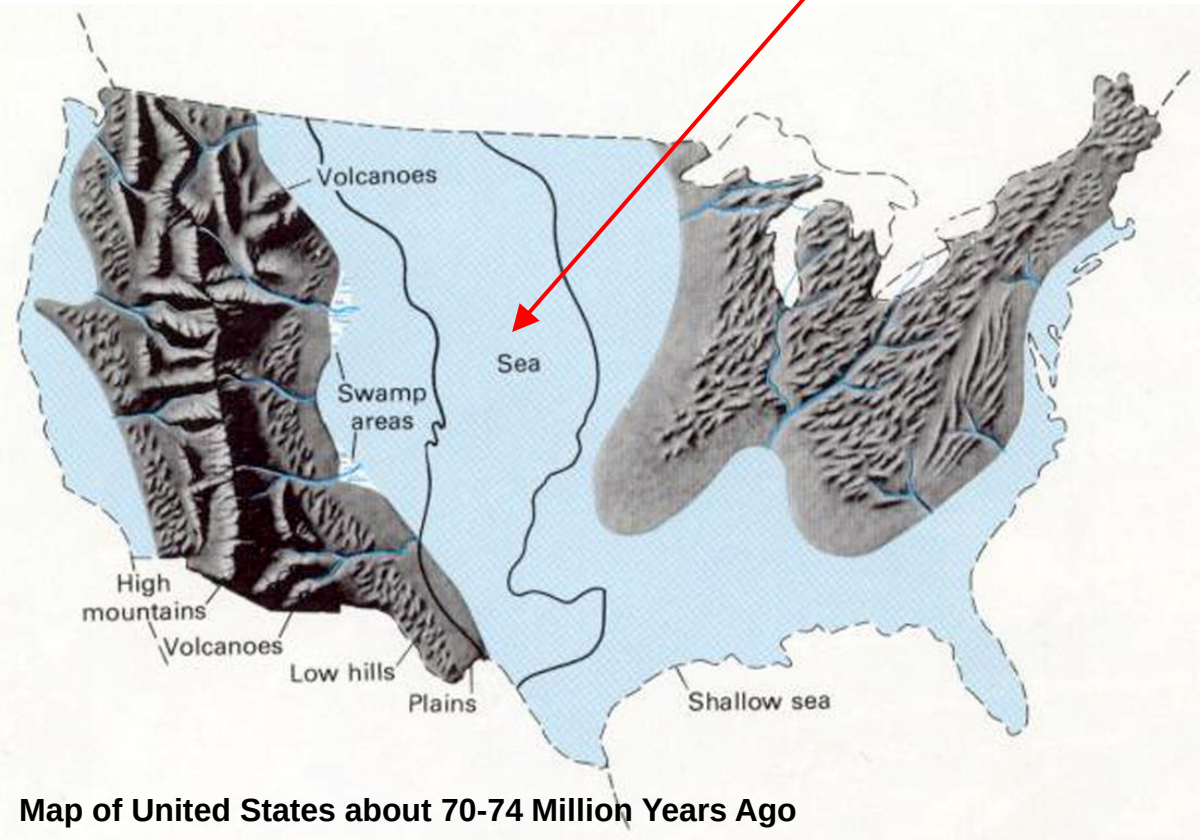
History of Sodium Bentonite

- 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

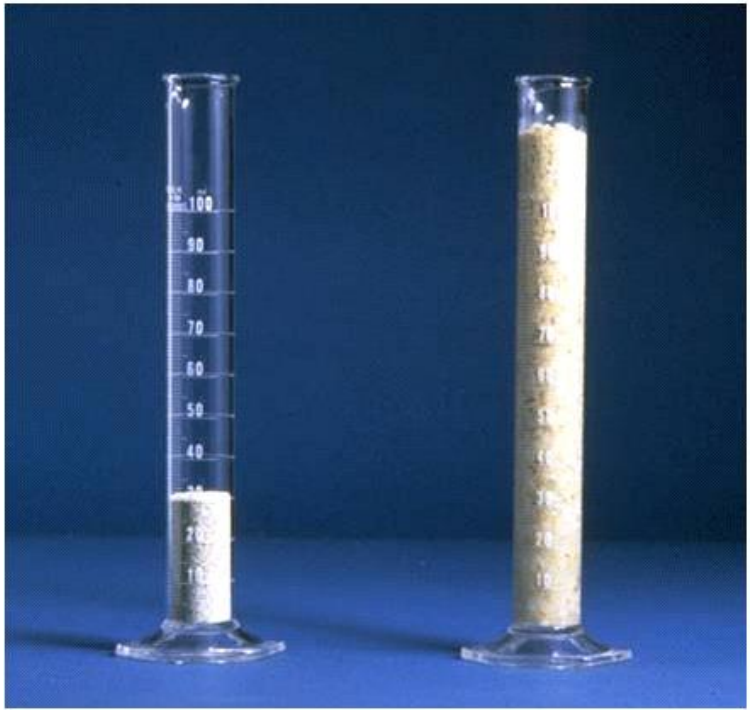


Map of United States about 70-74 Million Years Ago

History of Sodium Bentonite Cont.

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"



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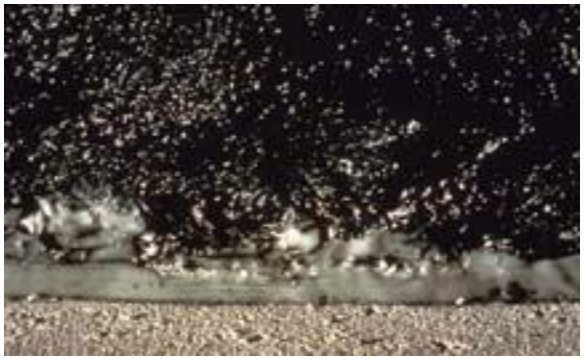
Bentonite Seals When Wetted Cont.

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

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Bentonite Requires Confinement

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

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

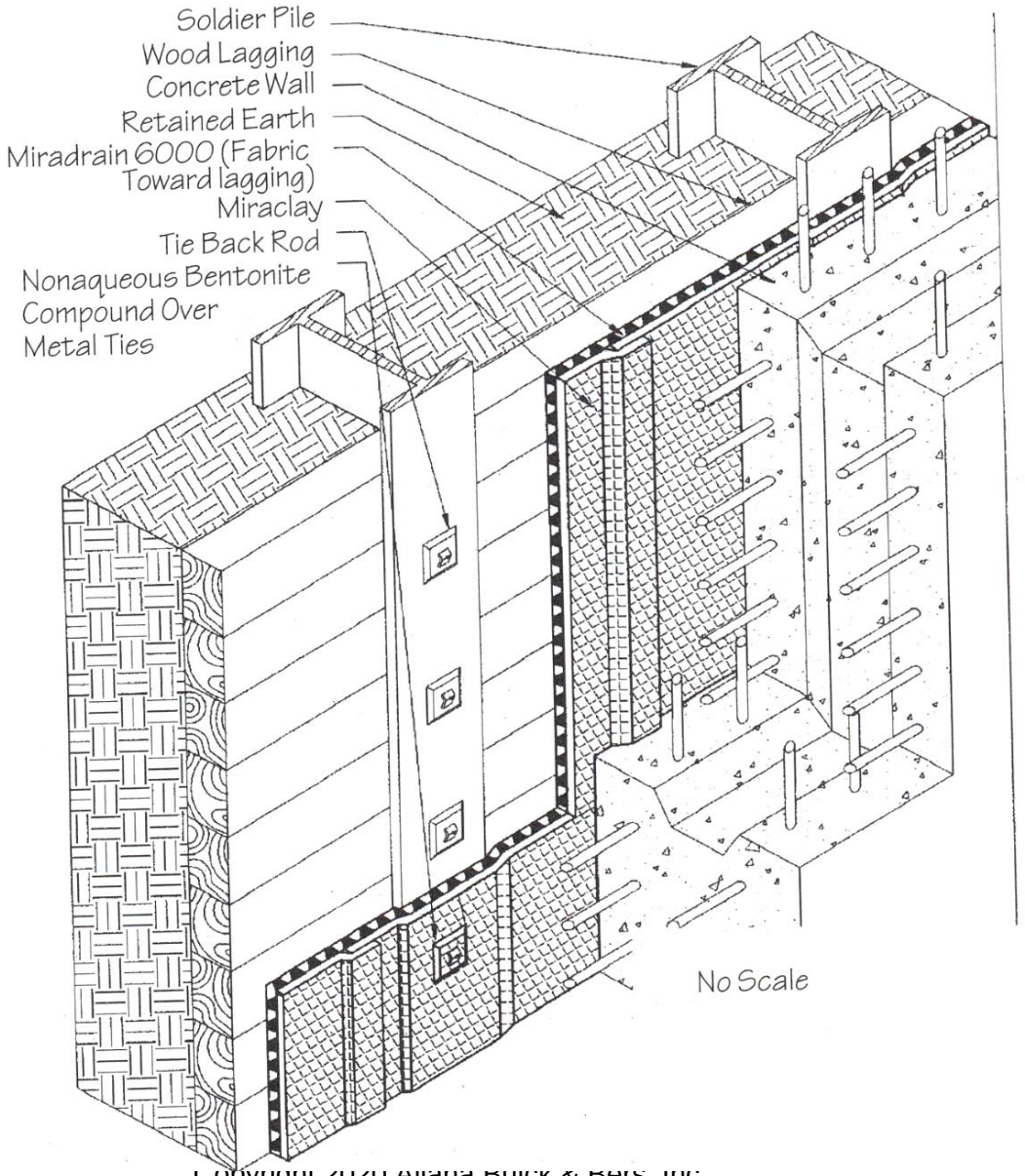
- Defined – Blind-side is positive-side
- Blind-side waterproofing systems are required where the exterior faces of foundation walls are not accessible, which requires application of the waterproofing system to the formwork surface facing the excavation.
- This results in the waterproofing's final location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

Property Line Applications

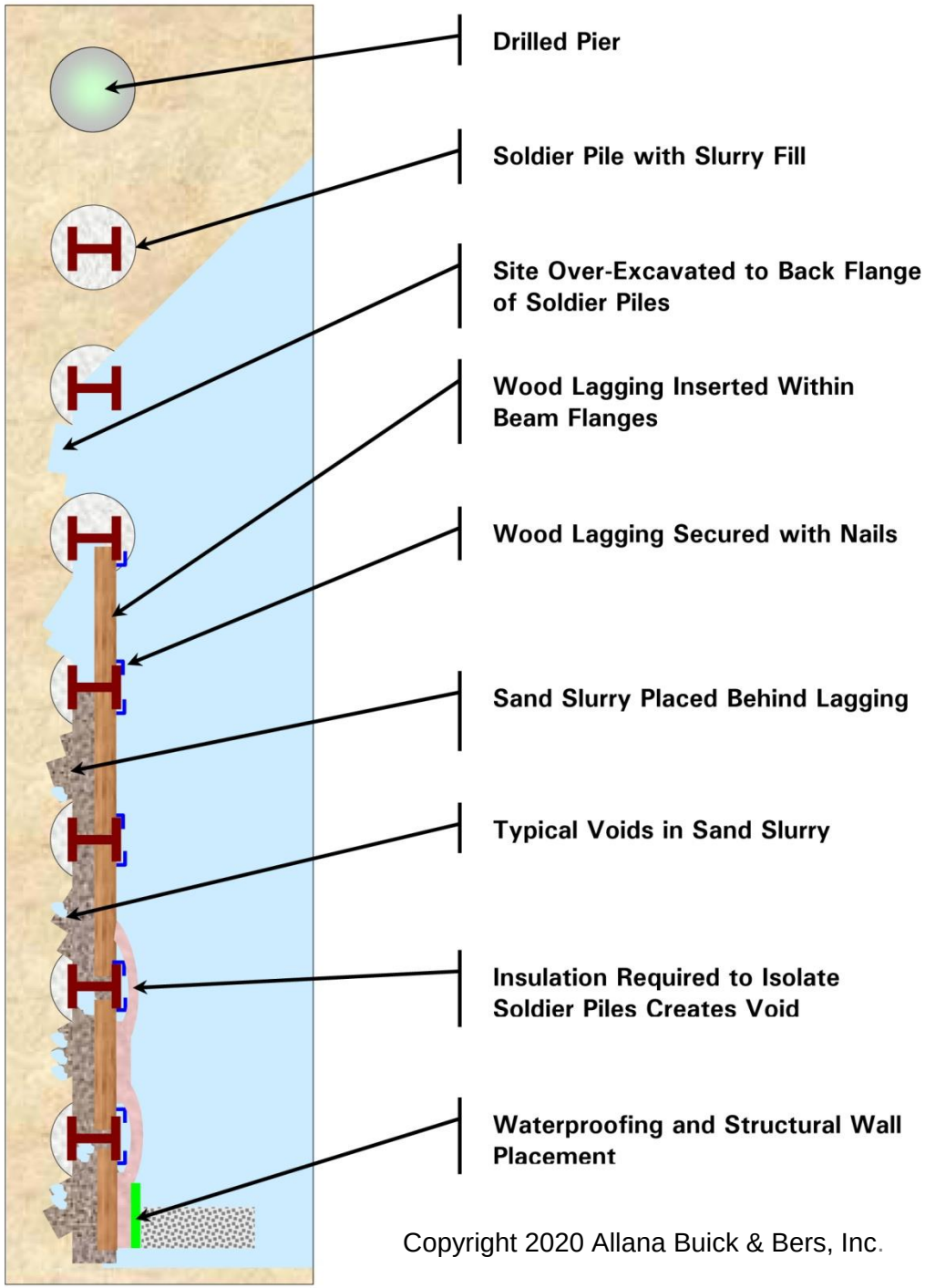
Earth Retention Systems

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

Wood Lagging - Earth Retention System



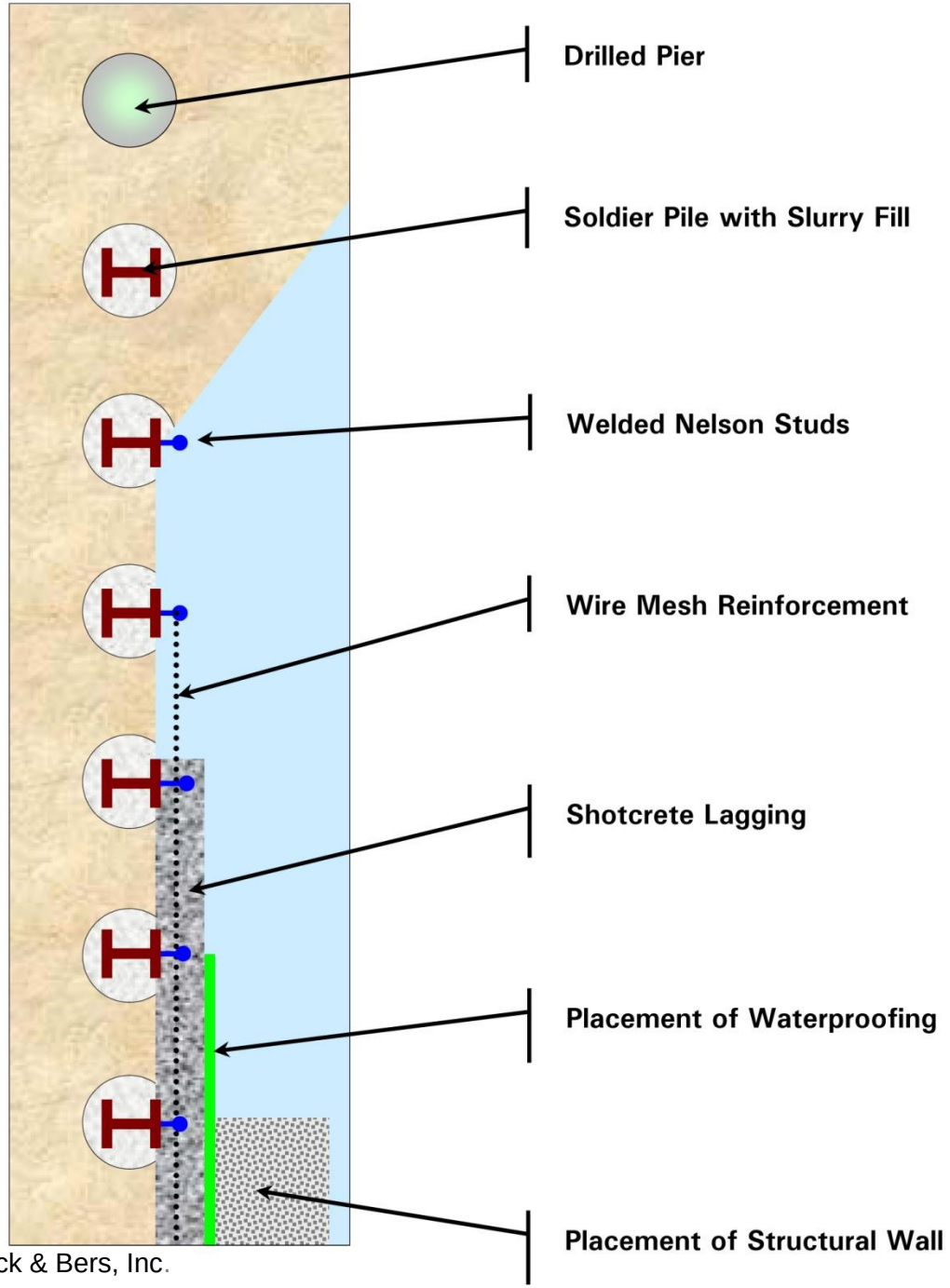
Conventional Wood Lagging



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

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

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

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.

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.

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.

- 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

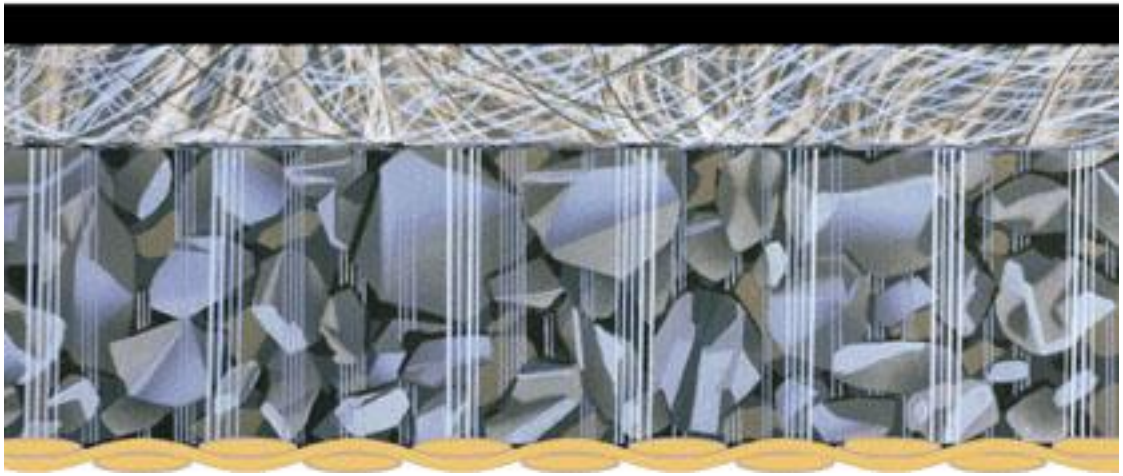
CROSS-SECTION ILLUSTRATION

HDPE LINER

NON-WOVEN FABRIC

GRANULAR BENTONITE
1.1-LBS./SF

WOVEN FABRIC



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VOLTEX DS®

BENTONITE GEOTEXTILE WATERPROOFING WITH INTEGRATED HDPE LINER

VOLCLAY VOLTEX
SOLDIER PILE & LAGGING 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

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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 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

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Repair work in progress

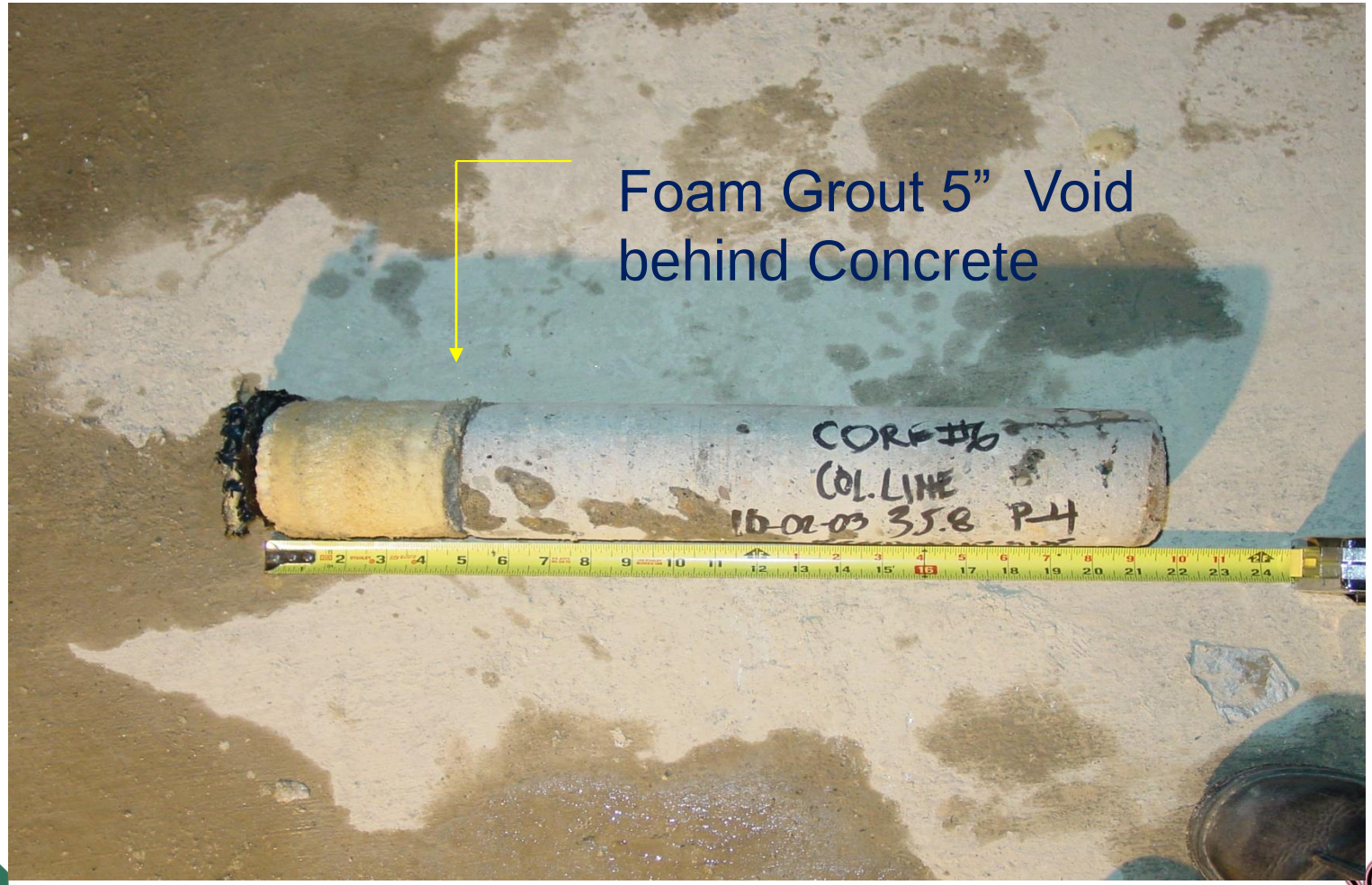
Typical Injection Equipment

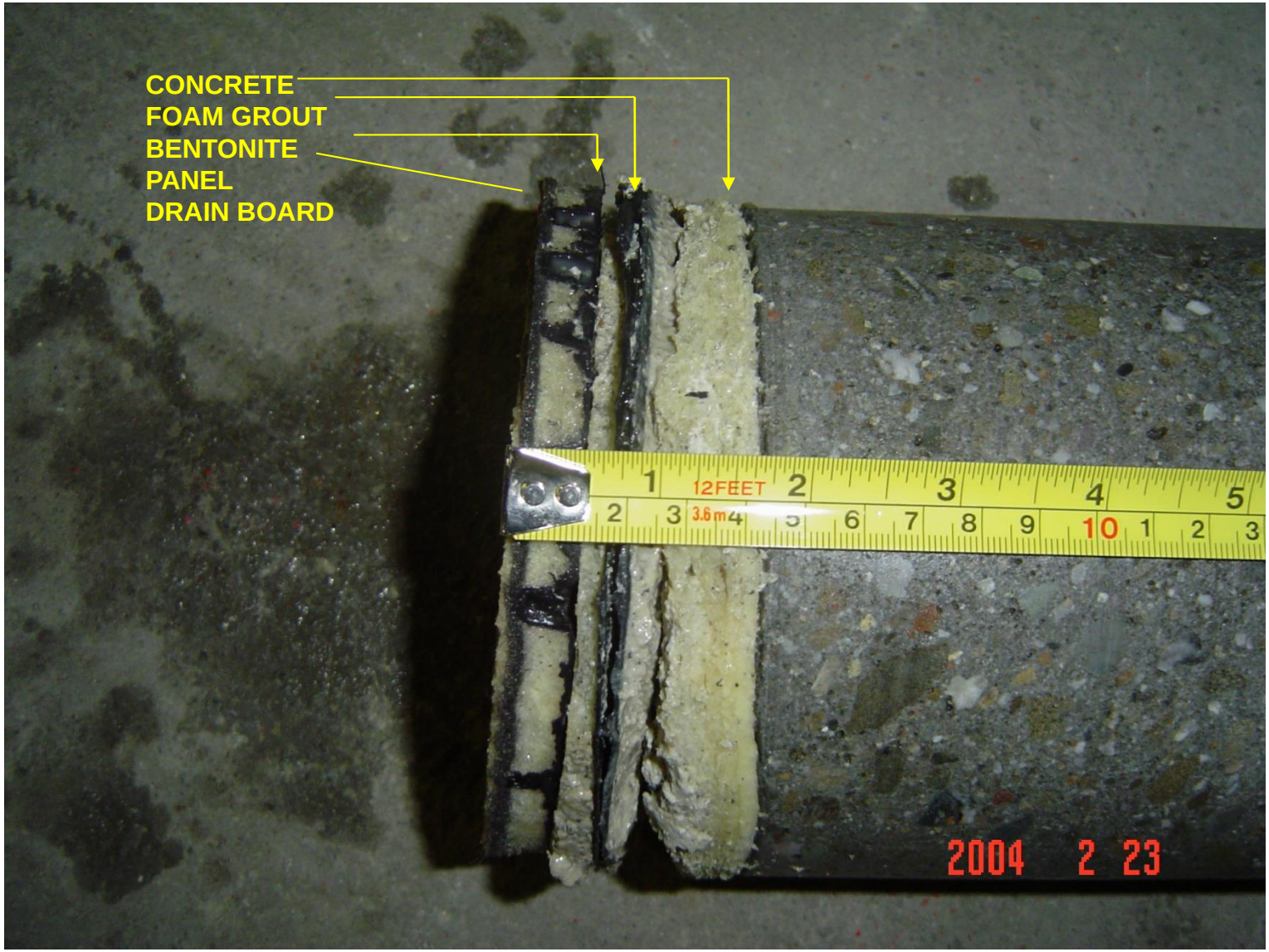
Grout Creates a “Curtain” Behind Concrete

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.

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Site was Excavated to Forensically Analyze Failure

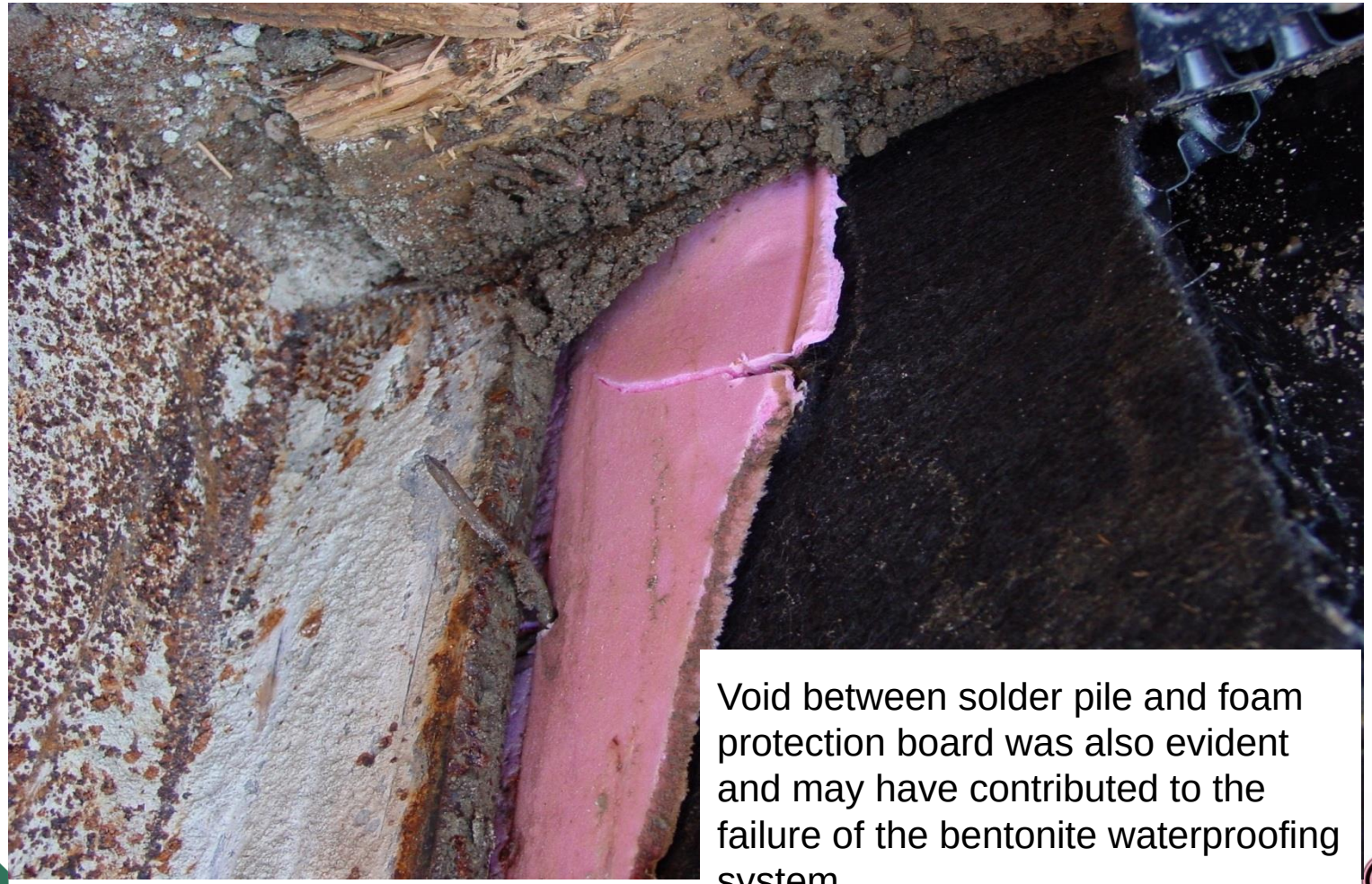
Site was Excavated to Forensically Analyze Failure

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

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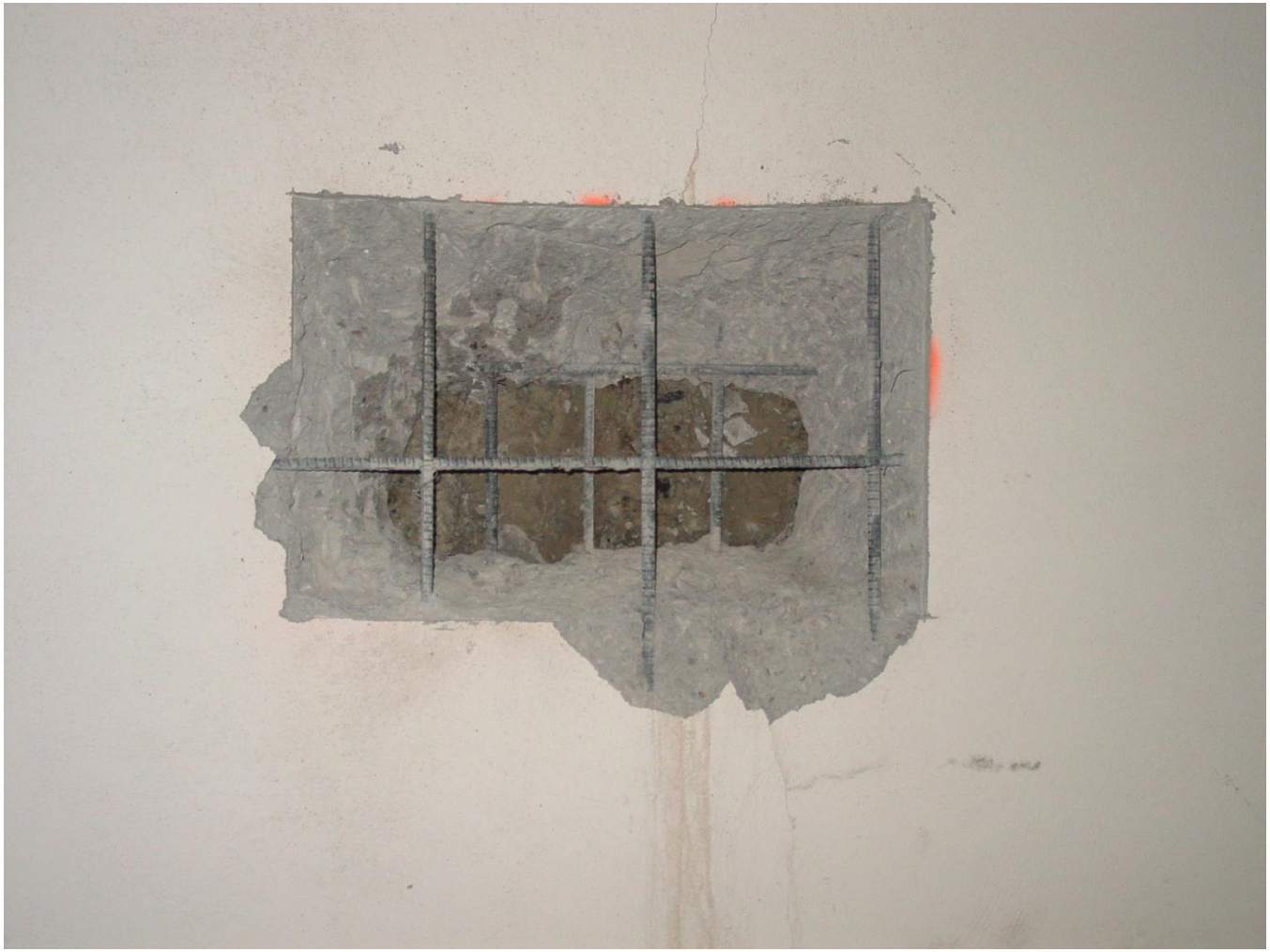
Void Behind Protection Board

Section of Concrete Was Jack Hammered and Removed Inside



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 large 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
- Voids can be large and require a lot more grout. Don’t under-estimate grout requirement
- Lessons learned – led to change in manufacturers specifications

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Karim P. Allana, PE, RRC, RWC

Senior Principal

Thank You

Questions?

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