Below Grade Waterproofing…

Introduction to Basic Types of Waterproofing and Vapor Barrier Systems, Common Failure Modes, and Design Considerations

Presented By:

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- **Education:** B.S., Civil Engineering, Santa Clara University
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- **Certification:** Registered Roof Consultant (RRC), Roof Consultants Institute, and Registered Waterproofing Consultant (RWC)
- **Overview:**
  - CEO and Senior Principal at Allana Buick & Bers.
  - Former Turner Construction Employee (Project Engineering and Superintendent)
  - Over 37 years experience providing superior technical standards in all aspects of building technology and energy efficiency.
  - Principal consultant in forensic investigations of building assemblies, failure analysis, evaluation and design of building infrastructure and building envelope evaluation and design.
  - Expert in all aspects of building envelope technology.
  - Completed numerous new construction, addition, rehabilitation, remodel and modernization projects for public and private sector clients.
  - Specialization in siding, roofing, cement plaster, wood, water intrusion damage, window assemblies, storefronts, below grade waterproofing, energy efficiency, solar engineering and complex building envelope and mechanical assemblies.

ABBAE Firm Overview

- Allana Buick & Bers (ABBAE) is an Architectural Engineering firm specializing in Building Envelope Systems
- ABBAE is one of the 5 largest building envelope consultants in the country
- ABBAE has over 33 years of experience & over 12,500 projects
- ABBAE is also a leading Forensic Defect firm with hundreds of forensic projects (litigation)
- Locations – 16 offices across California, Nevada, North Carolina, Oklahoma, Oregon, Texas, Virginia, Washington, Colorado and Hawaii

Staff & In-House Expertise

- Licensed Professional Engineers – Civil, Structural, and Mechanical
- Registered Architects
- Building Enclosure Commissioning Process Providers (BECxPs)
- Registered Building Envelope Consultant (RBEC)
- Registered Roofing Consultants (RRCs)
- Registered Waterproofing Consultants (RWCs)
- Registered Exterior Wall Consultant (REWCs)
- Registered Roof Observers (RROs)
- Certified Exterior Insulation and Finish System (EIFS) inspectors
- Curtain Wall Specialists
- ICC Certified Building Inspectors
- Quality Assurance Monitors
- Water Testing Experts
- Leak Investigation and Diagnosis Experts
- Infrared Imaging and Nuclear Moisture Scanning Experts

ABBAE Building Expertise

- Building Envelope Systems
  - Roofing Systems
    - High-Slope/Low-Slope Roofs
    - Green/Garden Roofs
    - Drainage Systems
    - Pedestrian Plazas
  - Exterior Wall Systems
    - Wall Cladding/Siding/GFRC/pre-cast
    - EIFS/cement plaster/stucco
    - Sheet Metal Flashings
  - Windows and Glazing Systems
    - Punched Windows
    - Curtain Wall/Window Wall Systems
    - Sliding Glass Doors
    - Skylights

- Building Envelope Systems (cont'd)
  - Roofing & Waterproofing Systems
    - Deck/Balcony/Lanai Waterproofing
    - Podium Waterproofing
    - Pool/Spa Deck Waterproofing
    - Above-Grade/Below-Grade Waterproofing
    - All types of low and steep sloped roofing
  - Commissioning BECx
    - OPR/BOD/Commissioning Plan
- Mechanical/HVAC Systems
  - HVAC design
  - Plumbing systems
  - Commissioning and testing

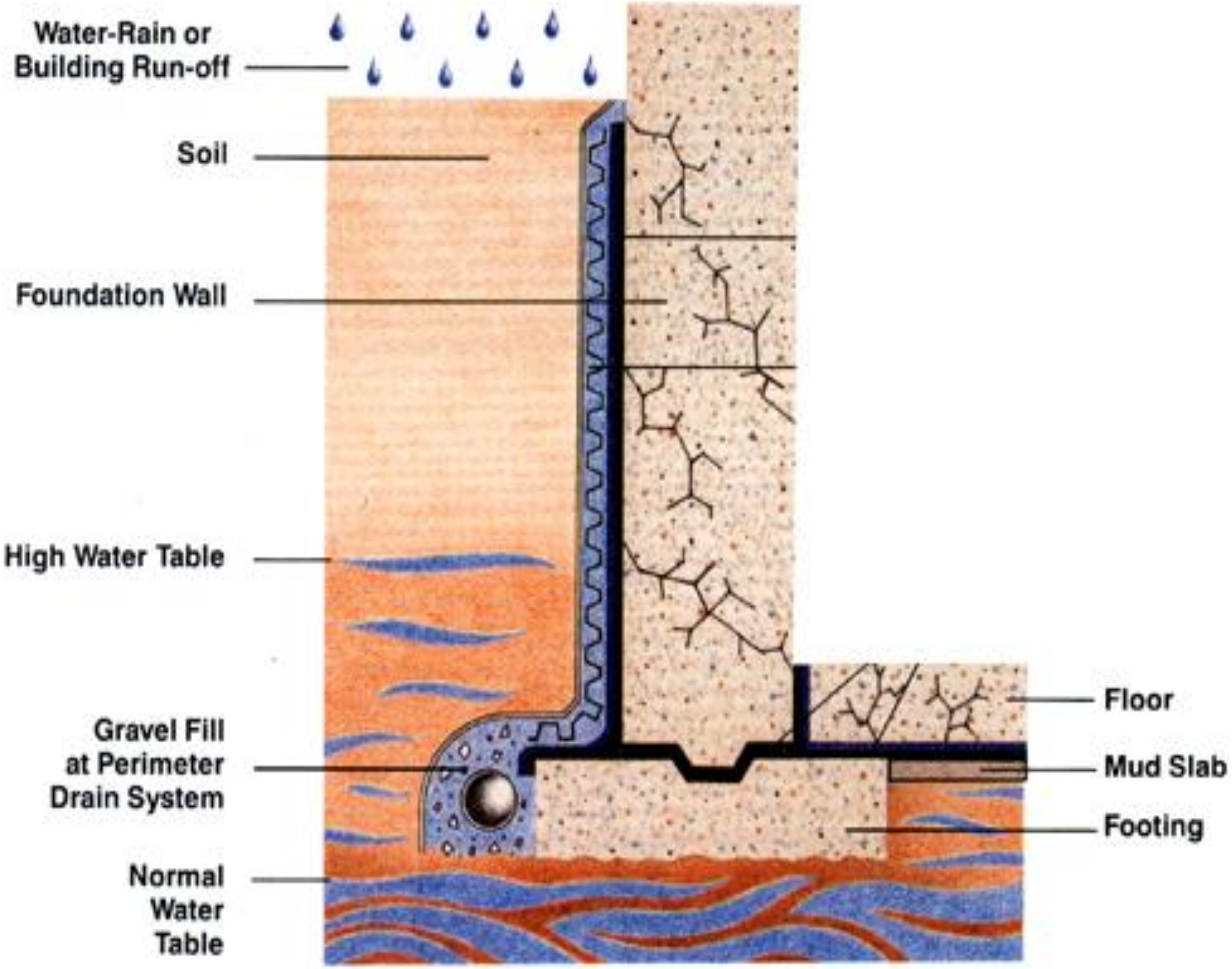
ABBAE Core Services

- Consulting and third-party peer review services
- Engineer of record for building envelope systems
- Contract administration services
- Inspection services (usually direct with owner)
- Air and water performance testing
- Mock-up design, observation, and testing
- Building assessments and forensic investigations
- Litigation support and expert witness services
- Educational seminars with AIA credits

Introduction

- We will discuss:
- Soil Retention Systems
    - Wood Lagging & Soldier Piles
    - Shotcrete Lagging
    - Soil Nailing
- Positive & Negative Side Waterproofing
    - Distinct Difference
    - Blind-side is Positive Side
- A general review of the various types of waterproofing systems
    - Below grade Application
        - Upside Down Fully Bonded
        - Pressure Sensitive HDPE and Modified Bitumen
        - Vapor Barriers
        - Bentonite
    - Sub Slab Application
        - Vapor Barriers and Drainage

Below Grade Waterproofing Basics



Waterproofing Vs. Dampproofing

- Often times the terms *Waterproofing* and *Dampproofing* are incorrectly interchanged. According to the ASTM definition:

Waterproofing : Is the treatment of a surface to *PREVENT* the passage of *liquid water* in the presence of hydrostatic pressure.

Dampproofing : Is the treatment of a surface to *RETARD* the absorption of *moisture* in the absence of hydrostatic pressure.

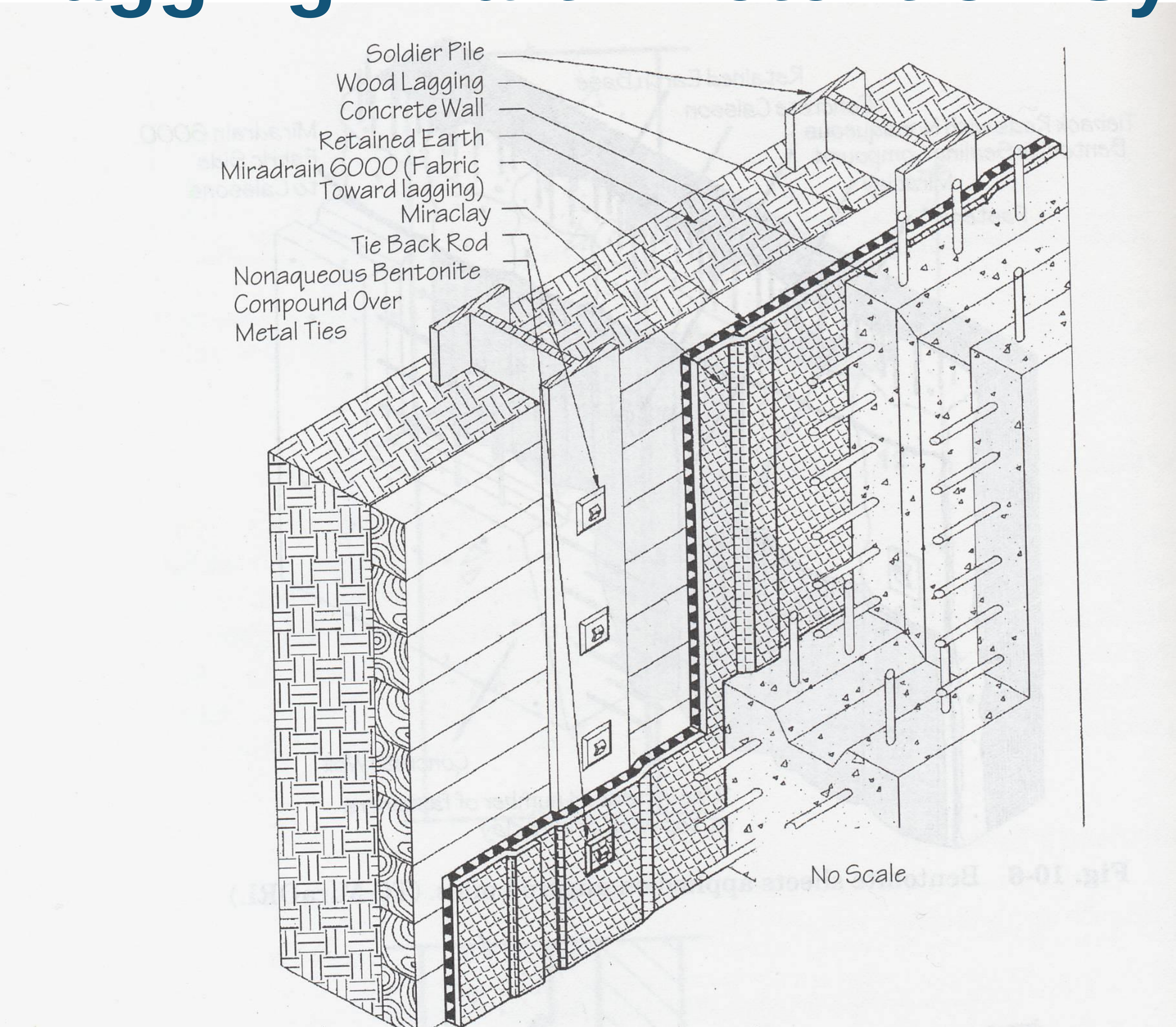
Soil Retention Systems

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

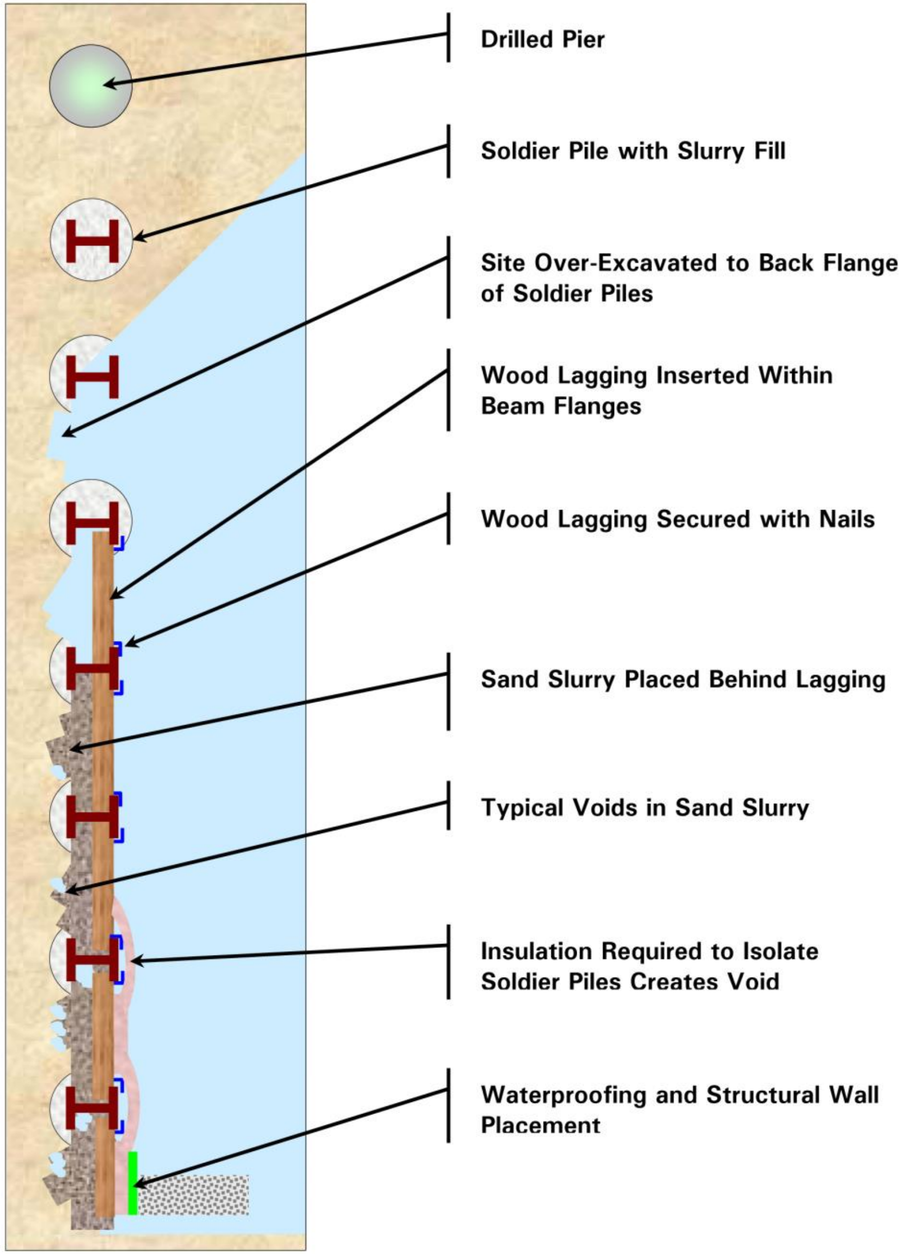
Wood Lagging & Soldier Piles

- 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.
- 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.

Wood Lagging - Earth Retention System



Conventional Wood Lagging

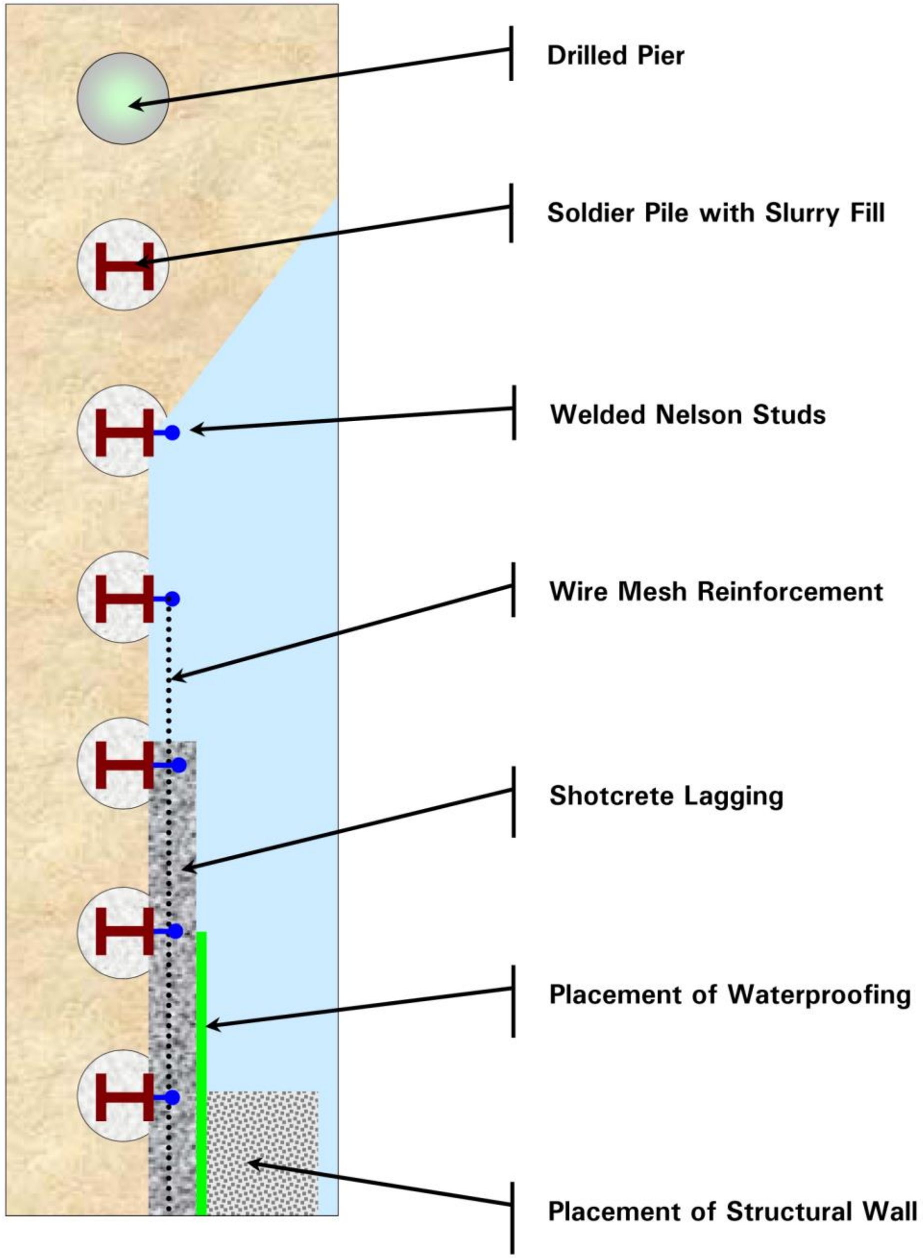


Conventional Wood Lagging

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.
- Typical construction sequence begins with the excavation of a shallow cut. Then shotcrete is applied to the face of the cut and soil nails are drilled and grouted. This sequence is then repeated until sub-grade is reached.

Other Types of Soil Retention Systems

- Other 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.

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.

Positive Side Waterproofing

- Positive Side is more widely specified in new construction
- Has many advantages over negative-side waterproofing such as:
  - Greater range of material
  - Protects against corrosive materials that can attack masonry, concrete, and even re-bar
  - Applicable to all subsurface building components whereas negative-side waterproofing is impractical for structural concrete slabs
- Additional uses besides below-grade include:
  - Inside faces of water containment structures such as planters, swimming pools, tanks, fountains, and dams

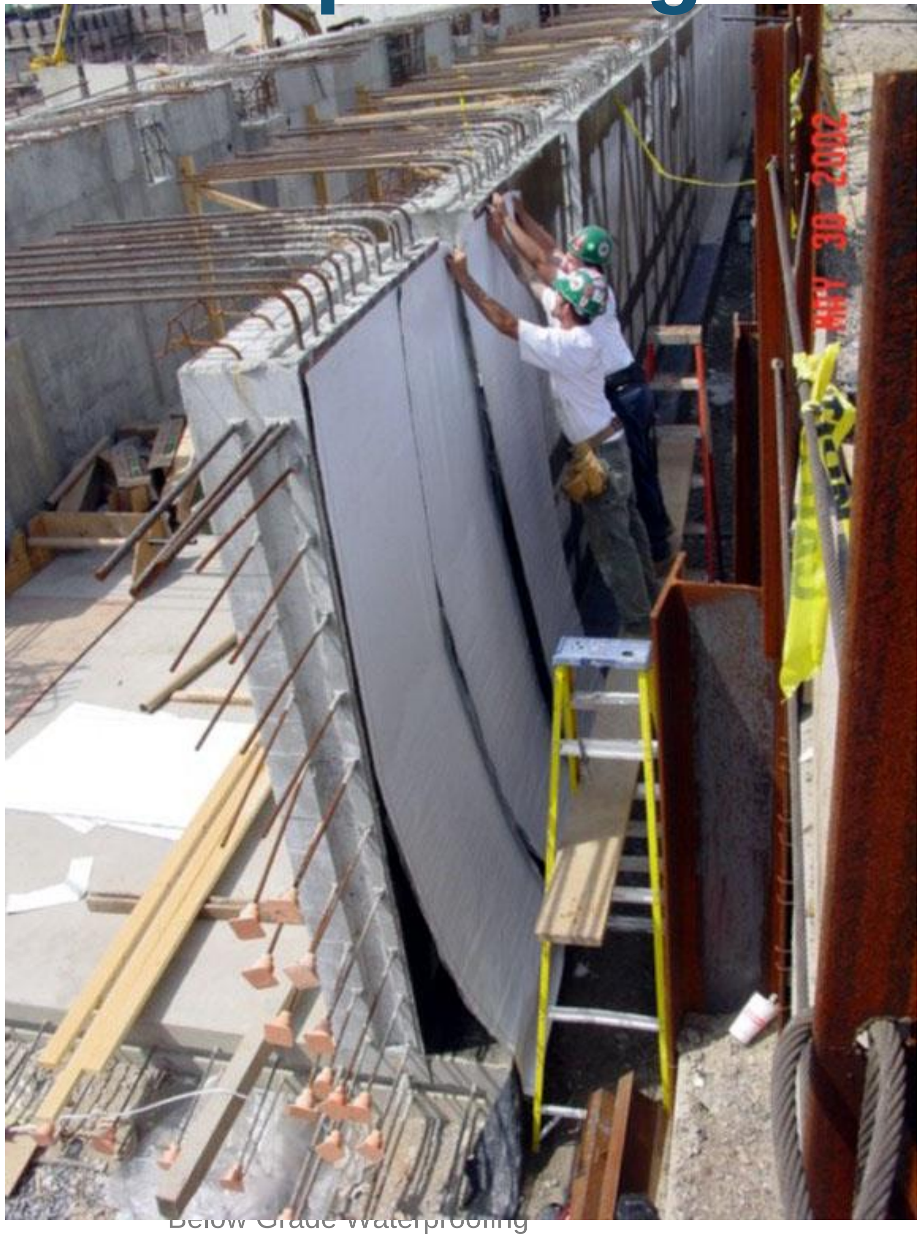
Negative Side Waterproofing

- More popular for remedial work
- Offers no protection against corrosive soils
- Rebar corrosion

Positive Side Waterproofing Systems

- History
- Waterproofing materials formerly limited to built-up bituminous membranes and cementitious coatings.
- In the past 20-30 years, newer systems have become available such as bentonite, several generic categories of single-ply sheets (elastomeric, thermoplastics, modified bitumen), built-up membranes comprising felts and fabrics, liquid-applied membranes, and self-adhering sheets.

Positive Side Waterproofing with Bentonite

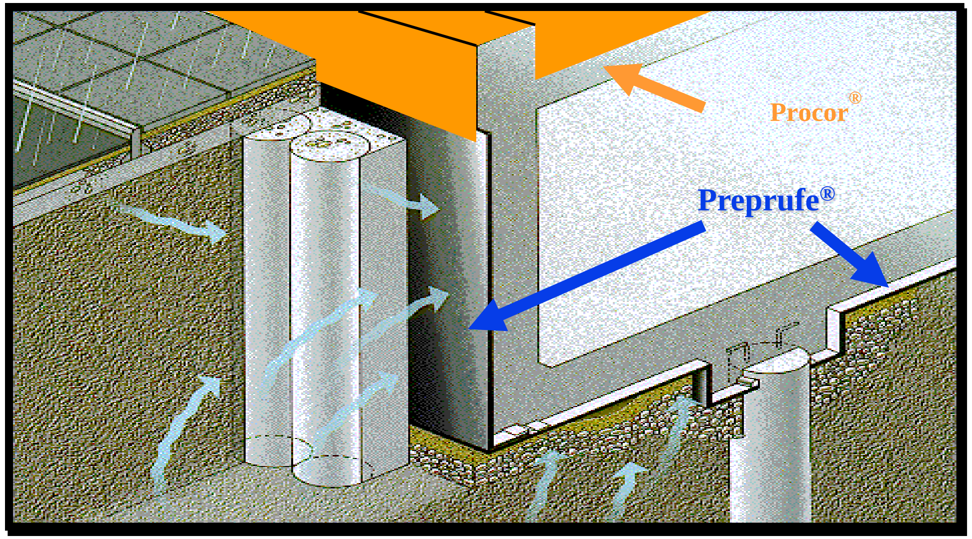


Positive Side Waterproofing Systems

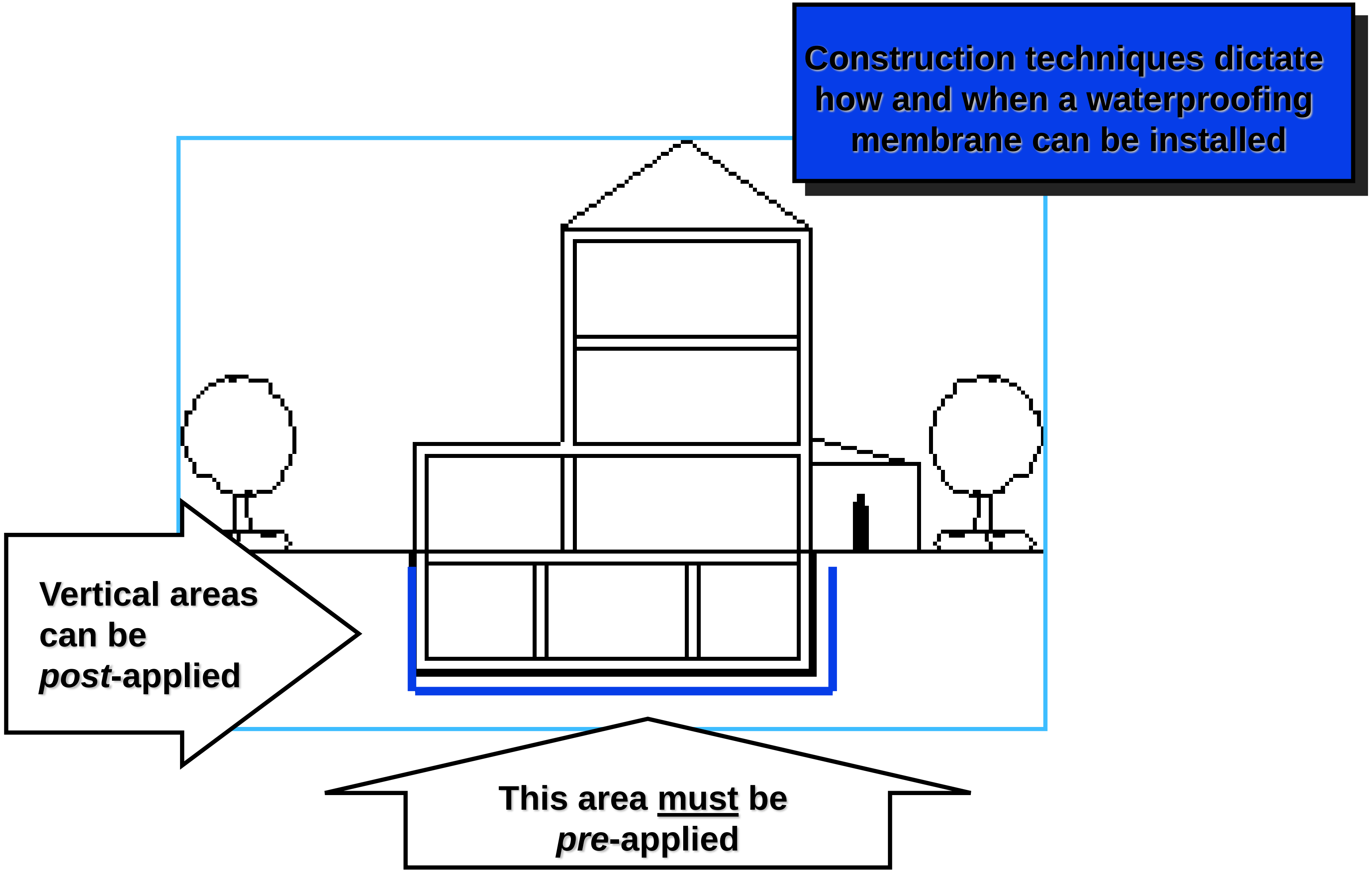
- Positive side waterproofing systems to be covered in this presentation include:
  - Sodium bentonite panels
  - Fluid applied modified bitumen
  - Peel and stick type products
  - Pressure sensitive HDPE film based WP
  - Sub-slab vapor barriers and drainage

Positive Side Waterproofing

- Positive side is same side of the structure as the source of the water
- Designed to stop water before it has a chance to enter the structure and cause structural damage
- Typically the most effective solution



Blind Side Waterproofing



Blind-side is Positive Side

- 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

Blind Side Waterproofing Problems

- Soil retention systems challenges:
- Soil retention system provide poor substrates for application of membranes
- Lagging and piling may require “boarding out” with plywood to provide plane substrates for waterproofing membranes
- Block outs in walls for tieback plates or rakers must be carefully detailed to maintain continuity of the waterproofing system

Blind Side Waterproofing Problems

- Systems limitations:
- System may offer good waterproofing but may not provide great vapor protection
- Sheeting systems may lack adhesion to the concrete
- Bentonite systems reliant on confinement or pressure from the soil retention system to create waterproofing barrier

Designer Checklist

- Process should resist the common temptation to select a system merely on the basis of past experience
- Prepare a checklist of each waterproofed building component and consider all conditions affecting each component
- Assign a level of importance to each item
- Rule out limiting factors - ease of application, chemically corrosive soils, anti-pollution ordinances, which will all narrow the range of eligible systems for further investigation, thereby facilitating the design process
- The final selection, the design process then becomes a tallying of assets and liabilities

Fully Bonded Upside-Down Membranes

- **Overcomes problems of unbonded membranes below slabs**

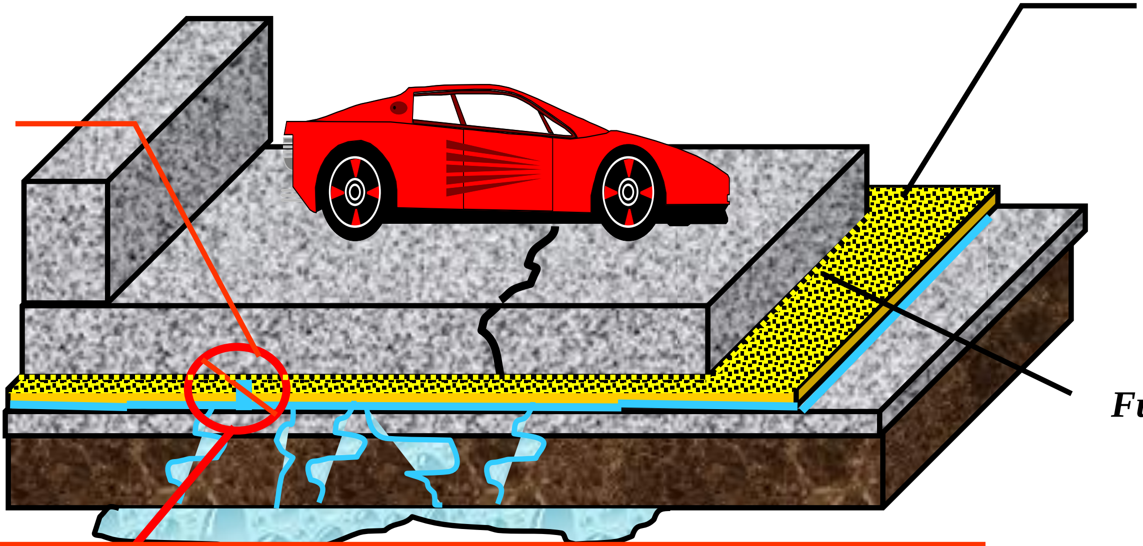
Laurenco

- **30+ years old, modified Bitumen Technology**

Grace Preprufe®

- **Recently developed technology allows "upside down" membrane**
- **Design based on self-adhesive concept**

Membrane discontinuity



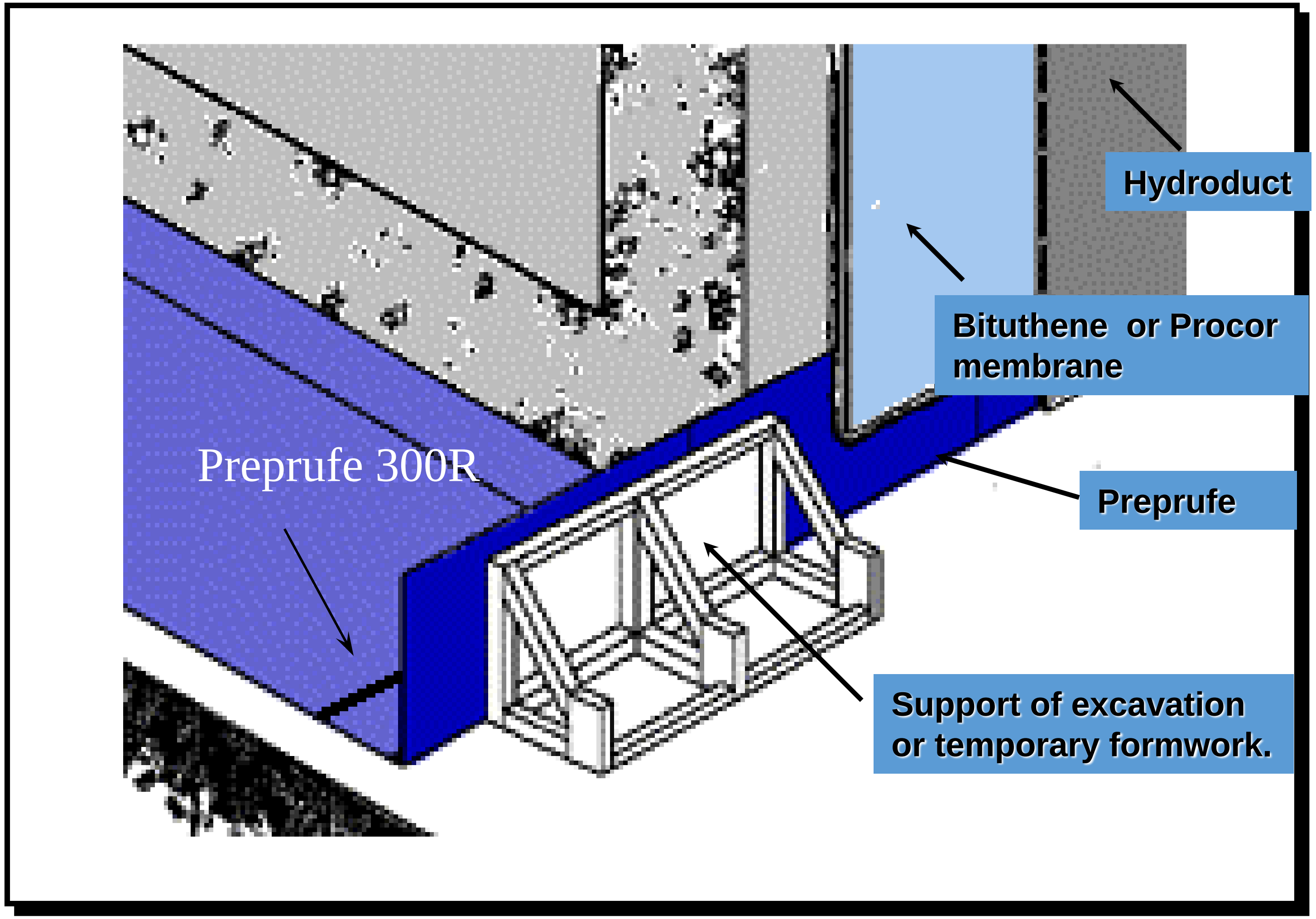
Pre-applied membrane: adhesive

Membrane is
- **non-tacky,**
- **trafficable,**
- **weatherable**

Full and Continuous Bond to Concrete Structure

Adhesive membrane seals entire surface - Protection!

The Preprufe Upside Down Membrane



Preprufe®

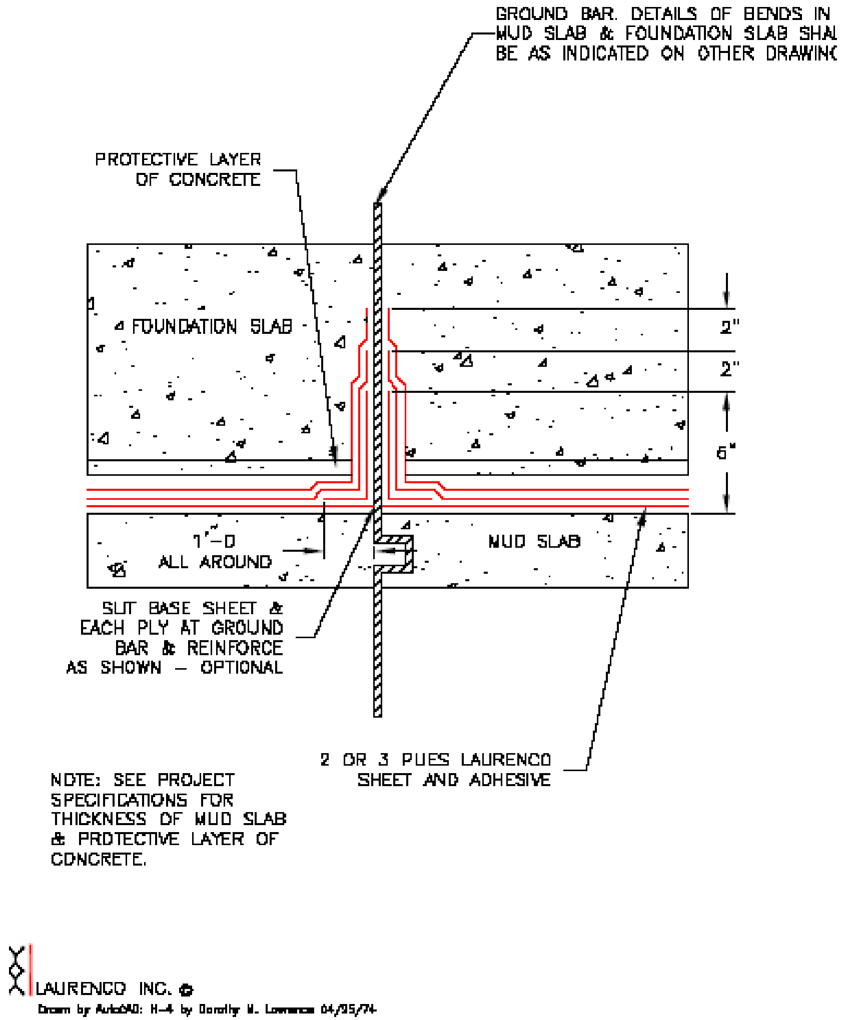
Preprufe

Fully Bonded Upside Down Membrane

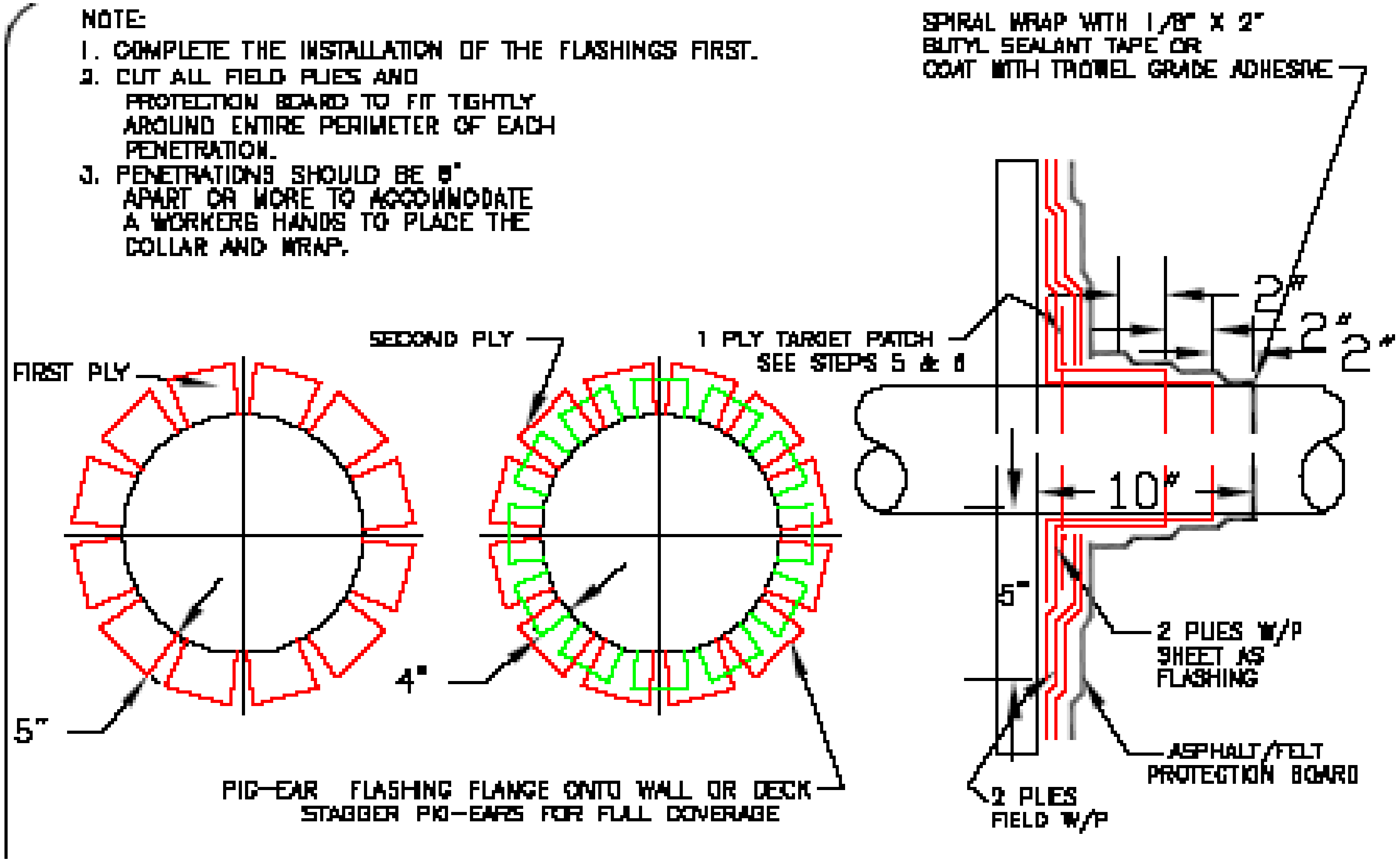
Preprufe Application Advantages

- Fully bonded system
- Remains unaffected by ground settlement
- Some are wet surface tolerant
- Protection course is generally not used
- Durable, unaffected by wet weather or standing water
- Year round application
- Prevents water migration between the membrane

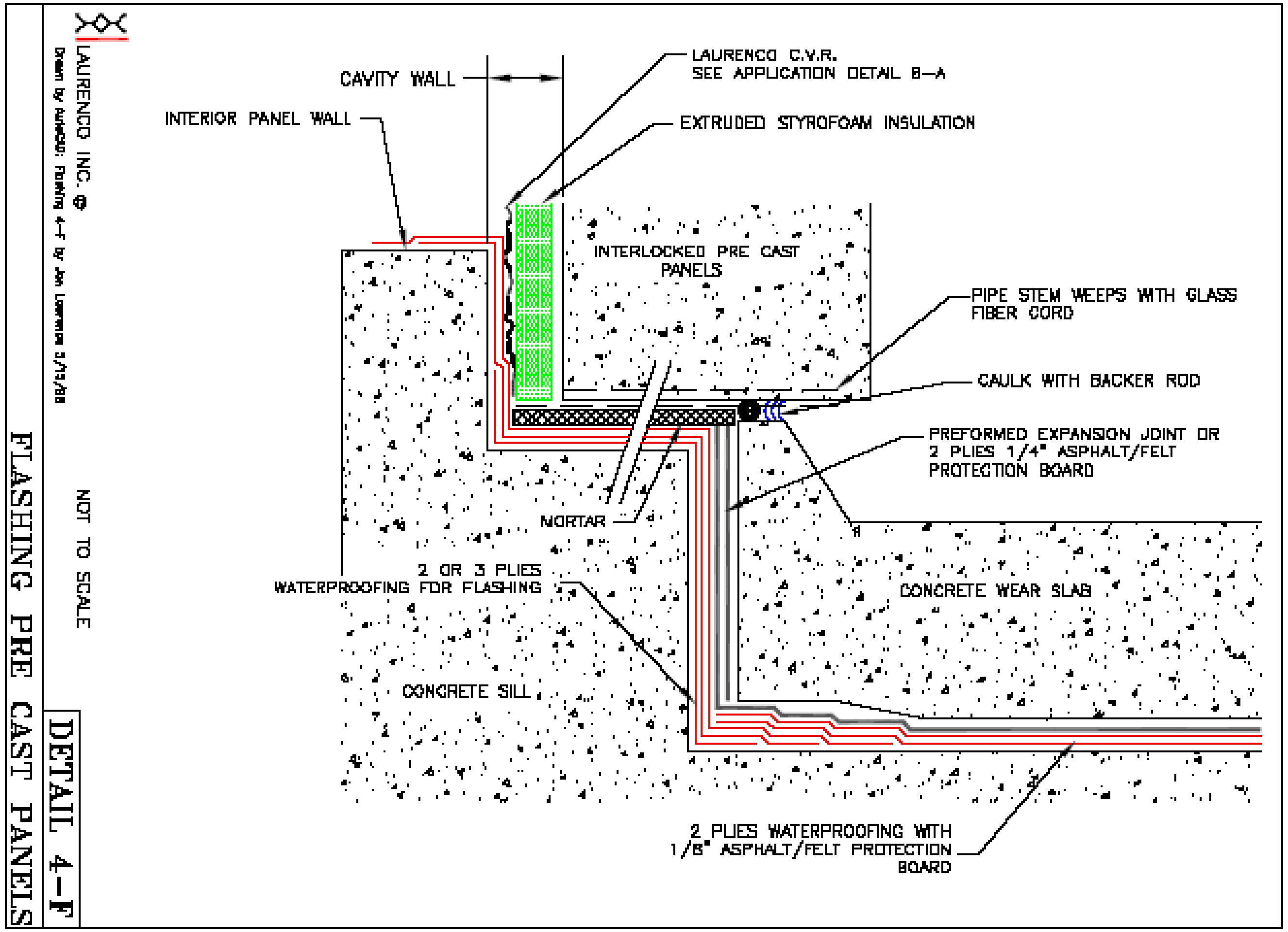
Laurenco Fully Bonded Upside Down



Laurenco Systems, fully bonded upside down



Laurenco Systems



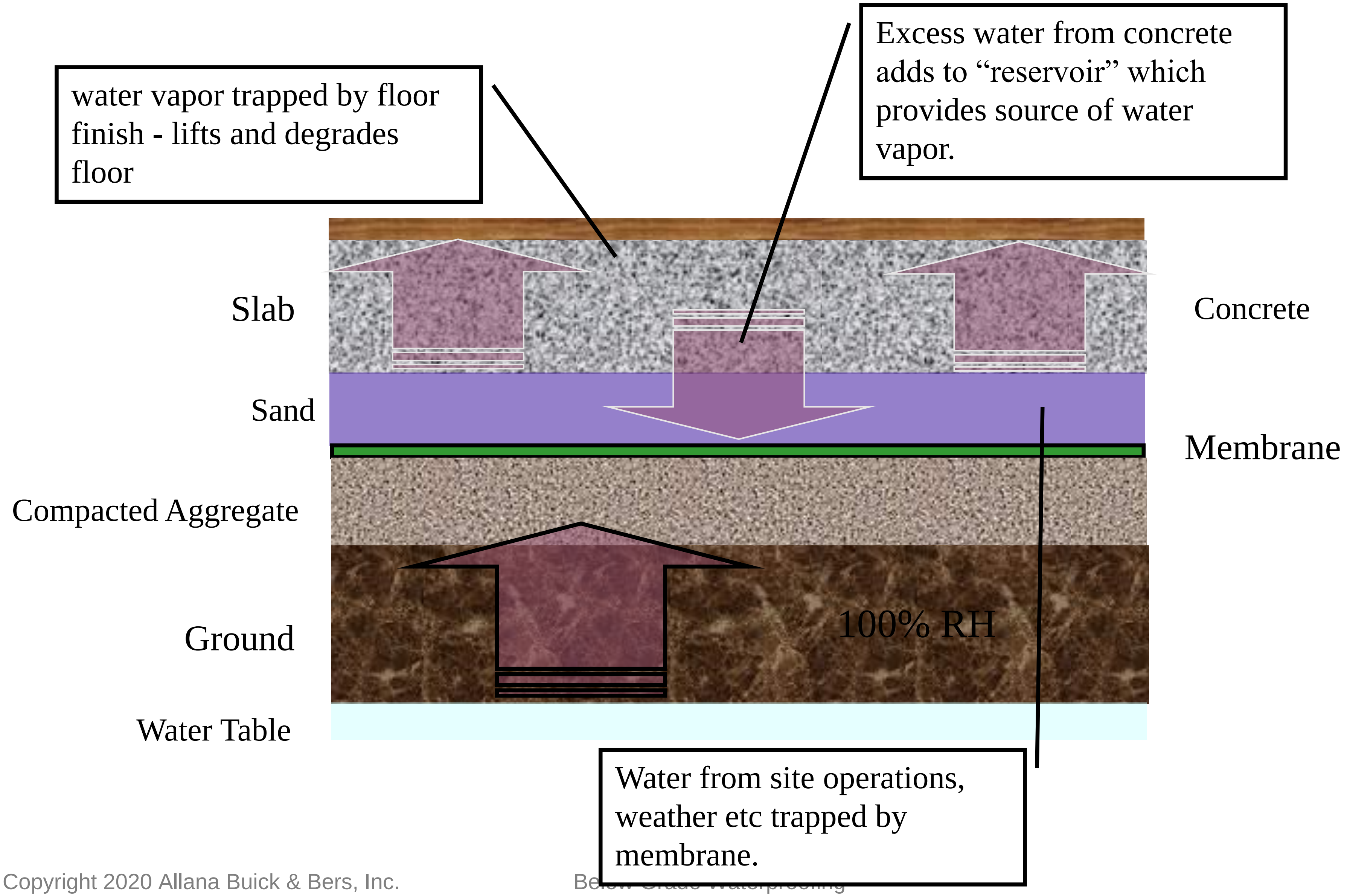
Fully Bonded Upside Down Membrane

Laurenco Application Advantages

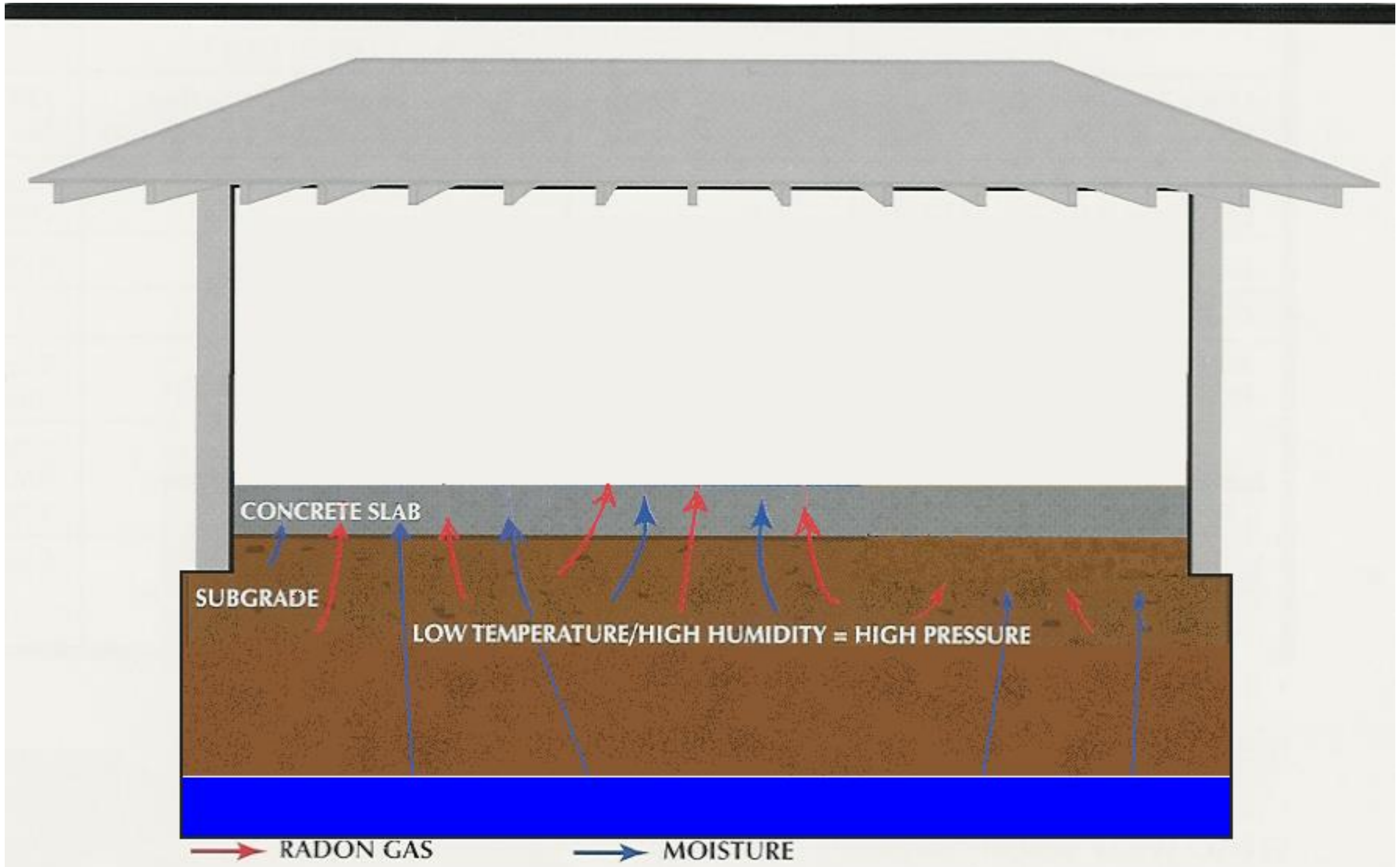
- Fully bonded system
- Remains unaffected by ground settlement
- Asphalt Board protection course is used and becomes part of the bonded membrane
- Year round application
- Prevents water migration between the membrane

Vapor Retarders/Barriers
Waterproofing vs. Vapor Barrior

Double Aggregate Layers



Where does the moisture come from?



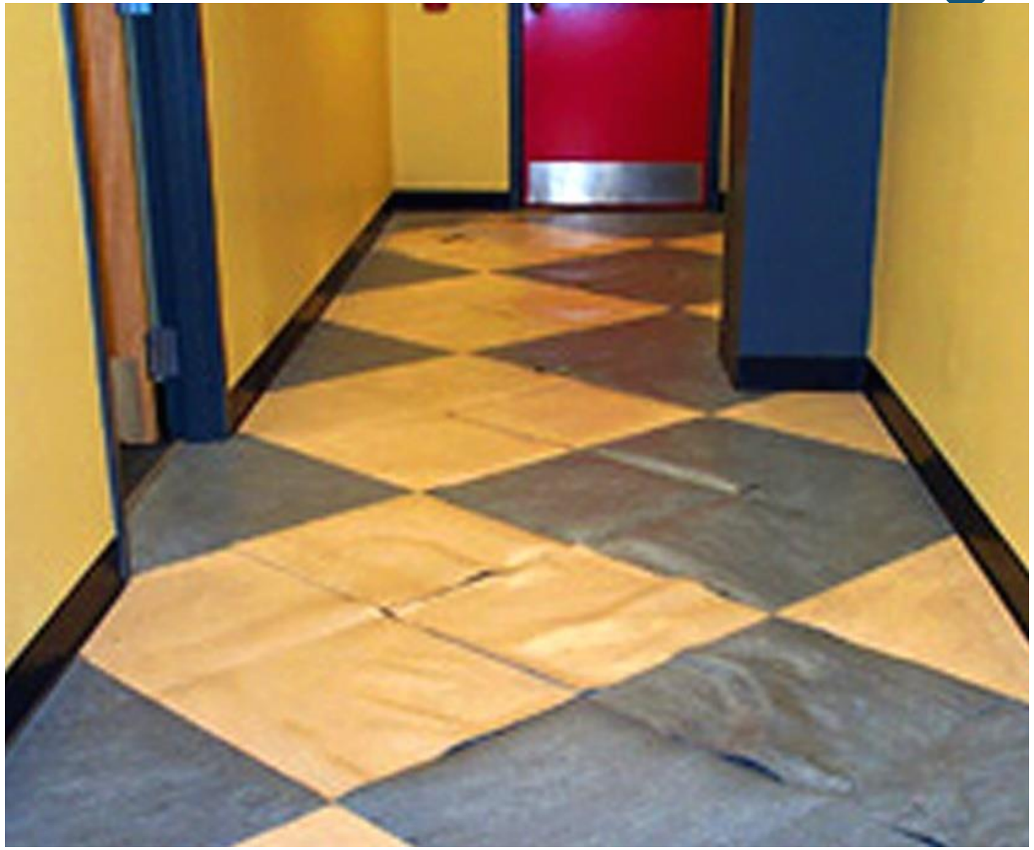
The higher the differential between low & high-pressure areas the stronger the flow of moisture and gas through the slab.

- **Even with dry soil, Relative Humidity of soil can be at 100%**

Moisture Related Floor Problems

- Adhesion loss
- Peeling
- Unacceptable appearance of resilient flooring
- Warping, decay, buckling of wood floors
- Ripping or separation of seams
- Air bubbles or efflorescence beneath continuous flooring
- Buckling of carpet and carpet tiles
- Offensive odors and growth of fungi

Vapor Retarders/Barriers Flooring Problems



Vinyl Floor Damage

Carpet Damage

Floor Covering Failures

Latest Industry Recommendations

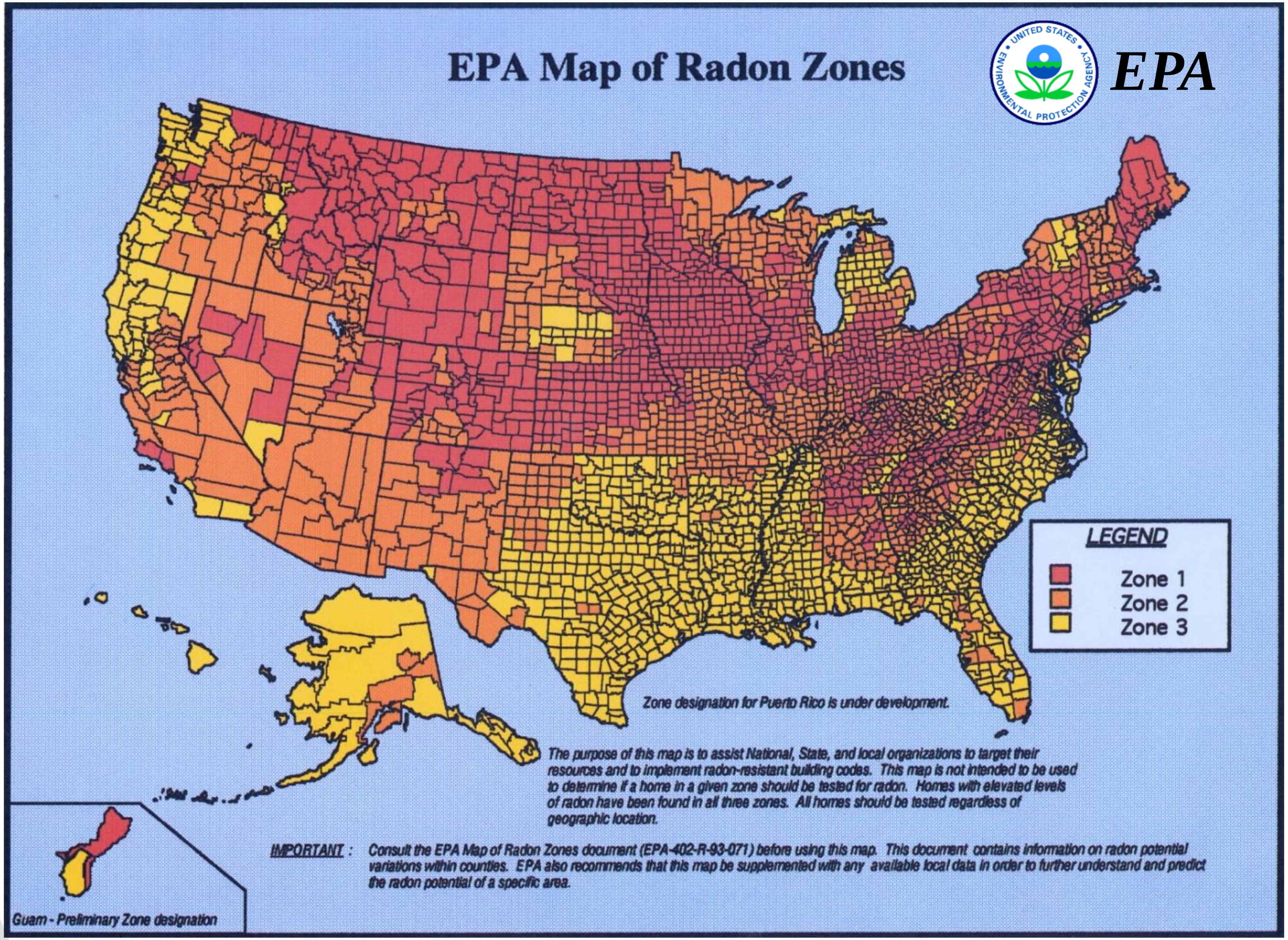
ACI 302-96 - Guide for Concrete Floor and Slab Construction

- moisture protection is desirable for any slab on ground covered by tile, wood, carpet, impermeable floor coatings
- strongly recommends thickness not less than 10 mils (0.25mm) because of increased moisture resistance and durability

ACI 302-96 Addendum (April 2001)

- Slabs with vapor sensitive coverings should *always* have the vapor barrier in direct contact with the slab

THE RADON PROBLEM



- Radon is a problem in 1 out of every 15 homes in the US
- Radon gas is attributed to 15,000 – 20,000 deaths annually
- Breathing in air with a radon concentration of 4 picocuries for a year is the equivalent of smoking a half a pack of cigarettes each day

Prepare Ground

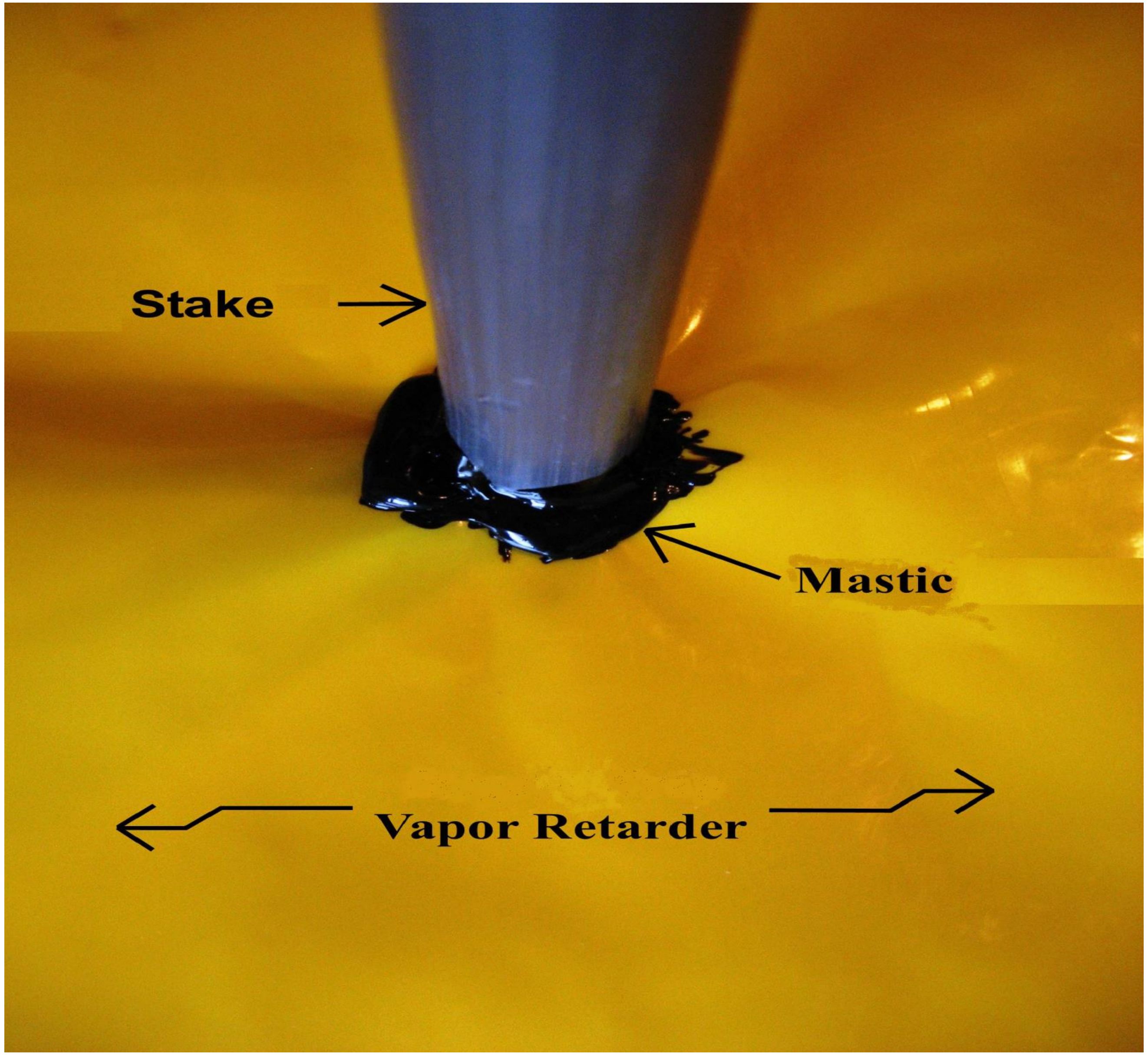
Install with as few seams as possible

6 Inch Overlap

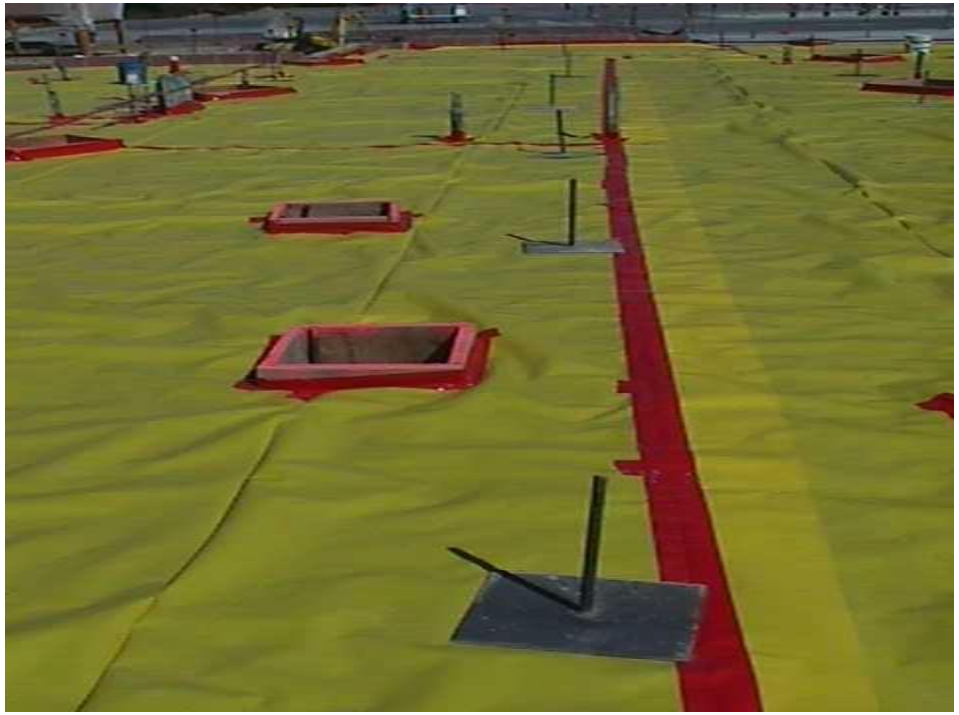
Manufacturer's Tape

Sealing All Penetrations

Forming for Concrete Without Punctures


Stake
Mastic
Vapor Retarder

Screeding Without Punctures



Grace Florprufe Vapor Barrier

Fully Bonded to Bottom of Concrete Slab

•Similar Bond Technology as Prepruf –

• A vapor barrier that bonds and seals to slab underside

•Prevents Water Migration Under Slab

•HDPE film

•Low vapor permeance

Recap of Vapor Barrier Issues

Radon & Methene

- Often Overlooked problem
- Effective solutions include both a barrier and ventilation system

- **Moisture Related Problems**
- Floor Covering Failures
- Mold & Mildew
- Alkaline Efflorescence
- ASR

Sodium Bentonite Waterproofing Systems

- 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.

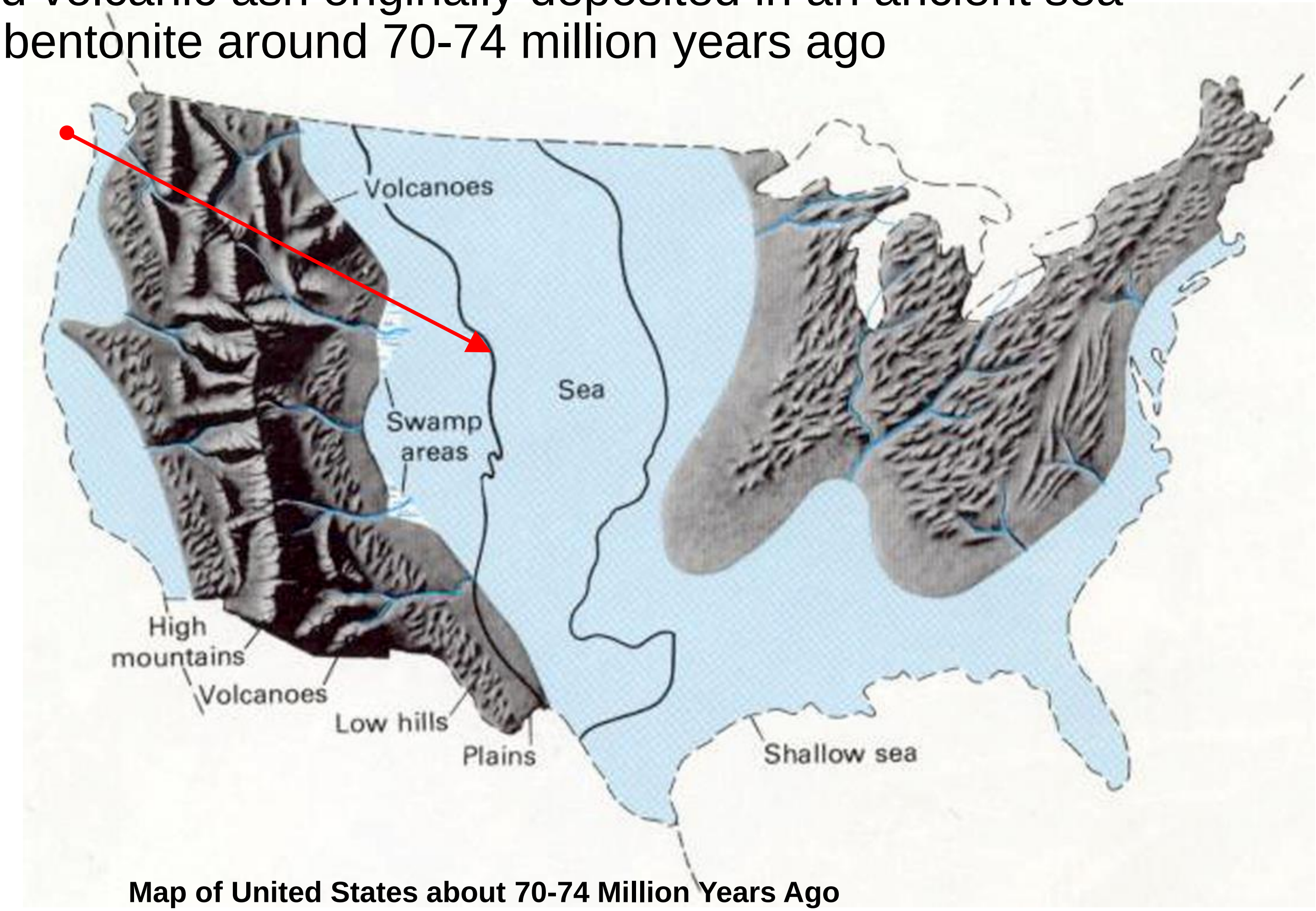
- Sodium Bentonite based Waterproofing Systems
- Many manufacturers offer a variety of bentonite waterproofing systems
- Some variations include:
  - Standard bentonite sheeting – basic water repulsion
  - Multi-layer sheeting combinations – water & gas repulsion
- Sheeting is designed based on the application

Introduction cont.

- Focus of this section:
- Sodium bentonite based waterproofing systems adhered to HDPE sheeting 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.

- 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

Historical Use in Below-grade Waterproofing

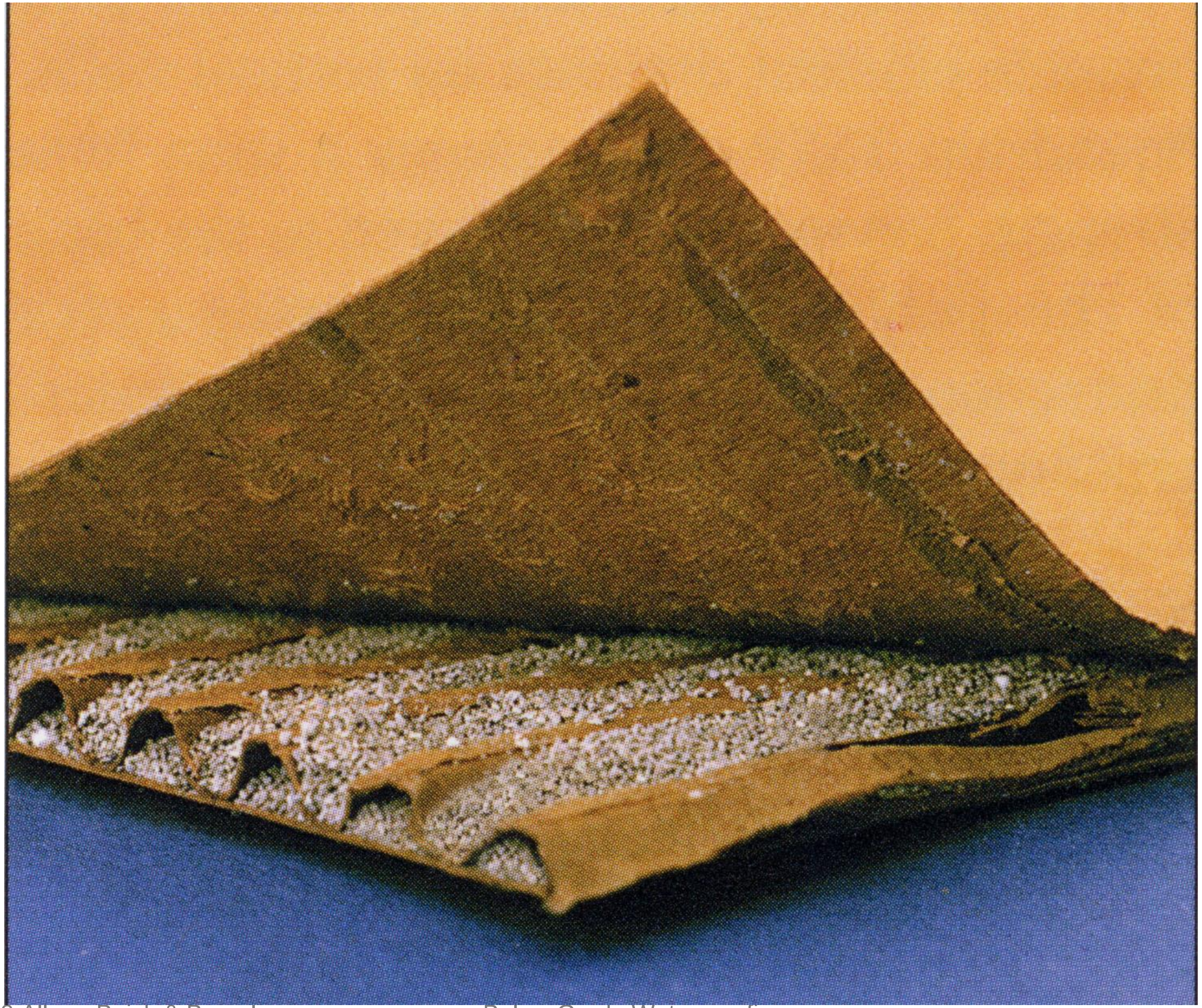
- Introduced as a product in the mid 1920’s
- Primarily used in granular form to seal ponds and compacted earth dams until the late 1950’s
- Introduced into building waterproofing market in the mid 1960’s
- Available product lines included panels, sheets, trowelable, and sprayed forms

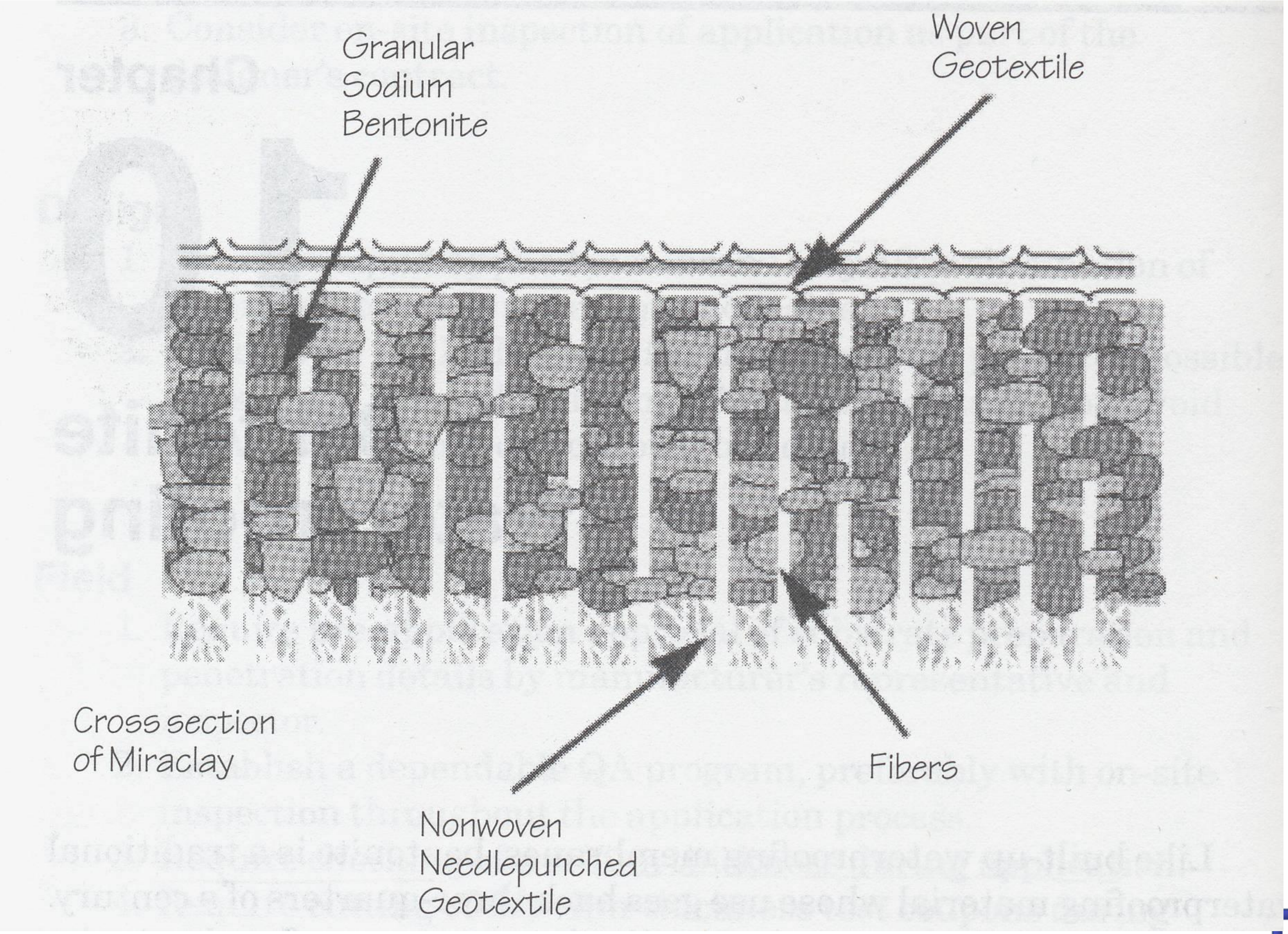
Historical Use in Below-grade Waterproofing Cont.

- 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




Granular Sodium Bentonite
Woven Geotextile
Cross section of Miraclay
Fibers
Nonwoven Needlepunched Geotextile

Commercial Bentonite/HDPE Products

- Product Examples:

- 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

Tremco – Paraseal LG Cont.

- 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

Prehydration Due to Rain can Lead to Failure

Hydration during construction is a huge problem

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
- Penetrations need to be detailed properly
- Puncture resistant HDPE liner of 169 lb point load
- Protect from moisture during storage. Do not double stack

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 it's recommended a 3" protection slab be provided for better defense

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/shotcrete walls
- Designed only for below-grade waterproofing applications

CETCO – Volclay Voltex DS Cont.

- Inherent limitations
- Application in brackish, slightly salt, or contaminated groundwater
- Standing water during construction – premature hydration
- Over snow – premature hydration

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)

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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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

Project Case Study Cont.

- Following Picture shows the excavation of the soil behind wood lagging revealed that once the wood got wet it was
- Swelling
- Bending
- Twisting
- Especially if there were voids between the soil and wood

Downtown Sunnyvale Garage Leaked Throughout From Day 1

Chemical Grout was Injected 24” O.C.

Injection in Progress

3/8” holes are drilled through the slab and injection ports inserted

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

Grout Creates a "Curtain" Behind Concrete

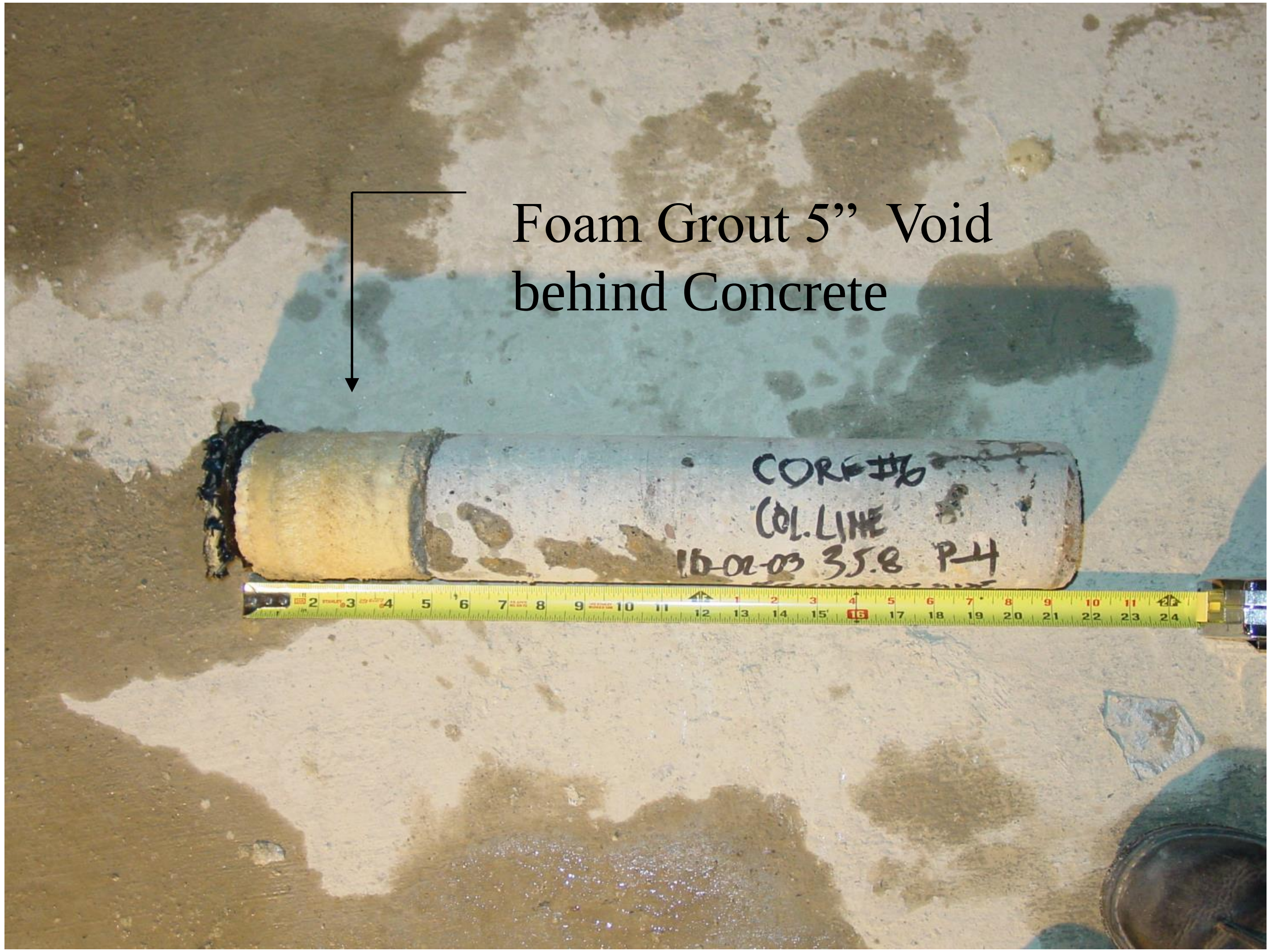
The Repair of Failed Garage Cost Over $3M

Polyurethene grout injection 2’ on center at a cost of $35/SF

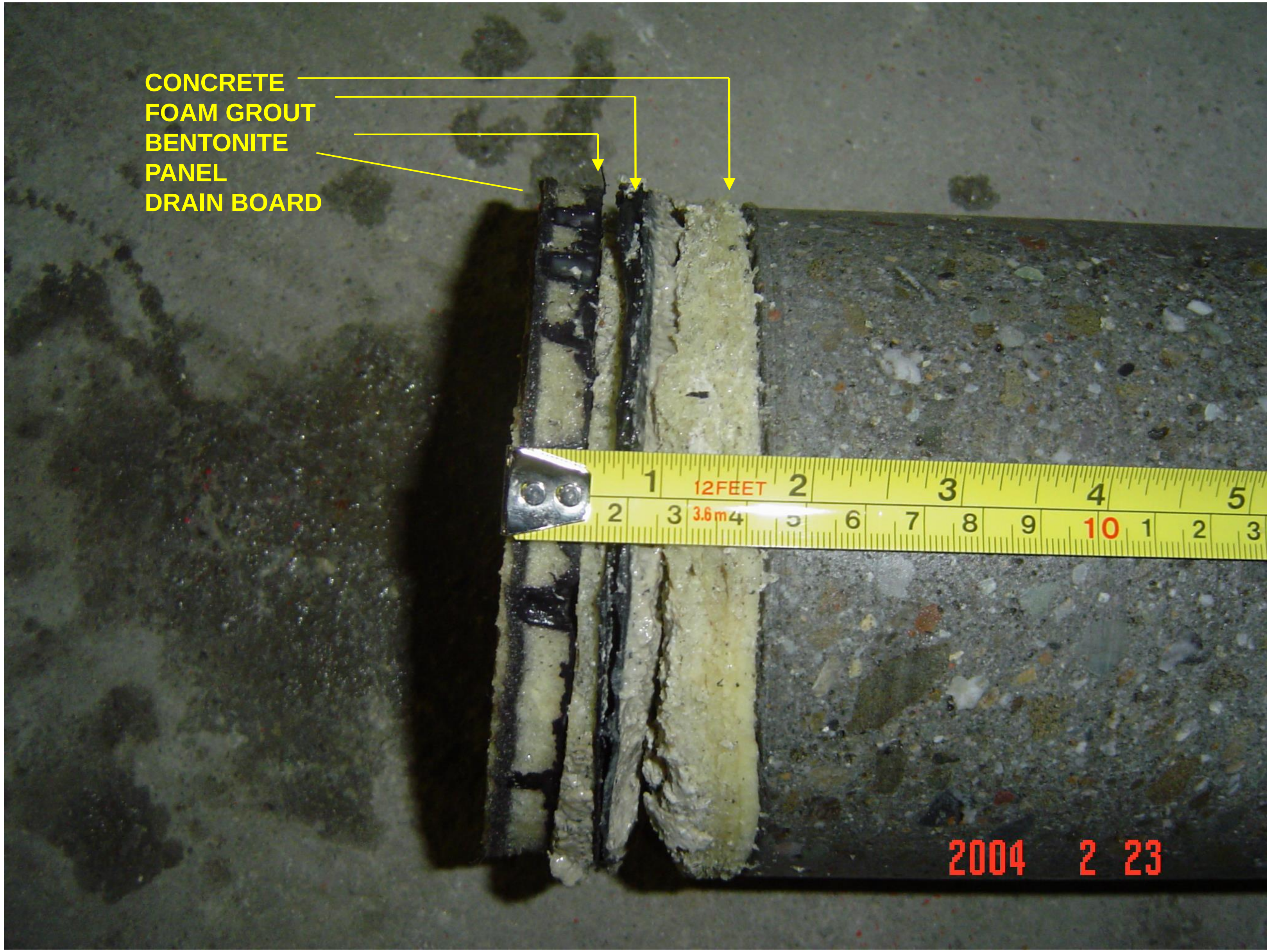
Typical Injection Equipment

Concrete Cores Were Taken To Asses Performance

Cores Showed Large Voids Behind Shotcrete



What Caused the Voids Behind Shotcrete?



Voids were present on both sides of the retaining wall and ranged from 1” thick to up to 4” thick.

Site was Excavated to Forensically Analyze Failure

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.

Conventional Wood Lagging

Void behind foam protection board

Voids and Lack of Confinement = Failure

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

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, pressure and makes foam closed cell and waterproof

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

- Mahalo

- Questions?