

# **Forensic Waterproofing Case Study 1**

## **Bentonite – Wood Lagging – Shotcrete Failure**

- **Downtown Sunnyvale, CA garage failure: 2<sup>nd</sup> largest below-grade structure in Northern California**
- **4 story deep parking garage located in the water table**
- **Project leaked during and post construction (repair attempts with positive side waterproofing failed)**
- **Soil shoring system was a zero lot line assembly consisting of soldier piles with soil nails and wood lagging.**
- **Bentonite/HDPE composite system was installed over blind drain panel attached to wood lagging system**
- **18-inch deep shotcrete foundation walls**
- **Largest below-grade waterproofing repair of it's kind in California \$ 3,000,000 to repair**



# Forensic Waterproofing Case Study 1

## Typical Active Below Grade Leaks



# Forensic Waterproofing Case Study 1

## Below Grade Failure Investigation

- Mapped leak locations
- Reviewed original construction drawings
- Reviewed construction photos of lagging installation
- Performed test pits to view soil and shoring system conditions at the edge of the slab
- Reviewed soil consolidation
- Performed water testing of the perimeter
- Developed and monitored curtain grout injection remedial repairs (12 months plus)
- Conducted core sampling from 18" thick shotcrete walls



# Forensic Waterproofing Case Study 1

## Chemical Grout Drilling and Injection



Polyurethane grout injection 2' on center at \$45-\$60/SF





# Forensic Waterproofing Case Study 1

## Chemical Grout Mixing and Pumping Equipment



# Forensic Waterproofing Case Study 1

## Foundation Wall After \$3,000,000 Curtain Grouting





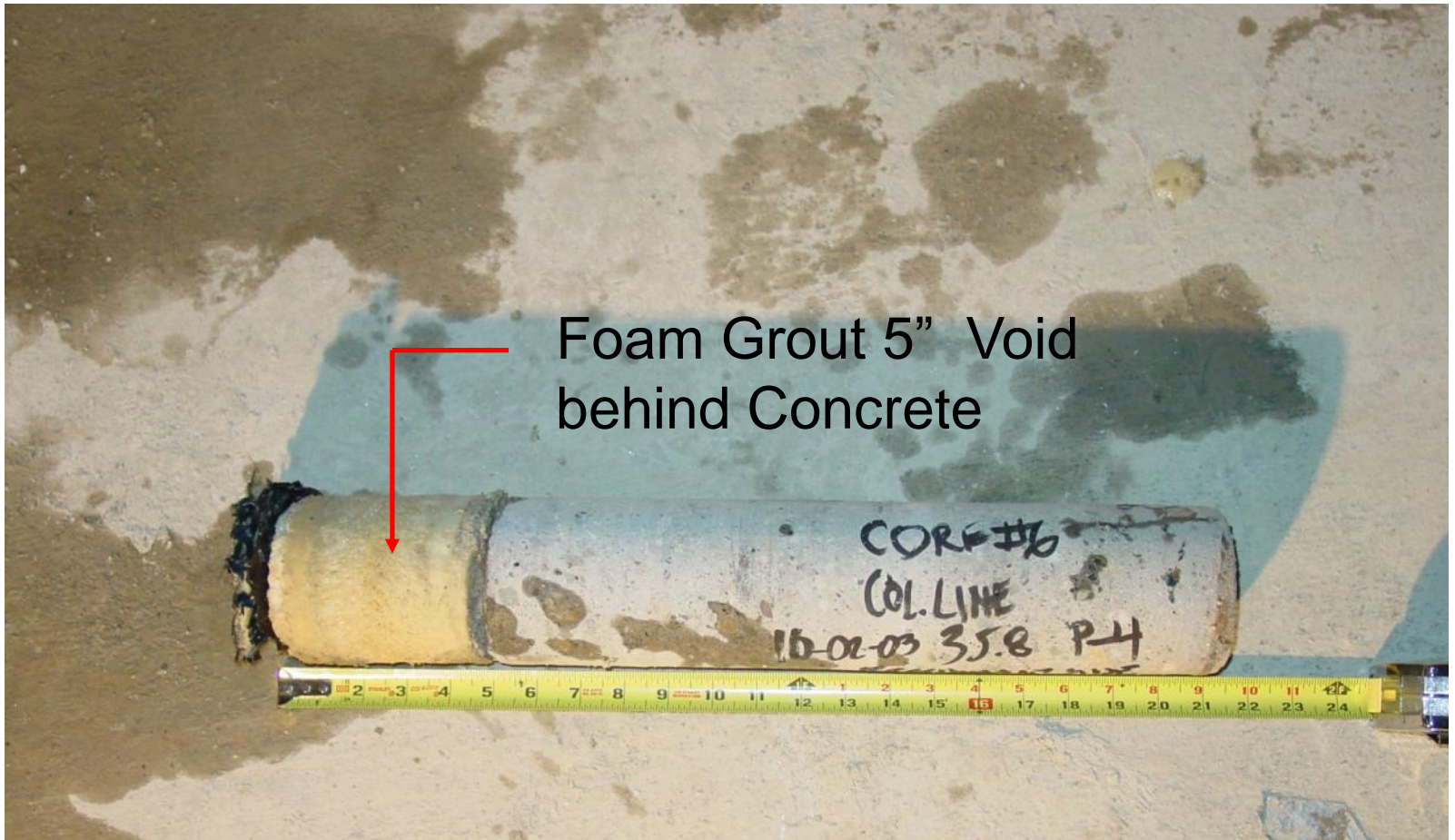
# Forensic Waterproofing Case Study 1

## Wall Coring to Determine Grout Performance



# Forensic Waterproofing Case Study 1

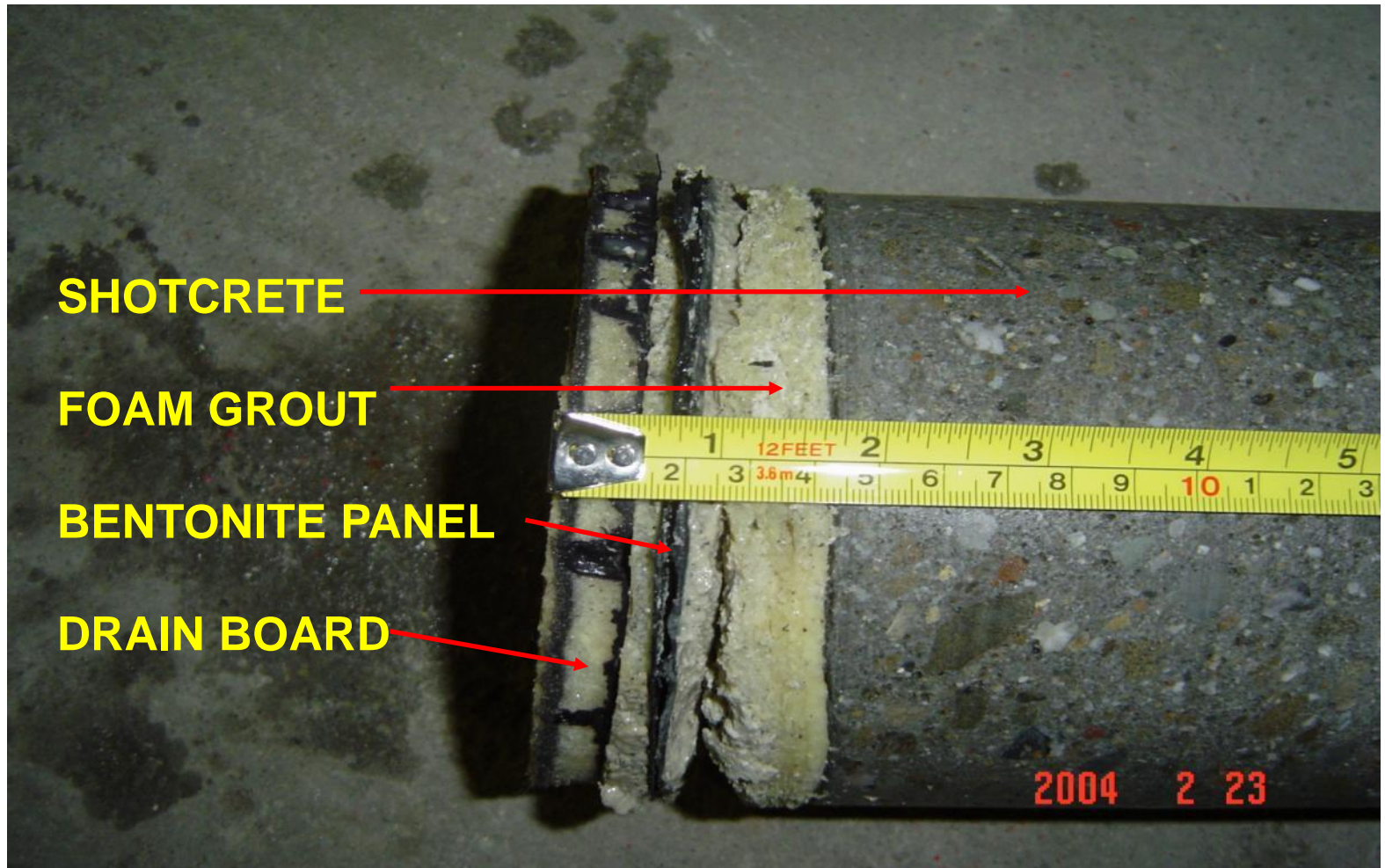
## Large Voids Found Behind Shotcrete Wall





# Forensic Waterproofing Case Study 1

## Large Voids Found Behind Shotcrete Wall





# Forensic Waterproofing Case Study 1



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.





# Forensic Waterproofing Case Study 1

## Typical Test Pit





# Forensic Waterproofing Case Study 1

## Voids Behind Foam Insulation Panels



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



# Forensic Waterproofing Case Study 1

## Forensic Investigation Findings

- Significant voids were found behind and in front of the wood lagging system.
- Wood lagging system was not fully back-grouted
- Wood lagging system was twisted and evidence of possible post construction movement was observed.
- Drain panel used as protection was not actively drained and behaved like a reservoir to collect and distribute water to the entire building foundation.
- Protection board used to span the face of the soldier piles created a consistent void in front of each soldier pile.



# Forensic Waterproofing Case Study 1

## Lessons Learned

- Bentonite based waterproofing must always have confinement pressure to work.
- Wood lagging does not provided a stable substrate for bentonite waterproofing when used in conjunction with shotcrete foundation walls.
- Shotcrete does not eliminate the inherent voids found within a conventional wood lagging wall system.
- When using bentonite waterproofing, use only shotcrete lagging as a blind side substrate and...
- Where possible, go with cast in place concrete foundation walls.
- Remedial curtain grouting is very expensive.





# FORENSIC CASE STUDY 2

## High Velocity Storm Water Flow Bentonite Geotextile



# **Forensic Waterproofing Case Study 2**

## **Bentonite Waterproofing Failure**

- **New two story department store located in South Florida**
- **First level of structure was partially underground**
- **Bentonite geotextile composite waterproofing**
- **Foundation was excavated using over-excavation then backfill**
- **Project leaks occurred only during very heavy rains**
- **Overflow roof drains were frequently active during rains**
- **Negative side waterproofing attempts failed**



# Forensic Waterproofing Case Study 2

## Typical Active Below Grade Leaks





# Forensic Waterproofing Case Study 2

## Elevation With Leakage



# **Forensic Waterproofing Case Study 2**

## **Forensic Investigation**

- **Reviewed original construction documents**
- **Interviewed installing contractor, general contractor and store maintenance team leader**
- **Walked project exterior, interior and roof area**
- **Open storm drain manholes and measured invert heights**
- **Conducted a significant test pit adjacent to the leak areas.**



# Forensic Waterproofing Case Study 2

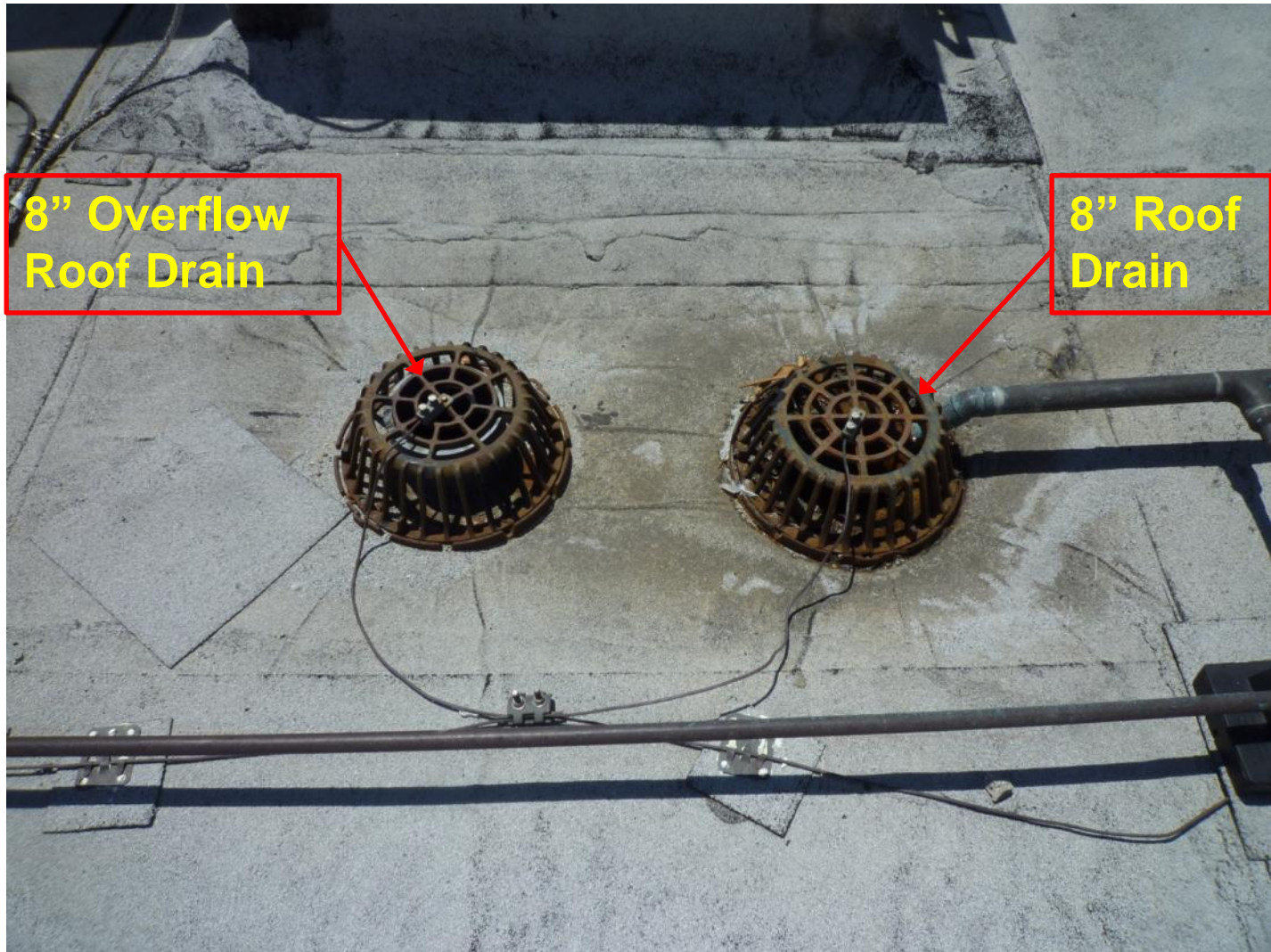
## Investigation Findings

- Primary roof drains were not freely draining. This area gets very intense rainfall (up to 10"/hr) resulting in huge storm drain volumes. (Roof has only 4 primary roof drains for entire roof).
- Overflow drains exit building 2 feet above grade and the discharge is directed down by overflow outlet covers
- Local area soils are very porous sand/silt and coral rock...water flows easily through the soil.
- Drain overflow outlets directed high volume of water into the bentonite waterproofing geotextile and washed the bentonite clay out of the sheet resulting in leaks through the foundation wall.
- Walls were not properly prepared prior to installing waterproofing (form ties and bentonite fillets).



# Forensic Waterproofing Case Study 2

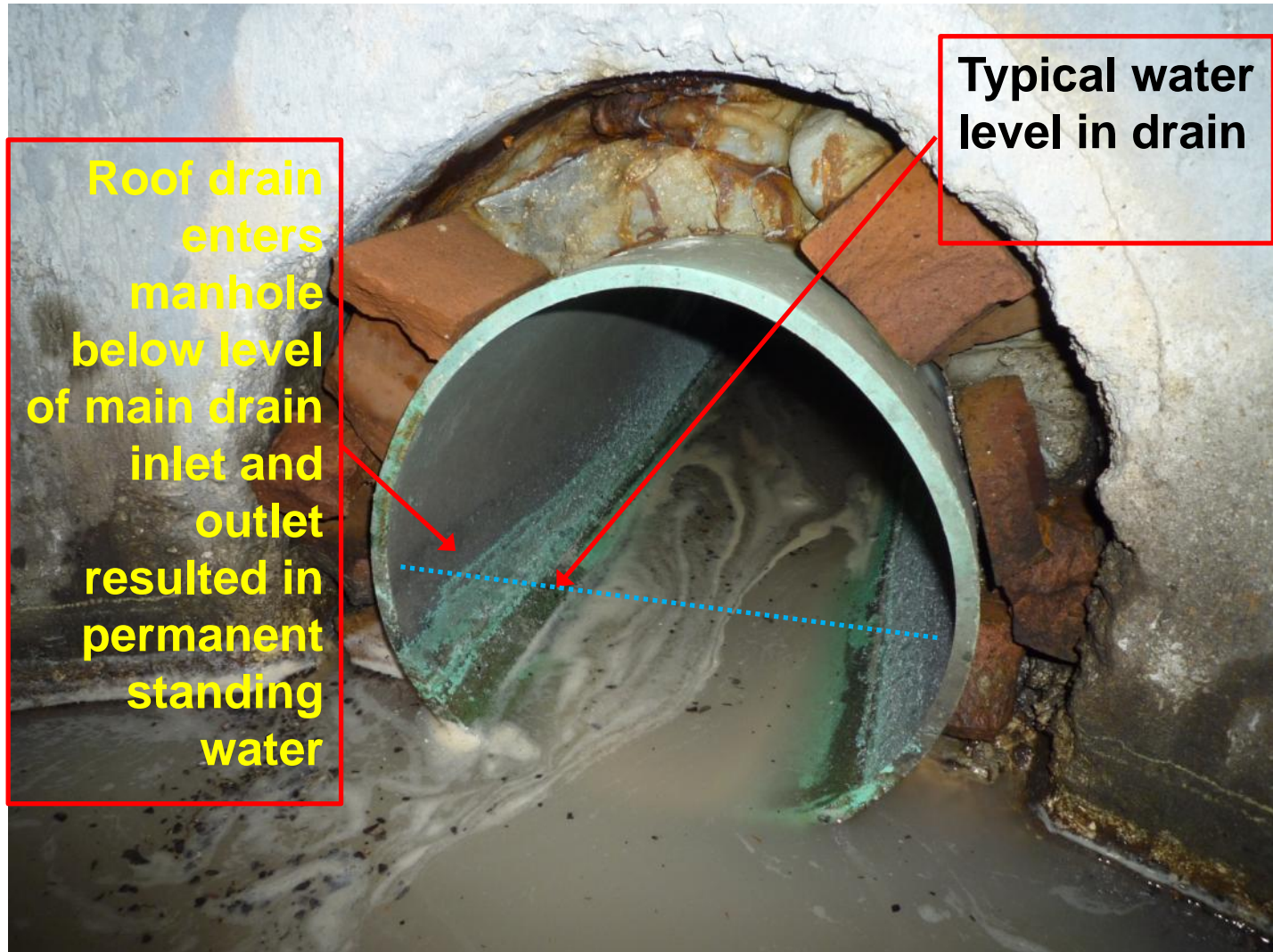
## Roof Drains are Large (8-inch lines)





# Forensic Waterproofing Case Study 2

## Roof Drain Inlet to Storm Drain Manhole



# Forensic Waterproofing Case Study 2

## Typical Overflow Drain Outlet





# Forensic Waterproofing Case Study 2

## Overflow Drain Cover with Chain Restraint



# Forensic Waterproofing Case Study 2

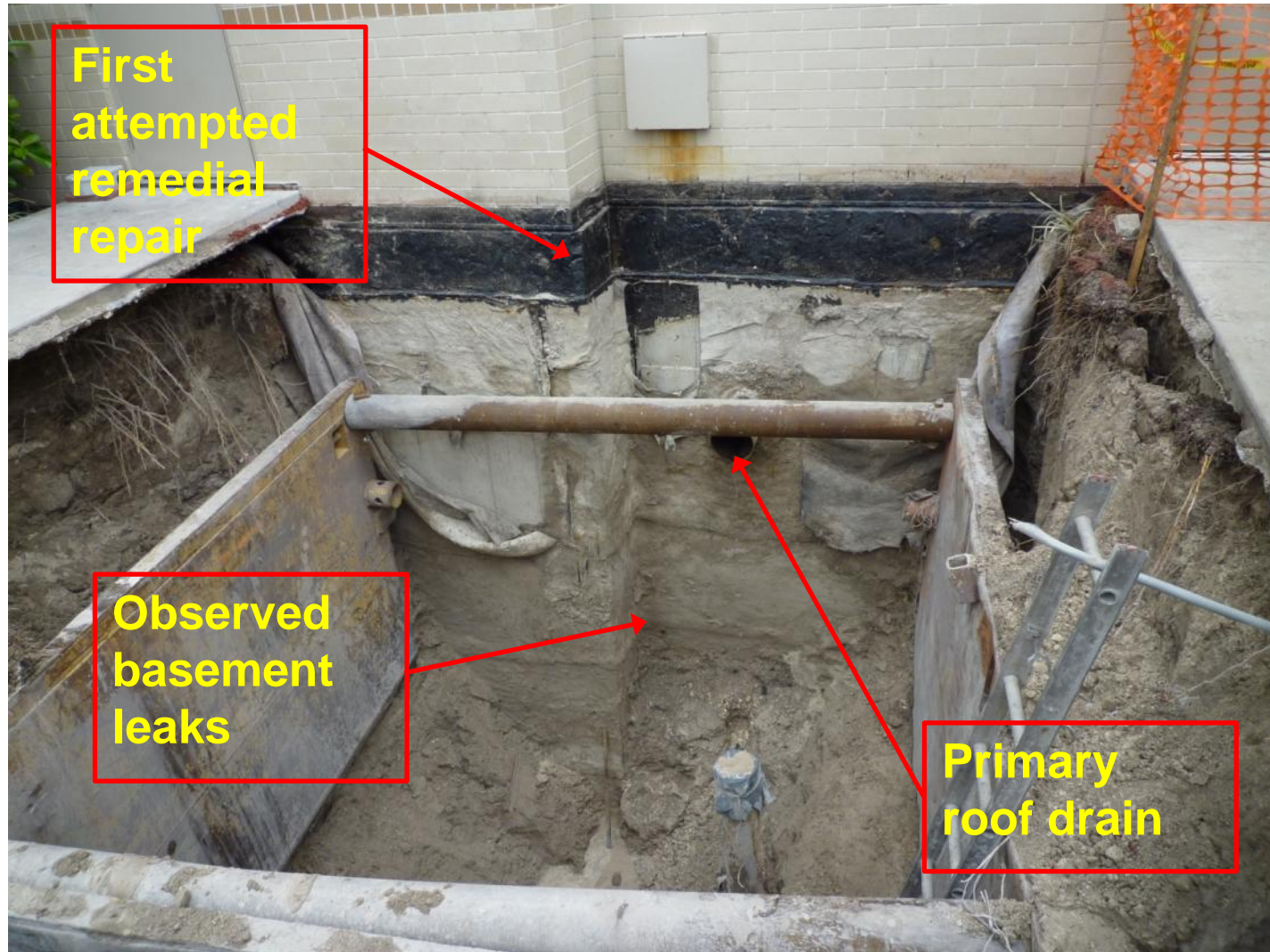
## General View of Test Pit





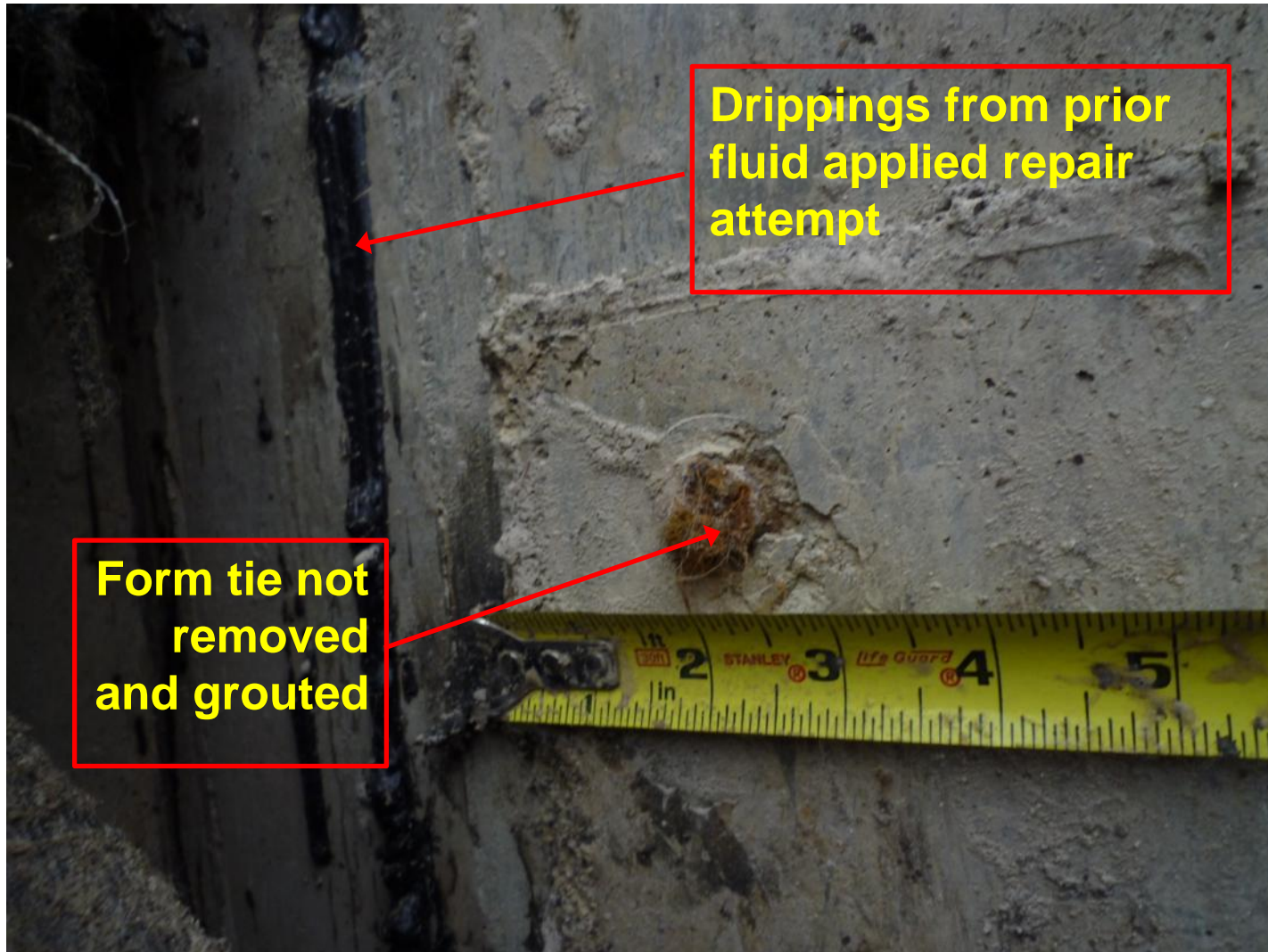
# Forensic Waterproofing Case Study 2

## Full Depth Test Pit



# Forensic Waterproofing Case Study 2

## Form Ties Not Removed and Hole Grouted





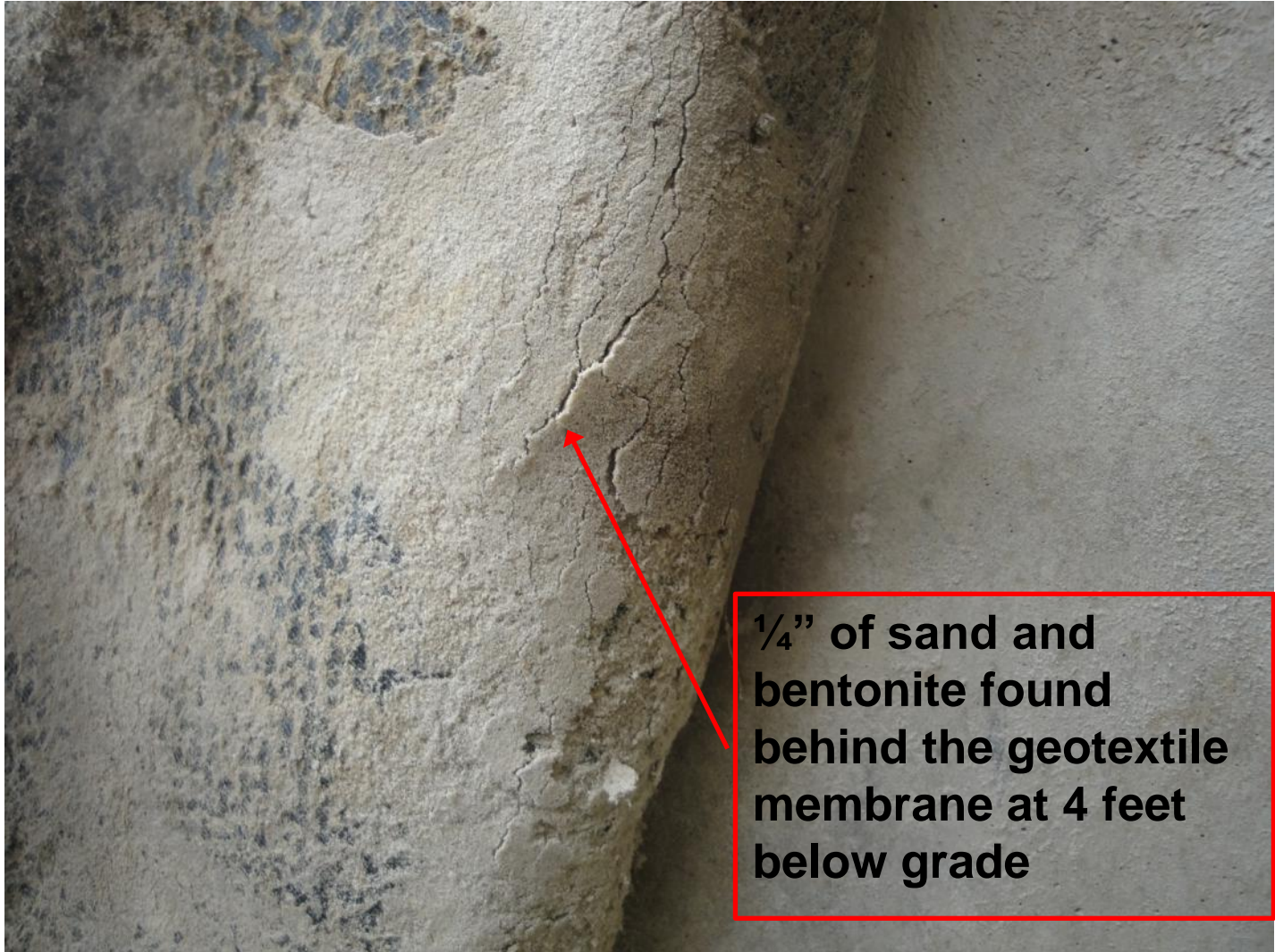
# Forensic Waterproofing Case Study 2

## Elevation With Leakage



# Forensic Waterproofing Case Study 2

## Sand and Bentonite Washed Behind Membrane





# Forensic Waterproofing Case Study 2

## No Bentonite Found in Sheet 2 Feet Below Grade



# Forensic Waterproofing Case Study 2

## Lessons Learned

- **Do not use bentonite based waterproofing in locations where water will be actively flowing**
- **Make sure substrates are properly prepared prior to application of any waterproofing system**
- **Confirm the site is properly engineered and constructed to rapidly remove storm water from roofs and overflow outlets**
- **Negative side waterproofing is not an effective approach to repair failures in positive side water proofing.**

