

Forensic Waterproofing Case Study 1

Bentonite – Wood Lagging – Shotcrete Failure

- **Downtown Sunnyvale, CA garage failure: 2nd 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**



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Typical Active Below Grade Leaks



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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



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Chemical Grout Drilling and Injection



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



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Chemical Grout Mixing and Pumping Equipment



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



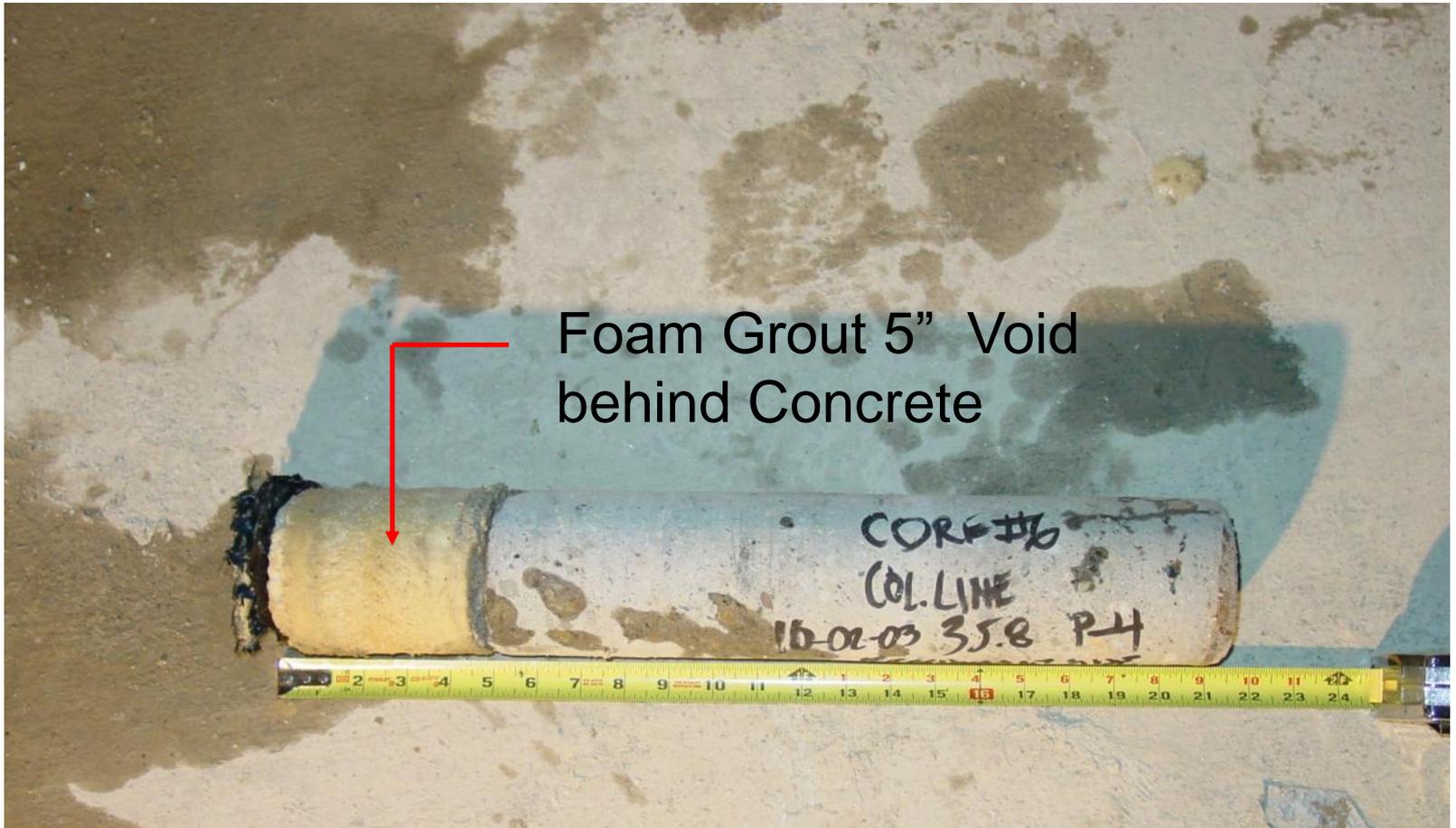
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Wall Coring to Determine Grout Performance



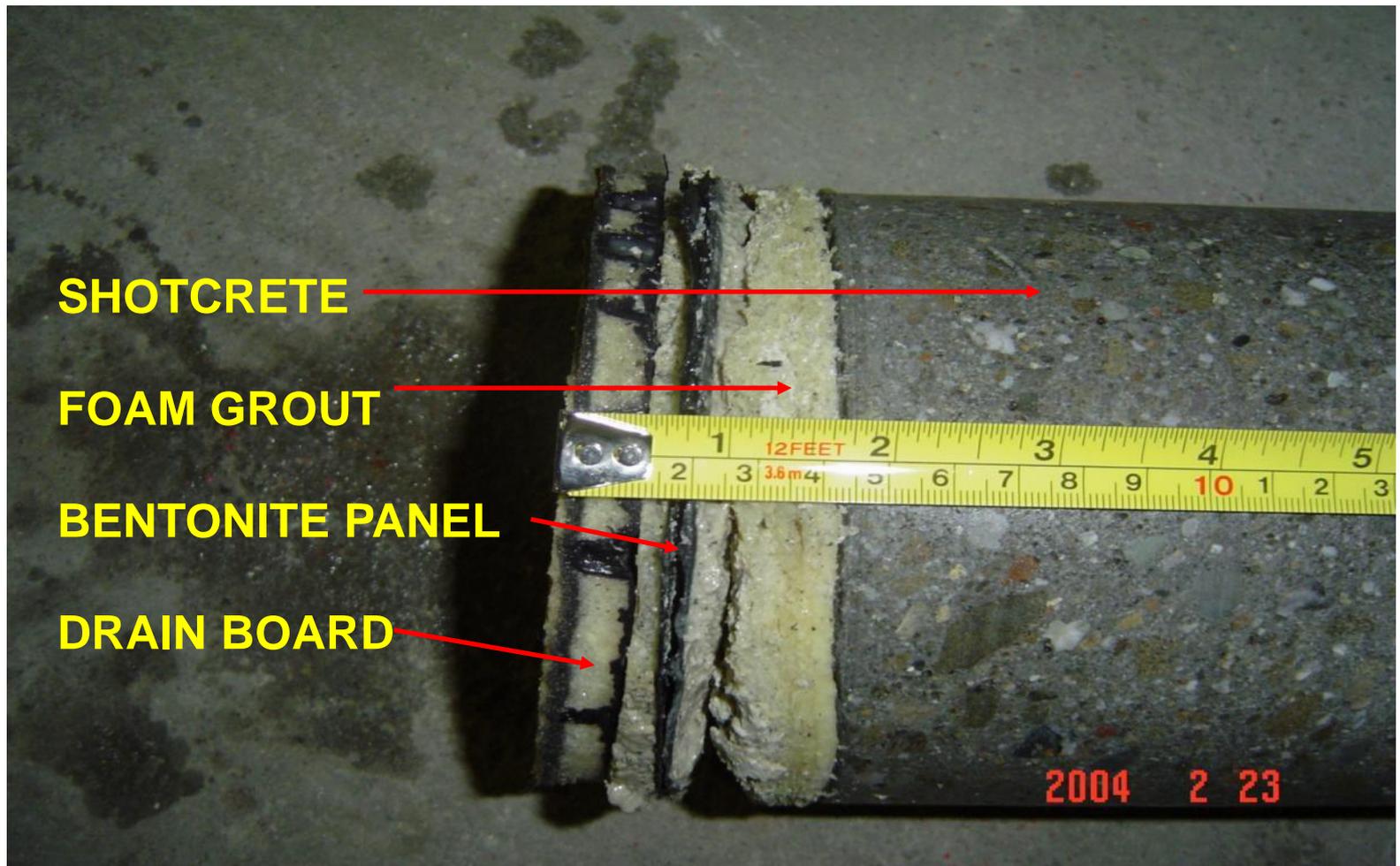
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Large Voids Found Behind Shotcrete Wall



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Large Voids Found Behind Shotcrete Wall



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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.



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Typical Test Pit



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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.



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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.**



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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

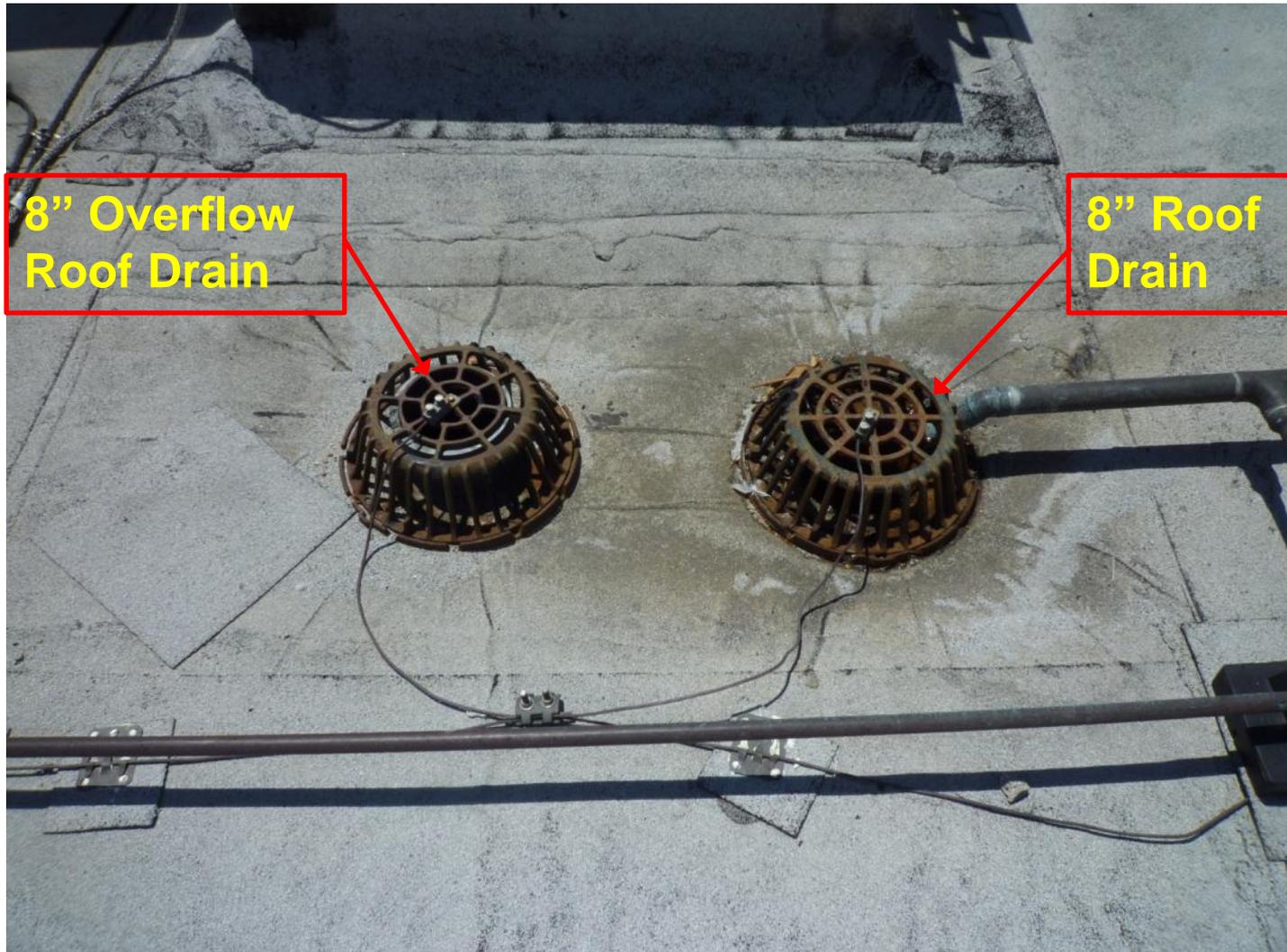
Investigation Findings

- **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).**



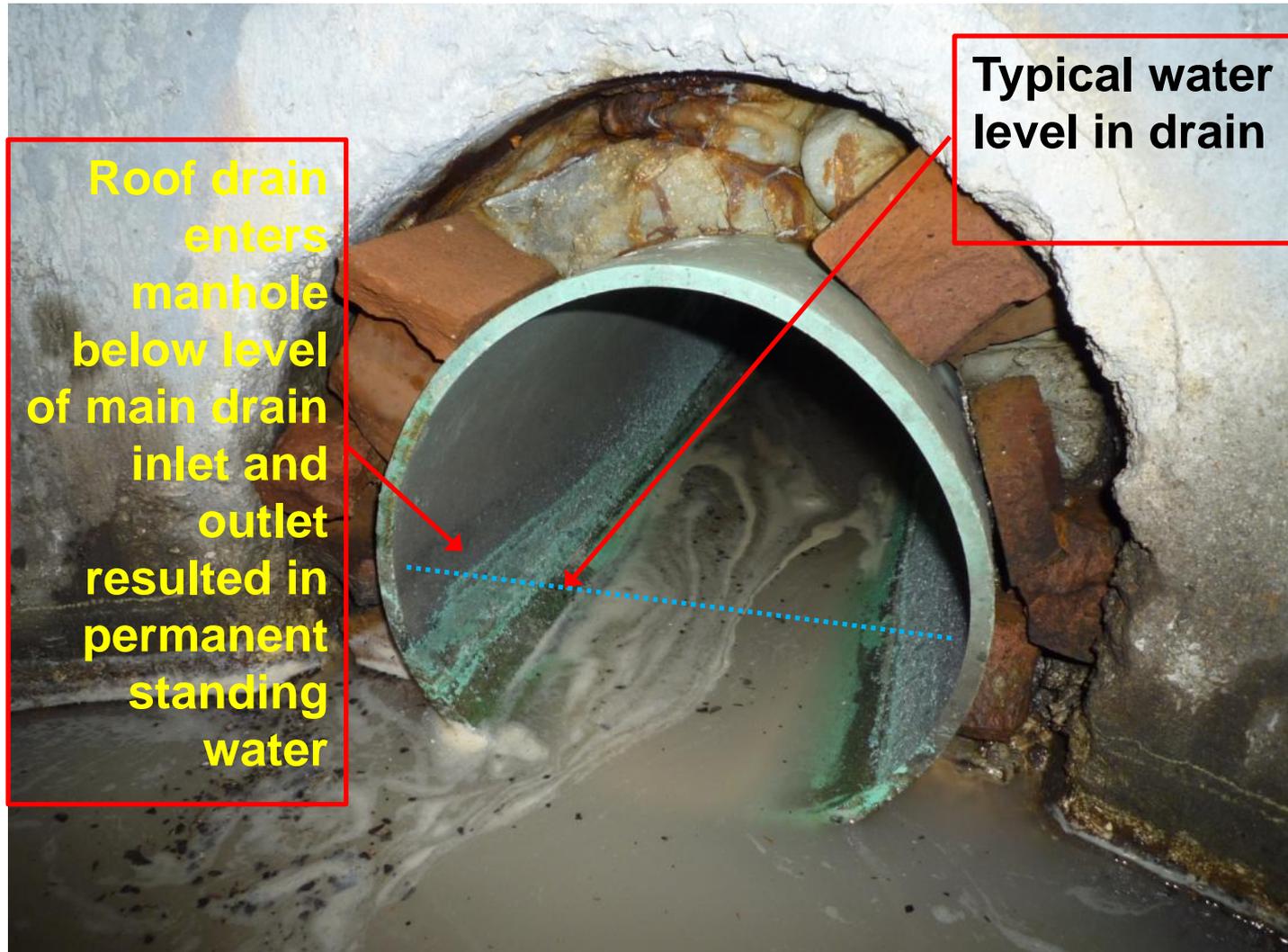
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Roof Drains are Large (8-inch lines)



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Roof Drain Inlet to Storm Drain Manhole



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Typical Overflow Drain Outlet



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Overflow Drain Cover with Chain Restraint



Water hits cover and is directed down against foundation wall



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General View of Test Pit



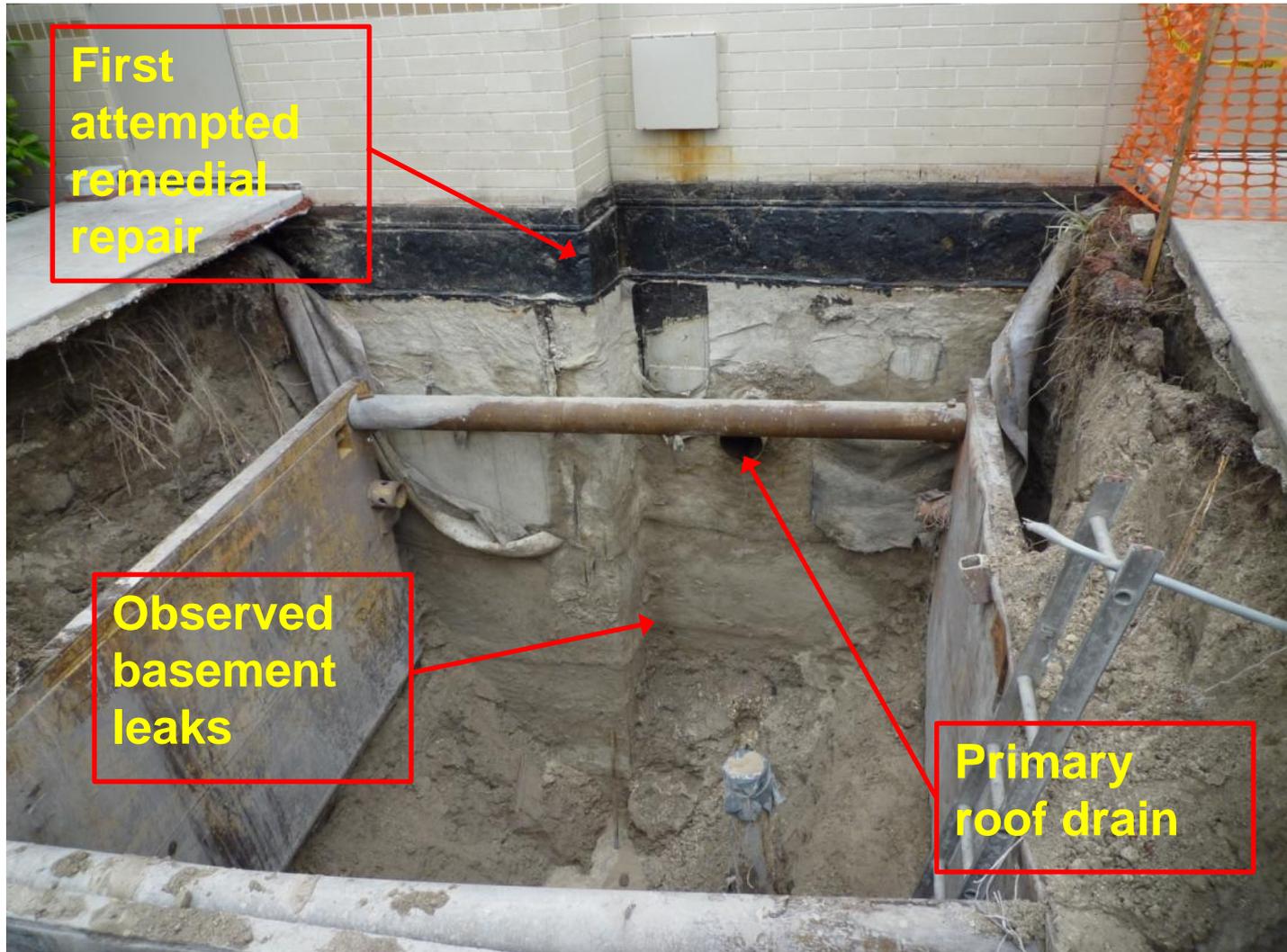
Overflow
rood drain
cover

Foundation
leaks



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Full Depth Test Pit



First attempted remedial repair

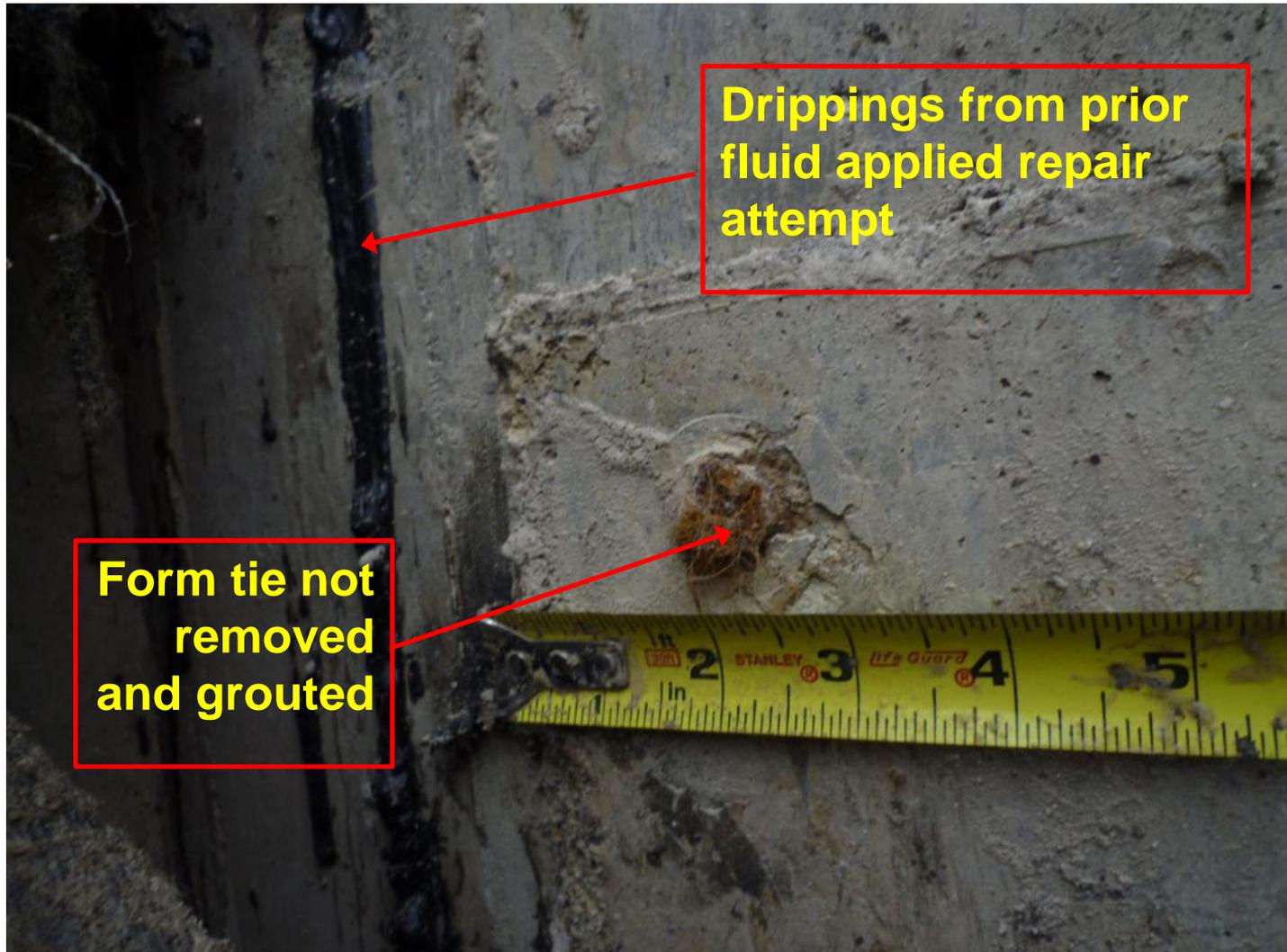
Observed basement leaks

Primary roof drain



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Form Ties Not Removed and Hole Grouted



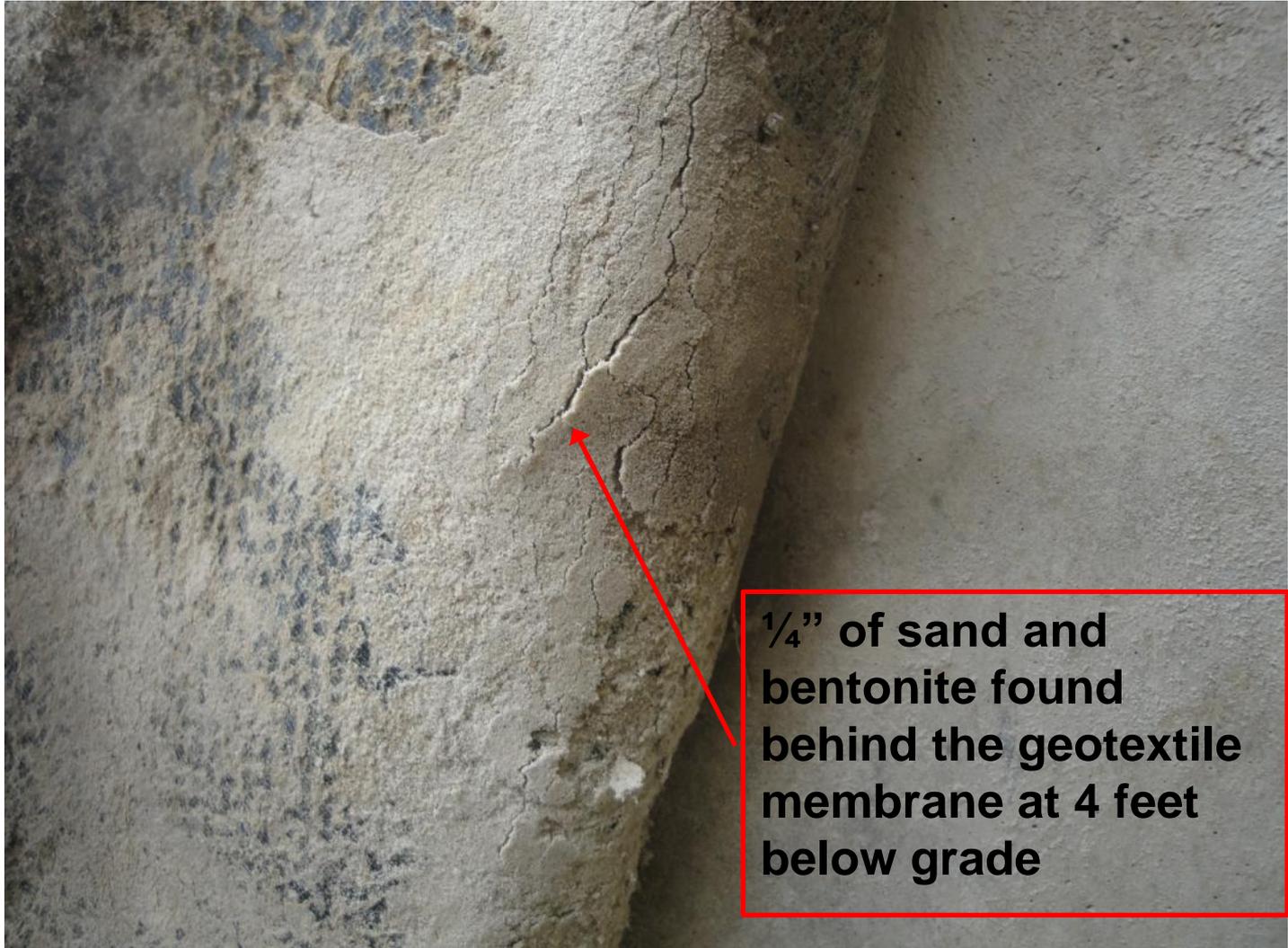
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Elevation With Leakage



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Sand and Bentonite Washed Behind Membrane



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No Bentonite Found in Sheet 2 Feet Below Grade



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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.**

