TEST METHODS FOR EVALUATING EXISTING FOUNDATIONS

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Presented to:	**Foundation Performance Association**
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OUTLINE

- Introduction
- Test Methods
- Foundation Characteristics and Defects
- Summary Table
- Case Study - Slab-on-Ground Cracking
- Key resources
- Conclusions

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Introduction

- Scope
  - Document type - general guideline
  - Audience - Engineers
  - Type of foundation - lightly loaded foundations and pavement
  - Material - concrete
  - Geographic boundary – Houston
  - Safety issues – not addressed

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Introduction

- General Considerations
  - Cost

    Least Expensive — Most Expensive

    $ ← $$ — $$$ — $$$$ → $$$$$

    - Rental
    - Equipment
    - Professional services
  - Calibration
    - Test results
    - Proprietary equipment
  - Test methods - not all-inclusive

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Introduction

- Format
  - General description
  - General applications
  - Some considerations
  - Relative cost
  - Additional resources

Test Methods

Test Methods – Carpenter Level

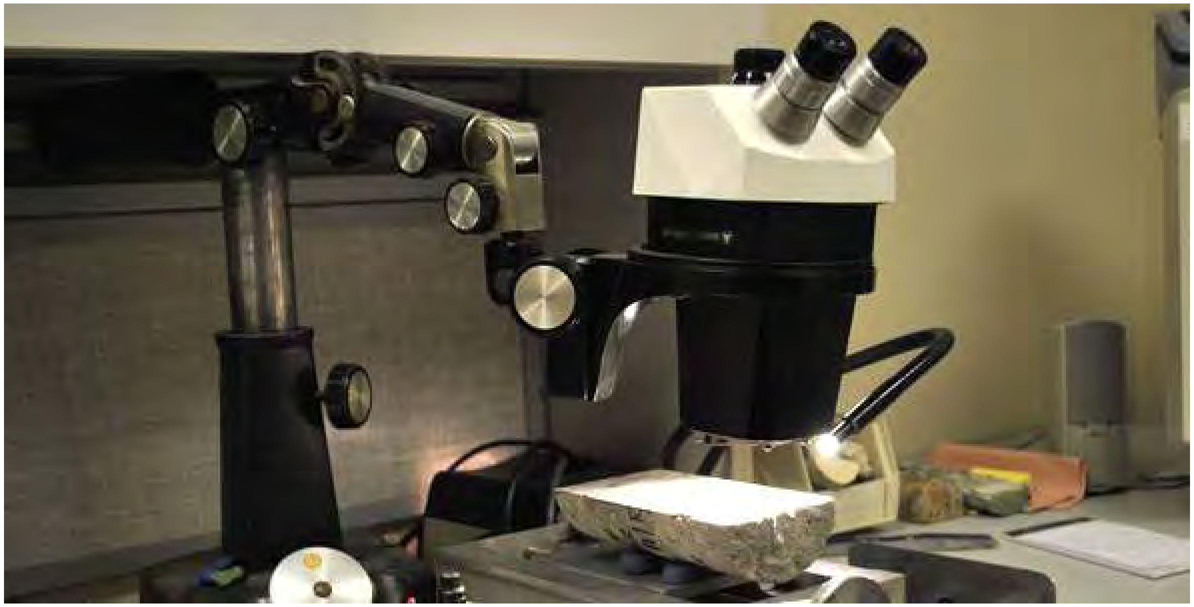
- Confirm elevation survey
- Levelness
- Plumb

Test Methods – Chain Dragging

- Estimate location and extent of delamination

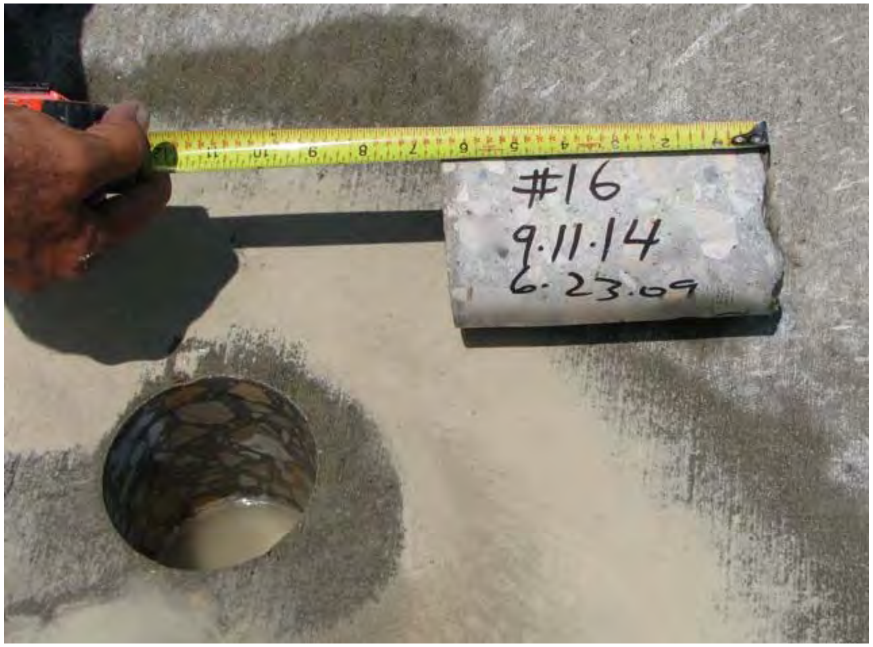
Test Methods – Chloride Content

- Analyze for chlorides at the level of steel reinforcement



Test Methods – Concrete Cores

- Testing - Compressive strength
- Confirm dimensions
- Petrographic analysis



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Test Methods – Concrete Screwdriver Test

- Relative hardness and durability

Test Methods – Geotechnical

- Causes and extent of foundation movement

Test Methods – Geotechnical

- Classify soil types
- Measure soil strength
- Report Atterburg limits
- Moisture content
- Ground water level
- Compaction
- Shear strength
- Active zone depth
- Swell potential
- Potential vertical movement (PVM)

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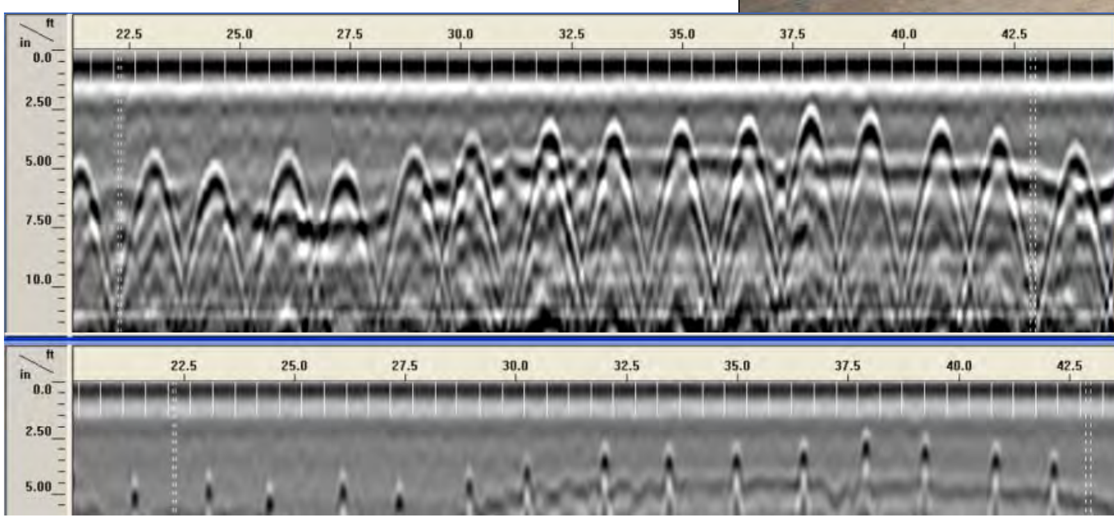
Test Methods – Ground Penetrating Radar

- Location, depth, spacing of steel reinforcement
- Presence of utility lines
- Voids underneath a slab
- Delamination
- Slab thickness
- Soil strata

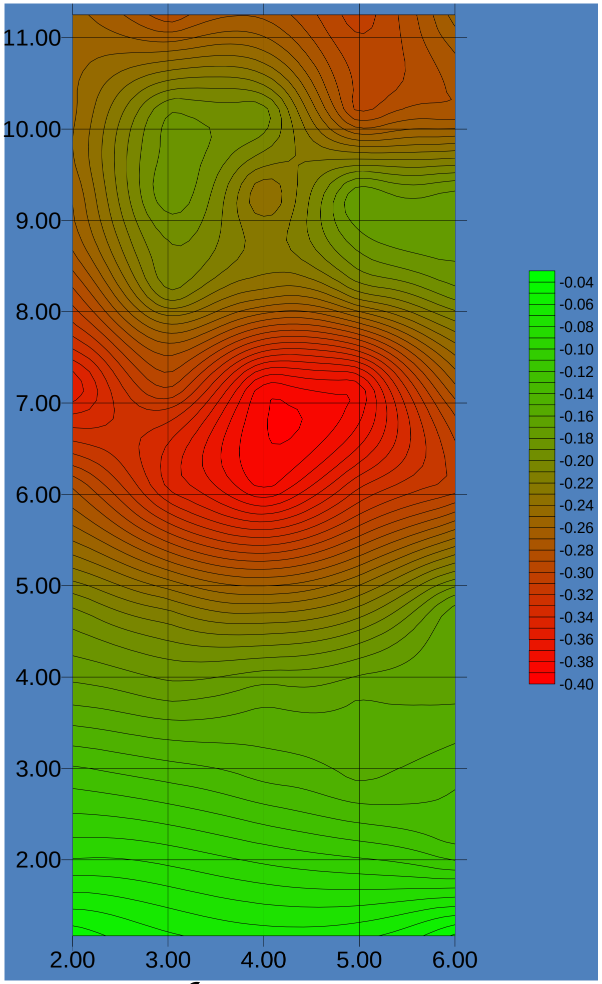


Test Methods – Ground Probing

- Depth of perimeter grade beams
- Soil type and color
- Soil moisture condition
- Relative soil shear strength

Test Methods – Half Cell Potential

- Probability of steel reinforcement corrosion



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Test Methods – Hammer Sounding

- Presence of delamination and voids

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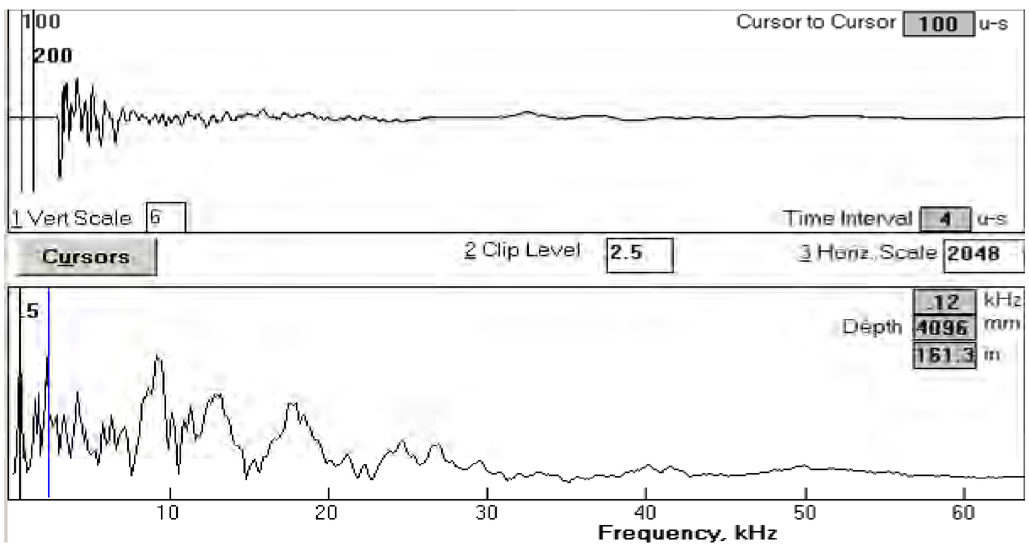
Test Methods – Impact Echo

- Delamination
- Internal voids
- Honeycombs
- Voids underneath a slab



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Test Methods – Inspection Openings and Excavations

Inspection opening

Test pit excavation

Test Methods – Inspection Openings and Excavations

- Inspection opening
  - Size and placement of steel reinforcement
  - Presence of vapor retarder below a slab
  - Slab thickness
- Excavations
  - Grade beam and bell pier dimensions
  - Presence of plumbing lines
  - Free water elevation and condition of fill

Test Methods – Laser Level

- Floor elevations

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Test Methods – Manometer

- Floor elevations

Closed Liquid/Gas

Water

Test Methods – Metal Detector

- Presence and general location of steel reinforcement

Test Methods – Optical Level

- Floor elevation

Test Methods – Petrographic Examinations

- Coarse aggregate segregation
- Air voids
- Poor curing
- Relative water cementitious ratio
- Relative age of cracks
- Type of cracks
- Detrimental chemical reactions – ASR, DEF

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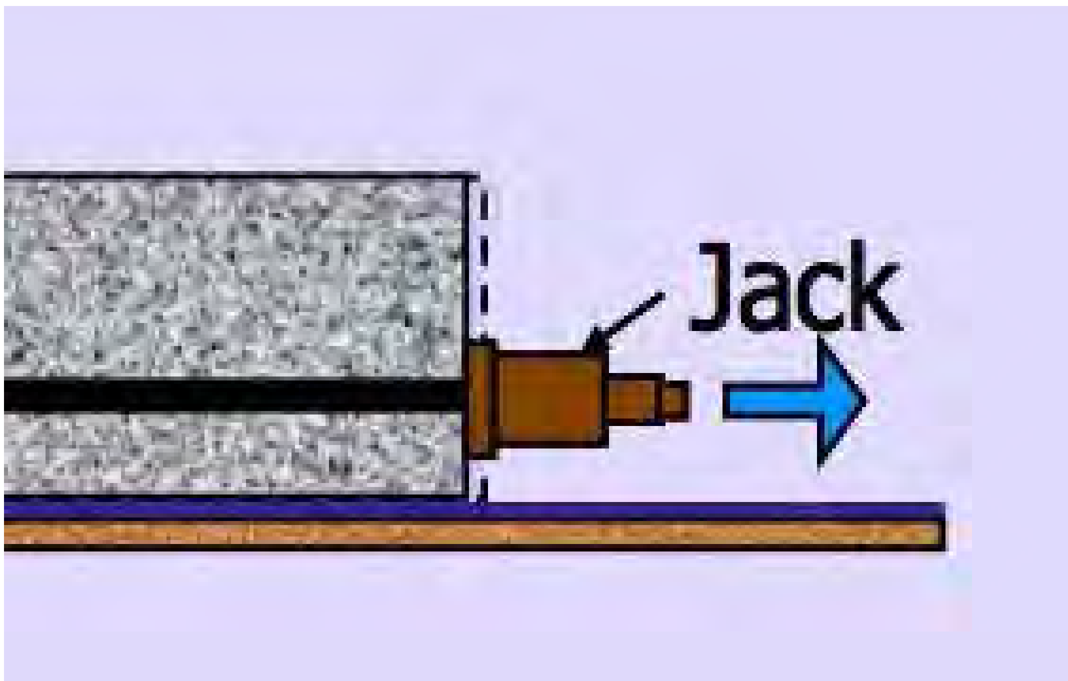
Test Methods – Plumbing Leak Detection

- Foundation movement due to below slab water leaks

Test Methods – Post-tension Lift-Off

- Measure effective tendon force in unbonded post-tensioned tendons



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Test Methods – Post-tension Screwdriver Penetration

- Evaluate presence of tension in post-tensioned tendons

Test Methods – Rebound Hammer

- Relative hardness of concrete

Test Methods – Reinforcement Locator

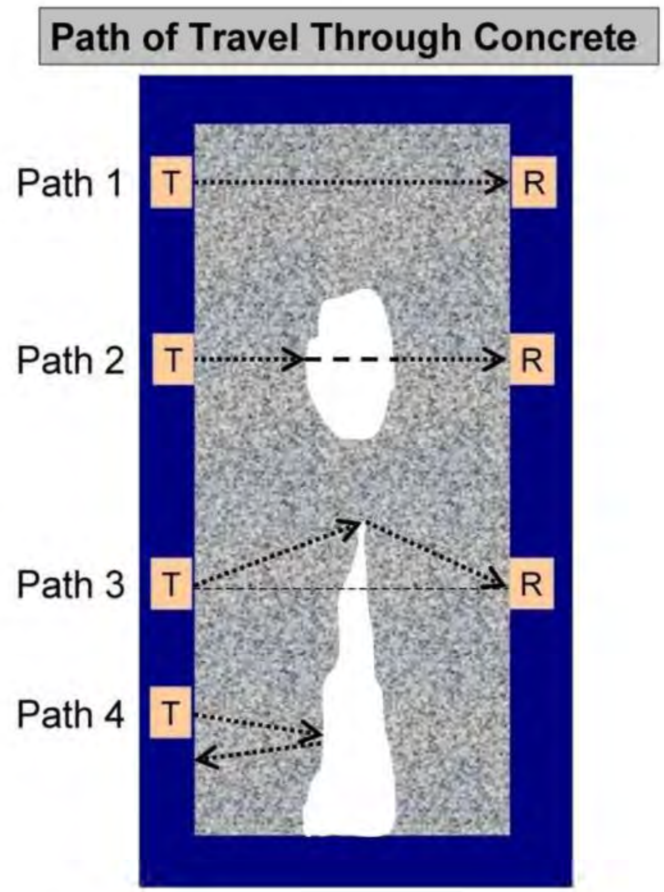
- Spacing, size, and depth of steel reinforcement

Test Methods – Resistivity

- Evaluate effects of
  - Location of pre-existing ponds, foundation, lakes, etc
  - Accumulation of ground water
  - Plumbing leaks
  - Poor drainage
  - Location of pipes
  - Soil strata variations
  - Tree root zones

Test Methods – Ultrasonic Pulse Velocity

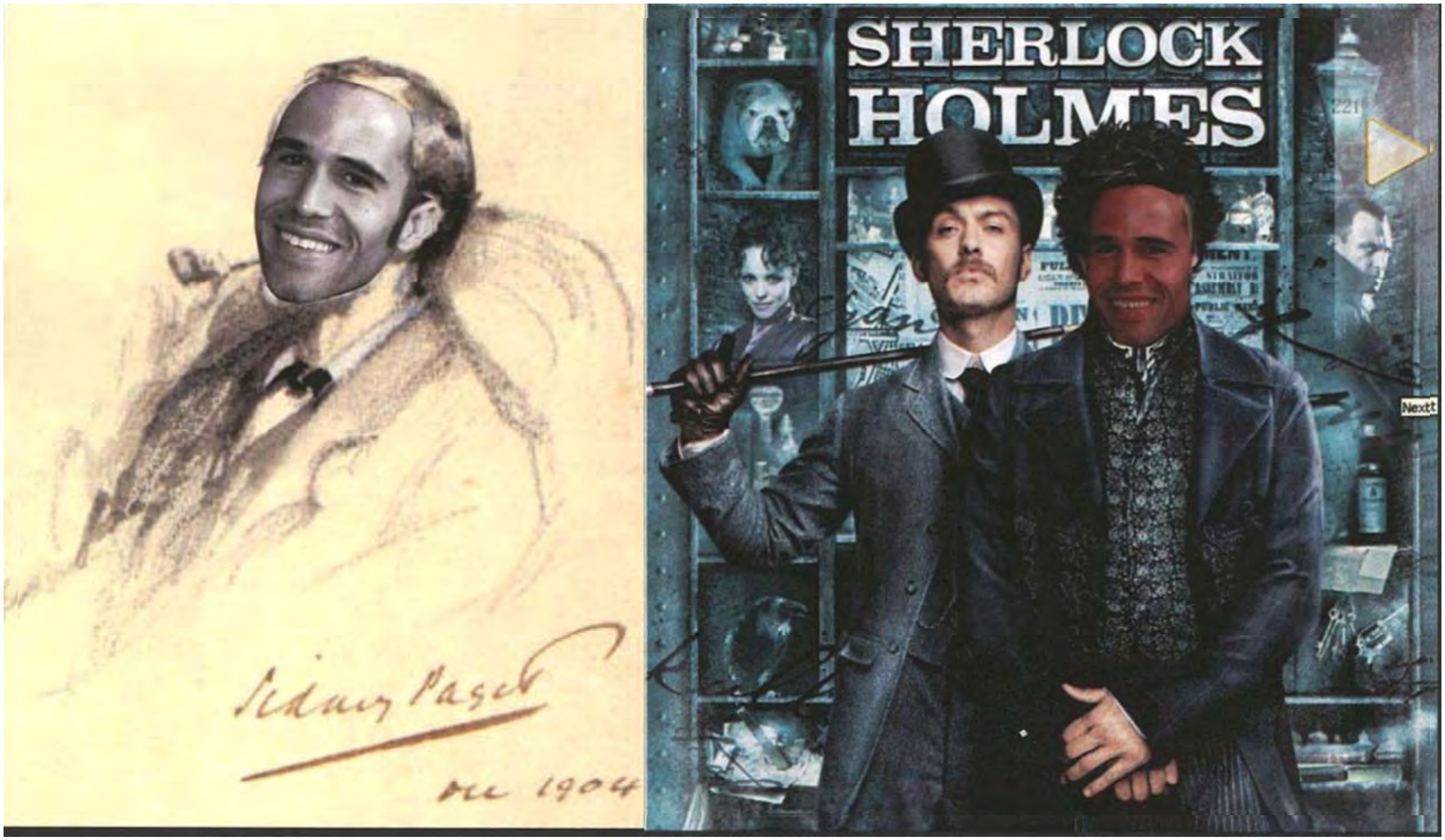
- Internal cracking
- Voids
- Honeycomb



Test Methods – Vapor Transmission

- Adequacy of slab-on-ground to receive floor finishes

Test Methods – Visual



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Test Methods – Visual

- Apparent damages
- Drainage
- Movement of flatwork
- Moisture conditions
- Soil condition
- Trees
- Topography
- Condition of exposed portion of foundations

Foundation Characteristics and Defects

Foundation Characteristics

- Concrete dimensional properties
- Concrete distress
    - Cracking
    - Delamination
    - Detrimental chemical reactions
    - Honeycombing
    - Joint deficiencies
    - Slab curling and warping
    - Spalling

Foundation Characteristics

- Concrete material properties
  - Air entrainment
  - Chloride content
  - Compressive strength
  - Durability
  - Hardness
  - Unit weight
  - Water cementitious ratio

Foundation Characteristics

- Post-tensioned reinforcement characteristics
  - Anchorages
  - Grease
  - Sheathing
  - Strand
  - Tendon
  - Tendon profile

Foundation Characteristics

- Soil characteristics
  - Moisture content
  - Plasticity index
  - Soil shear strength
  - Soil strata location
  - Soil type and color
  - Tree root
  - Water table presence/location

Summary Table

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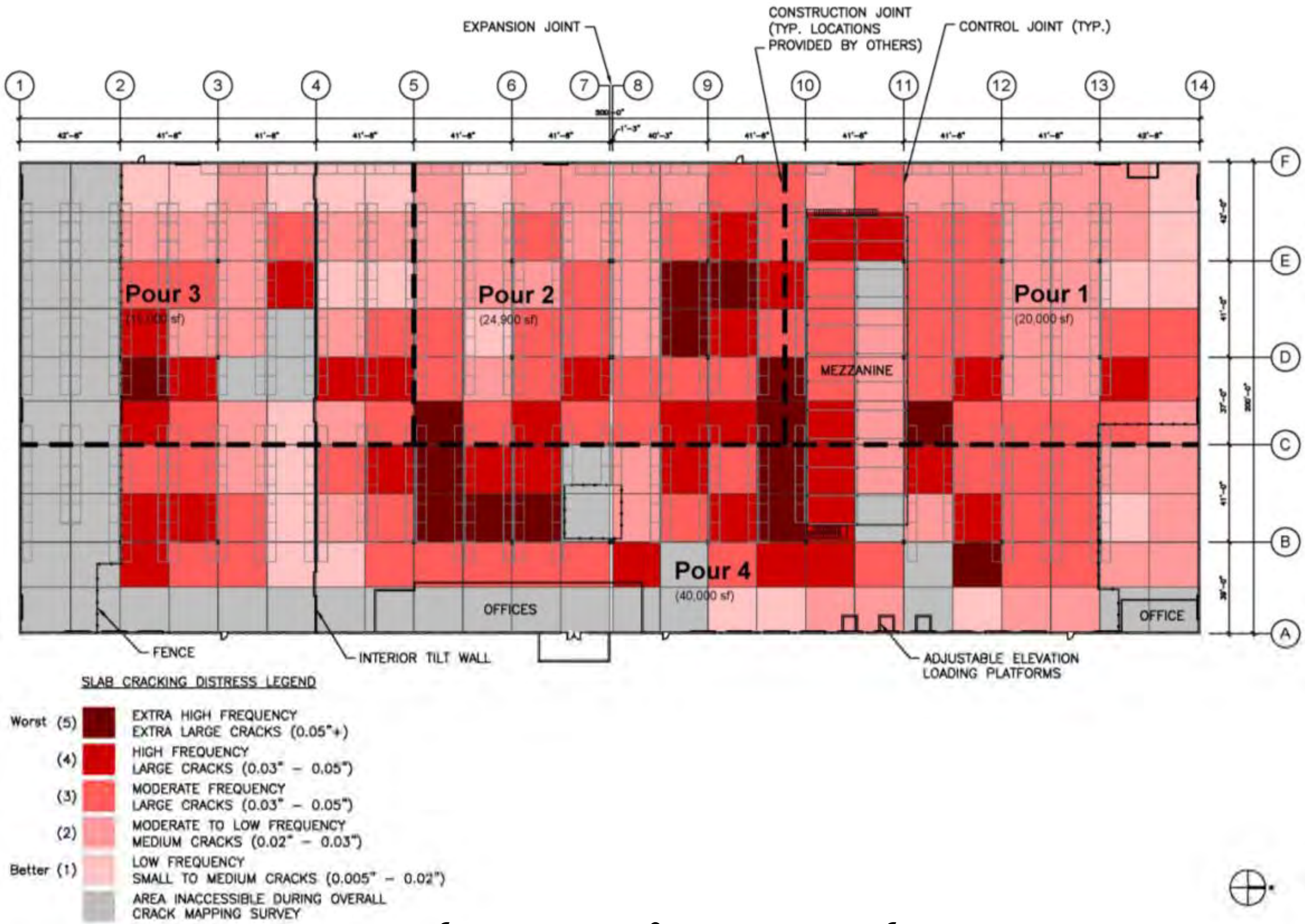
		Characteristics and Deficiencies	2.1 Carpenter Level	2.2 Chain Dragging	2.3 Chloride Ion Testing	2.4 Concrete Cores	2.5 Concrete Screwdriver Test	2.6 Geotechnical	2.7 Ground Penetrating Radar (GPR)	2.8 Ground Probing	2.9 Half-Cell Potential (HCP)	2.10 Hammer Sounding	2.11 Impact Echo	2.12 Inspection Openings/Excavations	2.13 Laser Level	2.14 Manometer	2.15 Metal Detector	2.16 Optical Level	2.17 Petrographic Examination	2.18 Plumbing (Leak Detection)	2.19 Post-Tension Tendon Lift-Off	2.20 Post-Tension Tendon Screw Driver	2.21 Rebound Hammer	2.22 Reinforcement Locator (R-Meter)	2.23 Resistivity	2.24 Ultrasonic-Pulse Velocity	2.25 Vapor Transmission	2.26 Visual
3.1	Concrete Dimensional Properties	Grade beam dimensions								●				●														
		Pier dimensions								●				●														
		Slab levelness and flatness	●												●	●		●										
		Slab thickness				●			●	●				●														
3.2	te Distress	Coarse aggregate segregation				●													●									
		Cracking/types of cracking																	●							●		●
		Delamination		●					●			●	●													●		●
		Detrimental chemical reactions																	●									
		Honeycombing							●				●													●		●

Test Methods

Case Study

Case Study – Slab-on-Ground Cracking



Case Study

- Warehouse located in Houston, TX
- Reinforced concrete slab-on-ground
  - 6” thick
  - Vapor retarder below slab-on-ground
  - No. 4 bars at 18” o.c. each way
  - Control joint spacing at ~ 21’ o.c.

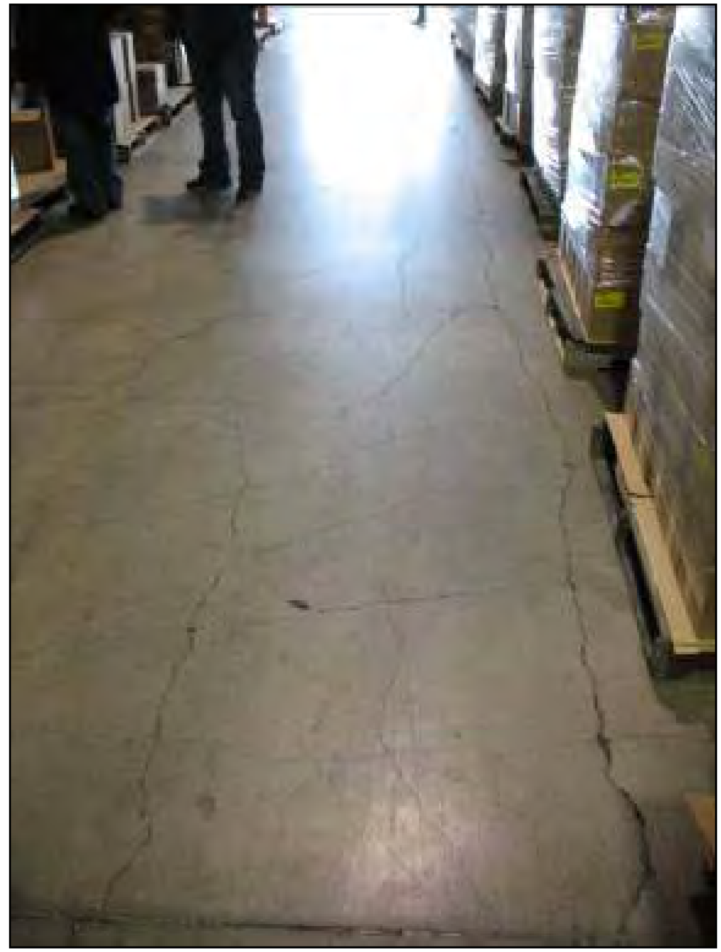
Case Study – Slab Cracking

View of a typical aisle in the east-west direction.

Crack previously repaired with epoxy injection

Case Study – Slab Cracking

Typical cracks located roughly in the middle of an aisle



Random crack pattern

Case Study – Slab Cracking

View of a crack pattern thought to be from a crane load stabilization point

Surface crazing cracking

Case Study – Spalling

Surface spall next to a pallet

Spall at edge of new concrete placed at equipment at overhead door (see arrow)

Case Study – Joint Distress

Spall and cracks at control joint

Missing control joint material (arrow)

Case Study – Crack Mapping

Grid layout for detailed crack mapping area

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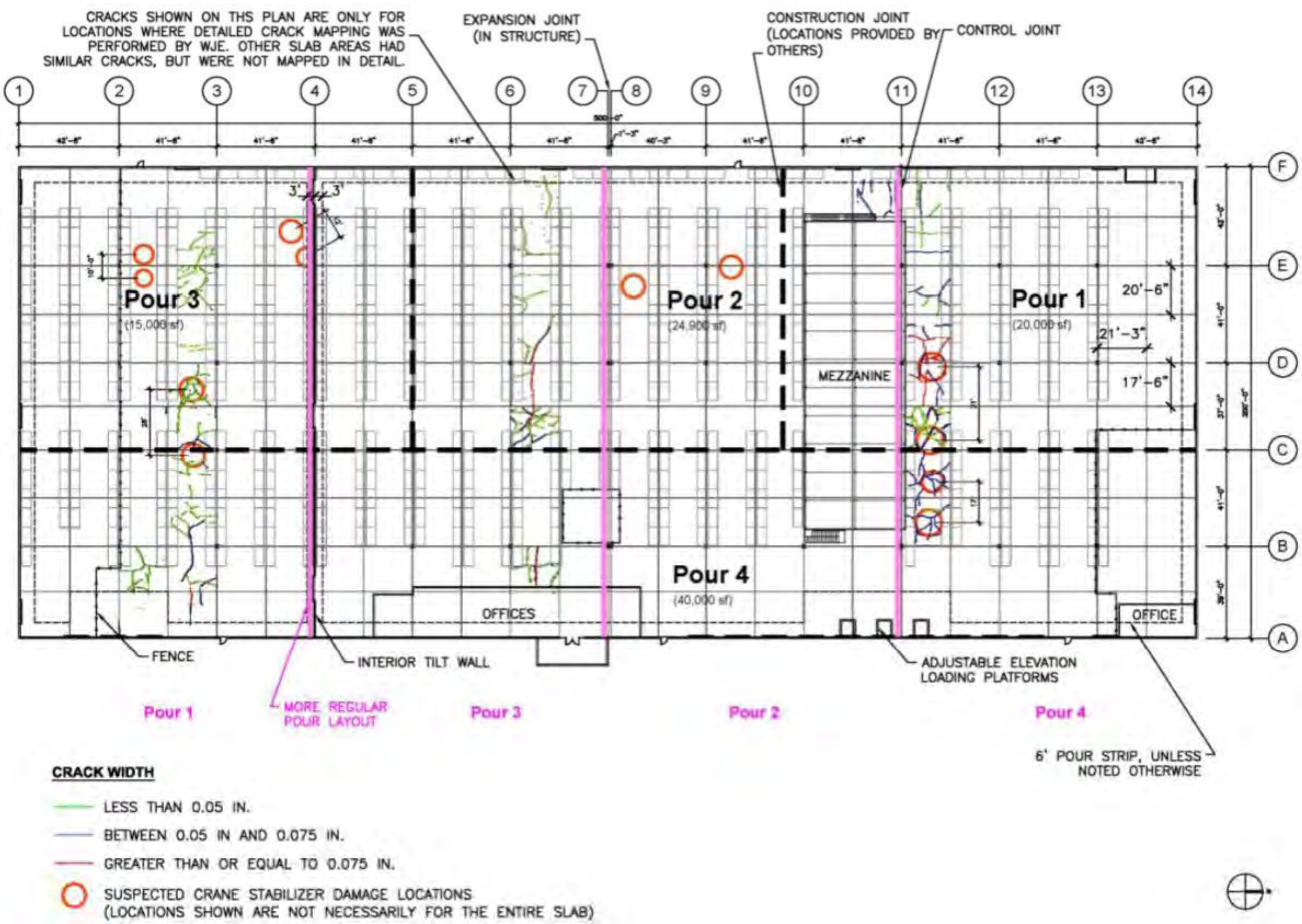
Case Study – Crack Mapping



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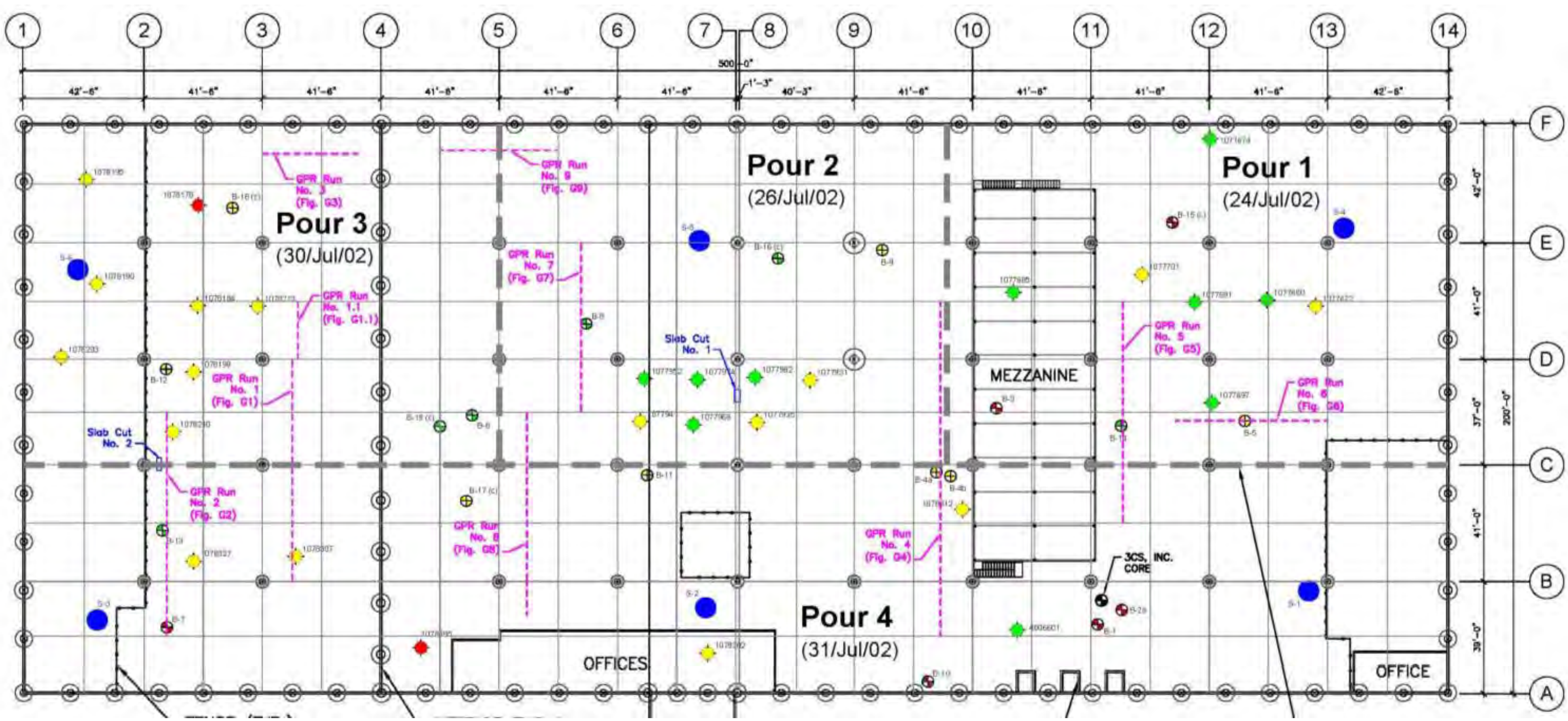
Case Study – Concrete Core Extraction

Case Study – Soil Boring

Case Study – Inspection Opening

Rebar located at the bottom of the slab. Note no cracking propagating from bottom of the control joint. (arrow).

Case Study – GPR Testing



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Case Study – GPR Testing

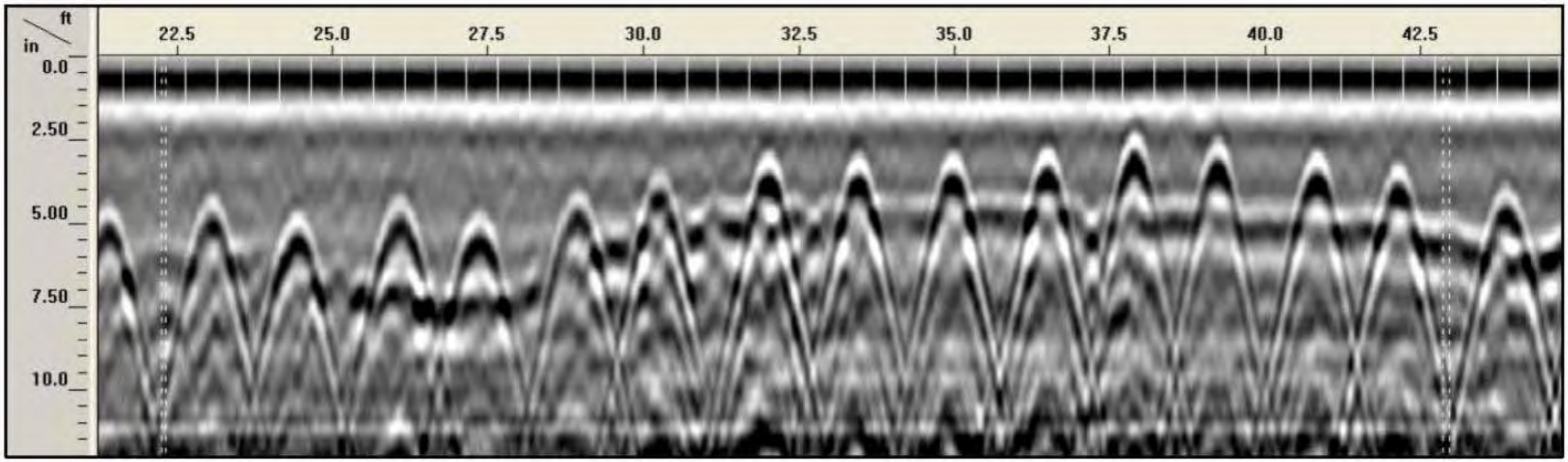

Figure 3. Original GPR Signal: Note variances in rebar and slab depths.

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Case Study – GPR Testing

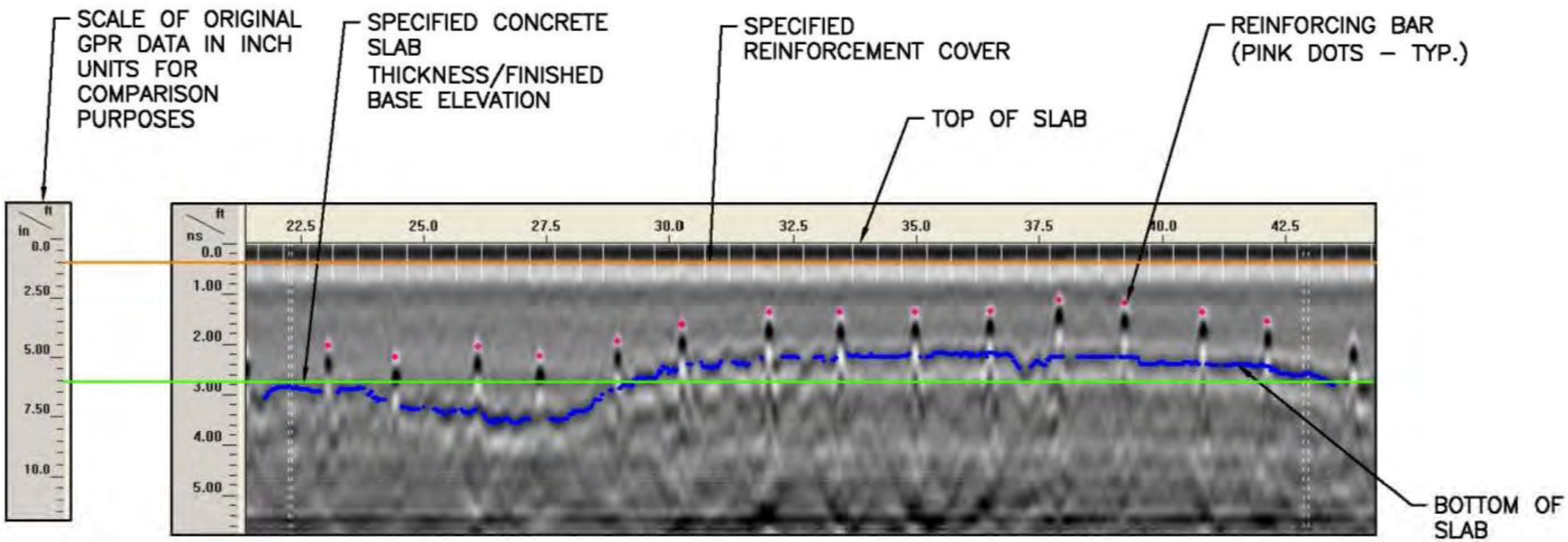

Figure 4. Migrated Data: Data points are shown for top of rebar (pink) and for bottom of the slab (blue).

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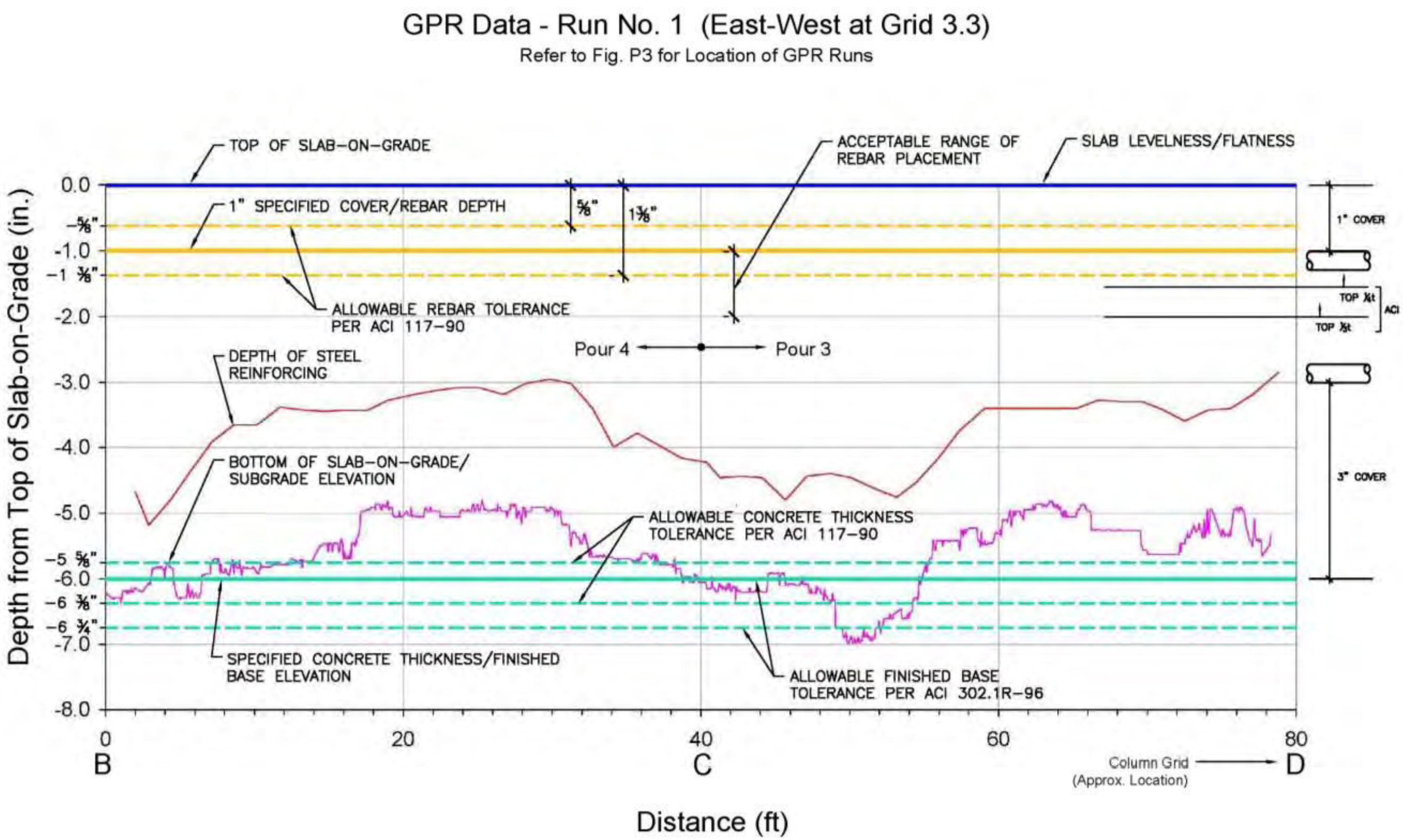
Case Study – GPR Testing



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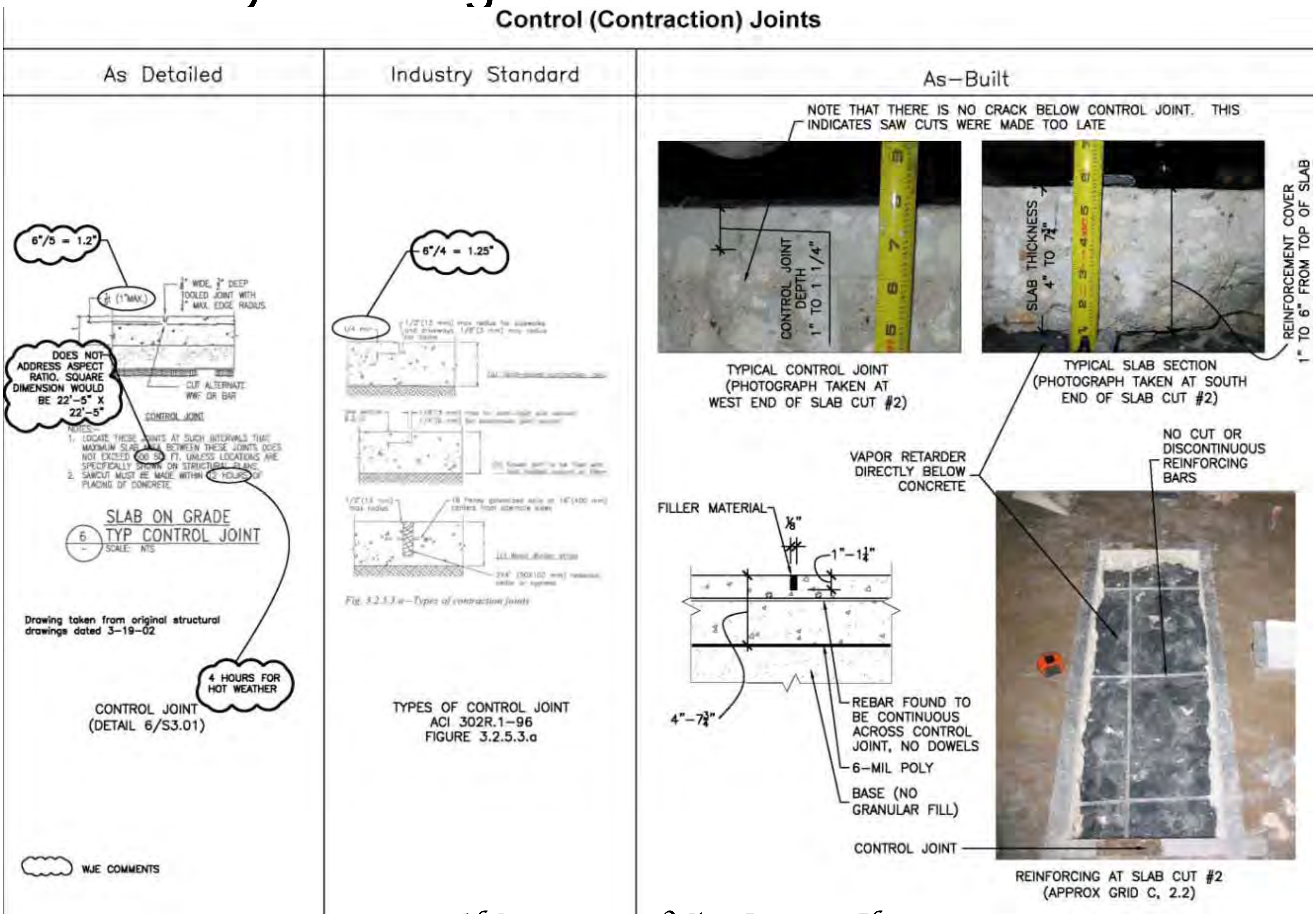
Case Study – Design and Construction Deficiencies



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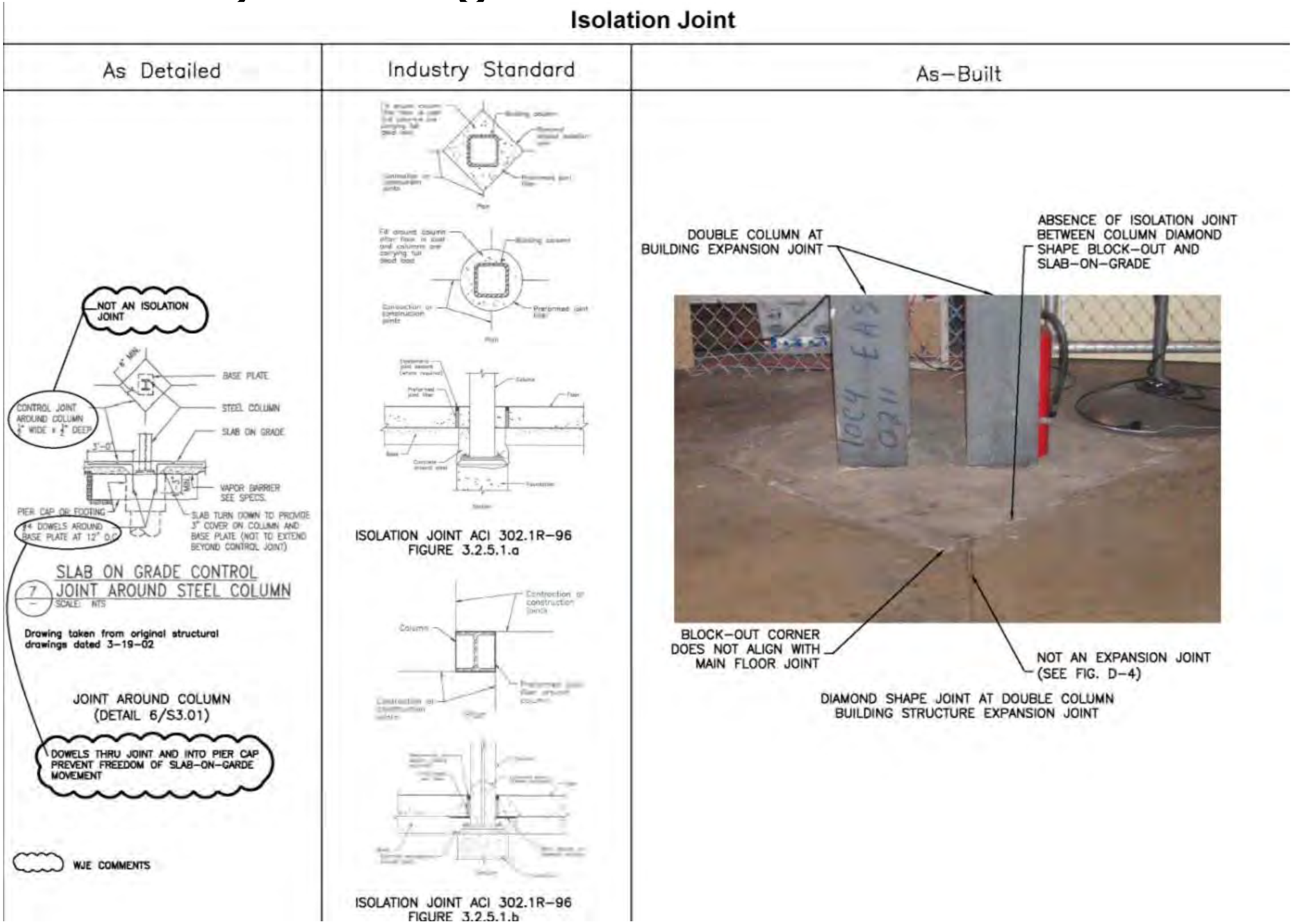

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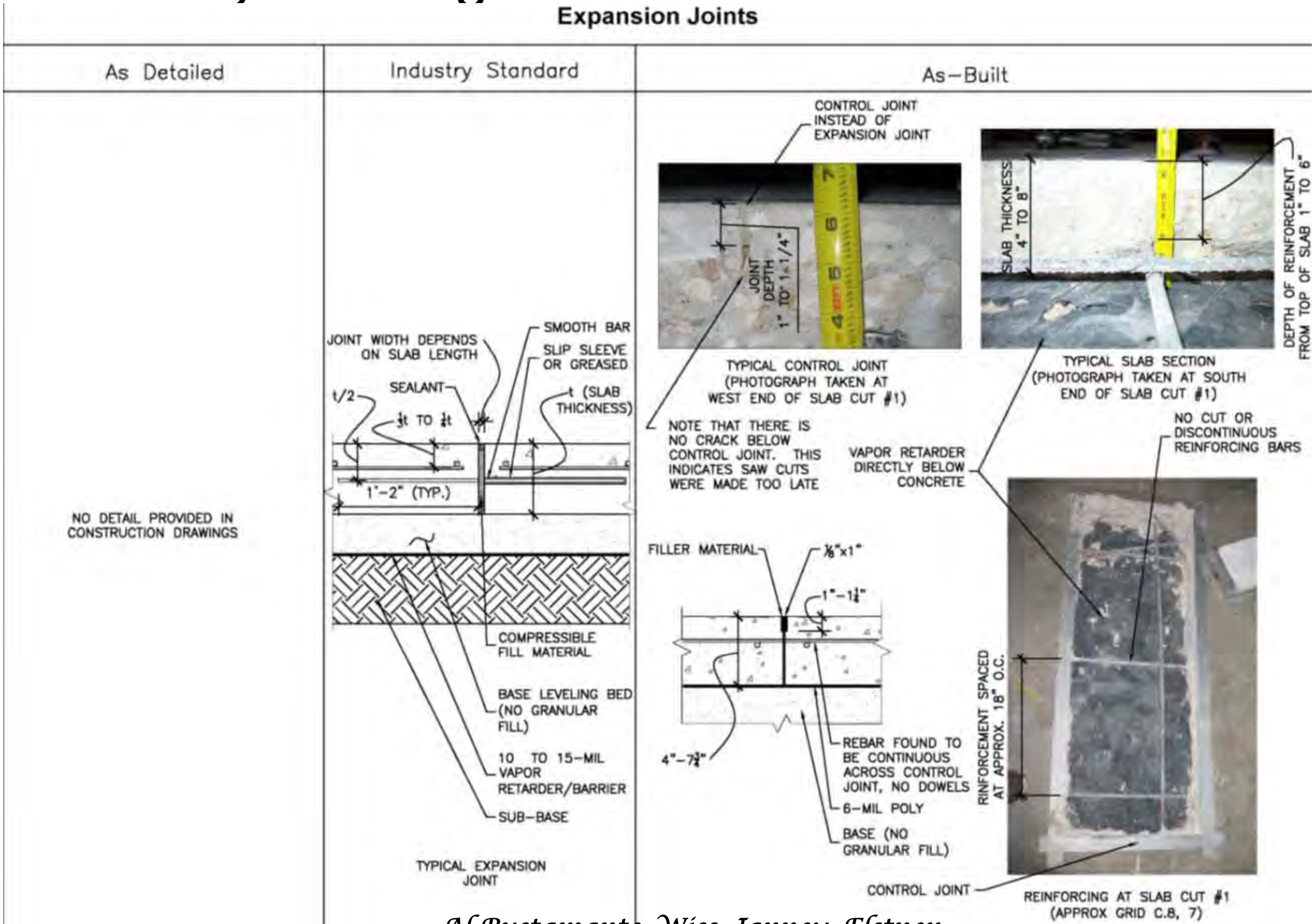
Case Study – Design and Construction Deficiencies



Key Resources

- FPA SC-04 *Recommended Practice for Geotechnical Explorations and Reports*
- ACI 228.2R *Nondestructive Test Methods for Evaluation of Concrete in Structures*
- ICRI Guideline No. 03736 *Guide for the Evaluation of Unbonded Post-tensioned Concrete Structures*

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Conclusion

Why do we test?

"Ask the Structure"…

Jack Janney

…but ask the right questions

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Questions?

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