

TEST METHODS FOR EVALUATING EXISTING FOUNDATIONS

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OUTLINE

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

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

Introduction

- General Considerations

- Cost

Least Expensive Most Expensive
\$ ← ——— \$ ——— \$\$\$ ——— \$\$\$\$ ———→ \$\$\$\$\$

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

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



Test Methods – Concrete Screwdriver Test

- Relative hardness and durability



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Test Methods – Geotechnical

- Causes and extent of foundation movement

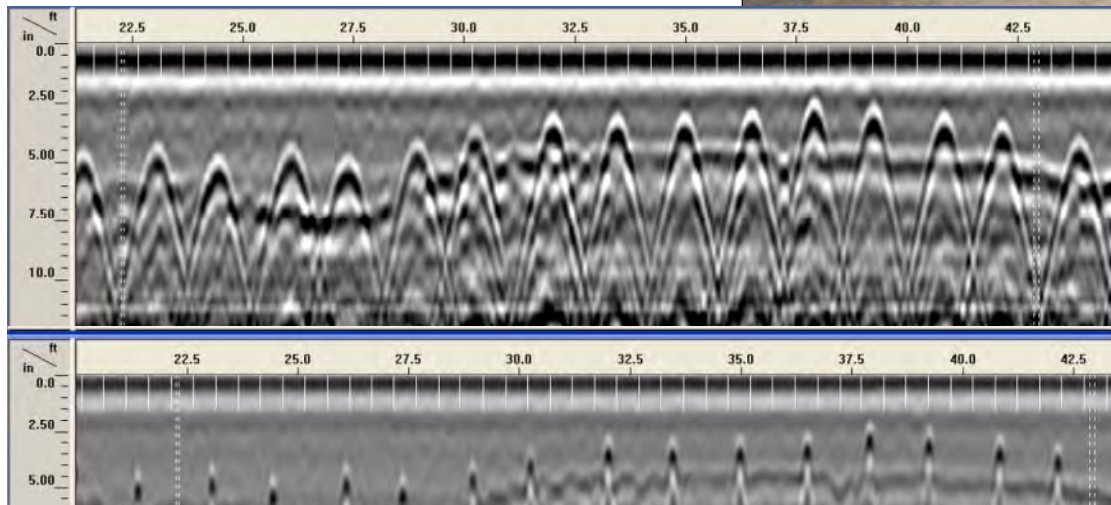


Test Methods – Geotechnical

- 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)

Test Methods – Ground Penetrating Radar

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



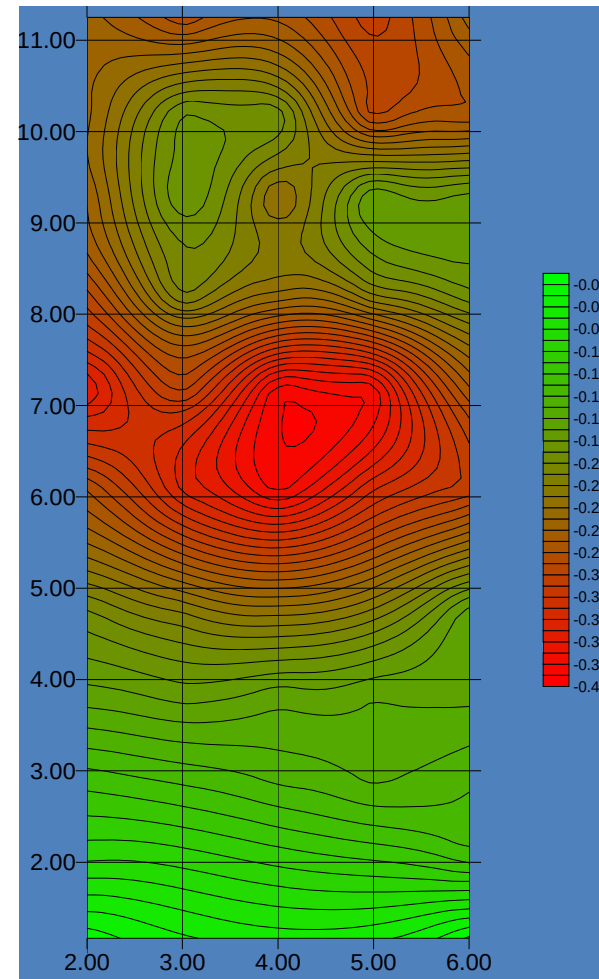
Test Methods – Ground Probing

- 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



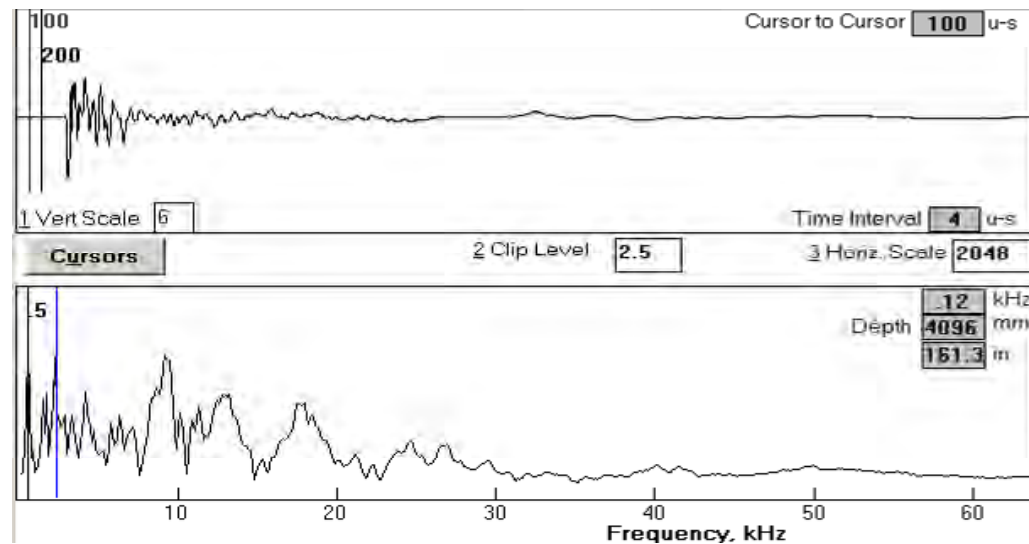
Test Methods – Hammer Sounding

- Presence of delamination and voids



Test Methods – Impact Echo

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



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



Test Methods – Manometer

- Floor elevations



Water



Closed Liquid/Gas

Test Methods – Metal Detector

- Presence and general location of steel reinforcement



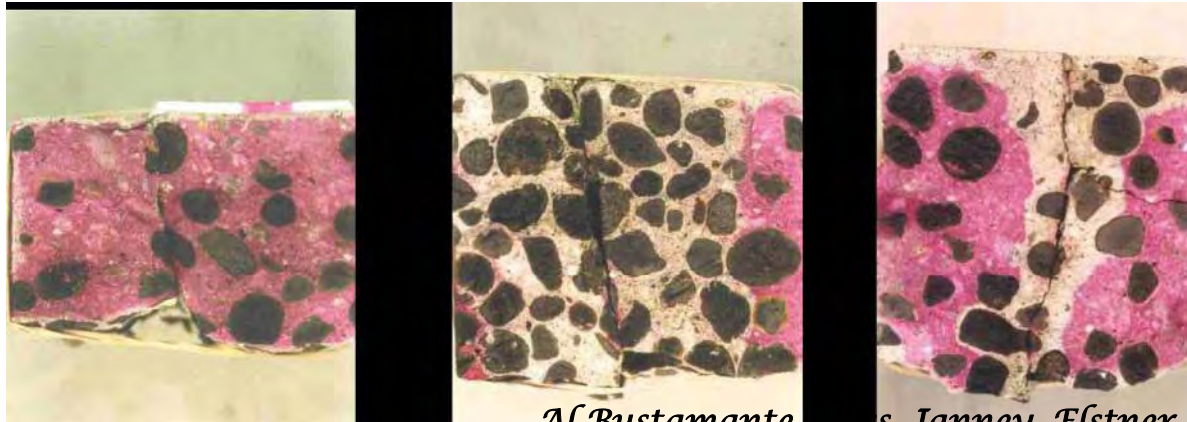
Test Methods – Optical Level

- 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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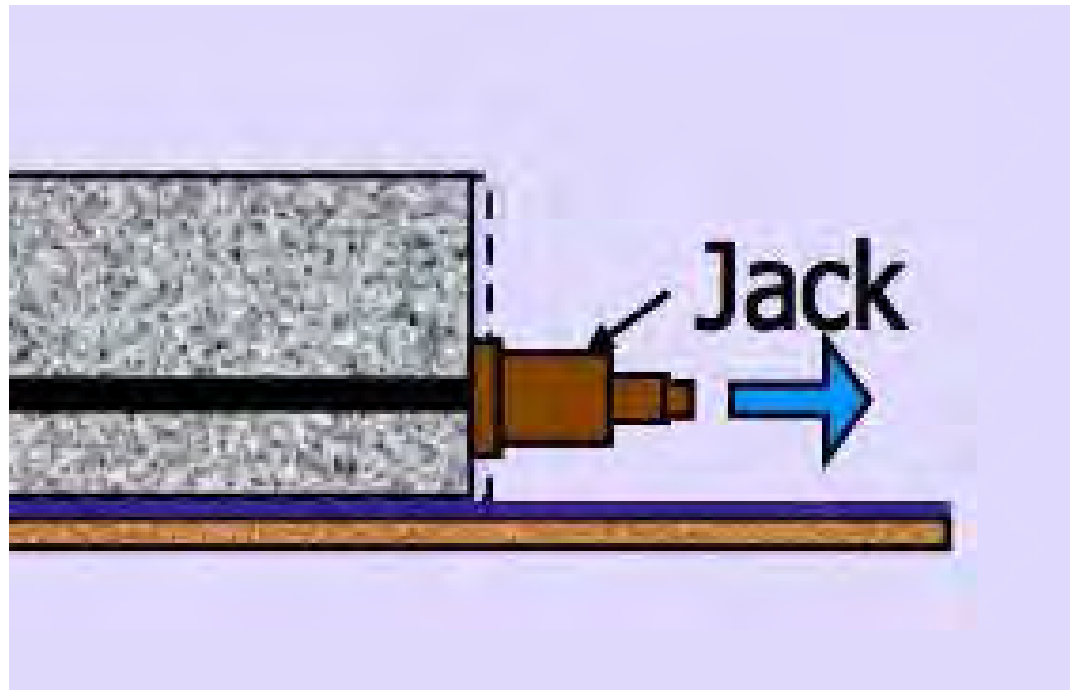
Test Methods – Plumbing Leak Detection

- Foundation movement due to below slab water leaks



Test Methods – Post-tension Lift-Off

- Measure effective tendon force in unbonded post-tensioned tendons



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



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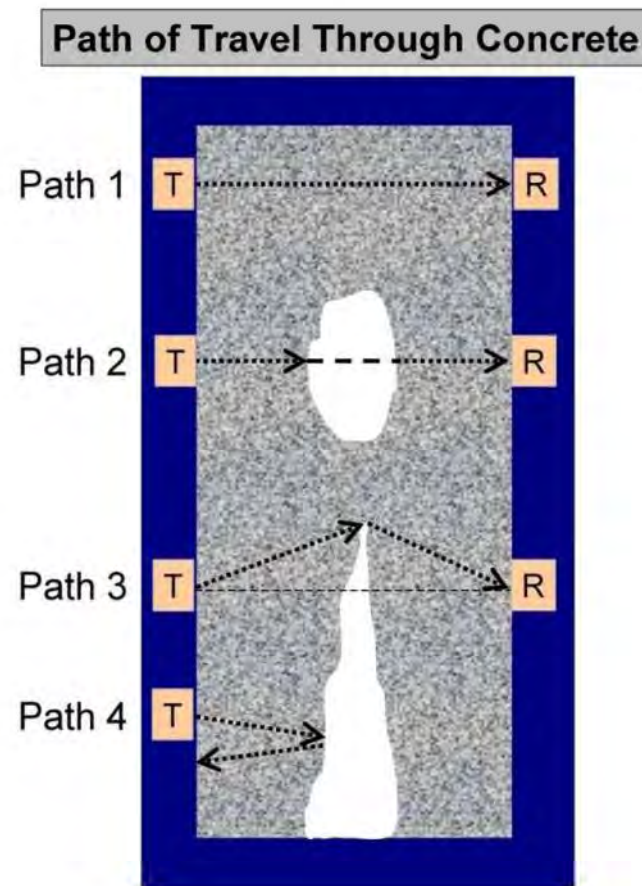
Test Methods – Resistivity

- 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

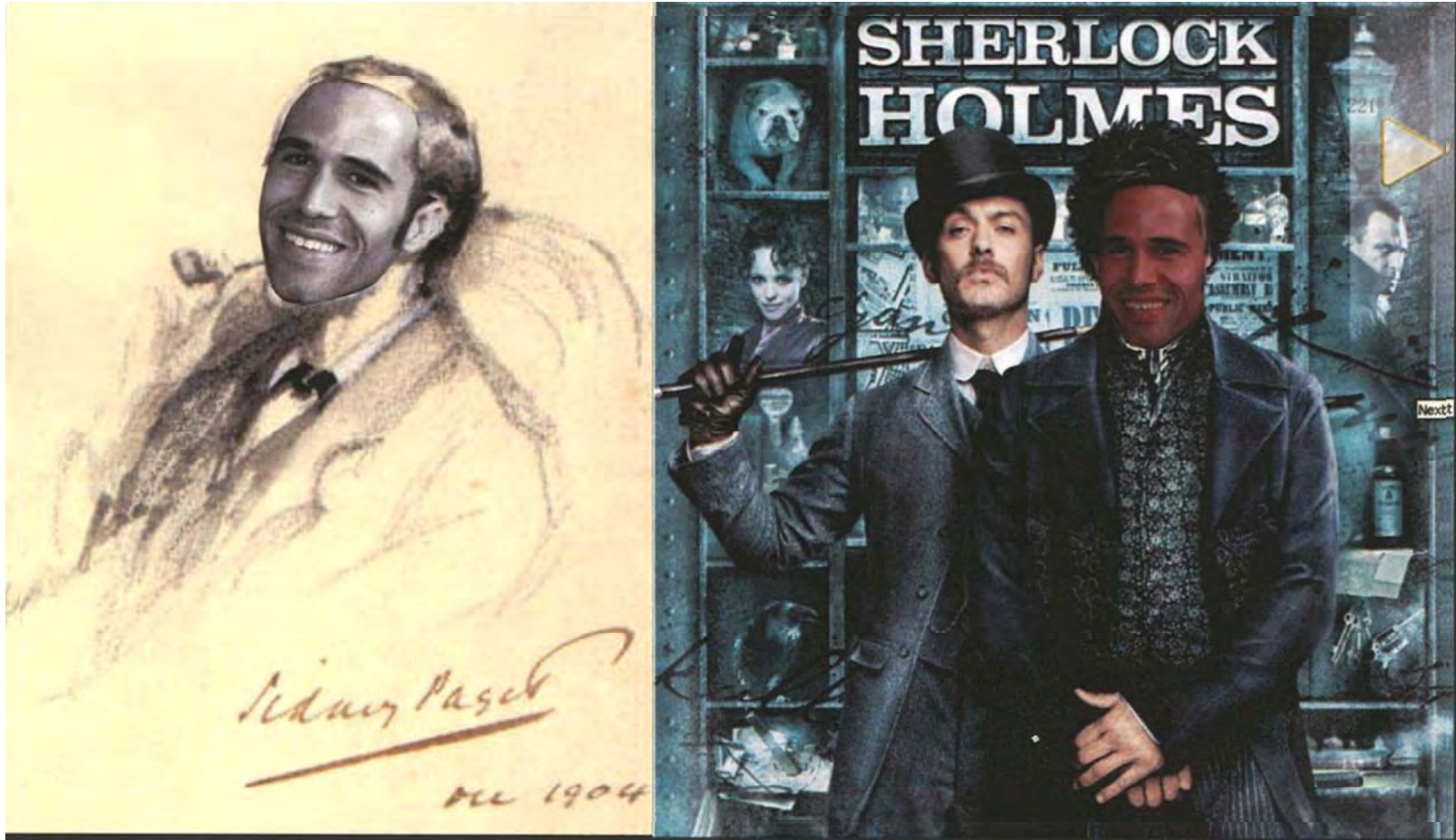


Test Methods – Vapor Transmission

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



Test Methods – Visual



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

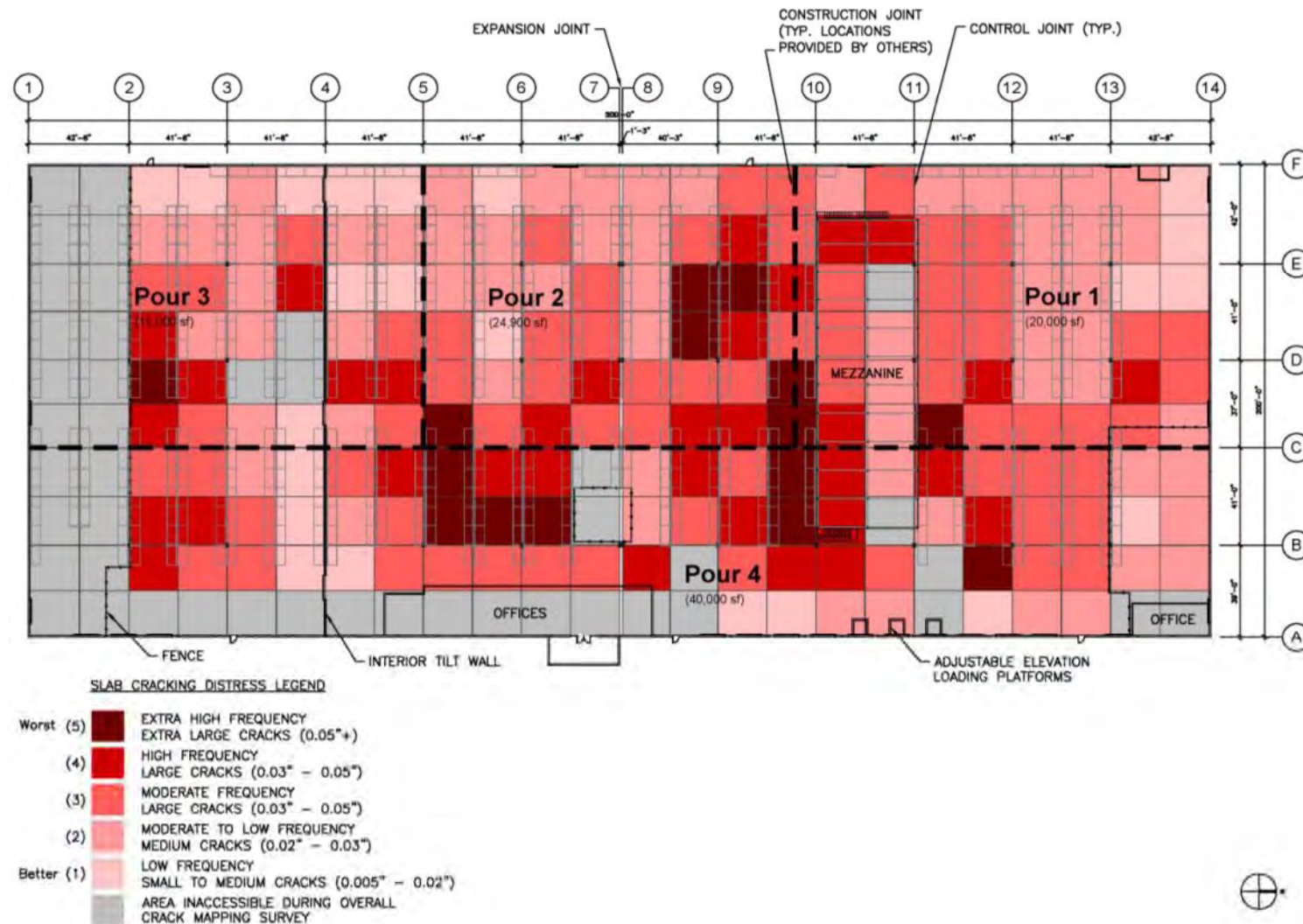
- Soil characteristics
 - Moisture content
 - Plasticity index
 - Soil shear strength
 - Soil strata location
 - Soil type and color
 - Tree root
 - Water table presence/location

Summary Table

Characteristics and Deficiencies			Test Methods																									
			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	Concrete Distress	Coarse aggregate segregation				●												●										
		Cracking/types of cracking																●							●		●	
		Delamination		●					●			●	●						●						●		●	
		Detrimental chemical reactions																●							●			
		Honeycombing						●				●													●		●	

Case Study

Case Study – Slab-on-Ground Cracking



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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
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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

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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)

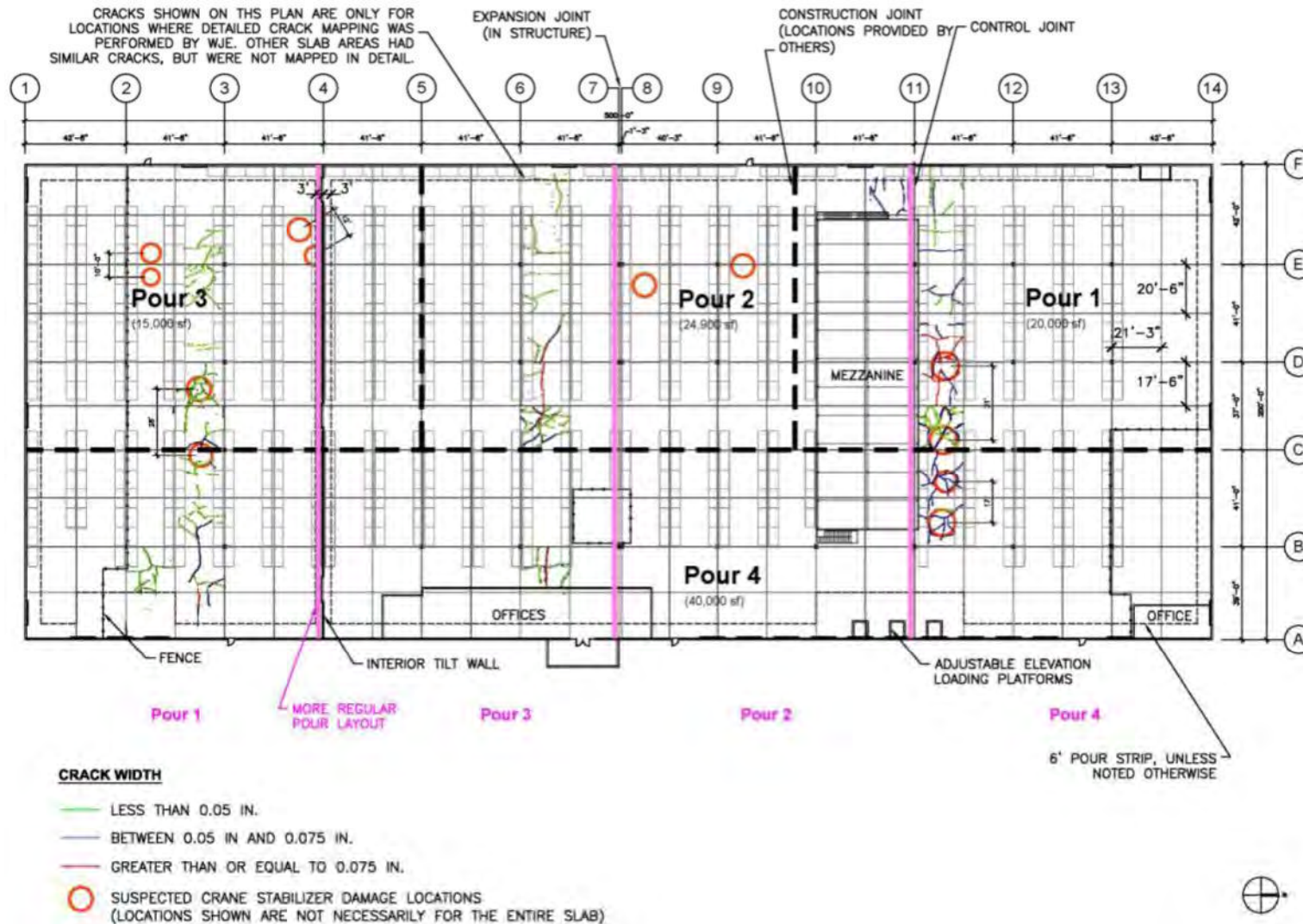
Case Study – Crack Mapping



Grid layout for detailed crack mapping area

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Case Study – Crack Mapping



Case Study – Concrete Core Extraction



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Case Study – Soil Boring



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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

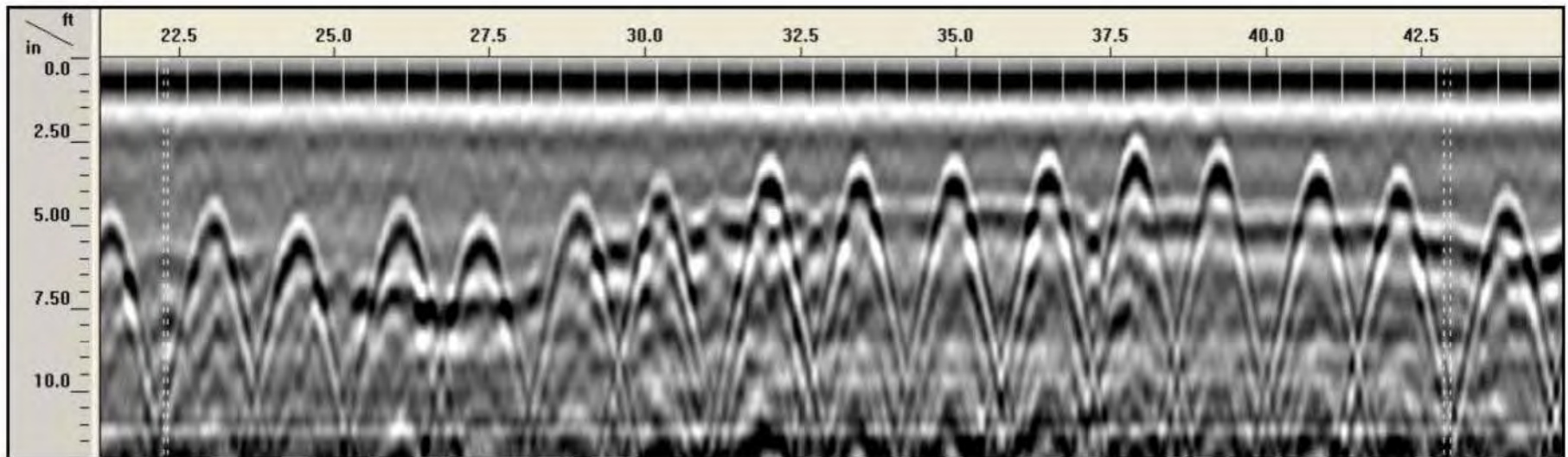


Figure 3. Original GPR Signal: Note variances in rebar and slab depths.

Case Study – GPR Testing

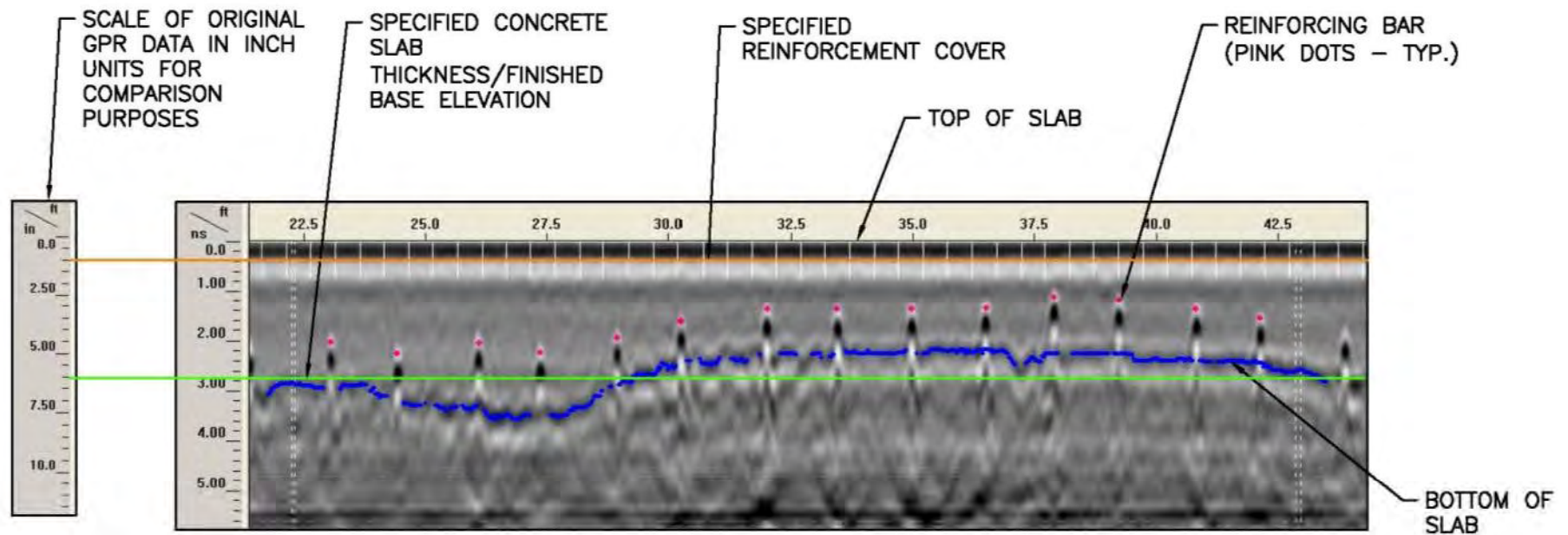
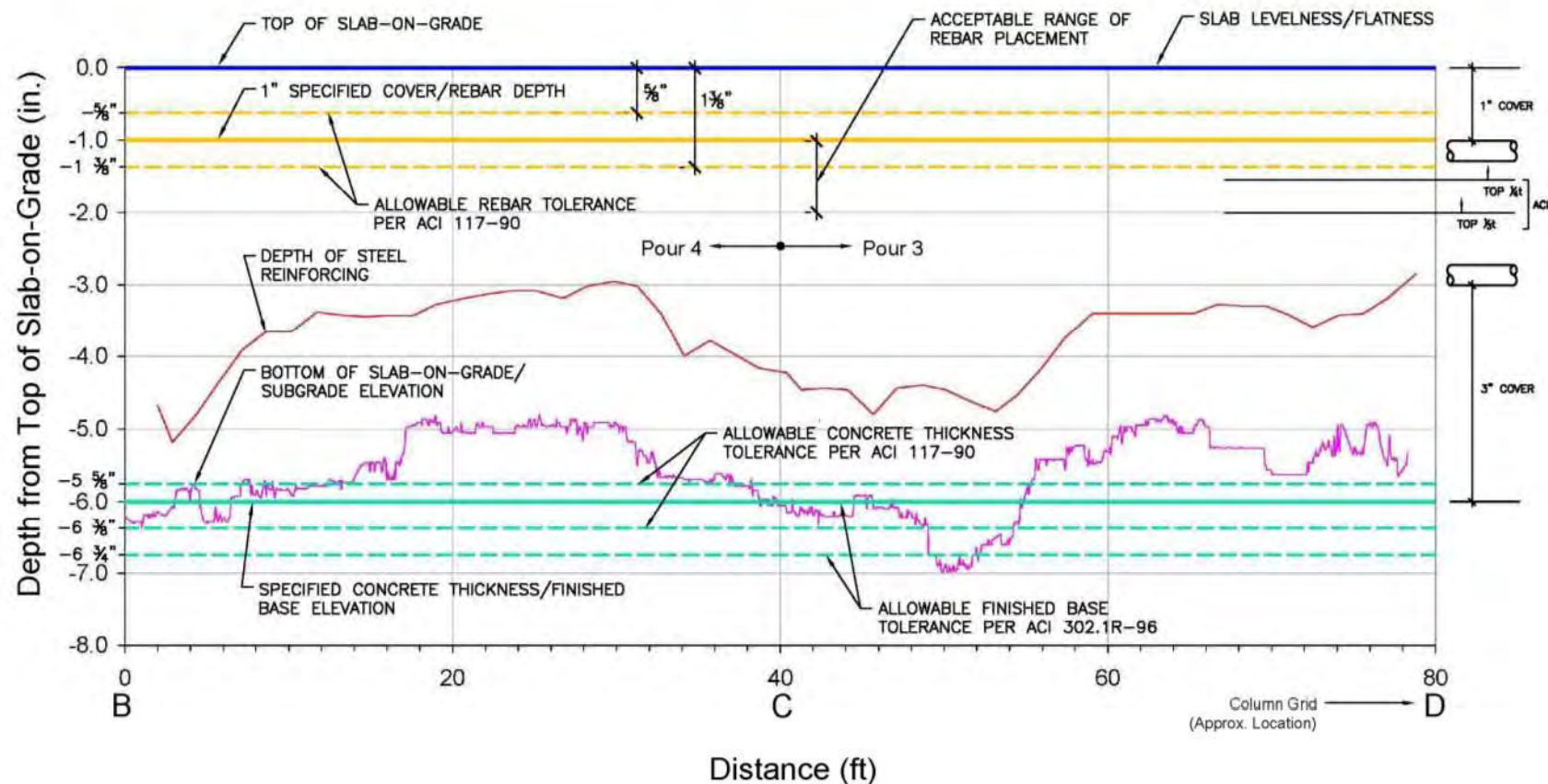


Figure 4. Migrated Data: Data points are shown for top of rebar (pink) and for bottom of the slab (blue).

Case Study – GPR Testing

GPR Data - Run No. 1 (East-West at Grid 3.3)

Refer to Fig. P3 for Location of GPR Runs



As Detailed	Industry Standard	As-Built
6"/5 = 1.2" #1 (1" MAX.) 1/2" WIDE, 3" DEEP TOoled JOINT WITH MAX. EDGE RADIUS CUT ALTERNATE W/W OR BAR CONTROL JOINT DOES NOT ADDRESS ASPECT RATIO. SQUARE DIMENSION WOULD BE 22'-5" X 22'-5" NOTES: 1. LOCATE THESE JOINTS AT SUCH INTERVALS THAT MAXIMUM SLAB AREA BETWEEN THESE JOINTS DOES NOT EXCEED 600 SQ FT, UNLESS LOCATIONS ARE SPECIFICALLY SHOWN ON STRUCTURAL PLANS. 2. SAWCUT MUST BE MADE WITHIN 4 HOURS OF PLACING OF CONCRETE. SLAB ON GRADE TYP CONTROL JOINT SCALE: NTS Drawing taken from original structural drawings dated 3-19-02 4 HOURS FOR HOT WEATHER CONTROL JOINT (DETAIL 6/S3.01) W/E COMMENTS	6"/4 = 1.25" Fig. 3.2.5.3.a—Types of construction joints TYPES OF CONTROL JOINT ACI 302R.1-96 FIGURE 3.2.5.3.a	NOTE THAT THERE IS NO CRACK BELOW CONTROL JOINT. THIS INDICATES SAW CUTS WERE MADE TOO LATE TYPICAL CONTROL JOINT (PHOTOGRAPH TAKEN AT WEST END OF SLAB CUT #2) CONTROL JOINT DEPTH 1" TO 1 1/4" SLAB THICKNESS 4" TO 7 1/2" TYPICAL SLAB SECTION (PHOTOGRAPH TAKEN AT SOUTH END OF SLAB CUT #2) REINFORCEMENT COVER 1" TO 6" FROM TOP OF SLAB VAPOR RETARDER DIRECTLY BELOW CONCRETE FILLER MATERIAL 1/8" 1"-1 1/4" 4"-7 1/2" REBAR FOUND TO BE CONTINUOUS ACROSS CONTROL JOINT, NO DOWELS 6-MIL POLY BASE (NO GRANULAR FILL) CONTROL JOINT NO CUT OR DISCONTINUOUS REINFORCING BARS REINFORCING AT SLAB CUT #2 (APPROX GRID C, 2.2)

Case Study – Design and Construction Deficiencies

Isolation Joint		
As Detailed	Industry Standard	As-Built
NOT AN ISOLATION JOINT SLAB ON GRADE CONTROL JOINT AROUND STEEL COLUMN SCALE: NTS Drawing taken from original structural drawings dated 3-19-02 JOINT AROUND COLUMN (DETAIL 6/S3.01) DOWELS THRU JOINT AND INTO PIER CAP PREVENT FREEDOM OF SLAB-ON-GRADE MOVEMENT WJE COMMENTS	ISOLATION JOINT ACI 302.1R-96 FIGURE 3.2.5.1.a ISOLATION JOINT ACI 302.1R-96 FIGURE 3.2.5.1.b	DOUBLE COLUMN AT BUILDING EXPANSION JOINT ABSENCE OF ISOLATION JOINT BETWEEN COLUMN DIAMOND SHAPE BLOCK-OUT AND SLAB-ON-GRADE BLOCK-OUT CORNER DOES NOT ALIGN WITH MAIN FLOOR JOINT NOT AN EXPANSION JOINT (SEE FIG. D-4) DIAMOND SHAPE JOINT AT DOUBLE COLUMN BUILDING STRUCTURE EXPANSION JOINT

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Case Study – Design and Construction Deficiencies

Expansion Joints

As Detailed	Industry Standard	As-Built
NO DETAIL PROVIDED IN CONSTRUCTION DRAWINGS		NOTE THAT THERE IS NO CRACK BELOW CONTROL JOINT. THIS INDICATES SAW CUTS WERE MADE TOO LATE TYPICAL SLAB SECTION (PHOTOGRAPH TAKEN AT SOUTH END OF SLAB CUT #1) VAPOR RETARDER DIRECTLY BELOW CONCRETE NO CUT OR DISCONTINUOUS REINFORCING BARS

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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*

Conclusion

Why do we test?

“Ask the Structure”...

Jack Janney

...but ask the right questions

Questions?

Contact: Al Bustamante - abustamante@wje.com

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