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GETTING THE MOST OUT OF NON-DESTRUCTIVE TESTING

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WHAT IS NON-DESTRUCTIVE TESTING

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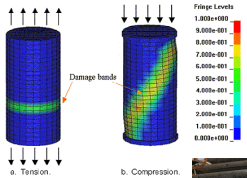
DEFINITION: NON-DESTRUCTIVE

- Nondestructive evaluation (NDE) of materials is, by definition, the science of identifying the physical and mechanical properties of a piece of material without altering its end-use capabilities.
- Such evaluations rely upon nondestructive testing (NDT) techniques or tools to provide accurate information pertaining to the properties and performance of the material in question.
- NDE vs. NDT

DEFINITION: NON-DESTRUCTIVE

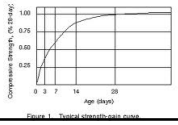
- Who defines is a Non-Destructive Test?
  - ACI Definition – "Any test performed that causes no structurally significant damage to the concrete."
    - How significant is "significant damage"
  - The definition and significance lies with the interested parties:
    - Owner, Manufacturer, Engineer, Testing Agency, etc.
  - NDT for Compressive Strength vs. NDT for Structural Evaluation

COMPRESSIVE STENGTH AND NDT



COMPRESSIVE STRENGTH AND NDT

- Surface Hardness – Rebound Hammer
- Penetration Resistance – Windsor Probe
- Maturity Method
- Ultrasonic Pulse Velocity
- Combined Methods
- Other – Pullout, Break-Off, Resonant Frequency



SUMMARY OF NDT METHODS

The "Paintbrushes" of the Trade

Visual Inspection	Backscatter Radiometry	Penetration Resistance
Ultrasonic Pulse Velocity	Gamma-Gamma Logging	Maturity
Ultrasonic Echo	Half-Cell Potential	Resonant Frequency
Polarization	Ultrasonic Inspection	Wave Propagation
Sonic Echo	Fluid Penetrability	Acoustic Emission
Impulse Response	Liquid Penetrant	Modulus of Elasticity
Impedance Logging	Magnetic Particle	Load Testing
Cross-hole Sonic Logging	Positive Material Identification	Vibration Monitoring
Infrared Thermography	Static Testing	Covermeter
Radar	Dynamic Testing	Surface Hardness
Parallel Seismic Testing	Microscopic Evaluation	Radiography

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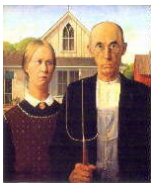
WHICH PICTURE DO I WANT TO PAINT?



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PERFORMING A NDT INVESTIGATION

- Understanding the Technology
- Understanding the components and design of the structure
- Site Logistics
  - Access
  - Environment
- Timeline
- SAFETY!

PERFORMING A NDT INVESTIGATION

- Correlation with Intrusive Testing
  - NDT in its best form is still "indirect information about the present conditions of a test subject."
  - Physical Testing to satisfy our analytical minds or make direct correlations to NDT results.
- Supplemental Testing
  - (ACI 228.2R-55)
    - Assess the conditions at selected points when the NDT results are inconclusive
    - Provide Samples for additional testing to supplement the NDT investigation
    - Refine correlation between NDT results and actual conditions

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PRESENTING A NDT INVESTIGATION

- Report, Presentation, and Expectations
- "The greatest challenge for an NDT evaluation is to select a data-presentation format that will be understood by those that have to make decisions based on the results of the investigation"

NDT & STRUCTURES EVALUATION AT BRAUN INTERTEC

- Servicing clients across the Midwest, Texas, Greater U.S. and International
- Support from CMT, NDT, Petrography, and Chemistry Laboratories
- Mobile Equipment and Capabilities

SO…… I HAVE THIS PROBLEM?

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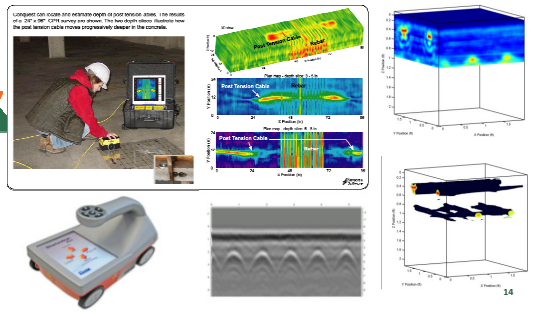
GROUND PENETRATING RADAR (GPR)



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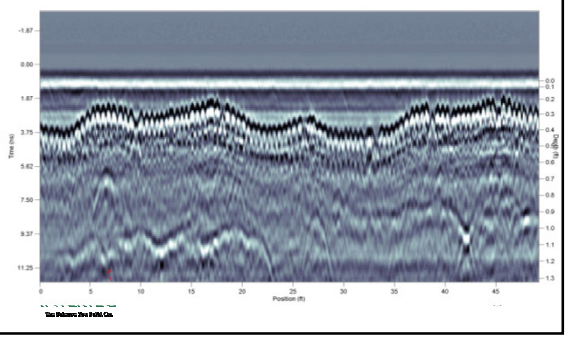
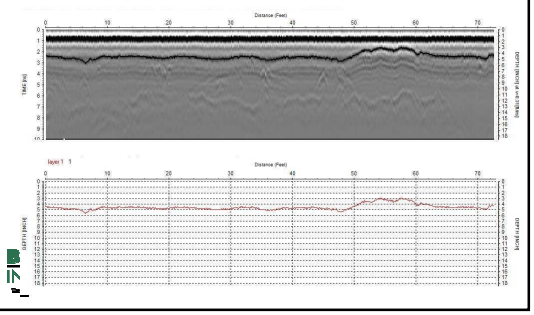
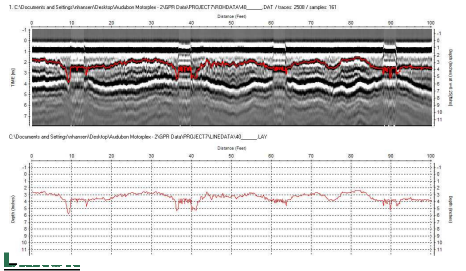
REINFORCING VERIFICATION



GPR – CONCRETE THICKNESS



CASE STUDY – CONCRETE THICKNESS



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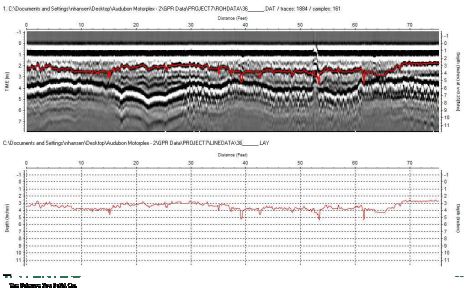
CASE STUDY – CONCRETE THICKNESS



CASE STUDY – CONCRETE THICKNESS

Line #	Location/Room #	Direction	Length of Line (ft)	Maximum Thickness (in)	Minimum Thickness (in)	Average Thickness (in)	Total Points Evaluated	% Of Data Points Less than 4 Inch Thickness
0	1139	N-S	16.01	4.64	3.04	3.77	400.00	64.00%
1	1139	W-E	37.24	4.98	3.32	4.34	681.00	25.14%
2	1139	W-E	42.28	5.54	3.69	4.62	1057.00	4.82%
3	1139	N-S	39.99	4.98	4.12	4.60	874.00	8.02%
4	1139	N-S	37.32	6.27	3.51	4.70	683.00	14.20%
5	1139	N-S	32.84	5.17	3.51	4.61	771.00	4.28%
6	1127	E-W	44.80	5.72	3.32	4.68	1103.00	10.24%
7	1131	E-W	45.96	6.46	4.06	4.77	1149.00	8.02%
8	2202 - Hallway	W-E	23.20	5.72	4.25	4.85	579.00	8.02%
9	F Wing Hallway	W-E	45.00	7.57	3.69	4.62	1123.00	12.29%
10	3026	W-E	27.92	5.35	3.51	4.35	695.00	13.47%
11	3027	W-E	29.00	4.98	3.51	4.35	720.00	16.09%
12	3027	N-S	25.30	4.98	3.69	4.30	629.00	11.67%
13	1139	N-S	54.44	5.72	3.51	4.61	1359.00	4.86%
14	MPR Room	E-W	42.64	6.46	3.51	4.46	1064.00	7.89%
15	Men's Locker Room	E-W	72.93	6.72	2.95	4.53	1814.00	13.79%
16	Men's Locker Room	N-S	30.48	4.80	2.95	3.72	760.00	73.16%
17	1134 - Auto Shop	S-N	26.55	4.98	3.51	4.34	662.00	19.79%
18	1134 - Auto Shop	W-E	53.03	7.38	3.32	4.14	1316.00	35.85%
19	1134 - Auto Shop	W-E	51.24	5.91	3.14	4.22	1030.00	29.41%

Line Statistics

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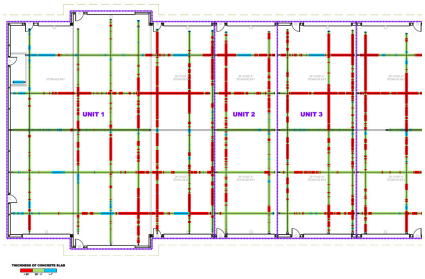
CASE STUDY – CONCRETE THICKNESS



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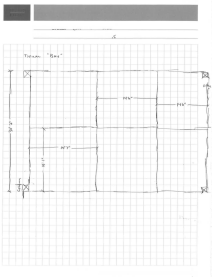
NEW SLAB DISTRESS



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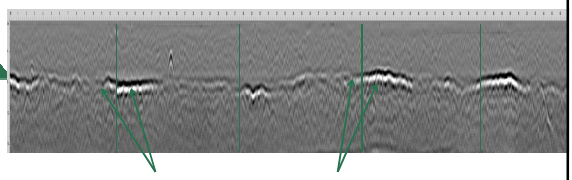
NEW SLAB DISTRESS

NEW SLAB DISTRESS

SLAB JOINTS



VOIDS ON EITHER SIDE OF JOINT

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RADIOGRAPHY

- Concrete Imaging – Broken PT Cable

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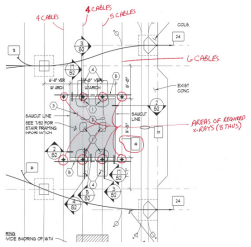
RADIOGRAPHY

- Concrete Imaging – Broken PT Cable



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RADIOGRAPHY

- Concrete Imaging – Broken PT Cable

RADIOGRAPHY

- Concrete Imaging – Finding the Details

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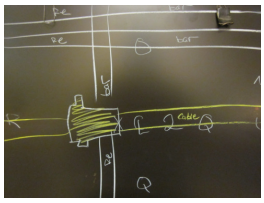
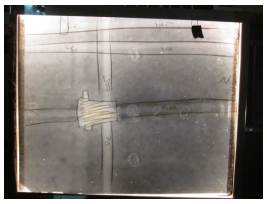
RADIOGRAPHY

- Concrete Imaging – Finding the Details





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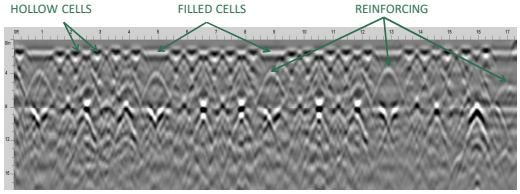
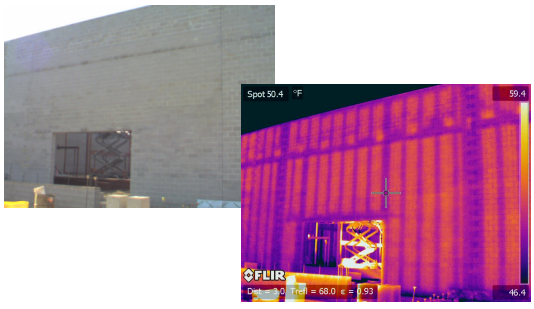
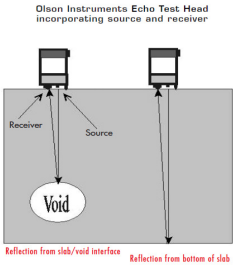
MISSED SPECIAL INSPECTION - MASONRY



MISSED SPECIAL INSPECTION - MASONRY

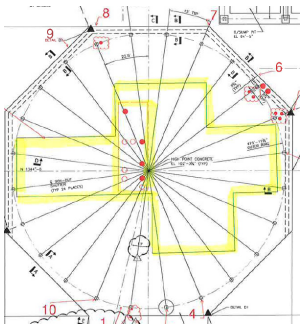


- ASTM C1383 “Standard Test Method for Measuring Plates Using The Impact-Echo Method”
- Impactor, Transducers
- Baseline
  - Initial Arrival
  - Wave form
  - Frequency Spectrum (FFT)
- Collection Patterns



Only Access to One Side

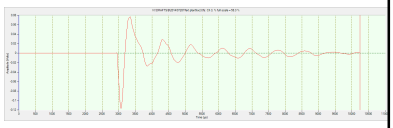
- 4 foot thick footing
- Yes there are voids
- How much?



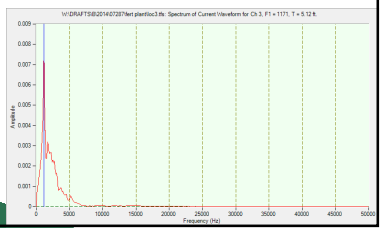
Already Discovered Voids

Wave analysis

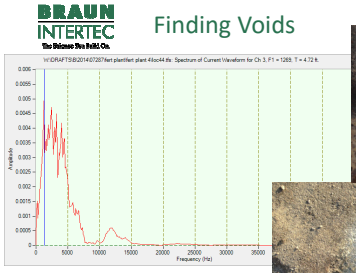
- Wave



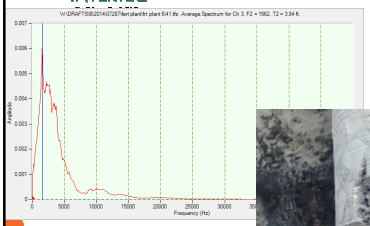
- Spectrum



Finding Voids



A little Different



Summary

- Found additional void and consolidation issues
- Were able to return and retest after repairs were complete.

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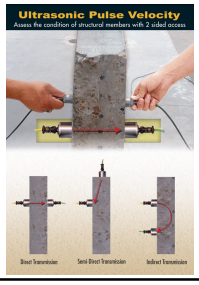
Impact Echo - Condition Evaluation

ULTRASONIC PULSE VELOCITY (UPV)

- ASTM C597 "Standard Test Method for Pulse Velocity Through Concrete
- Speaker, microphone
- Baseline
  - Initial Arrival
  - Wave form
  - Frequency Spectrum (FFT)
- Collection Patterns

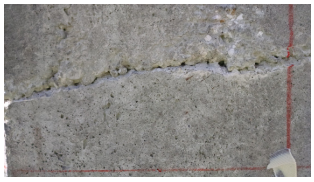


ULTRASONIC PULSE VELOCITY (UPV)

- 4 Columns
- 6 feet x 7feet x 36 feet
- 8 feet Max Hydrostatic Head
- Self Consolidating Concrete
- Delayed 22 inch lifts

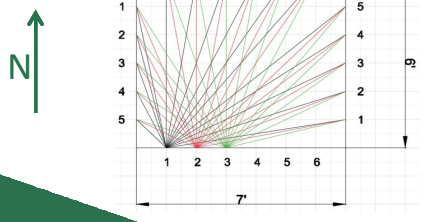
Background

- Surface Unconsolidation
- Cold Joints???



Collection Patterns

- Method 1 (Baseline) – 192 paths through plane



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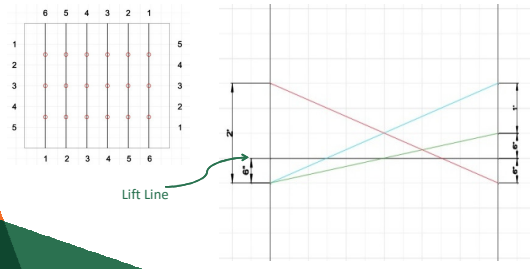
Collection Patterns

- Method 2 – 18 paths through plane



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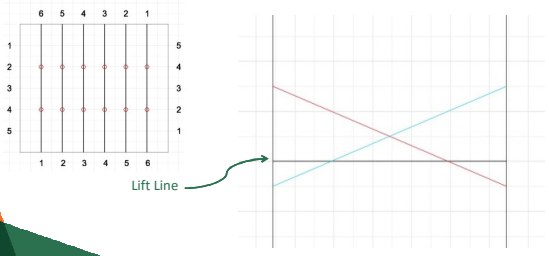
Collection Patterns

- Method 3 – 12 paths through plane



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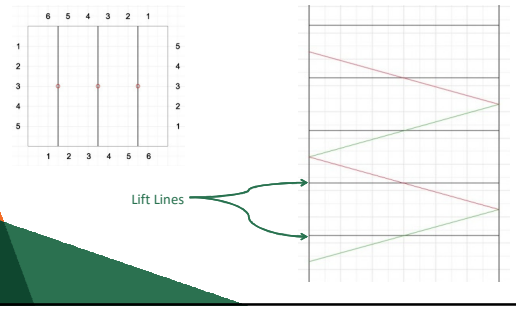
Collection Patterns

- Method 4 – 3 paths through plane



NDT – Data Analysis

- Good UPV Signal

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NDT – Data Analysis

- Bad UPV Signal

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NDT – Data Analysis

Folder	File	y(ft)	x(ft)	Path z(ft)	Amplitude (in/s)	Arrival Time (µs)	Velocity (ft/s)	Velocity (m/s)	Outside Range (3500 M/s - 5500 m/s)	Comment

Path = (x^2+y^2+1)^0.5

Velocity= Path/Arrival Time

PULSE VELOCITY	CONCRETE QUALITY
>4.0 km/s	Very good to excellent
3.5 – 4.0 km/s	Good to very good, slight porosity may exist
3.0 – 3.5 km/s	Satisfactory but loss of integrity is suspected
<3.0 km/s	Poor and los of integrity exist.

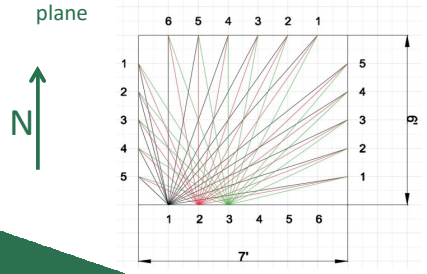
http://theconstructor.org/concrete/ultrasonic-pulse-velocity-upv-test/2847/

NDT – Data Analysis

Folder	File	y(ft)	x(ft)	Path z(ft)	Amplitude (in/s)	Arrival Time (µs)	Velocity (ft/s)	Velocity (m/s)	Outside Range (3500 M/s - 5500 m/s)	Comment
Column 1, Elevation: 5 Feet Above Slab, (Method 1) North and West Face										
1n5	1n51	6	1	6.16	0.005	458	13459	4102		
1n5	2	6	2	6.40	0.009	462	13860	4224		
1n5	3	6	3	6.78	0.004	491	13813	4210		
1n5	4	6	4	7.28	0.005	519	14027	4276		
1n5	5	6	5	7.87	0.013	538	14636	4461		
1n5	6	5	1	5.20	0.009	472	11009	3356	-144	Coupling issue
1n5	7	5	2	5.48	0.005	451	12145	3702		
1n5	8	5	3	5.92	0.006	407	14536	4431		
1n5	9	5	4	6.48	0.009	435	14898	4541		
1n5	10	5	5	7.14	0.009	496	14398	4389		
1n5	11	4	1	4.24	0.025	298	14237	4340		
1n5	12	4	2	4.58	0.007	325	14100	4298		
1n5	13	4	3	5.10	0.015	315	16187	4934		
1n5	14	4	4	5.74	0.004	399	14397	4388		
1n5	15	4	5	6.48	0.006	451	14370	4380		
1n5	16	3	1	3.32	0.03	236	14053	4284		
1n5	17	3	2	3.74	0.015	264	14173	4320		
1n5	18	3	3	4.36	0.008	303	14386	4385		
1n5	19	3	4	5.10	0.009	356	14323	4366		
1n5	20	3	5	5.92	0.002	406	14572	4441		
1n5	21	2	1	2.45	0.015	174	14078	4291		
1n5	22	2	2	3.00	0.013	220	13636	4156		
1n5	23	2	3	3.74	0.02	261	14336	4370		
1n5	24	2	4	4.58	0.01	325	14100	4298		
1n5	25	2	5	5.48	0.006	402	13625	4153		
1n5	26	1	1	1.73	0.05	125	13856	4223		
1n5	27	1	2	2.45	0.06	122	20078	6120	620	
1n5	28	1	3	3.32	0.03	230	14420	4395		
1n5	29	1	4	4.24	0.013	367	11560	3524		
1n5	30	1	5	5.20	0.008	390	13323	4061		

Collection Patterns

- Method 1 (Baseline) – 192 paths through plane



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NDT – Data Analysis

Folder	File	y(ft)	x(ft)	Path z(ft)	Amplitude (in/s)	Arrival Time (µs)	Velocity (ft/s)	Velocity (m/s)	Outside Range (3500 M/s - 5500 m/s)	Comment
Column 1, Elevation: 5 Feet Above Slab, (Method 1) North and West Face										
1n5	1n51	6	1	6.16	0.005	458	13459	4102		
1n5	2	6	2	6.40	0.009	462	13860	4224		
1n5	3	6	3	6.78	0.004	491	13813	4210		
1n5	4	6	4	7.28	0.005	519	14027	4276		
1n5	5	6	5	7.87	0.013	538	14636	4461		
1n5	6	5	1	5.20	0.009	472	11009	3356	-144	Coupling issue
1n5	7	5	2	5.48	0.005	451	12145	3702		
1n5	8	5	3	5.92	0.006	407	14536	4431		
1n5	9	5	4	6.48	0.009	435	14898	4541		
1n5	10	5	5	7.14	0.009	496	14398	4389		
1n5	11	4	1	4.24	0.025	298	14237	4340		
1n5	12	4	2	4.58	0.007	325	14100	4298		
1n5	13	4	3	5.10	0.015	315	16187	4934		
1n5	14	4	4	5.74	0.004	399	14397	4388		
1n5	15	4	5	6.48	0.006	451	14370	4380		
1n5	16	3	1	3.32	0.03	236	14053	4284		
1n5	17	3	2	3.74	0.015	264	14173	4320		
1n5	18	3	3	4.36	0.008	303	14386	4385		
1n5	19	3	4	5.10	0.009	356	14323	4366		
1n5	20	3	5	5.92	0.002	406	14572	4441		
1n5	21	2	1	2.45	0.015	174	14078	4291		
1n5	22	2	2	3.00	0.013	220	13636	4156		
1n5	23	2	3	3.74	0.02	261	14336	4370		
1n5	24	2	4	4.58	0.01	325	14100	4298		
1n5	25	2	5	5.48	0.006	402	13625	4153		
1n5	26	1	1	1.73	0.05	125	13856	4223		
1n5	27	1	2	2.45	0.06	122	20078	6120	620	Travel Along Steel
1n5	28	1	3	3.32	0.03	230	14420	4395		
1n5	29	1	4	4.24	0.013	367	11560	3524		
1n5	30	1	5	5.20	0.008	390	13323	4061		

Correlation of results

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NDT – Data Analysis

- 1152 Data points
- Data and cores revealed poor consolidation was limited to cover of rebar cage.
- The results indicated well consolidated concrete

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Coarse Crusher Concerns

- Crusher to be replaced August 2015
- Concerns of fatigue damage
- Visual distress on 2 of 4 columns

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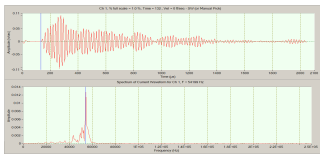
Approach

- Non-Destructive Testing (UPV)
- Core samples
- Petrography

55

Ultrasonic Pulse Velocity

- Compression wave
- ~55000 Hz
- Pulse Velocity

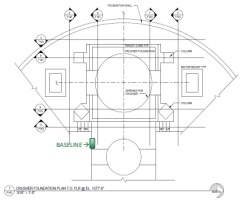


$$\frac{L}{t} = \frac{0.508\ m}{132\ \mu sec} = 3848\ m/sec$$

56

Baseline

- Selected in an area assumed to receive a lower level of vibrations
- Wingwall on level below crusher
- 15 data points collected
- Average = 3786 m/sec



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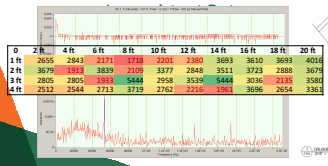
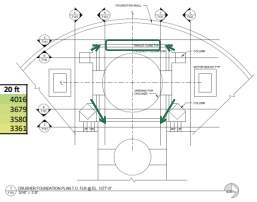
Crusher Pad

- East Face
  - Limiting Geometry
  - Frequency Domain
- West Face



	0	2 ft	4 ft	6 ft	8 ft	10 ft	12 ft	14 ft	16 ft	18 ft	20 ft
1 ft		2655	2843	2171	1718	2201	2380	3693	3610	3693	4016
2 ft		3679	1913	3839	2109	3377	2848	3511	3723	2888	3679
3 ft		2805	2805	1933	5444	2958	3535	5444	3036	2135	3580
4 ft		2512	2544	2713	3719	2762	2216	1961	3696	2654	3361



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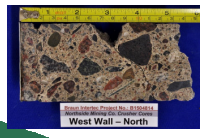
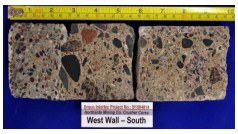
Crusher Pad Core Samples

- Large-scale cracking
- Limited microcracking
- Repair material





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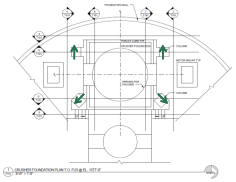
Columns

- West Columns vs. East Columns Visually
- East Columns
  - Pattern observed near rebar cage
- West Columns
  - No Signal
  - Inconsistent Signal



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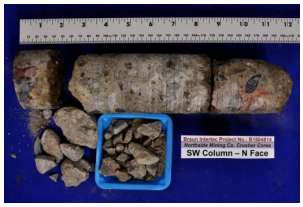
Southwest Column Core Sample

- Surface-parallel cracking



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Conclusions

- Cracking occurring near rebar cage
- No significant microcracking
- Damage on the west columns extends beyond the surface

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REINFORCING CORROSION

63

REINFORCING CORROSION

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REINFORCING CORROSION

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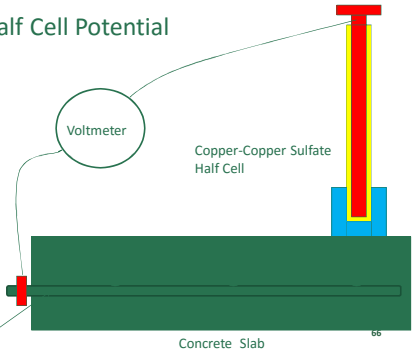
REINFORCING CORROSION

- Half Cell Potential



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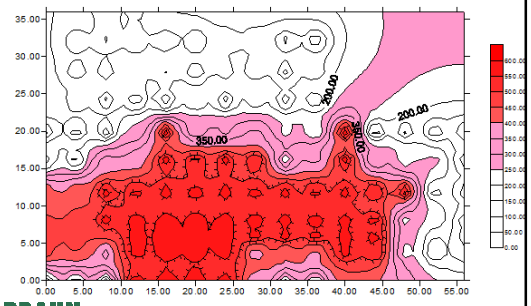
REINFORCING CORROSION



BRAUN INTERTEC

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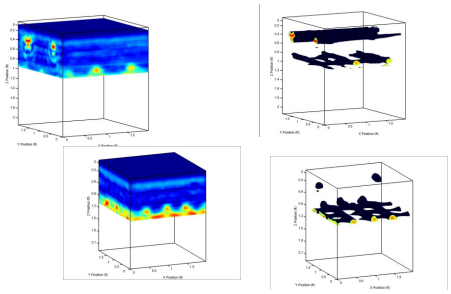
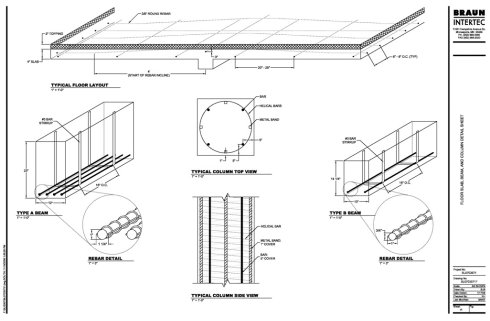
STRUCTURE EVALUATION



BRAUN INTERTEC

68

STRUCTURE EVALUATION

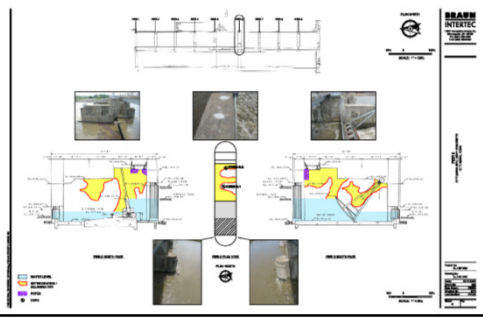


STRUCTURE EVALUATION

70

STRUCTURE EVALUATION

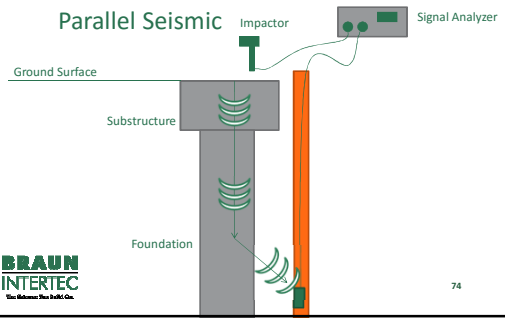
STRUCTURE EVALUATION



FOUNDATION INVESTIGATION

73

FOUNDATION INVESTIGATION



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FOUNDATION INVESTIGATION

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FOUNDATION INVESTIGATION

BRAUN INTERTEC

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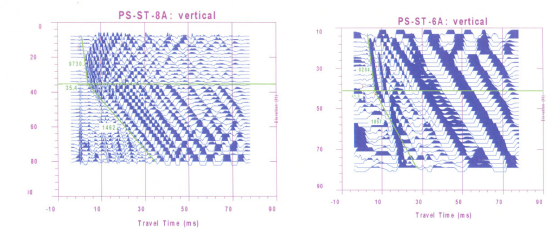
FOUNDATION INVESTIGATION



BRAUN INTERTEC

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LOAD TESTING

BRAUN INTERTEC

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WHEN THE TESTING PLAN CHANGES

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WHEN THE TESTING PLAN CHANGES

80

WHEN THE TESTING PLAN CHANGES

81

WHEN THE TESTING PLAN CHANGES

82

WHEN THE TESTING PLAN FAILS

83

WHEN THE TESTING PLAN FAILS

84

WHEN THE TESTING PLAN FAILS

BRAUN INTERTEC

85

WHEN THE TESTING PLAN FAILS

BRAUN INTERTEC

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QUESTIONS?

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