

WALTER P MOORE

**THE USE OF NDE AND ANALYTICAL TOOLS IN POST-TENSIONING REPAIRS**

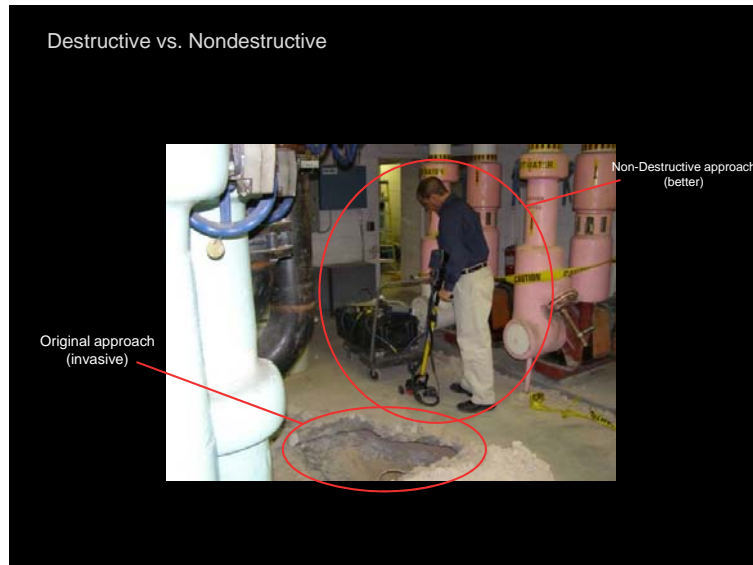
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### What is Nondestructive Evaluation?

Methods for assessing the condition of a structure without causing any structurally significant damage.




- ### When is Nondestructive Evaluation Used?
- Quality control of new construction
  - Condition assessment of structures
    - Rehab
    - Due diligence
    - Change of use
  - Quality control of repairs
  - Identify as-built construction

What are Types of NDE Methods?

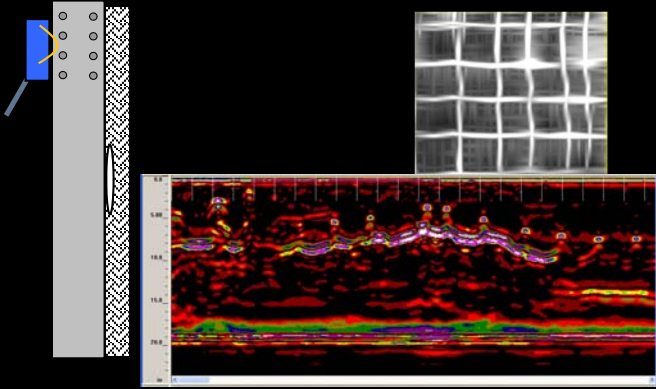
- Visual
- Short pulse radar
- Stress wave
  - Impact-echo
  - Impulse response
  - Ultrasonic pulse velocity
- Electric & Magnetic
  - Half-cell potential
  - Cover meters
- Infrared
  - Thermography

Short Pulse Radar (SPR)

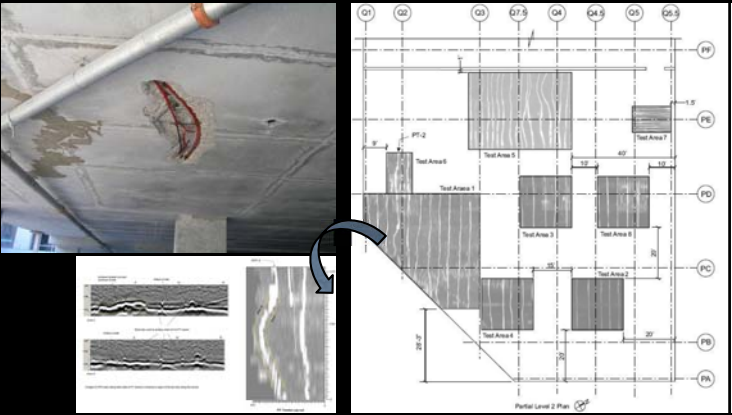
- Commonly known as GPR **\*Powerful Tool\***
- Reflected electromagnetic waves
- Applications
  - As-built conditions
  - Rebar cover and location
  - Voids beneath slabs
  - Post-Tensioned cable profiles
  - Honeycombing
- Limitations
  - Wet soils & freshly placed concrete
  - Cannot detect small discontinuities



SPR Schematic



Ground-penetrating radar



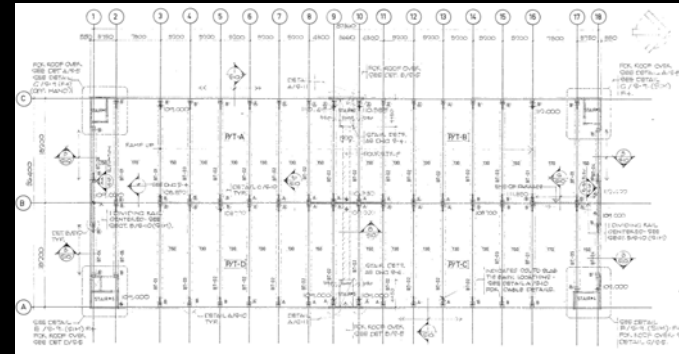
CASE STUDY #1

- A slab deflection of approximately 54 mm at the turning bay and a camber of approximately 22 mm in the adjacent end bay span were observed in the northwest quadrant of the roof level ramp.



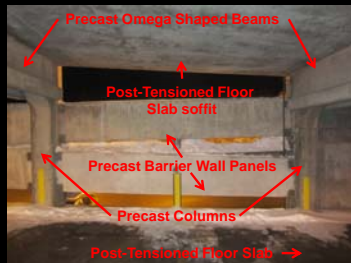
- Assessment of the parking facility which included visual observations, limited destructive and non-destructive testing, and analysis to determine its present condition

Roof Level

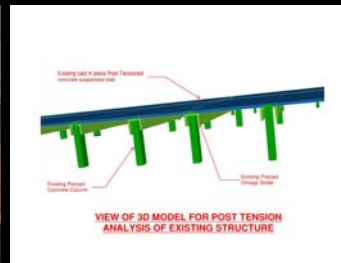


Excerpt of the record structural drawings for the roof level floor framing

Typical Structural Framing

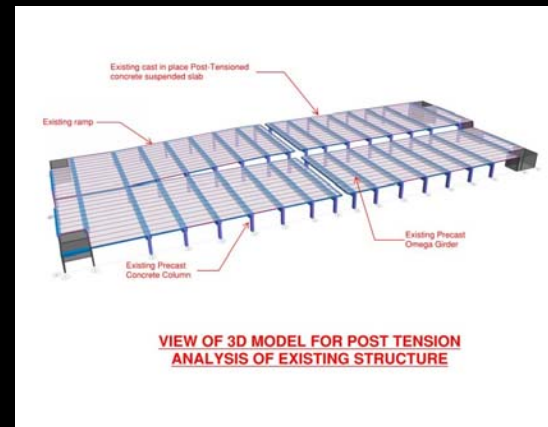


Typical view of structural members



3-D analytical model representation of the facility structural members for the vertical load carrying system.

Roof Level



3-D analytical model representation of the roof level structure

Visual Observation Photographs

→ Exploratory openings of tendons in areas of observed distress (slab cracking, deflections) revealed de-tensioned and loose post-tensioned tendons in addition to the failed tendon observed at the roof level slab soffit.



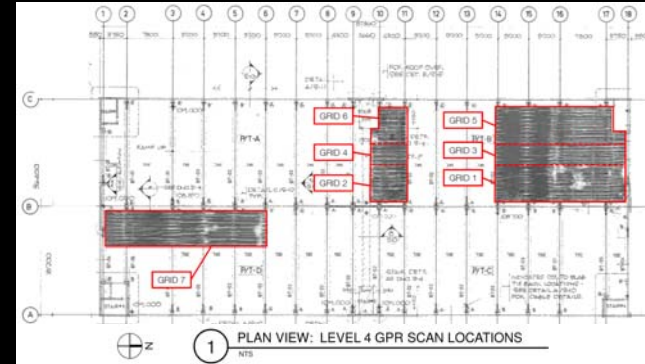
Screw drive penetration test indicating a de-tensioned PT tendon on the ramp at the Roof Level



Screw drive penetration test indicating a de-tensioned PT tendon on the flat portion of the Roof Level

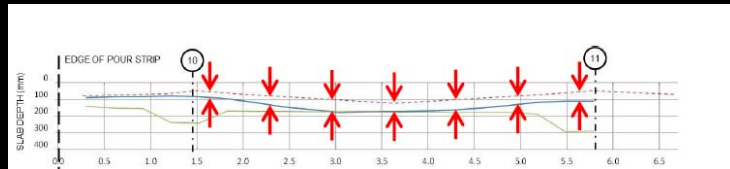
Ground Penetrating Radar Survey

→ A Ground Penetrating Radar (GPR) survey was performed at selected areas of the roof level floor slab to determine the as-built post-tensioning tendon profiles.



Ground Penetrating Radar Survey

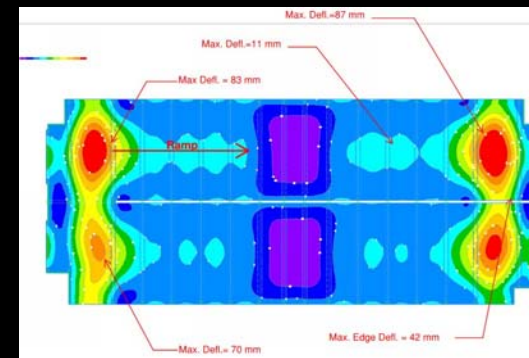
→ Individual vertical tendon profiles were determined for each tendon in the scan areas and were plotted against the design tendon profiles specified in the record drawings.



Structural Analysis

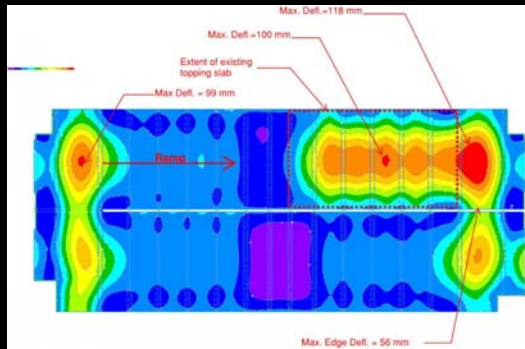
→ A structural analysis was performed based upon three structural configurations and the loading requirements of applicable code

- Case I – Analysis of the original design



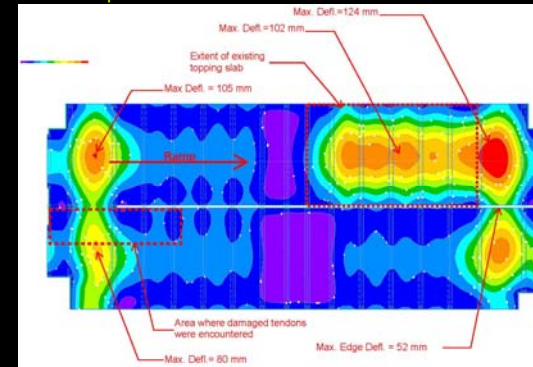
### Structural Analysis

- A structural analysis was performed based upon three structural configurations and the loading requirements of NBC 2005.
- Case II – Analysis of the as-built structure based upon information for tendon profiles obtained from the GPR survey.

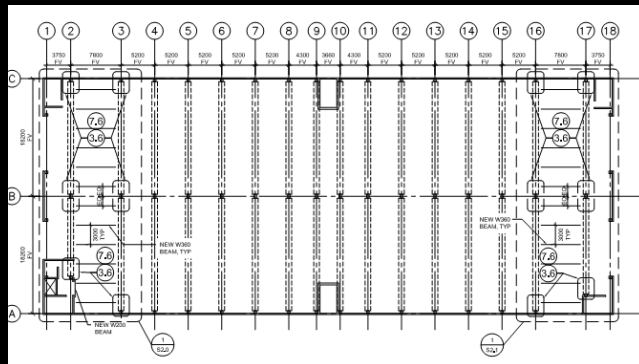


### Structural Analysis

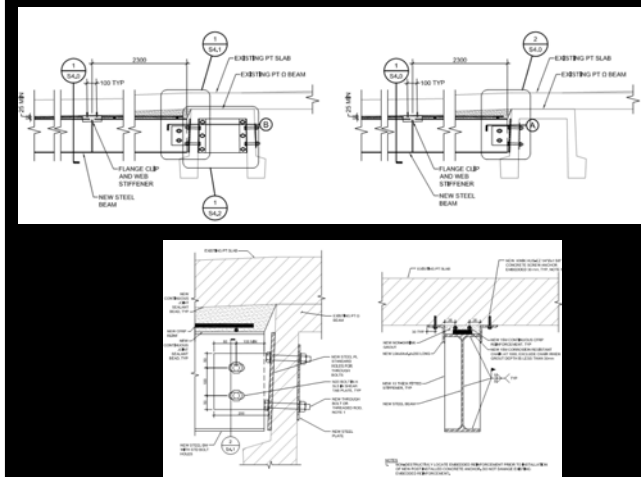
- A structural analysis was performed based upon three structural configurations and the loading requirements of NBC 2005.
- Case III - Analysis of the as-built structure with consideration of the effects of the observed post-tensioned tendon distress.



### Repairs



### Repairs





CASE STUDY #2

### Concrete Parking Garage Repair

#### Description of Structure

- Cast-in-place concrete structure
- Unbonded post-tensioned pan joist framing
- Severe deflections at cantilever ends

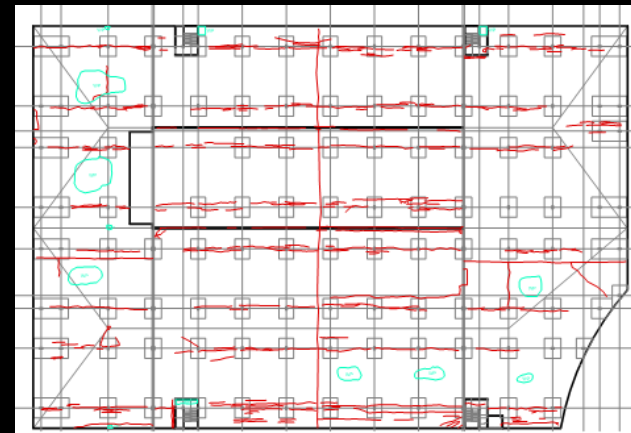
#### Severe Deflections at Cantilever ends

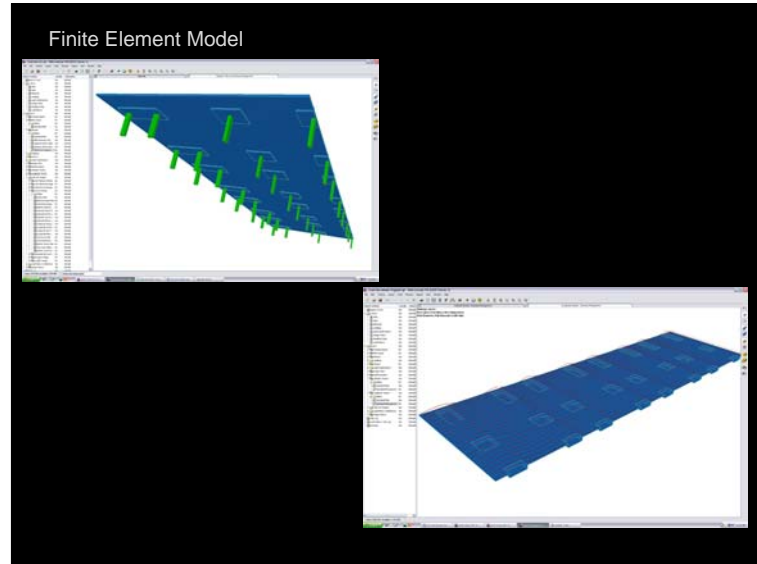
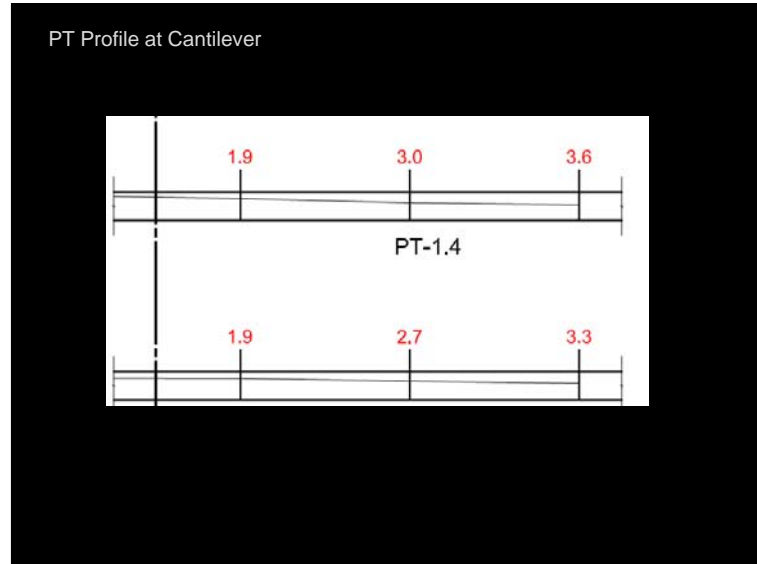
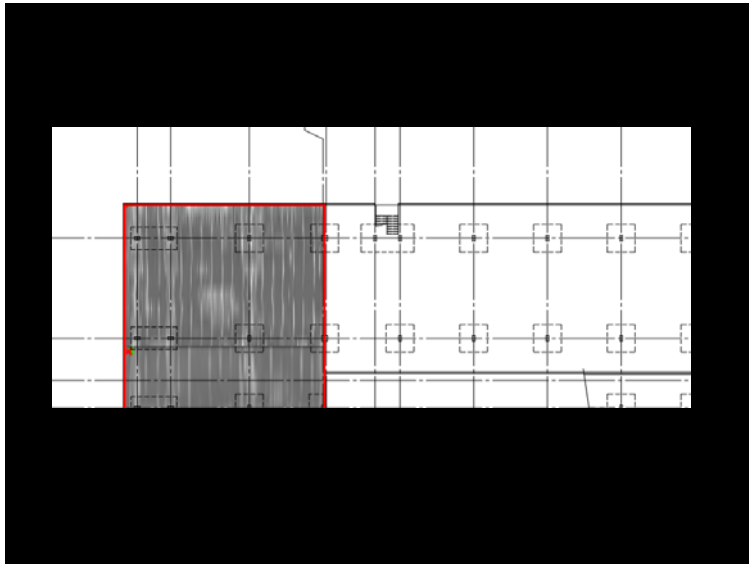


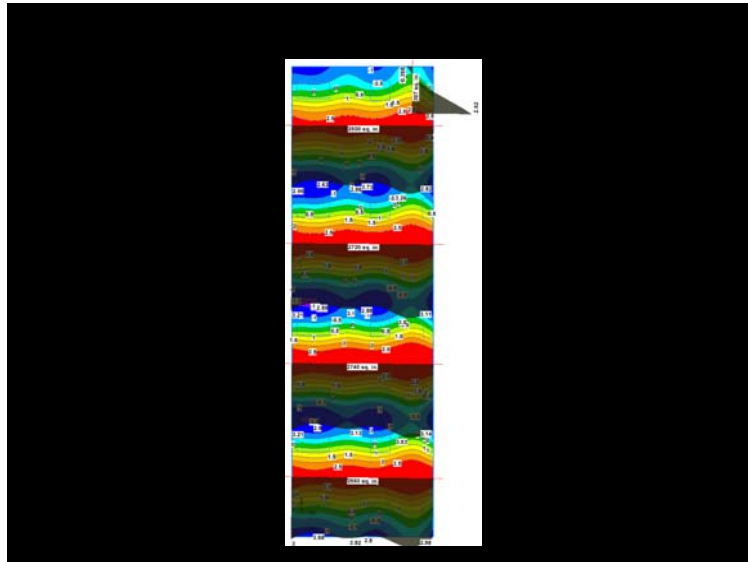
#### Severe Deflections – ponding water and cracking



#### Crack mapping





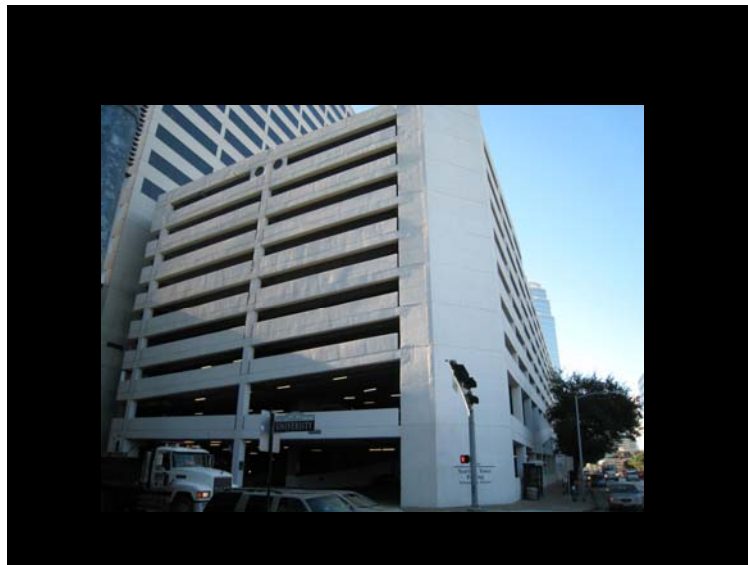


CASE STUDY #3

### Concrete Parking Garage Repair

#### Description of Structure

- Constructed 1978
- Cast-in-place concrete structure
- Unbonded post-tensioned pan joist framing
- **Repairs deferred!**





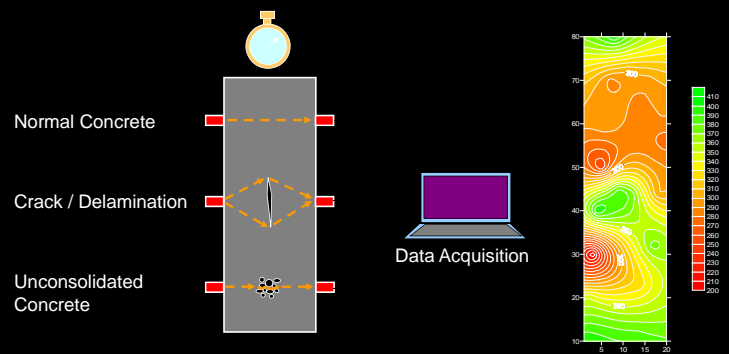
### Observed Distress



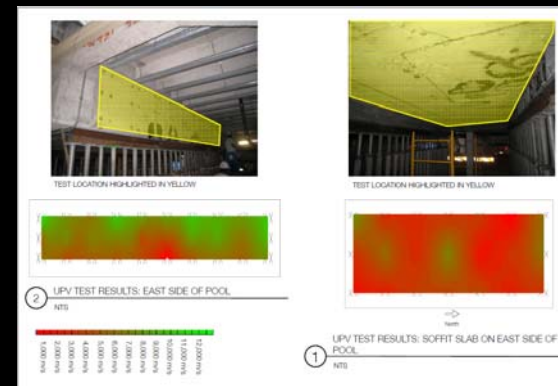
### Ultrasonic Pulse Velocity (UPV)

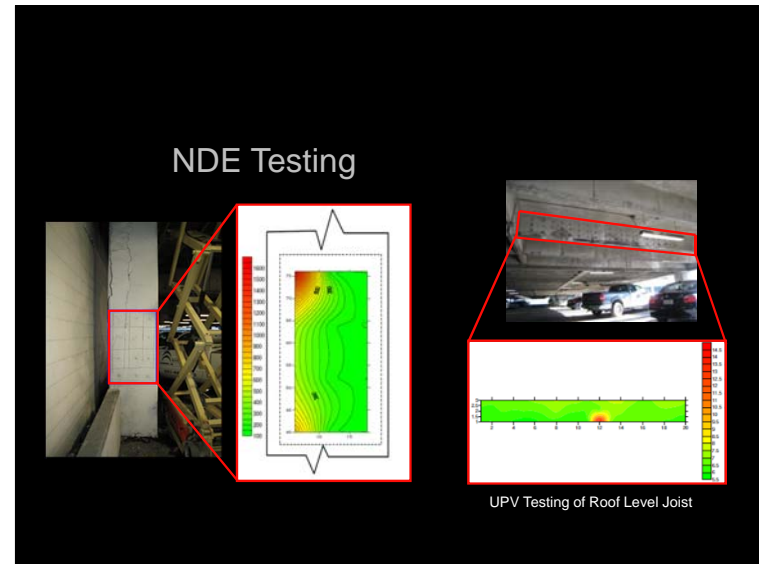
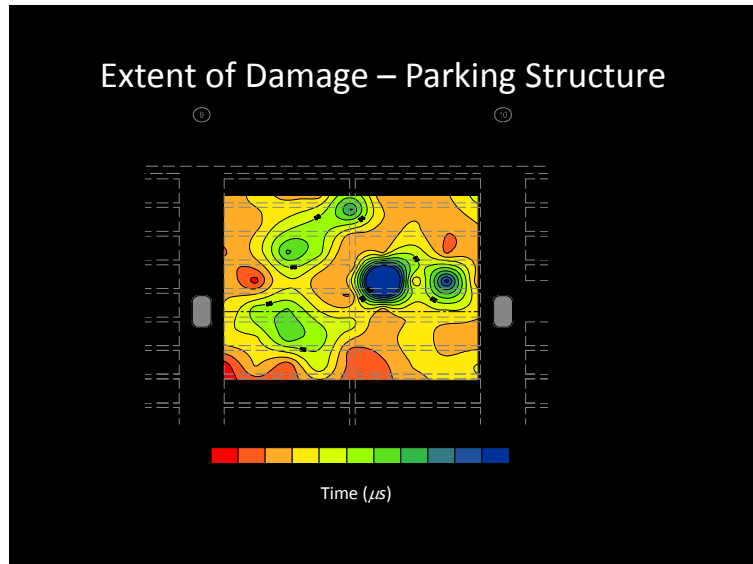
- Wave speed through concrete
- Applications
  - Delaminations
  - Unconsolidated Concrete
  - Concrete material properties
- Limitations
  - Access to both sides
  - Qualitative

### UPV Schematic



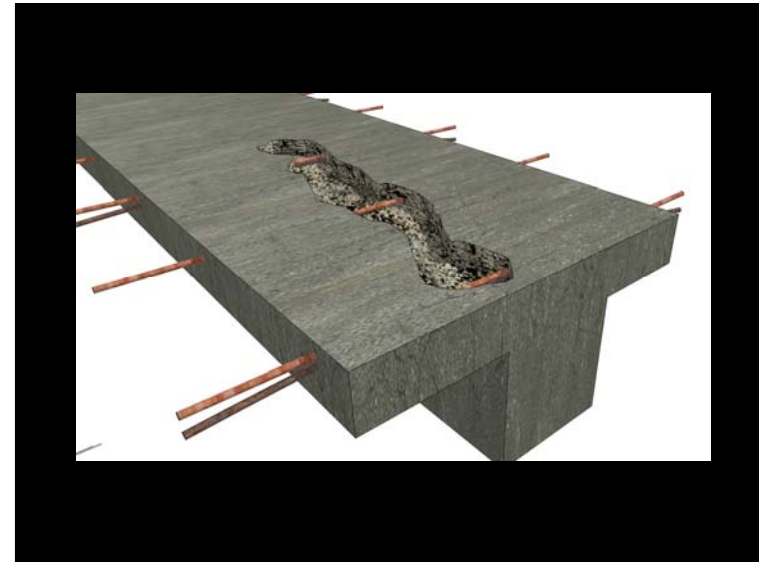
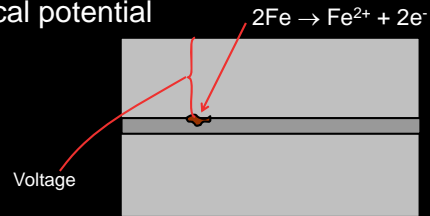
### Suspected Concrete Quality

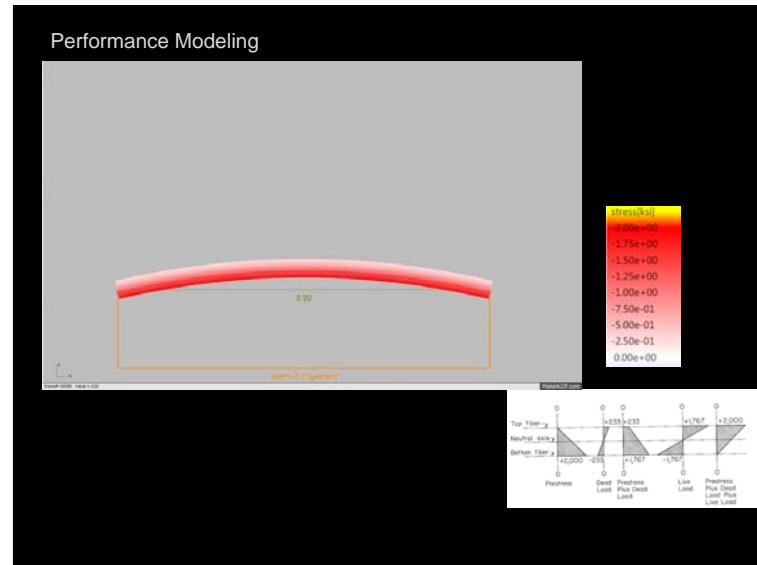
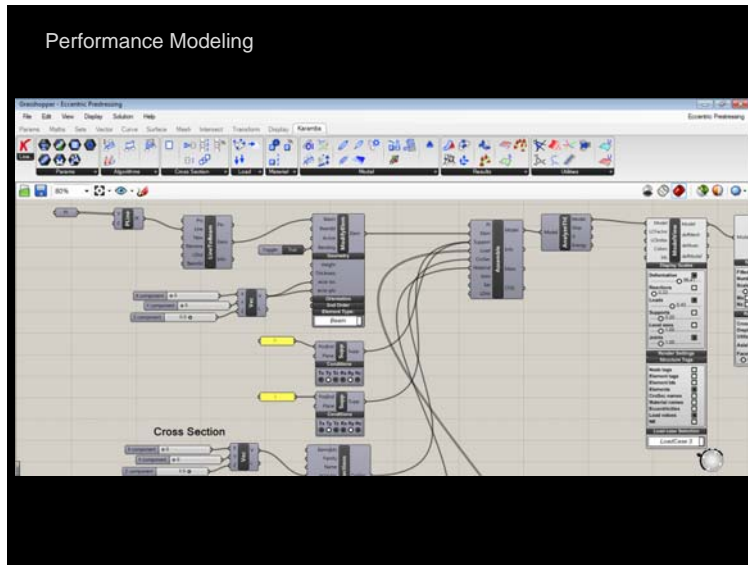
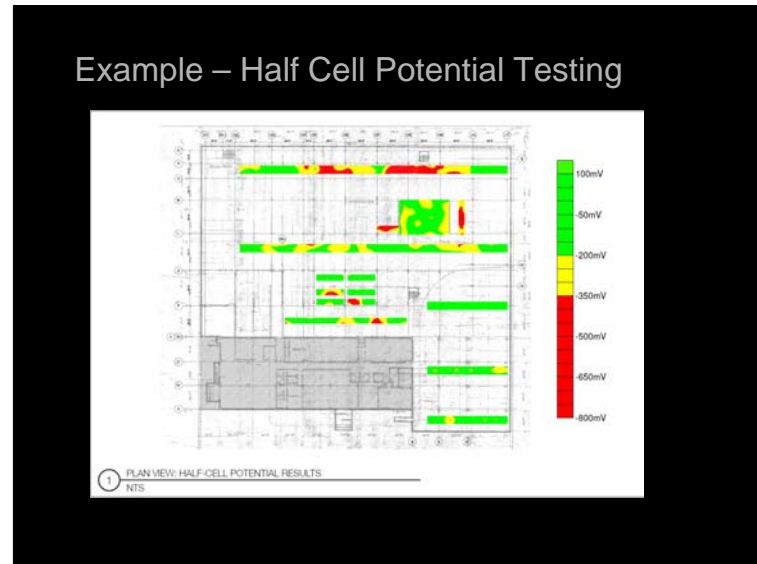
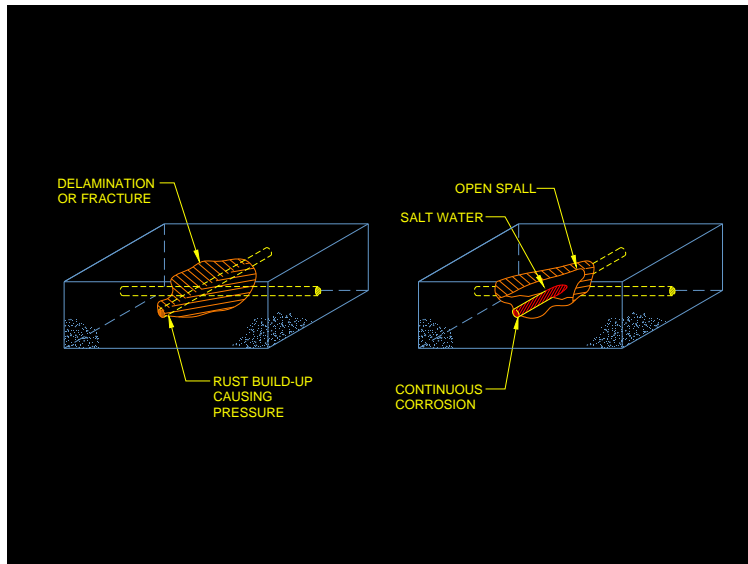




Case Study #4

- Half-Cell
- Electrochemical reaction
- Galvanic corrosion
  - $2\text{Fe} \rightarrow \text{Fe}^{2+} + 2\text{e}^-$
  - $2\text{H}_2\text{O} + \text{O}_2 + 4\text{e}^- \rightarrow 4\text{OH}^-$
- Measure electrical potential





A final thought...

*Better information = Better Decisions*

**Better Solutions**

