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# 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.

# Destructive vs. Nondestructive



# 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?

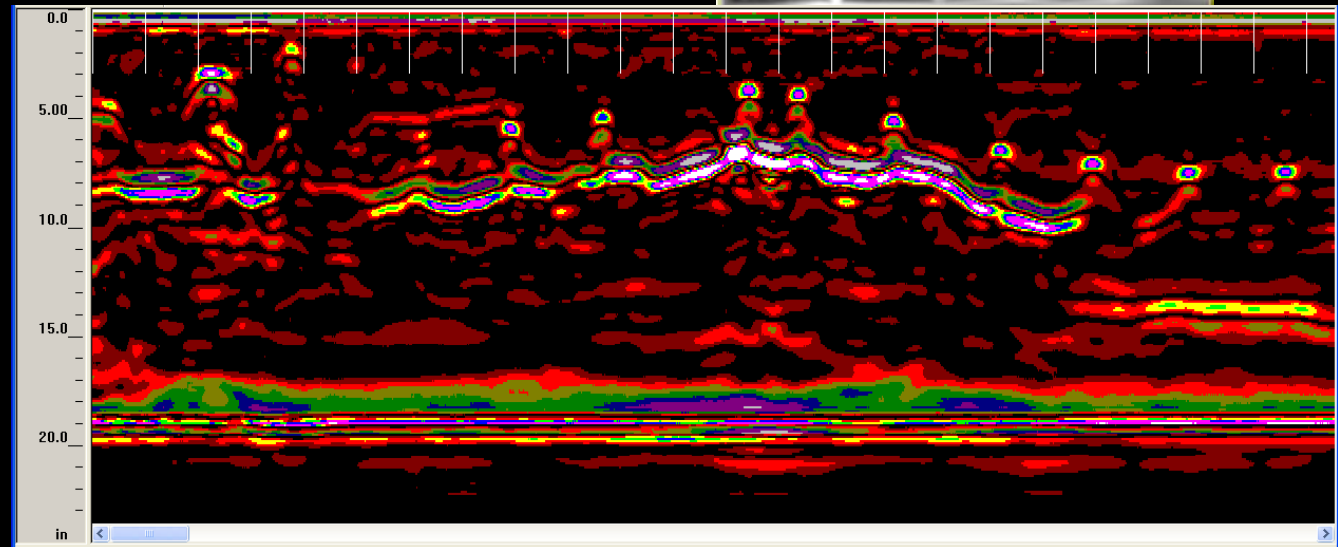
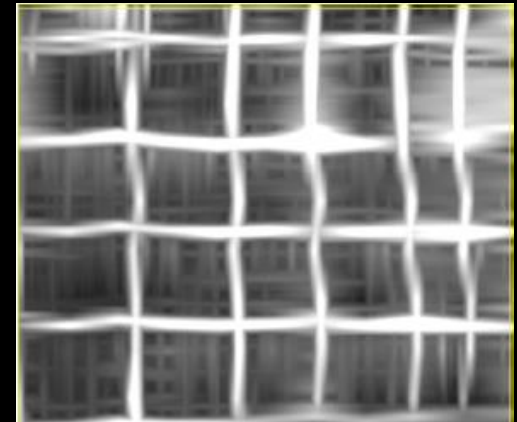
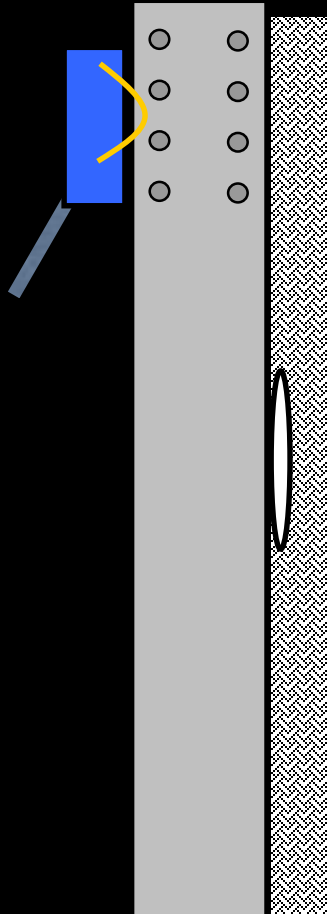
- Visual
- Short pulse radar
- Stress wave
  - Impact-echo
  - Impulse response
  - Ultrasonic pulse velocity
- Electric & Magnetic
  - Half-cell potential
  - Cover meters
- Infrared
  - Thermography

# Short Pulse Radar (SPR)

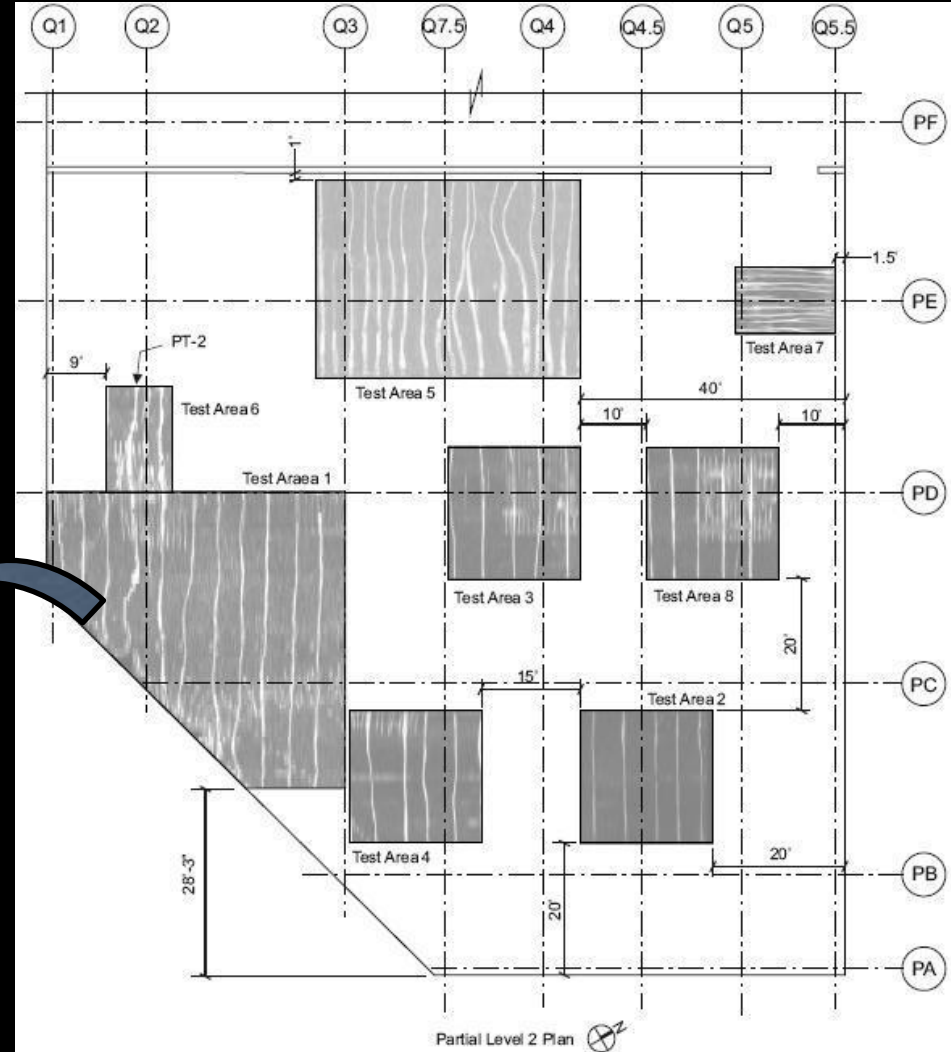
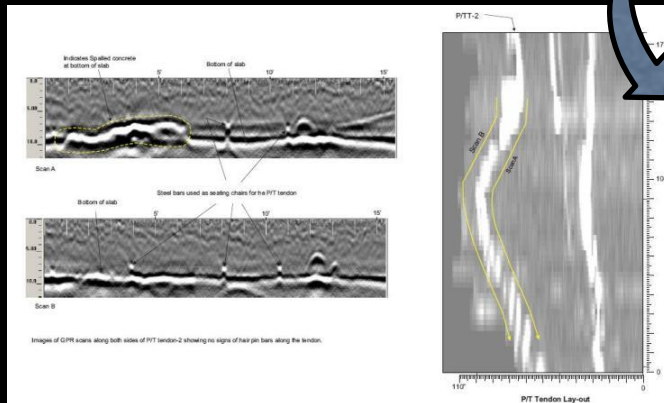
- Commonly known as GPR **\*Powerful Tool\***
- Reflected electromagnetic waves
- Applications
  - As-built conditions
  - Rebar size and location
  - Voids beneath slabs
  - Post-Tensioned cable profiles
  - Honeycombing
- Limitations
  - Wet soils
  - Cannot detect small discontinuities



# SPR Schematic



# Ground-penetrating radar





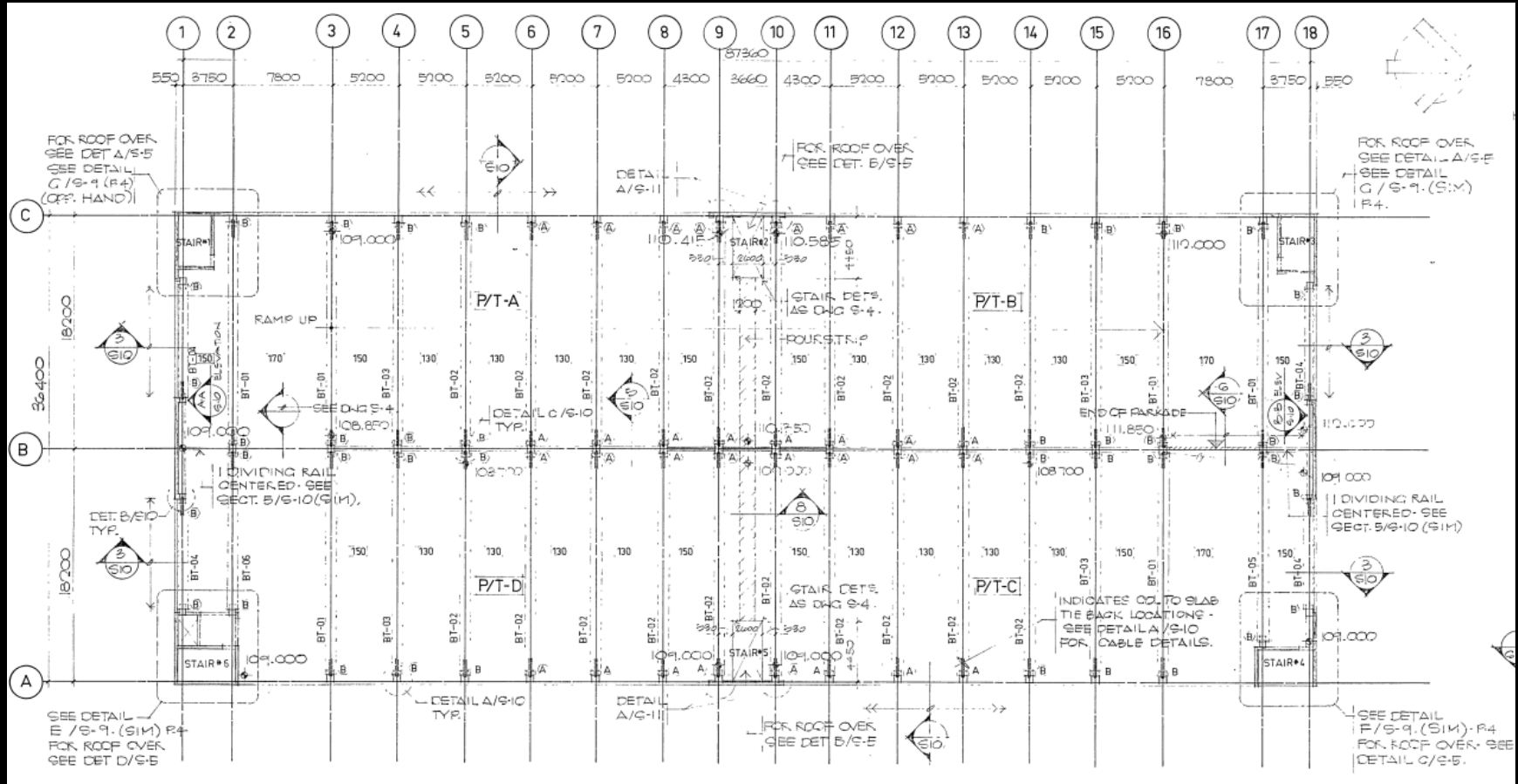
## CASE STUDY #1

- 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.



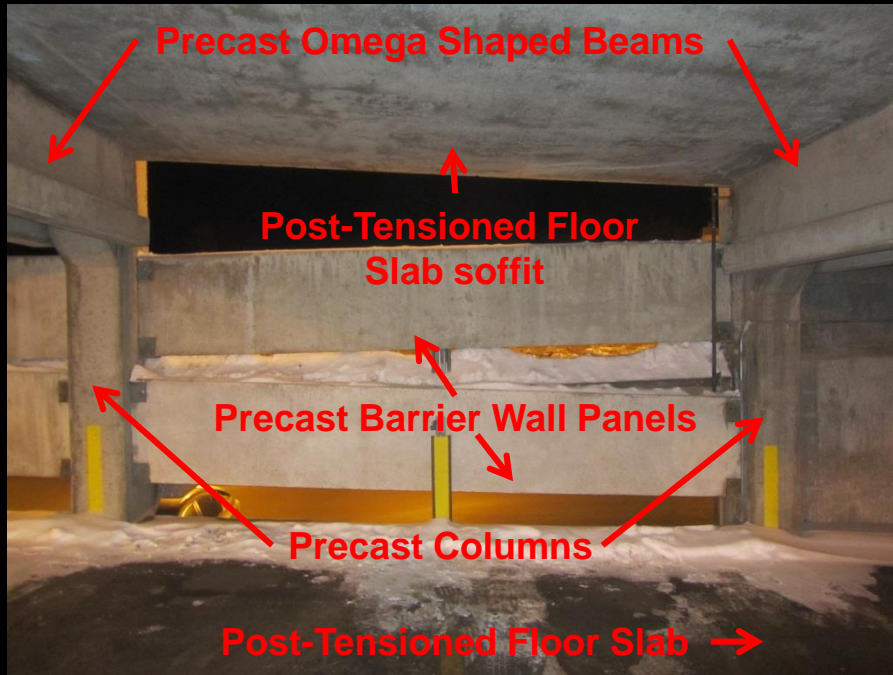
- Assessment of the parking facility which included visual observations, limited destructive and non-destruction testing, and analysis to determine its present condition

# Roof Level

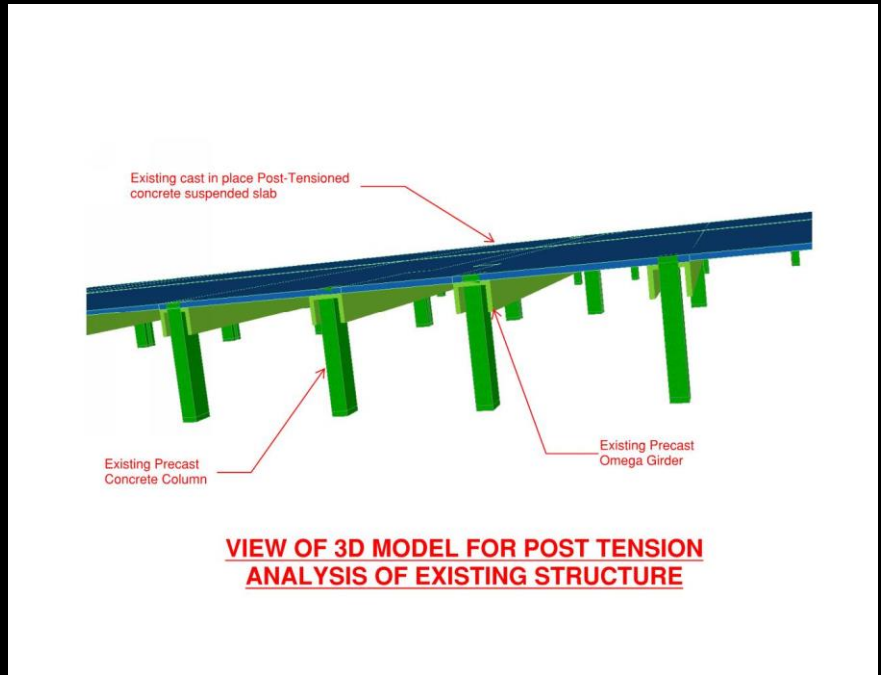


Excerpt of the record structural drawings for the roof level floor framing

# Typical Structural Framing

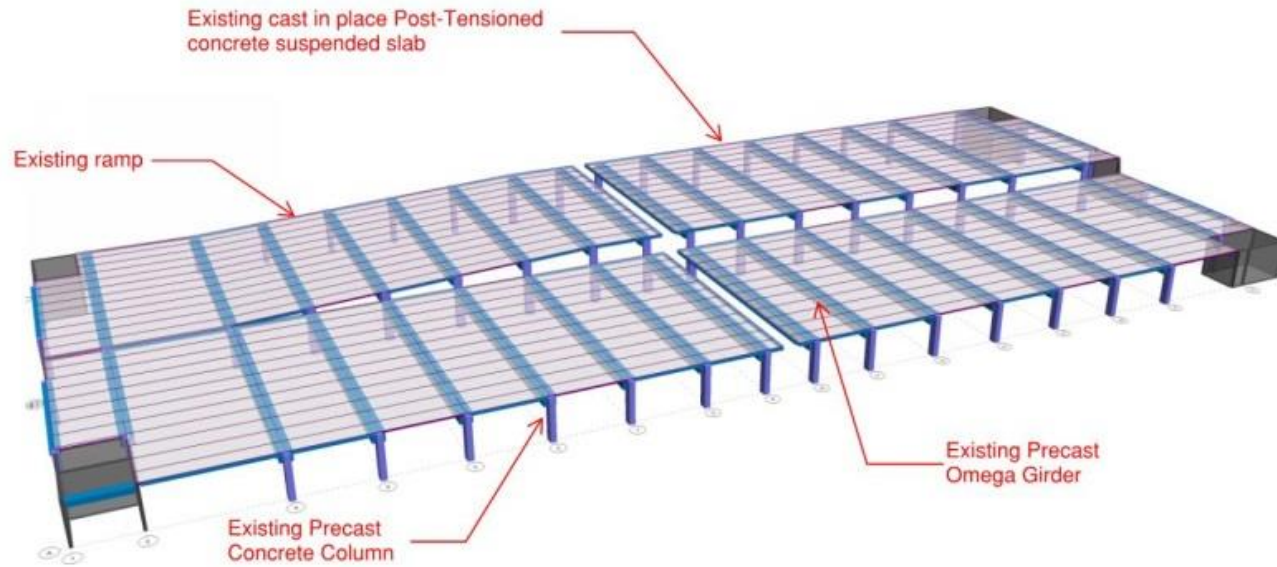


Typical view of structural members



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

# Roof Level



**VIEW OF 3D MODEL FOR POST TENSION  
ANALYSIS OF EXISTING STRUCTURE**

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.



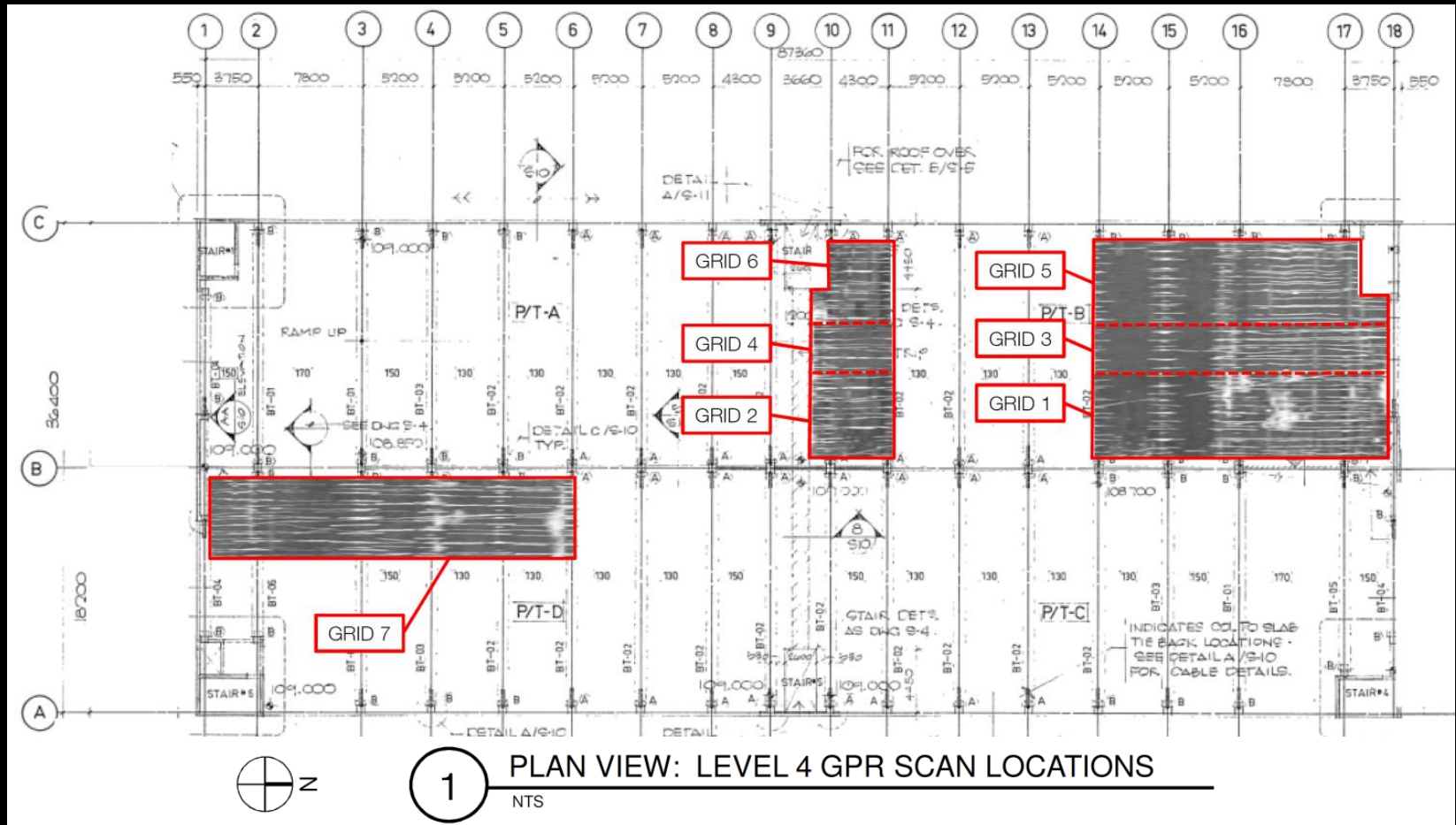
Screw drive penetration test indicating a de-tensioned PT tendon on the ramp at the Roof Level



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

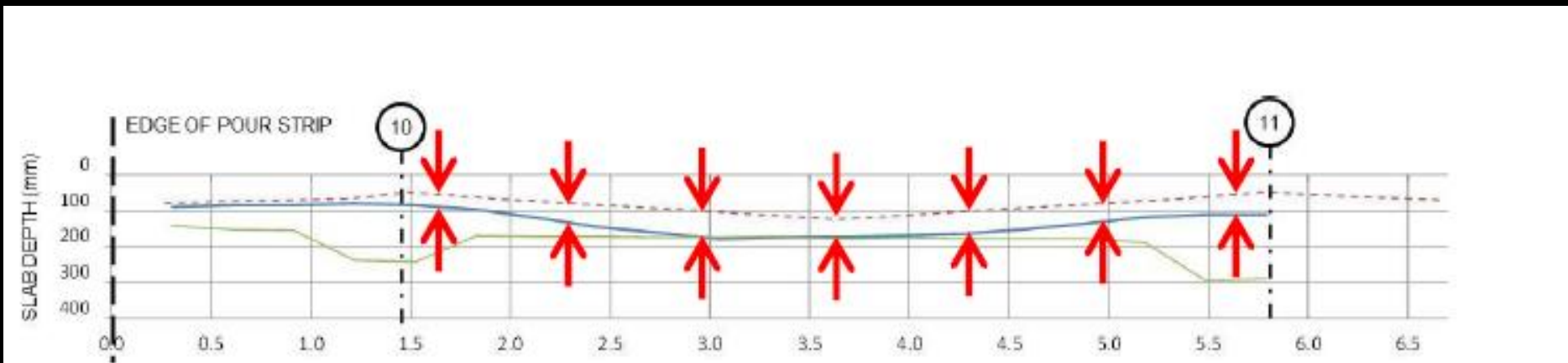
# Ground Penetrating Radar Survey

- 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

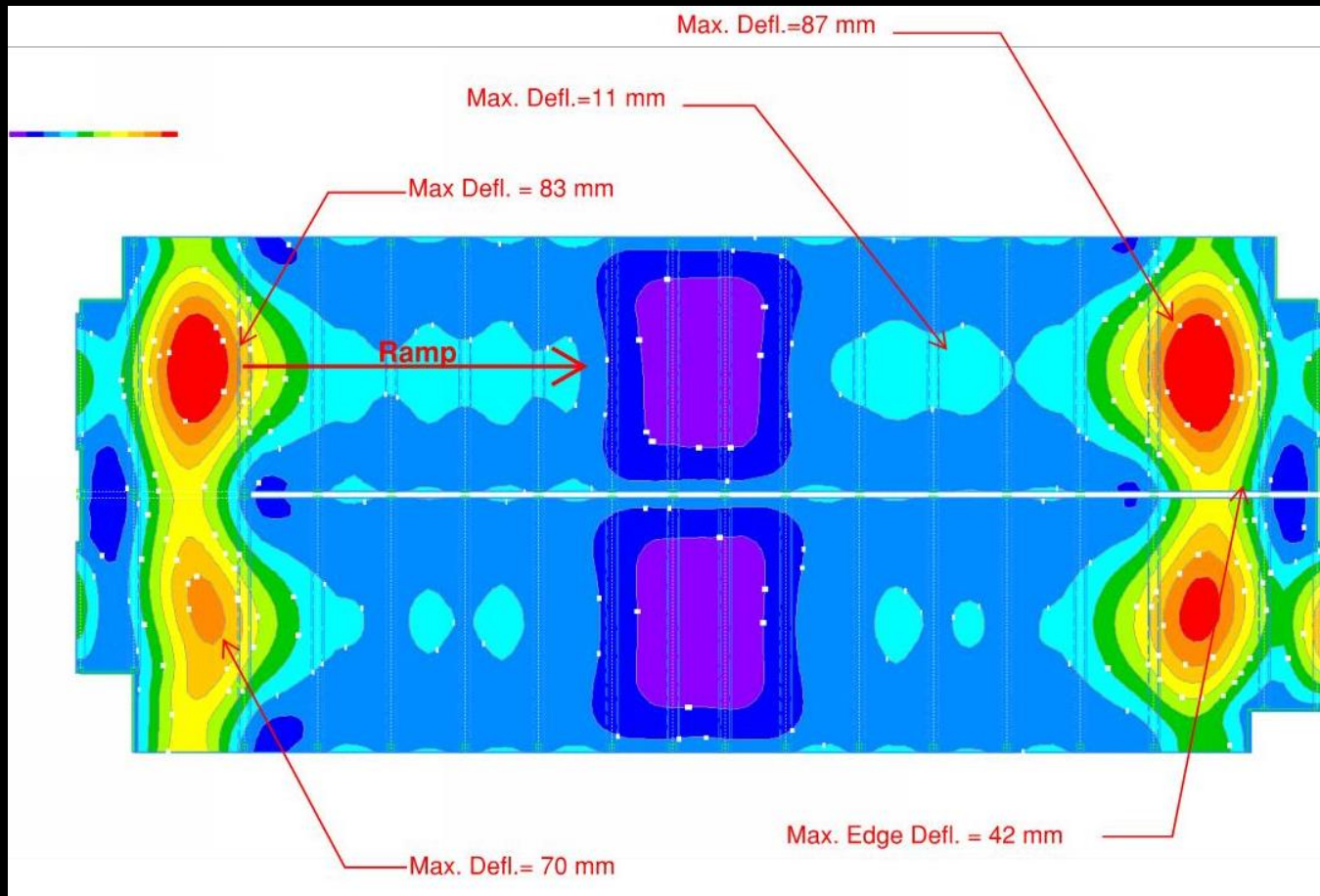
- Individual vertical tendon profiles were determined for each tendon in the scan areas and were plotted against the design tendon profiles specified in the record drawings.



# Structural Analysis

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

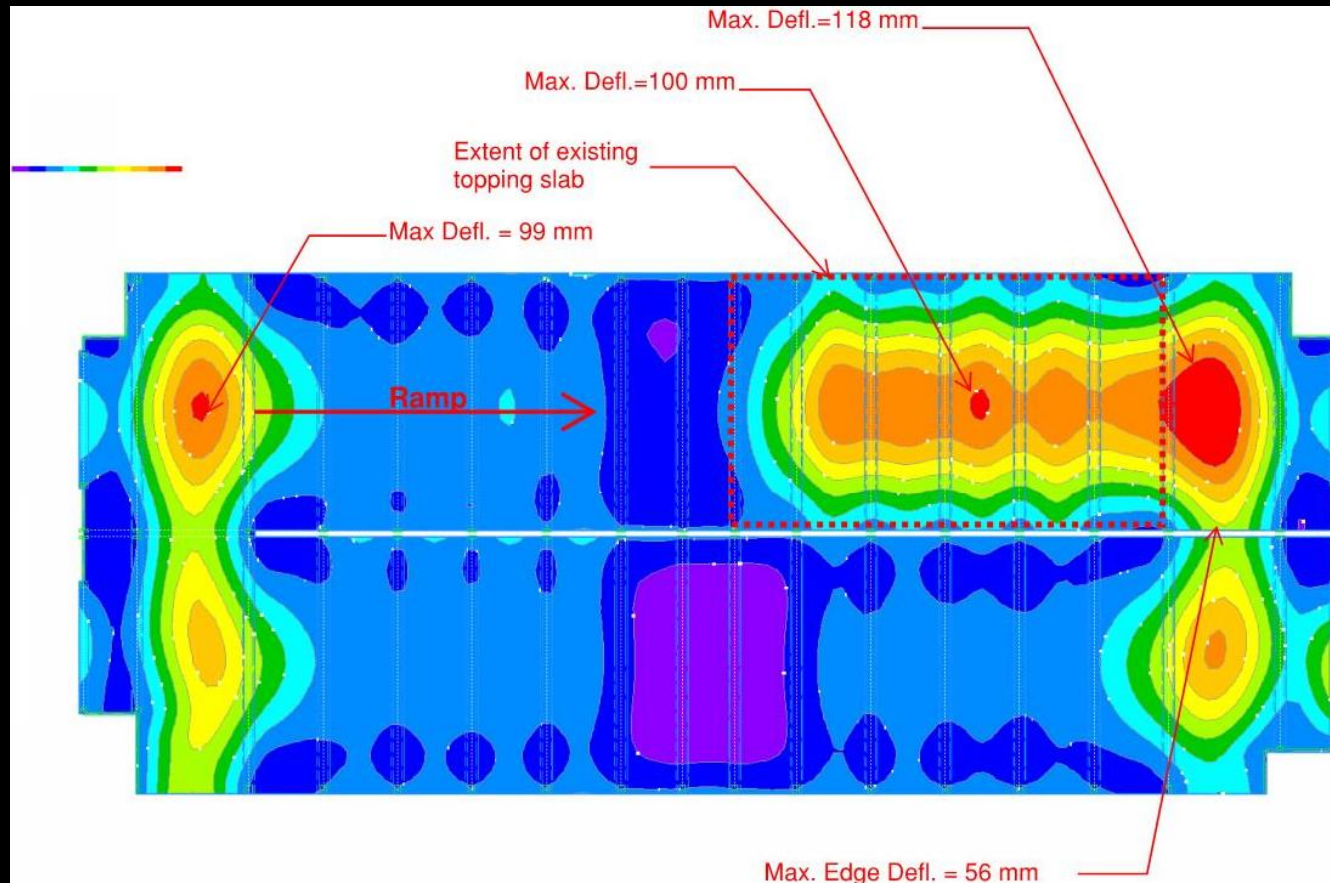
- Case I – Analysis of the original design





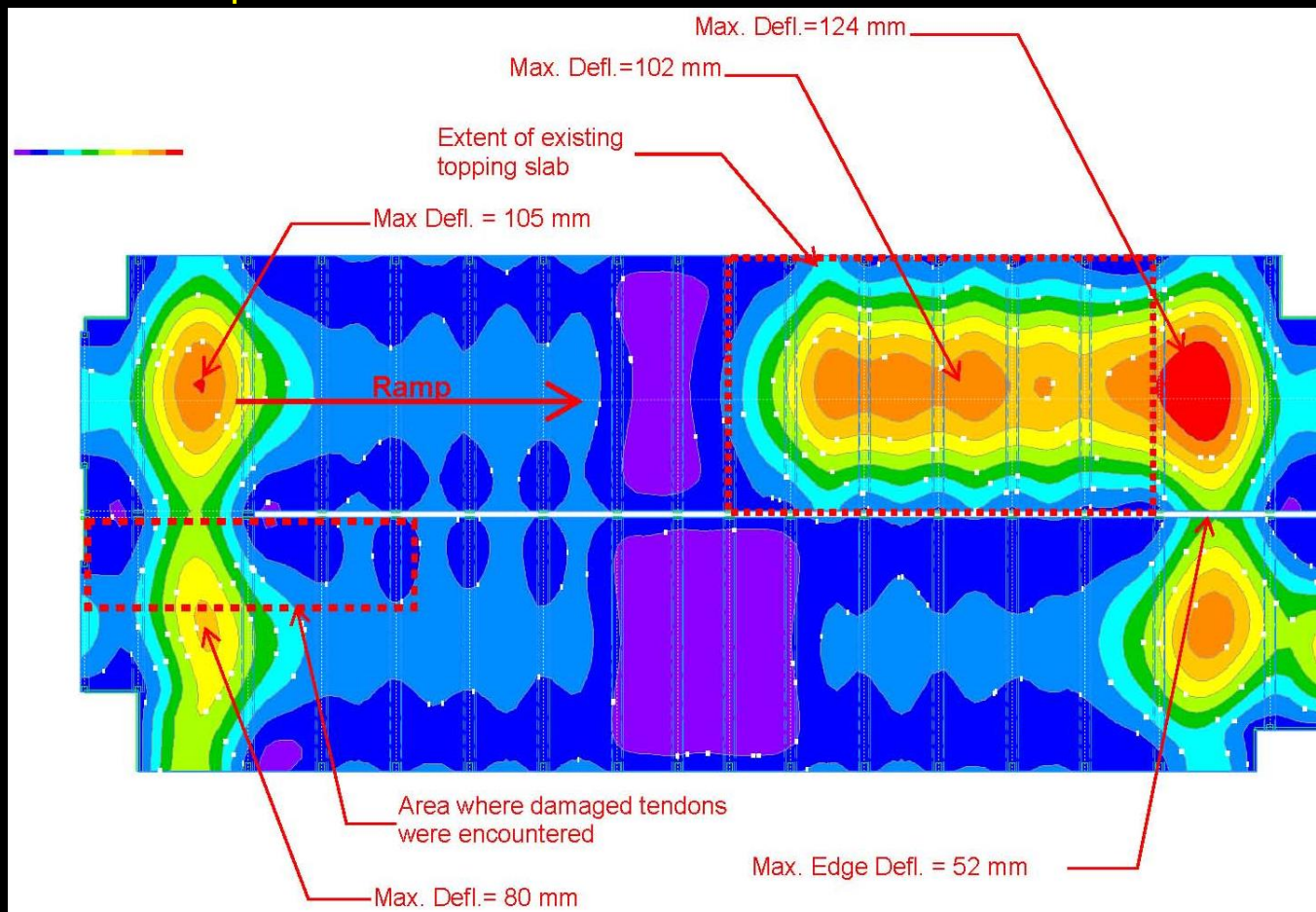
# Structural Analysis

- 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.

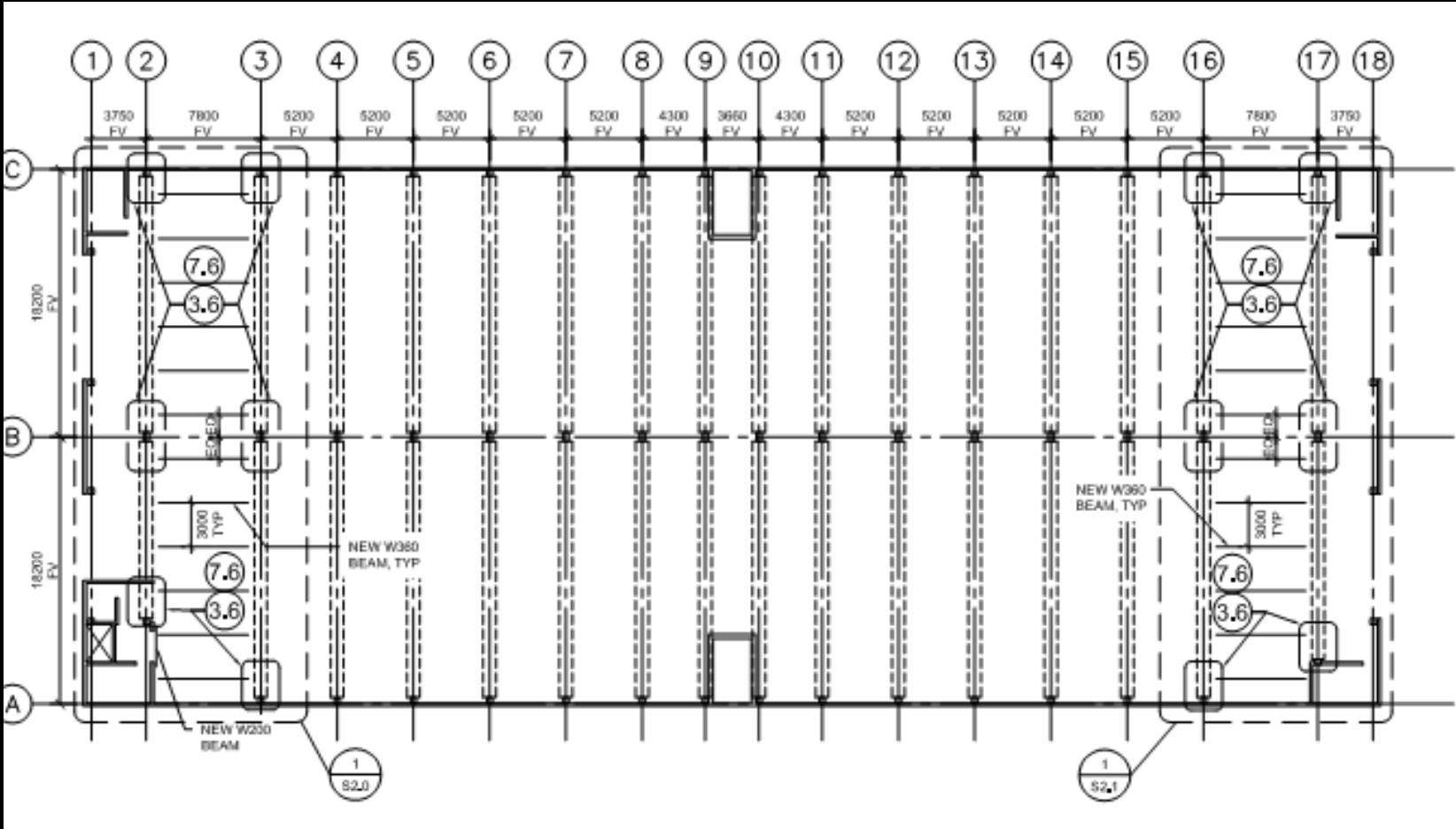


# Structural Analysis

- 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.

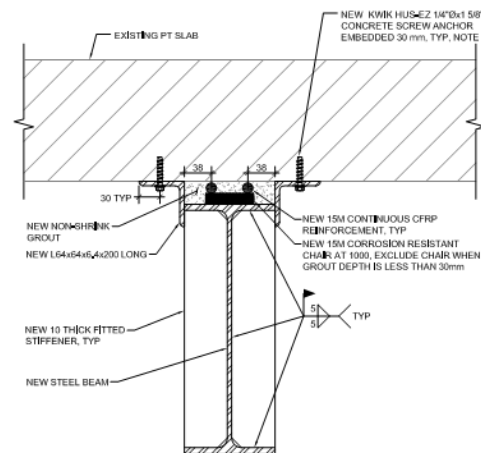
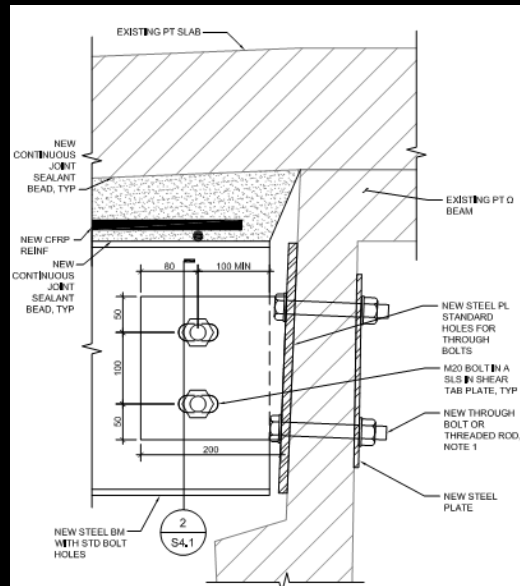
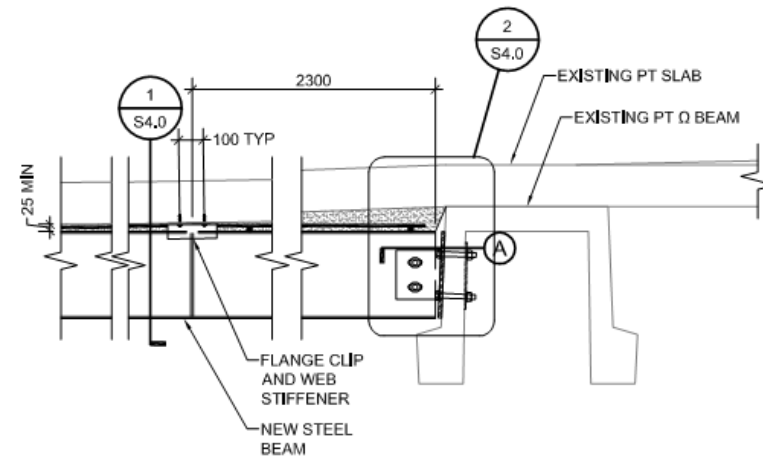
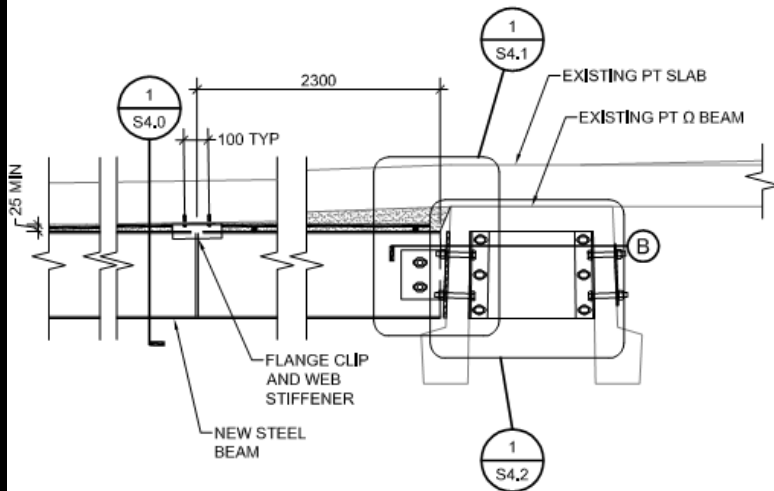


# Repairs



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# Repairs



NOTES:  
1. NON-DESTRUCTIVELY LOCATE EMBEDDED REINFORCEMENT PRIOR TO INSTALLATION OF NEW POST INSTALLED CONCRETE ANCHORS. DO NOT DAMAGE EXISTING EMBEDDED REINFORCEMENT.

## CASE STUDY #2

# Concrete Parking Garage Repair

## Description of Structure

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





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# Observed Distress



Column Distress  
on Level 1



Concrete Distress and  
Post-Tensioning Tendon  
Corrosion at Roof Joist



Cracking and Spalling in Overhead  
Concrete Pan on Roof Level

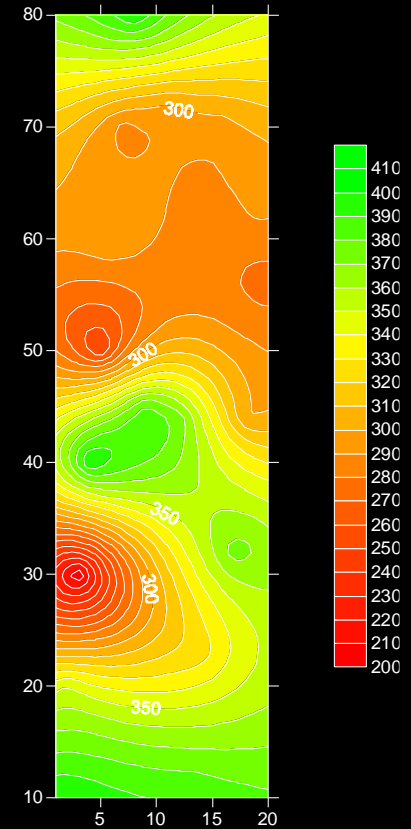
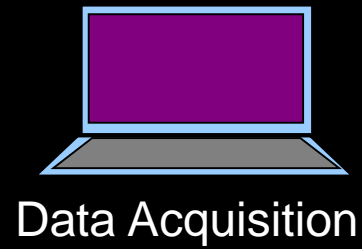
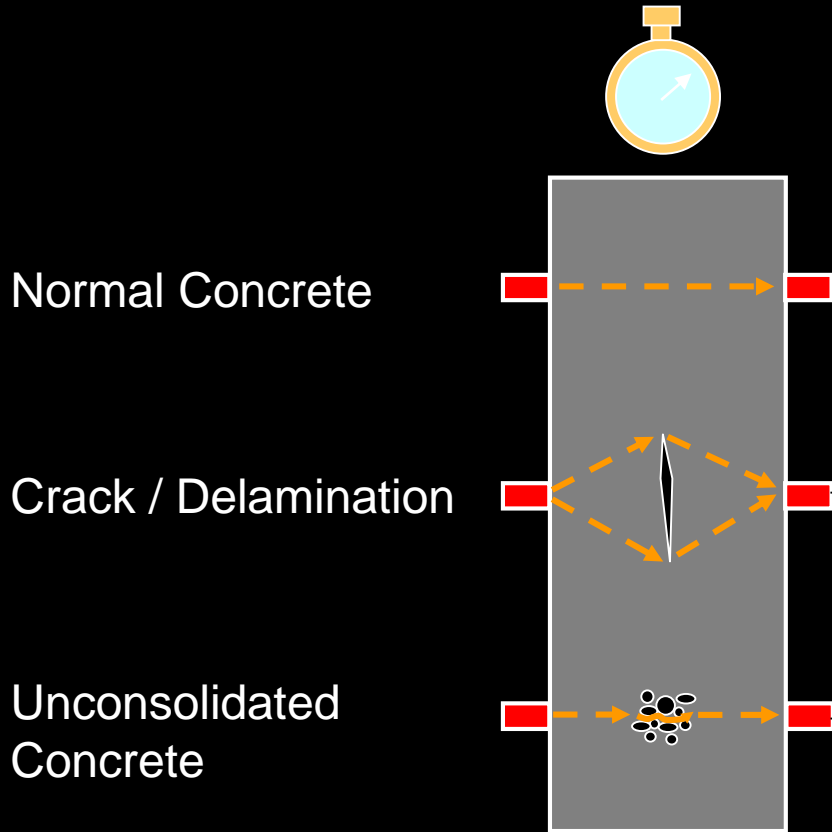
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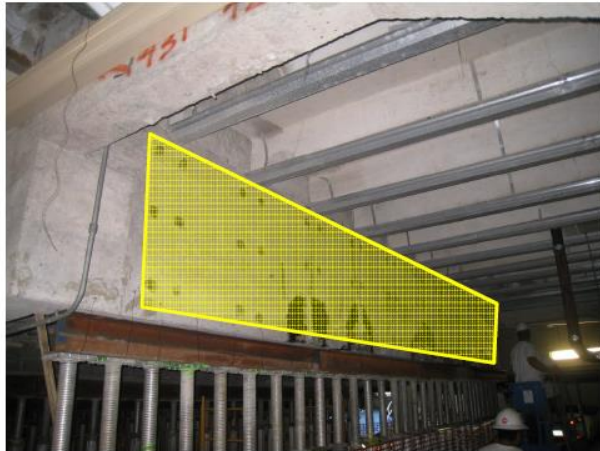
# Ultrasonic Pulse Velocity (UPV)

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

# UPV Schematic



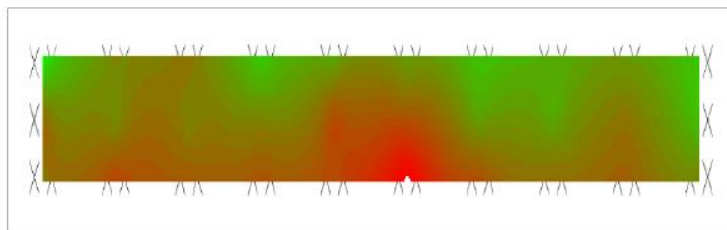
# Suspected Concrete Quality



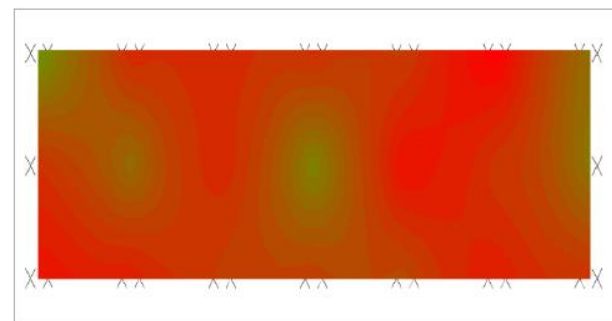
TEST LOCATION HIGHLIGHTED IN YELLOW



TEST LOCATION HIGHLIGHTED IN YELLOW



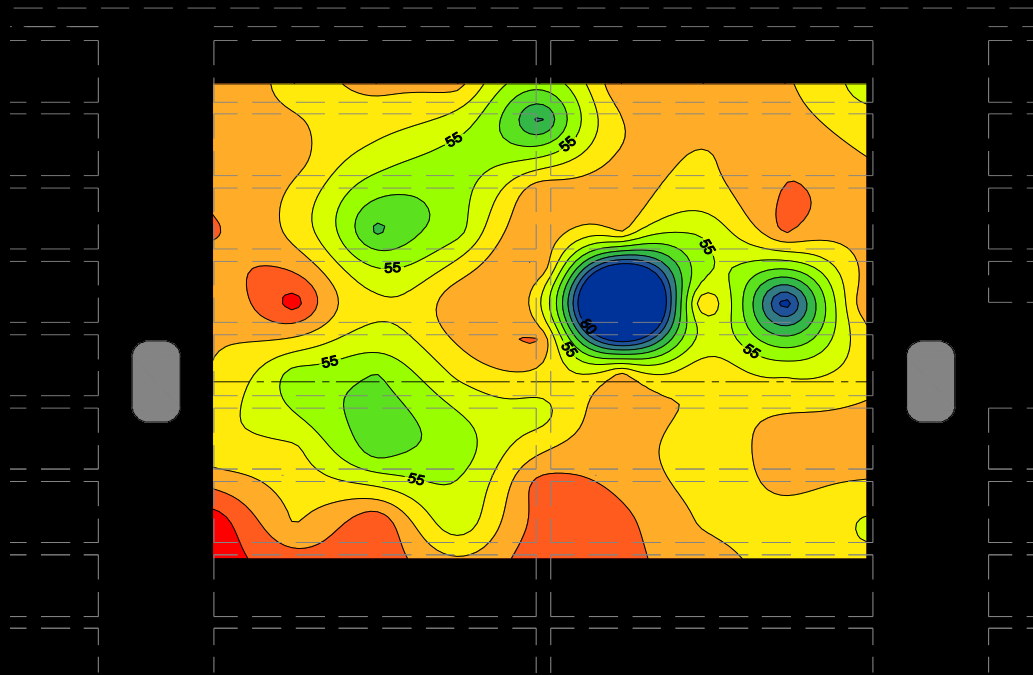
2 UPV TEST RESULTS: EAST SIDE OF POOL  
NTS



# Extent of Damage – Parking Structure

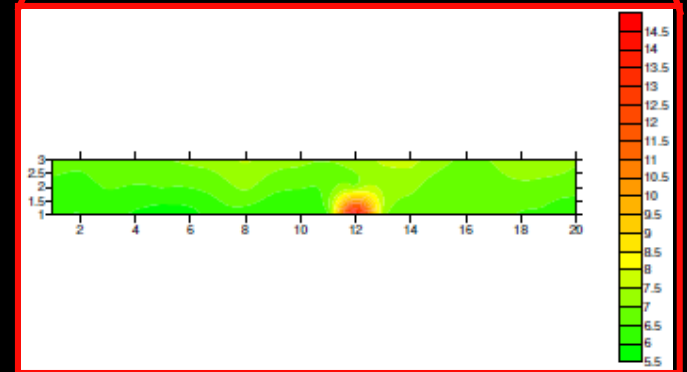
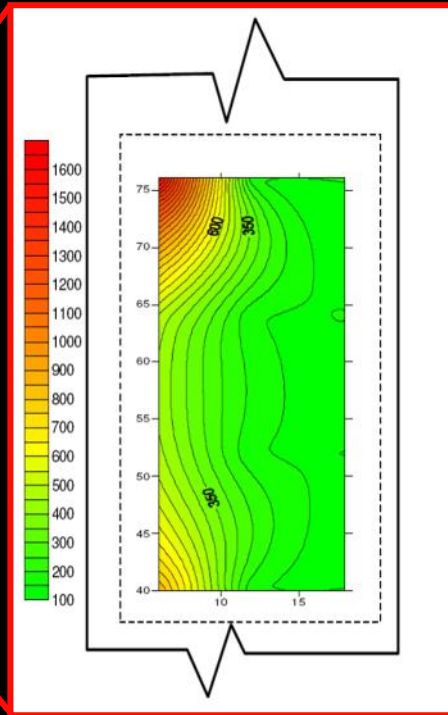
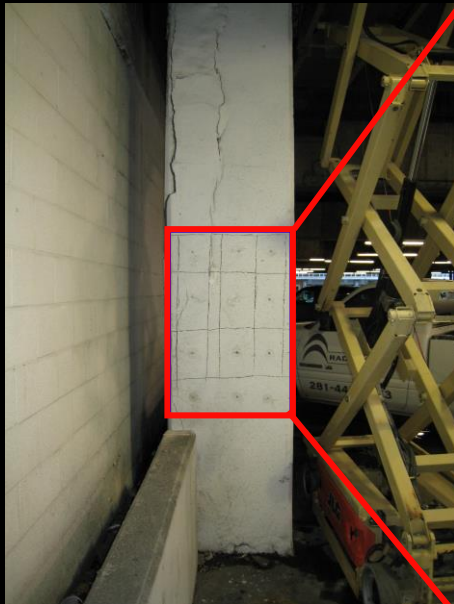
9

10



Time ( $\mu s$ )

# NDE Testing



UPV Testing of Roof Level Joist

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# Roof Joist Repair in Progress



Surface Preparation for Repairs to Roof Joist



Roof Joist – Installation of Supplemental Reinforcement / Shear Connectors, Repair of PT Sheathing

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# Final Repairs



Repaired Column



Repaired Roof Joist

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## Case Study #3

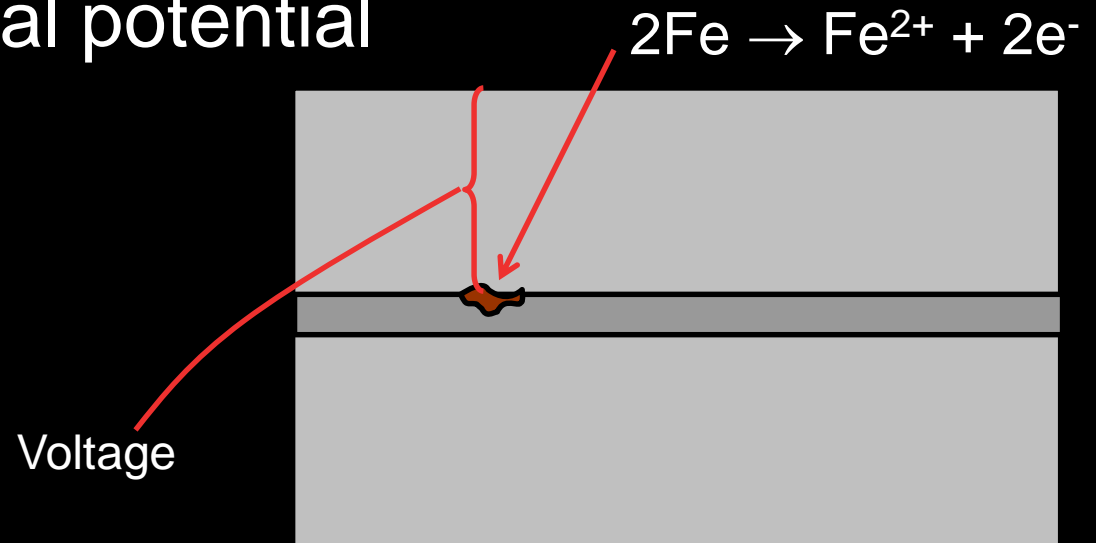
→ Half-Cell

→ Electrochemical reaction

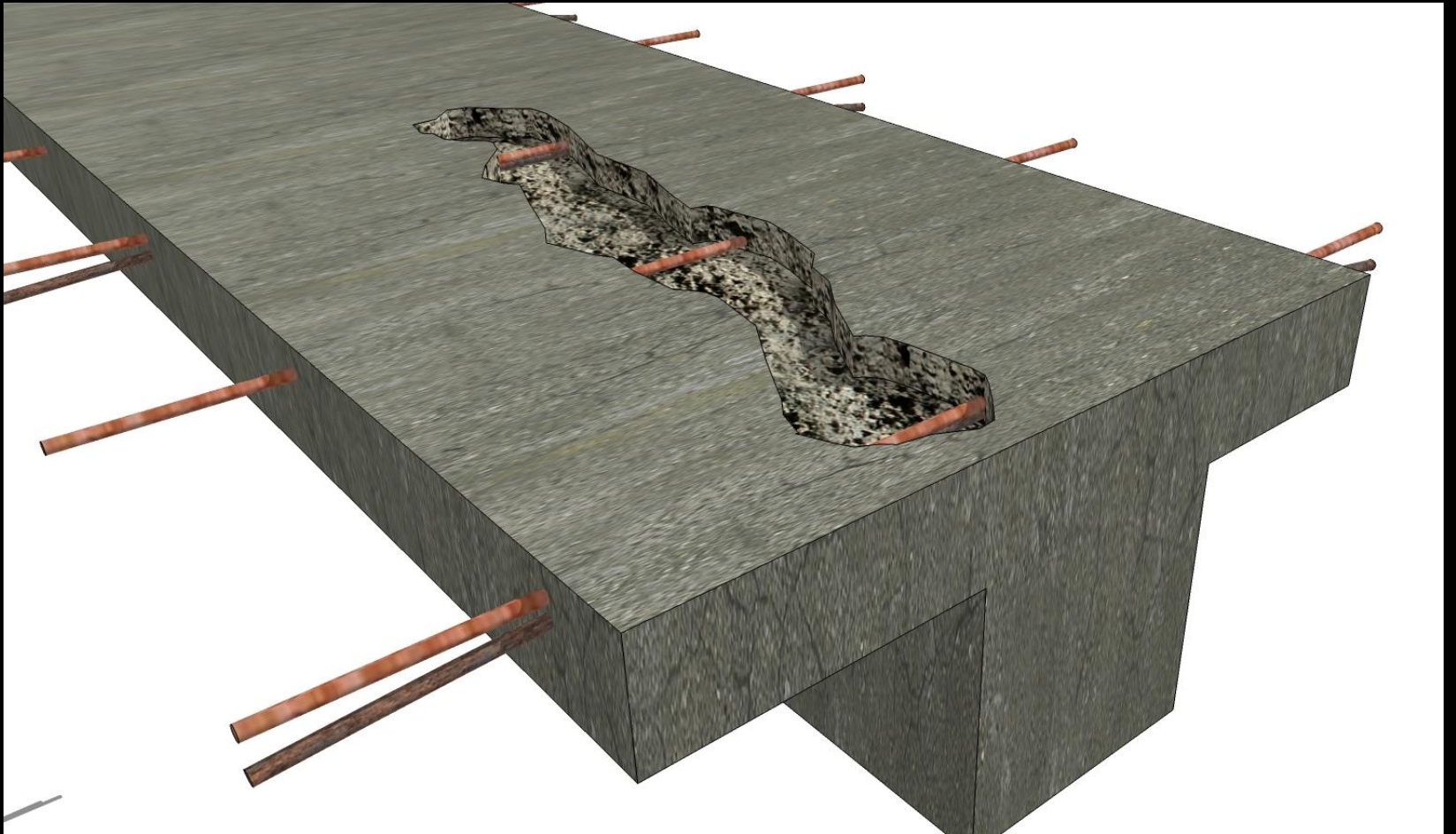
→ Galvanic corrosion

- $2\text{Fe} \rightarrow \text{Fe}^{2+} + 2\text{e}^-$
- $2\text{H}_2\text{O} + \text{O}_2 + 4\text{e}^- \rightarrow 4\text{OH}^-$

→ Measure electrical potential



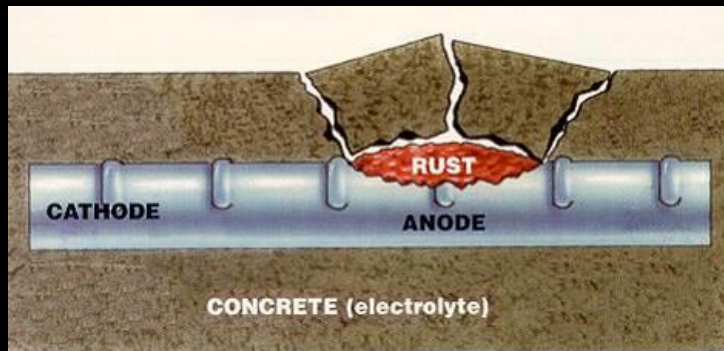


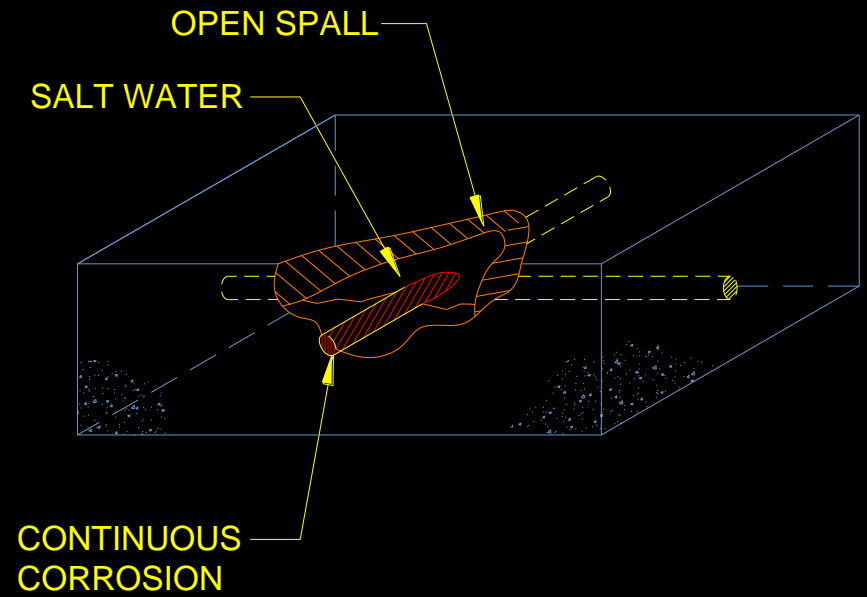
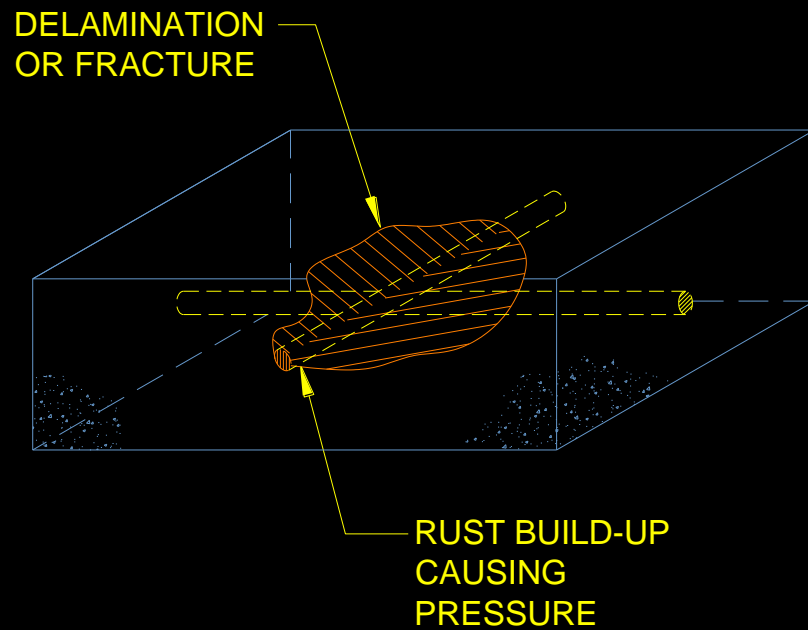




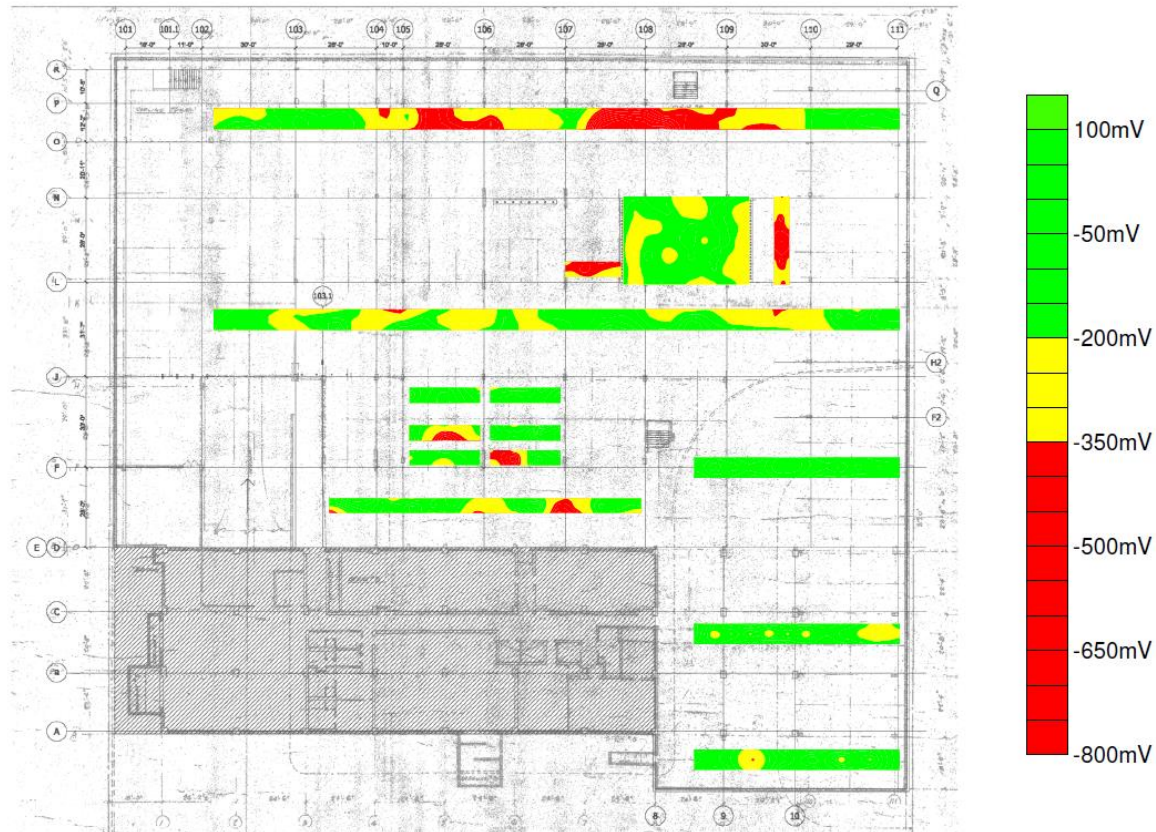


# Corrosion





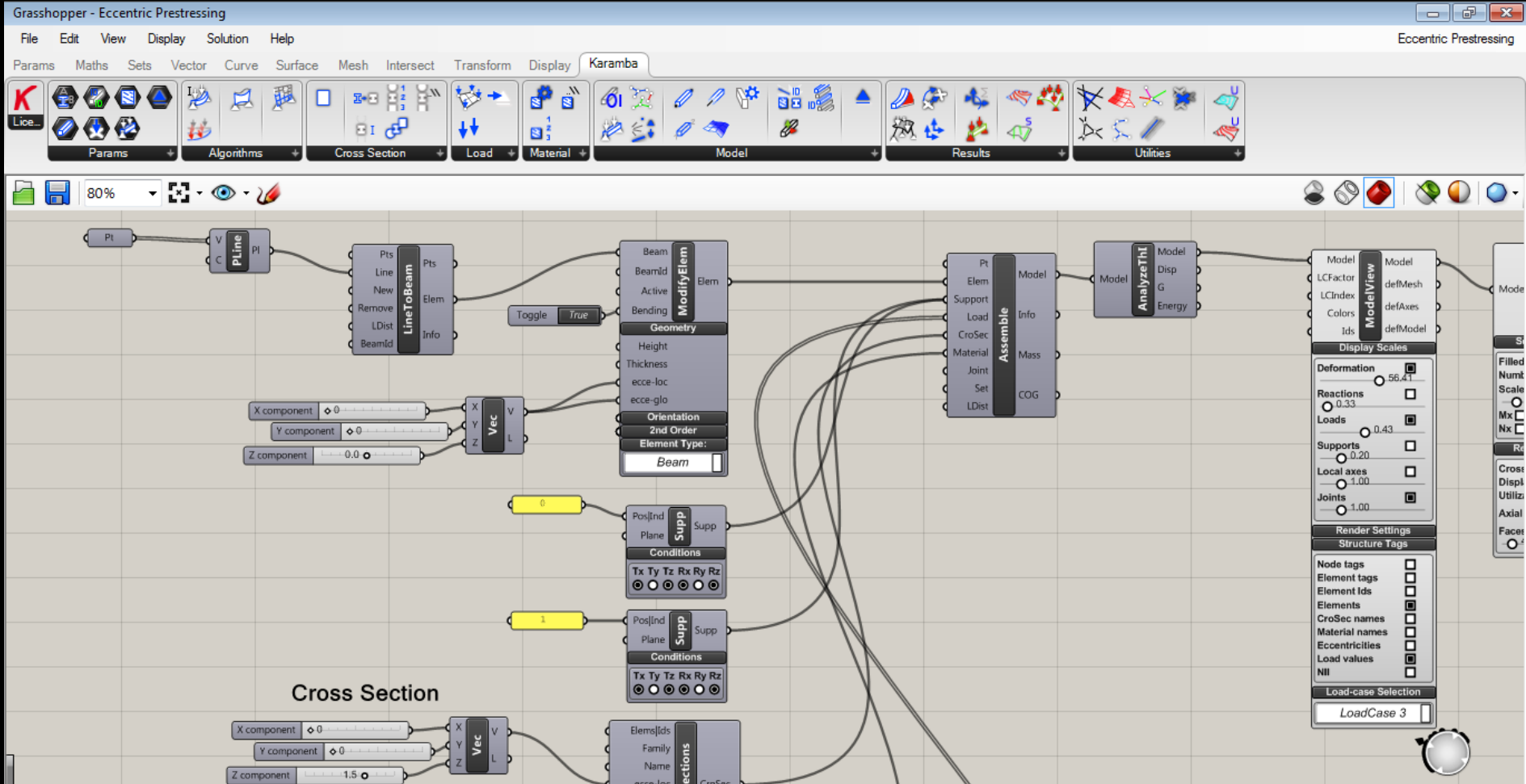
# Example – Half Cell Potential Testing



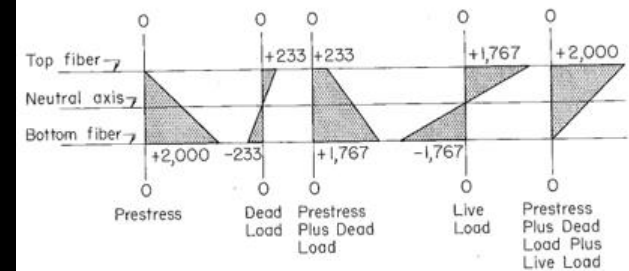
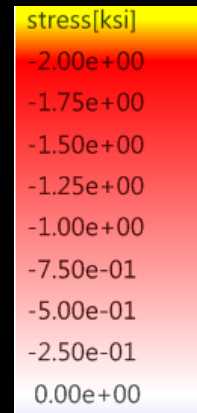
1 PLAN VIEW: HALF-CELL POTENTIAL RESULTS  
NTS



# Performance Modeling



# Performance Modeling



A final thought....

*Better information = Better Decisions*

**Better Solutions**





THANK YOU