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

Original approach (invasive)

Non-Destructive approach (better)
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:
- Precast Omega Shaped Beams
- Post-Tensioned Floor Slab soffit
- Precast Barrier Wall Panels
- Precast Columns
- Post-Tensioned Floor Slab

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
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.
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
Concrete Parking Garage Repair

Description of Structure

- Constructed 1978
- Cast-in-place concrete structure
- Unbonded post-tensioned pan joist framing
- Repairs deferred!
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
Ultrasonic Pulse Velocity (UPV)

• Wave speed through concrete

• Applications
  – Delaminations
  – Unconsolidated Concrete
  – Concrete material properties

• Limitations
  – Access to both sides
  – Qualitative
UPV Schematic

Normal Concrete

Crack / Delamination

Unconsolidated Concrete

Data Acquisition
Suspected Concrete Quality

TEST LOCATION HIGHLIGHTED IN YELLOW

UPV TEST RESULTS: EAST SIDE OF POOL

TEST LOCATION HIGHLIGHTED IN YELLOW
Extent of Damage – Parking Structure

Time ($\mu s$)
NDE Testing

UPV Testing of Roof Level Joist

WALTER P MOORE
Roof Joist Repair in Progress

Surface Preparation for Repairs to Roof Joist

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

- Repaired Column
- Repaired Roof Joist
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

$2\text{Fe} \rightarrow \text{Fe}^{2+} + 2\text{e}^-$
Corrosion
MOISTURE AND CHLORIDE ION ROAD SALT RUST BUILD-UP CAUSING PRESSURE DELAMINATION OR FRACTURE OPEN SPALL SALT WATER CONTINUOUS CORROSION
Example – Half Cell Potential Testing

PLAN VIEW: HALF-CELL POTENTIAL RESULTS
NTS
Performance Modeling
Performance Modeling
A final thought….

Better information = Better Decisions

Better Solutions
THANK YOU