Concrete Repairs: Tasks and Responsibilities

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Responsibilities of Construction Parties
- Owner
- Licensed Design Professional
- Contractor

Concrete Evaluation and Repair

Case Studies
- Waste Water Treatment Plant – Deterioration
- New Parking Garage – Construction Deficiencies
- Existing Parking Garage – Severely Deteriorated
Owner Responsibility:

- **Owner is the ultimate responsible party**
  - Maintenance and repair
  - Establish scope and objectives
  - Select design and construction team
  - Quality Assurance: Retain inspection & testing agencies
  - Site Safety: Delegated to the contractor through the CD’s
  - Environmental Regulations: Delegated to the contractor through the CD’s
  - Payment

Reference: ACI 132R-14 Guide for Responsibility in Concrete Construction
Responsibility of Licensed Design Professional (LDP):

**Professional Services**
- Understand Owner’s requirements
- Design as per the governing Codes & Standards – Establish Basis of Compliance
- Maintain the Standard of Care – Develop QA/QC program
- Evaluate structural conditions – Condition survey, NDT, Laboratory testing
- Perform repair design, develop Specifications – Prepare Contract Documents
- Perform field observations
- Perform or delegate inspections and tests
- Notify Owner of any maintenance requirements
- Identify unsafe conditions and report to the Owner and the Jurisdictional Authorities

**References:**
- ACI 132R-14 Guide for Responsibility in Concrete Construction
- ACI 562-16 Code Requirements for Evaluation, Repair, and Rehabilitation of Concrete Buildings
Contractor’s Responsibility:

**Construction Work**

- Perform work in accordance with the Contract Documents
- No design responsibilities, except of specialty items (formwork, shoring, SOE, other)
- Review Contract Documents, identify discrepancies, tolerances, compatibility issues. Inform Owner and LDP.
- Coordinate the work with subcontractors
- Maintain site safety (HASP, JHA)
- Establish Quality Control program

Reference: ACI 132R-14 Guide for Responsibility in Concrete Construction
ACI 562-13 Code Requirements for Evaluation, Repair, and Rehabilitation of Concrete Buildings

- Provides minimum requirements for the evaluation, repair, rehabilitation and strengthening of existing concrete structures
- Provides uniform standards for evaluation and repair design
- Establishes Responsibilities
Concrete Evaluation and Repair

Key Steps

• Determine applicable codes and standards – Establish “Design Basis Code”
• Preliminary evaluation – verify safety
• Evaluation:
  ▪ Condition survey
  ▪ NDT
  ▪ Lab testing
  ▪ Structural assessment: analysis, design, load test
• Repair & Rehabilitation Design:
  ▪ Code requirements (strength, serviceability)
  ▪ Durability
  ▪ Maintenance
• Quality Assurance - Specifications
• Construction
Case studies will illustrate the key steps of evaluation and repair and identifying the responsibilities of the LDP.

**Case A**
Evaluation and Repair of Waste Water Treatment Plant Concrete Tanks

**Case B**
Evaluation and Repair of a New Parking Garage that was Improperly Constructed

**Case C**
Evaluation of Severely Deteriorated Parking Garage that was poorly maintained
Case Studies: Case A

Northeast US City - Major Waste Water Treatment Plant Evaluation and Repair of Concrete Tanks

Jurisdiction: Northern US City
Owner: City DEP Agency
Original Construction: 1930’s
Current Building Code: City 2014 BC
Existing Building Code: NA
Design Basis Code: 1938 City BC
LDP is Responsible for Developing the Evaluation Program.

Phases of Concrete Evaluation and Repair:

A. Visual Inspection
B. Non-Destructive Testing (NDT)
C. Laboratory Testing
D. Structural Assessment - Service Life Evaluation
E. Repair Design
F. Repair Construction
Methodology used for Evaluation Program

LDP may use Industry Standards, including:

- ACI 350 Code Requirements for Environmental Structures
- ACI 364 Evaluation of Concrete Structures Prior to Rehabilitation
- ACI 201 Conducting Visual Inspection of Concrete in Service
- ACI 224.1R Evaluation and Repair of Cracks
- ACI 228.2R Nondestructive Test Methods for Evaluation of Concrete
- ACI 562 Code Requirements for Evaluation, Repair, and Rehabilitation of Concrete Buildings
Field Investigation Process

Part A: Visual Inspection

- **Identify visible damage:**
  - Cracks, spalls, leaks, scaling, efflorescence, exposed rebar, surface erosion, joint failures

- **Identify delaminations:**
  - Sounding
  - Chain dragging

Case Studies: Case A – Concrete Tanks
Case Studies: Case A – Concrete Tanks

Major problems at this Site included:

- Cracking
- Spalling
- Rebar Corrosion
- Joint Failures
- Surface Erosion
Field Investigation Process

Part B: Non-Destructive Testing (NDT)

- Pachometer Testing: Location and Depth of Rebars
- Impact-Echo: Identify internal faults
- Impulse Response: Identify general weaken areas
- GPR: Identify internal faults, rebars, hidden piping
- Half-Cell Potentials: Measure corrosion potentials
Case Studies: Case A – Concrete Tanks

NDT - Pachometer Testing
Provides location and depth of Rebars
Case Studies: Case A – Concrete Tanks

NDT - Impact-Echo Testing
Identifies internal faults
Case Studies: Case A – Concrete Tanks

NDT - Impulse Response Testing
Identifies general weakened areas
Case Studies: Case A – Concrete Tanks

NDT – GPR Testing
Identify internal faults, rebars, hidden pipes
Case Studies: Case A – Concrete Tanks

NDT – Half-Cell Potentials
This testing measures corrosion potentials
Part C: Laboratory Testing

- Compressive Strength Testing
- Petrographic & Chemical Analyses
  - Identify concrete properties & Quality
  - Chemical attack (Alkali-silica reactivity, sulfates)
  - Chloride content
  - Carbonation (pH levels)
  - Freeze-Thaw damage
  - Other properties

Case Studies: Case A – Concrete Tanks
Case Studies: Case A – Concrete Tanks

Part C: Laboratory Testing

Laboratory Testing by:
Case Studies: Case A – Concrete Tanks

Service Life Evaluation Office Studies

• Assessment of Visual Condition Surveys and Laboratory Testing
• Use Computer-Based Method to Evaluate Remaining Service Life
  ▪ Identify Concrete Characteristics (Lab Testing)
  ▪ Identify Environmental Conditions
  ▪ Evaluate Expected Life Based on Alternate Repair Methods and Materials
  ▪ Evaluate Alternates: Repair Vs. Replacement
• Development of Repair Design
Is NDT and Laboratory Testing warranted?

- NDT can provide information not visible to naked eye or by sounding. NDT can provide information on internal concrete flaws and rebar location.
- Lab testing can provide information on the strength, quality and durability characteristics of the in-place concrete.
- Life cycle analysis can analyze the effects of alternate repairs on the long term durability of the tanks.
Case Studies: Case B

Northeast US City – Evaluation and Repair of a New Parking Garage that was improperly constructed

Jurisdiction: Northern US City
Owner: Federal Agency
Original Construction: 2007
Original Building Code: City Building Code 1968
Existing Building Code: NA
Design Basis Code: 1968 City BC
Problem:
Soon after construction the garage exhibited excessive cracking and deflections.

Purpose of Investigation:
Determine cause of the problem and develop a repair program.
Responsibility of the investigator LDP: Identify cause of the failure.

- Develop an investigation program
  - Design verification
  - Condition survey
  - Nondestructive testing (NDT)
  - Material laboratory testing (if required)
- Develop repair design
- Provide QA/QC during construction
Case Studies: Case B – New Parking Garage

Problem:

Soon after construction, the Garage exhibited excessive cracking and deflections.
Problem:
Diagonal spider-type cracking around columns
Case Studies: Case B – New Parking Garage

Probing:
Top reinforcement steel was ±4” down instead of ¾”
Case Studies: Case B – New Parking Garage

NDT: Impact-Echo Testing
Performed Impact-echo testing to verify actual slab thickness along the spans.
Case Studies: Case B – New Parking Garage

**NDT: GPR Testing**

Performed GPR testing to verify the location of the steel bars.
### Design v. As-Built Conditions

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<thead>
<tr>
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<th>As-Designed</th>
<th>As-Built</th>
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<tbody>
<tr>
<td>Supported Slab Thickness:</td>
<td>10”</td>
<td>±10”</td>
</tr>
<tr>
<td>Top Reinforcement Cover:</td>
<td>¾”</td>
<td>2” to 4”</td>
</tr>
<tr>
<td>Plaza Slab Thickness:</td>
<td>14”</td>
<td>14”</td>
</tr>
<tr>
<td>Drop Panel Thickness:</td>
<td>14”</td>
<td>6”</td>
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Performed structural analysis and design verifications based on the As-Built conditions.

Effects of Shallow Drop Panels:
- 30 TO 40% Flexural Deficiency
- 30% Punching Shear Deficiency

Effects of Excessive Cover:
- 15 to 45% Flexural Deficiency
- 18 to 46% Punching Shear Deficiency
Safety Concerns and Responsibilities

Responsibility of Investigator LDP:

• Inform the Owner – Advise Owner on the steps to be taken.
• Report structural deficiencies to the Local Authorities, if so required by local building code requirements.

Responsibility of Owner:

• Initiate required repairs
• Initiate temporary safety measures to protect the public and property.
• Report structural deficiencies and repair work to the Local Authorities.

Case Studies: Case B – New Parking Garage
Case Studies: Case B – New Parking Garage

**Repair Concepts**

- New reinforced concrete topping
- Install column capitals to increase punching shear capacity
- FRP strips at slab underside to increase positive flexural capacity
- Increase drop panel depth to increase negative flexural capacity.
- Epoxy inject the cracks to establish continuity of slabs
- Load testing to verify effectiveness of repairs (ACI 437)
Case Studies: Case C

Northeast US City – Evaluation and Repair of an Existing Parking Garage that was poorly maintained

Jurisdiction: Northern US City
Owner: Private
Original Construction: 1960’s
Original Building Code: City Building Code 1938
Existing Building Code: NA
Design Basis Code: 1968 City BC
Spalled Concrete Slab.

Plywood was used to bridge damaged areas.

Repairs and maintenance were neglected for many years.
Case Studies: Case C – Existing Parking Garage

Severe Concrete Spalling at underside of concrete slab.

Questionable Temporary Shoring.
Severe Concrete Spalling at underside of concrete slab.

Severely corroded rebars were detached.

Questionable Temporary Shoring.
Severely corroded rebars with cross-sectional loss of over 50%.

Lab tests indicated chloride levels 3 times the ACI corrosion threshold levels.

Repair and maintenance were neglected for many years.
Clogged floor drains; evidence suggested this clogging had been present for several years.

Conditions showed that no repair or maintenance had been performed in a long time.
Responsibilities of the Investigator/Repair LDP (ACI 562):
• Understand the structure and the Owner’s needs.
• Develop evaluation program (review docs, condition survey, NDT, material testing, structural analysis/design).
• Develop repair design and detailing, and specifications
• Specify a quality assurance program.
• Notify Owner on required maintenance of repairs.
• Report unsafe conditions to the Owner and to the jurisdictional authorities in accordance with local ordinances.

Owner Responsibility:
Don’t Neglect Structure.
Implement maintenance program and provide timely repairs to avoid increased repair costs.