ACI 562, Code Requirements for Assessment, Repair & Rehabilitation of Concrete Structures

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ACI 562-16, soon 562-19, plus
ACI/ICRI Guide to the Code for Assessment, Repair and Rehabilitation of Concrete Buildings
What is wrong with concrete repair practice?

- Focus on new design in education
- Many design professionals do not consider repair a distinct area
  - Limited assessment and evaluation of structures
  - Lack of understanding of durability
  - Disdain from “historic preservationists”
- Lack of contractor focus on quality – except for ICRI members
- US national codes
  - IBC – comprehensive document for new design
  - IEBC – does not establish a clear standard of care for repair
Need for ACI 562

• Why?
  • Standard of care?
    • New design - follow code
    • What is it for repair projects?
    • Protect design professionals
    • Improve practice
  • Longer living structures
    • “Service-life” rarely ends
    • Deterioration does not end
  • Repairs will be required
    • Limited durability
    • Greater exposure
    • Are repaired structures safe?

Adapted from: Extending the Service Life of Parking Structures, Shiu, K, and Stanish, K. Concrete International V. 30 No. 4
Standard of Care vs. Codes

- Standard of Care - “level of effort a prudent LDP would be expected to provide on a project”
  - Determined from codes, industry standards, guidelines, tradition
  - Codes - Minimum requirements for design
Standard of Care – IEBC???

• Missing from IEBC
  • The how of minimum evaluation requirements
    • How bad is a structure?
    • Analysis considerations?
    • Reliability of repaired structures?
  • Durability considerations?
  • Consideration of service life
  • Construction quality assurance

- Set minimum requirements for repair and quality
- Provides clear requirements for strengthening
- Better and uniform assessment & evaluation
- Durable repaired structures
Unsafe & Substantial Structural Damage Conditions – ACI 562

• IEBC unclear
• Falling debris hazards
  • Make safe
• $U_c/\phi R_{nc} > 1.5$ $U_c/\phi R_{nc} > 1.33$
  • Current demand - $U_c$
  • Gravity and wind loads
  • Current capacity - $\phi R_{nc}$ (include damage)
  • Report consistent with Section. 1.5.2
  • Repairs to current or original code – $U_c/\phi R_{nc} \leq 1.05$
ACI 562 Adoption

- Limited ACI 562 statewide adoption to date (OH and HI)
- IEBC Alternate procedure
- IEBC – 2021
  - Preliminary hearings in April 2019
  - Final hearings in October 2019
- Why ACI 562
  - Current practice is not working
  - IEBC is not sufficient
  - Design professionals need help
  - Contractors need a “level field”
  - Owners need assurance
  - Code officials need a DOCUMENT
Example 4, Guide to the Code
Strengthening of a Parking Garage

11 Story office building over 2 story parking garage supporting open air plaza (flat slab with drop panels). Deflections and top surface cracking noted.

10 @ 30’-0” + 1 @ 20’-0”
Preliminary Assessment

- Document Review, Site Conditions, As-built, Basis of Design
- Design Basis Code: substantial damage → IBC 2009, ACI 318-08 (Sect. 1.2.4)
- Existing condition (Sect. 1.7.1, 1.7.3)
  - Reinforcement GPR: supplemented by chipping: 4-in. cover to top bars vs. ¾-in. as-designed for garage slab
  - $\phi M_n$ reduced 15-45% and $\phi V_n$ reduced 18-46% (use design values for $f' c$ and $f_y$)
Preliminary Assessment

- Drop panel “d” for plaza, actual = 18 ¾-in. vs design = 26 ¾-in.
- $\phi M_n$ and $\phi V_n$ reduced $\approx$ 30%
Assessment

- Existing geometry (Sect. 6.2.2, 6.2.3)
- Concrete strength $f_c'$ by testing lab reports and $f_y$ by mill cert. (6.3.4)
- Structural analysis (5.1.3)
  - Original design by planar equivalent frame analysis – OK
  - As-built using same procedure, $\phi$ factors not reduced
Repair Design – concept 1

- Location with excessive cover
  - Remove cover, place new bars plus shear friction reinforcement (7.4.4)
  - Unload slab before placement of new concrete (6.7.1)
Repair design – concept 1

- Location with thin drop panel
  - Install steel brackets to increase $b_o$ and shorten $L_n$
Repair design – Concept 2

- Location with and without drop panels
  - Build column capitals and some drop panels to increase \( b_o \) & \( d \), and shorten \( L_n \)
  - Apply Carbon FRP to bottom of slab – consider moment redistribution
  - Load Test (Sect. 6.8)
Moment redistribution: “as-is” not as “originally conceived”

ACI 440.2R, positive moment due to LL plus M redistribution (Chap. 7)
\[ \phi_{ex} R_{ex} \geq 1.2D + 0.5L + 0.2S \] (Sect. 5.5.3)

Elastomeric coating to seal cracks from water intrusion + epoxy injection for shear

FRP, Coat with intumescent paint

Actual moment diagram

Original analysis moment diagram
Design Concept 2 – drop panel + capital

- costs 20% less than concept 1
New Capital – Shear Friction
• Shoring by Licensed Design Professional (Specialty Engineer, 9.2)
  – Reviewed by Designer
  – All phases included removing DL
• Environmental issues including debris removal (Sect. 9.4)
• Inspection at critical phases (Sect. 10.2)
• Minimum roughness (Sect. 7.4.6)
• Pull-out testing of epoxy-grouted dowels (Sect. 7.6.5)
• Repair concrete flow and strength
• Impact echo of joint between drop panel and slab (Sect. 6.4.3.2)
• Bond test of CFRP strips (Sect. 7.8)
Inspection & Repair

LEGEND:
○ DESIGNATES POSSIBLE VOID BETWEEN BOTTOM OF CONCRETE SLAB AND TOP OF COLUMN CAPITAL

OUTLINE OF COLUMN CAPITAL BELOW

AREA TO BE INJECTED
Load Test per ACI 437.2-13 (Sect. 6.8.1)

- $TLM = 1.3(D_W + D_S)$
- $TLM = 1.0D_W + 1.1D_S + 1.6L + 0.5(L_r \text{ or } S \text{ or } R)$
- $TLM = 1.0D_W + 1.1D_S + 1.6(L_r \text{ or } S \text{ or } R) + 1.0L$
\[ \Delta_{\text{residual}} < \frac{\Delta_{\text{max}}}{4} \quad \text{or} \quad \Delta_{\text{max}} < 0.05 \text{ in.} \quad \text{or} \quad \Delta_{\text{max}} < \frac{L_{\text{short}}}{2000} \quad \text{or} \quad \Delta_{\text{max}} < \frac{L_{\text{short}}}{180} \]

\[
\Delta_{\text{residual}} = 0.358 \text{ in.} < 1.63 \text{ in} \rightarrow \text{passed test}
\]

\[
\Delta_{\text{residual}} \text{ after 24 hours} = 0.125 \text{ in} < 0.147 \text{ in} (\frac{L_{\text{short}}}{2000}) \rightarrow \text{passed test}
\]

\[ L_{\text{short}} = 24' - 6'' \text{ (294 in)} \quad l_g \text{ in the negative moment regions with injection} \]

\[ l_{cr} \text{ in the positive moment regions without injection} \]
Project completion

- The owner was provided with copies of the project and construction documents and the recommended monitoring and maintenance program (Sect. 1.5.3.1 & 1.6.3)
  - Visual inspection after one year
  - Monitoring and maintenance of crack repairs, top membranes, & CFRP
Conclusion & Questions

• Repair is a big part of ACI together with ICRI
  • 30% of ACI technical committees
  • ACI 562 Code and 563 Specifications v. ACI 318 and 301
  • Covering $20 Billion construction in U.S. annually