



The ACI 562 Code

“Design of Structural Repairs” – Chapter 7

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ICRI 2014 SPRING CONVENTION, MARCH 19-21, 2014

Design Basis Code

- ACI 318
- This presentation assumes familiarity with design of new concrete buildings using ACI 318.
- Purpose:
 - Similarities
 - Differences
 - New Concepts
- Please pick up the handout



Presentation Goals

- Design concepts – this presentation
- Design examples – wait for the all day seminar



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7.1 General

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- **7.1** Repaired structures, structural members, and connections shall be designed to have design strengths at all sections at least equal to the required strengths calculated for factored loads and forces in such combinations as stipulated in this code.
- Design Strength \geq Required Strength

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- **9.1** Structures and structural members shall be designed to have design strengths at all sections at least equal to the required strengths calculated for the factored loads and forces in such combinations as are stipulated in this Code.
- Design Strength \geq Required Strength



7.2 Strength and Serviceability

562

- **7.2.1** Repaired members shall be designed to have adequate stiffness to limit deflections, vibrations, cracking, or any deformations that adversely affect strength or serviceability of a structure.

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- **9.5.1** Reinforced concrete members subjected to flexure shall be designed to have adequate stiffness to limit deflections or any deformations that adversely affect strength or serviceability of a structure.



7.2 Strength and Serviceability

562

- **7.2.2** Repair design and construction procedures shall consider the loading, internal forces, and deformations in both the existing and repaired structure during the repair process.

318

- **10.2.1** Strength design of members for flexure and axial loads shall be based on assumptions given in 10.2.2 through 10.2.7, and on satisfaction of applicable conditions of equilibrium and compatibility of strains.



7.3 Behavior of Repaired Structures

562

- **7.3.1 Repairs** incorporating new members shall be designed to integrate the new members with the existing structure, creating a structural system capable of sharing and transferring loads.

318

- This is not addressed by ACI 318.
- However, 10.2.1 Strength design of members
on satisfaction of applicable conditions of equilibrium and compatibility of strains.



7.3 Behavior of Repaired Structures

562

- **7.3.1.1** The design of the repair system shall consider the structural interaction between the existing structure and new members. The effect of the new members on the existing structure shall be evaluated according to the design basis code.

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- Not directly addressed by ACI 318
- This addresses the possibility of added members *changing the load path* in an existing building.



7.3 Behavior of Repaired Structures

562

- **7.3.2** Repairs to existing members shall account for force transfer at the interface between the existing member and the repair material or repair system. It is permissible to use ACI 318-11 provisions in the design of force transfer between new and existing concrete.

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- **11.6** Shear-friction
- **17.5** Horizontal shear strength
- FRP is provided in ACI 440R.
- Composite structural steel sections are provided in the Steel Construction Manual (AISC 325-11).



7.3 Behavior of Repaired Structures

562

- **7.3.2.1** Structural repairs shall maintain composite behavior under service loads. Repairs shall be designed for the material and existing substrate to perform as a composite section at service loads.

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- Composite concrete flexural members — Concrete flexural members of precast or cast-in-place concrete elements, or both, constructed in separate placements but so *interconnected that all elements respond to loads as a unit.*



7.4 Bond

562

- **7.4.1** The required bond strength shall be at least 1.5 times greater than the calculated design bond force at the repair material to existing concrete interface.
- NOTE: the next edition will require *minimum* 80 psi.

318

- **17.5** Horizontal shear strength
- Bond stress in vertical pull off = horizontal shear stress:

$$v = \frac{Vq}{It} < 1.5 \text{ bond stress}$$

- This differs from 17.5.3.1 where maximum 80 psi is allowed at bond line.



7.4 Bond

562

- 7.4.1.1 The measured bond strength shall not be less than the lower of the required bond strength or the tensile strength of the existing concrete.

318

- Not addressed by ACI 318



7.4 Bond

562

- **7.4.1.2** Testing to measure bond strength of repair materials to existing concrete and the tensile strength of the existing concrete shall be in accordance with ASTM C1583.
- **7.4.1.3** It shall be permitted to provide supplementary reinforcement.

318

- Not addressed in ACI 318.
- **11.6** provides a method of supplementary reinforcement design



7.4 Bond

562

- **7.4.2** The licensed design professional shall verify the concrete substrate has adequate strength to sustain and transfer design forces of externally attached reinforcement.

318

- Not addressed in ACI 318 except this is similar to Appendix D.



7.4 Bond

562

- **7.4.3** Adhesives used to bond existing concrete, repair materials, and repair reinforcement shall transfer required forces between elements.

318

- Not addressed in ACI 318.



7.4 Bond

562

- **7.4.4** The selection of adhesives used in repair shall consider load type and duration and the effect of exposure conditions on adhesive properties.

318

- Not addressed in ACI 318 but addressed for anchors in Appendix D.



7.5 Materials

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- **7.5.1** The licensed design professional shall consider the properties of repair materials and systems in designing repairs and in specifying repair materials and repair procedures.

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Not directly addressed

562 Commentary:

- ACI and ICRI provide guidelines for the selection of repair materials (ACI 301, ACI 318-11, ACI 503R, ACI 503.5R, ACI 503.6R, ACI 546.3R, ICRI No. 320.2R, ICRI No. 320.3, ICRI No. 330.1, and ICRI No. 340.1).



7.5 Materials

- **7.5.2** Materials already in use in a structure shall be permitted to remain in use where such materials conform to the design basis code.
- **7.5.3** Materials conforming to ACI 318-11 or permitted by this code shall be used for repairs and alterations.
- **7.5.4** Alternate materials shall be permitted according to the licensed design professional's approval and in accordance with 1.4.



7.6 Design and detailing considerations

Entirely new section not addressed in ACI 318



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7.6 Design and detailing considerations

- **7.6.1** Repair design shall be based upon the member conditions identified in Chapter 6.
- **7.6.2 Concrete**—The in-place properties of the existing concrete, as identified in Chapter 6, shall be used in the repair design.



7.6 Design and detailing considerations

- **7.6.3.1** Reinforcement that is damaged or corroded shall be permitted to remain....
- At locations where deformations are no longer present, reinforcing bars shall be considered as smooth bars.
- **7.6.3.3** Both existing and new reinforcement shall be adequately developed.



7.6 Design and detailing considerations

- **7.6.4** *Prestressed structures*
- **7.6.4.1** The effects of existing prestressing shall be included in the repair design.
- **7.6.4.2** The effects of modifications to existing structure geometry, existing damage conditions, prestressing force release, and construction sequence shall be included in the repair design.
- **7.6.4.3** Stresses in remaining section after concrete removal shall not exceed the limits established in the design basis code.



7.6 Design and detailing considerations

- **7.6.5 Anchoring to concrete**—Post-installed anchors and dowels shall be designed to transfer design forces to the substrate considering anchor failure modes and the condition of the substrate into which the anchor is installed. The design of post-installed anchors shall be in accordance with ACI 318-11.



7.6 Design and detailing considerations

- **7.6.6 Repair geometry**—Configuration of repairs shall consider the potential for stress concentrations and cracking in both the existing structure and the repair area.



7.7 Repair using supplemental post-tensioning

Entirely new section not addressed in ACI 318.



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7.7 Repair using supplemental post-tensioning

- **7.7.1** Supplemental post-tensioning shall be permitted for repair and rehabilitation of structures.
- **7.7.2.1** Stresses due to supplemental post-tensioning shall be combined with existing stresses and the total shall not exceed the limits in the design basis code.

Essentially, use ACI 318 for design of supplemental PT.



7.8 Repair using fiber-reinforced polymer (FRP) composites

562

- **7.8.1** Fiber-reinforced polymer in conformance with ACI 440.6 shall be permitted to repair existing concrete structures.

Design utilizing FRP is now permitted.

318

- **318 Commentary R3.5.1:** Fiber-reinforced polymer (FRP) reinforcement is not addressed in this Code. ACI Committee 440 has developed guidelines for the use of FRP reinforcement.



7.8 Repair using fiber-reinforced polymer (FRP) composites

562

- **7.8.2** Structural members repaired or modified with externally-applied FRP composites shall have adequate unrepaired strength, as defined in 5.5.

(5.5.1):

$$U_{ex} \geq 1.2D + 0.5L + A_k + 0.2S$$

318

- Not addressed in ACI 318.



7.9 Performance under fire and elevated temperatures

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- **7.9.1** Design of the repair system shall consider elevated temperature performance and shall comply with the fire resistance ratings of the structural members and other fire safety requirements in accordance with the general existing building code.

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- **7.7.8 Fire protection**

If the general building code (of which this Code forms a part) requires a thickness of cover for fire protection greater than the concrete cover in 7.7.1 through 7.7.7, such greater thicknesses shall be specified.



7.9 Performance under fire and elevated temperatures

562

- **7.9.2** It shall be permitted to design a repair without supplemental fire protection if the unrepaired member has adequate strength in accordance with 5.5.

(5.5.1):

$$U_{ex} \geq 1.2D + 0.5L + A_k + 0.2S$$

318

- Not addressed in ACI 318.



7.9 Performance under fire and elevated temperatures

- **7.9.3** The properties of the specified repair materials at elevated temperatures shall be considered.
- **7.9.4** Repairs using adhesives shall consider their performance at elevated temperatures.
- **7.9.5** Supplemental fire protection to improve the fire rating of repaired systems shall be permitted.



7.9 Performance under fire and elevated temperatures

562

- **7.9.6** Fire rating of repaired systems, based on ACI 216.1, shall be permitted.

318 REFERENCE

- *ACI 216.1-07—Code Requirements for Determining Fire Resistance of Concrete and Masonry Construction Assemblies*



Concluding Remarks

- Repair design is straightforward:

Design Basis Code + Engineering Logic



Thank you

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