The ACI 562 Repair Code

Code Requirements for Evaluation, Repair and Rehabilitation of Concrete Buildings

by

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Why a Repair Code?

• Long-term industry need
  – Variations in practice
  – Variations in repair performance
  – Establish required minimum practice
  – Help for building officials

• Large segment of construction industry
  – 20 Billion dollars
  – 8 Billion dollars in corrosion damage
Why a Repair Code?

- Repair performance
  - COE - 50% of repairs are not performing satisfactorily
    - Design errors
    - Construction errors
    - Material selection errors
  - Con Rep Net
    - 5 years – 80% of repairs are satisfactory
    - 10 years – 30% of repairs are satisfactory
    - 25 years – 10% of repairs are satisfactory
Why not a Repair Code?

• Complicated process
  – Took 7 years to develop

• Lack of consensus on practice
  – Lots of arguments

• Establish minimum practice requirements
  – What are minimum requirements?

• Concern about limiting creative solutions

• Fear of something new
Motivation

• ACI 318 Survey
  – One-half use for repair of existing structures
  – Use for non-building structures
• Conclusions from ACI 318 Survey
  – ACI 318 functioning beyond its intent
  – Code guidance for repairs is needed
Motivation

• Vision 2020
• Create a repair/rehabilitation code to:
  – Establish evaluation, design, materials and construction practices
  – Raise level of repair/protection performance
  – Establish clear responsibilities
  – Provide Building Officials with means to issue permits
Motivation

- Challenges of existing structures
  - Hidden damage
  - Unknown structural conditions
Motivation

• Lack of specific code requirements:
  – Variations in repair practice
  – Different levels of safety and reliability
  – No direction for building officials
Building Codes

- Developed by consensus process
  - Written by code writing organization
  - Code committee
    - Membership balance
    - Producers / Users / General Interest
- Written for design professionals
  - Architects and engineers

Code of Hammurabi
1772 B.C.
Building Codes

• Adopted in law
  – Into a general building code

• ANSI Standardization Process
  – Approval of code writing committee
  – Approval of code writing organization
  – Publication for public comments
  – Verification process is followed
Codes vs. Guidelines

• Codes
  – Adopted by regulatory agencies
  – Mandatory language (shall not should)
  – Establish **required** practice
  – ACI 318, ASCE 7, IBC, IEBC - codes

• Guidelines
  – Non-mandatory language (**should** not shall)
  – Establish **recommended** practice
  – ACI 364, ICRI documents - guidelines
Code vs. Commentary

- **Code**
  - Mandatory language (shall not should)
  - Requirements to be followed
  - Only codes and standards as references

- **Commentary**
  - Guidance on how to satisfy code
  - Non-mandatory language
  - The why and the how
  - Any references can be used
How was ACI 562 Developed?

• Committee formed in Spring 2006
• ACI code committee – “Evaluation, Repair and Rehabilitation of Concrete Buildings”
• Starting points
  – Existing U.S. building codes
  – Existing international repair codes
  – Philosophy of code
Review of Existing Codes

• U.S. Codes
  – ACI 318, Chapter 20
  – IBC, Chapter 34
    • 5% rule trigger for upgrade to current code
    • Repair requirements vary with edition
  – International Existing Building Code
    • First published in 2003
    • ACI 562 developed for adoption into IEBC
ACI 562 - Philosophy

- Emphasize performance based rather than prescriptive requirements
- Encourage creativity and flexibility
- Enhance life safety (equivalent safety)
- Extend service life
- Provide sustainable and economic alternative
- Establish responsibilities
ACI 562 - Organization

- Part I – General
  - General Requirements – Chapter 1
  - Terms / Definitions – Chapter 2
  - Standards – Chapter 3

- Part II - Evaluation Requirements
  - Design Basis – Chapter 4
  - Loads – Chapter 5
  - Analysis of Existing Structures – Chapter 6

- Part III – Implementation
  - Structural Repair Design – Chapter 7
  - Durability – Chapter 8
  - Construction – Chapter 9
  - Quality Assurance – Chapter 10
Responsibilities

• Licensed Design Professional
  – Evaluation
  – Repair & durability design

• Constructor – through plans and specifications
  – Construction sequencing, means & methods
  – Follow evaluation and design specifications
  – Report uncovered defects

• Owner – through general building code
  – Known conditions and maintenance
ACI 562 – Key Points

- Determine design basis for repairs
- Preliminary evaluation
  - Substantial structural damage
- Analysis, design and durability
- Quality assurance
- Maintenance and monitoring
Design Basis Code

• General building code under which the project is completed

• Possible design basis codes:
  – IBC
  – IEBC
  – Local building code - general building code
  – ACI 318
  – Combination of ACI 318 and 562
When do structures need to satisfy current codes?

- IBC – Chapter 34
  - If alterations or additions increase force in a structural element by more than 5%
  - Repairs to elements that are found to unsound or structurally deficient
- IEBC
  - When substantial structural damage has occurred
- When required by a local code or building official
**Applicability**

- Existing concrete buildings
- Superstructure, foundations (slabs), precast elements – structural load path
- Structural vs. nonstructural – “Unsafe”
- Composite members – concrete
- Nonbuilding structures when required
Controversy – Maintenance

- To assure durable repairs
- “Maintenance recommendations shall be documented…”
- “A maintenance protocol should be provided…”
Preliminary Evaluation

- Preliminary evaluation
  - Determine extent of structural damage present
  - Evaluation based upon in-place conditions
  - Can use assumed material properties

- Substantial structural damage?
  - Determines if compliance with current code is required
Substantial Structural Damage

• Defined in IEBC
  – Reduction of greater than 33% to the vertical elements of the lateral force resisting system
  – Reduction of greater than 20% of the vertical capacity in an area that supports more than 30% of the structures area
  – Requirements vary with IEBC edition

• Trigger for upgrade of structure to current code requirements
Evaluation & Analysis

- Preliminary evaluation
- When there is reason to question
- Structural assessment/structural analysis
- As-measured section properties and dimensions
- Material properties
  - Available documents + historical tables
  - Tests
Evaluation

- Determine existing conditions
- Safety – shoring
- Based on in-situ geometric and material properties
- Number of samples (ACI 214)
- Load tests (ACI 437 versus ACI 318)
Load and Resistance Factors

- Resistance, capacity reduction factors, $\Phi$
  - Measured properties
  - Failure mode
  - Historic material properties
  - Default values
Loads and Load Combinations

- Essentially ASCE/SEI 7 (ACI 318)
- Construction, unoccupied ASCE/SEI 37
- External reinforcing systems
  - $U_{ex} = 1.2D + 0.5L + A_k + 0.2S$
  - Fire + elevated temperature with FRP
  - External unprotected reinforcement
Φ factors

• Encourage confirmation of material properties

• Φ factor from ACI-318
  – No confirmation of material properties

• ACI 318 Chapter 20 if material properties are confirmed
  – $\Phi_{\text{tension}} = 1$
  – $\Phi_{\text{compression}} = 0.9$
  – $\Phi_{\text{shear}} = 0.8$
Analysis, Design and Durability

- Performance based – 3D, nonlinear or…
  - Make a patch or add a wall
- Actual load and force distribution
- Reinforcement and repair materials
  - e.g. FRP’s and polymer concretes
- Compatibility
- Fire resistance
- Service life
Analysis

- Member properties
- Material degradation
- Deformed condition
- Redistribution of forces
- Shrinkage & creep
- Soil-structure interaction
- Load path
Seismic Resistance

• ASCE/SEI 31 – Seismic Evaluation
• ASCE/SEI 41 – Seismic Rehabilitation
• Implications for building officials, West coast vs.
Evaluation & Analysis - Testing

- Destructive & nondestructive
- Cores (ASTM C42 & C823)
- NDT when valid correlation is established.
- Steel Reinforcement: historical values, samples (ASTM A370)
Load Testing

• ACI 437-13
  – New code for load testing

• Why not ACI 318-11 Chapter 20?
Design of Structural Repairs

- Strength & Serviceability
- Effect of repair on structural system
- Composite behavior
  - Tensile strength
  - Adhesives
  - Pull-off test

Bond: 1.5 x required ++
Reinforcing

- FRP (ACI 440.6) and steel
- Fire (external reinforcement)
  \[ U_{ex} = 1.2D + 0.5L + A_k + 0.2S \]
- Existing prestressing
- Supplemental posttensioning
  - Secondary effects
  - Define repair sequence: removal, placement, stressing
Durability

• Durable materials
  – interaction with existing structure (compatibility)
  – in environment
  – anticipated maintenance
• Corrosion protection & cover
• Corrosion & deterioration of reinforcement
  – Corrosive environment
  – Existing reinforcement
  – Galvanic action
• Cracks
Construction

• Stability and shoring
  – Designed by an LDP
  – Consider: sequence, in-situ conditions, changes in conditions
Construction

• Temporary conditions
  – ASCE/SEI 37 when feasible
  – Stalled projects?

• Environmental
  – Instructions to contractor
    • Report new conditions
    • Control of debris
Quality Assurance

• Require testing and inspection
  – Commentary list of items to inspect

• Repair inspectors should be qualified by demonstrating competence

• LDP may inspect their projects

• Testing as required by LDP

• Existing conditions shall not be concealed
  – Construction observation
ACI 562 - Going Forward

- Published by ACI in March 2012
- New code cycle
  - Starts at upcoming ACI convention
  - Work towards adoption into IEBC
- Education on using ACI 562
  - ICRI 150 Notes
  - Seminars
  - Presentations
ACI 562 - Going Forward

- Improve the state of practice
- Incorporate work of other committees / groups
  - Repository of knowledge
  - ACI Guidelines
  - ICRI Documents
Impact

• Cost savings for repair of repair in $ billions
• Code requires accountability of both engineers and contractors
• Repair industry is a serious endeavor –
  – Education and skills required
• Engineering requirements lead to clear specifications and increased quality
• Safer structures
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Thank You

Questions?