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Learning Objectives:

- To recognize why a design code specific to concrete repair and rehabilitation is needed to ensure safe structures.
- To understand the difference between the ACI 562 Repair Code and the many guides to repair that are available.
- To describe the governing philosophy and organization behind the creation of the ACI 562 Repair Code and
- To identify the scope of each chapter of the new ACI 562 Repair Code.
THE ACI 562 REPAIR CODE

HOW DOES IT AFFECT YOUR CONCRETE REPAIR PROJECT?

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Presentation Goals

• Background on Code Requirements for Evaluation, Repair and Rehabilitation of Concrete Buildings (ACI 562-13)
• Code development process
• How ACI 562 works – How it affects your project
  Key provisions
  Changes in concrete repair practice

ACI 562 – Key Points

• Developed to improve concrete repair practice
• Performance-based code
• Help design professionals and building officials
• Work in progress
  Committee interested in feedback
  Working on adoption into IEBC-18
Presentation Outline

• Introduction
  – Why a Repair Code
  – Why not a Repair Code
• Code Attributes
  – Building Code Process
  – Codes vs. Guidelines
  – Code vs. Commentary
• ACI 562
  – Development
  – Revision of Existing Codes
  – Philosophy & Organization
  – Responsibilities
  – Changes in IBC / IEBC
• Specifics of 562
  – When Applicable
  – Maintenance
  – Preliminary Evaluation
  – Evaluation
  – Analysis
  – Load Testing
  – Reinforcement
  – Durability
  – Construction
• Future of 562
  – Going Forward
  – Impact

Why a Repair Code?

• Vision 2020 – ACI Strategic Development
  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
• 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 a Repair Code?

- Lack of specific code requirements:
  Variations in repair practice
  Different levels of safety / reliability
  No direction for building officials

- Challenges of existing structures
  Hidden damage
  Unknown structural conditions

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
Building Codes

- Developed by consensus process (ANSI approved)
  - Written by code writing organization
  - Code committee
  - Membership balance
  - Producers / Users / General Interest
- Written for design professionals
  - Architects and engineers
- Adopted in law
  - General building code
  - Feeder building codes – ACI 318

Code vs. Commentary vs. Guidelines

- Code
  - Adopted by regulatory agencies
  - Mandatory language (shall not should)
  - Establish required practice
- Commentary – usually written by code committee
  - Non-mandatory language (should not shall)
  - Guidance on how to satisfy code
- Guidelines
  - Non-mandatory language (should not shall)
  - Establish recommended practice

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
- Promote innovation and new materials
- Establish responsibilities
- Enhance life safety (equivalent safety)
- Extend service life
- Provide sustainable and economic alternatives
- Use ACI and other “code” documents by reference

Responsibilities

- Licensed Design Professional
  - Evaluation
  - Repair & durability design
- Constructor – through plans and specifications
  - Follow evaluation and design specifications
  - Report uncovered defects
  - Construction sequencing, means & methods
- Owner – through general building code
  - Known conditions and maintenance
Design Basis Code

• General building code under which the repair project is completed
• Possible design basis codes:
  IBC
  IEBC
  Local building code, i.e., NYC 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

Changes in IBC and IEBC

• 2012 Cycle (2015 IBC Code)
  ICC Board approves deletion of Chapter 34 of the IBC in favor of reference to the IEBC
• 2015 IBC
  Will no longer include Chapter 34 entitled Existing Structures
• 2015 IEBC
  Adopted for use in most states and jurisdictions
ACI 562 - Applicability

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

Preliminary Evaluation

- Preliminary evaluation
  - Determine extent of structural damage present
  - Evaluation based upon in-place conditions
  - Can use assumed material properties
  - Establish design basis code
- 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 structure’s 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 performance or safety
- Structural assessment/structural analysis
- As-measured section properties and dimensions
- Material properties
  - Available documents + historical tables
  - Tests

**Evaluation & Analysis - Testing**

- Destructive & nondestructive [6.4]
- Cores (ASTM C42 & C823) [6.4.3]
- NDT when valid correlation is established [6.4.3.1]
- Steel Reinforcement: historical values, samples (ASTM A370) [6.4.4 - 6.4.10]

**Load and Resistance Factors**

- Resistance, capacity reduction factors, $\Phi$ [5.3 & 5.4]
  - Measured properties [6.3]
  - Failure mode
  - Historic material properties [Table 6.3.1]
- Load Factors – Default values ASCE [6.3]
Loads and Load Combinations

- Essentially ASCE/SEI 7 (ACI 318) [5.1.6]
- Construction, unoccupied ASCE/SEI 37 [5.1.4]
- External reinforcing systems [5.5]
  \[ U_{ue} = 1.2D + 0.5L + A_d + 0.2S \]
  Fire + elevated temperature with FRP
  External unprotected reinforcement

Φ factors

- Encourage confirmation of material properties
- Φ factors from ACI-318
  No confirmation of material properties
- ACI 318 Chapter 20 if material properties are confirmed
  \[ \Phi_{tension} = 1 \]
  \[ \Phi_{compression} = 0.9 \]
  \[ \Phi_{shear} = 0.8 \]

Typical Repair Project

- Preliminary evaluation
  Determination if substantial structural damage has occurred
  IEBC trigger for upgrade to current code requirements
  Establish design basis code
- Must consider
  Impact of damage present
  In-place geometry and material properties
Typical Repair Project

• Structural evaluation [6.1]
  Structural assessment, structural analysis or both
• Structural assessment?
  How bad is the structure

Typical Repair Project

• Structural analysis – required when?
  Preliminary evaluation results
  Reason to question performance
  Insufficient information
• Similar elements?
  Consider if additional elements require evaluation and repair

Critical Code Sections [6.1]

• “If the strength of a structure is known, improvements to the strength, serviceability, durability, and fire performance of a structure shall be permitted without performing a structural evaluation.”

Voluntary improvements can be made

Intent is to simplify procedure
Critical Code Sections [6.1]

- "If determined by the structural assessment that the strength of a structure is not in question, structural analysis is not required."

  Performance criteria

  Responsibility of LDP to determine

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Critical Code Sections [6.1]

- "Where repairs are required on an element in a structure, it shall be determined if similar elements throughout the structure also require evaluation."

  Repetitive elements

  Isolated repairs may not be acceptable

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Unknown Structural Capacity

- Lack of design drawings
  - Determine geometry
  - Determine loads

- In-situ conditions
  - ACI 201
  - ACI 228.1
  - ACI 364
  - ACI 437
  - ASCE Guidelines
Unknown Structural Capacity

- Unknown material properties
  - Historical values
  - Physical testing
- # of samples?
- # of elements?
- NDT – with correlation

Analysis, Design and Durability

- Performance based – 3D, nonlinear or… [6.5]
  - Make a patch or add a structural wall
- Actual load and force distribution [6.5.4]
- Reinforcement and repair materials [7.5.1]
  - e.g. FRP’s and polymer concretes
- Compatibility [7.3.2]
- Fire resistance [7.9]
- Service life [8.1.2]

Seismic Resistance

- ASCE/SEI 31 – Seismic Evaluation
- ASCE/SEI 41 – Seismic Rehabilitation [1.1.8 & 7.6.4]
- ASCE/SEI Guidelines used in IBC and IEBC
Load Testing

• ACI 437-13 [6.8]
  New code for load testing
• Why not ACI 318-11 Chapter 20?

Load Testing

• Load testing (ACI 437-13) [6.8]
  More rational for existing structures
  Lower DL
  Shorter hold
  Service load evaluation
• Model testing
  Supplement analysis

Design of Structural Repairs

• Strength & Serviceability [7.1, 7.2]
• Effect of repair on structural system [7.3]
• Composite behavior
  Tensile strength
  Adhesives
  Pull-off test

  Bond: 1.5 x required ++ [7.4]
Repair Design

- Bond [7.4]
  - Critical to performance of a repair
  - Bond strength greater than 1.5 times the required bond capacity
  - Tensile strength of concrete
- Testing – ASTM C 1583
- $\sqrt{f'}c$ in lieu of testing

Supplemental measures

Reinforcing

- FRP (ACI 440.6) and steel
- Fire (external reinforcement)
  - $U_{u} = 1.2D + 0.5L + A_{k} + 0.2S$
- Existing prestressing
- Supplemental posttensioning
  - Secondary effects
  - Define repair sequence: removal, placement, stressing

Durability

- Durable materials [8.1.1 & 8.1.2]
  - Interaction with existing structure (compatibility)
  - In environment
  - Anticipated maintenance
- Corrosion protection & cover [8.2]
Durability

- Corrosion & deterioration of reinforcement [8.4]
  - Corrosive environment
  - Existing reinforcement
  - Galvanic action
- Cracks [8.3]

Construction

- Stability and shoring
  - Designed by an LDP
  - Consider: sequence, in-situ conditions, changes in conditions
- Temporary conditions
  - ASCE/SEI 37 when feasible
  - Stalled projects?
- Environmental
  - Instructions to contractor
  - Report new conditions
  - Control of debris
Controversy – Maintenance

- To assure durable repairs
- Protect design professionals
- "Maintenance recommendations shall be documented…” [1.5.2 & 1.7]
- “A maintenance protocol should be provided…” [1.7C]

Typical Repair Project

- Quality Assurance Plan [10.1]
  Required by general building code
  Part of contract documents
- Maintenance Plan [1.5.2 and 1.7]
  Document specific requirements for owner
  Protect design professional

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
Summary of ACI 562

- Performance-based code for existing concrete structures
- Intended to improve repair practice
  - More flexibility
  - More creativity
  - Greater ability to accommodate new materials
- Help design professionals
- Rational basis for repair permits

ACI 562 - Going Forward

- Improve the state of practice
- Incorporate work of other committees / groups
  - Repository of knowledge
  - ACI Guidelines
  - ICRI Documents
- Education on using ACI 562 - 13
  - ICRI / ACI Guide to Use of ACI 562
  - Seminars
  - Presentations

Impact of ACI 562

- 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 leading to clear specifications and increased quality
- Safer structures
Acknowledgements

15 Engineers, 4 Academics, 3 Contractors, 1 Material supplier, 1 Owner, 1 Building official

Thank You

Questions?
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Thank you
For the most up-to-date information please visit the American Concrete Institute at: www.concrete.org