# Introduction to the Concrete Repair Code (ACI 562)

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# Introduction to the Concrete Repair Code (ACI 562)

## 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.

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# THE ACI 562 REPAIR CODE

## HOW DOES IT AFFECT YOUR CONCRETE REPAIR PROJECT?

KEITH KESNER – CHAIR ACI 562

LARRY KAHN – FORMER CHAIR ACI 562



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- Fifth level



## 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 of Hammurabi
1772 B.C.



## 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 then 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 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, Φ [5.3 & 5.4]
  - Measured properties [6.3]
  - Failure mode
  - Historic material properties [Table 6.3.1]
- Load Factors – Default values ASCE [6.3]

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## 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]
  - $U_{ex} = 1.2D + 0.5L + A_k + 0.2S$
  - Fire + elevated temperature with FRP
  - External unprotected reinforcement

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## 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
  - $\Phi_{tension} = 1$
  - $\Phi_{compression} = 0.9$
  - $\Phi_{shear} = 0.8$

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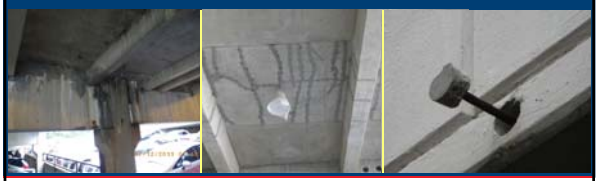
## Typical Repair Project

- 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



## 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

## 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



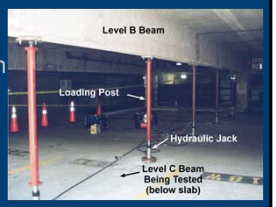
## Load Testing

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



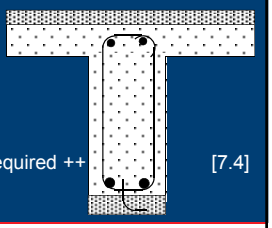

## Load Testing

- 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]



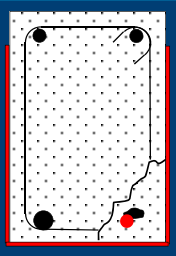
## Repair Design

- 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
- 4 √f'c in lieu of testing
  - Supplemental measures



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



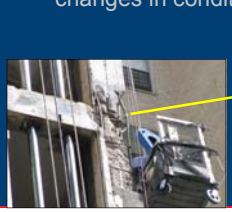
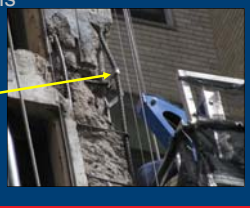

## Durability

- 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

## Construction

- Temporary conditions
  - ASCE/SEI 37 when feasible
  - Stalled projects?
- Environmental
  - Instructions to contractor
- Report new conditions
- Control of debris

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## 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]

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## 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

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## 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

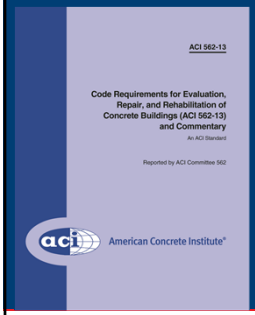


## Acknowledgements

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



## Thank You




**Questions?**

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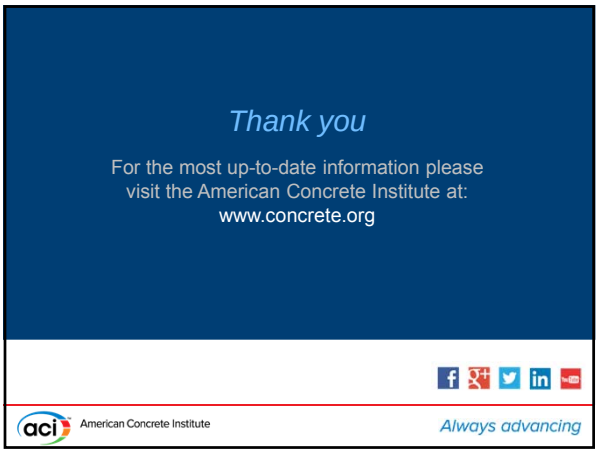
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