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

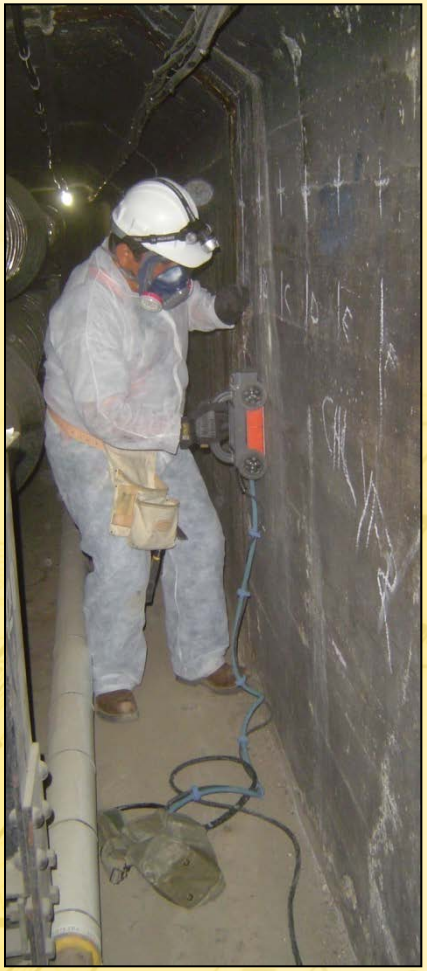
- Defined in IEBC
  - Reduction of greater than 33% to the vertical elements of the lateral force resisting system
  - Reduction of greater than 20% of the vertical capacity in an area that supports more then 30% of the structures area
  - Requirements vary with IEBC edition
- Trigger for upgrade of structure to current code requirements

Evaluation & Analysis

- Preliminary evaluation
- When there is reason to question
- 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

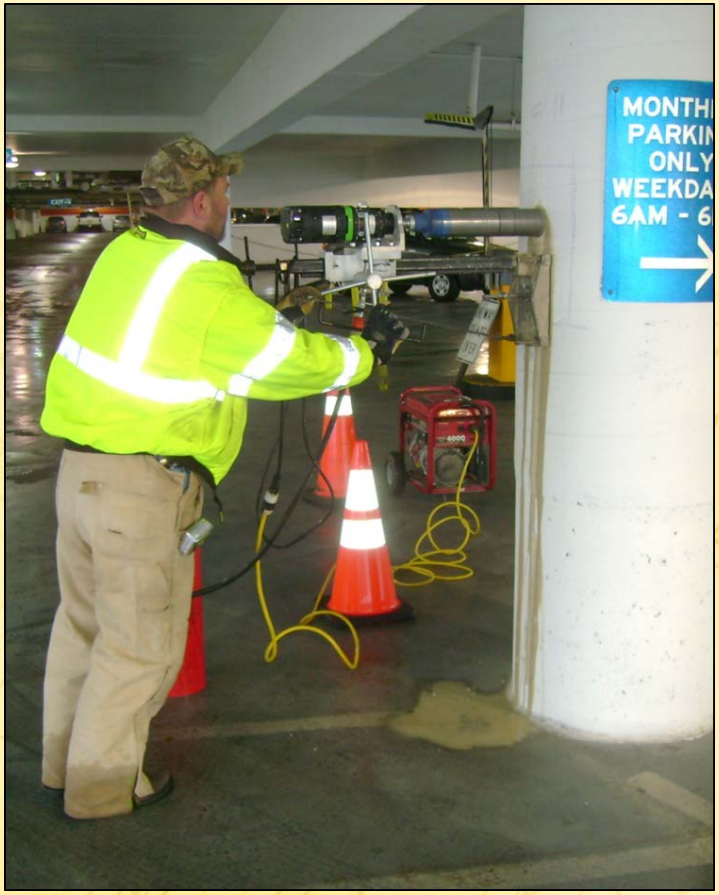
- Resistance, capacity reduction factors, Φ
  - Measured properties
  - Failure mode
  - Historic material properties
  - Default values

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



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

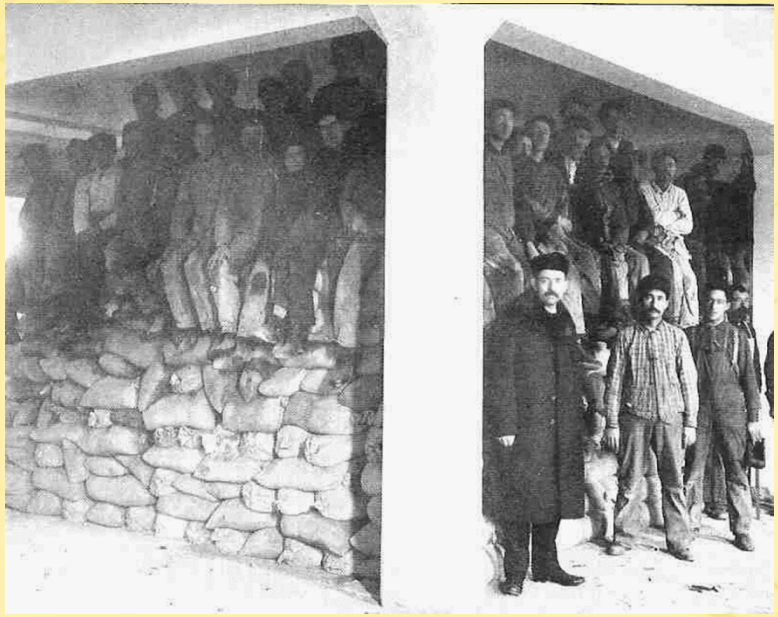
- ASCE/SEI 31 – Seismic Evaluation
- ASCE/SEI 41 – Seismic Rehabilitation
- Implications for building officials, West coast vs. ….

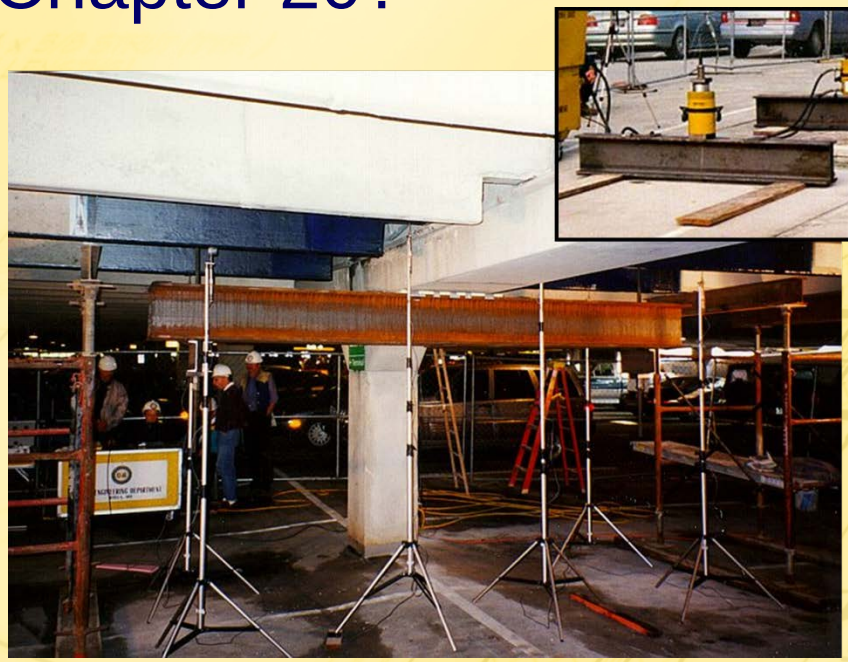
Evaluation & Analysis - Testing

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

Load Testing

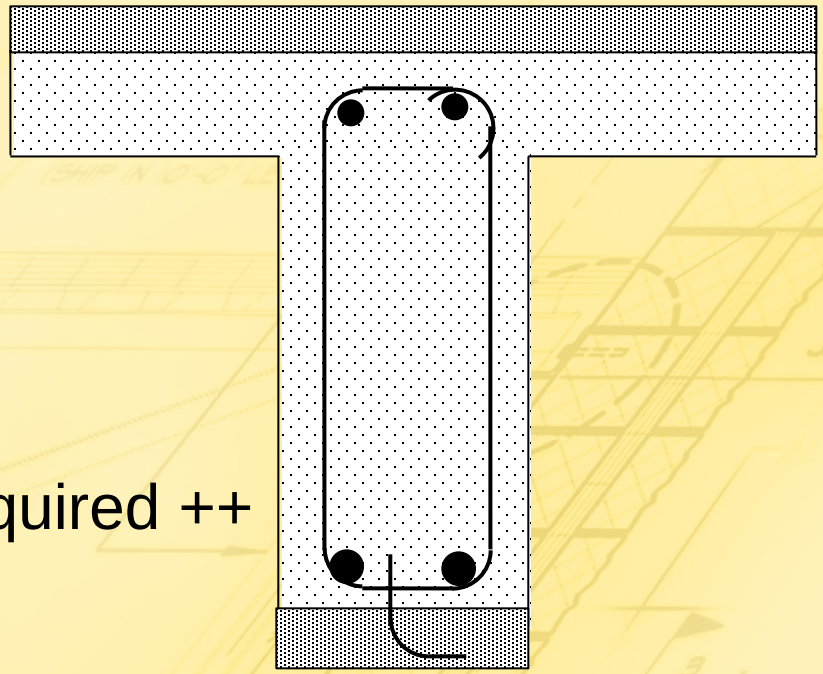
- ACI 437-13
  - New code for load testing
- Why not ACI 318-11 Chapter 20?





Design of Structural Repairs

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



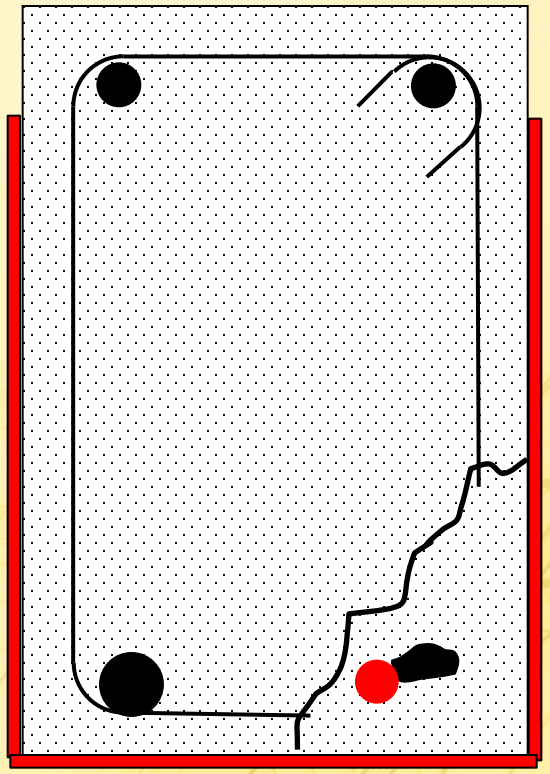
Bond: 1.5 x required ++

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

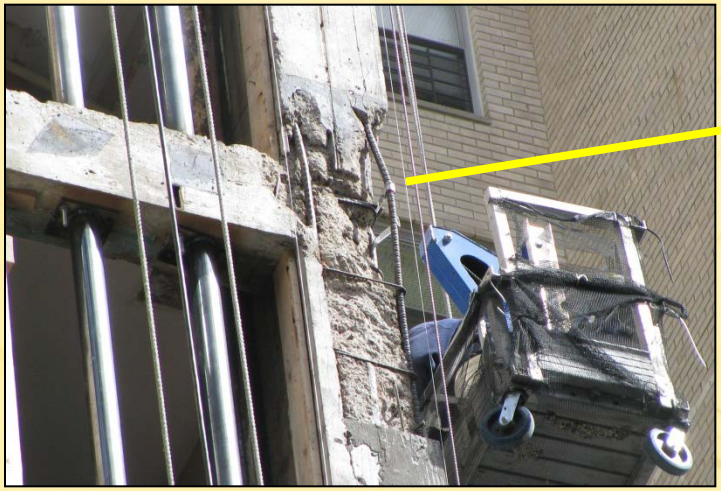


Durability

- 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

Acknowledgements

- ACI TAC for approval of code
- Efforts of ACI and ICRI members in creating code
  - 15 Engineers
  - 3 Academics
  - 3 Contractors
  - 1 Material supplier
  - 1 Owner
  - 1 Building code official

Thank You

Questions?