

An ACI Standard

Code Requirements for Assessment, Repair, and Rehabilitation of Existing Concrete Structures (ACI 562-19) and Commentary

Reported by ACI Committee 562

ACI 562-19



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Code Requirements for Assessment, Repair, and Rehabilitation of Existing Concrete Structures and Commentary

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Code Requirements for Assessment, Repair, and Rehabilitation of Existing Concrete Structures (ACI 562-19) and Commentary

An ACI Standard

Reported by ACI Committee 562

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ACI 562-19, "Code Requirements for Assessment, Repair and Rehabilitation of Existing Concrete Structures," was developed to provide design professionals a code for the assessment of the damage and deterioration, and the design of appropriate repair and rehabilitation strategies. The code provides minimum requirements for assessment, repair, and rehabilitation of existing structural concrete buildings, members, systems and where applicable, nonbuilding structures. ACI 562-19 was specifically developed to work with the International Existing Building Code (IEBC) or to be adopted as a stand-alone code.

Keywords: assessment; bond; corrosion; damage; durability; evaluation; existing structure; fiber-reinforced polymer (FRP); interface bond; licensed design professional; maintenance; rehabilitation; reliability; repair; strengthening.

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PREFACE

This code provides minimum requirements for assessment, repair, and rehabilitation of existing structural concrete buildings, members, systems and where applicable, nonbuilding structures. This code was developed by an ANSI-approved consensus process. This code can supplement the International Existing Building Code (IEBC), supplement the code governing existing structures of an authority having jurisdiction, or act as a stand-alone code in a locality that has not adopted an existing-building code. When this code is adopted as a stand-alone code, **Appendix A** should be used in place of **Chapter 4**.

The Code is specifically written for use by a licensed design professional. This code provides minimum requirements for assessment, design and construction, or implementation of repairs and rehabilitation, including quality assurance requirements, for structural concrete in service. This code has no legal status unless it is adopted by the authority having jurisdiction. Where the code has not been adopted, it serves as a standard to provide minimum requirements for assessment, and design and construction of repair and rehabilitation of existing structural concrete. **ACI 318** provides minimum requirements for the materials, design, and detailing of structural concrete buildings and, where applicable, nonbuilding structures, and for new construction within existing structures where noted herein.

Key changes from ACI 562-16 to ACI 562-19 include:

- (a) Text was added to simplify use of new materials that have the equivalent of an ICC-ES evaluation report in **Chapter 1**.
- (b) The requirements for the basis of design report were simplified in Chapter 1.
- (c) Requirements related to detailing of existing reinforcing steel in Chapter 4 have been clarified.
- (d) The commentary in **Chapter 8** was updated to include a listing of exposure categories that may affect durability.



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CODE

CHAPTER 1—GENERAL REQUIREMENTS

1.1—General

1.1.1 ACI 562, “Code Requirements for Assessment, Repair, and Rehabilitation of Existing Concrete Structures,” is hereafter referred to as “this Code.”

1.1.2 Scope—This code shall apply to assessment, repair, and rehabilitation of existing concrete structures as:

1. A code supplementing the International Existing Building Code (IEBC)
2. As part of a locally adopted code governing existing buildings or structures
3. Or as a stand-alone code for existing concrete structures

1.1.3 The intent of this Code is to safeguard the public by providing minimum structural requirements for existing structural concrete members, systems, and buildings.

1.1.4 All references in this code to the licensed design professional shall be understood to mean persons who possess the knowledge, judgment, and skills to interpret and properly use this code and are licensed in the jurisdiction where this code is being used. The licensed design professional for the project is responsible for, and in charge of, the assessment or rehabilitation design, or both.

COMMENTARY

R1—GENERAL REQUIREMENTS

R1.1—General

R1.1.2 This code defines assessment, design, construction and durability requirements for repair and rehabilitation of existing concrete structures. Throughout this code, the term “structure” means an existing building, member, system, and, where applicable, nonbuilding structures where the construction is concrete or mixed construction with concrete and other materials.

Chapter 4 provides assessment, repair, and rehabilitation criteria if this code is used as a supplement to the International Existing Building Code (IEBC) for concrete members and systems.

Appendix A provides assessment, repair, and rehabilitation criteria when this Code is adopted, including Appendix A, as a stand-alone code for repair of existing concrete structures.

R1.1.3 The intent of this code is to address the safety of existing structures through assessment requirements that demonstrate an approximation of the structural reliability using demand-capacity ratio limits of Chapter 4 or Appendix A and, if necessary as determined by the assessment, increase the structural capacity by repair or rehabilitation.

Unless prohibited by the authority having jurisdiction, if an existing structure is shown to be potentially dangerous in accordance with 4.3 or A.3, the structure should be rehabilitated using 4.3 or A.3.

Using the demand-capacity ratio limits of 4.5.1 or A.5.1, repair of the existing structural concrete to its predeteriorated state is permitted based on material properties specified in the original construction (per Chapter 6), and substantiated engineering principles of the original design. Where requirements of the original building code are appreciably changed in the current building code, the licensed design professional may consider using 4.5.2 or A.5.2.

Beyond the restoration assessment requirements of 4.5.1 and 4.5.3 or A.5.1 and A.5.3, the structural reliability principles of 4.5.2 or A.5.2 are permitted. These alternative requirements provide acceptable safety if the current building code demand exceeds the original building code demand or if the regulations of the original building code provide an unacceptable level of structural reliability.

CODE

1.1.5 The requirements of this code are provided using strength design provisions for demands and capacities, unless otherwise noted.

1.2—Criteria for the assessment and design of repair and rehabilitation of existing concrete structures

1.2.1 The “existing building code” refers to the code adopted by a jurisdiction that regulates existing buildings or structures.

1.2.2 The “current building code” refers to the general building code adopted by a jurisdiction that regulates new building design and construction.

1.2.3 The “original building code” refers to the general building code applied by the authority having jurisdiction to the structure in question at the time the existing structure was permitted for construction.

COMMENTARY

R1.1.5 When this code permits the original building code regulations to be used and that code uses allowable stress design, the following should be considered: those provisions should be substituted for strength design as noted in [4.5.3](#) or [A.5.3](#); the licensed design professional is not required to use, but should consider using strength design provisions of this code as a check in the assessment of existing structures originally designed with allowable stress methods.

R1.2—Criteria for the assessment and design of repair and rehabilitation of existing concrete structures

R1.2.1 The code governing existing buildings in the United States is commonly the **IEBC** developed by the International Code Council (ICC). The IEBC provides regulations for evaluations of damage and the limit for damage to be repaired using the original building code.

R1.2.2 The current building code establishes the design and construction regulations for new construction. Strength design regulations of the current building code include:

- (a) Required strengths computed using combinations of factored loads (strength design demands)
- (b) Design strengths (capacities) based on testing of materials, members, and systems
- (c) Analytical methods used to calculate member and system capacity
- (d) Strength reduction factors, which have been established to be consistent with reliability indices used with the strength design demands

The load factors and strength reduction factors in the current building code are obtained through rational design code calibration procedures to achieve the targeted reliability indices which produce historically acceptable structural safety for new structures. The targeted reliability indices are generally based on past structural behavior, engineering experiences, costs and consequences of loss, among other criteria. The resulting demand-capacity ratios for new structures provide the limits that are not to be exceeded if designing new construction, but these demand-capacity ratio limits need not to be the same as those for existing structures as noted in sections [4.5.2](#) and [A.5.2](#).

The general building code in the United States is usually based on the International Building Code (**IBC**) published by the ICC. Prior to 2015, Chapter 34 of the IBC included provisions for existing structures. For the design and construction of new concrete structures, the IBC and most other older general building codes often reference [ACI 318](#), Building Code Requirements for Structural Concrete and Commentary, with exceptions and additions.

R1.2.3 This definition of “original building code” is consistent with the building code in effect at the time of original permitted construction per the IEBC. In assessing existing structures, the licensed design professional may wish to consider changes in the codes enforced by the local authority.

CODE

COMMENTARY

1.2.4 *Design-basis code criteria*

1.2.4.1 The design-basis code criteria in this Code shall be used to assess and design repairs of existing members, systems, and structures.

having jurisdiction for the structure from the time of the original design through the time of the completion of construction. For buildings with major alterations or additions, the original building code should refer to the code in effect when the subject portion of the building was permitted, and different portions of a building may have different original building codes.

Reference to design requirements of the original building code should include: demands determined using either nominal loads, load factors, and load combinations of the original building code, or using allowable design loads and load combinations of the original building code; capacities determined using either strength design and reinforcement detailing provisions, and strength reduction factors of the original building code or using allowable stress design provisions of the original building code; and construction materials. Requirements for concrete design and construction include previous versions of **ACI 318**, concrete codes predating ACI 318, or concrete provisions within the original building code. A structural assessment using allowable stress design provisions of the original building code should be coupled with an evaluation using current standards or the strength design and reinforcement detailing provisions of this code to increase the understanding of structural behavior.

For a structure constructed prior to the adoption of a building code, the licensed design professional should research available standards and practices in effect at the time of construction. The Historic American Engineering Record, a program of the United States Park Service, has information on construction and preservation of historic structures (<https://www.nps.gov/hdp/haer/>).

R1.2.4 *Design-basis code criteria*

R1.2.4.1 The design-basis code criteria include requirements for assessment of the existing structure and for design when repairs are required based upon assessment results.

If a jurisdiction has adopted the **IEBC** and **ACI 562** is used, then the design-basis code criteria are based on the IEBC with supplemental requirements of this code for potentially dangerous structural conditions, damage less than substantial structural damage, deterioration of concrete and reinforcement, faulty construction, serviceability issues, and durability of existing concrete.

For substantial structural damage, additions, alterations, and changes in occupancy, the IEBC establishes limits to which an assessment and design of repair and rehabilitation can occur in accordance with the original building code. Above these limits, an assessment and design of the repair and rehabilitation is in accordance with the current building code. Current and original building code provisions are supplemented by this code to address existing concrete members, systems, and structures.

Appendix A applies if a jurisdiction has not adopted the IEBC and has adopted this code. Appendix A outlines how to provide design-basis code criteria for potentially dangerous

CODE

COMMENTARY

1.2.4.2 Assessment and design-basis criteria and the requirements for applying these criteria are provided in **Chapter 4** and **Appendix A**. Chapter 4 applies if a jurisdiction has adopted the International Existing Building Code (**IEBC**) as the existing building code. Appendix A applies if a jurisdiction has not adopted the IEBC or if a jurisdiction has adopted this code.

1.2.4.3 Assessment criteria shall be used to classify the work and to establish the design-basis criteria.

1.2.4.3.1 It shall be permitted to use the current building code as the assessment criteria for all existing structures.

1.2.4.4 Design-basis criteria shall be used to establish the applicable building code for repair and rehabilitation design.

1.2.4.5 The current building code shall be the design-basis code for new members and for connection of new members to existing structures.

1.2.4.5.1 The exceptions to 1.2.4.5 occur for the following: 1) when seismic retrofits are designed using the alternate design criteria of **ASCE 41**, or 2) when new members are added within the work area using the original building code as the design-basis code criteria for the repair.

1.3—Applicability of this code

1.3.1 This code provides minimum requirements when performing an assessment, repair or rehabilitation design and remedial construction of the structural components of existing concrete structures, including buildings and nonbuilding structures.

1.3.1.1 Regulations of the current building code need not be exceeded when assessing, designing repair and rehabilitation work, or installing remedial work of existing structures.

structural conditions, substantial structural damage, damage less than substantial structural damage, deterioration of concrete and reinforcement, faulty construction, additions, alternations, changes in occupancy, serviceability issues, and durability of existing concrete.

R1.2.4.2 Classifying the work category using criteria and requirements of **Chapter 4** or **Appendix A** defines the design-basis criteria, which is used to design the repair or rehabilitation work.

R1.2.4.3.1 Use of the current building code for assessment criteria may result in a conservative assessment of an older structure. The design professional should review use of the current building code with the Owner at the start of the project (refer to R1.3.1).

R1.2.4.5.1 The performance-based criteria in **ASCE 41** may result in new member design that will not satisfy current code requirements for strength, stiffness, or detailing. New concrete members and reinforcement may be designed by the original building code if integrated with the work area repair construction of the existing structure when the repair design-basis criteria for the existing structure is the original building code. The detailing of these new members and the connection of these members to the existing concrete should be according to the current building code.

R1.3—Applicability of this code

R1.3.1 In typical U.S. practice, Owners are required to maintain existing structures to prevent unsafe conditions from occurring, or repair an existing structure when unsafe conditions are present. The minimum level of repair for an existing building will typically address these unsafe and potentially unsafe conditions.

The licensed design professional is permitted to perform assessment, design, and quality assurance activities that exceed the minimum requirements of this Code. Considerations beyond the minimum requirements of this Code, such as those for progressive collapse resistance, redundancy, or integrity provisions are permitted. Exceeding the minimum requirements is not a violation of this Code.

CODE

COMMENTARY

1.3.2 This Code is applicable to existing nonbuilding concrete structures.

1.3.3 Foundations

1.3.3.1 This code shall apply to the assessment and repair or rehabilitation of existing structural concrete foundation members.

1.3.4 Soil-supported slabs

1.3.4.1 This code shall apply to the assessment and repair or rehabilitation of soil-supported structural slabs that transmit vertical loads or lateral forces from the structure to the soil.

1.3.5 Composite members

1.3.5.1 This code shall apply to the assessment and repair or rehabilitation of the concrete portions of composite members.

1.3.6 Precast and prestressed concrete

1.3.6.1 The code shall apply to the assessment and repair or rehabilitation of structural precast and prestressed concrete members, systems, and connections. The code shall apply to cladding transmitting vertical loads to supporting members or lateral loads to diaphragms or bracing members.

1.3.7 Nonstructural concrete

The Owner and the design professional should agree on the intent of the repair and rehabilitation program and desired outcome at the onset of the project. The desired repair outcome may include consideration of the design service life of the repairs, structural reliability, serviceability considerations, and other factors. Due to the uncertain remaining service life of existing structures and the technical requirements of repair construction, quality assurance and construction observations in excess of that required by general building code is commonly required. The desired outcome of the repair and rehabilitation program, quality assurance, and construction observation requirements should be documented in the basis of design (Section 1.5.3).

R1.3.2 Nonbuilding concrete structures can include, but are not limited to arches, tanks, reservoirs, bins and silos, blast- and impact-resistant structures, and chimneys.

R1.3.3 Foundations

R1.3.3.1 Foundation members and systems should include those constructed using plain or reinforced concrete including but not limited to spread footings, mat foundations, concrete piles, drilled piers, grade beams, pile and pier caps, and caissons embedded in the ground. The design and installation of new pilings fully embedded in the ground are regulated by the current building code. For repair of existing foundation members and systems, the provisions of this code apply if not in conflict with the code governing existing building. For the portions of concrete piling in air or water, or in soil not capable of providing adequate lateral restraint throughout the piling to prevent buckling, the provisions of this code govern.

R1.3.7 Nonstructural concrete

CODE

1.3.7.1 This code is not intended for repair of nonstructural concrete or for aesthetic improvements, except if failure of such repairs would result in a potentially dangerous condition.

1.3.8 Seismic resistance

1.3.8.1 Evaluation of seismic resistance and design of retrofit shall be in accordance with the code governing existing buildings if one has been adopted or this code if a code governing existing buildings has not been adopted. If using this code for evaluation of seismic resistance and retrofit design, **ASCE/SEI 41** shall apply.

1.3.8.2 If retrofit for seismic resistance is not required by the code governing existing buildings or by this code, voluntary seismic retrofit shall be permitted.

1.3.8.2.1 When this code is used without the **IEBC**, the licensed design professional shall use the current building code supplemented by **ASCE/SEI 41** and **ASCE/SEI 7** to design voluntary seismic retrofits.

COMMENTARY

R1.3.7.1 Where nonstructural concrete requires repair, that repair is not required to comply with or satisfy the requirements of this code. The licensed design professional designing repairs to nonstructural concrete should consider the consequence of repair failure to determine if there are provisions of this code that are applicable.

R1.3.8 Seismic resistance

R1.3.8.1 Provisions in Chapter 10 of **ASCE/SEI 41** are based on **ACI 369.1-17**, which provides specific guidance on evaluation, repair and rehabilitation for existing concrete structures.

R1.3.8.2 Conditions for evaluation of seismic resistance and design of retrofits are provided in Chapter 3 of **ACI 369R**, Chapter A2 of Appendix A of **IEBC**, and **ASCE/SEI 41**.

Critical conditions requiring engineering review include, but are not limited to: irregular building configurations; nonductile or strong-beam-weak-column frames; and anchorage of walls to diaphragms. Significant improvements to the seismic resistance of a building can be made using repair techniques that provide less than those detailing and reinforcement methods required for new construction. As an example, providing additional reinforcement to confine concrete in flexural hinging regions will increase the energy dissipation and seismic performance even though the amount of confinement reinforcement may not satisfy the confinement requirements for new structures (**Kahn 1980**; **Priestley et al. 1996**; **Harris and Stevens 1991**). Rapid Visual Screening of Buildings for Potential Seismic Hazards: A Handbook (**FEMA P-154**), Mitigation of Nonductile Concrete Buildings (**ATC-78 Project**), Seismic Performance Assessment of Buildings (**ATC-58**), Quantification of Building Seismic Performance Factors (**FEMA P-695 Report**), and Identification and Mitigation of Nonductile Concrete Buildings (**ATC-78-1**) address seismic assessment and resistance in existing concrete structures.

Components of the seismic-force-resisting system that require strength and ductility should be identified. Force-controlled (nonductile) action is acceptable for some classifications of components of the seismic-force-resisting system (**ASCE/SEI 41**). The strength requirement of this code, Section 7.1 is applicable to these force-controlled components. **ASCE/SEI 41** and **ACI 369R** provide information on rehabilitation for seismic resistance. Seismic-resisting components requiring energy-dissipating capability should maintain the ability to dissipate energy after repair. Design and detailing requirements for seismic resistance of cast-in-place or precast concrete structures are addressed in **ACI 318** and **ACI 369R**.

1.4—Administration

1.4.1 Whenever this code is in conflict with the regulations of the authority having jurisdiction or code governing

R1.4—Administration



CODE

existing buildings, the authority having jurisdiction or code governing existing buildings shall govern.

1.4.2 Whenever this code is in conflict with requirements in other referenced standards, this code shall govern.

1.4.3 *Approval of special systems of design or construction*—Systems that are approved by the authority having jurisdiction through alternative means and methods clauses in the building design-basis code shall be permitted.

1.4.4 Materials that are evaluated in a process equivalent to the requirements of the **IBC** shall be used in accordance with the requirements of the written evaluation report for the material. Material use shall satisfy requirements of this code.

1.5—Responsibilities of the licensed design professional

1.5.1 The licensed design professional for the project is responsible for 1) assessing; 2) designing, detailing, and specifying the work proposed and material requirements; 3) consideration of load paths for the work proposed; and 4) preparing construction documents of the work proposed and specifying a quality assurance program. Construction documents shall indicate the location, nature, and extent of the work proposed.

1.5.2 *Potentially dangerous structural conditions*—The licensed design professional for the project shall report observations of exposed structural defects in the existing construction within the work area representing visible potentially dangerous structural conditions requiring evaluation and possible mitigation to the Owner.

1.5.2.1 When required by the authority having jurisdiction, visible potentially dangerous conditions shall be reported by the licensed design professional to the authority having jurisdiction.

COMMENTARY

R1.4.3 New methods of design, new materials, and new uses of materials for repair and rehabilitation usually undergo a period of development before being specifically covered in a code. Hence, good systems or components might be excluded from use by implication if means are not available to obtain acceptance. For systems considered under this section, specific tests, load factors, strength reduction factors, deflection limits, and other pertinent requirements should be set by the authority having jurisdiction and should be consistent with the intent of this code. Provisions of this section do not apply to model analysis used to supplement calculations or to strength evaluation of existing structures.

R1.4.4 The **IBC** (Section 1703 in IBC 2018) includes provisions for approval of alternate materials in new construction. The approval process requires the evaluation to be completed by an approved agency, and the material properties and use requirements be summarized in a written evaluation report. The same process may be used for materials in repair applications, provided the materials satisfy the provisions of this code. This process is intended to allow for use of new materials and new classes of materials that do not have approved design or material standards.

R1.5—Responsibilities of the licensed design professional

R1.5.1 During the assessment part of the investigation, the licensed design professional should request that the Owner provide all available information regarding the condition of the building, construction documents, previous engineering reports, disclose the presence of any known hazardous materials in the work area, and any other pertinent information to the parties involved in the work. This information may require that remedial measures be taken before or during the construction process and should be considered in the scope of work.

R1.5.2 During investigation or repair construction, potentially dangerous structural conditions in the work area may be revealed. To protect the public safety, an observed potentially dangerous structural condition should be reported to the contractor and Owner to initiate mitigation of the condition. Mitigation may include temporary shoring or construction as part of the remedial work

CODE

1.5.3 The licensed design professional for the project shall document the basis of design. The basis of design shall address work categories and repair construction within the work area for each structural element and include:

- (a) A description of the building
- (b) Modifications such as additions, alterations, or changes in occupancy
- (c) Elements of existing structure to be shored
- (d) Quality assurance and quality control (QA/QC) requirements
- (e) Conditions and details of the proposed rehabilitation work
- (f) Assessment criteria and findings
- (g) Repair material requirements
- (h) Known history of repairs and rehabilitation

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R1.5.3 The basis of design provides a summary of the assessment of the existing structure, and a summary of the construction documents from original construction or prior rehabilitation used in developing the basis of design. The basis of design can be documented in a written report or included in construction documents. Information on some structures may be unavailable or unnecessary if strengthening is not required and should be so documented in the basis of design. The licensed design professional should review requirements of the authority having jurisdiction to determine the information to include in the basis of design documentation and filing requirements for the basis of design.

Additional materials that may be documented in the basis of design include:

- (a) Detailed building description, including age of construction, structural systems, identified original building code, and past and current uses
- (b) Documentation of potentially dangerous structural conditions in the work area of the structure determined in the assessment
- (c) Documentation of substantial structural damage in the work area
- (d) Members and systems of the work area requiring increase in capacity beyond the demand of the original building code
- (e) Conditions and details of the proposed rehabilitation work
- (f) Assessment criteria and findings
- (g) Design-basis code criteria and basis of rehabilitation design
- (h) Shoring requirements such as loads and spacing of shoring members
- (i) Quality assurance and quality control (QA/QC) requirements
- (j) Types and frequency of future inspection
- (k) Types and frequency of future maintenance
- (l) Recommendations to address serviceability conditions as discussed in [Section 6.6](#)

A maintenance protocol that addresses project-specific conditions provides the most effective method to ensure durability and should be established as part of the repair or rehabilitation design that includes inspections and period of time between inspections, after completion of the repair installation. Maintenance and frequent preventative approaches that occur early in the service life of the structure generally result in improved service life with less interruption and a lower life-cycle cost ([Tuutti 1980](#); [ACI 365.1R](#)). Recommendations should be provided to the Owner on inspection and maintenance to be undertaken during the remaining design service life of the repair material or the repaired part of the structure.

A maintenance protocol should be provided in the basis of design, or in as-built or close-out documents. Maintenance of the repair can be incorporated in the instruction manuals from the licensed design professional, contractor, or material manufacturers. Documents and reports of observations

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1.6—Construction documents

1.6.1 The construction documents for rehabilitation work proposed shall provide sufficient detail and clarity to convey the location, nature and extent of the work, and the necessary information to perform the work in conformance with the requirements of this code and the local authority having jurisdiction. Specifications shall require that materials used for repair and rehabilitation construction satisfy this code and governing regulatory requirements at the time the work is implemented.

1.6.2 Calculations pertinent to design shall be submitted with the construction documents if required by the authority having jurisdiction. Scale-model testing and analysis shall be permitted to supplement calculations.

1.6.3 To the extent required by the contract between the licensed design professional and Owner, the licensed design professional shall provide the Owner with copies of the basis of design report, assessment reports, project documents, field reports, locations of completed repairs, and other project documents.

1.7—Preliminary assessment

1.7.1 Preliminary assessment of an existing structure shall include investigation and review of the structure, construction documents, reports, local jurisdictional codes, and other available documents of the existing structure. Existing in-place conditions shall be visually or otherwise investigated to verify existing geometry and structural conditions.

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inspections and tests should be provided to the Owner as necessary for future work.

R1.6—Construction documents

R1.6.1 As necessary, the construction documents should indicate:

- (a) Name and date of issue of the building code and supplements to which the assessment, repairs, or rehabilitation conforms
- (b) Design-basis code criteria used for conditions addressed by the documents
- (c) Design assumptions and construction requirements including specified properties of existing and remedial materials used for the project and the strength requirements at stated ages or stages of the construction
- (d) Details, locations and notes indicating the size, configuration, reinforcement, anchors, repair materials, preparation requirements, and other pertinent information to implement the repairs, strengthening, or rehabilitation of the structure
- (e) Magnitude and location of prestressing forces
- (f) Anchorage details for prestressing reinforcement
- (g) Development length of reinforcement and length of lap splices
- (h) Type and location of mechanical or welded splices of reinforcement
- (i) Shoring or bracing criteria necessary before, during, and at completion of the assessment, repair, or rehabilitation projects
- (j) Quality assurance program including specific inspections and testing requirements

ACI 563 is a reference specification that is written to be consistent with the requirements of this Code.

R1.6.2 Analyses and designs should include calculations, evaluation and design assumptions. If computer-based analyses and designs, such as finite element methods are used, they should include input, and computer-generated output.

R1.6.3 Documentation of the project and repairs that have been carried out, including structural observations, inspection reports by others, test results, and recommendations on inspection and maintenance to be undertaken during the remaining design service life of the repaired part of the concrete structure, should be provided to the Owner. The extent and type of quality assurance records should include those required in the construction documents. It is good practice for the Owner to keep documentation of repairs, inspections, testing, monitoring, and investigations for future reference.

R1.7—Preliminary assessment

R1.7.1 The goal of the preliminary assessment is to examine available information about the structure within the work area, and to make an initial determination of its adequacy to withstand in-place environmental conditions and design loads. The results of the preliminary assessment should be used to make decisions regarding the current

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in-place condition, need for additional information, work items necessary as part of the assessment, possible rehabilitation design and construction work to consider, and if there is a need for temporary shoring for safety of the existing structure. The preliminary assessment results should be updated as additional data regarding the examined structure become available.

The licensed design professional may determine that 4.6 or A.6 applies in a preliminary assessment based on engineering judgment and without analysis if all of the following are confirmed:

(a) Historical performance of the structure and visual observation of the structural condition of members and systems indicate acceptable behavior precluding assessment by 4.3 or A.3

(b) Review of construction documents and observation of current structural conditions indicate damage or deterioration of the structure below the level requiring assessment by 4.4 and 4.5 or A.4 and A.5

(c) Modifications for additions, alterations, and changes in occupancy are not planned.

Repairs are permitted that address durability and serviceability of 4.6 or A.6 without analyzing members and systems and checking the demand-capacity ratio limits of 4.3 through 4.5 or A.3 through A.5 if the structure is determined to be structurally acceptable. Structural performance should be considered acceptable if past and present performance has been satisfactory and observations do not indicate structural distress beyond levels expected.

The extent of damage or deterioration should be limited and the licensed design professional should not have a concern about the capacity of the structure if repairs are completed using the provisions of 4.6 with verifying the demand to capacity limits of 4.4 and 4.5 or A.4 and A.5.

1.7.2 The preliminary assessment shall determine if visibly potentially dangerous structural conditions are present. If present, they shall be reported in accordance with 1.5.2.

1.7.3 For the purpose of performing a preliminary assessment, it is permitted to use the criteria of the original or current building code for assessment criteria of Chapter 4 or Appendix A.

1.7.4 The in-place strength of the existing structure shall be determined considering in-place geometric dimensions and material properties including effects of material deterioration and other deficiencies. If material properties are not immediately available, a preliminary assessment is permitted to be completed using material properties as described in Section 6.3.2.

R1.7.2 Potentially dangerous structural conditions may require the Owner to install shoring, limit access, or take other measures to mitigate these conditions.

R1.7.3 The assumed preliminary assessment criteria should be substantiated or modified in accordance with the assessment details of Chapter 6.

R1.7.4 When required as a part of the preliminary assessment, strength calculations should be based on in-place conditions and should include an assessment of the loss of strength due to deterioration mechanisms. Guidelines for assessing in-place conditions include ACI 201.2R, ACI 214.4R, ACI 228.1R, ACI 228.2R, ACI 364.1R, ACI 437.1R, FEMA P-58, FEMA P-154, FEMA 306, FEMA 307, ASCE/SEI 11, ASCE/SEI 41, ATC-20, ATC-45, and ATC-78 as well as The Concrete Society Technical Report 68 (2008). When material test results are initially unavailable, the physical properties based on typical values used at the time of

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1.7.5 A structural assessment in accordance with **Chapter 6** shall be performed when a member or structure exhibits damage, displacements, deterioration, or structural deficiencies, or behavior is observed during the preliminary assessment that is unexpected or inconsistent with available design and construction documents or code requirements in effect at the time of construction.

construction can be used in preliminary evaluation. If available, material properties from construction documents can also be used in a preliminary evaluation.

The assessment of existing structures should initially focus on critical gravity-load-resisting members such as columns, walls, and members that are expected to have limited ductility, followed by an assessment of the lateral-load-resisting system.

Assessing fire damage and other deterioration mechanisms that result in a change in material properties (such as compressive strength or modulus of elasticity) should include an evaluation of the effect of the damage on the material properties and the impact of the damage on the performance of the existing structure. Examples of deterioration mechanisms that result in possible changes in material properties include corrosion of steel reinforcement, thermal damage, concrete reactions such as alkali-aggregate, and freezing and thawing.

Conditions to be documented include cracking, spalls, member deflection, cross-section dimensions different than specified on the original construction drawings, and construction deviating from tolerances permitted under the original design criteria.

R1.7.5 The preliminary assessment is generally the first portion of the work necessary to determine the rehabilitation category. Based upon preliminary assessment results, a structural assessment may be required to determine the extent of damage or if potentially dangerous structural conditions are present. However, in some cases the licensed design professional may deem that a structural assessment is not required based on judgement in accordance with 1.7.1 and R1.7.1.

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CHAPTER 2—NOTATION AND DEFINITIONS

R2—NOTATION AND DEFINITIONS

2.1—Notation

This chapter defines notation and terminology used in this code.

c	=	depth of neutral axis, mm
D	=	dead load acting on the structure
d_t	=	distance from extreme compression fiber to centroid of extreme tension reinforcement, mm
$\bar{f}_c$	=	average core strength modified to account for the diameter and moisture condition of the core, MPa
f'_c	=	specified concrete compressive strength, MPa
f_{ceq}	=	equivalent specified concrete strength used for evaluation, MPa
f_y	=	specified yield strength of steel reinforcement, MPa
$\bar{f}_y$	=	average yield strength value for steel reinforcement, MPa
f_{yeq}	=	equivalent yield strength of steel reinforcement used for evaluation, MPa
k_c	=	coefficient of variation modification factor for concrete testing sample sizes
k_s	=	coefficient of variation modification factor for steel testing sample sizes
L	=	live load acting on the structure, kg/m ³
ℓ_t	=	span of member under load test and taken as the smaller of: (a) distance between centers of supports; and (b) clear distance between supports plus thickness h of member; for a cantilever, it shall be taken as twice the distance from face of support to cantilever end, mm
n	=	number of sample tests
R_a	=	service load capacity of structural member, system, or connection including effects of damage, deterioration of concrete and reinforcement, and faulty construction determined using allowable stresses according to the original building code
R_{cn}	=	current in-place nominal capacity of structural member, system, or connection including the effects of damage, deterioration of concrete and reinforcement, and faulty construction
R_{ex}	=	nominal resistance of the structure during an extraordinary (that is, low-probability) event computed using the probable material properties
R_n	=	nominal capacity of structural member, system, or connection excluding the effects of damage, deterioration of concrete and reinforcement, and faulty construction
S	=	snow load acting on the structure, kg/m ²
T_g	=	glass transition temperature, °C
U	=	demand using nominal loads and factored load combinations for strength design provisions (LRFD)
U_c	=	demand using nominal loads of the current building code and factored load combinations of ASCE/SEI 7 for strength design provisions (LRFD)

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- U_o = demand using nominal loads and factored load combinations of the original building code for strength design provisions (LRFD)
- U_o^* = demand using nominal loads of the original building code and factored load combinations of **ASCE/SEI 7** for strength design provisions (LRFD)
- U_s = demand using service loads of the original building code and load combinations of the original building code
- V = coefficient of variation (a dimensionless quantity equal to the sample standard deviation divided by the mean) determined from testing of concrete or steel samples from structures
- v_{ni} = nominal interface shear stress capacity, MPa
- v_u = resultant interface stress demand from the transfer of tension and shear, MPa
- ϵ_t = net tensile strain in the extreme tension reinforcement at nominal strength
- ϵ_y = yield strain of steel reinforcement
- ϕ = strength reduction factor
- ϕ_{ex} = strength reduction factor used to check strength of the structure without external reinforcement after an extraordinary event
- ϕ_o = strength reduction factor from the original building code used in the design of an existing structure

2.2—Definitions

ACI provides a comprehensive list of definitions through an online resource, “ACI Concrete Terminology.” Definitions provided here complement that resource.

assessment—refer to **structural assessment**.

assessment criteria—codes, standards, loads, demands, capacities, strength reduction factors, materials, material properties, connections, details, and protections used in the evaluation.

authority having jurisdiction—person or entity that has legal control over the applicable building code and permitting procedures for a structure.

bond—(1) adhesion of applied materials to reinforcement or other surfaces against which they are placed, including friction due to shrinkage and longitudinal shear in the concrete and repair materials engaged by the bar deformations; (2) adhesion or cohesion between layers of a repair area or between a repair material and a substrate produced by adhesive or cohesive properties of the repair material or other supplemental materials throughout the service life of the repair.

bond-critical application—strengthening or repair system that relies on load transfer from the substrate to the system material achieved through shear and tension transfer at the interface, where bond rather than mechanical attachment is used as the primary load transfer mechanism.

capacity—the strength, stiffness, ductility, energy dissipation and durability, of a material, member or system as determined by analysis or testing.

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R2.2—Definitions

Additional repair-related definitions are provided by “ICRI Concrete Repair Terminology”.

An example of an authority having jurisdiction is the local building official.

This definition has been expanded from “ACI Concrete Terminology” for this code.

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compatible—the ability of two or more materials to be placed in contact or in sufficiently close proximity to interact with no significant detrimental results with respect to the intended service life.

connector steel—steel elements, such as reinforcing bars, shapes, or plates, embedded in concrete or connected to embedded elements to transfer load, restrain movement, or provide stability.

contact-critical application—strengthening or repair system that relies on load transfer from the substrate to the system material achieved through bearing perpendicular to the interface.

construction documents—written and graphic documents and specifications prepared or assembled that describe the location, design, materials, and physical characteristics of the elements of a project necessary for obtaining a building permit and for construction of the project.

damage—a decrease in the capacity of an existing member or structure resulting from events, such as loads and displacements, or as a result of deterioration of the structure.

dangerous—any building, structure, or portion thereof that meets any of the conditions described below shall be deemed dangerous:

1. The building or structure has collapsed, has partially collapsed, has moved off its foundation, or lacks the necessary support of the ground.
2. There exists a significant risk of collapse, detachment or dislodgement of any portion, member, appurtenance, or ornamentation of the concrete building or structure under service loads.

demand—the force, deformation, energy input, and chemical or physical attack imposed on a material, member, or system which is to be resisted.

design-basis code—legally adopted code requirements under which the assessments, repairs, and rehabilitations are designed and constructed.

design-basis criteria—codes, standards, loads, displacement limits, material properties, connections, details, and protections used in the design of mandated or voluntary work.

design service life (of a building, component, or material)—the period of time after installation or repair during which the performance satisfies the specified requirements if routinely maintained but without being subjected to an overload or extreme event.

deterioration—(1) physical manifestation of failure of a material (for example, cracking, delamination, flaking, pitting, scaling, spalling, and staining) caused by environmental or internal autogenous influences on rock and hardened concrete as well as other materials; (2) decomposition of material during either testing or exposure to service. (See also **disintegration** and **weathering** in ACI CT.)

durability—ability of a material or structure to resist weathering action, chemical attack, abrasion, and other conditions of service and maintain serviceability over a specified time or service life.

An example of a contact-critical application is the addition of a confinement jacket around a column.

This definition has been adopted from the **IEBC**. Potentially dangerous conditions of an existing concrete member, system, or structure may include those defined as dangerous from the IEBC. Circumstances may render some conditions defined as dangerous to be potentially dangerous within a limited period of time or may be concluded to be less of an imminent hazard.

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equivalent cover—a system to supplement insufficient concrete cover to improve durability or fire protection to that equivalent to the minimum cover specified in the design-basis code.

evaluation—refer to **structural evaluation**.

existing structure—structure for which a legal certificate of occupancy has been issued. For structures that are not covered by a certificate of occupancy, existing structures are those that are complete and permitted for use or otherwise legally defined as an existing structure or building.

factored load—product of the nominal load and load factor.

faulty construction—deficient construction resulting from errors or omissions in design or improper construction causing displacement of supporting portions of the structure or resulting in deficient materials, geometry, size or location of concrete members, reinforcement or connections that result in a decrease in the capacity of an existing structure or an adverse impact on the long-term durability or serviceability of the structure.

in-place condition—current condition of an existing structure, system, member, connection including component sizes and geometry, material properties, faulty construction, deterioration, and damage from an event.

interface reinforcement—(1) existing or supplemental reinforcement that is properly anchored on both sides of an interface; (2) post-installed reinforcement such as adhesive anchors or mechanical anchors, or other mechanical connections providing a method of force transfer across an interface.

interface shear stress—shear stress resulting from transfer of forces at bonded interfaces between repair material and existing substrate used to achieve composite behavior.

licensed design professional—(1) an engineer or architect who is licensed to practice structural design as defined by the statutory requirements of the professional licensing laws of a state or jurisdiction; (2) the engineer or architect, licensed as described, who is responsible for the structural design of a particular project (also historically engineer of record).

nominal load—magnitude of load specified by the design-basis code before application of any load factor.

nonstructural concrete—any element or portion thereof made of plain or reinforced concrete that is not required to transfer gravity load, lateral load, or both, along a load path of a structural system to the ground.

Owner—corporation, association, partnership, individual, or public body or authority with whom the contractor enters into an agreement and for whom the work is provided. The Owner is the party in legal possession of the structure.

potentially dangerous—(1) structural state of existing concrete within a work area for an individual structural member, structural system, or structure meets the definition of dangerous or unsafe, is unstable, has potential of collapse of overhead components or pieces (falling hazards), has

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The definition is different from the **IEBC** definition of an existing building. The IEBC definition is “A building erected prior to the date of adoption of the appropriate code, or one for which a legal building permit has been issued.” When using this code with the IEBC, use of the IEBC definition is appropriate.

This definition is adopted from “ACI Concrete Terminology.”

Potentially dangerous conditions of an existing concrete member, system, or structure include conditions that may be defined as dangerous or unsafe in the **IEBC**. These conditions may be overtly hazardous, dangerous, or unsafe.

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been determined to have demand/capacity ratio exceeding the limit of **Section 4.3.2.2** or has potentially hazardous resistance for seismic events. (2) A limit state of unacceptably low margin of safety against collapse without supplemental resistance.

rehabilitation—repairing or modifying an existing structure to a desired useful condition.

repair—the reconstruction or renewal of concrete parts of an existing structure for the purpose of its maintenance or to correct deterioration, damage, or faulty construction of members or systems of a structure.

repair reinforcement—reinforcement used to provide additional strength, ductility, confinement, or any combination of the three, to the repaired member.

repair, structural—restoring a damaged or deteriorated structure or increasing the capacity of a structure.

repair system—the combination of existing and new components, which may include existing reinforcement, repair materials, supplementary reinforcement and supplemental structural members.

retrofit—modification of an existing member, system, or structure to increase its strength, ductility, or both as a means of improving the seismic performance of the structure.

serviceability—structural performance under service conditions.

shoring—props or posts of timber, steel, or other material used for the temporary support of excavations, formwork, members during repairs, or potentially dangerous structures; the process of erecting shores.

on the circumstances or load probability between the time of determination and repair.

This definition is adapted from ACI Concrete Terminology – “the process of repairing or modifying a structure to a desired useful condition.” The definition is specific for concrete rehabilitation and is inclusive of the **IEBC** definition – “Any work, as described by the categories of work defined herein, undertaken in an existing building.” Herein, concrete rehabilitations include: repair to restore original capacity; strengthening to increase the capacity to the current building code requirements; seismic retrofits per **ASCE/SEI 41**; and modifications addressing additions, alterations, and change of occupancy.

The definition of repair from ACI Concrete Terminology is “to replace or correct deteriorated, damaged, or faulty materials, components, or elements of a structure.” The definition of repair from IEBC is “The reconstruction or renewal of any part of an existing building for the purpose of its maintenance or to correct damage.” The definition herein is adapted from the IEBC and is specific for repair of materials, components, or elements of existing concrete structures where structural repair or durability is addressed. Faulty materials, components, or elements of a structure are interpreted to be faulty construction resulting from errors or omissions in design or construction.

This definition is adapted from ACI Concrete Terminology – “increasing the load-carrying capacity of a structural component beyond its current capacity or restoring a damaged structural component to its original design capacity.” Herein, the definition addresses increasing the capacity to include enhancements such as ductility of existing concrete members. Repairs to nonstructural members, whose failure would cause or result in potentially dangerous structural conditions are considered structural repairs.

Typically used to refer to seismic modifications to increase resistance in an existing structure per **ASCE/SEI 41**. The definition is adapted from ASCE/SEI 41 – “Improving the seismic performance of structural or nonstructural components of a building.”

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specialty engineer—a licensed design professional retained by a contractor to design a delegated portion of the project.

stability, global—stability of the overall existing structure with respect to vertical support, uplift, overturning, sway instability, or sliding failure.

stability, local—the stability of an individual member or part of an individual member.

strengthening—process of increasing the capacity of an existing structure or a portion thereof.

structural analysis—process of using engineering mechanics to determine internal demands on, and capacities of a structure, member, or system.

structural assessment—the process of investigating by systematically collecting information regarding the performance of an existing structure; and evaluating the collected information to make informed decisions regarding the need for repair or rehabilitation; and detailing of findings as conclusions and reporting recommendations for the examined structural concrete work area (member, system, or structure).

COMMENTARY

The term “specialty engineer” is used in [Chapter 9](#). In this code, the specialty engineer will typically be a licensed design professional that is retained by the contractor to design specific types of components such as precast concrete or shoring members.

This definition with specific details for existing concrete is adapted from [ASCE/SEI 11](#) – “Systematic collection and analysis of data, evaluation, and recommendations regarding the portions of an existing structure which would be affected by its proposed use.”

A structural assessment is the process of acquiring knowledge of the existing structure used for the purpose of judging the future performance. The results of the investigation and evaluation are used to make decisions on the appropriate course of action regarding the future use of the structure and the suitability of the structure to continue in service.

Herein, assessments should be limited to the work area and may include:

(a) Investigation of the in-place condition of the existing structure by:

- i. Collection and review of field data for the structure, such as geometry, material strengths, conditions, symptoms of distress, extent of damage, measurement of displacements, environmental factors and reinforcement sizes, and placement
- ii. Collection of background data, such as construction plans, construction records, original, current, and code governing existing buildings, and historical events

(b) Evaluation of an existing structure, member or system of the work area (refer to commentary for structural evaluation)

(c) Findings and conclusions of the investigation and evaluation include:

- i. Define the existing structure, member, or system rehabilitation category using the assessment criteria of this code
- ii. Identify the work area, scope of work and likely cause or mechanism of damage, distress and deterioration
- iii. Identify faulty construction limitations
- iv. Evaluate test results to determine cause of failure and predict future performance.

(d) Determine repair and rehabilitation concepts, strategies, alternates and recommendations

- i. Develop cost-impact or economic study as necessary to appraise remedial work and maintenance
- ii. Describe repair and recommendations

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structural concrete—plain or reinforced concrete in a member that is part of a structural system required to transfer gravity loads, lateral loads, or both, along a load path to the ground.

structural evaluation—the process of determining and judging the structural adequacy of a structure, member, or system for its current intended use or performance objective.

- (e) Report conclusions and recommendations include:
- i. Work area limits and limitations of information collected and evaluated
 - ii. Assessment criteria and work of the evaluation such as calculations, tests and analyses
 - iii. Details of findings (conclusions) and recommendations
 - iv. Safety issue requirements (for example, recommendation for any temporary shoring)

This definition is adapted from **ASCE/SEI 11** – “The process of determining the structural adequacy of the structure or component for its intended use, performance, or both. Evaluation by its nature implies the use of personal and subjective judgment by those functioning in the capacity of experts.” An evaluation should determine, to the best of the license design professional’s knowledge, the level of quality (structural adequacy, serviceability, or durability) of an existing structure based upon a measured criteria and the judgment of the licensed design professional. An evaluation may require professional judgment to gage structural adequacy. Structural analyses may be required to determine possible ranges of existing structure capacities and variations in demands. The goal of the evaluation process is to appraise the in-place condition to determine adequacy for current or proposed future use. Structural evaluation requires determining capacity and demand, which may vary widely depending on the acquired information, tests, models, and analyses; determining the demand-capacity ratios; and judging structural reliability limits, which may be open to interpretation based on project requirements, structural experience, knowledge, and past performance.

Evaluation activities may include:

- (a) Tests to confirm reinforcement location, strength of material properties or structural capacity of existing members or systems or for presence of contaminants.
- (b) Analysis of test results to establish reinforcement, statistical equivalent material properties, limits of faulty construction, and structural capacity
- (c) Screening of observations and tests for mechanisms and causes of damage, distress, and deterioration
- (d) Establishing the assessment criteria
- (e) Calculating demand loadings, serviceability limits, lateral displacements, and durability requirements
- (f) Analysis of the structure to determine the capacity of the structure to withstand current or future load demands and comply with serviceability limits
 - i. Determination of demand-capacity ratios to appraise structural adequacy, ascertain classifications, and judge the need for repair and rehabilitation
 - ii. determination of maintenance requirements necessary for the service life of the structure

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substantial structural damage—except when using **Appendix A**, substantial structural damage shall be as defined in the IEBC.

When using this code as a stand-alone code, substantial structural damage shall be as defined in **A.4**.

temporary bracing—non-permanent supplemental members added to an existing structure to prevent local or global instability during assessment and repair construction.

undercutting—concrete removal around the reinforcement circumference to allow for existing reinforcement to be encapsulated in repair material.

COMMENTARY

The definition of substantial structural damage is from the **IEBC**. The definition has been modified, as noted in **A.4**, when using this code as a stand-alone code.



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CHAPTER 3—REFERENCED STANDARDS

American Concrete Institute

ACI 216.1-14—Code Requirements for Determining Fire Resistance of Concrete and Masonry Construction Assemblies

ACI 318-19—Building Code Requirements for Structural Concrete and Commentary

ACI 369.1-17—Standard Requirements for Seismic Evaluation and Retrofit of Existing Concrete Buildings

ACI 437.2-13—Code Requirements for Load Testing of Existing Concrete Structures and Commentary

ACI 440.6-08—Specification for Carbon and Glass Fiber-Reinforced Polymer Bar Materials for Concrete Reinforcement

ACI 440.8-13—Specification for Carbon and Glass Fiber-Reinforced Polymer (FRP) Materials Made by Wet Layup for External Strengthening of Concrete and Masonry Structures

American Institute of Steel Construction

ANSI/AISC 360-16—Specification for Structural Steel Buildings

American Society of Civil Engineers

ASCE/SEI 7—Minimum Design Loads for Buildings and Other Structures

ASCE/SEI 37—Design Loads on Structures during Construction

ASCE/SEI 41—Seismic Evaluation and Retrofit of Existing Buildings

American Welding Society

AWS D1.4/D1.4M:2011—Structural Welding Code—Reinforcing Steel

ASTM International

ASTM A15—Specification for Billet-Steel Bars for Concrete Reinforcement (withdrawn 1969)

ASTM A16—Specification for Rail-Steel Bars of Concrete Reinforcement (withdrawn 1969)

ASTM A61—Specification for Deformed Rail Steel Bars for Concrete Reinforcement with 60,000 psi Minimum Yield Strength (withdrawn 1969)

ASTM A160—Specification for Axle-Steel Bars for Concrete Reinforcement (withdrawn 1969)

ASTM A185/A185M-18—Standard Specification for Steel Welded Wire Reinforcement, Plain, for Concrete (withdrawn 2013)

ASTM A370-14—Standard Test Methods and Definitions for Mechanical Testing of Steel Products

ASTM A408—Specification for Special Large Size Deformed Billet-Steel Bars for Concrete Reinforcement (withdrawn 1968)

ASTM A431—Specification for High-Strength Deformed Billet-Steel Bars for Concrete Reinforcement with 75,000 psi Minimum Yield Strength (withdrawn 1968)

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R3—REFERENCED STANDARDS

Both current and withdrawn standards are referenced. Standards that are referenced in the design-basis code are applicable for the assessment of existing structures. These standards may have been withdrawn by the developing organization; however, they provide information on the materials used at the time of original construction. Refer to 4.3.3 and Chapter 6.

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ASTM A432—Specification for Deformed Billet Steel Bars for Concrete Reinforcement with 60,000 psi Minimum Yield Point (withdrawn 1968)

ASTM A497/A497M—Standard Specification for Steel Welded Wire Reinforcement, Deformed, for Concrete (withdrawn 2013)

ASTM A615/A615M-14—Standard Specification for Deformed and Plain Carbon-Steel Bars for Concrete Reinforcement

ASTM A616/A616M-96a—Standard Specification for Rail-Steel Deformed and Plain Bars for Concrete Reinforcement (withdrawn 1999)

ASTM A617/A617M-96a—Standard Specification for Axle-Steel Deformed and Plain Bars for Concrete Reinforcement (withdrawn 1999)

ASTM A706/A706M-14—Standard Specification for Low-Alloy Steel Deformed and Plain Bars for Concrete Reinforcement

ASTM A955/A955M-15—Standard Specification for Deformed and Plain Stainless Steel Bars for Concrete Reinforcement

ASTM A1061/A1061M-09—Standard Test Methods for Testing Multi-Wire Steel Strand

ASTM C42/C42M-13—Standard Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete

ASTM C823/C823M-12—Standard Practice for Examination and Sampling of Hardened Concrete in Constructions

ASTM C1580-15—Standard Test Method for Water-Soluble Sulfate in Soil

ASTM C1583/C1583M-13—Standard Test Method for Tensile Strength of Concrete Surfaces and the Bond Strength or Tensile Strength of Concrete Repair and Overlay Materials by Direct Tension (Pull-off Method)

ASTM D516-16—Standard Test Method for Sulfate Ion in Water

ASTM D4065-12—Standard Practice for Plastics: Dynamic Mechanical Properties: Determination and Report of Procedures

ASTM D4130-15—Standard Test Method for Sulfate Ion in Brackish Water, Seawater, and Brines

ASTM E329-14a—Standard Specification for Agencies Engaged in Construction Inspection, Testing, or Special Inspection

BSI Group

BS EN 1504-10:2017—Products and systems for the protection and repair of concrete structures. Definition, requirements, quality control and evaluation of conformity. Site application of products and systems and quality control of the works

International Code Council

IBC—International Building Code

IEBC—International Existing Building Code



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CODE

CHAPTER 4—CRITERIA WHEN USING THIS CODE WITH THE INTERNATIONAL EXISTING BUILDING CODE (IEBC)

4.1—General

4.1.1 This chapter applies if a jurisdiction has adopted the International Existing Building Code (IEBC) as the existing building code. When this chapter is used, Appendix A does not apply.

4.1.2 The design-basis code criteria of the project shall be determined based upon the results of the preliminary assessment (1.7) and the detailed assessment (Chapter 6), if performed, using the requirements set forth in this chapter.

4.1.3 It shall be permitted to use the current building code in place of the original building code as the design-basis criteria for all damage states, deterioration, faulty design, or faulty construction.

4.1.4 It shall be permitted to use this code in conjunction with the IEBC to determine the work category as shown in Table 4.1.4.

COMMENTARY

R4—CRITERIA WHEN USING THIS CODE WITH THE INTERNATIONAL EXISTING BUILDING CODE (IEBC)

R4.1—General

R4.1.1 Appendix A is used when this code is used for existing concrete structures as a stand-alone code without the IEBC and may be used to supplement provisions of Chapter 34 in 2012 and previous versions of the IBC.

R4.1.2 Structures constructed under previously adopted codes or before the adoption of a building code may not satisfy all current building code requirements. This Code and the IEBC contain specific requirements that determine if existing structures should be repaired, rehabilitated, or retrofitted to satisfy the requirements of the design-basis code. Local ordinances may also require that a structure be rehabilitated to satisfy the current codes. These requirements should be reviewed at the start of a project.

In the absence of mandatory local ordinances, the licensed design professional should determine if a seismic evaluation is necessary for potentially hazardous conditions using Section 4.3.3. Section 4.3.3 provides minimum assessment criteria for potentially hazardous seismic conditions. Provisions of ASCE/SEI 41 may be applicable to nonbuilding structures being assessed.

R4.1.3 Refer to Section R1.2.4.3.1 for additional commentary on use of current building code as the design-basis criteria.

R4.1.4 Unless the local jurisdiction provides more restrictive requirements, this chapter with the IEBC should be used to determine the assessment and design-basis criteria based on the work category of Table 4.1.4.

CODE

COMMENTARY

Table 4.1.4—Design-basis code criteria references for work categories

Work category	Design-basis code criteria reference
Potentially dangerous structural conditions for gravity and wind loads	4.3.2
Potentially hazardous structural conditions for seismic resistance in regions of high seismicity	4.3.3
Substantial structural damage, definition	IEBC
Substantial structural damage to vertical elements of the lateral-force-resisting system	IEBC
Substantial structural damage to vertical elements of the gravity-load-resisting system	IEBC
Damage less than substantial structural damage with strengthening	4.5
Damage less than substantial structural damage without strengthening	4.6
Deterioration and faulty construction with strengthening	4.5
Deterioration and faulty construction without strengthening	4.6
Additions	IEBC
Alterations	IEBC
Changes in occupancy	IEBC

4.1.5 This code shall be used to assess and design repairs of existing structures. The current building code shall be used to detail new concrete members and connections between new concrete members and existing construction. When the original building code is used as the design-basis criteria for repairs and new concrete or reinforcing members are integrated with the repairs, the original building code shall be used for design; otherwise, these new members shall be designed using the current building code.

4.1.6 In design of repair to existing structures using the original building code, detailing of the existing reinforcement within the work area need not comply with the current building code, if both of the following conditions are satisfied:

- (a) The damage or deterioration to the existing reinforcement is addressed
- (b) The repaired work area of the structure has capacity equal to or greater than demand per 5.2.2 using the original building code requirements or satisfies the requirements of 4.5.3 when using allowable stress design

R4.1.5 New member or reinforcement that is part of the work area repairs and built jointly with the existing structure should be designed using the same criteria as other repairs to the structure. However, the detailing of new members and detailing of added reinforcement, including connections to the existing structure, should comply with the current building code.

R4.1.6 The licensed design professional should review the development of existing reinforcing steel, when cracking damage is evident near the ends of reinforcement, to determine if the cracking is indicative of potential development failure beyond the restrictions of this section. Research has shown that development length equations from previous versions of ACI 318 may be unconservative for top cast plain reinforcing steel bars (Feldman and Cairns 2017). Significant changes have occurred in the building code requirements increasing the development of reinforcing steel.

When the basis of design is the current building code, the licensed design professional should consider the following:

- (a) Assessing demand/capacity ratios for the existing reinforcing steel with current development length provisions
- (b) Confinement details of the reinforcement when assessing seismic resistance

The licensed design professional should determine if structural behavior indicates adequate performance.

CODE

4.2—Compliance method

4.2.1 The compliance method selected and the design-basis criteria shall be used consistently for all assessment and rehabilitation design, excluding other options.

4.3—Potentially dangerous structural conditions

4.3.1 A structural assessment shall be performed in the work area to determine if potentially dangerous structural conditions are present when there is a reason for the licensed design professional to question the capacity of the structure or when potentially dangerous structural conditions are observed as a part of the preliminary assessment.

4.3.1.1 Potentially dangerous structural conditions shall be reported in accordance with **1.5.2**.

4.3.2 For gravity, fluid, soil, and wind loads, potentially dangerous structural conditions exist in members or structures where the demand/capacity ratio is greater than 1.5, as shown in Eq. (4.3.2).

$$U_c/\phi R_{cn} > 1.5 \quad (4.3.2)$$

In Eq. (4.3.2), U_c is the strength design demand determined by using the nominal loads identified in the current building code and the factored load combinations of **ASCE/SEI 7**, excluding seismic forces; and ϕR_{cn} is the capacity adjusted by the strength reduction factor ϕ in **Section 5.3** or **5.4** of this code.

4.3.2.1 If the demand/capacity ratio exceeds 1.5 for the work area, the design-basis criteria shall be the current building code.

4.3.2.2 For structures with no potentially dangerous conditions, Sections 4.4 through 4.9 shall be used to determine the design-basis criteria.

COMMENTARY

224.1R, **ACI 437R**, and **ACI 437.1R** provide guidance in judging acceptable performance.

R4.2—Compliance method

R4.2.1 For all existing structures, only one of the compliance methods listed in the **IEBC** should be used and these should not be used in combination with each other.

R4.3—Potentially dangerous structural conditions

R4.3.1 Structural assessments are required when damage, deterioration, structural deficiencies or behavior are observed during the preliminary assessment that are unexpected or inconsistent with available construction documents. The structural condition assessment will be performed in accordance with **1.7** or **Chapter 6**, or both. The commentary to **1.7.4** has information on methods to determine if there is a reason to question the capacity of the structure. Results of the condition assessment should also be reviewed to identify if potentially dangerous structural conditions are present. Potentially dangerous structural conditions include any instability, the potential for collapse of overhead components or pieces (falling hazards), or a significant risk of collapse exists under service load conditions.

R4.3.2 Demand/capacity ratios are used to quantify the adequacy of the member or structure. The threshold demand/capacity ratios determine when different levels of intervention may be required. For each demand/capacity ratio, this code provides direction on how the demand and capacity are determined. Demands may be determined based upon loads associated with current building codes (U_c as defined above) or loads specified during the original design of the structure (U_o as defined in Section 4.5.1). The calculated capacity of the structure will vary depending upon the condition of the structure and extent of evaluation used to confirm as-built properties of the structure.

In assessing potentially dangerous structural conditions, the demand of Eq. (4.3.2) combines current building code nominal gravity loads (dead, live and snow) with lateral loads from fluid, soil and wind (excluding seismic forces), using the factored load combinations of **ASCE/SEI 7**. A demand/capacity ratio greater than 1.5, calculated using Eq. (4.3.2), represents a condition with limited to potentially no margin of safety against failure for **ASCE/SEI 7** loads (**Stevens and Kesner 2016**).

In the assessment of potentially dangerous structural conditions, the licensed design professional should determine if it may be appropriate to include structural redundancies, alternate load paths, primary and secondary supporting elements, redistribution of loads, collapse mechanisms, reduced live loads, measured displacements (sagging, listing, leaning and tilting), second-order effects, and other loads specific to the structure, such as drifting snow, self-straining loads, ice, and floods. References for potentially dangerous structural conditions are **Galambos et al. (1982)**, **Ellingwood et al. (1982)**, and **Ellingwood and Anderson (1972)**. These references