# Codes and Standards

updates and discussions related to codes and standards

## ACI 562

### Requirements for Evaluation, Repair and Rehabilitation of Concrete Buildings

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It is estimated that the concrete repair industry in the United States generates between 18 and 25 billion dollars per year in construction spending. Unfortunately, repairs that do not perform as intended, either due to poor design or execution, require "repairs to the repairs", which form a substantial component of the total figure. Seeing a lack of minimum standards, several organizations believed the concrete repair industry would benefit from a repair standard that would assist engineers, improve the concrete repair process, and reduce the extent of "repairs to the repairs." After several years of development, the American Concrete Institute (ACI) published its first repair standard, *Code Requirements for Evaluation, Repair and Rehabilitation of Concrete Buildings* (ACI 562-13) in 2013. ACI 562-13 became (*Figure 1*) the first material-specific standard for the repair of existing concrete buildings, the first performance-based standard developed by ACI, and the first standard developed to work with the International Existing Building Code (IEBC). In areas that have not adopted an existing building code, ACI 562 can function as a stand-alone document providing guidance to structural engineers who perform evaluations of existing concrete structures and develop structural concrete repair designs.

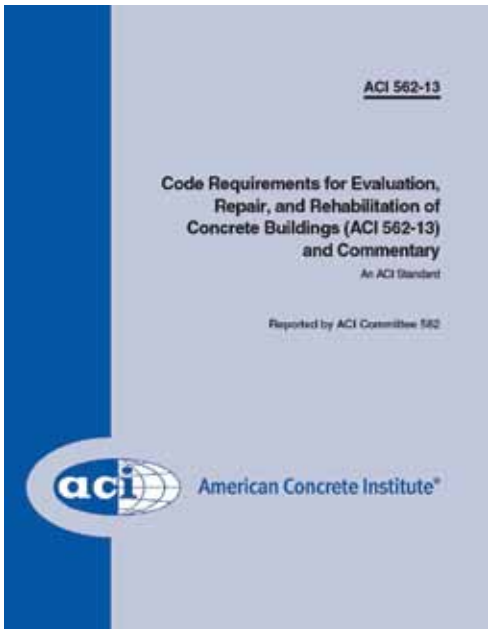


*Figure 1. New ACI 562-13 repair code.*

## Background

For new concrete structures, the *International Building Code* (IBC) and ACI 318 *Building Code Requirements for Structural Concrete*, provide the design professional with minimum requirements for strength, serviceability and durability. At some point a building will require repairs or rehabilitation. Design professionals, owners and contractors involved with the existing structure are then faced with the challenges of damaged or deteriorated members, possible hidden deterioration, or construction defects.

The lack of a material-specific repair standard for existing concrete structures has allowed for variations in concrete repair practice, inconsistent levels of reliability of repaired structures, and placed a burden on building code officials that must approve repair construction documents based upon a lack of specific requirements. In the absence of any guidance, decisions have often defaulted to requiring a repaired structure to satisfy all criteria of a code designed to address new buildings, like ACI 318, which can result in overly costly repairs and even in decisions to demolish and rebuild entire buildings.

The IEBC and IBC Chapter 34 require repair of significant structural damage and, in some cases, require structural improvements as well. Except for seismic elements, for which the codes cite ASCE 31 and ASCE 41, the I-codes do not contain specific requirements for the evaluation of damage and design of repairs for concrete structures.

Seeing a void in the industry and a desire to improve the practice, ACI Strategic Development Council along with the International Concrete Repair Institute (ICRI) and other organizations developed *Vision 2020* in 2006, a strategic plan for the concrete repair, protection, and strengthening industry. One of their specific goals was the creation of a repair/rehabilitation code which would:

1) establish evaluation, design, materials and construction practices,
2) raise the level of repair and durability performance,
3) establish clear responsibilities between owners, designers and constructors, and
4) provide building officials with means to evaluate rehabilitation design.

It has been estimated that 50 percent of repairs are not performing satisfactorily due to errors in design, construction and/or material selection [REMR and BRE]. *Vision 2020* concluded that minimum code requirements would ensure that all designers engaged in evaluation, repair, and strengthening would work from a consistent and defined level of expectations. As more professionals become engaged in repair and rehabilitation design, the need for minimum code requirements is of increased importance to assure life safety and repair performance. Overall, clearly defined and uniform code standards would lead to increased quality of structural rehabilitation leading to decisions to repair and sustain existing structures rather than to demolish and replace them with new structures.

ACI took the lead in pursuing this goal, forming Committee 562, Evaluation, Repair and Rehabilitation of Concrete Buildings, to develop the repair/rehabilitation code. A total of 31 members, comprised of engineers, contractors and manufacturers from across the United States and Canada were appointed and spent 7 years developing the document titled *Code Requirements for Evaluation, Repair and Rehabilitation of Concrete Buildings* (ACI 562-13).

## Code Applicability

IEBC and ACI 562-13 define an "existing building" as a building for which a certificate of occupancy has been issued, or when no certificate exists, a building that is complete and permitted for use. Where adopted, IEBC classifies the repair or alteration of the existing building and it specifies code requirements for the project. One of the code requirements delineates whether the repair needs to satisfy code requirements for new buildings, or whether building code requirements at the time of a building's original construction may be used. ACI 562-13 details that selection process and the specific requirements for structural concrete.

## Code Philosophy

ACI 562's goal was to establish minimum life safety requirements for rehabilitated structures while providing a sustainable and economic alternative to demolition and replacement. At the start of the standard's development process, it was recognized that a tremendous variety of existing concrete buildings are in use, and that those buildings were constructed under a variety of building codes and exhibit a myriad of structural problems. Due to the wide scope of repair and rehabilitation issues, the committee concluded that a "one-size-fits-all" prescriptive standard was impractical, and that a performance-based standard would be better and allow the design professional more flexibility. Performance-based requirements provide the design professional with minimum performance requirements to yield a safe and satisfactory repair in lieu of providing a set of "do it this way" requirements. This performance-based approach allows for use of engineering judgment and encourages creative solutions for repair design, provided it still complies with code requirements.

## Key Provisions of ACI 562

The use of ACI 562 is described in the following sections. The first step in the process is the determination of a *design basis code* for the repairs, which is the design code that the repaired structure will satisfy. The *design basis code* is likely an older, locally adopted (state or city) code, possibly using an older edition of the IBC or IEBC. Other special codes for existing or historic buildings might also apply. After the design basis code is established, the remaining steps in the process include evaluation of the structure, design of repairs, construction requirements including quality assurance testing, and development of maintenance recommendations for the owner's future reference for the repaired structure.

## Evaluation Criteria for Existing Structures

Evaluation of existing structures is based upon the in-situ properties of the structure, accounting for deterioration and as-built

*Figure 2. Corrosion damage in tunnel section.*

member dimensions. The commentary to ACI 562 provides guidance and references that describe how to evaluate existing structures. When existing materials appear in good condition and design drawings and other information about the original construction are not available, ACI 562-13 allows historic material properties, such as concrete compressive strength and the yield strength of reinforcing steel, to be used in analyses. ACI 562-13 encourages testing to determine material properties by specifying the use of higher strength reduction factors when existing material properties and structural geometry are confirmed. While testing to verify material properties is not required, nor imposes extra effort on the part of the owner, the testing may provide a more economical solution for the repair design.

Another optional strategy for verifying the strength of an existing structure is to perform in-situ load testing which can be useful particularly on older structures with obsolete structural systems. ACI 562-13 specifies the use of recently developed AC1 437-13 *Code Requirements for Load Testing of Existing Concrete Structures*, which was specifically developed for existing structures and includes acceptance criteria based upon monotonic and cyclic test results, and provides for lower load ratings based upon load testing results.

## Design of Structural Repairs

The design of structural repairs using ACI 562-13 is based upon standard concepts of structural concrete behaviour and the *design basis code*, which is typically the version of ACI 318 used for the original design. The standard's provisions are not new to the design professional and require many of the same items as traditional design: repaired structures shall have design strengths at least equal to the required strength based upon factored loads and members have adequate stiffness to prevent serviceability problems. In addition to the traditional topics, provisions have been included for items that are unique to repair design such as bond of repair materials to substrates, detailing of repairs, and consideration of the interaction between repaired and non-repaired portions of a structure. The overall theme of the provisions is to direct the repair design professional to consider the behavior of the structure at all times during the repair process which, if ignored, can lead to failures of the repair.

Another addition to the standard is permitting fiber reinforced polymer (FRP) materials in repair. ACI 562-13 incorporated the FRP design standard (ACI 440.6) along with a section dedicated to ensure that FRP is properly integrated into the existing structure.

## Durability Requirements

Satisfying strength requirements is just one step towards long-term performance of a repaired structure. Improving the durability of repairs and repaired structures is a key goal of ACI 562, since the high rate of repair failure is partially due to repairs lacking adequate durability.

Durability in repaired structures is complicated as it requires consideration of many conditions outside of the repair area, such as structure use and exposure. Additionally, the service life of both the repair area and the repaired structure need to be taken into account. One example would be failure of concrete adjacent to a repair (*Figure 2*) due to the *anodic ring effect*, which is when reinforcing steel in the adjacent original material corrodes due to differing environments.

To avoid such conditions, ACI 562 requires the designer to consider the durability of the repaired area, interaction of the repaired area with the original structure, and the overall system durability at the start of the repair process. The standard's provisions also direct the repair designer to consider the impact of cracks, corrosion and moisture transmission on the durability of repairs, which are major mechanisms that impact the repair's performance. Like the other sections, ACI 562-13's commentary provides discussion and references on how to design and detail durable repairs.

Another major contributor to premature failure of repairs is the lack of ongoing maintenance, such as repairing damaged coatings or aged sealants. While the repair design professional has no control over when and if maintenance is performed, ACI 562-13 dictates that maintenance requirements be provided to the owner so that the owner is aware of maintenance needs for specific repair materials and systems.

## Construction

The construction provisions in ACI 562 were developed to help ensure the stability of both the existing construction and the repairs during the construction phase. These provisions recognize that the repair process, particularly the removal of materials, can have detrimental effects on the structure. Such changes include increases in the unbraced length of a member, removal of confining materials (*Figure 3*), and altered load paths in the structural system which can create localized unintended overstresses in unrepaired members. The standard specifically requires repair documents to define shoring

and bracing requirements during all phases of the repair, if required. ACI 562-13 does not require that the repair engineer-of-record design the shoring or bracing elements; however, it does require that shoring and bracing be designed by an engineer.

## Quality Assurance

General building codes contain special inspection requirements for testing of concrete materials in new construction, and these requirements typically include a number of concrete tests based on the volume of concrete placed. Using these inspection requirements for repair construction is not realistic, as a very limited amount of materials testing would be performed since repair construction is often completed in smaller increments. While ACI 562-13 does not mandate additional testing beyond these requirements, it leaves the testing and inspection requirements to the discretion of the design professional. As with any project, the design professional has the ability to specify additional testing if it is warranted for unique conditions. ACI 562-13's commentary provides a listing of items that the design professional can include as part of a quality assurance program.

## Impact of ACI 562

Use of the ACI 562-13 standard will provide designers consistent code requirements for repair of structures, and building code officials a means to examine repair documents for permitting. Most importantly, ACI 562-13 provides a minimum level of life safety for repaired buildings, along with setting a standard of care for structural repair.▪

*Figure 3. Buckled reinforcing steel bar.*

## References


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2. *International Existing Building Code*, International Code Council, Country Club Hills, IL, 2006, 484 pp.
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4. *Building Code Requirements for Structural Concrete* (ACI 318-05), American Concrete Institute, Farmington Hills, MI, 2005, 443 pp.
5. *Vision 2020: A Vision for the Concrete Repair, Protection and Strengthening Industry*, ACI Strategic Development Council, Farmington Hills, MI, 2006.
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9. *Specification for Carbon and Glass Fiber-Reinforced Polymer Bar Materials for Concrete Reinforcement* (ACI 440.6-08), American Concrete Institute, Farmington Hills, MI, 44 pp.