ACI 562-16: The ACI Concrete Repair Code

BY KEITH KESNER AND KEVIN CONROY

INTRODUCTION

In 2006, an American Concrete Institute (ACI) technical committee began working on the development of a building code for the repair of existing concrete structures. The committee published the first version in 2013 (ACI 562-13), and an updated version (ACI 562-16[1]) in 2016 (Fig. 1). The *Code Requirements for Assessment, Repair and Rehabilitation of Existing Concrete Structures*, was developed by design professionals, repair contractors, material suppliers and academics to provide a standard for existing concrete structure assessment and durable repair design. Development of a concrete repair code was a key goal of the Vision 2020[2] program which identified strategies to improve the concrete repair practice.

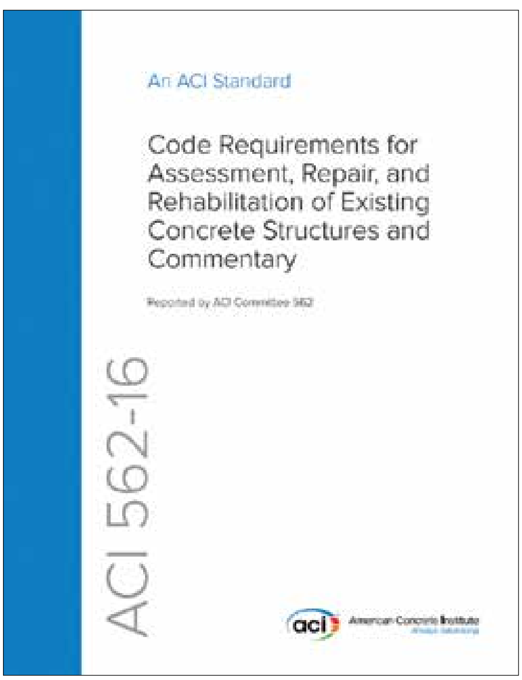

Fig. 1: Cover of ACI 562-16 document

ACI 562-16 was developed to be integrated with the current US general building codes for existing structures, such as the 2015 International Existing Building Code (IEBC 2015[3]), and the current ACI code for design of new concrete structures (ACI 318-14[4]). To provide a clear delineation between new and existing construction, ACI 562 defines an existing structure as a structure for which a legal certificate of occupancy has been issued.

Some of the challenges in the development of a concrete repair code included:

- Development of rational standards to identify when existing structures are unsafe or in need of strengthening;
- Development of code provisions that improve the performance of repaired structures without limiting solutions;
- Development of a code supported by design professionals, contractors and other code users;
- Integration of the ACI 562 code with existing general building codes; and
- Adoption of the code by reference into the general building codes.

DEVELOPMENT OF ACI 562-16

The process of creating the ACI 562 Repair Code started with the selection of a performance-based code in lieu of a more traditional prescriptive framework. A performance-based document allows design professionals creativity and flexibility in the assessment and repair design process, while providing necessary levels of structural reliability. A second major consideration was to create a standard that works both in jurisdictions with the IEBC and functions as a stand-alone code where no general existing building code exists.

The IEBC is the most commonly adopted general existing building code in the US and provides general requirements that specify when an existing structure needs to satisfy current code requirements or can be repaired. ACI 562-16 provisions were developed to be consistent with these requirements.

Because ACI 562-16 is a performance-based code, the detailed commentary provides guidance and references to the user on how to satisfy the intent of the provisions. The following sections describe some of the requirements, unique to ACI 562-16, that supplement requirements contained in the 2015 IEBC.

The development of ACI 562-16 included a review of terminology for consistency with documents produced by the American Society of Civil Engineers (ASCE) and the International Standards Organization (ISO). The terminology changes adopted into ACI 562-16 (Stevens and Kesner, 2016a[5]) were intended to provide code users a consistent framework when working with documents from different sources.

Unsafe Structures

A key question in the assessment of damage to existing structures is, when should an existing structure be considered unsafe and in need of immediate shoring or other measures to protect the public? The obvious definition of an unsafe condition involves situations where loose materials are present and represent a falling debris hazard. Situations can also exist where the extent of damage to the structure (from deterioration, design errors or construction defects) is sufficient to create an unsafe condition under service loads. To provide clear direction to design professionals in these situations, a demand / capacity ratio was developed, using reliability principles, to determine when a risk of collapse exists under service load conditions (Stevens and Kesner, 2016b[6]).

Assessment of Existing Structures

Assessment of existing structures can be a significant challenge, particularly when limited or no information is available regarding the as-built construction. In ACI 562-16, the assessment requirements are performance-based and take into account the in-situ condition of the structure. Investigation and structural evaluation are required when the structure exhibits signs of deterioration, damage, or behavior inconsistent with available design and construction documents. The performance basis of the provisions allows the design professional to determine the extent of evaluation required. In many durability-driven repair projects, when the capacity of the structure is not in question, a structural evaluation may not be required.

To assist design professionals in the evaluation of in-place concrete compressive strength and reinforcing steel yield strength, historic material properties (adopted from ASCE 41-13[7]) are included in ACI 562-16. These generally conservative values are determined based upon the structures initial construction date, and are intended to provide values to be used in preliminary analyses or to help reduce costs associated with material testing. ACI 562-16, consistent with Chapter 27 of ACI 318-14, does allow for higher strength reduction factors (providing higher capacities) when in-place geometry and material strengths are confirmed by testing.

As an alternative to (or to supplement) traditional analyses, load testing in accordance with ACI 437.2-13[8] is permitted by ACI 562-16 to evaluate the strength of existing structures. The ACI 437.2 standard was selected as it was specifically developed for use on existing structures and includes criteria for acceptance based upon either monotonic or cyclic testing results.

Design of Repairs

ACI 562-16 requires design professionals to satisfy strength requirements and to consider durability in repair design. Design of structural repairs using ACI 562-16 is based upon traditional concepts of satisfying minimum strength and serviceability requirements. The required design strength for a repaired structure or member will be based upon the requirements of the design basis code. The design professional determines the design basis code during the initial phases of the assessment; it is typically the ACI 318 version that is in effect during original construction. The user also has the option to design the repairs to comply with the current version of ACI 318. ACI 562-16 is the first document that permits the use of fiber reinforced polymer (FRP) materials in repairs, when the FRP is designed in accordance with ACI 440.6-08[9].

ACI 562-16 also includes provisions that are unique to repair such as the evaluation of the interfacial bond of repair materials, repair detailing to minimize the potential for cracking, consideration of the repair sequence, and the interaction of the repaired areas with the non-repaired portions of the structure. These provisions were developed based upon the experiences of the ACI 562 committee members and various ACI and ICRI guide repair documents (referenced in the commentary to ACI 562-16).

Interfacial bond failure is a common cause of concrete surface repair failure. ACI 562-16 includes revised criteria for the interfacial bond strength provisions (Brewe, et al., 2016[10]) introduced in ACI 562-13. These provisions assess the required strength between a cementitious repair material and a concrete substrate. The ACI 562-16 provisions were developed from the horizontal shear strength provisions in Chapter 16 of ACI 318-14.

The provisions require the design professional to evaluate interfacial shear stress demand between a repair and substrate. Based upon the shear stress (v_u), different levels of reinforcement and quality assurance testing are required as summarized in Table 1. At low bond stress demand levels, hammer sounding or other acoustic methods can be used to confirm repair bond integrity. At higher demand levels, quantitative methods such as tensile pulloff

Table 1: Bond Testing and Interface Reinforcement Requirements in ACI 562-16

Bond Stress (v_u)	Interface Reinforcement Required	Quality Assurance Required
Less than 0.21 MPa	No	Bond integrity testing
0.21 to 0.41 MPa	No	Quantitative bond strength testing
Greater than 0.41 MPa	Yes	Quantitative bond strength testing

bond tests (Fig. 2) are required. Bond testing requirements are waived when v_u is entirely resisted by interface reinforcement.

ACI 562-16 also requires consideration of durability in the design of repairs. Durability in new construction is obtained through prescriptive requirements related to minimum amounts of concrete cover, air content and water/cementitious materials ratios. In contrast, durability of repaired structures is a function of the characteristics of the repair materials, quality of surface preparation prior to repair, the substrate condition, and interaction of the repair material with the substrate.

Fig. 2: Pull-off bond testing equipment

Ideally, the durability aspects of the repair design will include consideration of the desired service life of the repaired structure. However, the provisions are not intended to establish a minimum service life. A primary goal of the durability provisions is to reduce the potential for future deterioration (Fig. 3) adjacent to the repair areas (anodic ring effect). Provisions also instruct the design professional to consider the impact of cracks, concrete cover, and surface treatments on the expected durability of repaired areas. Similar to the structural design provisions, the commentary provides a detailed source of information on how durable repairs can be obtained.

Fig. 3: Sacrificial anode installed within concrete repair area

Quality Assurance and Maintenance Requirements

General building codes contain special inspection requirements (distinct from quality assurance 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. In addition to special inspection requirements, a quality assurance program is required to be included in repair construction documents. The commentary to ACI 562-16 provides a listing of items that the design professional can include as part of a quality assurance program. The design professional also has the ability to specify additional testing, such as tensile bond strength testing when required.

ACI 562-16 includes requirements for the design professional to document and notify the Owner of future maintenance requirements for the repaired structure. While the design professional has no control over the timing and frequency of future maintenance, these provisions are intended to make the Owner aware of the need for maintenance to prolong the life of existing structures.

CURRENT STATUS OF ACI 562-16 ADOPTION

In 2016, representatives of ACI and other industry organizations tried to get ACI 562-16 adopted by reference into the 2018 IEBC. Unfortunately, the proposal to adopt ACI 562-16 into the 2018 IEBC was not approved, despite broad support from the structural engineering and concrete repair community. The ACI 562 committee is currently working to incorporate feedback received during the code adoption process into the next version. The 562 committee is also working on adoption of ACI 562-16 into state and municipal building codes, and into the regulatory standards of other groups.

As a published standard, ACI 562-16 establishes a standard of care for design professionals involved with repair of existing concrete structures consistent with IEBC requirements. Use of ACI 562-16 in US concrete practice is expected to help design professionals develop sustainable solutions that improve the performance of existing structures and limit the cost of future repair programs.

GUIDE TO THE ACI 562-16 REPAIR CODE

To assist design professionals in how to use ACI 562-16, ACI/ICRI 562MAN-16[11], *Guide to the Code for Assessment, Repair, and Rehabilitation of Existing Concrete Structures* (Fig. 4) was jointly developed by ACI and ICRI. The guide provides plain language explanation and context to the provisions in the code, including how to work with the IEBC. The guide also includes five worked example

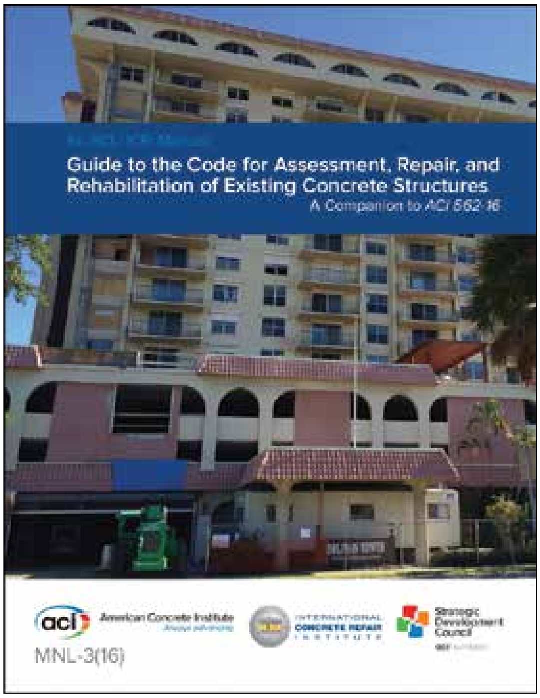

Fig. 4: Cover of guide for the use of the ACI 562-16 document

projects, which provide step-by-step descriptions of how to use the code from evaluation through construction quality assurance. The worked example projects were selected to represent common types of concrete repair projects.

REFERENCES

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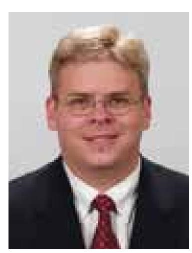

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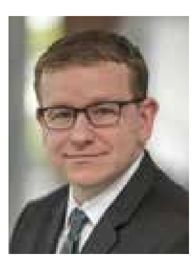

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Conroy is a member of both ACI and ICRI. He is a member of ACI Committees 562, 546 Repair, and 364 Rehabilitation. He has served on ICRI Committee 150 Notes on the ACI 562 Repair Code and its subcommittee on Chapter 7 Design and Structural Repairs.