Guide to the Code for Assessment, Repair, and Rehabilitation of Concrete Buildings

Second Edition

Updated by Khaled Nahlawi, ACI Senior Engineer, under the review and approval of an ACI/ICRI review group consisting of Chair Jay H. Paul and members Eric L. Edelson, Fred R. Goodwin, Keith E. Kesner, and Antonio Nanni. The first edition was prepared by the team from Wiss, Janney, Elstner Associates, Inc., of Project Manager Richard A. Walther, Stephen W. Foster, Gary J. Klein, and Richard C. Reed with comments by ACI Committee 562, Evaluation, Repair, and Rehabilitation of Concrete Buildings, and ICRI Committee 150, ICRI Notes on ACI 562 Code Requirements.

Guide to the Code for Assessment, Repair, and Rehabilitation of Concrete Buildings

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On the Cover

Dolphin Tower Condominiums

High-Rise Category 2015 ICRI Project of the Year Finalist

The following summary is taken from the November/December 2015 issue of Concrete Repair Bulletin.

Constructed in 1974, the Dolphin Tower Condominiums in Sarasota, FL, is a 15-story, 117-unit building with the first three levels devoted to parking. To accommodate the parking spaces, the fourth floor was designed to be a 24 in. (610 mm) thick column transfer slab, distributing the 12-story column loads above to the non-aligning columns below. The building is conventionally reinforced concrete flat slabs supported by concrete columns and pile foundations.

On June 24, 2010, the resident manager who lived on the fourth floor observed the walls within her unit were buckling and the tile floors were cracking. She immediately contacted a structural engineer, who confirmed a major failure and incipient collapse and arranged for a contractor to immediately install emergency shoring. By the time shoring was installed, the crack spanned four column bays and in some areas the concrete floor had lifted as much as 4 in. (102 mm). The building was evacuated.

Fourth-level transfer slab crack repair after demolition

Helical pile installation in the foundation area

Post-tensioned drop panels with formwork

Inspection/Evaluation and Testing

To identify the cause of the failure and determine feasibility and methods of repair, the building was intensely scrutinized. In addition to the Association's primary structural engineer, forensic engineers were employed by the insurance company and the association's coverage counsel. Following removal of interior walls and finishes, test methods included visual inspection, strength testing, petrographic analysis, surface-penetrating radar, and ultrasonic pulse velocity testing. Full building finite element analysis was performed to evaluate the stresses in the building and correlate the materials testing results with the observed failures.

Although no "trigger" was identified, the failure was determined to be punching shear caused by a combination of inadequate design for overlapping punching shear perimeters, low-strength concrete, poor-quality concrete, inadequate consolidation, and inadequate reinforcing steel detailing.

A side effect of the intense analysis of the building was the discovery of vulnerabilities, in addition to the failed transfer slab. These included inadequate lateral design for hurricane wind resistance and inadequate punching shear capacity at the upper-level slabs.

Repairs/Repair Process

Once the initial analysis and repair design was completed, a preferred contractor was selected. To help bring the cost of the project within budget, the contractor was afforded the opportunity to further refine the design, allowing the unit dimensions to be altered. The removal of this design constraint permitted a substantial

Steel lug keys and reinforcing bars in the drop panels

Steel and cables in the post-tensioned beam

Exterior shear walls

cost savings. The design evolved from removal and replacement of the fourth-floor slab and installation of exterior shear walls to installation of post-tensioned drop panels combined with a structural overlay and interior shear walls. This ultimately resulted in a cost reduction of more than $500,000 at the end of the project, and completion of the $9 million structural repair on time.

Repair Implementation

Sequencing

When work began on site, there were already 1100 post shores in place, originally installed as an emergency measure and set up in clusters throughout the three levels of the garage. This shoring needed to be incorporated into the construction sequence and remained in place to support the tower columns above, and also relieved the damaged transfer slab while the repair work was being done. Due to the required shoring, access and storage space within the garage was limited; therefore, safety for the workers in these areas was paramount. Weekly safety meetings were held on site with all crews and subcontractors to make everyone aware of the specific safety concerns present in their work areas. Work proceeded concurrently on multiple levels of the garage and extra precautions were taken and monitored to ensure workers were safe from falling debris from the extensive coring operation above.

I—Fourth-Level Crack Repair and Phase 1 Foundations

The first phase of the repair was to fix the large shear failure crack within the fourth-level transfer slab, which spanned four column bays. The repair comprised conventional selective demolition and replacement along with epoxy injection. This would further weaken the already damaged transfer slab, so additional shoring was installed. Additional steel was added to the repair areas where concrete was removed, and the floor was re-placed to its original level.

Simultaneously, work began on Phase 1 of the foundation strengthening, which consisted of areas that fell outside of the existing shoring and could easily be accessed. The foundation work consisted of demolishing and removing the slab-on-ground concrete, excavating down to the existing concrete pile caps, installing new steel helical piles, placing steel reinforcement, and placing of the new expanded pile caps.

During excavation of the first pile cap location, it was discovered that the existing cap was only 16 in. (406 mm) deep. However, the original construction as-built drawings showed a pile cap depth of 29 in. (737 mm). The same was true for 10 out of 12 of the Phase 1 pile caps. Based on these existing conditions, the structural engineers had to revise their original designs.

II—Level 3 Drop Panels and Upper-Level Exterior Shear Walls

The second phase of the project was to install the post-tensioned drop panels on the underside of the fourth-floor slab. The ceiling was prepped using hydrodemolition, and then column enlargements were installed on Level 3. Six-hundred 8 in. (203 mm) holes were cored through the fourth-level slab to install "shear lug keys." These would tie the new drop panel to the fourth-level overlay, creating a new composite slab.

The area of the drop panel construction was over 7700 ft2 (715 m2) and was split up into four subphases. The process took over 2 months, 400 yd3 (305 m3) of concrete, 22,000 ft (6705 m) of post-tensioning cable, and over 42 tons (38,000 kg) of reinforcing steel to complete. Because access within the formwork was limited, self-consolidating concrete was used. The steel cages for the new drop panels were hung from the lug keys, and the post-tensioning cables were installed within the cage. Post shores were installed underneath the drop panel formwork and across 100% of the tower area on all three levels of the garage. This shoring would support the new construction of the drop panels and overlay. In total, 2800 post shores and 200 shoring towers were used for the drop panel and overlay construction.

Also during the second phase, exterior wall segments at the four corners of the building were converted to concrete shear walls. The existing windows and concrete masonry unit (CMU) walls were removed, reinforcing steel was installed, and concrete was placed.

III—Level 4 Overlay Slab, Interior Shear Walls, Upper-Level Shear Repairs

The third phase commenced with construction of the fourth-level overlay slab. The overlay was roughly 13,500 ft2 (1250 m2) split into two subphases. Over 68 tons (61,700 kg) of reinforcing steel and 300 yd3 (230 m3) of concrete was used. Additionally, because the floor height was being increased by 6 in. (152 mm), the two elevator doors required relocating.

After the overlay slab was completed, interior shear wall construction began starting on the fourth level and continuing up to the penthouse. In conjunction with the installation of new interior shear walls, upper-level slab overstress was relieved through jacking. Once the concrete cured, the shoring would be released, redirecting stresses in the floor to the new shear wall.

To supplement lateral wind load capacity and address upper-floor punching, existing CMU walls were filled with grout and 108 steel "T-columns" were installed at various locations. Originally, these columns were to be placed-in-place concrete, much like those done on the garage levels.

IV—Phase 2 Foundations

The final stage of work was to finish the second phase of the new foundation pile caps—those areas which were previously inaccessible due to the substantial amount of shoring required for the fourth-level repairs. For these foundations, the existing pile caps were 4 ft (1.2 m) or more below the upper slab-on-ground, resulting in excavations extending 2 ft (0.6 m) or more below the water table. Consequently, undermining of the slab surrounding the excavation areas was a major concern. Temporary sump-pump pits were created to lower the water table level and reduce soil erosion. Several large concrete piers buried within the existing foundations were discovered, making it very difficult to install helical piles, so these had to be removed. The final foundation area to be completed was within a subgrade mechanical pump room. Due to limited headroom, holes were punched in the ramp slab above to install the helical piles. Because of the depth of this excavation, the water was again an issue and undermining of the surrounding slab needed to be controlled. Therefore, soil grouting was used to maintain support of the existing mechanical units and prevent further erosion.

Project Completed

The Dolphin Tower project was very challenging and used many interesting and groundbreaking design concepts. Constant communication between the contractor, design engineer, and owner was a necessity to adapt to continuously changing conditions, which required quick solutions to maintain the aggressive schedule. Despite many challenges, the repairs were completed on schedule and under budget.

The Dolphin Tower building

Steel overlay

Dolphin Tower Condominiums

Owner
Dolphin Tower Condominium Association
Sarasota, FL

Project Engineers/ Designers
Karins Engineering
Sarasota, FL
Morabito Consultants
Sparks, MD

Repair Contractor
Concrete Protection & Restoration, Inc.
Baltimore, MD

Material Suppliers/ Manufacturers
CEMEX
Sarasota, FL
Aluma Systems
Tampa, FL

Acknowledgments

The development of "Code Requirements for Evaluation, Repair, and Rehabilitation of Concrete Buildings (ACI 562-13) and Commentary" and the 1st edition of the "Guide to the Code for Evaluation, Repair, and Rehabilitation of Concrete Buildings" were major milestones in the concrete repair industry. Prior to the publication of these documents in 2013, the industry lacked code requirements specific to the repair of concrete buildings, leading to inconsistent repair practices. To provide guidance to the repair community yet maintain the flexibility necessary to address widely varying conditions, many of the Repair Code requirements took the form of performance requirements rather than the prescriptive requirements seen in many other concrete industry codes. Because of the performance nature of the requirements, however, there was significant room for interpretation when deciding whether a particular code requirement had been met.

Early in the development of ACI 562-13, the need was recognized for a document that would provide guidance and examples to assist engineers in understanding how to satisfy the Repair Code requirements. This was particularly important considering that ACI 562 was a new code that engineers would be using for the first time and with which they would have no prior experience. The current edition of the repair code, "Code Requirements for Assessment, Repair, and Rehabilitation of Existing Concrete Structures (ACI 562-16) and Commentary," and this guide corresponding to the new repair code have been updated to address comments received from these first-time users. Chapters 1 and 4 were reorganized and properly define the difference between evaluation and assessment. A new section in Chapter 7 addresses bond interface between an existing concrete substrate and a new concrete overlay. Appendix A has been added to provide requirements in cases where a jurisdiction has not adopted a repair code, allowing ACI 562-16 to be used as a stand-alone code. If a jurisdiction has adopted a repair code, then the licensed design professional must use Chapter 4. Examples were updated to reflect the changes in the new ACI 562-16.

ACI and ICRI agreed to have ACI staff update the original guide with review and approval by a small review group consisting of both ACI and ICRI members. The review group consisted of the same members that reviewed the 1st edition of the guide.

ACI and ICRI wish to acknowledge the efforts of several groups involved in the development of the original guide document upon which the current guide is based, as well as those that contributed to the update. Wiss, Janney, Elstner Associates, Inc., the original author of the guide used Project Examples based on work performed by the company and modified to illustrate the requirements of ACI 562-13. Their experience in repair and rehabilitation projects provided excellent background knowledge regarding the questions and issues that repair engineers would have and that the guide should attempt to address. ACI and ICRI would like to thank Wiss, Janney, Elstner Associates, Inc., as the original developer of the 1st edition of this guide.

"Vision 2020: A Vision for the Concrete Repair, Protection and Strengthening Industry" was published in 2006 with the facilitation of the Strategic Development Council (SDC) (a council of the ACI Foundation). One goal in Vision 2020 was the development of a concrete repair code. SDC also called for the development of documents in a more expedient manner than typically achieved in the volunteer committee development process. Their support of these goals continues with this document. ACI and ICRI would like to thank SDC for their vision in calling for the development of a concrete repair code and for providing financial support toward the development of both editions of this guide.

Members of ACI Committee 562, Assessment, Repair, and Rehabilitation of Concrete Buildings, and ICRI Committee 150, ICRI Notes on ACI 562 Code Requirements, provided comments on the initial drafts of the chapters and project examples in the 1st edition of this guide. ACI and ICRI would like to thank the members that volunteered their time to provide constructive comments to ensure that the guide addressed the major components of the repair code and would meet the expectations of the repair industry.

Finally, ACI and ICRI would like to thank the review group for this guide, as well as the 1st edition, consisting of Chair Jay H. Paul and members Eric L. Edelson, Fred R. Goodwin, Keith E. Kesner, and Antonio Nanni. Their careful review and dedication to the project on top of all their other volunteer time for both institutes made it possible to develop and revise this guide in a timely manner while maintaining the quality expected by the industry.

Khaled Nahlawi
Managing Editor

Preface

Introduction to the ACI 562-16 Code

The necessity of advancing the assessment, repair, rehabilitation, and strengthening of concrete structures has continued to develop in the last century through a collaboration of design professionals, contractors, suppliers, manufactures, researches, educators, and lawyers. The annual cost to owners for repair, protection, and strengthening of existing concrete structures is estimated between $18 and $21 billion in the U.S. alone (Vision 2020). Simply put, even sound concrete may require repair, rehabilitation, maintenance, or strengthening throughout the service life of a structure. Accordingly, from 2004 to 2006, the Strategic Development Council (SDC), an inter-industry development group dedicated to supporting the concrete industry's strategic needs, facilitated the development of, "Vision 2020: A Vision for the Concrete Repair, Protection, and Strengthening Industry," to establish a set of goals that would improve the efficiency, safety, and quality of concrete repair and protection activities. One of the goals established by Vision 2020 was to create a concrete repair and rehabilitation code by 2015. The ACI 562-13 standard entitled, "Code Requirements for Evaluation, Repair, and Rehabilitation of Concrete Buildings and Commentary," is the end result of that initiative. ACI 562-16 is the second edition of the Code with revisions, additions, and reorganized information to enhance the Code, providing more clarity and additional, updated information to assist the design professional.

The purpose of the ACI 562 Code is to provide minimum material and design requirements for the assessment, repair, and rehabilitation of structural concrete members. Like other ACI codes, ACI 562 is organized in a dual column format, with mandatory code provisions to the left of each page, and nonmandatory commentary to the right to provide additional guidance and information on the content presented in the code provisions. Unlike other ACI standards, ACI 562 includes both prescriptive and performance requirements. The performance requirements provide great latitude and flexibility to the licensed design professional in satisfying the requirements of ACI 562. Accordingly, ACI 562 serves to unify and strengthen concrete assessment, repair, and rehabilitation projects while accommodating the diverse and unique strategies and materials used in the industry.

In general, the overall use and function of ACI 562, with respect to existing concrete structures, can be compared to that of ACI 318-14, "Building Code Requirements for Structural Concrete and Commentary," with new concrete construction. As with ACI 318 and the 2015 International Building Code (2015 IBC), plans are underway for ACI 562 to be adopted into the International Existing Building Code to address matters pertaining to assessment, repair, rehabilitation, and strengthening of concrete members within existing buildings. Local jurisdictions and building authorities can also adopt ACI 562 directly. Accordingly, while ACI 562 currently defines the standard for the concrete assessment, repair, and rehabilitation industry, the code provisions of ACI 562 will likely then become mandatory requirements as part of the governing building codes that regulate work in existing buildings.

Overview of the guide to ACI 562 Code Content

The primary purpose of this guide is to help licensed design professionals gain more knowledge, skill, and judgment to interpret and properly use the ACI 562 Code. Although specifically developed for licensed design professionals (LDP), this guide also provides insight into the use and benefits of ACI 562 for contractors, material manufacturers, and building owners and building officials. To achieve this goal, the guide is separated into two main components: Chapter Guides and Project Examples.

The Chapter Guides and Project Examples are provided in tandem for clarity and understanding of the relative portions of ACI 562 Code. The Project Examples illustrate the process of carrying out a concrete building assessment, repair, rehabilitation, or strengthening project from inception through completion. This guide, including the Project Examples, is intended as a supplement to the ACI 562 Code and not as a "how-to" manual for performing concrete assessment, repair, rehabilitation, or strengthening. Several additional documents are referenced in ACI 562 Commentary and this guide to assist in evaluating the various options and approaches to performing successful concrete assessment, repair, rehabilitation, or strengthening projects. The intent of each Project Example is not to be a prescriptive formula for each of the project scenarios presented, but to illustrate how various sections of ACI 562 are applied together to execute the project. For convenience, related provision numbers from ACI 562 are given at the top of each corresponding paragraph of the project example text. Five Project Examples are included within the guide:

1. Typical parking structure repairs
2. Typical façade repairs
3. Repair of historic structure for adaptive reuse
4. Strengthening of two-way flat slab
5. Strengthening of double-tee stems for shear

The Chapter Guides follow the general organization of ACI 562, broken down by the corresponding sections of ACI 562. Section numbers in Chapters 1 to 10 and Appendix A of this guide correspond to the provision numbers in ACI 562. The Chapter Guides include background information and an explanation of the various ACI 562 provisions, with particular insight into how the particular chapter and section of the Code fit within the project. Where applicable, flowcharts are provided to illustrate how to navigate the various provisions of ACI 562. References to Project Examples are provided where applicable to illustrate how specific provisions within each chapter of ACI 562 are incorporated into the design process. In some instances, additional limited-scope examples are included to better illustrate a point that is not covered by the Project Examples.

The first edition of ACI 562 was published in 2013, and was not available when the work for the projects discussed in the Project Examples was actually performed. All Project Examples assume that ACI 562 was available and accepted by local jurisdiction when the example projects were performed.

The second edition of ACI 562, published in 2016, includes additional definitions used in the Code, bringing it into conformance with 2015 IEBC and other similar standards for existing structures. The title of the ACI 562 was changed by replacing the word "Evaluation" with "Assessment." The two terms, which are used interchangeably by other standards and the first version of this Code, have received distinct definitions in the second edition of ACI 562 (Stevens et al. 2016). Specific criteria requirements for assessment and design of repair and rehabilitation for varying levels of damage, deterioration, or faulty construction was added in Chapter 4 when using the Code with IEBC, and in Appendix A when using the Code as a stand-alone code. Chapters 1 and 4 were revised to include specific criteria requirements for assessment and design of repair and rehabilitation for varying levels of damage, deterioration, or faulty construction. Load combinations in Chapter 5, which defines the minimum strength of a structure with unprotected external reinforcement, were revised. Chapter 6 directs the design professional to provide an assessment before rehabilitation of an existing structure. This chapter includes historical material property data to help the design professional in the assessment if existing documents related to the existing structure are not available or physical samples cannot be extracted, because of the historical value of the structure. The interface bond provisions in Chapter 7 were revised to provide specific requirements based on shear test, as well as when to provide interface reinforcement, and commentary in Chapter 8 was clarified.

Lastly, a summary of the various provisions of ACI 562, as well as the corresponding location where each provision is covered within the guide, is provided in Provision Coverage Matrix at the end of this guide. This serves as a useful tool when searching for additional information to a specific provision of ACI 562.

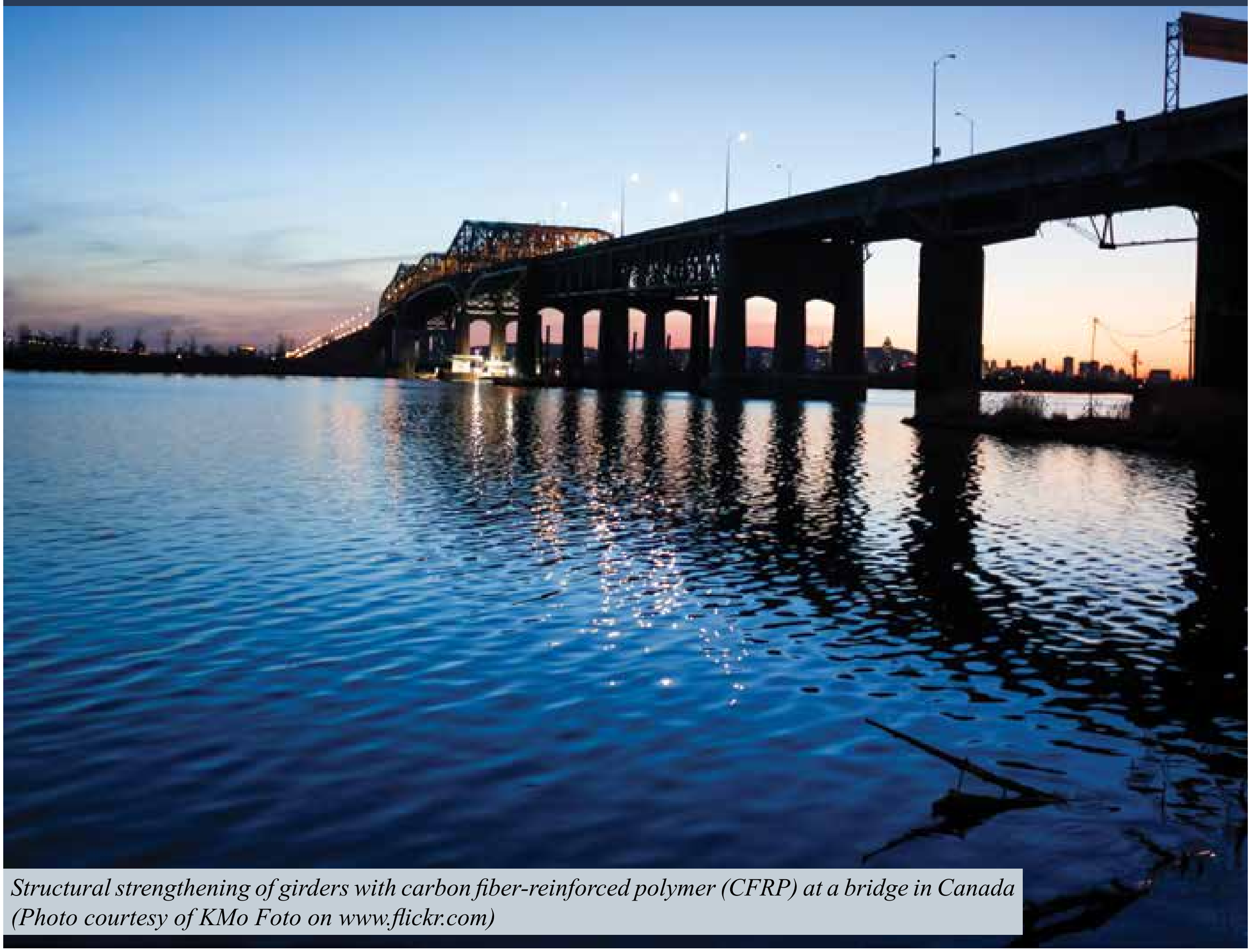
Contents

About This Book

The Chapter Guides in Chapters 1 to 11 and Appendix A of this guide correspond to the identically numbered sections of ACI 562-16, "Code Requirements for Assessment, Repair, and Rehabilitation of Existing Concrete Structures." Related ACI 562 provision numbers are included at the top of each corresponding paragraph of the Project Example text in Examples 1 to 5.

This Guide is intended to provide examples and guidance for how licensed design professionals may satisfy the performance provisions of ACI 562. It does not, however, purport to represent the only suitable way to satisfy the requirements for every project. Engineering judgment must be applied to the unique requirements of individual projects.

Chapter 1: General Requirements



Structural strengthening of girders with carbon fiber-reinforced polymer (CFRP) at a bridge in Canada (Photo courtesy of KMo Foto on www.flickr.com)

Overview

Chapter 1 of ACI 562 specifies the applicability of ACI 562 including review of the various building codes that might affect the repair design, as well as selecting the building code for the repair design; applicability of the code; responsibilities of the licensed design professional, including submittals to building officials and the owner; and development of maintenance recommendations. Chapter 1 also specifies the requirements for performing a preliminary evaluation by examining the available information and determining if the proposed changes, imposed changes, or both, are safe, followed by how the structure will be affected by these changes.

1.1—General

ACI 562 Code is written to the licensed design professional (LDP) and provides guidance and consistency when assessing, designing, repairing, and rehabilitating concrete structures. It is intended to supplement the International Existing Building Code (IEBC), as part of a locally adopted code governing existing buildings or structures, or as a stand-alone code for existing concrete structures. The intent of the Code is to address minimum safety requirements and provide some uniformity and standardization to the industry for assessing existing concrete structures. The mostly performance requirements included in the Code direct the design professional to satisfy specific requirements, while providing some leeway, flexibility, and direction with the repair and rehabilitation of concrete structures. Concrete structures constructed before 1971 that require repair, rehabilitation, or strengthening were probably designed based on the allowable stress approach whereas the demand and capacity requirements of ACI 562 are based on strength design. The demand and capacity requirements in ACI 562, however, are based on the strength design approach. The engineer is encouraged to consider strength design provisions of this Code as a check when assessing existing structures originally designed with allowable stress methods.

An existing structure, as defined in Chapter 2 and consistent with the definition in the International Building Code (IBC)/IEBC, is one for which a legal certificate of occupancy has been issued, or one that is finished and permitted for use. If no certificate of occupancy has been issued, or the building has not been permitted for use, the building is still considered new construction, and provisions of ACI 318 used in its design will govern.

Licensed design professional—The LDP, as defined in the Code and consistent with ACI Concrete Terminology (CT), refers to an individual for a project who is licensed to provide design services as defined by the statutory requirements of professional licensing laws of the state or jurisdiction in which the project is to be executed and who is in responsible charge of the structural assessment, rehabilitation design, or both. The LDP should exercise sound engineering knowledge, experience, and judgment when interpreting and applying ACI 562.

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

Determination of applicable building codes—Before performing an assessment, repair, rehabilitation, or strengthening of an existing concrete building or concrete structural element, the LDP of the project should first determine the building codes applicable to the project, understand their relevance to assessment and repair, rehabilitation, and strengthening design decisions, and the relationship between the different standards. Per ACI 562, the LDP should identify the following codes per the specific section numbers of ACI 562:

a. *Current building code* (1.2.2)
b. Original building code (1.2.3)
c. Existing building code (1.2.1)
d. Design basis code (1.2.4)

In the U.S., the *current building code* is usually based on an edition of the IBC, which was first published in 2000; a few large cities have their own customized building codes. The *current building code* establishes the design and construction regulations for new construction and provides limits that need not be exceeded if designing new construction or assessing and designing repairs and rehabilitation of existing structures. For the design and construction of new concrete structures, IBC references ACI 318. The code used to initially design the building is referred to as the *original building code* and is typically identified in the construction documents, or may be obtained by contacting the local jurisdiction and requesting information regarding the building code in effect at the time of original construction. The most common original codes prior to the IBC in the U.S. include the Building Officials Code Administrators National Building Code (BOCA/NBC), the Uniform Building Code (UBC), and the Standard Building Code (SBC) that typically reference previous versions of ACI 318 with modification.

In the U.S., the *existing building code* is most often based on an edition of the IEBC, which was first published in 2003. As of January 2016, the IEBC has been adopted in approximately 80 percent of the states, Guam, and Puerto Rico (International Code Council 2014). Chapter 34 of the IBC, before the 2015 edition, also covers existing structures and has similar provisions as IEBC that permit the use of the original code for rehabilitations, and when it is required to upgrade an existing structure to the current code. Chapter 34 has since been deleted from the 2015 IBC. The intent of ACI 562 is that *existing building code* refers to IEBC and not sections of other *current building codes* that contain provisions pertinent to existing construction. For jurisdictions that have not adopted an edition of the IEBC or the IBC with Chapter 34 version before 2015, that jurisdiction is considered to have no *existing building code*. In this case, the provisions of Appendix A of ACI 562 and any chapters in the *current building code* that address existing buildings must be met.

Once the *original building code* and *current building code* have been identified, the LDP can use the flowchart presented in Fig. 1.2 as a guide to determine the *design basis code* for repair, rehabilitation, or strengthening design. The *design basis code* is dependent on the adoption of an *existing building code* within the jurisdiction of the project. If a jurisdiction has not adopted an *existing building code*, Appendix A of ACI 562, is used to determine the *design basis code*. In jurisdictions that have adopted an *existing building code*, the *design basis code* is determined in accordance with Chapter 4 of ACI 562. The Project Examples included within this guide illustrate how Fig. 1.2 is used to determine the *design basis code*. Chapter 4 and Appendix A provide the design-basis criteria for the repair and rehabilitation work. Designing new members and their connections to existing structures must be based on ACI 318-14.

1.3—Applicability of the Code

ACI 562 is applicable to existing concrete structures including the concrete elements of buildings; nonbuilding structures; building foundation members, both plain and reinforced concrete; soil-supported structural slabs; concrete portions of composite members; and prestressed and precast concrete structures including cladding, which transmits lateral loads to diaphragms or bracing members. ACI 562 includes provisions specific to performing assessment, repair, rehabilitation, and strengthening of existing concrete elements of buildings or nonbuilding concrete structures. The LDP can exceed the minimum requirements of ACI 562, such as those for progressive collapse resistance, redundancy, or integrity provisions. Regulations of the current building code, however,

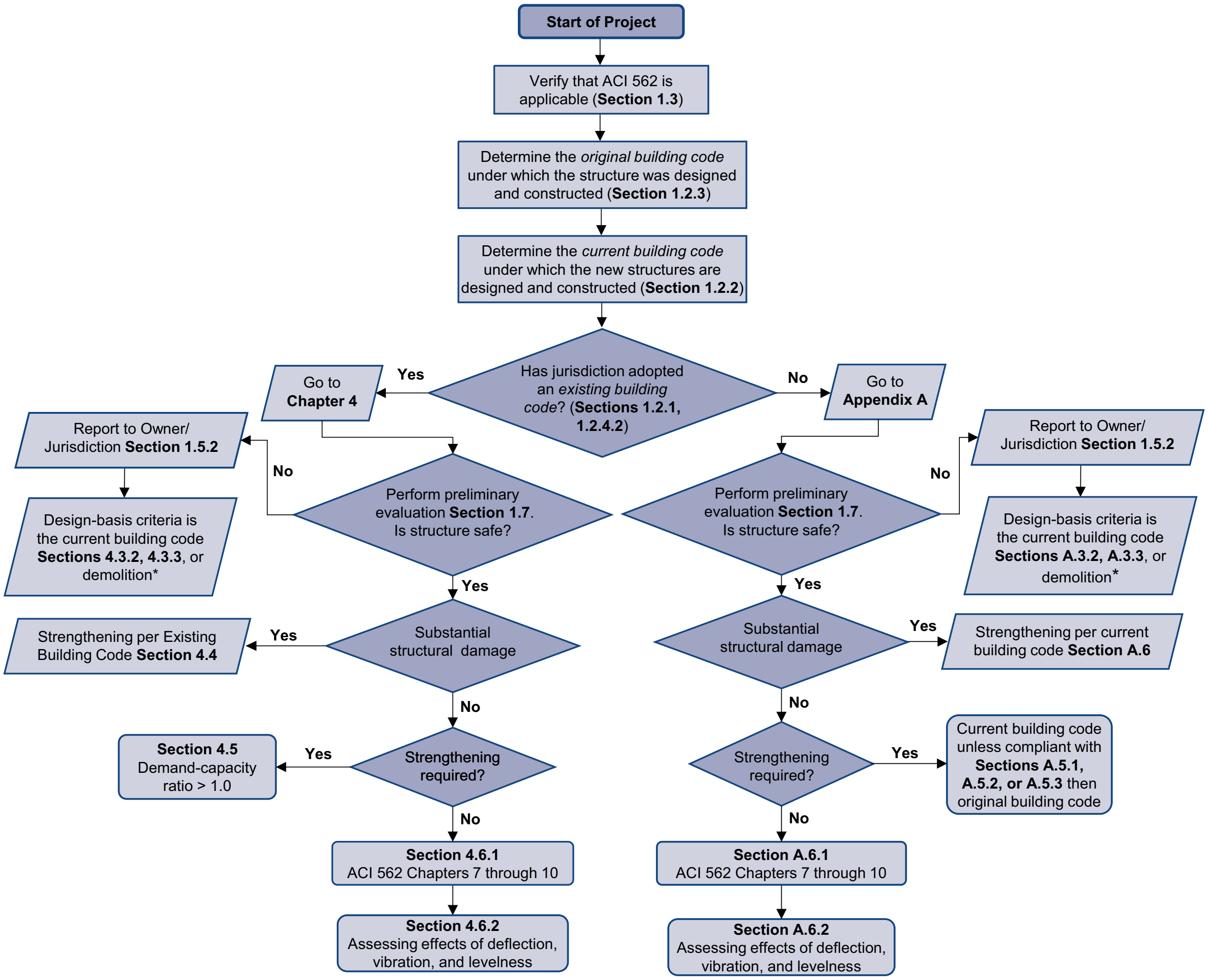


Fig. 1.2—Flowchart for determination of design basis code in ACI 562-16.

need not be exceeded when assessing, designing repair and rehabilitation work, or installing remedial work of existing structures. The Code applies to nonstructural concrete or for aesthetic improvements, if there is a potential for these materials to fail resulting in an unsafe condition.

Provisions for seismic resistance—ACI 562 refers to the *existing building code* for the evaluation of seismic resistance and seismic rehabilitation design. If an existing building code has not been adopted, ACI 562 requires that the LDP use ASCE/SEI 41 to design seismic retrofits supplemented by ACI 369R. These references provide guidance for the LDP regarding forces, analysis and modeling procedures, and seismic rehabilitation design. The effect of repairs or rehabilitations to existing concrete buildings should be considered in the assessment of the structure's seismic response per ACI 562, Section 6.7.4.

ACI 562 permits voluntary retrofit for seismic resistance if the existing building code or ACI 562 do not require rehabilitation for existing buildings. If IEBC is adopted, then IEBC and ACI 562 are used for voluntary retrofit of seismic resistance. If, however, an existing building code has not been adopted, then ACI 562 directs the LDP to use the current building code supplemented by ASCE/SEI 41 and ASCE/SEI 7 to design seismic retrofits.

1.4—Administration

This Code, unless it is in conflict with the IEBC or jurisdiction authority regulations, will govern in the assessment and repair or rehabilitation of existing concrete structures. If this Code, however, is in conflict with requirements in referenced standards in this Code, then this Code will govern. ACI 562 permits the use of repair design or construction systems that do not conform to ACI 562, provided such systems are approved by the building official based on successful use, analysis, or testing in accordance with ACI 562, Section 1.4.2.

1.5—Responsibilities of the licensed design professional

The LDP for the project is responsible for the repair process from assessing a structure to specifying repair materials,

Which ACI Code Governs?

The assessment, repair, and rehabilitation of existing concrete structures present several unique considerations as compared to the design and construction of new concrete structures. Accordingly, ACI 562 provides directions for how existing structures are treated with respect to various building codes. For example, repairs, additions, or alterations to structures may result in the redistribution of moments in continuous flexural members. ACI 562 provisions address these effects and allow the analysis of existing structures to consider the actual state of redistributed moments, even if they exceed the moment distribution permitted in ACI 318 (ACI 562, Section 6.5.4C).

Some of the provisions, calculations, and methods presented in ACI 318 are also applicable to the design of repair and rehabilitation measures for existing concrete structures. In these instances, ACI 562 provides direction regarding the scope and applicability of ACI 318 provisions for use with existing structures. For example, horizontal shear and shear-friction provisions presented in ACI 318 are applicable for force transfer at the interface between existing members and repair materials, and designing supplementary reinforcement for repairs (ACI 562, Sections 7.3.2 and 7.4.1). Similarly, post-installed anchors and dowels are often used in repairs of existing concrete members. Accordingly, the provisions provided in ACI 318, Chapter 17, are applicable for the design of post-installed anchors in existing structures (ACI 562, Section 7.6.5).

Chapter 1 of ACI 562 describes how ACI 562, ACI 318, and other codes adopted by the local jurisdiction are used by the LDP in the assessment, repair, and rehabilitation of existing concrete structures.

developing details to producing quality assurance programs covering the repairs, and advising the owner on future maintenance requirements to maintain a durable structure.

The Code, ACI 562, Section 1.5.2, requires the LDP to report observations of exposed structural defects within the work area representing obvious unsafe conditions requiring immediate attention to the appropriate authorities and that they should immediately alert the contractor and owner of unsafe conditions that require urgent action that may be discovered during construction to protect the public.

The LDP should document these findings in a report that includes a summary of the assessment of the existing structure, and a summary of or reference to the construction documents used for rehabilitation. These findings may be presented to the owner and jurisdictional authorities in form of a basis of design report. The items to be included in a basis of design report are summarized in the following titled text box "Basis of design report example."

The Project Examples presented in this guide provide specific examples of the responsibilities of the LDP, including the responsibility for notifying and communicating information to the owner through the duration of the assessment, repair, and rehabilitation. Specifically, Project Example 4 presents the reporting of unsafe structural conditions.

1.6—Construction documents

Construction documents need to clearly communicate the information necessary to perform the repair, rehabilitation, or strengthening work, and the material specified must satisfy ACI 562 and the local jurisdictional authority. The LDP may perform calculations necessary to evaluate the structure and design the repairs. Computer analyses and model analysis may be used. Pertinent calculations are required to be submitted to the building official if required. The LDP will furnish the owner with copies of the project documents, including reports, repair documents, construction submittals, field reports, and locations of completed repairs to the extent of the LDP's contractual obligations. The Project Examples presented in this guide provide specific examples of the types of information that are to be specified in the construction documents, as well as any additional information that should be delivered to the owner, the building official, or both throughout the duration of the assessment, repair, and rehabilitation. Essential information that should be included in the construction documents is listed in the following titled text box "Construction document example."

1.7—Preliminary evaluation

A preliminary evaluation is the first step in the assessment and repair process where the LDP reviews plans, construction data, reports, local jurisdictional codes, and other available documents of the existing structure to assess the damage, capacity, or load thresholds that will determine the *design basis code.* The preliminary evaluation is done to determine if the structure is in compliance with the original design code and if the structure is safe (ACI 562, Section 1.7.2). For additions and alterations, the preliminary evaluation will generally include the determination of the effect of the work on live and dead loads and the capacity of members. The level of damage to an existing structure is also an important determining factor in selecting the *design basis code* and, therefore, a preliminary evaluation is carried out to assess the level of structural damage.

Chapter 4 applies if a jurisdiction has adopted the International Existing Building Code and it defines the Design-Basis Code Criteria References. In the case of a jurisdiction that has not adopted an *existing building code*, Appendix A of ACI 562 is applicable and it provides criteria for selecting the design basis code.

The level and extent of the preliminary evaluation is subject to the professional judgment of the LDP. In some cases, where the repair project addresses structural damage,