

An ACI Standard

Specifications for Repair of Concrete in Buildings (ACI 563-18)

Reported by ACI Committee 563

ACI 563-18



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Specifications for Repair of Concrete in Buildings (ACI 563-18)

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Reported by ACI Committee 563

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Tony Murray was the first committee chair of ACI Committee 563 and a committee member of ACI 563 at the time of his death in 2016. The committee expresses its appreciation for his friendship and leadership.

Special acknowledgement to Matthew R. Hansen* for his contribution to this Specification.

This is a Reference Specification that the Architect/Engineer can apply to any construction repair and rehabilitation project involving structural concrete by citing it in the Project Specifications. Mandatory requirements and Optional requirements checklists are provided to assist the Architect/Engineer in supplementing the provisions of this Specification, as required or needed, by designating or specifying individual project requirements. The first section covers general construction requirements for all repair Work. The second section covers shoring and bracing of the structure or member to be repaired, and addresses sequencing of repair Work as the structure is unloaded and reloaded. The third section covers concrete removal and preparation of the concrete substrate for repair; and defines common equipment and methods. The next five sections cover materials and proportioning of concrete; proprietary cementitious and polymer repair materials; reinforcement; production, placing, finishing, and curing of repair materials; formwork performance criteria and construction; treatment of joints; embedded items; repair of surface defects; mockups; and finishing of formed and unformed surfaces. Provisions governing testing, evaluation, and acceptance of repair materials as well as acceptance of the repair Work are included. Sections 9 and 10 incorporate by reference two other specifications—ACI 503.7 and ACI 506.2—into this ACI Standard to cover crack repair by epoxy injection and shotcrete, respectively.

Keywords: bracing, cold weather; compressive strength; consolidation; curing; durability; epoxy injection; finish; formwork; grouting; hot weather; inspection; joints; mockups; placing; precast; repair; rehabilitation; reshoring; shoring; shotcrete; slab; steel reinforcement; surface preparation; testing; tolerance; welded wire.

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SECTION 1—GENERAL REQUIREMENTS

1.1—Scope

1.1.1 This Specification covers repair of concrete in existing structures.

1.1.2 This Specification is incorporated by Contract Documents and provides requirements for Contractor.

1.1.3 This Specification governs for construction within its scope, except other Contract Documents govern if there is a conflict.

1.1.4 This Specification governs if there is a conflict with referenced material and testing standards.

1.1.5 Contractor is permitted to submit written alternatives to any provision in this Specification for consideration.

1.1.6 Do not use this Specification in conjunction with ACI 301, ACI 350.5, or ACI 530.11 unless Contract Documents state that this Specification governs for Work covered by 1.1.1.

1.1.7 Ignore provisions of this Specification that are not applicable to Work.

1.1.8 Values in this Specification are stated in inch-pound units. A companion specification in SI units is available.

1.1.9 The Notes to Specifiers are not part of this Specification.

1.2—Interpretation

1.2.1 Unless otherwise explicitly stated, this Specification shall be interpreted using the following principles:

1.2.1.1 Interpret this Specification consistent with the plain meaning of the words and terms used.

1.2.1.2 Definitions provided in this Specification govern over the definitions of the same or similar words or terms found elsewhere.

1.2.1.3 Whenever possible, interpret this Specification so that its provisions are in harmony and do not conflict.

1.2.1.4 Headings are part of this Specification and are intended to identify the scope of the provisions or sections that follow. If there is a difference in meaning or implication between the text of a provision and a heading, the meaning of the text governs.

1.2.1.5 Footnotes are part of this Specification. The meaning of the provision text governs in the event of a difference in meaning or implication between the provision text and a footnote to that provision.

1.2.1.6 Where a provision of this Specification involves two or more items, conditions, requirements, or events connected by the conjunctions “and” or “or,” interpret the conjunction as follows: “and” indicates that all the connected items, conditions, requirements, or events apply; “or” indicates that the connected items, conditions, requirements, or events apply singularly.

1.2.1.7 The use of the verbs “may” or “will” indicates that the Specification provision is for information to the Contractor.

1.2.1.8 The phrase “as indicated in Contract Documents” means the specifier included the provision requirements in Contract Documents.

1.2.1.9 The phrase “unless otherwise specified” means the specifier may have included an alternative to the default requirement in Contract Documents.

1.2.1.10 The phrase “if specified” means the specifier may have included a requirement in Contract Documents for which there is no default requirement in this Specification.

1.3—Definitions

acceptable or **accepted**—determined by Architect/Engineer to be in compliance with Contract Documents.

acceptance—acknowledgment by Architect/Engineer that submittal or completed Work is acceptable.

Architect/Engineer—the architect, engineer, architectural firm, designing, or engineering firm developing Contract Documents, or administering the Work under Contract Documents, or both.

architectural concrete—concrete that is typically exposed to view, or is indicated as architectural concrete in Contract Documents, and therefore requires special care in selection of the concrete materials, forming, placing, and finishing to obtain the desired architectural appearance.

bracing—temporary supplemental members used to avoid local or global instability during construction, evaluation, or repair that are intended to be removed after completion of construction.

bruised surface—a surface layer weakened by interconnected microcracks in concrete substrates caused by use of high-impact, mechanical methods for concrete removal and surface preparation; fracture layer typically extends to a depth of 3 to 10 mm (1/8 to 3/8 in.) and, if not removed, frequently results in lower bond strengths compared to surfaces prepared with nonimpact methods.

cast-in-place concrete—concrete that is deposited and allowed to harden in the place where it is required to be in the completed structure, as opposed to precast concrete.

construction joint (repair material)—the interface where two successive placements of repair material meet.

Contract Documents—set of documents that form the basis of a contractual relationship between an Owner and Constructor or Design-Builder. These documents are defined by the contractual agreement, and can contain contract forms, contract conditions, specifications, drawings, addenda, and contract changes.

Contractor—the person, firm, or entity under contract for construction of the Work.

delamination—a planar separation in a material that is roughly parallel to the surface of the material.

drawings—graphic presentations that detail requirements for Work and may include written notes.

formwork, engineer-designed—formwork that is required by the Contract Documents to be designed by a specialty engineer

formwork, non-engineer-designed—formwork that is not required by the Contract Documents to be designed by a specialty engineer

install—operations at the Project site including the actual unloading, unpacking, assembly, erection, placing, anchoring, applying, working to dimension, finishing, curing, protecting, cleaning, and similar operations.

lightweight concrete—structural concrete containing lightweight aggregate conforming to **ASTM C330/C330M** and having an equilibrium density, as determined by **ASTM C567/C567M**, between 1440 and 1840 kg/m³.

microcrack—crack too small to be seen by the unaided eye.

national standards body—organization whose primary activities are developing, coordinating, promulgating, revising, amending, reissuing, interpreting, or otherwise producing technical standards that are intended to address the needs of a group of affected adopters.

normalweight concrete—structural concrete containing aggregate that conforms to **ASTM C33/C33M** and that typically has a density between 2160 and 2560 kg/m³.

Owner—the corporation, association, partnership, individual, public body, or authority for whom the Work is constructed.

post-tensioning—a method of prestressing reinforced concrete in which tendons are tensioned after the concrete has attained a specified minimum in-place strength or a specified minimum age.

precast concrete—concrete cast elsewhere than its final position.

provide—furnish and install, complete, and ready for the intended use.

quality assurance—actions taken by an organization to provide and document assurance that what is being done and what is being provided are in accordance with the Contract Documents and standards of good practice for the Work.

quality control—actions taken by an organization to provide control and documentation over what is being done and what is being provided so that the applicable standard of good practice or the Contract Documents for the work are followed.

reference specification—a standardized mandatory-language document prescribing materials, dimensions, and workmanship, incorporated by reference in Contract Documents.

reference standards—standardized mandatory-language documents of a technical society, organization, or association, including codes of local or federal authorities, which are incorporated by reference in Contract Documents.

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 its maintenance or to correct deterioration, damage, or faulty construction of members or systems of a structure

required—mandatory in this Specification or Contract Documents:

shop drawing—drawings that provide details for a portion of Work that are prepared by Contractor in accordance with Contract Documents and are reviewed by Architect/Engineer.

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

specifications—the written document that details requirements for Work.

shoring—(1) props or posts of timber or other material in compression used for the temporary support of excavations, formwork, or unsafe structures; (2) the process of erecting shores.

strength test—standard test conducted for evaluation and acceptance of concrete determined as the average of the

compressive strengths of at least two 150 x 300 mm cylinders or at least three 100 x 200 mm cylinders made from the same sample of concrete, transported, and standard cured in accordance with **ASTM C31/C31M** and tested in accordance with **ASTM C39/C39M** at 28 days or at test age designated for f'_c .

submit—provide to Architect/Engineer for review.

submittal—documents or materials provided to Architect/Engineer for review and acceptance.

termination joint (repair material)—the interface where a placement of repair material meets existing concrete, the edge of an expansion joint, or other existing surfaces

unsound concrete—concrete that is fractured, delaminated, spalled, deteriorated, defective, contaminated, or otherwise damaged.

Work—the entire construction or separately identifiable parts thereof required to be furnished under Contract Documents.

1.4—Referenced standards

Standards of AASHTO, ACI, ASCE, ASTM, AWS, CRD, and CRSI cited in this Specification are listed by name and designation, including year.

1.4.1 American Association of State Highway and Transportation Officials (AASHTO)

AASHTO M182:2012—Standard Specification for Burlap Cloth Made from Jute or Kenaf and Cotton Mats

1.4.2 American Concrete Institute (ACI)

ACI 117-10(15)—Specification for Tolerances for Concrete Construction and Materials and Commentary

ACI 503.7-07—Specification for Crack Repair by Epoxy Injection

ACI 506.2-13—Specification for Shotcrete

ACI 562-16—Code Requirements for Assessment, Repair, and Rehabilitation of Existing Concrete

1.4.3 American Society of Civil Engineers (ASCE)

ASCE 37-14—Design Loads on Structures during Construction

1.4.4 ASTM International

ASTM A184/A184M-17—Standard Specification for Welded Deformed Steel Bar Mats for Concrete Reinforcement

ASTM A615/A615M-16—Standard Specification for Deformed and Plain Carbon-Steel Bars for Concrete Reinforcement

ASTM A706/A706M-16—Standard Specification for Deformed and Plain Low-Alloy Steel Bars for Concrete Reinforcement

ASTM A767/A767M-16—Standard Specification for Zinc-Coated (Galvanized) Steel Bars for Concrete Reinforcement

ASTM A775/A775M-17—Standard Specification for Epoxy-Coated Steel Reinforcing Bars

ASTM A780/A780M-09(2015)—Standard Practice for Repair of Damaged and Uncoated Areas of Hot-Dip Galvanized Coatings

ASTM A820/A820M-16—Standard Specification for Steel Fibers for Fiber-Reinforced Concrete

ASTM A884/A884M-14—Standard Specification for Epoxy-Coated Steel Wire and Welded Wire Reinforcement

ASTM A934/A934M-16—Standard Specification for Epoxy-Coated Prefabricated Steel Reinforcing Bars

ASTM A955/A955M-18—Standard Specification for Deformed and Plain Stainless-Steel Bars for Concrete Reinforcement

ASTM A970/A970M-17—Standard Specification for Headed Steel Bars for Concrete Reinforcement

ASTM A996/A996M-16—Standard Specification for Rail-Steel and Axle-Steel Deformed Bars for Concrete Reinforcement

ASTM A1022/A1022M-16b—Standard Specification for Deformed and Plain Stainless Steel Wire and Welded Wire for Concrete Reinforcement

ASTM A1035/A1035M-16b—Standard Specification for Deformed and Plain, Low-Carbon, Chromium, Steel Bars for Concrete Reinforcement

ASTM A1044/A1044M-16a—Standard Specification for Steel Stud Assemblies for Shear Reinforcement of Concrete

ASTM A1055/A1055M-16—Standard Specification for Zinc and Epoxy Dual-Coated Steel Reinforcing Bars

ASTM A1060/A1060M-16b—Standard Specification for Zinc-Coated (Galvanized) Steel Welded Wire Reinforcement, Plain and Deformed, for Concrete

ASTM A1064/A1064M-17—Standard Specification for Carbon-Steel Wire and Welded Wire Reinforcement, Plain and Deformed, for Concrete

ASTM C31/C31M-18—Standard Practice for Making and Curing Concrete Test Specimens in the Field

ASTM C33/C33M-16e1—Standard Specification for Concrete Aggregates

ASTM C39/C39M-18—Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens

ASTM C42/C42M-16—Standard Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete

ASTM C94/C94M-17a—Standard Specification for Ready-Mixed Concrete

ASTM C143/C143M-15a—Standard Test Method for Slump of Hydraulic-Cement Concrete

ASTM C144-17—Standard Specification for Aggregate for Masonry Mortar

ASTM C150/C150M-17—Standard Specification for Portland Cement

ASTM C157/C157M-17—Standard Test Method for Length Change of Hardened Hydraulic-Cement Mortar and Concrete

ASTM C171-16—Standard Specification for Sheet Materials for Curing Concrete

ASTM C172/C172M-17—Standard Practice for Sampling Freshly Mixed Concrete

ASTM C173/C173M-16—Standard Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method

ASTM C192/C192M-16a—Standard Practice for Making and Curing Concrete Test Specimens in the Laboratory

ASTM C231/C231M-17a—Standard Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method

ASTM C260/C260M-10a—Standard Specification for Air-Entraining Admixtures for Concrete

ASTM C309-11—Standard Specification for Liquid Membrane-Forming Compounds for Curing Concrete

ASTM C330/C330M-17a—Standard Specification for Lightweight Aggregates for Structural Concrete

ASTM C387/C387M-17—Standard Specification for Packaged, Dry, Combined Materials for Concrete and High Strength Mortar

ASTM C404-11(2017)—Standard Specification for Aggregates for Masonry Grout

ASTM C494/C494M-17—Standard Specification for Chemical Admixtures for Concrete

ASTM C567/C567M-14—Standard Test Method for Determining Density of Structural Lightweight Concrete

ASTM C595/C595M-17—Standard Specification for Blended Hydraulic Cements

ASTM C597-16—Standard Test Method for Pulse Velocity through Concrete

ASTM C618-17a—Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete

ASTM C685/C685M-11—Standard Specification for Concrete Made by Volumetric Batching and Continuous Mixing

ASTM C803/C803M-17—Standard Test Method for Penetration Resistance of Hardened Concrete

ASTM C805/C805M-13a—Standard Test Method for Rebound Number of Hardened Concrete

ASTM C845/C845M-12—Standard Specification for Expansive Hydraulic Cement

ASTM C873/C873M-15—Standard Test Method for Compressive Strength of Concrete Cylinders Cast in Place in Cylindrical Molds

ASTM C881/C881M-15—Standard Specification for Epoxy-Resin-Base Bonding Systems for Concrete

ASTM C900-15—Standard Test Method for Pullout Strength of Hardened Concrete

ASTM C928/C928M-13—Standard Specification for Packaged, Dry, Rapid-Hardening Cementitious Materials for Concrete Repairs

ASTM C989/C989M-17—Standard Specification for Slag Cement for Use in Concrete and Mortars

ASTM C1012/C1012M-18a—Standard Test Method for Length Change of Hydraulic-Cement Mortars Exposed to a Sulfate Solution

ASTM C1017/C1017M-13e1—Standard Specification for Chemical Admixtures for Use in Producing Flowing Concrete

ASTM C1059/C1059M-13—Standard Specification for Latex Agents for Bonding Fresh to Hardened Concrete

ASTM C1074-11—Standard Practice for Estimating Concrete Strength by the Maturity Method

ASTM C1077-17—Standard Practice for Agencies Testing Concrete and Concrete Aggregates for Use in Construction and Criteria for Testing Agency Evaluation

ASTM C1116/C1116M-10a(2015)—Standard Specification for Fiber-Reinforced Concrete

ASTM C1157/C1157M-17—Standard Performance Specification for Hydraulic Cement

ASTM C1218/C1218M-17—Standard Test Method for Water-Soluble Chloride in Mortar and Concrete

ASTM C1240-15—Standard Specification for Silica Fume Used in Cementitious Mixtures

ASTM C1315-11—Standard Specification for Liquid Membrane-Forming Compounds Having Special Properties for Curing and Sealing Concrete

ASTM C1399/C1399M-10(2015)—Standard Test Method for Obtaining Average Residual-Strength of Fiber-Reinforced Concrete

ASTM C1436-13—Standard Specification for Materials for Shotcrete

ASTM C1480/C1480M-07(2012)—Standard Specification for Packaged, Pre-Blended, Dry, Combined Materials for Use in Wet or Dry Shotcrete Application

ASTM C1550-12a—Standard Test Method for Flexural Toughness of Fiber Reinforced Concrete (Using Centrally Loaded Round Panel)

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 C1600/C1600M-17—Standard Specification for Rapid Hardening Hydraulic Cement

ASTM C1602/C1602M-12—Standard Specification for Mixing Water Used in the Production of Hydraulic Cement Concrete

ASTM C1609/C1609-12—Standard Test Method for Flexural Performance of Fiber-Reinforced Concrete (Using Beam with Third-Point Loading)

ASTM C1611/C1611M-14—Standard Test Method for Slump Flow of Self-Consolidating Concrete

ASTM D994/D994M-11(2016)—Standard Specification for Preformed Expansion Joint Filler for Concrete (Bituminous Type)

ASTM D1751-04(2013)e1—Standard Specification for Preformed Expansion Joint Fillers for Concrete Paving and Structural Construction (Non-extruding and Resilient Bituminous Types)

ASTM D1752-04a(2013)—Standard Specification for Preformed Sponge Rubber Cork and Recycled PVC Expansion Joint Fillers for Concrete Paving and Structural Construction

ASTM E329-18—Standard Specification for Agencies Engaged in Construction Inspection, Testing, or Special Inspection

ASTM E1155-14—Standard Test Method for Determining FF Floor Flatness and FL Floor Levelness Numbers

1.4.5 American Welding Society (AWS)

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

1.4.6 U.S. Army Corps of Engineers (CRD)

CRD-C513-74—Specifications for Rubber Waterstops

CRD-C572-74—Specifications for Polyvinylchloride Waterstops

1.4.7 Concrete Reinforcing Steel Institute (CRSI)

CRSI RB4.1—Supports for Reinforcing Steel Used in Concrete

1.5—General procedures

1.5.1 Construction loads

1.5.1.1 Loading and support of structural member or structure—Do not allow construction loads to exceed the loads for a structural member or structure as indicated in Contract Documents. Retain designated structure or members necessary for dead loads as counterweights as indicated in the Contract Documents. Provide necessary shoring and temporary bracing to resist loadings during repair operations that the structure is otherwise unable to safely support without damage or unacceptable deformation in accordance with [Section 2](#).

1.5.2 Work areas and cleanliness—Work only in areas permitted by Owner within approved schedule as indicated in Contract Documents. Unless otherwise specified, do not stockpile materials, debris, or equipment except where approved by Owner. Dispose of materials in accordance with all applicable laws and regulations.

1.5.3 Delivery, storage, and handling—Deliver packaged materials clearly marked with legible and intact labels with manufacturer's name, brand name, lot number, and identifying contents of containers. Store materials in areas where conditions conform with repair material manufacturer's recommendations and instructions.

1.5.4 Protection

1.5.4.1 Structure and project location—Protect the structure and its contents, specific Work areas, and adjacent construction from risks associated with Work in this Specification as indicated in Contract Documents, including impact, marring of surfaces, and other types of damage. Protect areas adjacent to repair Work from damage and stains with appropriate barriers and masking. Repair damage and remove stains resulting from Work of this Specification to its condition at the start of work, or if such cannot be determined, to its original condition.

1.5.4.2 Project site—Provide site protection necessary to protect the public and adjacent property while Work is being performed.

1.5.4.3 Completed repair work

1.5.4.3(a) Mechanical damage—Protect repaired and adjacent areas from damage by public and construction traffic, equipment, and materials. During the curing period, protect repair materials from damage by mechanical disturbances, including load-induced stresses, shock, and vibration.

1.5.4.3(b) Environmental conditions—During the curing period, protect repair materials from damage by temperature, humidity, sunlight, wind, precipitation, water, and deleterious materials.

1.6—Preinstallation conference

Before providing submittals, and unless otherwise specified:

(a) Conduct preinstallation meeting(s) to discuss and review Contract Documents, scope of Work, repair process, repair materials performance requirements, repair materials, dust control, preparation, acceptance criteria, tolerances, quality assurance program, quality control program, and roles and responsibilities for Work.

(b) Coordinate mutually agreed upon time(s) and location(s) for meeting(s) with Owner and Architect/Engineer.

(c) Require Contractor or their designated representative(s), and other involved trades to attend.

1.7—Submittals

1.7.1 General—Provide submittals required by this Specification as indicated in Contract Documents.

1.7.2 Substitution—Substitution requests shall specifically identify proposed substitution, reason for substitution, demonstrate compliance with performance requirements, and cost and schedule impacts.

1.7.3 Contractor's quality control plan—Unless otherwise specified, submit quality control plan defining means and methods to control the purchase, use, and placement of materials. Provide information related to quality control in accordance with 1.8.2.

1.8—Quality assurance, quality control, testing, and inspection

1.8.1 General—Repair materials and operations may be tested and inspected as Work progresses. Failure to detect defective Work or material will not prevent rejection if a defect is discovered later nor shall it obligate Architect/Engineer for final acceptance. 

1.8.2 Quality control: duties and responsibilities of Contractor

1.8.2.1 Field technicians—Field tests of repair materials required in 1.8.2 shall be performed by field personnel with specified credentials and experience as indicated in Contract Documents.

1.8.2.2 Unless otherwise specified, Contractor assumes the duties and responsibilities given in 1.8.2.2(a) through 1.8.2.2(j).

1.8.2.2(a) Allow access to the project site or to the source of materials and assist Owner's testing agency in obtaining and handling samples at the project site or at the source of materials.

1.8.2.2(b) Advise Owner's testing agency at least 24 hours in advance of operations that require services specified in 1.8.3.2(a) through 1.8.3.2(c) to allow for scheduling of quality assurance tests, review of project requirements, and assignment of personnel.

1.8.2.2(c) Provide secure location and sources of water and electrical power on project site acceptable to Owner's testing agency for initial curing of concrete strength test specimens as required by [ASTM C31/C31M](#). Unless noted otherwise, provide similar secured location and sources of water and electrical power for repair materials.

1.8.2.2(d) Submit procedures for executing the Work as indicated in Contract Documents.

1.8.2.2(e) Submit test data and documentation for repair materials as indicated in Contract Documents.

1.8.2.2(f) Inspect and test surface preparation in accordance with [Section 3](#).

1.8.2.2(g) Inspect reinforcement in accordance with [Section 5](#).

1.8.2.2(h) Inspect Work in progress to verify that Work is being performed in accordance with approved procedures, manufacturer's instructions, specific instructions from Architect/Engineer if given, or reference standards cited in Contract Documents.

1.8.2.2(i) Unless otherwise specified, inspect completed Work, including visually examining repairs for cracks, testing for debonded repair materials, and verifying conformance with repair performance requirements. Correct defective Work.

1.8.2.2(j) Inspect bracing and shoring on an ongoing basis as Work progresses.

1.8.3 Quality assurance: duties and responsibilities of Owner's testing agency

1.8.3.1 Owner's testing agencies—Owner's agencies that perform required tests of concrete materials will meet the requirements of **ASTM C1077**, which includes the certification requirements for technicians. Owner's testing agencies that test or inspect placement of reinforcement will meet the requirements of **ASTM E329**. If specified, personnel requirements for repair materials other than concrete shall conform to the requirements of the repair material manufacturer.

1.8.3.2 Unless otherwise specified, the Owner's testing agency will provide the necessary services given in 1.8.3.2(a) through 1.8.3.2(c).

1.8.3.2(a) Owner's testing agency will inspect, sample, and test fresh and hardened repair materials for conformance with requirements in Contract Documents. If repair material furnished or work performed by Contractor fails to conform to Contract Documents, testing agency shall report such deficiency to Architect/Engineer, Owner, Contractor, and repair material supplier.

1.8.3.2(b) Owner's testing agency and its representatives are not authorized to revoke, alter, relax, enlarge, or release requirements of Contract Documents, nor to accept or reject any portion of Work.

1.8.3.2(c) Owner's testing agency will report test and inspection results of the Work to Owner, Architect/Engineer, Contractor, and repair material supplier within 7 days after tests and inspections are performed. Strength test reports will include location in the Work where the repair material represented by each test was deposited or installed, the time it was placed, and if concrete is the repair material, the batch ticket number. Strength test reports will include detailed information of storage and curing of specimens before testing.

1.8.3.3 Testing services—If required by Owner or Architect/Engineer, Owner's testing agency will perform testing services given in 1.8.3.3(a) through 1.8.3.3(i) at no cost to Contractor.

1.8.3.3(a) Review and test to verify Contractor's test results on proposed materials for compliance with Contract Documents.

1.8.3.3(b) Review and test to verify Contractor's test results on proposed concrete mixture.

1.8.3.3(c) Obtain samples of production materials at plants or stockpiles during the course of the Work and test for compliance with Contract Documents.

1.8.3.3(d) Obtain samples of fresh concrete in accordance with **ASTM C172/C172M** and test as indicated in Contract Documents.

1.8.3.3(e) Owner's testing agency will conduct concrete strength tests during construction by making and curing test specimens in accordance with **ASTM C31/C31M** and testing them according to **ASTM C39/C39M**. Unless otherwise specified, concrete strengths for acceptance shall be the average of at least two 150 x 300 mm or at least three 100 x 200 mm cylinders tested at 28 days.

1.8.3.3(g) If proprietary materials are specified, Owner's testing agency will perform tests as indicated in Contract Documents.

1.8.3.3(h) Examine completed repairs for cracking and sound repairs to check for disbondment from substrate.

1.8.3.3(i) Unless otherwise specified, direct-tension bond testing of prepared surfaces and completed repairs.

1.8.3.4 Additional testing and inspection services—If specified, Owner's testing agency will perform the following testing and inspection services (1.8.3.4(a) through 1.8.3.4(e)) to verify conformance with Contract Documents.

1.8.3.4(a) Inspect the batching, mixing, and delivery operations.

1.8.3.4(b) Inspect forms, foundation preparation, surface preparation, reinforcement, embedded items, reinforcement placement, and repair material placing, finishing, and curing operations.

1.8.3.4(c) Sample repair materials at point of placement and other locations as directed by Architect/Engineer and perform required tests as indicated in Contract Documents.

1.8.3.4(d) Review the manufacturer's report for each shipment of repair materials, including, but not limited to, cement, reinforcement, proprietary materials, and prestressing tendons, and conduct laboratory tests or spot checks of the materials received for compliance with specifications.

1.8.3.4(e) Other testing or inspection services as required by Architect/Engineer as indicated in Contract Documents.

1.8.3.5 Other testing services as needed—Contractor shall pay for the following testing services listed in 1.8.3.5(a) and 1.8.3.5(b) performed by Owner's testing agency:

1.8.3.5(a) Additional testing and inspection required because of changes in repair materials or concrete mixture proportions requested by Contractor

1.8.3.5(b) Additional testing of repair materials or concrete because of failure to meet specification requirements.

1.8.4 Tests on hardened concrete in-place

1.8.4.1 General—If specified, Owner's testing agency will perform tests on hardened concrete. Testing shall be at Contractor's expense when this Specification requires such tests to verify strength of the concrete in the structure because strength test specimens prepared and tested in accordance with Contract Documents fail to meet acceptance criteria. Owner will pay costs if tests are at the Owner's request and not required by this Specification.

1.8.4.2 Nondestructive tests for uniformity—Unless otherwise specified, use of the rebound hammer in accordance with **ASTM C805/C805M** or the pulse velocity method in accordance with **ASTM C597** may be permitted by Archi-

tect/Engineer to evaluate uniformity of in-place concrete or to select areas to be cored or tested by other in-place test methods. These methods shall not be used to evaluate in-place strength.

1.8.4.3 Core tests

1.8.4.3(a) Unless otherwise specified, if concrete strength is in doubt as defined in 1.8.6.1 or core testing required for other reasons, cores will be obtained, moisture conditioned, prepared, and tested in accordance with **ASTM C42/C42M**. Unless otherwise specified, cores will be tested no earlier than 48 hours after drilling or last wetting and no later than 7 days after the cores were drilled from the structure.

1.8.4.3(b) At least three representative cores will be taken from each area of in-place concrete that is considered potentially deficient. Architect/Engineer determines the location of cores to limit damage to the strength of the structure. If, before testing, cores show evidence of having been damaged after or during removal from the structure, replacement cores will be taken.

1.8.4.3(c) Contractor shall fill core holes with low-slump concrete or mortar of strength equal to or greater than the original concrete. Unless otherwise specified, provide moist curing for at least 3 days.

1.8.5 Evaluation of concrete strength tests

1.8.5.1 Standard molded and cured strength specimens—Test results from standard molded and cured test cylinders will be evaluated separately for each specified concrete mixture. Evaluation is valid only if tests have been conducted in accordance with procedures specified. For evaluation, each specified mixture shall be represented by at least five strength tests. When strength test results do not meet the requirements of 1.8.6.1, take steps to increase the average of subsequent strength test results. Submit documentation of actions to increase strength test results.

1.8.5.2 Core tests—Core test results will be evaluated by Architect/Engineer and are valid only if tests are conducted in accordance with specified procedures. Do not use core tests in place of standard-cured specimens specified in 1.8.5.1 for initial acceptance testing of concrete.

1.8.5.3 In-place strength tests—Test results will be evaluated by Architect/Engineer and are valid only if tests are conducted using properly calibrated equipment in accordance with recognized standard procedures and an acceptable correlation between test results and concrete compressive strength is established and submitted.

1.8.6 Acceptance of concrete strength

1.8.6.1 Standard molded and cured strength specimens—Strength of concrete is acceptable provided that the criteria of 1.8.6.1(a) and 1.8.6.1(b) are met. Unless otherwise specified, these criteria also apply to accelerated strength testing.

1.8.6.1(a) Every average of three consecutive strength tests equals or exceeds f'_c .

1.8.6.1(b) No strength test result falls below f'_c by more than 3.5 MPa when f'_c is 35 MPa or less, or by more than $0.10f'_c$ when f'_c is more than 35 MPa.

1.8.6.2 Core tests—Strength of concrete in the area represented by core tests is considered adequate when average compressive strength of the cores is at least 85% of f'_c , and if

no single core is less than 75% of the specified compressive strength f'_c .

1.8.6.3 In-place tests—Unless otherwise specified, do not use in-place tests as the sole basis for accepting or rejecting concrete. Use in-place tests to evaluate concrete where strength test results of standard molded and cured cylinders fail to meet the criteria in 1.8.6.1(b).

1.8.7 Field acceptance of repair materials

1.8.7.1 If concrete is specified, comply with requirements 1.8.7.1(a) through 1.8.7.1(c).

1.8.7.1(a) Air content—If the measured air content at delivery is greater than the upper limit of 6.2.2.6(b), immediately perform a check test of air content on a new sample. If the check test fails, the concrete did not meet the requirements of this Specification. Unless otherwise specified, if the measured air content is less than the lower limits of 6.2.2.6(b), make adjustments in accordance with **ASTM C94/C94M**. If the check test of the adjusted mixture fails, the concrete did not meet the requirements of this specification.

1.8.7.1(b) Slump—If the measured slump at delivery does not meet the requirement of 6.2.2.2, immediately perform a check test on a new sample. If the check test fails, the concrete is considered to have failed to meet the requirements of this Specification. Unless otherwise specified, if the measured slump is less than specified in 6.2.2.2, make adjustments in accordance with **ASTM C94/C94M**. If the check test of the slump of the adjusted mixture fails, the concrete did not meet the requirements of this Specification.

1.8.7.1(c) Temperature—Unless otherwise specified, if the measured concrete temperature at delivery is not within the limits of 6.2.2.5, a check test will be performed immediately at a new location in the sample. If the check test fails, the concrete is considered to have failed to meet the requirements of this specification.

1.8.7.2 If specified or permitted, proprietary repair materials shall comply with requirements as indicated in Contract Documents.

1.9—Acceptance of repair Work

1.9.1 General—Completed concrete repair Work shall conform to this Specification and Contract Documents.

1.9.1.1 Concrete repair Work that fails to meet one or more requirements of Contract Documents but subsequently is repaired to bring the Work into compliance may be accepted.

1.9.1.2 Concrete repair Work that fails to meet one or more project requirements and cannot be brought into compliance is subject to rejection.

1.9.1.3 Submit proposed repair methods, materials, and modifications needed to correct rejected concrete repair Work to meet the requirements of Contract Documents.

1.9.1.4 Correct rejected concrete repair Work by removing and replacing or by strengthening or otherwise improving properties to address deficiencies with additional construction acceptable to the Architect/Engineer. To bring rejected Work into compliance, use repair methods that meet applicable requirements for function, durability, dimensional tolerances, and appearance as determined by Architect/Engineer.

1.9.1.5 Contractor shall be responsible to bring concrete repair Work into compliance with requirements of Contract Documents.

1.9.2 Dimensional tolerances

1.9.2.1 Unless otherwise specified, construction tolerances for repair Work shall conform to **ACI 117**.

1.9.2.2 Where existing conditions do not allow tolerances to conform to ACI 117, use the details and materials for such conditions as indicated in Contract Documents. For conditions not shown or that are different than indicated in Contract Documents, notify the Architect/Engineer before proceeding with the Work at those locations.

1.9.2.3 Formed surfaces resulting in concrete members with dimensions smaller than permitted by the tolerances of ACI 117 shall be brought to the attention of the Architect/Engineer. These may be considered structurally deficient and subject to additional testing.

1.9.2.4 Formed surfaces resulting in concrete members with dimensions larger than permitted by ACI 117 are subject to rejection. Remove excess materials when required by Architect/Engineer.

1.9.2.5 Inaccurately formed concrete surfaces that exceed ACI 117 tolerances are subject to rejection.

1.9.2.6 Slabs not meeting the tolerances in **7.3.4.3** may be corrected provided they are brought into compliance with 1.9.1.3, 1.9.1.4, and 1.9.1.5.

1.9.2.7 Concrete members placed against formwork surfaces exceeding the limitations of **4.2.2.4** are subject to rejection.

1.9.3 Appearance

1.9.3.1 Concrete surfaces not meeting the requirements of **7.3.3** shall be brought into compliance in accordance with 1.9.1.

1.10—Repair material manufacturer's technical support and field representative

1.10.1 Obtain and coordinate services of a repair material manufacturer's field representative at the project site before mixing or installing proprietary materials or components to train personnel in preparation, installation, and quality control procedures. Unless otherwise specified, they shall remain at the job site as Work commences and continue to observe the Work until the project manufacturer's field representative, the Contractor, and the Owner are satisfied that the crew has mastered the technique of preparing and installing the proprietary products acceptably. Unless otherwise specified, manufacturer's field representative shall make periodic visits to review completed Work and distribute reports describing workmanship and conformance with manufacturer's requirements.

1.10.2 The repair material manufacturer's field representative shall be qualified to perform the Work as indicated in Contract Documents and subject to the approval of the Owner.

SECTION 2—SHORING AND BRACING

2.1—General

2.1.1 Description—This section covers design, construction, installation and removal of shoring and bracing to

support the structure before, during, and after the performance of repairs, until the structure or members of the structure is/are self-supporting and accepted by Architect/Engineer. Use temporary shoring to accommodate in-place conditions in the structure and expected superimposed loads. Consider the effects of compatibility of deformations on the shoring system and supported/supporting structural members.

2.1.1.1 Design of shoring and bracing—Employ a Specialty Engineer to design all shoring and bracing that shall address preexisting unsafe structural conditions, load and deflection requirements during repair, and to maintain stability of the structure and structural members during construction for locations as indicated in Contract Documents. Comply with limits on concrete or reinforcement removal prior to shoring as indicated in Contract Documents. Shoring design and scheduling shall meet requirements for location, spacing, placement, and sequencing to minimize impact on building operations as indicated in Contract Documents. The design shall comply with the requirements of **ACI 562** and 2.1.1.2(a) through 2.1.1.2(b).

2.1.1.2(a) Unloading—When the removal of applied loads is desired, either from redistribution of loads as a result of distress, deterioration or deformation of a member, to permanently remove a member or portion of a structure, or to create load sharing between the existing member and the repair, jacking loads applied to the existing construction shall be accounted for in assessing the need for and in the design of shoring and temporary bracing.

2.1.1.2(b) Prestressed reinforcement—When repairs involve altering forces in prestressed reinforcement, whether intentional or due to the unintentional damage to prestressing reinforcement, deterioration of prestressing, or the imposition of new forces, the change in forces shall be considered in the design of bracing and shoring. Install appropriate shoring or temporary bracing, as required, until the final prestress forces are re-imposed on the member or structure.

2.1.2 Submittals

2.1.2.1 Unless otherwise specified, submit data required in 2.1.2.1(a) through 2.1.2.1(d).

2.1.2.1(a) Calculations—Submit calculations delineating the load effects on the structure and parts thereof occurring throughout the duration of the repair Work, and establish that all loadings are supported by the shoring and bracing system, unless more stringent requirements are delineated by the Architect/Engineer. When shoring is continuous over several floors or across several bays, the calculations shall delineate the sharing of loads between the existing structure and the shoring. Submittals shall delineate locations and maximum reactions at all points of bearing of the shoring against the existing structure, sufficient to permit Architect/Engineer to assess the impact of the proposed shoring on the overall structure.

2.1.2.1(b) Shop drawings—Submit shoring layout shop drawings depicting the arrangement of equipment for shoring, inclusive of installation details, maintenance requirements, and permitted changes.

2.1.2.1(c) Sequencing—Submit sequencing requirements of shoring installation and removal, concrete removals,

surface preparation, repair installation, curing and minimum concrete strength at removal. Demonstrate that safety of structure is maintained through calculations prepared by specialty engineer.

2.1.2.1(d) Certifications—Submit documentation of inspections and certifications required from specialty engineer as specified by this Section.

2.2—Products

2.2.1 Materials

2.2.1.1 Shoring and bracing—Unless otherwise specified, use commercially manufactured and engineered shoring and bracing systems and components.

2.2.2 Performance and design requirements

2.2.2.1 The design of the bracing and shoring shall be based on **ASCE 37**.

2.2.2.2 Calculations shall be signed and sealed by a specialty engineer.

2.2.2.3 In accordance with the manufacturer's recommendations, use members of manufactured shoring systems, consisting of pre-engineered components designed and produced specifically for structural shoring.

2.2.2.4 Design members of shoring systems that are not a pre-manufactured system in accordance with the provisions of the governing building code for the specific material of the member.

2.3—Execution

2.3.1 Construction and erection of shoring and bracing

2.3.1.1 Install shoring and bracing in accordance with sequencing documentation.

2.3.1.1(a) Establish and maintain survey controls and benchmarks in an undisturbed condition.

2.3.1.1(b) Maintain and adjust shoring and bracing during the repair process to comply with 2.1.2.1(b).

2.3.2 Removal of shoring and bracing

2.3.2.1 Unless otherwise specified, remove shoring and bracing after concrete repairs achieve specified strength.

2.3.2.2 Remove shoring and bracing after completion of all stressing operations.

2.3.3 Field quality control

2.3.3.1 Inspect shoring and temporary bracing before beginning the repair process and at appropriate intervals throughout the process.

2.3.3.2 Specialty engineer who designed the shoring shall inspect the installation and certify that the shoring and bracing, as installed, meets the intent of their design, as indicated in Contract Documents.

SECTION 3—CONCRETE REMOVAL AND PREPARATION FOR REPAIR

3.1—General

3.1.1 Description—This section covers the removal of concrete for repair and preparation of substrate to receive repair material.

3.1.1.1 Furnish all labor, materials, tools, equipment, and supervision to remove concrete and to prepare surfaces for

the placement of repair materials. Maintain project site in compliance with **1.5.2**.

3.1.1.2 Provide surface profile and remove laitance, debris, and bond-inhibiting materials using methods that shall satisfy these requirements as indicated in Contract Documents.

3.1.2 Submittals

3.1.2.1 Unless otherwise specified, provide submittals as required by 3.1.2.2 to 3.1.2.4.

3.1.2.2 Before concrete removal, submit proposed equipment for concrete removal and surface preparation.

3.1.2.3 If the proposed concrete removal equipment uses water, submit a plan outlining the methods for control of water and the disposal of the removed materials.

3.1.2.4 Submit documentation of existing conditions, especially areas of preexisting damage and deterioration unrelated to the Work, including finishes of surfaces, before starting demolition.

3.1.3 Quality assurance

3.1.3.1 Test for the minimum pull-off tensile bond strength between the repair material and the prepared substrate surface in accordance with **ASTM C1583/C1583M** as indicated in Contract Documents.

3.1.3.1(a) The required pull-off strength shall be at least equal to the minimum pull-off value as indicated in Contract Documents.

3.1.3.1(b) Report pull-off strength values to the Architect/Engineer.

3.1.3.2 Mockups—Provide mockups as indicated in Contract Documents to demonstrate the effectiveness and suitability of various methods intended to be used for concrete removal and surface preparation. Architect/Engineer will evaluate the mockups and testing results to determine if extent of concrete removal and proposed methods satisfy the project requirements and achieve desired tensile pull-off strengths.

3.1.3.2(a) Prepared substrate surface within the mockup shall be made available for testing to determine if the required pull-off strength, profile, and moisture condition can be met.

3.1.3.2(b) Change or modify the concrete removal and surface preparation methods if the prepared substrates in the mockups do not satisfy the project requirements and the specified pull-off strengths are not met.

3.2—Products

3.2.1 Equipment for concrete removal

3.2.1.1 Select the means and methods for concrete removal that will minimize damage to the structure and bruised surfaces on the concrete substrate that remains within and adjacent to the work areas.

3.2.1.2 Removal equipment and techniques shall be suitable to produce required concrete surface profiles and remove laitance, debris, and bond-inhibiting materials in designated areas.

3.2.1.3 Concrete breakers—Unless otherwise specified, limit the maximum breaker size, style, or breaker type that required to provide a substrate surface consistent with

the indicated requirements, without creating unintentional removal of concrete beyond designated areas. Provide sharp tips on breaker equipment to minimize bruised surfaces in partial depth removal.

3.2.1.4 Hydrodemolition—Implement hydrodemolition only in locations as indicated in Contract Documents.

3.2.1.5 Scarifying, scabbling, and milling/rotomilling—Minimize damage to the substrate that remains and provide surface profiles as indicated in Contract Documents.

3.2.2 Equipment for concrete and reinforcement surface preparation and cleaning—Unless otherwise specified, select the means and methods for surface preparation and provide cleaning of the concrete, reinforcement, and accessories that will produce results that satisfy specified requirements.

3.2.2.1 Abrasive- and shot-blasting—Use oil-free abrasive blasting capable of removing loose microfractured (bruised surface) or otherwise damaged/pulverized concrete surfaces, and providing a surface profile as indicated in Contract Documents.

3.2.2.2 Compressed air—Use equipment that delivers oil-free air that removes loose material and debris.

3.2.2.3 High- and ultra-high-pressure water jetting—35 to 310 MPa at 8 to 190 L/min water delivery equipment capable of removing loose/fractured concrete, and providing a surface profile as indicated in Contract Documents.

3.2.2.4 Low-pressure water cleaning—7 to 35 MPa at 8 to 38 L/min water delivery equipment capable of removing loose/fractured concrete, and providing a surface profile as indicated in Contract Documents.

3.2.2.5 Vacuum methods—Use equipment that removes loose material and debris.

3.3—Execution

3.3.1 Identification of extent of concrete removal

3.3.1.1 Configure geometry of removal area to maximize the use of right-angle geometry, avoiding reentrant corners, and to obtain uniformity of depth, as indicated in Contract Documents.

3.3.1.2 Unless otherwise specified, perform visual inspection and hammer sounding, chain drag sounding, or other methods acceptable to the Architect/Engineer to identify cracked, delaminated, spalled, disintegrated, and otherwise unsound concrete for removal. Mark boundaries of repair area before concrete removal.

3.3.1.3 Inspect the marked boundaries with the Architect/Engineer prior to commencing with the concrete removal. Revise the repair area boundaries as instructed by the Architect/Engineer.

3.3.2 Concrete removal

3.3.2.1 Notify the Architect/Engineer before beginning concrete removal and surface preparation as indicated in Contract Documents.

3.3.2.2 Remove concrete from repair areas to indicated depth and profile. Unless otherwise specified, notify Architect/Engineer if additional delaminated, fractured, or unsound concrete is present, and attain approval before proceeding.

3.3.2.2(a) Operate equipment so as to not damage embedded reinforcement or other embedded items, and adjacent concrete. Removal methods producing bruised surfaces (microcracking) of the prepared substrate shall be followed by secondary removal/surface preparation methods to remove the bruised surface layer. Avoid directly striking reinforcement with impact tools used for concrete removal.

3.3.2.2(b) Provide perpendicular edges at perimeter of repair area. Unless noted otherwise, perimeter of the repair areas shall be saw cut to a depth of 13 to 20 mm. Do not cut or damage embedded reinforcement or other embedded items. If embedded reinforcing bars or other embedded items are too close to the surface to provide the perpendicular edge cut, notify Architect/Engineer for direction before proceeding.

3.3.2.3 Removal of concrete around corroded reinforcement

3.3.2.3(a) Extend concrete removal along the reinforcement to a point where there is no further delamination, concrete cracking, or reinforcement corrosion, and where the reinforcement is bonded to the surrounding concrete.

3.3.2.3(b) Unless otherwise specified, remove concrete around the exposed layers of reinforcement to a uniform depth within the repair areas and provide a minimum clearance between exposed reinforcement and surrounding concrete of 20 mm, or at least 6 mm larger than the maximum nominal size of the coarse aggregate in the repair material. If specified, extend the concrete removal beneath other layers of reinforcement within the repair area.

3.3.2.3(c) Unless otherwise specified, do not remove concrete behind vertical reinforcing bars in columns. Obtain direction from the Architect/Engineer if further concrete removal is required.

3.3.3 Preparation of concrete substrate surface after concrete removal

3.3.3.1 Confirm perpendicular edges at repair area perimeter, and reinstate if damaged by concrete removal process. Remove loosely bonded concrete, bruised surface or fractured concrete, and bond-inhibiting materials such as dirt, concrete slurry, or any other detrimental materials from the concrete substrate using approved methods.

3.3.3.1(a) Provide substrate surface profiles as specified.

3.3.3.1(b) Visually inspect and sound substrate surface to confirm that no further delaminations or otherwise unsound concrete remains. If encountered, notify Architect/Engineer per 3.3.2.1.

3.3.3.2 Remove laitance, debris, and bond-inhibiting materials and prepare substrate with approved methods.

3.3.3.3 Provide substrate moisture conditions as indicated in Contract Documents.

3.3.4 Prepared surface verification

3.3.4.1 Unless otherwise specified, immediately before placing the repair material or installing formwork, make the repair area available for observation by Architect/Engineer.

3.3.4.2 Verify the adequacy of the substrate as indicated in Contract Documents. If delaminated, contaminated, or unsound concrete; bond-inhibiting materials including dirt, dried concrete slurry, moisture, and loose bond-inhibiting aggregate; bruised surface; or any other condition that may inter-

ferre with the bond or performance of the repair material are present, remove all unsuitable materials and repeat previous steps for the preparation of the concrete substrate surface. Notify Architect/Engineer that remedial preparation work is complete and ready for observation.

SECTION 4—FORMWORK

4.1—General

4.1.1 Description—This section covers design, construction, and treatment of formwork to support, confine, and shape repair materials to required dimensions.

4.1.2 Submittals

4.1.2.1 Unless otherwise specified, submit data required in 4.1.2.1(a) through 4.1.2.1(e).

4.1.2.1(a) Form-facing materials—Submit data on form-facing materials proposed if different from that specified in 4.2.1.1.

4.1.2.1(b) Construction and contraction joints—Submit location and detail of repair material construction and contraction joints if different from as indicated in Contract Documents.

4.1.2.1(c) Testing for formwork removal—Submit data on method for determining repair material strength for formwork removal in accordance with 4.3.4.2 when method other than field-cured cylinders is proposed.

4.1.2.1(d) Reshoring and backshoring procedure—Before using reshoring or backshoring that is required or permitted, submit procedure, including drawings signed and sealed by a specialty engineer. Include on shop drawings formwork removal procedure and magnitude of construction loads permitted during reshoring or backshoring.

4.1.2.1(e) Submit data on formwork release agent or form liner proposed for use with each formed surface.

4.1.2.2 Submit data required in 4.1.2.2(a) through 4.1.2.2(e) as indicated in Contract Documents.

4.1.2.2(a) Submit shop drawings for engineer-designed formwork signed and sealed by a specialty engineer as required by jurisdiction where Work will be done.

4.1.2.2(b) Submit design calculations for engineer-designed formwork, shoring, reshoring and backshoring, signed and sealed by a specialty engineer as required by jurisdiction where Work will be done.

4.1.2.2(c) Submit manufacturer's product data sheet for form ties and anchors to existing concrete.

4.1.2.2(d) Submit manufacturer's product data sheet for expansion joint materials.

4.1.2.2(e) Submit manufacturer's product data sheet for waterstop materials and splices.

4.1.3 Shoring—Requirements specified herein for reshoring and backshoring refer to shoring of formwork for new repair materials. For shoring of the existing structure, refer to [Section 2](#).

4.2—Products

4.2.1 Materials

4.2.1.1 Form-facing materials—Unless otherwise specified, form-facing material in contact with repair material

shall be lumber, plywood, tempered concrete-form-grade hardboard, metal, plastic, or paper that creates the specified appearance and texture of repair material surface.

4.2.1.2 Formwork accessories—Use commercially manufactured and engineered formwork accessories that are partially or wholly embedded in concrete or repair material, including ties and hangers. Use manufactured form ties designed to be removed or so that ends or end fasteners can be removed without damage to concrete and repair material. Unless otherwise specified, use form ties in members with integral water barrier plates or other acceptable positive water barriers. Unless otherwise specified, for ferrous ties, the breakback distance of ties for Surface Finish-2.0 or Surface Finish-3.0 shall be at least 20 mm, as defined in [7.3.3.3](#). Unless otherwise specified, drilled anchor bolts in existing concrete may be used. Anchor bolts shall be able to be removed without spalling concrete.

4.2.1.3 Formwork release agents—Use commercially manufactured formwork release agent that reduces formwork moisture absorption, prevents bond with repair material, does not stain concrete and repair material surfaces, and does not interfere with bond of subsequently-applied sealers, coatings, waterproofing materials, and other finishes.

4.2.1.4 Expansion joint filler—Premolded expansion joint filler shall conform to [ASTM D994/D994M](#), [D1751](#), or [D1752](#).

4.2.1.5 Other embedded items—Use waterstops, sleeves, inserts, anchors, and other embedded items of material and design as indicated in Contract Documents. Waterstop materials shall meet requirements of [CRD C513](#) for rubber waterstop, or [CRD C572](#) for polyvinyl chloride waterstop. Splice waterstops and use molded pieces as recommended by manufacturer. When connected to and made continuous with existing waterstop materials, new waterstop materials shall match existing in configuration and material.

4.2.1.6 Chamfer materials—Unless otherwise specified, use lumber materials 20 x 20 mm. When mating to existing chamfers, match existing chamfer sizes.

4.2.2 Performance and design requirements

4.2.2.1 Contractor is responsible for design and engineering of all formwork. Unless otherwise specified, design calculations and drawings for engineer-designed formwork shall be signed and sealed by a specialty engineer as required by state or jurisdiction where Work will be done.

4.2.2.2 Design formwork, shores, reshores, and backshores to support loads transmitted to them and to comply with applicable building code requirements. Design formwork to withstand repair material pressures, as well as pressure resulting from placement, and consolidation procedures to maintain specified tolerances.

4.2.2.3 Unless otherwise specified, do not use earth cuts as forms for vertical or sloping surfaces.

4.2.2.4 Unless otherwise specified, maximum deflection of facing materials reflected on repair material surfaces exposed to view shall be 1/240 of span between structural members of formwork.

4.2.2.5 Construction, expansion, and contraction joints

4.2.2.5(a) Locate and install repair material construction joints that least impair strength of structure and meet